Bay Area Clean Water Agencies

Nutrient Reduction Study

Potential Nutrient Reduction
by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means

Final Report

June 22, 2018

BACWA
BAY AREA
CLEAN WATER
AGENCIES

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FINAL

June 2018

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1. Executive Summary

On April 9, 2014 the San Francisco Bay Regional Water Quality Control Board (RWQCB) issued Order No. R2-2014-0014, *Waste Discharge Requirements for Nutrients from Municipal Wastewater Discharges to San Francisco Bay* (Watershed Permit). The five-year Watershed Permit became effective on July 1, 2014 and covers each municipal Publicly Owned Treatment Works (POTW) that discharges to the San Francisco Bay (SF Bay) and its tributaries. The purpose of the Watershed Permit is to track and evaluate treatment plant performance, fund nutrient monitoring programs, support load response modeling, and conduct studies to better understand treatment plant optimization opportunities and upgrade needs to achieve nutrient removal.

This Nutrient Reduction Study was prepared in response to the requirements outlined in the Watershed Permit to conduct studies to evaluate potential nutrient discharge reduction by treatment optimization and sidestream treatment and by treatment upgrades or other means.

1.1 Background

Nutrients in the SF Bay are a growing concern for the Bay Area water quality community. Historically, the SF Bay has not been adversely impacted by nutrient loading, although there are indications that its historic resilience to the effects of nutrient enrichment may be weakening.[1,2] While the definition of impairment has not been reached, there is concern that the SF Bay has reached a tipping point that might lead to impairment. Numerous scientific studies are being conducted to understand the impact of nutrients on the SF Bay. As a result, it may be necessary to limit the availability of essential nutrients, by implementing some form of wastewater treatment nutrient removal to address three potential challenges:

1. Ammonia toxicity and/or inhibition of phytoplankton growth. Full or partial nitrification may be required.
2. Eutrophication. Denitrification may be required where total inorganic nitrogen is the limiting nutrient.
3. Undesirable phytoplankton assemblage changes due to the ratio of nitrogen to phosphorus. Phosphorus reduction may be required.

The Watershed Permit sets forth a regional framework to facilitate collaboration on studies that will inform future management decisions and regulatory strategies. The permit includes three special provisions to support the further understanding of nutrient loads and their impacts in the SF Bay:

1. Evaluation of Potential Nutrient Discharge Reduction by Treatment Optimization and Sidestream Treatment
2. Evaluation of Potential Nutrient Discharge Reduction by Treatment Upgrades or Other Means

[1] Cloern, J.E. and Jassby, A.D. (2012) Drivers of change in estuarine-coastal ecosystems: Discoveries from four decades of study in San Francisco Bay. Reviews of Geophysics, 50, RG4001, page 21.
[2] San Francisco Estuary Institute (SFEI) (2013) Nutrient Conceptual Model Draft, May 1, 2013, page 14. San Francisco Estuary Institute, Richmond, CA.

3. Monitoring, Modeling, and Embayment Studies

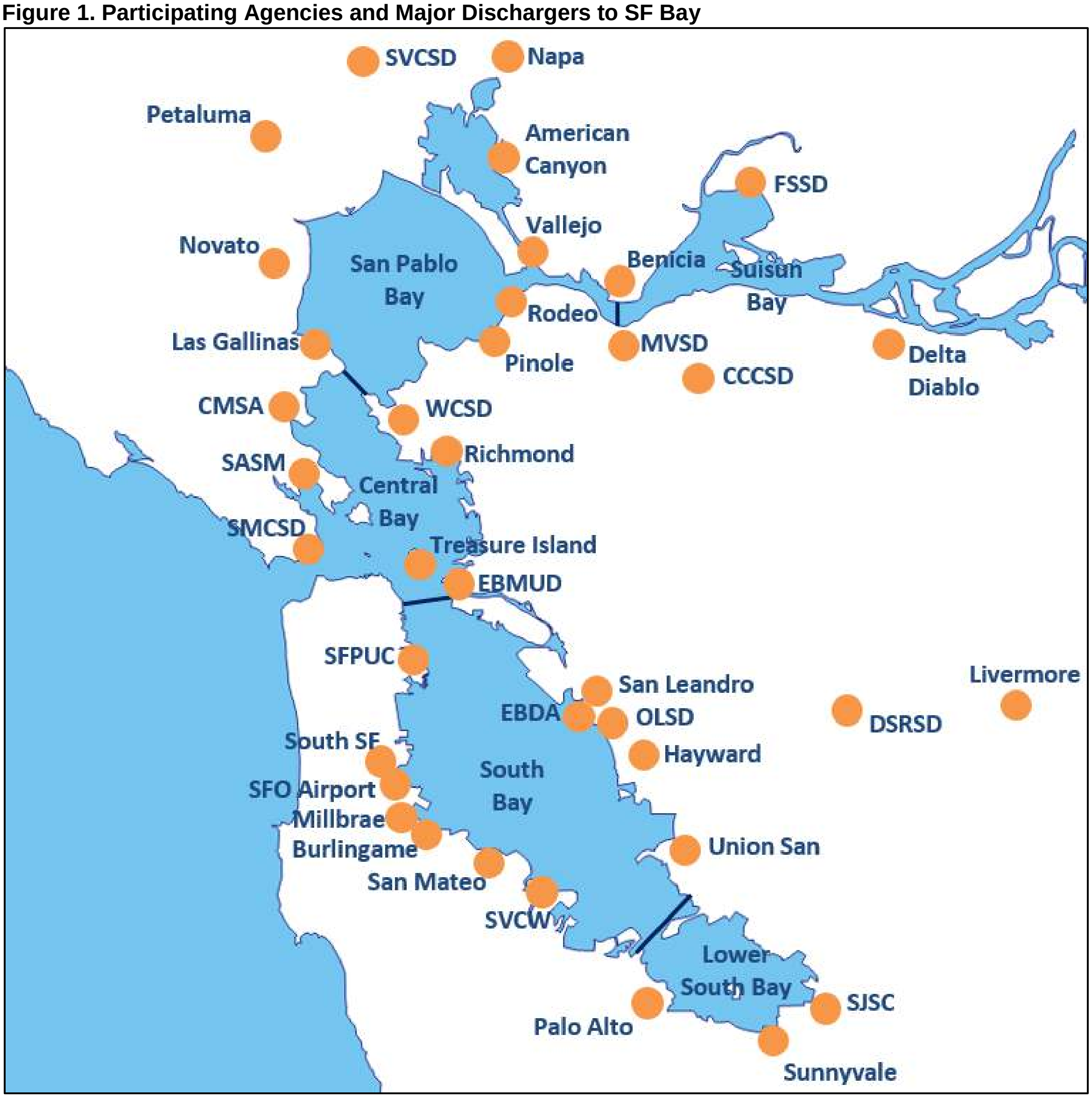
This Nutrient Reduction Study was prepared in response to the first two special provisions listed above. As envisioned by the Watershed Permit, the POTWs are working collectively under the joint powers agency, Bay Area Clean Water Agencies (BACWA), to submit one coordinated study.

The third special provision, Monitoring, Modeling, and Embayment Studies, is being addressed through a separate, parallel effort, being undertaken by the San Francisco Estuary Institute (SFEI).

1.2 Participating Agencies

The Watershed Permit requires major POTW dischargers to participate in the Nutrient Reduction Study. The participating agencies are illustrated in Figure 1.

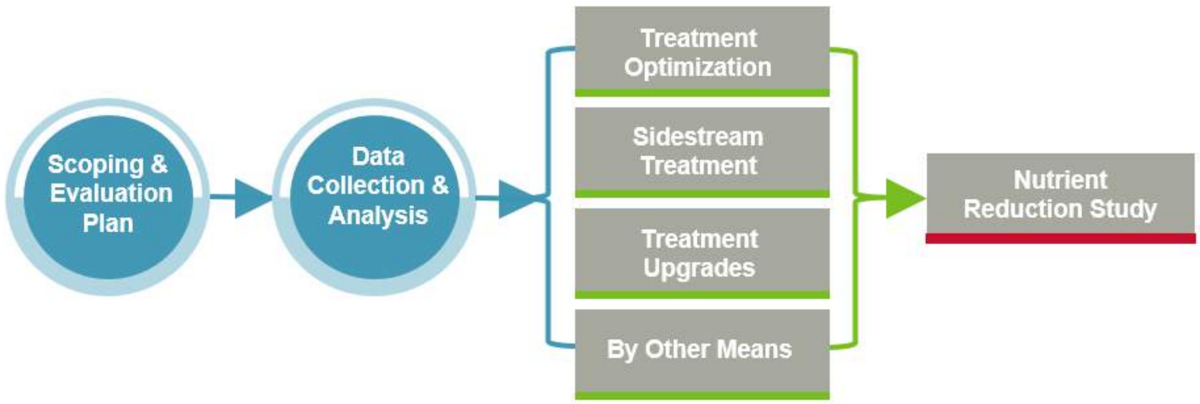
Figure 1. Participating Agencies and Major Dischargers to SF Bay



1.3 Project Approach

Figure 2 illustrates the approach employed for conducting this study, including the four major components which comprise this Nutrient Reduction Study: Treatment Optimization; Sidestream Treatment; Treatment Upgrades; and Nutrient Removal by Other Means.

Figure 2. Project Approach



The Scoping and Evaluation Plan, submitted to the RWQCB in February 2015, established a range of nutrient removal levels, shown in Table 1, which became the basis for the study.

Table 1. Nutrient Removal Levels

Level	Ammonia	Total Nitrogen	Total Phosphorus
Level 1	Varies by Facility	Varies by Facility	Varies by Facility
Level 2	2 mg N/L	15 mg N/L	1.0 mg P/L
Level 3	2 mg N/L	6 mg N/L	0.3 mg P/L

Level 1 does not have established numerical targets, but was established to represent the optimization opportunities where nutrient loads could be reduced as much as possible with relatively minimal capital investment to improve existing facilities.

Levels 2 and 3 were selected based on the typical tipping point for treatment technologies to achieve the respective effluent water quality benchmarks. For most plant configurations, the less stringent Level 2 benchmark can be achieved with conventional nutrient removal processes without adding an external carbon source or effluent filtration. The more stringent Level 3 benchmark typically requires an external carbon source for nitrogen removal and metal salt coagulant addition with filtration for most plant configurations. These factors contribute to a tipping point due to the increase in cost, operational and safety burdens, energy demand, additional solids production, and GHG emissions.

Ammonia levels were established to provide stable ammonia reduction (typically through nitrification). The total nitrogen benchmark of 6.0 mg N/L was selected based on an assessment of the capabilities of conventional nitrogen reduction technologies in the Northern California climate. It is expected that a lower effluent nitrogen concentration would require additional treatment and associated costs.

Total nitrogen and phosphorus typically have seasonal impacts on receiving waters. Thus, the analysis considered both dry season and year round averaging periods.

Following completion of the Scoping and Evaluation Plan, each of the 37 participating agencies was evaluated individually. The evaluation included data collection and synthesis, a site visit and interviews with plant staff, and desktop analyses to develop treatment concepts for the treatment optimization, sidestream treatment and treatment upgrades components of the study. In addition, existing and planned, future methods of reducing nutrients by other means were identified. Appendix D includes the reports that were prepared for each of the 37 participating agencies.

For the purposes of this Nutrient Reduction Study, the recommended upgrades to meet the Level 2 and 3 benchmarks are based on established technologies. Established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. However, there are many emerging technologies that may achieve lower levels of nutrient discharges, be more cost-effective, and/or have other benefits. As a result, innovative and/or emerging technologies were also considered, and at least 2 were identified for plant for future consideration (refer to Appendix D).

1.4 Study Results

A summary of the load reduction that can be achieved with each treatment strategy, including the implementation of treatment optimization, sidestream treatment, and plant upgrades to meet the Level 2 and Level 3 water quality benchmarks, is presented in Table 2. These load reductions, and their associated costs, are based on year round operation of the treatment strategies, where facilities are sized to treat year round flows and loads. For comparison, the estimated total nitrogen reduction that is anticipated through existing and planned recycled water use is approximately 8,900 lb N/d by 2040, which is most comparable to the load reductions achievable through treatment optimization. The associated costs and incremental increase of greenhouse gas emissions are also presented in Table 2.

Overall, the estimated load reductions increase with increasing degrees of treatment, from optimization through Level 3. Implementation of the optimization strategies could result in a load reduction of approximately seven percent for total nitrogen for a short term (approximately 10 years) capital investment of approximately $120M, whereas implementation of sidestream treatment could result in a total nitrogen load reduction of nearly 20 percent for a longer period (approximately 30 years) at a capital cost of nearly $380M. While the load reductions that could be achieved with implementation of the upgrades to meet the Level 2 and 3 benchmarks are substantially more than that for optimization or sidestream treatment, the capital costs are also substantially higher (as illustrated in Figure 3B).

Table 2 also presents three unit cost metrics. The first is the unit present value per gallon of treated capacity ($/gpd), which can be useful in comparing the relative magnitude of present value costs for the wide range of plant capacities (the plants in the study range in capacity from

1.1 to 167 mgd design capacity). Similar to capital costs, the unit present value per gallon of treated capacity increases from optimization through Level 3 (as illustrated in Figure 3C).

Table 2. Summary of Nutrient Load Reduction and Associated Costs, Year Round Operation

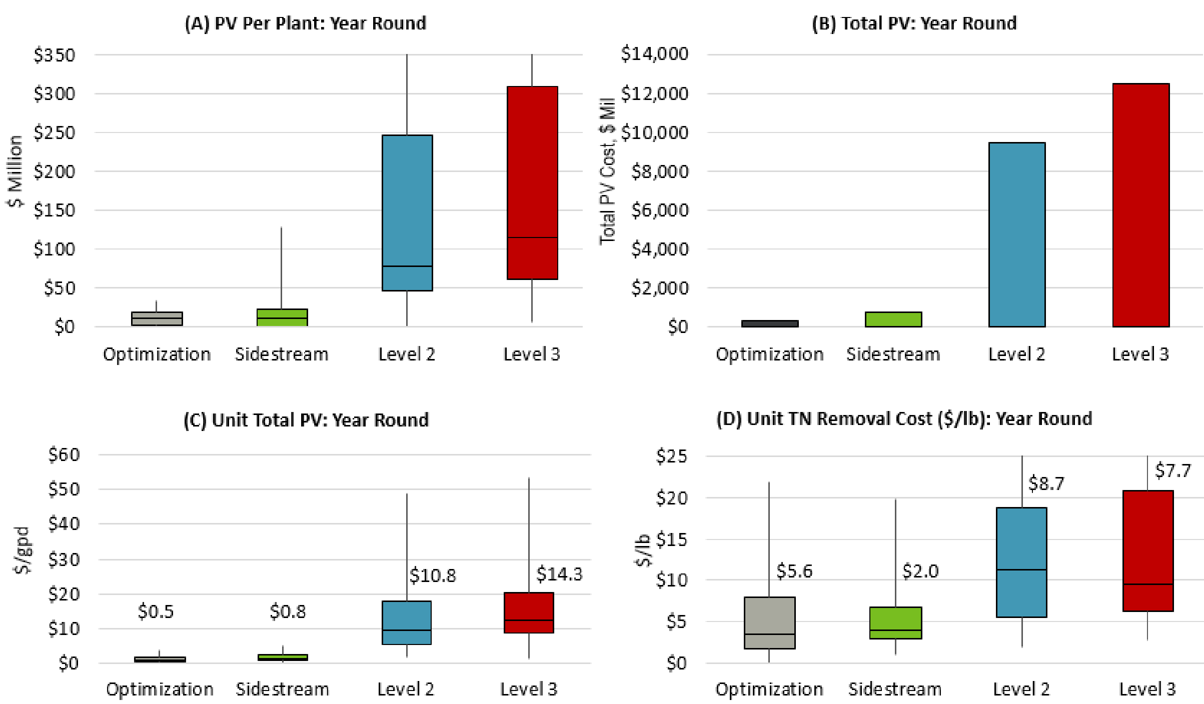
Parameter	Unit	Projected Discharge Load, without Opt.[1]	Projected Discharge Load, without Sidestream or Upgrades[1]	Treatment Strategy			
				Optimization[2]	Sidestream[2]	Level 2[2]	Level 3[2]
Design Flow	mgd	--	--	546	869	869	869
Load Reduction[4]							
Ammonia	lb N/d	87,900	114,700	12,300	27,400	106,900	106,900
TN	lb N/d	129,700	166,300	8,600	32,000	95,000	136,300
TP	lb P/d	9,200	11,900	3,100	1,400	7,000	10,500
Load Reduction							
Ammonia	%	--	--	14%	24%	93%	93%
TN	%	--	--	7%	19%	57%	82%
TP	%	--	--	34%	12%	59%	88%
Costs[4,5]							
Capital	$M	--	--	119	391	6,976	8,517
O&M PV	$M	--	--	147	345	2,443	3,888
Total PV	$M	--	--	266	736	9,420	12,405
Average Unit Costs							
Per gpd[6]	$/gpd	--	--	0.5	0.8	10.8	14.3
Per lb N[7]	$/lb N	--	--	5.6	2.0	8.7	7.7
Per lb P[7]	$/lb P	--	--	8.6	2.8	44	59
Incremental Increase in Greenhouse Gas Emissions							
Total GHG Increase [8]	MT CO_2 eq/yr	--	--	63,100	5,100	257,400	306,900

1. The projected discharge loads are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015) and projected to the midpoint of the respective planning period. The reported flows and loads for optimization, upgrades, and sidestream represent average projected load reduction for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream). Sidestream design flow reflects only the candidate plants.
2. Facilities were sized for year round loads and operated year round. The results for each treatment strategy are stand alone.
3. Load values are rounded to the nearest hundred.
4. Costs are referenced to the ENR SF CCI for January 2018 at 12,015. Costs are not additive for scenarios (e.g., the Level 3 costs shown are inclusive of facilities needed to meet Level 2). Costs do not account for changes in any other process, including solids handling or associated energy requirements.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. Unit cost ($/gpd) was calculated by dividing the total present value by the design flow.

7. Unit cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the projection duration (e.g., for upgrades: Total PV for TN Removal facilities divided by (Average Annual TN Removed times 30-years)).
8. Values are based on increase in energy and chemicals and reflect the average projected incremental increase over the respective period of analysis.

The second unit cost is the cost to remove one pound of total nitrogen ($/lb N removed) and includes only those treatment facilities needed to remove nitrogen (i.e., does not include the capital or O&M costs for treatment elements that are only required for phosphorus removal). Similarly, the third unit cost is the cost to remove one pound of total phosphorus ($/lb P removed). These latter two unit cost metrics can be thought of as a measure of efficiency and used in comparing the cost to remove total nitrogen (or total phosphorus) between plants. This metric could also be useful in identifying the best plant(s) for a regional solution(s) under a nutrient trading scenario. Those plants with the lowest unit cost for nitrogen (or phosphorus) removal would be more desirable than plants with higher unit costs.

Figure 3. Summary of PV Cost per Plant, Total PV, and Unit Costs, Year Round Operation



Notes:
1. Graphs A, C and D are presented as box and whisker plots, where the boxes represents the range of costs falling within the 25th to 75th percentiles, the horizontal bar within the box represents the median cost, and the ends of the whiskers represent the minimum and maximum present value costs, respectively.
2. The maximum value for Level 2 and Level 3 are not illustrated in the box and whisker plots in A and D due to scale. For Figure A, the maximums are $2.7B and $2.9B for Levels 2 and 3, respectively. For Figure D, the maximums are $145 and $41 for Levels 2 and 3, respectively.

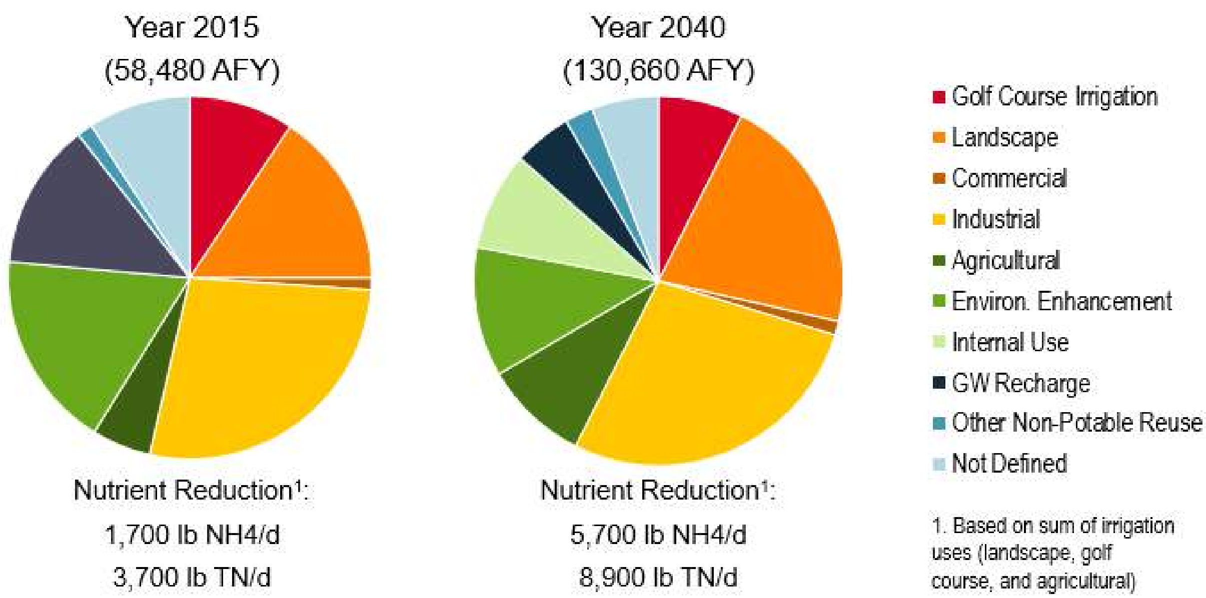
As shown in Table 2, sidestream treatment is the most cost-effective means of reducing both total nitrogen (see also Figure 3D) and total phosphorus, when comparing the cost per pound removed. However, sidestream treatment is not feasible at all plants and there may be site-specific optimization opportunities that are more cost-effective and/or would warrant consideration for other reasons. For example, an agency may wish to first pursue optimization if it is the quickest and easiest way to meet a near term no net load increase requirement or if it addresses other process issues or results in a more stable overall process.

The analysis also evaluated the incremental increase in greenhouse gas (GHG) emissions due changes in energy and chemical demands with the transition from existing secondary treatment to the additional treatment required for nutrient removal. Table 2 shows that GHG emissions increase with more advanced treatment.

Figure 3A illustrates the range of present value costs for the individual plants. The treatment optimization strategies range from less than $1M for some plants to over $40M for San Jose. For sidestream treatment, the range is larger, with some plants having a present value cost of less than $1M compared to over $140M for EBMUD (for total nitrogen removal). The range in costs for the Level 2 and Level 3 upgrades is stark. The present value costs range from as low as $1.3M at American Canyon to achieve the Level 2 benchmark, to as high as $2.6B at EBMUD. To meet the Level 3 benchmark, the present value costs range from $8.9M at the Sonoma Valley plant to nearly $2.9B at the EBMUD plant.

In addition to the treatment optimization, sidestream treatment, and treatment upgrades analyses, the potential nutrient load reduction that could be achieved through other means was also considered. Several potential methods were anticipated, including effluent management (e.g., recycled water use), effluent polishing (e.g., wetlands treatment), source control, and non-point source reduction. For the agencies participating in this Nutrient Reduction Study, the primary method of reducing nutrient effluent loads by other means is through the use of recycled water. Figure 4 illustrates the distribution of existing and future recycled water by use category as well as the estimated nutrient reduction for ammonia and total nitrogen due to recycled water use.

Figure 4. Recycled Water Projections by Use Category



As shown, an estimated 3,700 lb-TN/d was diverted from the bay in 2015 through recycled water use. An additional 5,200 lb-TN/d is anticipated to be diverted by 2040, which is most comparable to the load reduction achievable through treatment optimization, estimated at approximately 8,600 lb N/d. Although the estimated load reduction through recycled water use is less than that achievable through treatment plant improvements, recycled water use has other important benefits for the region.

It is notable that some recycled water use categories do not result in a reduction in nutrient loads discharged to SF Bay. In fact, some uses, such as potable reuse, could increase concentrations discharged to the bay due to the concentrated brine streams created during the advanced treatment processes. Generally, irrigation uses (i.e., landscape, golf course, and agricultural) result in a decrease of nutrient loads since the water is completely consumed at the application site. However, uses such as potable reuse and often times industrial uses, will have a concentrated stream that is either returned to the plant for discharge or otherwise discharged to SF Bay. Thus, with respect to identifying the nutrient reductions associated with future recycled water uses, it is important to understand the type of use anticipated and whether there will be a concentrated return stream that ultimately needs to be discharged.

1.5 Study Limitations

This Nutrient Reduction Study presents high level concepts for implementing nutrient removal at the 37 participating agencies which discharge effluent to the SF Bay. It is a useful tool for gaining a region-wide and subembayment perspective on the relative impacts of treatment options, but should not be used without further study on an individual plant basis. These planning-level concepts were developed to quantify the potential load reduction possible and the associated order of magnitude costs required to implement nutrient removal. The use of parametric cost estimating tools limits site-specific factors. For example, construction with congested sites can often have a cost premium. Such premiums were not captured in this analysis.

Due to the high-level nature of the findings presented herein, if nutrient effluent limits are defined in the future, each agency should undertake its own site-specific study to further evaluate its options, considering both conventional and emerging technologies, and develop more detailed recommendations and costs. Technology selection and overall cost would likely be reduced if future limits included fewer nutrients than considered in this study (ammonia, total nitrogen, and total phosphorus). For example, some facilities may be avoided if, in the future, total phosphorus limits are not implemented. Further, although several emerging technologies could reliably achieve the total nitrogen benchmarks in this study, they may not reliably meet the ammonia benchmarks. As a result, inclusion of ammonia in future nutrient limits could limit the use of some emerging technologies that would have otherwise been beneficial. In addition to technologies, the analysis prepared by each agency should also include further refinement of influent loads, more plant performance data, condition assessment of existing facilities, more detailed consideration of plant hydraulics, plant-specific process modeling, greenhouse gas emissions, solids handling impacts, and future growth within the service area, among other plant-specific factors. Preparation of more detailed cost estimates is also recommended, using plant-specific information (e.g., chemical costs, energy costs, etc.).

1.6 Key Findings and Next Steps

Ultimately, the costs to upgrade treatment plants to achieve the Level 2 and 3 effluent quality benchmarks are substantial. As a result, it is recommended that the other ongoing scientific studies be further developed or completed to provide a better understanding of nutrient processing and confirm whether or not the SF Bay is impaired, and if so, to determine the specific nutrients (and speciation) causing impairment. As that is better understood, appropriate water quality objectives can be established.

It is important to emphasize the impact that permit limits can have on technology selection and facility sizing, and their associated costs, footprint requirements, and GHG emissions. Traditional permit structures for POTWs generally include both monthly and weekly limits on both a concentration and mass basis. This may inadvertently eliminate the most effective watershed solutions to nutrient management by creating disincentives to wastewater dischargers to explore combinations of advanced wastewater treatment and other watershed management practices, such as reuse. Flexible permits, with longer averaging periods and mass-based limits (as opposed to concentration-based limits) will foster innovation and create opportunities for the most creative and economical approaches to managing nutrients.

When the relationship between nutrient loading and water quality responses is not well defined, it is advisable to avoid overly restrictive effluent limits at the outset, since they may later prove unnecessary to meeting actual receiving water needs when they eventually become better understood. Preserving an opportunity for adaptive management approaches to guide the process of nutrient management over time may improve water quality incrementally, without overly restrictive discharge permits that result in over investment in advanced treatment. Permits structured around no net increase in existing loadings, or simple seasonal or annual loading reductions, may provide a foundation for adaptive management.

Once permit requirements are defined, and for the avoidance of doubt, each agency should conduct a thorough facilities planning study to determine the best way to achieve the limits at their respective facility prior to initiating preliminary design, design, and construction. As previously described, the findings presented in this study are based on well-established technologies for the purpose of providing reasonable costs and space requirements for long-term planning. There are many emerging technologies that could be more cost-effective and/or have other benefits that should also be considered.

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2. Introduction

On April 9, 2014 the RWQCB issued Order No. R2-2014-0014, *Waste Discharge Requirements for Nutrients from Municipal Wastewater Discharges to San Francisco Bay* (Watershed Permit). The Watershed Permit became effective on July 1, 2014 and covers each municipal POTW that discharges to SF Bay and its tributaries. The purpose of the Watershed Permit is to track and evaluate treatment plant performance, fund nutrient monitoring programs, support load response modeling, and conduct studies to better understand treatment plant optimization opportunities and upgrade needs to achieve nutrient removal.

This Nutrient Reduction Study was prepared in response to the requirements outlined in the Watershed Permit to conduct studies to evaluate potential nutrient discharge reduction by treatment optimization and sidestream treatment and by treatment upgrades or other means. The following sections describe the study background, the participating agencies, and other permit-required nutrient-related activities, and presents the report organization.

2.1 Background

Nutrients in the SF Bay are a growing concern for the Bay Area water quality community. Historically, the SF Bay has not been adversely impacted by nutrient loading, although there are indications that its historic resilience to the effects of nutrient enrichment may be weakening.[3,4] While the definition of impairment has not been reached, there is concern that the SF Bay has reached a tipping point that might lead to impairment. Numerous scientific studies are being conducted to understand the impact of nutrients on the SF Bay. As a result, it may be necessary to limit the availability of essential nutrients, by implementing some form of wastewater treatment nutrient removal to address three potential challenges:

1. Ammonia toxicity and/or inhibition of phytoplankton growth. Full or partial nitrification may be required.
2. Eutrophication. Denitrification may be required where total inorganic nitrogen is the limiting nutrient.
3. Undesirable phytoplankton assemblage changes due to the ratio of nitrogen to phosphorus. Phosphorus reduction may be required.

The Watershed Permit sets forth a regional framework to facilitate collaboration on studies that will inform future management decisions and regulatory strategies. The permit includes three special provisions to support the further understanding of nutrient loads and their impacts in the SF Bay:

1. Evaluation of Potential Nutrient Discharge Reduction by Treatment Optimization and Sidestream Treatment
2. Evaluation of Potential Nutrient Discharge Reduction by Treatment Upgrades or Other Means
3. Monitoring, Modeling, and Embayment Studies

[3] Cloern, J.E. and Jassby, A.D. (2012).
[4] SFEI (2013).

This Nutrient Reduction Study was prepared in response to the first two special provisions listed above. As envisioned by the Watershed Permit, the POTWs are working collectively under the joint powers agency, Bay Area Clean Water Agencies (BACWA), to submit one coordinated study.

The third special provision, Monitoring, Modeling, and Embayment Studies, is being addressed through a separate, parallel effort, being undertaken by the San Francisco Estuary Institute (SFEI), as described in Section 2.3.

2.1.1 Nutrients and SF Bay

The SF Bay is the largest estuary along the US Pacific coast and its watershed drainage includes about 40 percent of California's land (over 60,000 square miles) and 47 percent of the state's total runoff. The land surrounding SF Bay is home to approximately 7.5 million people while Central Valley supports an additional 6.5 million people.

While commonly referred to as "the Bay", SF Bay is better characterized as a series of connected subembayments, as shown in Figure 1, having distinct physical, chemical, and biological characteristics.[5] Approximately 90 percent of SF Bay's annual freshwater supply enters through the Sacramento-San Joaquin Delta, causing Suisun and San Pablo Bays to (generally) experience the lowest salinities and also have the shortest residence times (days to weeks).[6] Central Bay, the deepest subembayment, receives little direct freshwater input, but exchanges readily with the Pacific Ocean. The Lower South Bay and South Bay receive considerably less freshwater than northern SF Bay and have the longest residences times (weeks to months).[7]

SF Bay receives large inputs of the nutrients nitrogen and phosphorus from anthropogenic sources.[8,9] On a Bay-wide and annual-average basis, effluent from POTWs accounts for over 60 percent of nitrogen loads to SF Bay. In Lower South Bay, South Bay, and Central Bay, POTWs account for over 90 percent of nitrogen loads.

Nitrogen and phosphorus are essential components of a healthy estuary, supporting primary production at the base of the food web. However, ambient nitrogen and phosphorus concentrations in SF Bay exceed those in many other estuarine ecosystems[10], including those that experience nutrient-related impairment, such as excessive phytoplankton blooms and prolonged periods of low dissolved oxygen (DO). Unlike those other nutrient-enriched estuaries,

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[5] Kimmerer, W. (2004) Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses. San Francisco Estuary and Watershed Science, 2(1). Retrieved from https://escholarship.org/uc/item/9bp499mv

[6] Smith S and Hollibaugh JT. (2006) Water, salt, and nutrient exchanges in San Francisco Bay. Limnology and Oceanography. 51. 504-517. 10.4319/lo.2006.51.1_part_2.0504.

[7] Kimmerer 2004; Smith and Hollibaugh, 2006

[8] Cloern, J. E., and A. D. Jassby (2012) Drivers of change in estuarine-coastal ecosystems: Discoveries from four decades of study in San Francisco Bay, *Rev. Geophys.*, 50, RG4001, doi:10.1029/2012RG000397.

[9] SFEI (2014) Scientific Foundation for the San Francisco Bay Nutrient Management Strategy. SFEI Contribution #731.

[10] Cloern and Jassby (2012).

though, SF Bay has exhibited resistance to classic eutrophication symptoms. High turbidity and strong tidal mixing in SF Bay cap light levels available to phytoplankton, leading to low growth rates, and allowing only a small portion of available nutrients to be converted into phytoplankton biomass.[11] During some years and in some regions, large populations of filter-feeding clams also limit phytoplankton accumulation.[12]

Observations over the past decade, though, suggest that SF Bay's resistance to nutrient enrichment is weakening, or that SF Bay is more prone to nutrient-related impacts than previously thought.[13] These observations include:

- A two-fold increase in summer-fall phytoplankton biomass in South Bay since 1999;[14]
- Frequent detections of algal species that form harmful algal blooms (HABs), and frequent detection of the toxins they produce.[15,16,17]
- Evidence of low dissolved oxygen in some sloughs and tidal creeks.[18]

The combination of SF Bay's high nutrient concentrations and potential changes in the environmental factors that regulate nutrient-related responses has generated concern about whether some SF Bay habitats are moving toward experiencing nutrient-related impairment. To address this concern, the RWQCB worked collaboratively with stakeholders to develop the San Francisco Bay Nutrient Management Strategy (refer to Section 2.3), which lays out an approach for gathering and applying information to inform major nutrient management decisions.

2.1.2 Nutrient Loads

Nutrient loads arise from point and nonpoint sources. Point sources are typically from POTWs, which treat municipal wastewater, and treated industrial wastewater resulting from industrial operations, processing, cleaning, and cooling. Municipal Separate Storm Sewer Systems (MS4s) permitted under Phase I and Phase II stormwater National Pollutant Discharge Elimination System (NPDES) are also considered point sources.

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[11] Cloern JE (1999) The relative importance of light and nutrient limitation of phytoplankton growth - a simple index of coastal ecosystem sensitivity to nutrient enrichment: Aquatic Ecology 33(1): 3-16.
[12] Cloern, J.E., (1982) Does the benthos control phytoplankton biomass in south San Francisco Bay? Marine Ecology Progress Series, 9:191-202.
[13] Cloern, J.E., A.D. Jassby, J.K. Thompson, K.A. Hieb, (2007) A cold phase of the East Pacific triggers new phytoplankton blooms in San Francisco Bay, Proceedings of the National Academy of Sciences of the United States of America, 104 (47): 18561-18565.
[14] Cloern et al, (2007).
[15] Sutula M, Kudela, RM, Hagy JD, Harding LW, Senn DB, Cloern JE, Bricker S, Berg, GM, Beck M (2017) Novel analyses of long-term data provide a scientific basis for chlorophyll-a thresholds in San Francisco Bay, *Estuarine, Coastal and Shelf Science* 196:1-12.
Peacock MB, Gibble CM, Senn DB, Cloern JE, Kudela RM (2018) Blurred lines: Multiple freshwater and marine algal toxins at the land-sea interface of San Francisco Bay, California, *Harmful Algae*, 73:138-147.
[16] SFEI (2016) Nutrient Management Strategy Science Program FY16 Annual Report. SFEI Contribution #791.
[17] Peacock MB, Gibble CM, Senn DB, Cloern JE, Kudela RM (2018) Blurred lines: Multiple freshwater and marine algal toxins at the land-sea interface of San Francisco Bay, California, *Harmful Algae*, 73:138-147.
[18] SFEI 2016, 2017.

Nonpoint sources are essentially everything that is not a point source including diffuse agricultural pollutant runoff, as well as urban sources, stormwater runoff from areas not covered by MS4 stormwater permits, groundwater discharges, and atmospheric deposition. "Nonpoint source pollution is considered one of the top threats to the Bay's ecological health and may account for a considerable proportion of the Bay's total pollutant load. The Bay receives 90 percent of its freshwater from the Sacramento and San Joaquin Rivers and 10 percent from the watershed surrounding San Francisco Bay[19]". Since most of the flow is from the Delta, most of the nonpoint source load is also from upstream. "Nonpoint source pollutants transported to the Bay come from Sacramento and San Joaquin Rivers, the Delta and the surrounding watersheds" (SFBCDC, 2003).

Municipal wastewater treatment plants were significantly improved in the late 1970s, reducing the pollutant loads from POTWs. Today, the minimum level of performance is secondary treatment to remove organic matter and solids, but little reduction is made in nutrients as most plants were not designed to remove nutrients. At the secondary treatment level, effluent nutrient discharges are typically about 30 to 35 mg/L total nitrogen and 2 to 3 mg/L total phosphorus. Lower effluent concentrations are possible with the addition of more advanced treatment.

Table 3 presents a summary of the nutrient concentrations discharged to SF Bay from the agencies included in the Watershed Permit.

Table 3. Total POTW Flow and Average Nutrient Concentrations Discharged to SF Bay

Constituent	2012/13	2013/14	2014/15	2015/2016	2016/2017
Flow, mgd	453	434	421	425	510
Ammonia, mg N/L	20	22	23	23	21
TKN, mg N/L	22	25	26	26	23
NOx, mg N/L	8.7	8.8	8.9	8.7	7.4
TN, mg N/L	31	33	35	34	31
Orthophosphate, mg P/L	2.8	2.8	1.9	2.0	1.7
TP, mg P/L	2.3	2.3	2.3	2.4	2.1

1. Data is from the 2017 Group Annual Report, required as part of the Watershed Permit. Data is from July 1 – June 30.

The 2017 Group Annual Report[20] reported the five year annual average total daily nitrogen load discharged by the participating POTWs was approximately 55,600 kg N/d and the total daily phosphorus load was 3,900 kg P/d. A study conducted by Smith and Hollibaugh in 2006,[21] prior to the start of effluent monitoring at POTWs, found that, "Effluent from sewage treatment plants accounts for approximately 50 percent of the nutrient loading to the bay in winter and 80 percent of the summer loading."

[19] SFBCDC (2003) Water Quality Protection and Nonpoint Source Pollution Control in San Francisco Bay. San Francisco Bay Conservation and Development Commission, San Francisco, CA.
[20] BACWA (2017) Group Annual Report, Nutrient Watershed Permit Annual Report, 2017
[21] Smith, S and J.T. Hollibaugh (2006).

2.1.3 Watershed Permit

As described above, this Nutrient Reduction Study was prepared to address two special provisions in the Watershed Permit requiring the evaluation of potential nutrient discharge reduction. The first was to include an evaluation of potential nutrient reduction by treatment optimization and sidestream treatment. The second was to include an evaluation of potential nutrient reduction by treatment upgrades or other means.

For the purpose of preparing this report, the evaluations required by these two special provisions have been combined. The following subsections present a brief summary of the key elements of the special provisions.

OPTIMIZATION OF CURRENT TREATMENT WORKS

This element includes a plant-specific evaluation of alternatives to reduce nutrient discharges through methods such as operational adjustments to existing treatment systems, process changes, or minor upgrades. For example, a plant could implement chemically enhanced primary treatment (CEPT) as means to remove total phosphorus and increase aeration basin capacity for ammonia removal. Optimization strategies are intended to be relatively low- or no-cost improvements that can be implemented quickly. Additional examples include: use of existing, offline tankage to provide additional treatment; modification of operational mode, such as raising the solids residence time (SRT); or operation in split treatment mode.

This element includes consideration of beneficial and adverse ancillary impacts, development of planning level costs, and evaluation of nutrient load reduction.

SIDESTREAM TREATMENT

The sidestream refers to the return streams from biosolids processing, with particular emphasis on the mechanical dewatering return stream for plants with anaerobic digesters. Despite their small flows (typically less than a few percent of plant influent flow), the sidestream typically represents approximately 15 to 25 percent of the total ammonia and total nitrogen from an individual plant.[22] This element of the study includes an evaluation of sidestream treatment opportunities and associated ammonia, total nitrogen, and total phosphorus load reductions, and capital and O&M costs.

TREATMENT UPGRADES

This element of the study considers potential upgrade technologies to reduce effluent nitrogen and phosphorus for each plant. To facilitate this analysis, the Scoping and Evaluation Plan identified nutrient removal levels such that facilities needs could be identified and sized, costs could be evaluated, and greenhouse gas emissions could be quantified. The nutrient removal levels are described in Section 3.1.

This element of the study also includes consideration of beneficial and adverse ancillary impacts, development of planning level capital and operating costs, and evaluation of nutrient load reduction.

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[22] Fux, C and Siegrist, H. (2004) Nitrogen removal from sludge digester liquids by nitrification/denitrification or partial nitritation/anammox: environmental and economical considerations. Water Science & Technology. 50(10):19-26.

REDUCTION BY OTHER MEANS

The Watershed Permit includes a provision to consider other ways to reduce nutrient loading through alternative discharge scenarios, such as water recycling or use of wetlands, in combination with, or in-lieu of, the upgrades to achieve similar levels of nutrient load reductions at the treatment plants. As a result, this study summarizes the results of a survey that was conducted to characterize current and future plans by the participating agencies for water reuse.

SEA LEVEL RISE

In addition to the above described nutrient reduction elements, the Watershed Permit also includes an element related to sea level rise. In accordance with the Scoping and Evaluation Plan (Appendix A), this study identifies participating agencies that are vulnerable to the impacts of sea level rise. For each agency, the impacts of sea level rise were analyzed with respect to the potential for inundation of facilities required to achieve nutrient reduction.

2.2 Participating Agencies

The Watershed Permit requires major POTW dischargers to conduct a Nutrient Reduction Study. A list of major dischargers identified in the Watershed Permit is provided in Table 4 and the location of each discharger is shown in Figure 5.

Table 4. Major Dischargers Included in the SF Bay Watershed Permit

Discharger (Abbreviation)	POTW Facility Name
American Canyon, City of (American Canyon)	Wastewater Treatment and Reclamation Facility
Benicia, City of (Benicia)	Benicia Wastewater Treatment Plant
Burlingame, City of (Burlingame)	Burlingame Wastewater Treatment Plant
Central Contra Costa Sanitary District (CCCSD)	Central Contra Costa Sanitary District Wastewater Treatment Plant
Central Marin Sanitation Agency (CMSA)	Central Marin Sanitation Agency Wastewater Treatment Plant
Delta Diablo (Delta Diablo)	Wastewater Treatment Plant
East Bay Dischargers Authority (EBDA) [City of Hayward (Hayward), City of San Leandro (San Leandro), Oro Loma Sanitary District (OLSD), Castro Valley Sanitary District, Union Sanitary District (Union San), Livermore-Amador Valley Water Management Agency (LAVWMA), Dublin San Ramon Services District (DSRSD), and City of Livermore (Livermore)]	EBDA Common Outfall
	Hayward Water Pollution Control Facility
	San Leandro Water Pollution Control Plant
	Oro Loma/Castro Valley Sanitary Districts Water Pollution Control Plant
	Raymond A. Boege Alvarado Wastewater Treatment Plant
	Livermore-Amador Valley Water Management Agency Export and Storage Facilities
	Dublin San Ramon Services District Wastewater Treatment Plant

Discharger (Abbreviation)	POTW Facility Name
	City of Livermore Water Reclamation Plant
East Bay Municipal Utility District (EBMUD)	East Bay Municipal Utility District, Special District No. 1 Wastewater Treatment Plant
Fairfield-Suisun Sewer District (FSSD)	Fairfield-Suisun Wastewater Treatment Plant
Las Gallinas Valley Sanitary District (Las Gallinas)	Las Gallinas Valley Sanitary District Sewage Treatment Plant
Millbrae, City of (Millbrae)	Water Pollution Control Plant
Mt. View Sanitary District (Mt View)	Mt View Sanitary District Wastewater Treatment Plant
Napa Sanitation District (Napa)	Soscol Water Recycling Facility
Novato Sanitary District (Novato)	Novato Sanitary District Wastewater Treatment Plant
Palo Alto, City of (Palo Alto)	Palo Alto Regional Water Quality Control Plant
Petaluma, City of (Petaluma)	Ellis Creek Water Recycling Facility
Pinole, City of (Pinole)	Pinole-Hercules Water Pollution Control Plant
Rodeo Sanitary District (Rodeo)	Rodeo Sanitary District Water Pollution Control Facility
San Francisco (San Francisco International Airport), City and County of (SFO Airport)	Mel Leong Treatment Plant, Sanitary Plant
San Francisco (Southeast Plant), City and County of (SFPUC Southeast)	Southeast Water Pollution Control Plant
San Jose/Santa Clara Water Pollution Control Plant and Cities of San Jose and Santa Clara (San Jose)	San Jose/Santa Clara Water Pollution Control Plant
San Mateo, City of (San Mateo)	City of San Mateo Wastewater Treatment Plant
Sausalito-Marin City Sanitary District (SMCSD)	Sausalito-Marin City Sanitary District Wastewater Treatment Plant
Sewerage Agency of Southern Marin (SASM)	Sewerage Agency of Southern Marin Wastewater Treatment Plant
Sonoma Valley County Sanitary District (Sonoma Valley)	Municipal Wastewater Treatment Plant
Silicon Valley Clean Water (SVCW)	SVCW Wastewater Treatment Plant
South San Francisco and San Bruno, Cities of (South SF)	South San Francisco and San Bruno Water Quality Control Plant
Sunnyvale, City of (Sunnyvale)	Sunnyvale Water Pollution Control Plant
U.S. Department of Navy (Treasure Island)	Wastewater Treatment Plant

Discharger (Abbreviation)	POTW Facility Name
Vallejo Flood and Wastewater District (Vallejo)[2]	Vallejo Wastewater Treatment Plant
West County Agency (West County) (West County Wastewater District and City of Richmond Municipal Sewer District)	West County Agency Combined Outfall

1. As defined in the Watershed Permit.
2. Formerly known as the Vallejo Sanitation and Flood Control District

Figure 5. Participating Agencies and Major Dischargers to SF Bay

2.3 Related Activities

The San Francisco Bay Nutrient Management Strategy (NMS) Science Program was launched in 2014 to build the scientific foundation to support nutrient management decisions. The NMS Steering Committee, representing 13 stakeholder groups (regulators, dischargers, water purveyors, non-governmental organizations, resource agencies) oversees the NMS' implementation, including financial oversight and alignment of NMS science activities with high priority management questions. SFEI serves as the technical lead on implementing the NMS Science Program (sfbaynutrients.sfei.org), and collaborates with researchers from academia, USGS, and other agencies to carry out NMS projects, including field investigations, monitoring, and data interpretation.

NMS Science Program activities are guided by management questions (shown in Table 5) that tie back to identifying protective nutrient loads for SF Bay habitats and that target priorities laid out in the NMS multi-year Science Plan (SFEI 2016) and related technical reports. The primary technical program areas explored include: nutrient loads and cycling; phytoplankton blooms and DO in deep subtidal habitats; DO in shallow margin habitats; HAB abundance, toxin abundance, and phytoplankton assemblage; and coastal ocean impacts.

Table 5. Nutrient Management Strategy – Management Questions

1. What conditions would be considered adverse impacts or impairments that would require management actions?
2. Monitoring and condition assessment: Are adverse impacts or impairment currently occurring?
3. How do SF Bay habitats respond to nutrient inputs -- dose:response? Are nutrients causing or contributing to current impacts or impairment?
4. What potential future impacts or impairments warrant pre-emptive management actions?
5. What change in conditions (e.g., nutrient loads or nutrient concentrations) would mitigate impacts or impairment in questions 3 or 4?
6. How do individual nutrient sources contribute to ambient concentrations throughout SF Bay as a function of space and time?
7. What management actions or load reductions are needed to prevent or mitigate current or future impairment?

Major NMS focus areas over the past few years include:

- Building and refining the NMS Observation Program
- Developing and applying biogeochemical models
- Developing an assessment framework
- Synthesis and Interpretation of long-term and new datasets

The NMS 2017 Annual Report and 2016 Annual Report provide overviews of recent work. All NMS related work products can be found at sfbaynutrients.sfei.org.

2.4 Report Organization

This Nutrient Reduction Study is organized into eight chapters and five appendices, as follows:

Chapter 1 – Executive Summary

Chapter 2 – Introduction. This chapter describes the study background, the participating agencies and other Watershed Permit-required nutrient-related activities.

Chapter 3 – Basis of Evaluation. This chapter presents the project approach used to develop the strategies and concepts for nutrient reduction through treatment optimization, sidestream treatment, and treatment upgrades. This chapter also presents the common approach for preparing cost estimate and evaluating greenhouse gas emissions. The methodology for evaluating sea level rise is introduced and study limitations are described.

Chapter 4 – Nutrient Reduction Findings. This chapter presents a summary of the findings for the treatment optimization, sidestream treatment and treatment upgrades analyses, as well as a comparison of the three.

Chapter 5 – Nutrient Reduction by Other Means. This chapter describes the assessment of nutrient reduction by other means assessment.

Chapter 6 – Sea Level Rise. This chapter presents the results of the sea level rise analysis that was conducted to identify plants that may be vulnerable to the impacts of sea level rise.

Chapter 7 – Discussion and Observations. This chapter summarizes the key observations of this Nutrient Reduction Study with respect to water quality objectives, averaging periods, permit structures, constrained sites, technology selection, GHG emissions, and factors influencing capital costs.

Chapter 8 – Summary and Next Steps. This chapter summarizes the results and findings of the study and describes next steps that agencies should take.

Appendices

A. Scoping and Evaluation Plan
B. Basis of Cost Estimates
C. Sea Level Rise Methodology
D. Individual Plant Reports
E. Agency Acceptance Letters

2.5 Acknowledgements

During the development of this Nutrient Reduction Study, the project team received invaluable assistance and cooperation from each of the participating agencies and their respective staff. We gratefully acknowledge the members of the Contract Management Group, listed below, for their guidance and active participation, as well as the BACWA Executive Board. In addition, the study was conducted in close collaboration with the EPA Regional Sidestream Grant Project executed by EBMUD.

The BAWCA Contract Management Group included the following (listed alphabetically by agency name):

- David Williams, PE (BACWA)
- Lorien Fono, PE (BACWA)
- Nitin Goel, PE (Central Contra Costa Sanitary District)
- Jean-Marc Petit, PE (Central Contra Costa Sanitary District)
- Lori Schectel (Central Contra Costa Sanitary District)
- Amanda Roa, PE (Delta Diablo)
- Mike Connor, PhD (East Bay Dischargers Authority)
- Eileen White, PE (East Bay Municipal Utility District)
- Yun Shang, PhD, PE (East Bay Municipal Utility District)
- Greg Baatrup, PE (Fairfield-Suisun Sewer District)
- Jason Warner, PE (Oro Loma Sanitary District)
- Amy Chastain (San Francisco Public Utilities Commission)
- Stephanie Harrison (San Francisco Public Utilities Commission)
- Jim Ervin (Cities of San Jose-Santa Clara)
- Theresa Herrera (Silicon Valley Clean Water)
- Bhavani Yerrapotu, PE (City of Sunnyvale)

2.6 Abbreviations

The following abbreviations are used in this study:

AA	average annual
ADWF	average dry weather flow
AFY	acre-feet per year
AOB	ammonia-oxidizing bacteria
BACC	Bay Area Chemical Consortium
BACWA	Bay Area Clean Water Agencies
BAF	biological aerated filter
BNR	biological nutrient removal
BOD	biological oxygen demand
$CaCO_3$	calcium carbonate
CARB	California Air Resources Board
CBOD	Carbonaceous Biochemical Oxygen Demand
CCCSD	Central Contra Costa Sanitary District
CEC	cation exchange capacity

CEPT	chemically enhanced primary treatment
CFR	Code of Federal Regulations
CIP	capital improvement program or plan
CMG	contract management group
CMSA	Central Marin Sanitation Agency
DO	dissolved oxygen
DSRSD	Dublin San Ramon Services District
EBDA	East Bay Dischargers Authority
EBMUD	East Bay Municipal Utilities District
ENR SF CCI	Engineering News Record San Francisco Construction Cost Index
EPA	US Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FSSD	Fairfield-Suisun Sewer District
GHG	greenhouse gas
gpd	gallon per day
HAB	harmful algal bloom
IFAS	integrated fixed film activated sludge
IPCC	Intergovernmental Panel on Climate Change
kWh	kilowatt hour
lb/d	pounds per day
LAVMA	Livermore-Amador Valley Water Management Agency
MABR	membrane aerated biofilm reactor
MBBR	moving bed biofilm reactor
MBR	membrane bioreactor
mg/L	milligrams per liter
mgd	million gallons per day
MLE	Modified Ludzack-Ettinger
MM	maximum month
MT CO_2 eq/yr	metric tonnes of carbon dioxide equivalents per year
N	nitrogen
NMS	San Francisco Bay Nutrient Management Strategy

NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NTF	nitrifying trickling filter
O&M	operation and maintenance
OLSD	Oro Loma Sanitary District
P	phosphorus
PG&E	Pacific Gas & Electric
PV	present value
POTW	publicly owned treatment works
RWQCB	Regional Water Quality Control Board
SASM	Sewerage Agency of Southern Marin
SBR	sequencing batch reactor
SF Bay	San Francisco Bay
SFEI	San Francisco Estuary Institute
SFPUC	San Francisco Public Utilities Commission
SMCSD	Sausalito-Marin City Sanitary District
SND	simultaneous nitrification and denitrification
SON	soluble organic nitrogen
SOP	soluble organic phosphorus
SRT	solids retention time
SVCW	Silicon Valley Clean Water
TKN	Total Kjeldahl Nitrogen
TMDL	total maximum daily load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	total suspended solids
Union San	Union Sanitary District
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	ultraviolet

WCSD	West County Wastewater District
WERF	Water Environment Research Foundation
WPCP	water pollution control plant
WRRF	water resource recovery facility
WWTP	wastewater treatment plant
y	year

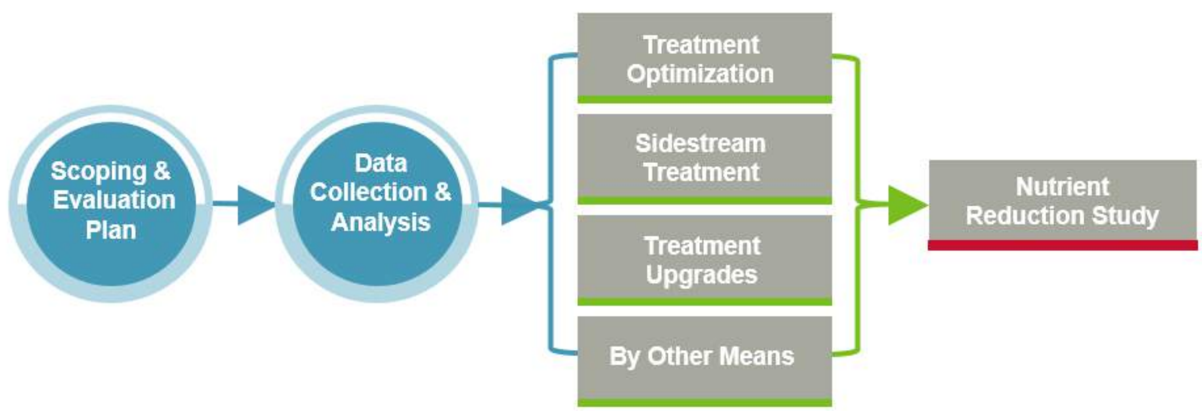
3. Basis of Evaluation

This chapter presents the project approach used to develop the strategies and concepts for nutrient reduction through treatment optimization, sidestream treatment, and treatment upgrades. The approach to documenting nutrient reduction by other means is also described. In addition, the basis of evaluation includes assumptions with respect to the computation of greenhouse gas (GHG) emissions, cost estimates, and sea level rise. Through the application of a uniform set of planning assumptions, strategies and concepts were developed in a consistent manner for all POTWs to allow comparison and evaluation of the resulting load reductions and costs.

3.1 Project Approach

The general approach to the Nutrient Reduction Study is presented in Figure 6. In addition to the Scoping and Evaluation Plan and data collection and analysis, the approach includes preparation of four major components that comprise this Nutrient Reduction Study: Treatment Optimization; Sidestream Treatment; Treatment Upgrades; and Reduction by Other Means. The following subsections describe the major elements of the approach.

Figure 6. Project Approach



3.1.1 Scoping and Evaluation Plan

The Scoping and Evaluation Plan, submitted to the RWQCB in February 2015 and included as Appendix A, describes the approach for conducting the study. A key component of the plan was the establishment of a range of nutrient removal levels that would become the basis for the study. The nutrient removal levels are presented in Table 6.

Table 6. Nutrient Removal Levels

Level	Ammonia	Total Nitrogen	Total Phosphorus
Level 1	Varies by Facility	Varies by Facility	Varies by Facility
Level 2	2 mg N/L	15 mg N/L	1.0 mg P/L
Level 3	2 mg N/L	6 mg N/L	0.3 mg P/L

Level 1 does not have established numerical targets, but was established to represent the optimization opportunities where nutrient loads are reduced as much as possible with minimal capital investment to improve existing facilities.

Levels 2 and 3 were selected based on the typical tipping point for treatment technologies to achieve the respective effluent water quality benchmarks. For most plant configurations, the less stringent Level 2 benchmark can be achieved with conventional nutrient removal processes without adding an external carbon source or effluent filtration. The more stringent Level 3 benchmark typically requires an external carbon source for nitrogen removal and metal salt coagulant addition with filtration for most plant configurations. These factors contribute to a tipping point due to the increase in cost, operational and safety burdens, energy demand, additional solids production, and GHG emissions.

Ammonia levels were established to provide stable ammonia reduction (typically through nitrification). The total nitrogen benchmark of 6.0 mg N/L was selected based on an assessment of the capabilities of conventional nitrogen reduction technologies in the Northern California climate. It is expected that a lower effluent nitrogen concentration would require additional treatment and associated costs.

Total nitrogen and phosphorus typically have seasonal impacts on receiving waters. Thus, the analysis considered both dry season and year round averaging periods. The dry season is defined as May 1 to September 30.

3.1.2 Data Collection and Analysis

Following completion of the Scoping and Evaluation Plan, the data collection and analysis phase of the study began, which included four questionnaires for the utilities, as well as site visits at each plant.

QUESTIONNAIRE 1 – PLANT PERFORMANCE

The first questionnaire focused on gathering information related to plant wide performance, including influent and effluent water quality, plant process and site layout, major unit processes, annual energy and chemical usage, and existing permit requirements.

QUESTIONNAIRE 2 – SIDESTREAM TREATMENT

The purpose of the sidestream treatment questionnaire was to identify which plants were potential candidates for sidestream treatment and specifically sought information related to existing solids handling facilities and their operation.

QUESTIONNAIRE 3 – RECYCLED WATER

The recycled water questionnaire was used to summarize existing and planned future recycled water use to better estimate nutrient loads diverted from SF Bay through water recycling. Consistent with existing state requirements to project future recycled water use, the questionnaire requested estimates of future recycled water production/use through 2040 in five year increments as well as the anticipated type of use (e.g., landscape, industrial, etc.).

QUESTIONNAIRE 4 – CAPITAL IMPROVEMENT PLANS

The capital improvement questionnaire was used to gather information about planned capital improvement projects and costs related to nutrient removal, including secondary treatment and recycled water projects. The objective was to identify planned projects that could reduce nutrient discharge loads.

PLANT SITE VISITS

Following the review and synthesis of the data collected from the questionnaires, two-person teams conducted site visits to each participating plant. The purpose of the site visits was to confirm the understanding of existing plant operations, validate chemical usage, discuss data gaps, and review potential concepts for optimizing plant operation to achieve greater nutrient removal. The optimization strategies were discussed with plant operations staff, and often included alternate flow routing, chemical dosing, and aeration strategies.

A facility evaluation memorandum was prepared to summarize basic facility information, current conditions, site layout, major unit processes, and potential optimization strategies and upgrade requirements to meet the Level 2 and 3 benchmarks. Then, following review by each agency, respectively, the detailed analyses for treatment optimization, sidestream treatment, and treatment upgrades were initiated.

3.1.3 Treatment Optimization

The objective of this element of the Nutrient Reduction Study was to review the current facilities and operations at each POTW and, in collaboration with plant staff, identify potential strategies to optimize current operations to achieve nutrient removal, to the extent possible.

The treatment optimization strategies are based on each individual plant's documented plans for future growth for the 10-year period between 2015 and 2025. For plants without documented growth projections, a 15 percent increase in BOD and nutrient loadings was assumed for the 10-year period with no increase in flows. A 10-year planning period was selected because optimization strategies are considered an interim solution because most strategies require the use of existing, yet-to-be required treatment capacity (i.e., facilities not needed to meet the current load but which may be required to treat the future design load).

The following treatment optimization strategies were considered for each plant:

- Use offline tankage
- Operate in split treatment mode
- Modify operational mode (e.g., raise SRT)
- Modify blower operating set points
- Shut down aeration to create anoxic zones
- Process control instrumentation (e.g., for ammonia based aeration control)

- Add additional chemicals (e.g., add coagulant for phosphorus removal, or to reduce load and unlock downstream capacity)
- Add anoxic and/or anaerobic zones for biological nutrient removal (BNR)
- Add internal recycle for denitrification
- Add mixers for un-aerated zones

The potential feasibility of these strategies was discussed with facility staff during the site visits and those with the greatest potential for success were further evaluated. The evaluation considered potential capital investments and complexity of operation, among other factors. Based on the evaluation, the best strategy, or combination thereof, was further developed. Facility changes and layouts were prepared and nutrient load reductions were estimated. In addition, capital and O&M costs were developed, ancillary benefits and impacts were identified, and the incremental increase (if any) in GHG emissions was quantified.

3.1.4 Sidestream Treatment

Sidestream treatment is a cost effective way to reduce effluent nutrient loads because the sidestream is typically a nutrient rich, low flow stream that can be treated with relatively small sized treatment processes. However, not all plants are candidates for sidestream treatment.

The sidestream treatment strategies are based on each individual plant's ADWF permitted capacity for a 30 year period. A 30 year planning period was selected because sidestream treatment is viewed as a capital improvement project.

Sidestream data collection occurred in two parts. First, a questionnaire was submitted to participating BACWA members that requested historical plant data and relevant operational information. The initial questionnaire was distributed to all 37 participating POTWs that requested historical plant performance data, a description of discharge requirements and general POTW information, and a list of existing assets. This information was used to identify potential candidate POTWs for sidestream treatment using a structured approach.

Following compilation of information, a subsequent sampling request and questionnaire was issued to POTWs initially identified as potential candidates for sidestream treatment (32 out of 37 POTWs). The sampling request included three separate sampling events in July 2015 to better understand sidestream flows and loads. In addition to sampling, information was gathered about existing solids handling operations (e.g., dewatering frequency) to further identify suitable POTWs for sidestream treatment.

The suitability of a sidestream flow for nitrogen removal and the types of treatment available are heavily dependent on solids handling, particularly with regard to dewatering equipment and operation. The following information was considered in determining suitability:

- Dewatering equipment type and size
- Biosolids dewatering feed rate

- Washwater added, if applicable (for belt filter press)
- Digester feed flow for plants that add washwater to the dewatering equipment
- Dewatering operation schedule for selecting an appropriate sidestream treatment technology and the corresponding facility needs
- Sidestream temperature

For sidestream treatment to be viable, the following criteria were required:

- Year round sidestream flow: Biological nitrogen removal requires a steady, nutrient-rich flow to maintain the microbial population necessary for treatment. A seasonal sidestream flow is not appropriate as it disrupts the biological process.
- A dewatering frequency of at least four days per week: Dewatering operation must be frequent enough to limit the amount of equalization volume needed to produce a steady flow.

Two nitrogen removal technologies were considered for sidestream treatment, including deammonification and conventional nitrification. Deammonification was the preferred method of sidestream treatment due to its well documented energy and chemical savings. However, the deammonification process requires a relatively high temperature in the feed flow (e.g., 25 to 35 degrees C preferred). Thus, conventional nitrification was recommended when sidestream water temperatures were comparable to ambient air temperatures, where dewatering operation is limited to four or five days per week, or where the dewatering technology uses considerable backwash water. In all other cases, deammonification was selected as the recommended technology.

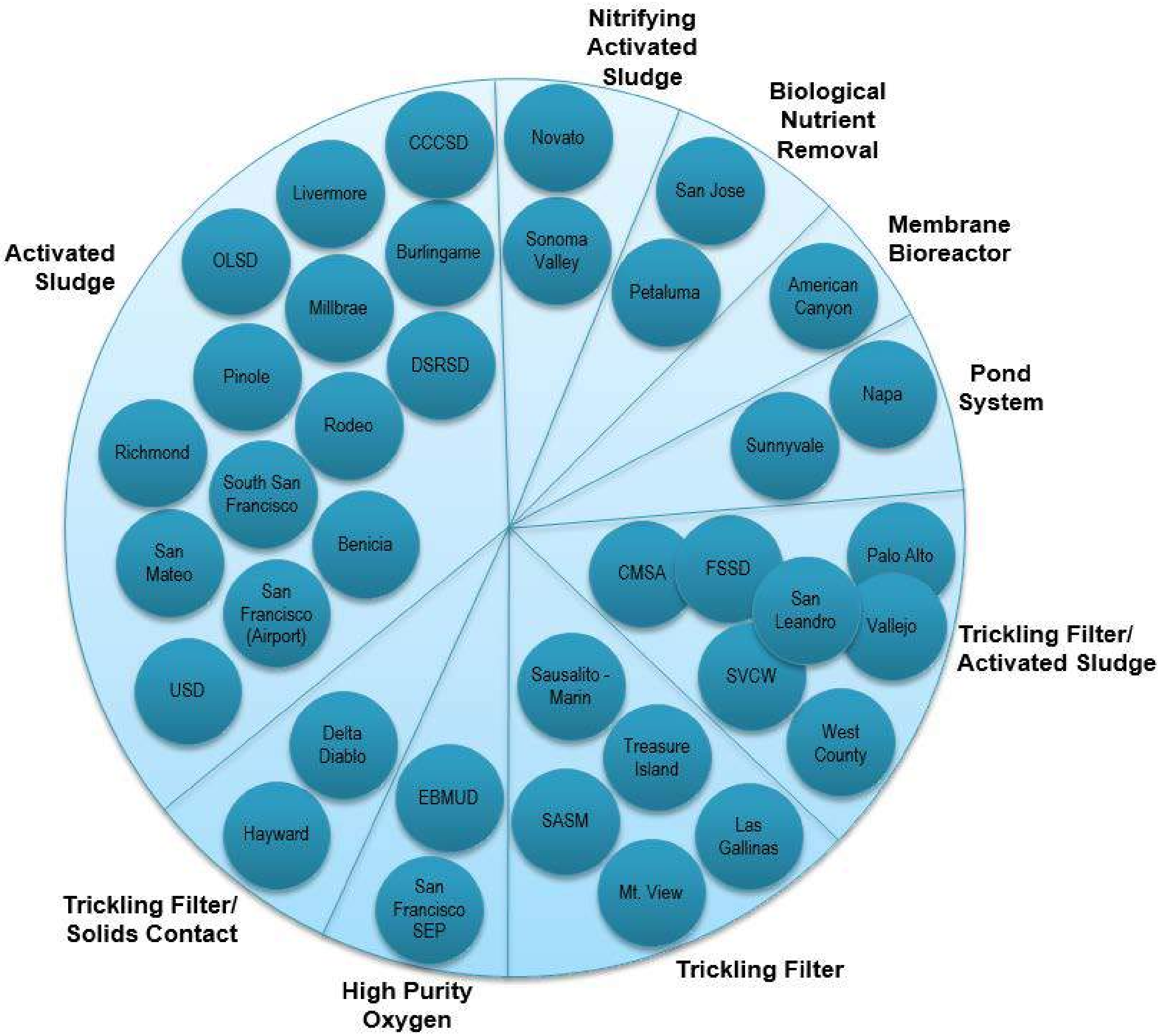
The sidestream treatment of phosphorus typically relies on either chemical precipitation using metal salts or phosphorus recovery through struvite precipitation. There are two commonly used phosphorus removal and recovery technologies for sidestream phosphorus reduction. For candidate plants, the evaluation considered either conventional phosphorus removal by metal salts and settling, or phosphorus recovery (typically struvite precipitation technology) for plants using biological phosphorus removal.

Once the appropriate technology was selected for each of the candidate plants, facilities needs and layouts were prepared and nutrient load reductions were estimated. In addition, capital and O&M costs were developed, ancillary impacts and benefits were identified, and the incremental increase in GHG emissions was quantified.

3.1.5 Treatment Upgrades

The objective of this element of the study was to identify an appropriate treatment technology and the associated facilities required to meet the Level 2 and 3 water quality benchmarks described in Table 6. To facilitate conservative, long-range planning, the treatment technologies considered for this study were based on conventional nutrient removal technologies that would work well with each plant’s existing secondary treatment process. A summary of the existing secondary treatment process for each plant is presented in Figure 7 and the list of treatment technologies that were considered to meet the Level 2 and 3 water quality benchmarks is presented in Table 7.

Figure 7. Classification of Existing Secondary Processes for Participating POTWs



In determining upgrade requirements, each plant was evaluated based on existing infrastructure and plant site space constraints, and new facilities were sized to treat the plant's design condition (i.e., design flow and load). Existing infrastructure was incorporated into the recommended upgrade strategies as much as possible. Available space was a key factor in technology selection. For example, a membrane bioreactor (MBR) would be required for a facility with limited available space, whereas a facility with ample available space could entertain a wider variety of larger footprint technology options.

Table 7. Technologies Considered for Ammonia, Nitrogen, and Phosphorus Removal

Level 2 Technologies	Level 3 Technologies[1]
Nitrifying Technologies	
Nitrifying air activated sludge	Level 2 meets Level 3 ammonia benchmarks
Integrated fixed film activated sludge (IFAS)	
Membrane bioreactor (MBR)	
Nitrifying trickling filter (NTF)	
Biological aerated filter (BAF)	
Oxidation ditch	
Nitrogen Removal Technologies	
Modified Ludzack-Ettinger (MLE)	4-stage Bardenpho[2]
Denitrification filter[2]	Denitrification filter[2]
Moving bed biofilm reactor (MBBR)[2]	MBBR[2]
Step feed activated sludge	Oxidation ditch
Oxidation ditch	
Phosphorus Removal Technologies	
Oxidation ditch	Direct filtration[3]
2-stage Phoredox (P only)	Sedimentation/filtration[3]
3-stage Phoredox	Membrane filtration[3]
5-stage Bardenpho (both N and P)	
Chemical[3] addition to primary clarifiers	
Chemical[3] addition to aeration basin	
Tertiary chemical[3] addition/solids removal	

1. Level 3 technologies are considered in addition to or expansion of Level 2 technologies.
2. Carbon source may be required (e.g. methanol)
3. Metal salt or other chemical added

Upgrade strategies were devised such that the technology and associated facilities recommended to meet the Level 2 water quality benchmark could be expanded upon to meet the Level 3 benchmark. This approach avoids situations where infrastructure constructed to meet a Level 2 benchmark would subsequently become stranded assets if a future Level 3 benchmark was later required within the facility's lifespan. While this can add some additional cost for the Level 2 facilities, it is a more conservative approach and is consistent with typical engineering practice to stage improvements in logical increments.

Once an appropriate technology was selected to achieve the Level 3 benchmarks, the required facilities and layouts were prepared for both Level 2 and 3 and nutrient load reductions were estimated. Then capital and O&M cost estimates were prepared for each. In addition, ancillary impacts and benefits were identified and the incremental increase in GHG emissions was quantified.

3.1.6 Reduction by Other Means

While the treatment optimization, sidestream treatment and treatment upgrade analyses focus on concepts that would be implemented within the plant, there are other ways to reduce the effluent nutrient loads discharged to SF Bay. Other means of nutrient reduction include:

- Effluent Management: Nutrient trading, water recycling and reuse
- Effluent Polishing: Wetlands treatment (e.g., Hayward Marsh. Horizontal Levee or Ecotone Project, etc.)
- Source Control: Septic source abatement, urine separation, elimination of phosphorus from some consumer products (e.g., phosphorus bans in lawn fertilizer and dish detergent because of state legislation, etc.)
- Non-Point Sources: Non-point source reduction programs, load trading and offsets, etc.

The approach for this element of the study relied on feedback from each of the participating agencies. As previously described, questionnaires were used to solicit information regarding planned capital improvement projects that could impact nutrient removal as well as existing and future recycled water use. The information gathered from these questionnaires formed the basis for the information presented in this Nutrient Reduction Study.

3.1.7 Greenhouse Gas (GHG) Emissions

GHG emissions were evaluated for the recommended treatment optimization, sidestream treatment, and treatment upgrades. The GHG emissions evaluation is focused on the incremental increase in GHG emissions associated with the recommendations (i.e., does not include current emissions).

The GHG emissions accounting methodology considers the operating energy and chemical demand for the recommended treatment strategies. The approach relies on the USEPA eGRID values[23] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/y) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

3.1.8 Sea Level Rise

The Watershed Permit also requires consideration of the potential impacts of sea level rise on nutrient removal facilities. The intent of the requirement was to avoid identifying nutrient removal options that would be infeasible due to actions implemented or planned to address sea level rise. As a result, the plants that are vulnerable to the impacts of sea level rise were identified. The methodology, described in detail in Appendix C, is based on publicly available data from the United States Army Corps of Engineers (USACE), the Federal Emergency Management Agency (FEMA), and publicly available topography data.

The location of each POTW was determined and a representative ground surface elevation was identified and used to compare against water surface elevations. FEMA's Flood Insurance Rate Maps (FIRMs) were used to determine if the POTW is already within the one-percent annual

[23] http://www.epa.gov/cleanenergy/energy-resources/egrid/

chance (100-year) floodplain. Then, the USACE Sea Level Change Curve Calculator[24] was used to determine the projected water surface elevation due to sea level rise for low, intermediate, and high rise scenarios over the next 30, 50, and 100 years. The water surface elevations were then compared to the ground surface elevation to identify those POTWs that could be impacted by sea level rise.

Recognizing that there are many related studies, opinions, and ongoing work related to sea level rise, the USACE calculator was selected, and employed consistently for each of the 37 POTWs, because the USACE is a highly recognized federal agency responsible for designing and constructing flood control structures throughout the United States, including throughout the SF Bay.

The methodology employed in this study has certain limitations. For example, one point elevation was used to represent the respective elevation for each plant and some areas of the plant could be at higher or lower elevations. The methodology does not account for other, non-certified flood protection structures, such as existing embankments or coastal dikes. Nor does the methodology consider the future protection that would be provided by flood protection projects currently in the planning or design phase. Thus, it is important to note that while many agencies have identified their vulnerabilities with respect to coastal flooding and sea level rise, and may have projects underway to address it, those projects are not necessarily reflected in the findings of this study.

In addition, the analysis performed for this Nutrient Reduction Study is focused on the potential impacts to the treatment plant sites. There are many other wastewater-related facilities that could be impacted by sea level rise, such as piping and sewage lift stations within the collection system (particularly those in low lying areas which could become more susceptible to sea water intrusion) and effluent discharge facilities. With respect to the latter, sea level rise could impact the hydraulics and capacity of effluent pump stations and pipelines. Sea level rise could potentially result in additional pumping requirements to discharge effluent, increasing both energy requirements and associated costs.

3.2 Basis of Cost Estimates

The approach to developing the estimated capital and O&M costs for treatment optimization, sidestream treatment, and treatment upgrades was consistent for each of the 37 POTWs included in this Nutrient Reduction Study, as described further in Appendix B.

A parametric cost analysis was used to estimate the construction costs for each facility. The planning level estimates are considered accurate within a range of -25 percent to +50 percent. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. An additional 15 percent contingency was added to the capital cost to reflect the current bidding climate in the SF Bay Area.

[24] http://www.corpsclimate.us/ccaceslcurves.cfm

The incremental increase in O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. Unit chemical costs can be volatile (e.g., agencies are reporting ferric chloride unit cost increases of greater than 10 percent over the last year). In addition, equipment replacement costs were included for major equipment items that would require replacement during the planning period, such as membranes for membrane bioreactors.

The capital and O&M costs are presented in current dollars, referenced to the construction cost index prepared by the Engineering News Record for San Francisco (ENR SF CCI) for January 2018 at 12,014.72. For simplicity, the value has been rounded to 12,015 throughout this study.

Present value costs were developed based on the discount rate and respective period for each scenario, as shown in Table 8.

Table 8. Assumptions for Life Cycle Cost Analysis

Scenario	Discount Rate[1]	Period (yr)
Optimization	2%	10
Sidestream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

1. A 2% discount rate was used assuming a 5% interest rate minus a 3% inflation rate.

In order to understand the relative costs for each of the 37 POTWs, the present value costs are also expressed as unit costs:

- Unit present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus. The cost per gallon is based on the design flow and is calculated as the total present value divided by design flow.
- Unit cost for total nitrogen and total phosphorus reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project. The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the present value divided by the average nutrient load reduction over the design period.
  - Unit costs for total nitrogen reduction were estimated based only on the cost elements that contribute to total nitrogen removal (e.g., expansion of activated sludge basins). The unit cost is calculated as the total present for total nitrogen removal facilities divided by the average annual total nitrogen removed times 30-years.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus (e.g., metal salt coagulant at primary clarifiers). The unit cost is calculated as the total present for total phosphorus removal facilities divided by the average annual total phosphorus removed times 30-years.

Unless specifically noted with a table or figure, all cost information presented in this Nutrient Reduction Study is based on year round facility design parameters and year round operation.

3.3 Study Limitations

This Nutrient Reduction Study presents high level concepts for implementing nutrient removal at the 37 participating agencies which discharge effluent to the SF Bay. It is a useful tool for gaining a region-wide and subembayment perspective on the relative impacts of treatment options, but should not be used without further study on an individual plant basis. These planning-level concepts were developed to quantify the potential load reduction possible and the associated order of magnitude costs required to implement nutrient removal. The use of parametric cost estimating tools limits site-specific factors. For example, construction with congested sites can often have a cost premium. Such premiums were not captured in this analysis.

Due to the high-level nature of the findings presented herein, if nutrient effluent limits are defined in the future, each agency should undertake its own site-specific study to further evaluate its options, considering both conventional and emerging technologies, and develop more detailed recommendations and costs. Technology selection and overall cost would likely be reduced if future limits include fewer nutrients than considered in this study (ammonia, total nitrogen, and total phosphorus). For example, some facilities may be avoided if total phosphorus limits are not implemented. Also, although several emerging technologies could reliably achieve the total nitrogen benchmarks in this study, they may not reliably meet the ammonia benchmarks. As a result, inclusion of ammonia in future nutrient limits could limit the use of some emerging technologies that could have otherwise been preferred. In addition to technology selection, the analysis undertaken by each agency should also include further refinement of influent loads, more plant performance data, condition assessment of existing facilities, more detailed consideration of plant hydraulics, plant-specific process modeling, greenhouse gas emissions, solids handling impacts, and future growth within the service area, among other plant-specific factors. Preparation of more detailed cost estimates is also recommended, using plant-specific information (e.g., chemical costs, energy costs, etc.).

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4. Nutrient Reduction Findings

The following sections present a summary of the findings for the treatment optimization, sidestream treatment and treatment upgrades analyses, as well as a comparison of the three.

4.1 Treatment Optimization

The optimization of existing facilities could be a potential first step toward nutrient reduction by taking advantage of existing facilities and/or capacity on site, changing process approaches, or improving instrumentation.

Many plants are already achieving some effluent nutrient removal. In some cases, the treatment is intentional; for example, all three plants in the Lower South Bay each have ammonia effluent limits and have a nitrification process in place to achieve those limits. More interestingly, there are plants that are achieving some nutrient reduction due to existing treatment processes that may have been implemented for other reasons (i.e., the nutrient removal is an unintended ancillary benefit).

Eleven plants already have full nitrification. Of those, seven plants currently meet the Level 2 total nitrogen benchmark (15 mg N/L) and two meet the Level 3 total nitrogen benchmark (6 mg N/L). In addition, approximately two-thirds of the raw influent total phosphorus loads are being removed. Three plants reliably meet the Level 2 effluent benchmark (1 mg P/L) and an additional six nearly meet the Level 2 total phosphorus benchmark, with values ranging between 1 and 2 mg P/L.

As previously mentioned, there are also situations where nutrients are being removed “opportunistically”. For example, some plants employ metal salt coagulants that opportunistically precipitate soluble reactive phosphorus, others have anaerobic selectors for enhanced settling in their secondary clarification process that opportunistically foster biological phosphorus removal. The optimization analysis considered ways to enhance existing performance, regardless of whether nutrient removal was already being achieved.

While not possible at all plants, optimization strategies were identified for 32 of the 37 participating plants. In each case, the strategies were formulated to achieve as much nutrient reduction as possible, with the assumption that there would be no numerical effluent limits, and as such, a safety factor was not included when preparing facility needs and estimating resulting effluent loads. In addition, it is important to note that the proposed optimization strategies are considered interim or short-term solutions because they may rely on currently unused capacity (i.e. facilities not needed to meet the current wastewater load but which may be required to treat the design load in the future).

The most common optimization strategies are summarized below for nitrogen and phosphorus removal, respectively:

- Common Optimization Strategies for Nitrogen Removal
  - Increase SRT for plants with activated sludge to encourage nitrification
  - Operate trickling filters as nitrifying trickling filters

- Common Optimization Strategies for Phosphorus Removal
  - Metal salt coagulant addition
  - CEPT, including a metal salt and polymer

In most cases, optimization would result in marginal increases in energy and GHG emissions. Additional chemicals were commonly recommended which have the disadvantage of adding process complexity and can often impact solids production and dewatering performance. Where CEPT is recommended for phosphorus removal, additional organics would be diverted to the digesters which could enhance biogas production (where applicable), but could also generate additional solids.

Table 9 summarizes the annual nutrient load reductions for each of the participating agencies. As shown, optimization strategies were identified to reduce ammonia at 12 plants, total nitrogen at 15 plants, and 29 plants had optimization strategies to reduce total phosphorus. The total potential load reduction is also presented, as well as the percentage reduction. Phosphorus removal is often easier to implement, since many plants already have metal salt coagulant chemical feed facilities on site, so it follows that the percentage reduction would be greater.

Table 9. Average Daily Nutrient Load Reduction with Treatment Optimization

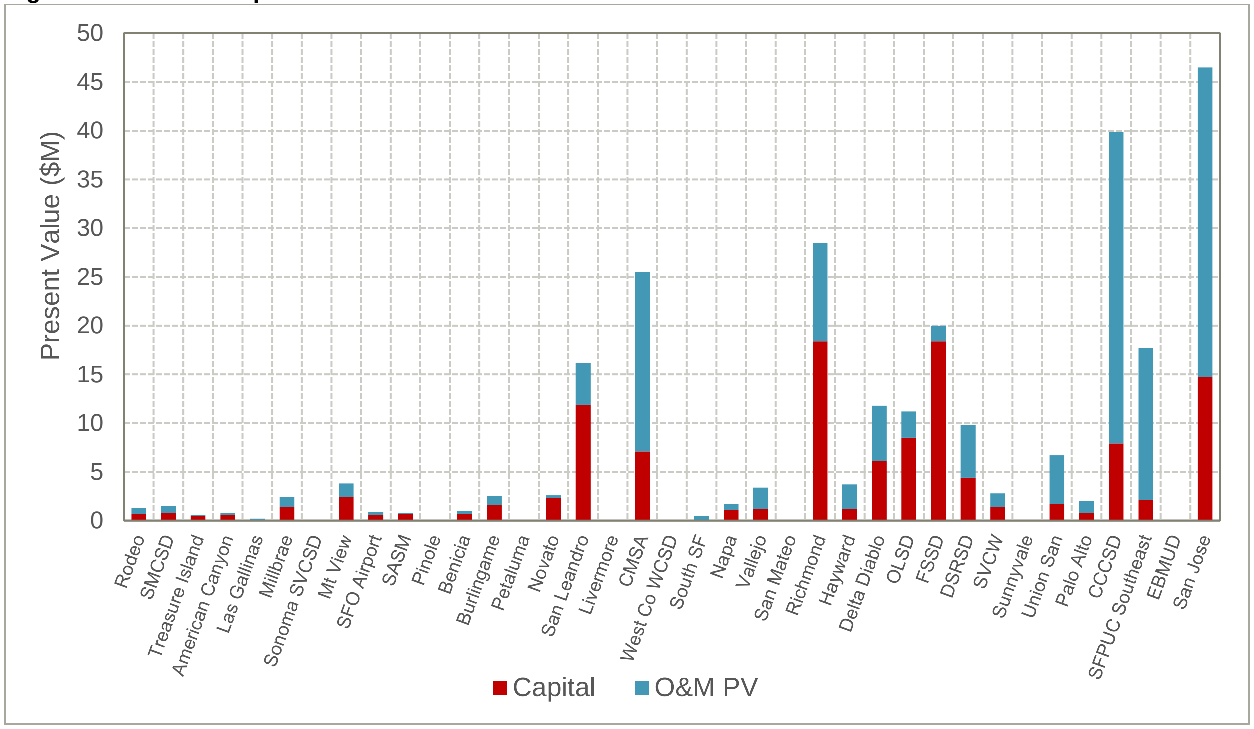
Plant[1]	Permitted ADWF Capacity (mgd)	Projected Nutrient Load Reduction[2,3]		
		NH3 (lb N/d)	TN (lb N/d)	TP (lb P/d)
Rodeo	1.1	0	19	14
SMCSD	1.8	30	0	23
Treasure Island	2.0	0	0	3.7
American Canyon	2.5	0	0	52
Las Gallinas	2.9	0	0	28
Millbrae	3.0	340	150	20
Sonoma SVCSD	3.0	0	0	0
Mt View	3.2	0	130	29.3
SFO Airport	3.4	0	0	27
SASM	3.6	50	0	60
Pinole	4.1	0	0	0
Benicia	4.5	0	0	47
Burlingame	5.5	230	230	170
Petaluma	6.7	0	0	0
Novato	7.0	0	0	13
San Leandro	7.6	1,150	370	8
Livermore	8.5	0	0	17
CMSA	10.0	670	0	80
West Co WCSD	12.5	0	0	0
South SF	13.0	0	0	270
Napa	15.4	0	0	6

Plant[1]	Permitted ADWF Capacity (mgd)	Projected Nutrient Load Reduction[2,3]		
		NH3 (lb N/d)	TN (lb N/d)	TP (lb P/d)
Vallejo	15.5	0	0	220
San Mateo	15.7	0	0	0
Richmond	16.0	1,300	600	50
Hayward	18.5	0	0	161
Delta Diablo	19.5	760	750	20
OLSD	20.0	2,860	1,490	130
FSSD	23.7	0	950	100
DSRSD	23.9	2,310	970	30
SVCW	29.0	0	0	320
Sunnyvale	29.5	0	0	0
Union San	33.0	0	0	380
Palo Alto	39.0	0	0	720
CCCSD	53.8	2,590	930	0
SFPUC Southeast	85.0	0	0	140
EBMUD	120	0	0	0
San Jose	167	0	1,970	0
Total Projected Nutrient Load Reduction with Optimization[2,3,4]	--	12,300	8,600	3,100
Projected Nutrient Discharge Loads without Optimization [2,4]	--	87,900	129,700	9,200
Projected Nutrient Discharge Loads with Optimization[2,3,4]	--	75,600	121,100	6,100
Projected Percent Load Reduction with Optimization[2,3]	--	14%	7%	34%

1. Plants are organized in ascending order of permitted ADWF capacity.
2. Values are average projected loads/reductions to SF Bay over the 10 year period of analysis for treatment optimization.
3. Values are based on operating with the optimization strategy in place on a year round basis.
4. Values rounded to the nearest hundred.

Figure 8 presents a summary of the present value costs for each plant as well as the associated average annual load reductions for ammonia, total nitrogen, and total phosphorus. Note that the plants are organized, left to right, in increasing permitted capacity, with Rodeo having the smallest permitted capacity flow (1.1 mgd ADWF), while the San Jose WPCP has the largest permitted capacity flow (167 mgd ADWF).

Figure 8. Treatment Optimization PV Cost



As shown in Figure 8, the present value costs to implement optimization range from less than $1M for some plants to over $45M for San Jose. With the exception of FSSD and Richmond, it is notable that for those plants with total present value greater than $15M, more than half of the present value cost is attributed to operating costs.

The total present value to implement the optimization strategies at all of the facilities is approximately $270M, of which the total capital cost is $120M (approximately 45 percent of total) and the O&M PV cost is approximately $150M (approximately 55 percent of total). These results are consistent with the intent of the optimization strategies, which was to modify the operation of existing facilities, with minimal capital investment.

Figure 9 illustrates the daily average load reduction for year round operation at each plant for total nitrogen and total phosphorus. The total nutrient load reduction for all plants is approximately 8,600 lb total nitrogen-N/d, and 3,100 lb total phosphorus-P/d. Figure 9 illustrates that the majority of the total nitrogen load reduction is coming from about five plants while phosphorus load reduction is more widely distributed across many of the utilities.

Figure 9. Treatment Optimization Daily Average TN and TP Load Reduction

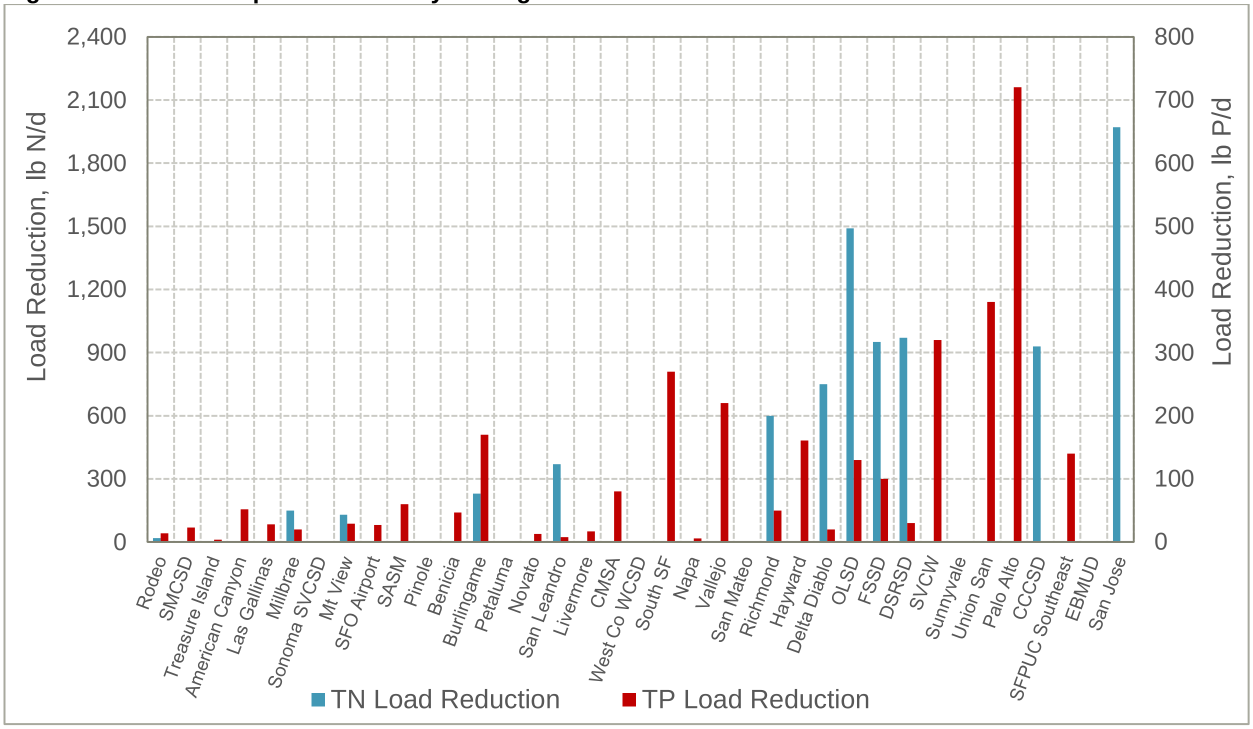
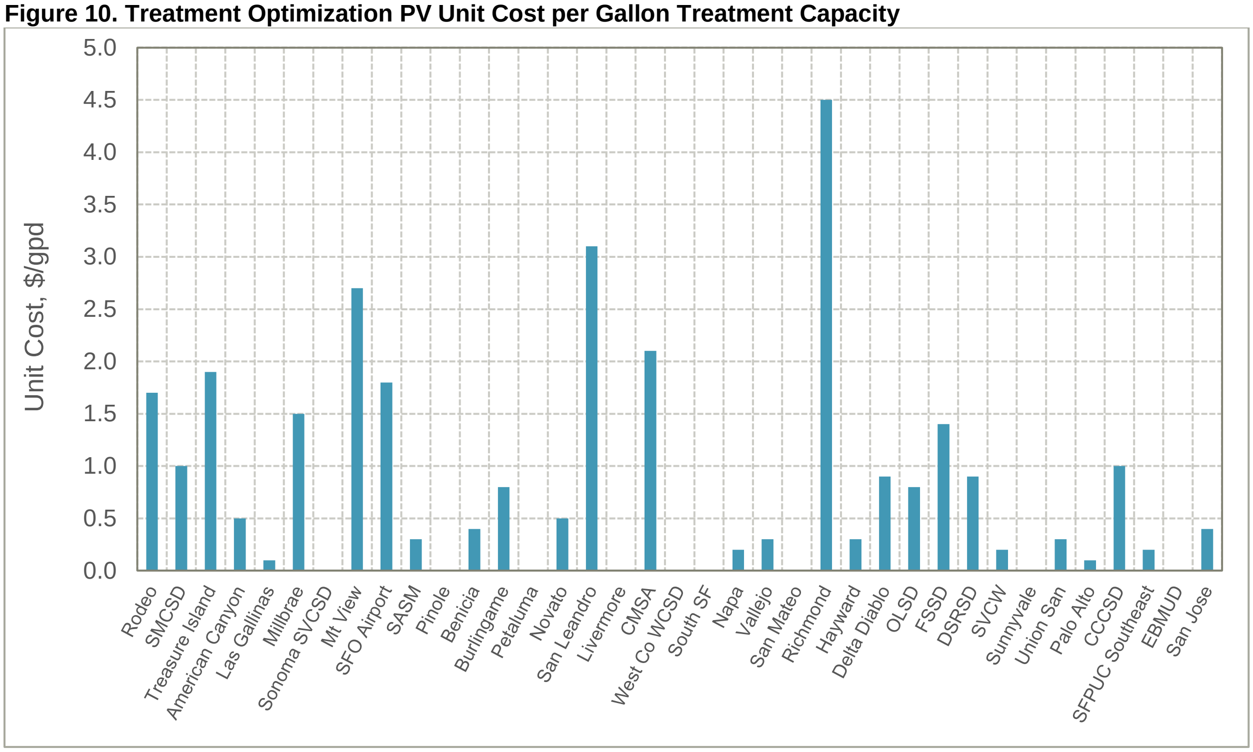


Figure 10 introduces the present value as a unit cost for each plant based on design flow (i.e., total PV divided by the optimization design flow). The unit cost is used to better compare the relative magnitude of the costs for the wide range of plants.

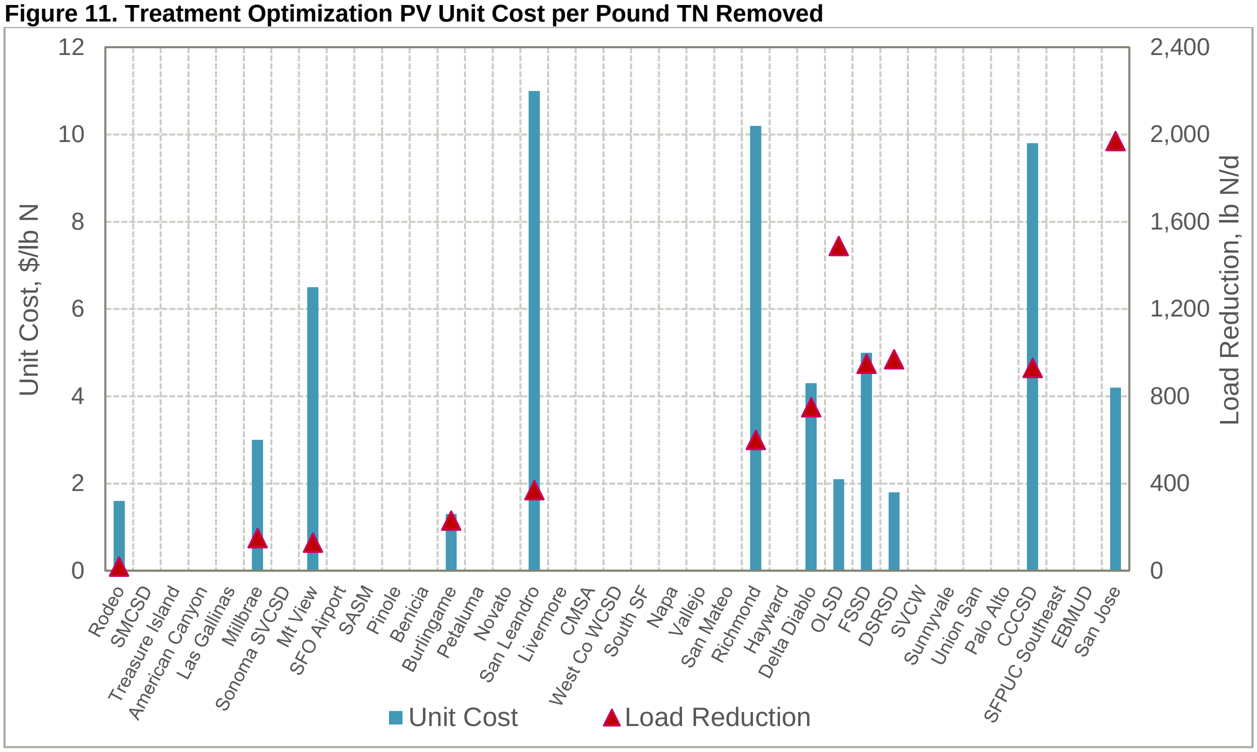
Figure 10. Treatment Optimization PV Unit Cost per Gallon Treatment Capacity



The average unit present value cost is approximately $0.5/gpd based on the plants for which a nutrient load reduction optimization strategy was identified. Most of the larger plants have a unit cost lower than the average, while many of the smaller plants have a unit cost higher than the average, which reflects the savings associated with economies of scale introduced at the larger plants.

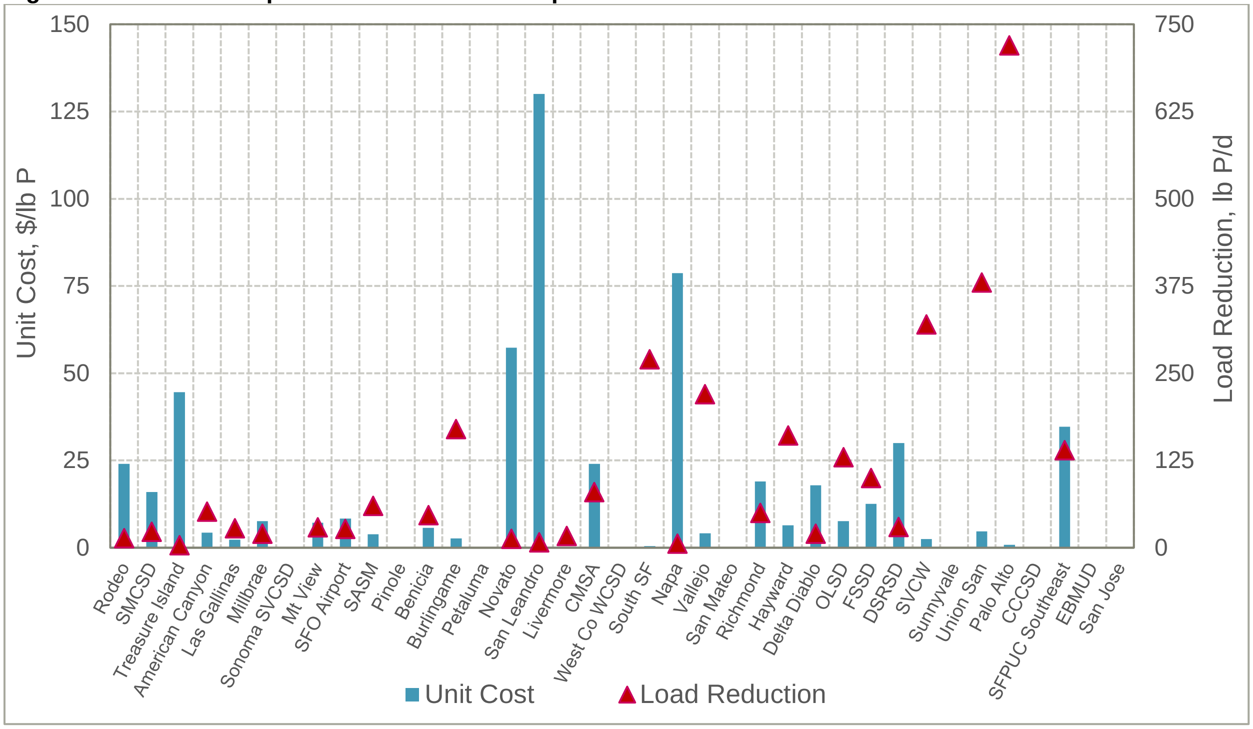
Figure 11 and Figure 12 show the total present value cost per average load reduction over the 10-year optimization period for both total nitrogen and total phosphorus, respectively. The cost per pound removed is used as a measure of efficiency to compare the implementation of a project at one plant compared to that of another plant. For example, as shown, the cost per pound of total nitrogen removed at OLSD is $2.1/lb N as compared to FSSD with a cost of $5.0/lb N. In this case, the cost per pound of nitrogen removed is lower at OLSD.

Figure 11. Treatment Optimization PV Unit Cost per Pound TN Removed



The average unit cost for total nitrogen removal is approximately $5.6/lb N removed, whereas total phosphorus removal is approximately $8.6/lb P removed. As shown in Figure 11, SMCSD has the highest cost per pound of nitrogen removed and as shown in Figure 12, San Leandro has the highest cost per pound of phosphorus removed at just under $130/lb P removed. Note that there is a difference in scale for unit cost between nitrogen and phosphorus. The scale for TP is larger as load reduction is in the denominator and TP has a lower load reduction across the Bay than TN of approximately 4 times.

Figure 12. Treatment Optimization PV Unit Cost per Pound TP Removed



4.2 Sidestream Treatment

As described in Chapter 3, a screening process was conducted to identify which plants were candidates for sidestream treatment. The key criteria of the screening process included the production of a sidestream throughout the year, effluent discharge throughout the year, and sufficient dewatering frequency, which was defined as four or more days per week.

Table 10 summarizes the annual average daily nutrient load reductions for ammonia, total nitrogen and total phosphorus for each plant. The total load reduction is also presented, as well as the percentage reduction.

Table 10. Average Daily Nutrient Load Reduction with Sidestream Treatment

Plant[1]	Permitted ADWF Capacity (mgd)	Projected Nutrient Load Reduction[2,3]		
		NH3 (lb N/d)	TN (lb N/d)	TP (lb P/d)
Rodeo	1.1	0	46	4
SMCSD	1.8	20	20	0
Treasure Island	2.0	0	0	0
American Canyon	2.5	0	0	0
Las Gallinas	2.9	0	0	0
Millbrae	3.0	120	110	8
Sonoma SVCSD	3.0	0	0	0

Plant[1]	Permitted ADWF Capacity (mgd)	Projected Nutrient Load Reduction[2,3]		
		NH3 (lb N/d)	TN (lb N/d)	TP (lb P/d)
Mt View	3.2	0	0	0
SFO Airport	3.4	0	0	0
SASM	3.6	0	0	0
Pinole	4.1	0	170	11
Benicia	4.5	80	70	16
Burlingame	5.5	240	210	30
Petaluma	6.7	0	0	37
Novato	7.0	0	0	0
San Leandro	7.6	330	300	24
Livermore	8.5	480	430	0
CMSA	10.0	430	380	0
West Co WCSD	12.5	0	180	22
South SF	13.0	610	540	60
Napa	15.4	0	0	0
Vallejo	15.5	0	0	0
San Mateo	15.7	0	240	0
Richmond	16.0	0	0	0
Hayward	18.5	730	640	0
Delta Diablo	19.5	770	690	0
OLSD	20.0	1,070	1,070	0
FSSD	23.7	0	600	40
DSRSD	23.9	0	0	0
SVCW	29.0	1,400	1,300	100
Sunnyvale	29.5	0	630	160
Union San	33.0	2,400	2,200	130
Palo Alto	39.0	0	0	0
CCCSD	53.8	0	0	0
SFPUC Southeast	85.0	5,000	4,500	0
EBMUD	120	13,700	12,100	750
San Jose	167	0	5,600	0
Total Projected Nutrient Load Reduction with Sidestream Treatment[2,3,4]	--	27,400	32,000	1,400
Projected Nutrient Discharge Loads without Sidestream Treatment[2,4]	--	113,100	166,300	11,900
Projected Nutrient Discharge Loads with Sidestream Treatment[2,3,4]	--	85,700	134,300	10,500

Plant[1]	Permitted ADWF Capacity (mgd)	Projected Nutrient Load Reduction[2,3]		
		NH3 (lb N/d)	TN (lb N/d)	TP (lb P/d)
Projected Percent Load Reduction with Sidestream Treatment[2,3]	--	24%	19%	12%

1. Plants are organized in ascending order of permitted ADWF capacity.
2. Values are average projected loads/reductions to SF Bay over the 30-year period of analysis for sidestream treatment.
3. Values are based on operating with sidestream treatment on a year round basis.
4. Values are rounded to the nearest hundred.

As shown in Table 10, implementation of sidestream treatment at the candidate facilities has the potential to remove approximately 24 percent of the effluent ammonia load, and about 19 and 12 percent of the effluent total nitrogen and total phosphorus loads, respectively.

Figure 13 and Figure 14 present the total present value cost distribution between capital and O&M at each candidate plant for total nitrogen and total phosphorus load reduction, respectively. The plants without cost shown in the figure were not candidates for sidestream treatment. As shown, the present value costs for candidate plants range from less than $1.0M to over $120M at EBMUD for total nitrogen. The present value costs for total phosphorus removal are much lower and O&M costs make up a substantially larger portion of the total present value.

Figure 13. Sidestream Treatment PV Costs for TN Load Reduction

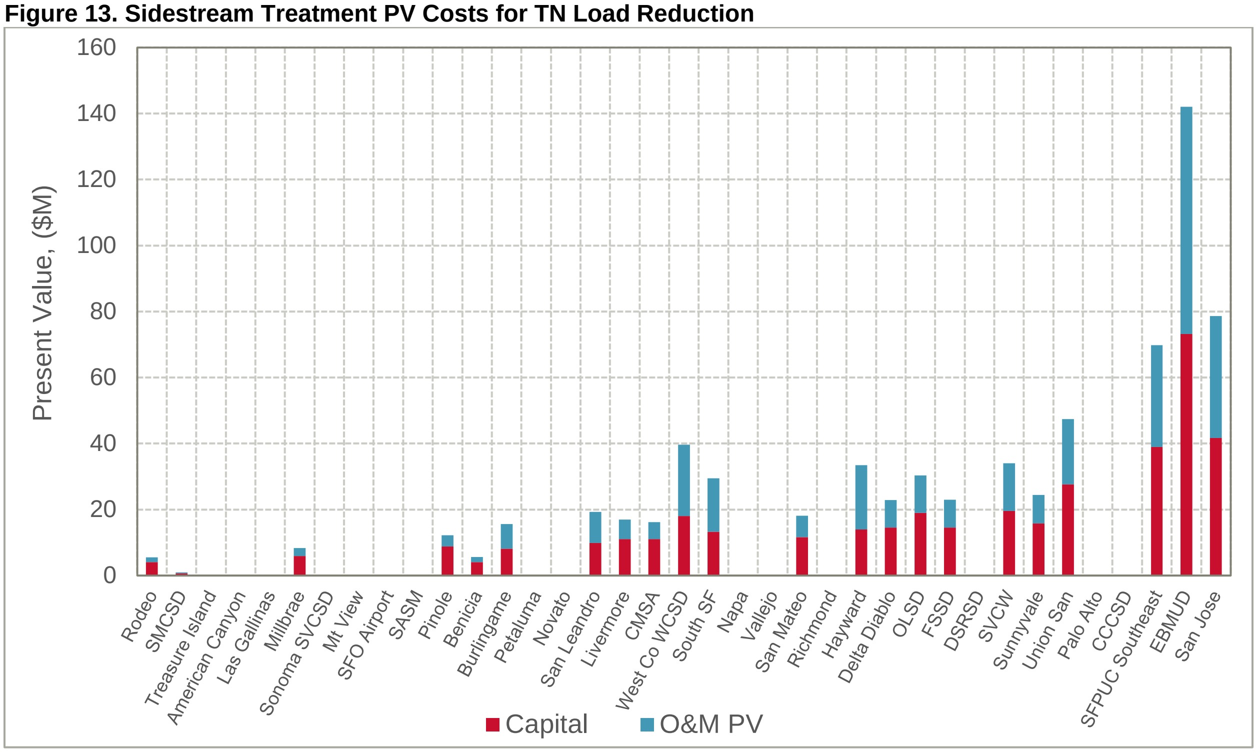
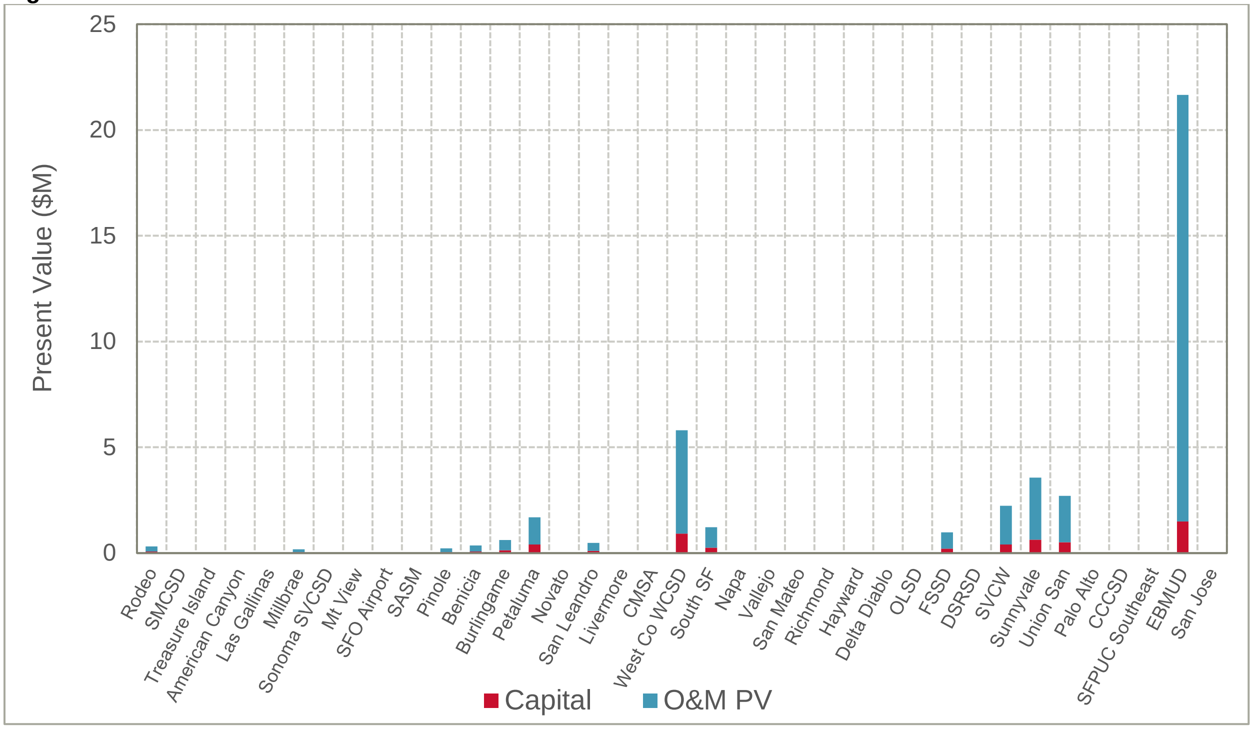


Figure 14. Sidestream Treatment PV Costs for TP Load Reduction



The total present value to implement total nitrogen sidestream treatment is approximately $680M, of which the total capital cost is $371M (approximately 55 percent of total) and the O&M PV cost is approximately $308M (approximately 45 percent of total). The total present value to implement total phosphorus sidestream treatment is approximately $43M for all eligible facilities.

Figure 15 illustrates the daily average load reduction for sidestream treatment at each plant for total nitrogen and total phosphorus. The total nutrient load reduction for all plants is approximately 32,250 lb N/d, and 1,560 lb P/d, respectively. Figure 15 demonstrates that the majority of the load reduction by sidestream treatment would be achieved from the three largest plants, representing approximately 65 percent for total nitrogen and 74 percent for total phosphorus load reduction.

Figure 15. Sidestream Treatment Daily Average TN and TP Load Reduction

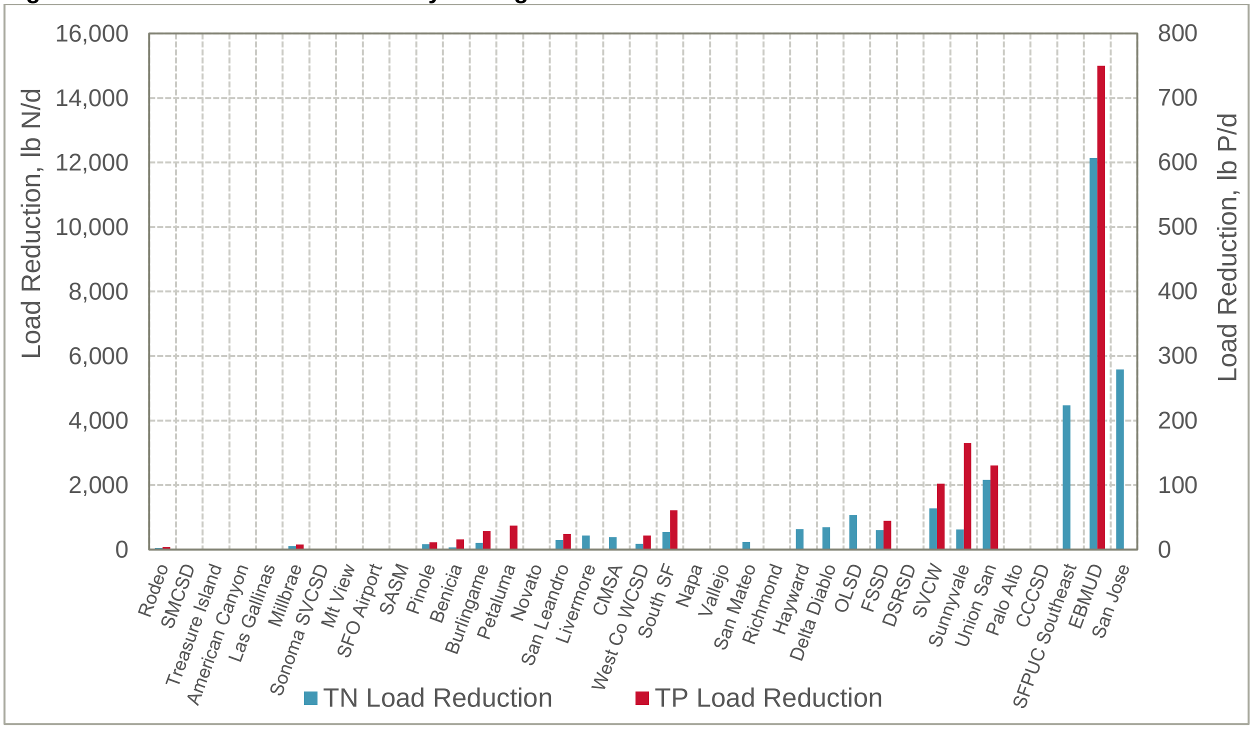


Figure 16 presents the present value as a unit cost for each plant based on design flow (i.e., total PV divided by the plant design capacity). The average unit present value cost of the plants for which sidestream treatment is feasible is approximately $1.1/gpd.

Figure 16. Sidestream Treatment PV Unit Cost per Gallon Treatment Capacity

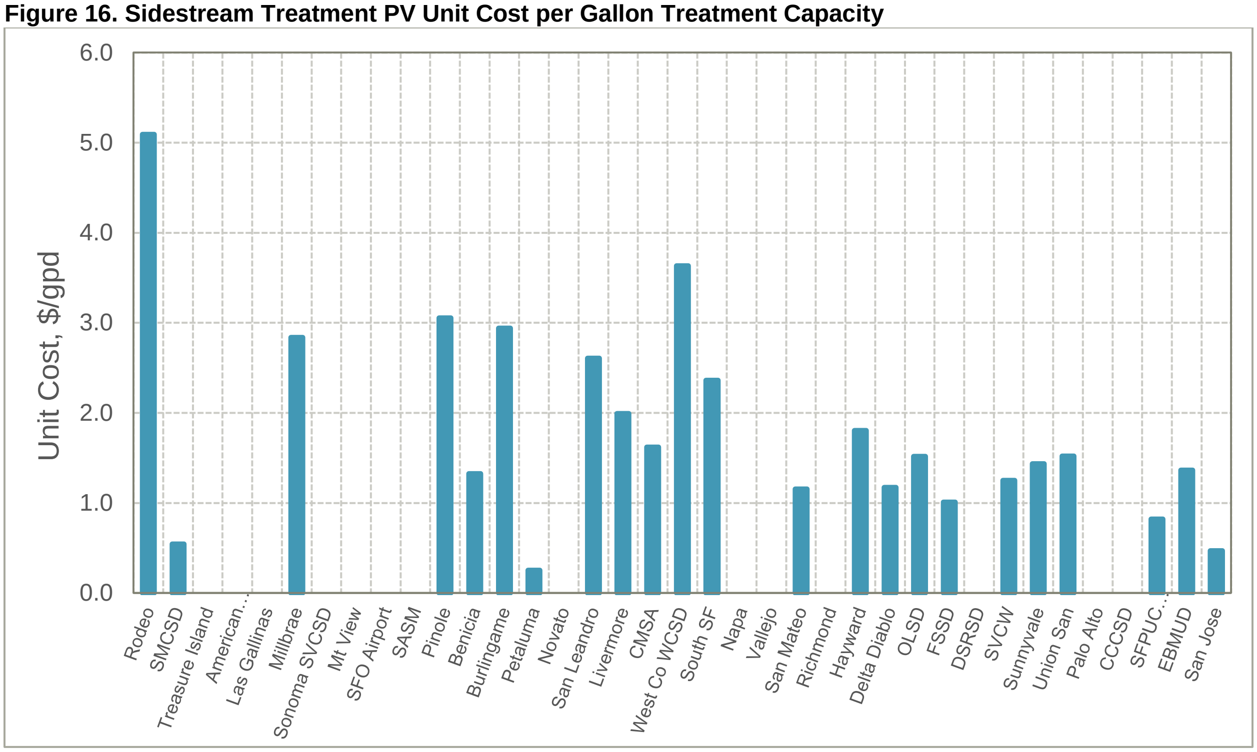


Figure 17 and Figure 18 show the total present value cost per average load reduction over the 30-year design period for both total nitrogen and total phosphorus, respectively. The cost per pound removed is used as a measure of efficiency to compare the implementation of a project at one plant to that of another plant. Similar to Optimization, the scale for TP load reduction is greater than TN load reduction. As shown, West County has the highest cost per pound of total nitrogen removed at approximately $20/lb N, compared to the average for all plants at approximately $2.0/lb N. Similarly, West County has the highest unit cost for sidestream phosphorus removal also, at nearly $25/lb P, compared to an average of only $2.7/lb P.

Figure 17. Sidestream Treatment PV Unit Cost per Pound TN Removed

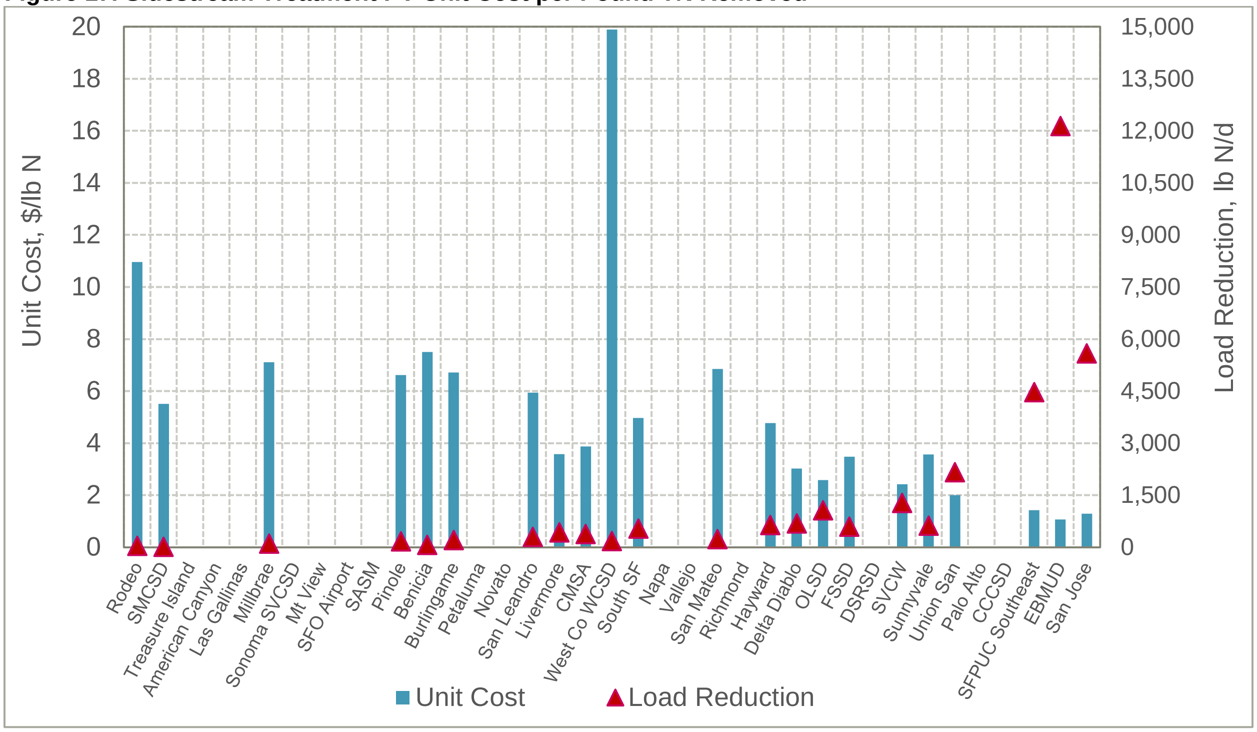
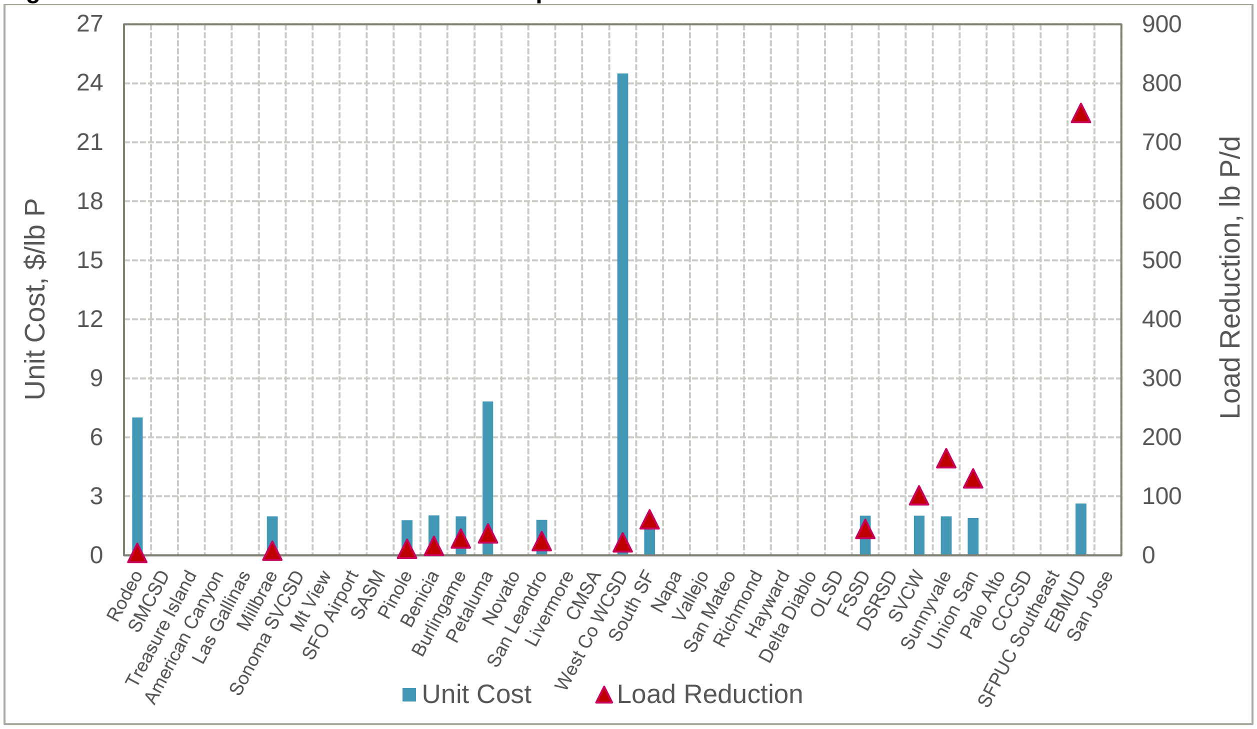


Figure 18. Sidestream Treatment PV Unit Cost per Pound TP Removed



4.3 Treatment Upgrades

As described in Chapter 3, treatment targets were identified to facilitate the evaluation of facilities needs for each plant. The targets for treatment upgrades are referred to as Levels 2 and 3. These levels were selected based on the typical tipping point for treatment technologies to achieve the respective effluent levels. For most plant configurations, the less stringent Level 2 can be achieved with conventional nutrient removal processes, without adding an external carbon source and without adding effluent filtration. The more stringent Level 3 would typically require an external carbon source for nitrogen removal and metal salt coagulant addition with filtration for phosphorus removal for most plant configurations. It is also notable that both levels included an effluent ammonia target of 2 mg N/L. Since established treatment technologies (each with a nitrification step) were used to determine cost estimates, the upgrades identified for each plant will meet the effluent ammonia target of 2 mg N/L.

As previously described, many plants already have some form of nutrient removal. American Canyon and Petaluma currently meet the Level 2 ammonia and total nitrogen targets. Sunnyvale typically meets the ammonia target and occasionally meets the Level 2 total nitrogen target in the dry season. In addition, the Pinole WWTP is currently under construction, and once complete, will also be capable of meeting the Level 2 targets.

Common upgrades to achieve the Level 2 effluent quality target include conventional nitrification/denitrification or the addition of a membrane bioreactor (MBR) for nitrogen removal, while Level 3 commonly required the addition of an effluent filter, or denitrification filter, an external carbon source, alkalinity, and metal salt coagulant addition.

Overall, the core recommendation for most plants was to expand or modify existing activated sludge reactor basins (or trickling filters) to accommodate biological nutrient removal. However, due to space constraints, or other constraints, the addition of an MBR was recommended for eight plants.

Implementation of the Level 2 and Level 3 treatment upgrades would increase both energy consumption and GHG emissions. In most cases, more chemicals are required and additional solids are also generated. Other impacts include the increased complexity to operate the new facilities and potential safety concerns if methanol is selected as an external carbon source. For those plants with an MBR, the effluent is likely to be of a higher quality and more desirable for recycled water uses (particularly for future potable reuse applications).

Table 11 summarizes the annual average daily nutrient load reductions for each plant for nutrient reduction Levels 2 and 3. The total load reduction is also presented, as well as the percentage reduction in nutrient loadings from POTWs.

Table 11. Average Daily Nutrient Load Reduction with Treatment Upgrades

Plant[1]	Permitted ADWF Capacity (mgd)	Projected Nutrient Load Reduction[2,3]					
		Ammonia (lb N/d)[5,6]		TN (lb N/d)[5,6]		TP (lb P/d)	
		Level 2	Level 3	Level 2	Level 3	Level 2	Level 3
Rodeo	1.1	1	1	7	75	18	23
SMCSD	1.8	100	100	160	280	40	50
Treasure Island	2	30	30	120	160	28	33
American Canyon	2.5	0	0	0	80	64	73
Las Gallinas	2.9	10	10	120	240	30	40
Millbrae	3	750	750	600	780	30	43
Sonoma SVCSD	3	0	0	0	0	15	21
Mt View	3.2	0	0	120	220	28	36
SFO Airport	3.4	640	640	480	600	32	41
SASM	3.6	80	80	250	490	100	120
Pinole	4.1	530	530	550	720	30	50
Benicia	4.5	590	590	360	620	65	85
Burlingame	5.5	810	810	890	1,230	230	250
Petaluma	6.7	0	0	0	0	40	60
Novato	7	0	0	0	230	8.8	32
San Leandro	7.6	1,490	1,490	950	1,270	92	130
Livermore	8.5	2,060	2,060	1,430	1,870	14	41
CMSA	10	1,930	1,930	1,600	2,300	180	240
West Co WCSD	12.5	0	0	250	420	40	50
South SF	13	2,180	2,180	1,820	2,660	350	420
Napa	15.4	0	0	0	260	6	38
Vallejo	15.5	1,570	1,570	1,200	2,200	260	340

Plant[1]	Permitted ADWF Capacity (mgd)	Projected Nutrient Load Reduction[2,3]					
		Ammonia (lb N/d)[5,6]		TN (lb N/d)[5,6]		TP (lb P/d)	
		Level 2	Level 3	Level 2	Level 3	Level 2	Level 3
San Mateo	15.7	2,960	2,960	2,450	3,110	190	260
Richmond	16	2,530	2,530	1,700	2,300	40	110
Hayward	18.5	2,300	2,300	1,500	2,490	180	260
Delta Diablo	19.5	3,640	3,640	3,060	3,820	5	64
OLSD	20	4,040	4,040	2,460	3,750	60	160
FSSD	23.7	0	0	2,100	3,100	480	590
DSRSD	23.9	3,120	3,120	2,200	2,800	30	90
SVCW	29	6,860	6,860	5,180	6,800	460	590
Sunnyvale	29.5	220	220	440	1,460	400	480
Union San	33	10,300	10,300	8,400	10,900	490	690
Palo Alto	39	0	0	2,770	4,810	740	900
CCCSD	53.8	8,870	8,870	6,800	9,200	0	220
SFPUC Southeast	85	21,700	21,700	18,100	22,800	170	536
EBMUD	120	27,600	27,600	25,100	32,200	2,100	2,700
San Jose	167	30	30	1,800	10,100	--	600
Total Projected Load Reduction with Upgrades[2,3,4]	--	106,900	106,900	95,000	136,300	7,000	10,500
Projected Nutrient Discharge Loads Project without Upgrades[2,4]	--	114,700	114,700	166,300	166,300	11,900	11,900
Projected Nutrient Discharge Loads with Upgrades[2,3,4]	--	7,800	7,800	71,300	30,000	4,900	1,400
Projected Percent Load Reduction with Upgrades[2,3]	--	93%	93%	57%	82%	59%	88%

1. Plants are organized in ascending order by plant permitted ADWF capacity.
2. Values are average projected loads/reductions to SF Bay over the 30-year period of analysis for upgrades.
3. Values are based on meeting the Level 2 and 3 benchmarks on a year round basis.
4. Values are rounded to the nearest hundred.
5. For plants where the ammonia load reduction values are less than the total nitrogen load reduction load values, this primarily occurs for instances where the existing plant partially or fully nitrifies.
6. The total nitrogen load reduction values are typically less than ammonia as the TN treatment targets are not as stringent. It is anticipated that the predominant nitrogen species that comprise total nitrogen are nitrate and refractory dissolved organic nitrogen with ammonia contributing 2 mg N/L or less.

As shown in Table 11, implementation of the recommended upgrades to meet the Level 2 targets would result in the reduction of POTW loads of approximately 93 percent of the effluent ammonia load, and about 60 percent for both effluent total nitrogen and total phosphorus loads. With additional treatment processes added to achieve the Level 3 benchmarks, approximately 80 percent of the effluent POTW total nitrogen loads and nearly 90 percent of the total phosphorus loads would be removed.

Figure 19 presents a summary of the present value costs to achieve the Level 2 effluent quality benchmarks on an annual basis. Similarly, Figure 20 shows the present value cost to meet the Level 3 effluent benchmarks. Level 3 costs are inclusive of facilities needed for Level 2.

As shown in Figure 19, the present value costs range from as low as $1.3M at American Canyon to achieve the Level 2 benchmark, to as high as $2.6B at EBMUD. To meet the Level 3 benchmark, the present value costs range from $8.9M at the Sonoma Valley plant to nearly $2.9B at the EBMUD plant.

The total present value cost to achieve the Level 2 benchmark is approximately $9.4B, while the cost to achieve the Level 3 target is an additional $3B, for a total of approximately $12.4B. It is notable that the plants with an MBR process typically have a lower marginal increase from Level 2 to Level 3 because the membrane tank volume does not increase. For the MBR options, the increase in cost is due to the carbon addition and larger aeration basins.

In contrast to the treatment optimization cost analysis, the treatment upgrade capital costs generally make up a larger proportion of the present value for each plant. For Level 2, the capital costs make up nearly 75 percent of the total present value. For Level 3, the capital costs make up nearly 70 percent of the total present value. It is logical that the capital proportion of total costs would drop slightly from Level 2 to Level 3 due to the additional chemicals and energy that are typically required to meet the lower effluent limits.

Figure 19. PV Cost for Treatment Upgrades for Level 2

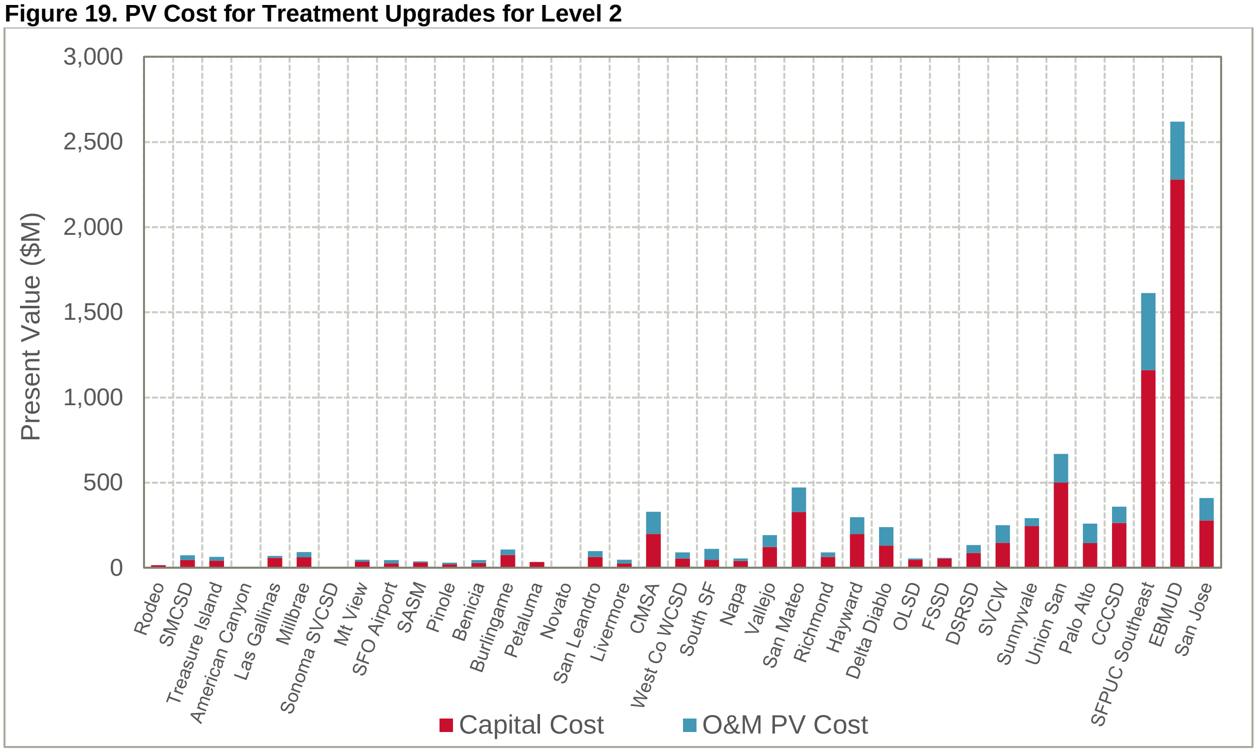


Figure 20. PV Cost for Treatment Upgrades for Level 3

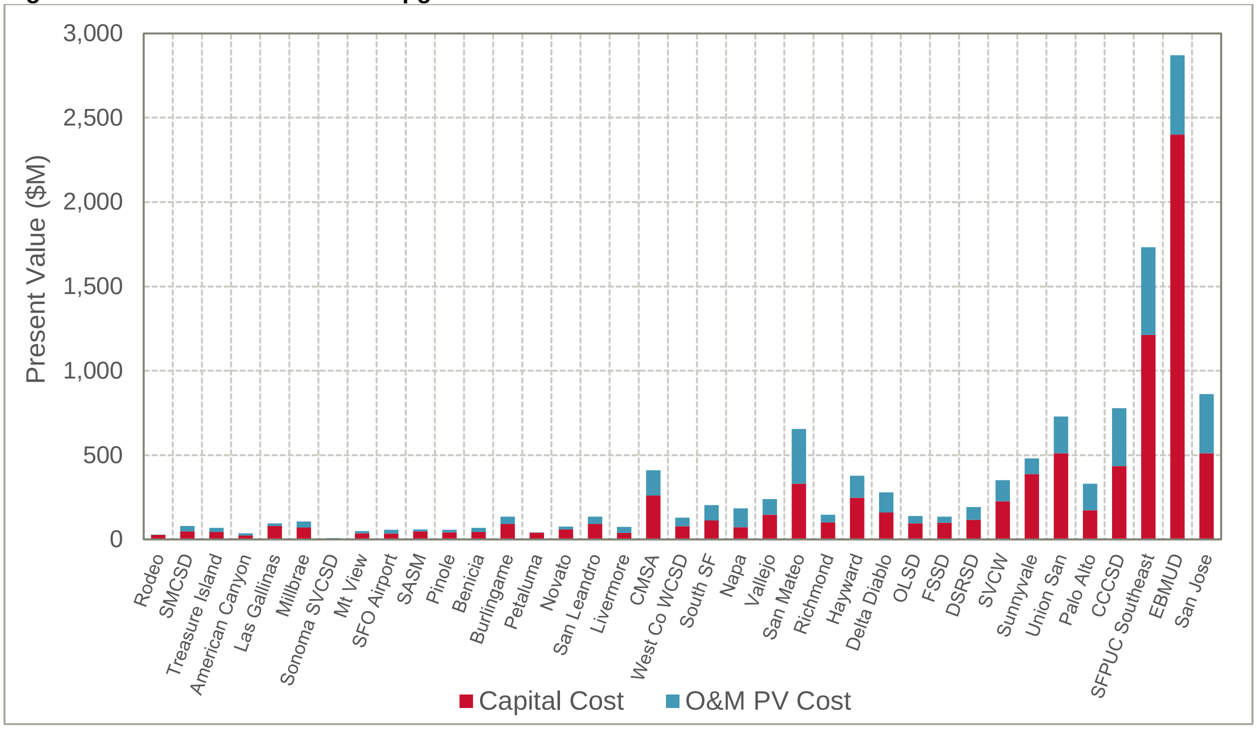


Figure 21 and Figure 22 illustrate the present value as a unit cost for each plant based on permitted capacity for Level 2 and Level 3, respectively. In addition, annual average daily total nitrogen load reduction is also presented.

Figure 21. PV Unit Cost per Gallon Capacity for Level 2 Treatment Upgrades

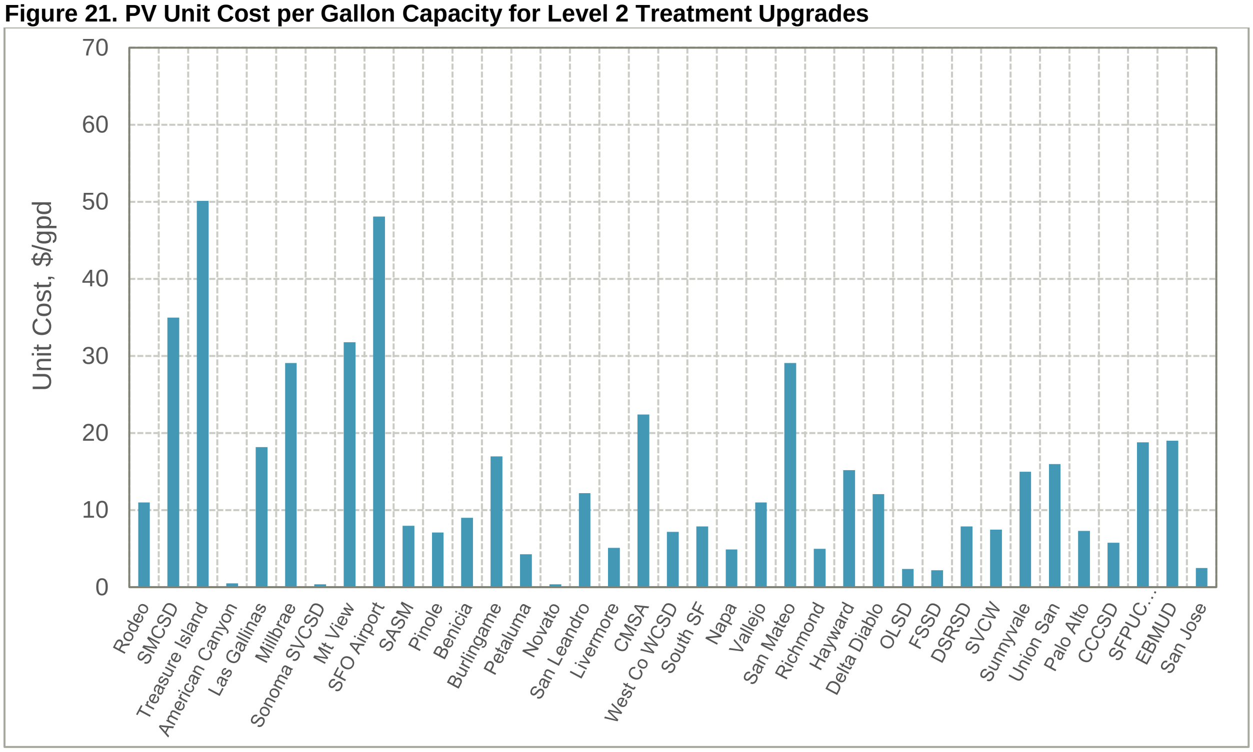
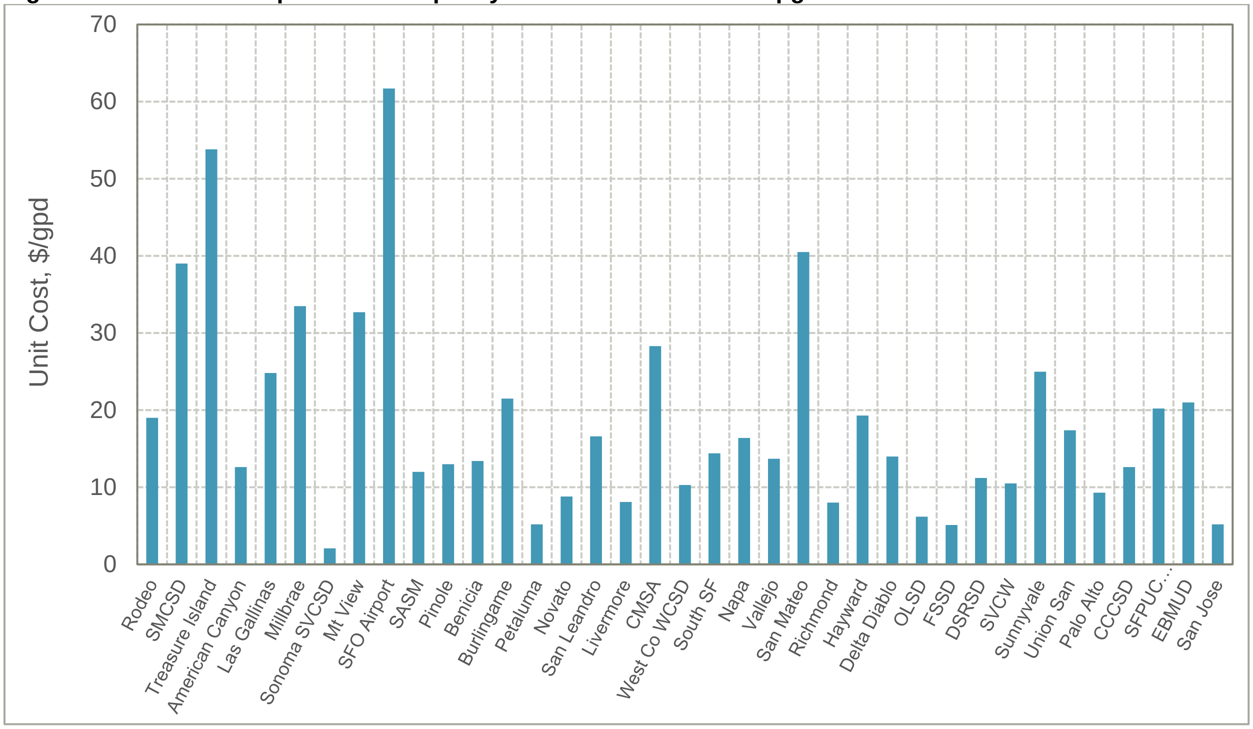


Figure 22. PV Unit Cost per Gallon Capacity for Level 3 Treatment Upgrades



As expected, there are economies of scale. Typically, the unit costs are higher for the smaller plants and lower for the larger plants. The average unit cost to achieve the Level 2 target is $10.8/gpd compared to $14.3/gpd to achieve the Level 3 target.

Figure 23 and Figure 24 show the present value cost per pound of total nitrogen removed for Level 2 and Level 3. Similarly, Figure 25 and Figure 26 show the present value cost per pound of total phosphorus removed for Level 2 and Level 3, respectively. Similar to Optimization and Sidestream, the scale for TP load reduction is greater than TN load reduction.

Figure 23. PV Unit Cost per Pound TN Removed for Level 2 Treatment Upgrades

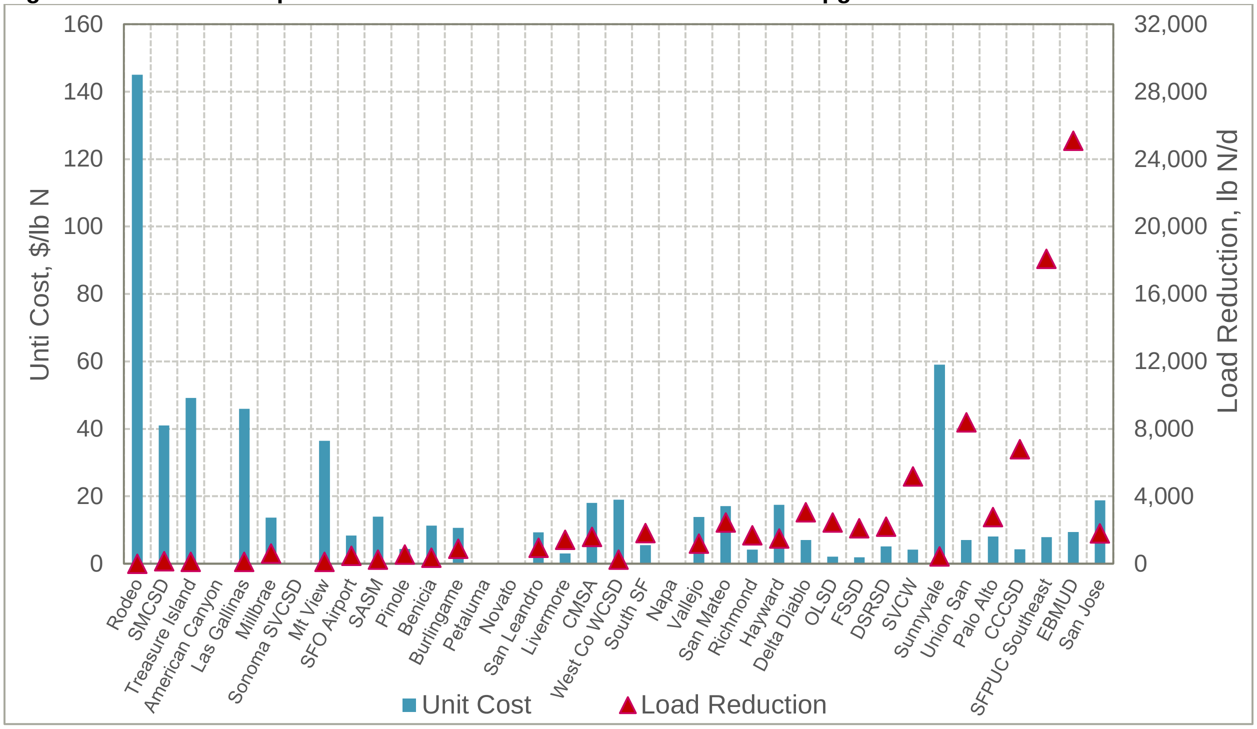


Figure 24. PV Unit Cost per Pound TN Removed for Level 3 Treatment Upgrades

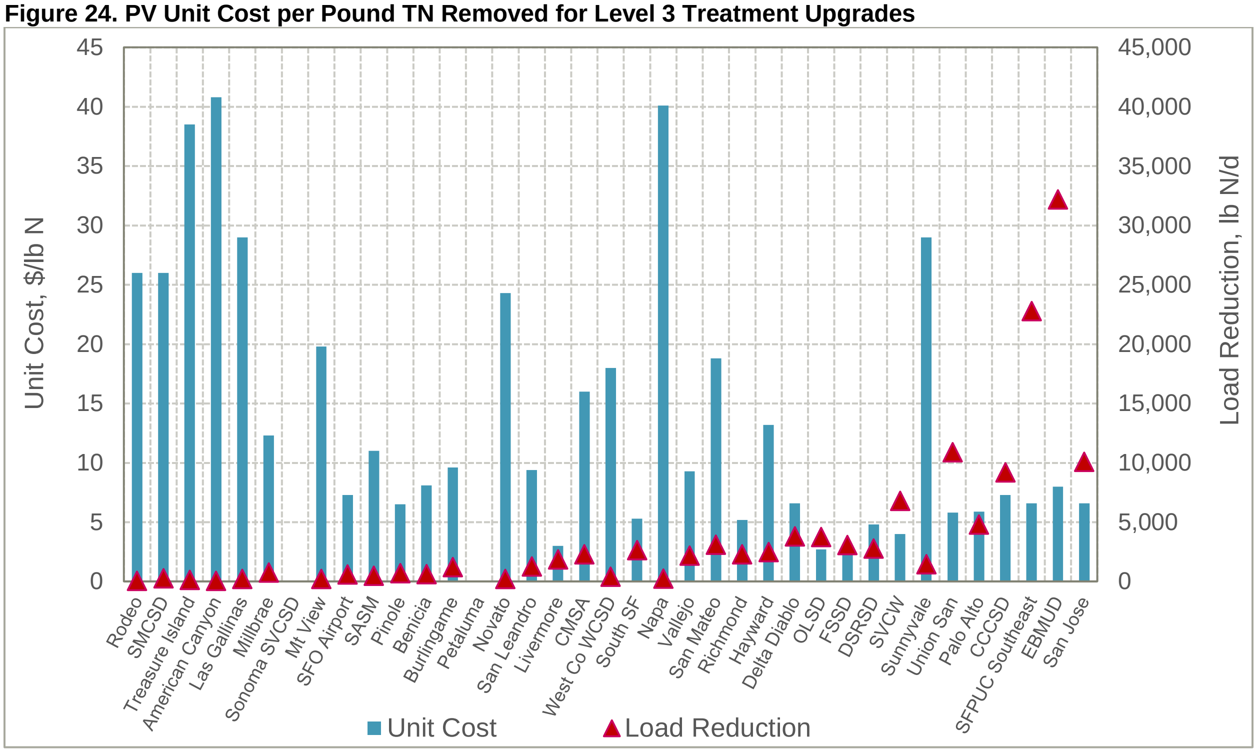


Figure 25. PV Unit Cost per Pound TP Removed for Level 2 Treatment Upgrades

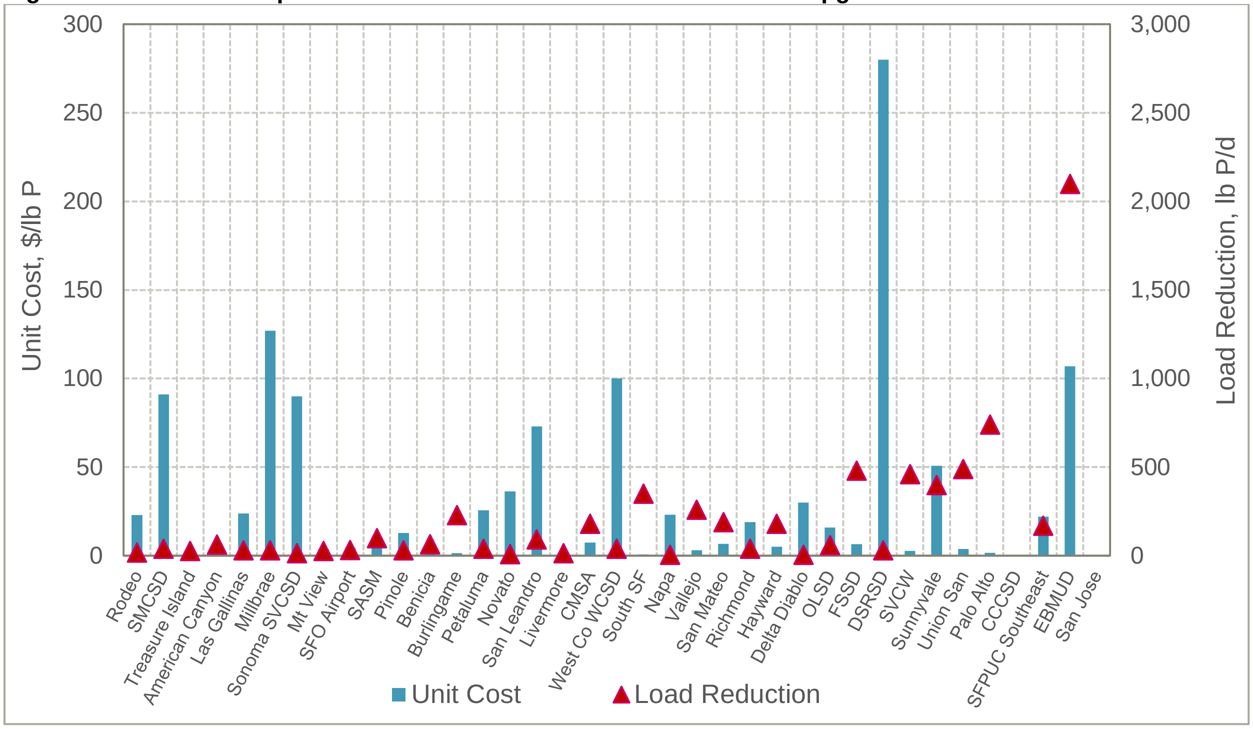
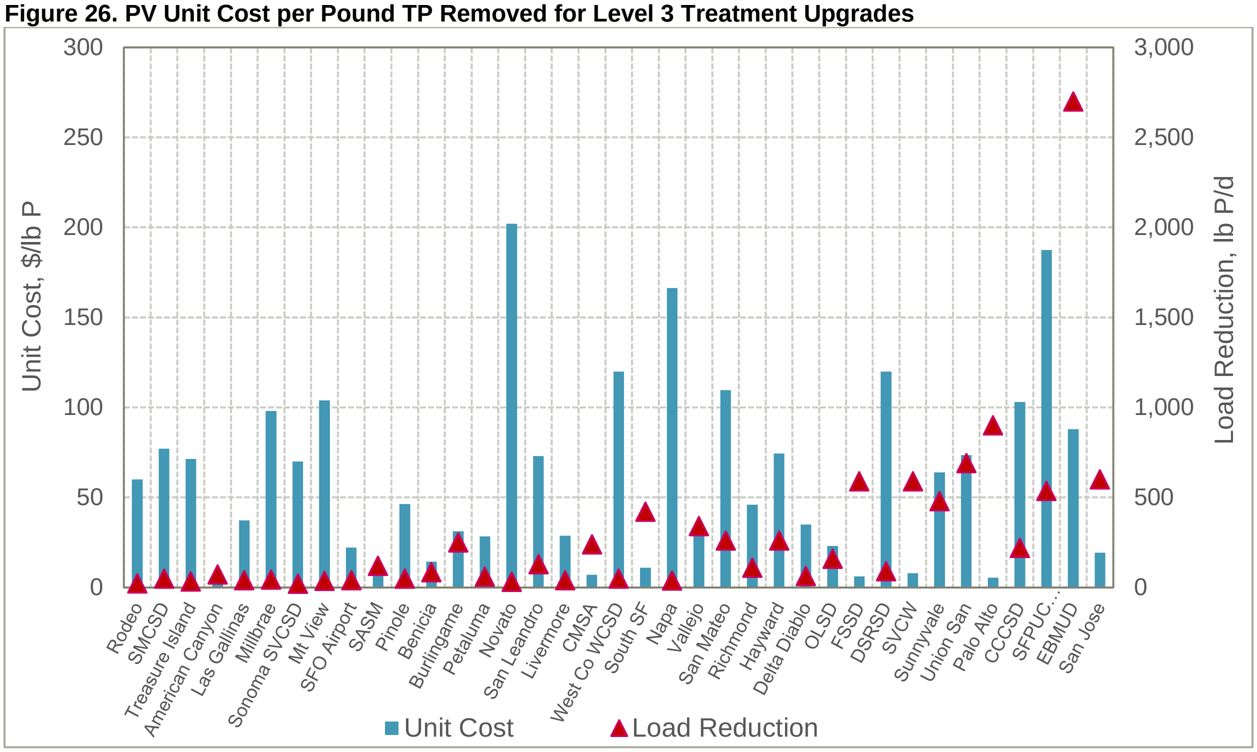


Figure 26. PV Unit Cost per Pound TP Removed for Level 3 Treatment Upgrades



The average unit cost for total nitrogen removal is approximately $8.7/lb N to meet the Level 2 target and $7.7/lb N to meet the Level 3 target. The average unit cost for total phosphorus removal is approximately $43/lb P to meet the Level 2 target and nearly $59/lb P to meet the

Level 3 target. The plants with the highest unit costs per pound remove are typically those that are currently meeting or almost meeting the respective water quality benchmarks, because there is a significant investment required to achieve the marginal reduction on a reliable basis.

As previously described, the recommended upgrades to meet the Level 2 and 3 benchmarks, and the associated costs described above, are based on established technologies. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. However, there are many emerging technologies that may achieve lower levels of nutrient discharges and/or be more cost-effective. As such, for each of the participating agencies, at least 2 emerging technologies were identified for future consideration. Emerging technologies that were considered include:

- Granular Activated Sludge
- Simultaneous nitrification / denitrification
- Nitrite Shunt
- Zeolite-Anammox
- Treatment Wetlands
- Membrane Aerated Biofilm Reactor (MABR)
- Ballasted Activated Sludge

Many of these technologies are early in their development. Bench-, pilot-, and/or demonstration-scale testing would be prudent to confirm design and sizing criteria, potential process benefits and further define potential cost and plant site footprint space savings. For planning purposes, pilot studies can commonly represent approximately one percent of anticipated project costs, or more, and provide a positive return on investment.

4.4 Summary Comparison

A summary of the load reduction that can be achieved with each treatment strategy, including the implementation of treatment optimization, sidestream treatment, and plant upgrades to meet the Level 2 and Level 3 water quality benchmarks, is presented in Table 12. These load reductions, and their associated costs, are based on year round operation of the treatment strategies, where facilities are sized to treat year round flows and loads. Similar information is presented in Table 13 for dry season conditions. As previously described, the dry season represents the period between May 1 and September 30, and facilities were sized to meet the loads during that period, which are lower than year round loads. However, it was assumed that facilities would operate on a year round basis. In all cases, it was assumed that sidestream treatment would be operated on a year round basis.

Table 12. Summary of Nutrient Load Reduction and Associated Costs, Year Round Design and Operation

Parameter	Unit	Projected Discharge Load, without Opt.[1]	Projected Discharge Load, without Sidestream or Upgrades[1]	Treatment Strategy			
				Optimization[2]	Sidestream[2]	Level 2[2]	Level 3[2]
Design Flow	mgd	--	--	546	869	869	869
Load Reduction[4]							
Ammonia	lb N/d	87,900	114,700	12,300	27,400	106,900	106,900
TN	lb N/d	129,700	166,300	8,600	32,000	95,000	136,300
TP	lb P/d	9,200	11,900	3,100	1,400	7,000	10,500
Load Reduction							
Ammonia	%	--	--	14%	24%	93%	93%
TN	%	--	--	7%	19%	57%	82%
TP	%	--	--	34%	12%	59%	88%
Costs[4,5]							
Capital	$M	--	--	119	391	6,976	8,517
O&M PV	$M	--	--	147	345	2,443	3,888
Total PV	$M	--	--	266	736	9,420	12,405
Average Unit Costs							
Per gpd[6]	$/gpd	--	--	0.5	0.8	10.8	14.3
Per lb N[7]	$/lb N	--	--	5.6	2.0	8.7	7.7
Per lb P[7]	$/lb P	--	--	8.6	2.8	44	59

1. The projected discharge loads are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015) and are projected forward to the midpoint of the planning period. The reported flows and loads for optimization, upgrades, and sidestream represent average projected load reduction for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream). Sidestream design flow reflects only the candidate plants.
2. Facilities were sized for year round loads and operated year round. The results for each treatment strategy are stand alone.
3. Load values are rounded to the nearest hundred.
4. Costs are referenced to the ENR SF CCI for January 2018 at 12,015. Costs are not additive for scenarios (e.g., the Level 3 costs shown are inclusive of facilities needed to meet Level 2). Costs do not account for changes in any other process, including solids handling or associated energy requirements.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. Unit cost ($/gpd) was calculated by dividing the total present value by the design flow.
7. Unit cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the projection duration (e.g., for upgrades: Total PV for TN Removal facilities divided by (Average Annual TN Removed times 30-years)).

Table 13. Summary of Nutrient Load Reduction and Associated Costs, Dry Season Design with Year Round Operation

Parameter	Unit	Projected Discharge Load, without Opt.[1]	Projected Discharge Load, without Sidestream or Upgrades[1]	Treatment Strategy			
				Optimization[2]	Sidestream[2]	Level 2[2]	Level 3[2]
Design Flow	mgd	--	--	494	788	788	788
Load Reduction[4]							
Ammonia	lb N/d	87,800	114,600	11,900	27,400	106,400	106,400
TN	lb N/d	129,200	165,800	7,000	32,000	90,300	110,800
TP	lb P/d	9,100	11,800	3,000	1,400	6,800	8,300
Load Reduction							
Ammonia	%	--	--	14%	24%	93%	93%
TN	%	--	--	5%	19%	54%	67%
TP	%	--	--	32%	12%	58%	70%
Costs[4,5]							
Capital	$M	--	--	107	391	6,544	7,866
O&M PV	$M	--	--	134	345	2,226	2,945
Total PV	$M	--	--	241	736	8,770	10,811
Average Unit Costs							
Per gpd[6]	$/gpd	--	--	0.5	0.9	11.1	13.7
Per lb N[7]	$/lb N	--	--	6.2	2.0	8.5	8.4
Per lb P[7]	$/lb P	--	--	8.1	2.8	44	66

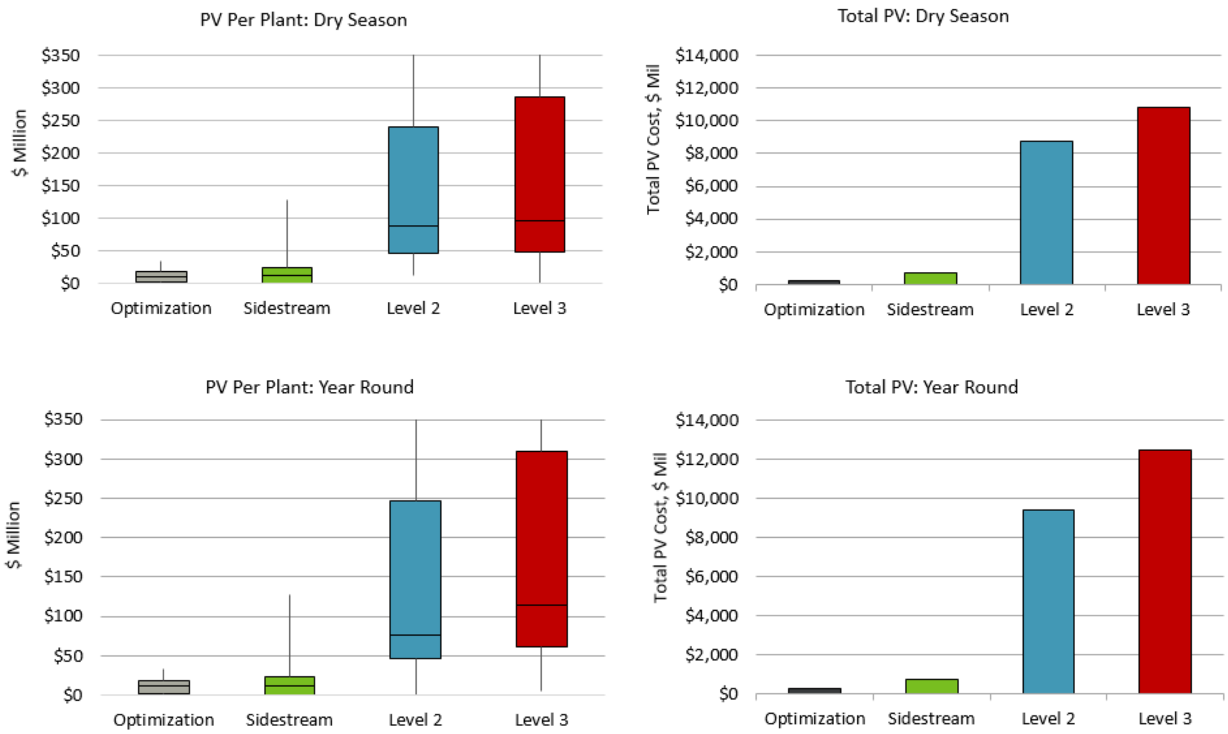
1. The projected discharge loads are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015) and are projected forward to the midpoint of the planning period. The reported flows and loads for optimization, upgrades, and sidestream represent average projected load reduction for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream). Sidestream design flow reflects only the candidate plants.
2. Facilities were sized for dry season loads and operated year round. The results for each treatment strategy are stand alone.
3. Load values are rounded to the nearest hundred.
4. Costs are referenced to the ENR SF CCI for January 2018 at 12,015. Costs are not additive for scenarios (e.g., the Level 3 costs shown are inclusive of facilities needed to meet Level 2). Costs do not account for changes in any other process, including solids handling or associated energy requirements.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. Unit cost ($/gpd) was calculated by dividing the total present value by the design flow.
7. Unit cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the projection duration (e.g., for upgrades: Total PV for TN Removal facilities divided by (Average Annual TN Removed times 30-years)).

As illustrated in both Table 12 and Table 13, the load reductions increase with increasing degrees of treatment, from optimization through Level 3. Implementation of the optimization strategies could result in a load reduction of approximately seven percent for total nitrogen for a short term (approximately 10 years) capital cost investment of approximately $120M, whereas implementation of sidestream treatment could result in a total nitrogen load reduction of over 19 percent for a longer period (approximately 30 years) at a capital cost of approximately $390M. The cost per pound of nitrogen removed is lower for sidestream treatment than that for optimization, it also has a longer term benefit and is expected to be a more reliable nutrient reduction strategy. The results are similar for total phosphorus when comparing the cost per pound removed for optimization and sidestream treatment.

The incremental present value cost to go from Level 2 to 3 upgrades is approximately $2B for upgrades based on dry season loads and $3B for upgrades based on year round loads. The major factor causing the large cost differential is the need for additional facilities to reliably achieve the lower benchmarks (e.g., additional denitrifying filter and ancillary equipment). This incremental increase is reflected in the unit cost per gallon capacity ($/gpd). The unit cost for total nitrogen removal ($/lb TN removed) are comparable for Levels 2 and 3, regardless of season (all approximately $8/lb TN removed). In contrast, the unit cost for total phosphorus removal ($/lb TP removed) has a pronounced increase from Levels 2 and 3 and a marginal increase from dry season to year round limits.

Overall, the present value costs increase with increasing treatment, ranging from $241M to implement dry season optimization up to $12.4B to implement treatment upgrades to meet Level 3 effluent quality benchmarks year round. This substantial increase in present value costs is illustrated in Figure 27, which also illustrates the range of present value costs for each plant to implement the treatment strategies. The present value costs range from less than $1M to implement optimization strategies at several plants to well over $1B to implement upgrades at some of the larger plants, including EBMUD and SFPUC’s Southeast plant.

Figure 27. Summary of Present Value Costs



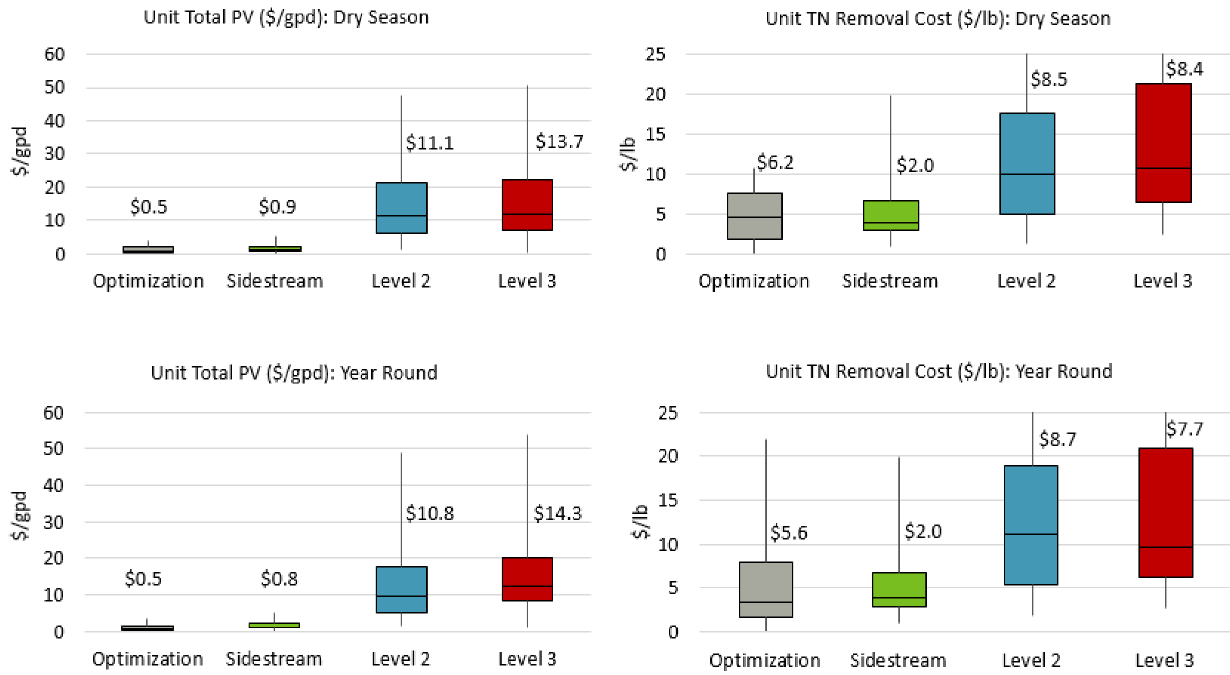
Notes:

1. The PV Per Plant graphs are presented as box and whisker plots, where the boxes represents the range of costs falling within the 25th to 75th percentiles, the horizontal bar within the box represents the median cost, and the ends of the whiskers represent the minimum and maximum present value costs, respectively.
2. The maximum value for Level 2 and Level 3 are not illustrated in the box and whisker plots due to scale. For dry season conditions, the maximums are $2.5B and $2.6B for Levels 2 and 3, respectively. For year round conditions, the maximums are $2.7B and $2.9B for Levels 2 and 3, respectively.

The unit costs are also revealing (illustrated in Figure 28). While optimization has the lowest unit cost per gallon treated, sidestream treatment has the most efficient unit removal cost for both total nitrogen and total phosphorus ($/lb TN or TP).

While there is a significant increase in the average unit cost per pound of phosphorus removed between Level 2 to Level 3 treatment (refer to Table 12 and Table 13), there is a reduction in the average unit cost per pound of nitrogen removed. The former is due to the relatively small increment in pounds removed required to reduce from an effluent total phosphorus of 1.0 mg P/L to 0.3 mg P/L, yet a substantial cost to achieve that increment. On the other hand, there is considerable reduction in total nitrogen load with the reduction from 15 mg N/L to only 6 mg N/L which balances with the additional costs required to achieve that reduction.

Figure 28. Summary of Unit Costs



Notes:

1. The unit cost graphs are presented as box and whisker plots, where the boxes represent the range of costs falling within the 25th to 75th percentiles, the horizontal bar within the box represents the median cost, and the ends of the whiskers represent the minimum and maximum unit costs, respectively.

Finally, the consideration of the impact of new unit processes on GHG emissions is a requirement of the Watershed Permit. The analysis is not intended to be a plant-wide GHG emissions analysis with indirect and direct emissions reporting. Rather, the analysis was limited to the identification of potential changes in energy and chemical demands with the transition from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will increase the plant-wide GHG emissions in most cases. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

A summary of the relative increase in GHG emissions with respect to current emissions is provided in Table 14. In general, the GHG emissions increase with more advanced treatment. Chemicals are the predominant contributor to GHG emissions, except for sidestream treatment. The increase in GHG emissions for the most stringent Level 3 targets is primarily due to additional electrical energy demand to reduce both TN and TP, compounded with additional chemicals. The increase in GHG emissions are associated with the production and hauling of chemicals, fugitive biogenic emissions, and emissions due to offsite energy generation and increased import of grid electricity. Such increases in GHG emissions are not considered on-site anthropogenic emissions and as such, are not expected to impact a POTWs ability to stay below the California Air Resources Board Cap and Trade Threshold.

Table 14. Incremental Increase in Greenhouse Gas Emissions for All 37 Plants

Parameter	Unit[3]	Annual Increase in GHG Emissions[1, 2]			
		Optimization	Sidestream	Level 2	Level 3
Increase in GHG Emissions from Energy	MT CO_2 eq/yr	14,400	4,500	119,000	138,500
Increase in GHG Emissions from Chemicals	MT CO_2 eq/yr	48,700	600	138,400	168,400
Total Increase in Increase in GHG Emissions from Energy/Chemicals	MT CO_2 eq/yr	63,100	5,100	257,400	306,900

1. Values represent the projected average incremental increase in GHG emissions for all 37 plants over the planning period (Optimization = 10 years; Sidestream and Level 2 and 3 Upgrades = 30 years).
2. Values are based on year round operation.
3. MT CO_2 eq/yr = metric tonnes of carbon dioxide equivalents per year.

As shown in Table 14, with each successive step of treatment (except for sidestream treatment), the average annual increase in GHG emissions increases.

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5. Nutrient Reduction by Other Means

The analyses and results described in Chapter 4 are based on improvements that can be achieved through optimization and upgrade of the respective treatment plants. The focus of the nutrient reduction by other means assessment is to identify other ways to reduce the nutrient loads discharged to SF Bay.

As described in Chapter 3, several potential methods were anticipated, including effluent management (e.g., recycled water use), effluent polishing (e.g., wetlands treatment), source control, and non-point source reduction. For the agencies participating in this Nutrient Reduction Study, the primary method of reducing nutrient effluent loads by other means is through the use of recycled water.

A survey was conducted to collect information about existing recycled water usage and plans for the future. The survey requested forecasted use in five year increments through 2040 as well as the type of use. The following categories were included in the questionnaire:

- Golf Course Irrigation
- Landscape Irrigation
- Commercial Use
- Industrial Use
- Agricultural Use
- Environmental Enhancement
- Internal Use
- Groundwater Recharge for Indirect Potable Reuse
- Surface Water Augmentation
- Direct Potable Use
- Other Non-Potable Uses

Recognizing that some of the use categories listed above may have return streams that are high in nutrient concentration, the projected concentrate from advanced treatment and/or other return streams (e.g., cooling tower blow down) was also requested.

Table 15 presents a summary of existing and future recycled water use for each of the five subembayments. Values are presented as acre-feet per year and do not include concentrated return streams that are discharged to the SF Bay.

Approximately six percent of the current effluent volume is being diverted for recycled water use on an annual basis. Recycled water use is expected to more than double by 2040. Suisun Bay is currently using the highest volume of recycled water; however, over time, the other subembayments are projecting greater growth. By 2040, the South Bay is anticipating having the highest volume of recycled water use.

Table 15. Recycled Water Projections by Subembayment (AFY)

Subembayment	2015	2020	2030	2040
Suisun Bay	20,040	24,070	25,980	27,050
San Pablo Bay	8,010	13,350	15,450	17,250
Central Bay	10,680	14,620	25,120	28,880
South Bay	12,020	24,160	29,450	30,970
Lower South Bay	7,730	16,130	21,360	26,500
Total	58,480	92,330	117,360	130,660

1. Values are acre-feet per year and do not include concentrate and other streams that are returned to the plant and discharged with plant effluent.

Figure 29 illustrates the distribution of existing and future recycled water by use category. As shown, industrial use is currently the largest use type, making up approximately 28 percent of the total use, followed by irrigation at approximately 27 percent when combining golf course irrigation with general landscape irrigation. By 2045, irrigation is anticipated to make up a larger portion of recycled water use. Environmental enhancement, such as the water diverted to the Hayward Marsh, currently makes up approximately 21 percent of total recycled water use and this annual volume is projected to be stable over the planning period. While no potable reuse was reported for 2015, ground water recharge, a form of potable reuse, is anticipated to make up approximately seven percent of the total use in 2040.

Figure 29. Recycled Water Projections by Use Category

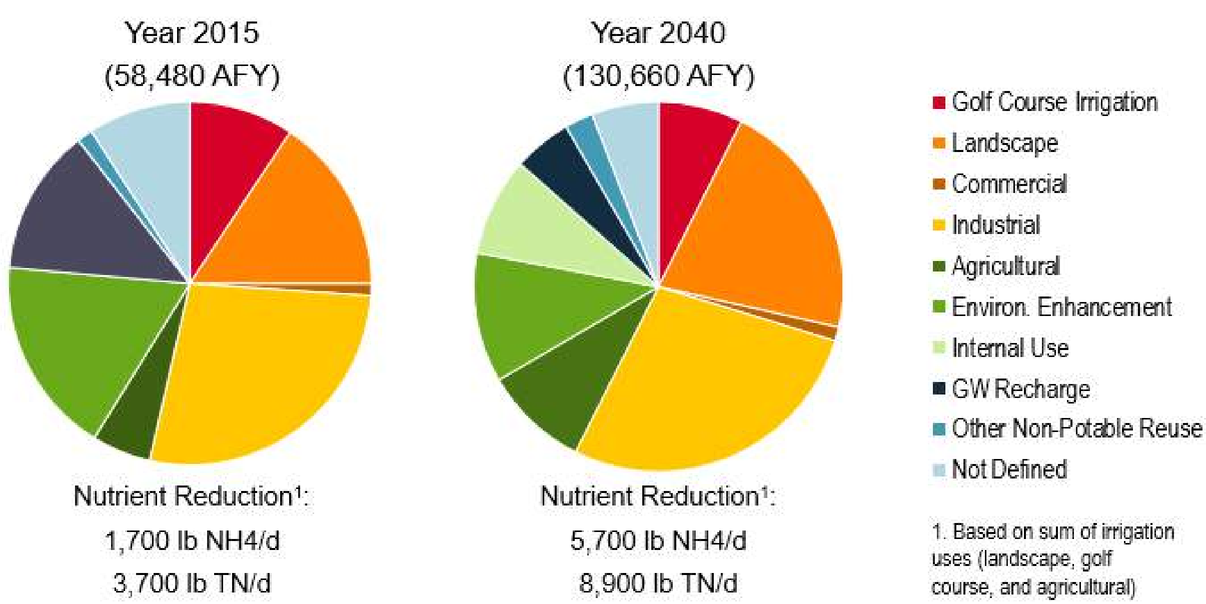

Figure 29 also presents the estimated nutrient reduction for ammonia and total nitrogen due to recycled water use. As shown, an estimated 3,700 lb-TN/d was diverted from the bay in 2015 through recycled water use. An additional 5,200 lb-TN/d is anticipated to be diverted by 2040, for a total of approximately 8,900 lb-TN/d. Although these load reductions are less than that achievable through treatment plant improvements, recycled water use has other important benefits for the region.

It is notable that some recycled water use categories do not result in a reduction in nutrient loads discharged to SF Bay. In fact, some uses, such as potable reuse, could increase concentrations discharged to the bay due to the concentrated return streams created during the advanced treatment processes. Generally, irrigation uses (i.e., landscape, golf course, and agricultural) result in a decrease of nutrient loads since the water is completely consumed at the application site. However, uses such as potable reuse and often times industrial uses, will have a concentrated stream that is either returned to the POTW for discharge or otherwise discharged to SF Bay. Thus, with respect to identifying the nutrient reductions associated with future recycled water uses, it is important to understand the type of use anticipated and whether there will be a concentrated return stream that ultimately needs to be discharged.

In addition to recycled water, another potential opportunity to reduce nutrients by means other than treatment within the fenceline is the horizontal levee project. OLSD recently constructed a horizontal levee, known as the Ecotone Project. It is the first of its kind in the Bay Area. The horizontal levee has several anticipated benefits to the OLSD WWTP:

- Protection against sea level rise
- Reduction in nutrient loads to the Bay by polishing in the levees wetland system
- Equalization of wet weather flows
- Protection against flooding and habitat loss

Tracking the Ecotone Project performance will provide valuable information to assist other agencies in determining whether such a project is appropriate for other sites.

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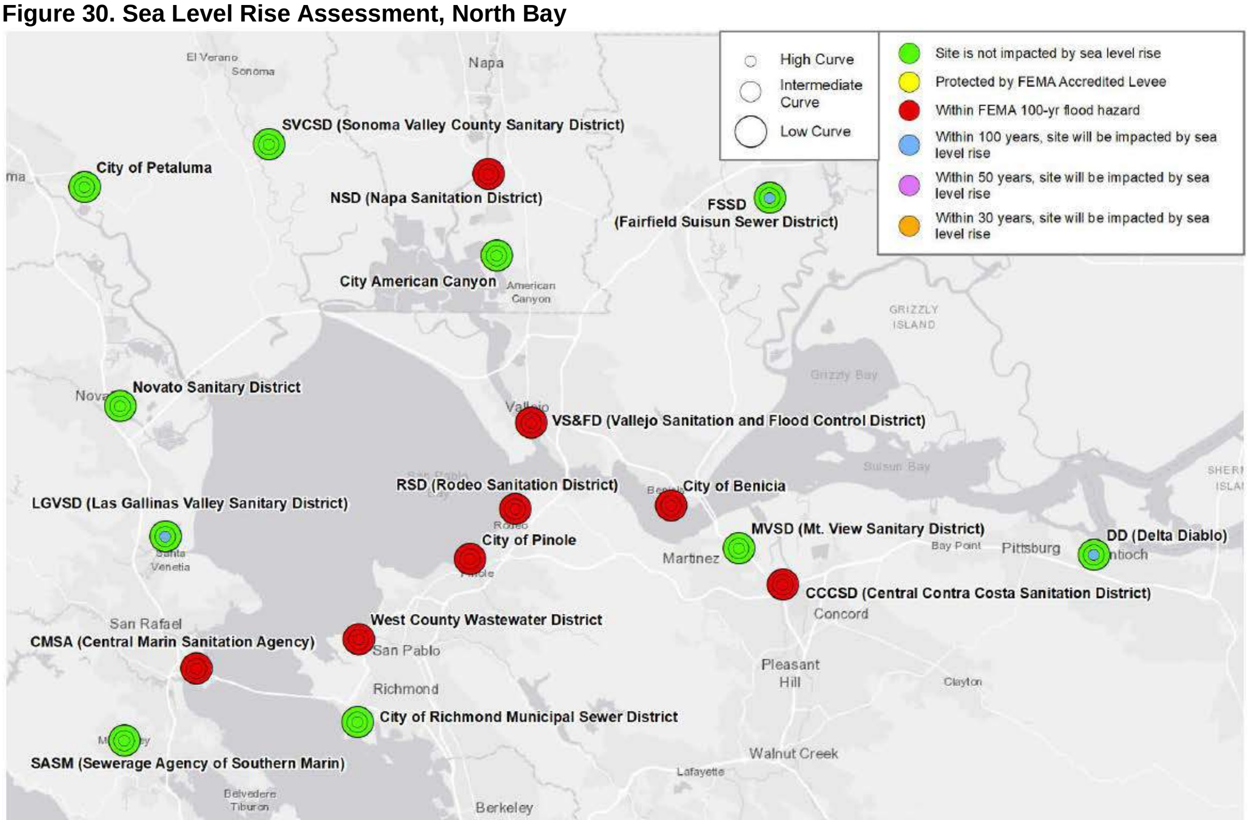
6. Sea Level Rise

As described in Chapter 3, the Watershed Permit requires consideration of the potential impacts on facilities due to sea level rise. The intent of the requirement was to avoid identifying nutrient removal options that would be infeasible due to actions implemented or planned to address sea level rise. Thus, the plants that are vulnerable to the impacts of sea level rise were identified. The methodology, described in detail in Appendix C, is based on publicly available data from the USACE, FEMA, and publicly available topography data.

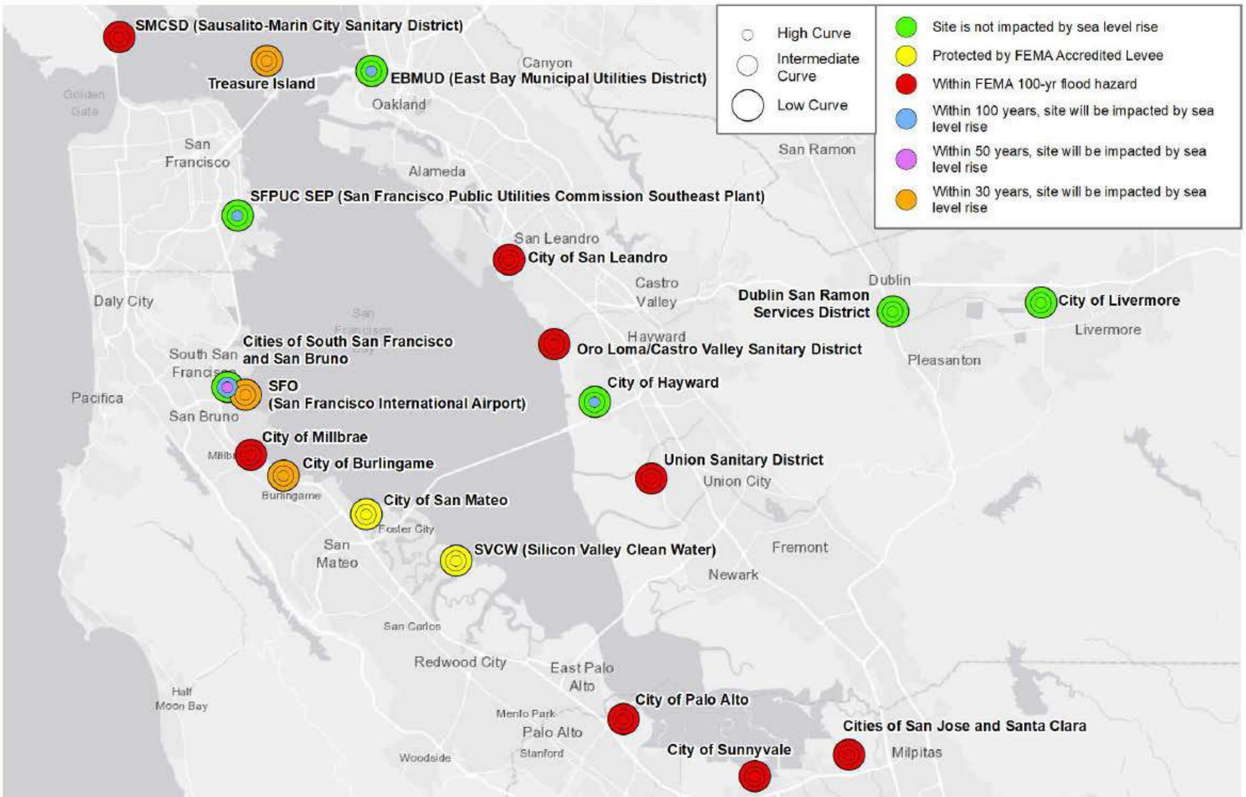
The results of the analysis are illustrated in Figure 30 and Figure 31 for the north and south bay, respectively, and presented in detail in Appendix C. The figures present the results of the analysis under three rates of sea level rise conditions, as defined by the USACE:[25] low, intermediate, and high. The low rate of sea level rise reflects the historical rate of sea level change. The intermediate rate of rise is based on the modified National Research Council (NRC) Curve I considering both the most recent Intergovernmental Panel on Climate Change (IPCC) projections and modified NRC projections with the local rate of vertical land movement added. The high rate of rise is based on the modified NRC Curve III considering both the most recent IPCC projections and modified NRC projections with the local rate of vertical land movement.

Figure 30. Sea Level Rise Assessment, North Bay



25 http://www.corpsclimate.us/ccaceslcurves.cfm

Figure 31. Sea Level Rise Assessment, South Bay



Sixteen plants are currently within the FEMA 100-yr flood hazard, which indicates that they are currently vulnerable to sea level rise and other flooding conditions. Nine plants are not vulnerable to sea level rise under the low, medium, or high rate of rise conditions. Two plants are protected by existing FEMA accredited levees. The remaining ten plants are vulnerable to the effects of future sea level rise, particularly under the high level rise condition forecast. Many agencies are aware of their vulnerability and have already begun planning for future flood protection facilities. For example, the City of Sunnyvale is constructing a flood wall to protect its plant as part of an on-going upgrade of the headworks and primary treatment facilities.

As previously described, in addition to the 37 plants, there are many other wastewater-related facilities that could be impacted by sea level rise, such as piping and sewage lift stations within the collection system (particularly those in low lying areas which could become more susceptible to sea water intrusion) and effluent discharge facilities. With respect to the latter, sea level rise could impact the hydraulics and capacity of effluent pump stations and pipelines. Sea level rise could potentially result in additional pumping requirements to discharge effluent, increasing both energy requirements and associated costs.

7. Discussion and Observations

The following sections summarize the key observations of this study with respect to water quality objectives, averaging periods, permit structures, constrained sites, technology selection, GHG emissions, and factors influencing capital costs.

7.1 Water Quality Objectives Influence Technology Selection

As previously described, there are ongoing studies to evaluate the impact of nutrients, nitrogen and phosphorus, on the health of SF Bay. The outcome of those studies will determine whether nutrients are impacting the bay, and if so, which nutrient (nitrogen, phosphorus, or both) and which species (organic, inorganic, soluble, particulate, etc.) impact the bay. It is anticipated that future water quality objectives (i.e., numeric effluent limits, species, averaging periods, etc.) would be established based on those results, and those objectives will have a strong influence on the selected nutrient technology and the resulting cost of nutrient removal.

LOWER LIMITS DICTATE ADDITIONAL TREATMENT

The Water Environment Research Foundation (WERF) Nutrient Removal Challenge[26] research program found that inorganic nutrients are readily used by algae while organic nutrients are typically slow to stimulate algal growth. The research also concluded that inorganic nutrients (nitrogen and phosphorus) are readily removable through conventional treatment methods, while soluble organic nutrient species (SON and SOP) resist conventional and even advanced treatment methods.

The Level 2 benchmarks are sufficiently high such that conventional nutrient removal technologies could be employed without the need for chemical addition (e.g., additional carbon for total nitrogen removal and metal salts for total phosphorus removal) or filtration. Conversely, the Level 3 benchmarks were selected to capture the lower range wherein chemical addition and filtration would be needed to remove particulate nutrients while reliably meeting water quality objectives and allowing for SON and SOP in the effluent.

AMMONIA LIMITS MAY PRECLUDE EMERGING TECHNOLOGIES

A requirement to achieve complete ammonia reduction (i.e., through nitrification) could constrain the ability to implement emerging technologies. With a few exceptions, near complete nitrification is unavoidable with conventional biological processes. Fixed film processes (trickling filters, MBBR, BAF, etc.) or split treatment strategies can avoid complete nitrification. However, emerging technologies such as shortcut nitrogen removal processes, have the major benefit of reduced energy and footprint requirements, but do not achieve complete ammonia removal. With incomplete nitrification, ammonia remains in the effluent. As a result, the establishment of a low water quality objective for ammonia would inhibit the use of some emerging technologies.

[26] Jeong, J.; Liu, H.; Sedlak, D.L. (2013) Uptake by Algae of Dissolved Organic Nitrogen from BNR Treatment Plant Effluents. Water Environment Research Federation, Alexandria, VA. NUTR1R06e.
Li, Bo and Brett, M. (2015). The Bioavailable Phosphorus (BAP) Fraction in Effluent from Advanced Secondary and Tertiary Treatment. Water Environment Research Federation, Alexandria, VA. NUTR1R06m.

PERMITTING UNCERTAINTY INCREASES CAPITAL COSTS

A typical consideration in the selection of nutrient removal treatment technologies is to plan for future flexibility if future permitted effluent limits change. Specifically, facilities planners often prefer process technologies that do not complicate future changes in nutrient removal requirements or which would not result in stranded assets. For this Nutrient Reduction Study, technologies were selected to facilitate phased implementation of facilities without stranding assets. First, the existing facilities were incorporated, or modified to be incorporated, into process needs for optimization, then that was expanded for Level 2 (when possible), and ultimately to achieve the Level 3 benchmarks. While the potential for leaving an asset stranded is reduced with this approach, it may not result in the optimal solution for the first phase of improvements if future, lower nutrient objectives never materialize. That is, facilities designed to meet the Level 2 benchmark as the endpoint would likely differ from those designed to be expanded from Level 2 to meet a future Level 3 endpoint. Thus, long-term nutrient discharge permit certainty could result in more cost-effective solutions from the outset.

7.2 Averaging Periods Influence Footprint and Cost

The appropriate averaging period for nutrient discharges depends on the sensitivity of the water body to nutrient enrichment and water quality degradation, and the location of the discharge in the watershed. The federal NPDES regulations in 40 CFR 122.45(d) require that effluent limits be expressed as monthly and weekly limits for municipal permits "unless impracticable." Maximum daily limits focused on an effluent mixing zone are appropriate for protection of aquatic life from toxicity. In general, longer averaging periods for nutrient discharges are appropriate due to slower growth responses for algae and time for enrichment to result in water quality degradation on a broader watershed scale. For larger water bodies, such as bays, estuaries, reservoirs, and lakes, monthly, seasonal, or yearly averaging periods are more appropriate.[27]

Nitrogen and phosphorus typically have seasonal impacts on receiving waters. Thus, water quality objectives for total nitrogen and phosphorus removal should be based on long averaging periods linked to the specific water body response to nutrient enrichment. Short averaging periods based on protection of aquatic life from toxics would result in unnecessarily restrictive nutrient limits that would, in turn, lead to overly conservative designs for nutrient removal facilities with little, or no, additional water quality benefit. However, the incremental reduction in nutrient effluent loads would be minor.

Longer averaging permit periods and median limits maintain the average loading below water quality targets, such as waste load allocations in TMDLs, while accommodating the variability in effluent quality and occasionally higher discharge concentrations that are offset by lower effluent concentrations during normal operation. For example, EPA determined that annual nutrient effluent limits were appropriate for the Chesapeake Bay because it is impracticable to express

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[27] EPA (2003) Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll for the Chesapeake Bay and Its Tidal Tributaries. Office of Water. Washington, D.C.

limits on a shorter time scale.[28] For the Spokane River[29], it was determined that it is impracticable to calculate appropriate average monthly and average weekly limits for total phosphorus, ammonia, and carbonaceous biochemical oxygen demand (CBOD). Future variability of the key TMDL constituents, total phosphorus, ammonia, and CBOD, are likely to be highly variable at the low concentration levels targeted in the TMDL. This makes it difficult to calculate appropriate monthly average and weekly limits with any degree of certainty, and may result in artificially stringent limits which are unnecessary for protection of water quality. Further, water quality modeling of the Spokane River demonstrated that Lake Spokane is insensitive to short-term increases in loading of oxygen-demanding pollutants from point source discharges. The effluent limits for total phosphorus, ammonia, and CBOD for the Spokane River are based on far-field, as opposed to near-field, water quality concerns. Seasonal average mass loadings result in water quality protection equivalent to the TMDL. Clean Water Services of Washington County, south of Portland, OR, has challenging monthly limits (previously 0.07 mg/L and currently 0.1 mg/L TP) based on a median effluent concentration. By using the median concentration, occasional higher discharge concentrations do not threaten permit compliance.

The permit averaging period determines both the design criteria and loading used to size the treatment process for nutrient removal. The structure of effluent discharge limits can govern the cost and size of treatment facilities, as illustrated in the following example.

Table 16 contains the design of a hypothetical total nitrogen load reduction facility if the permit conditions change from average, to monthly, and to daily limits. The design loading increases as the averaging period decreases; the maximum month loading is 12 percent higher than the average loading and the maximum day loading is 45 percent higher. The design temperature for the shorter period results in a higher sludge age. All of these factors combine to increase the reactor volume and footprint space requirements by 30 percent and 65 percent, respectively. The capital costs increase by 7 percent and 30 percent respectively, as the averaging period is shortened to monthly and to daily.

This example illustrates the additional cost and footprint space requirements as the averaging period decreases from annual to monthly, and to daily. The estimated additional total nitrogen load reduction over an entire year is just over 10 percent.

In addition to the above considerations, longer averaging periods could support the implementation of emerging and innovative technologies.

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[28] Hanlon, J. H., Director Office of Wastewater Management. (2004) Memorandum to Jon Capacasa, Director Water Permits Division, EPA Region and Rebecca Hammer, Director Chesapeake Bay Program Office, "Annual Permit Limits for Nitrogen and Phosphorus for Permits Designed to Protect Chesapeake Bay and its tidal tributaries from Excess Nutrient Loading under the National Pollutant Discharge Elimination System." http://www.epa.gov/reg3wapd/npdes/pdf/ches_bay_nutrients_hanlon.pdf

[29] Spokane County (2011) National Pollutant Discharge Elimination System Waste Discharge Permit No. WA-0093317, Spokane County Division of Utilities.

Table 16. Impact of Averaging Period on Facility Sizing for Hypothetical Loading Scenario

Parameter	Unit	Permit Averaging Period		
		Annual Average	Maximum Month	Maximum Day
Total Nitrogen Design Load	lb N/d	44,000	49,300	64,200
Design Temperature	deg C	20	15	12
Design SRT	d	8	10	15
Footprint Requirement	Relative	100%	133%	167%
Capital Cost	$	200	214	260
Estimated Annual Total Nitrogen Removal[1]	Million lb/yr	9.4	10.3	10.4
Additional removal[2]	%	Base	10%	11%

1. Estimated removal operating for 10 days at Maximum Day, 60 days at Maximum Month, and 295 days at average conditions.
2. Additional removal compared to Annual Average condition

7.3 Flexible Permit Structures Facilitate Innovation

Emphasis in nutrient discharge permitting should focus on providing the maximum flexibility possible in the structure of nutrient limits in order to preserve the opportunity for the most creative and economical approaches to managing nutrients. Traditional permit structures for POTWs generally include both monthly and weekly limits on both a concentration and mass basis. This may inadvertently eliminate the most effective watershed solutions to nutrient management by creating disincentives to wastewater dischargers to explore combinations of advanced wastewater treatment and other watershed management practices, such as reuse.

It is important to structure nutrient discharge permits in a manner that avoids inadvertent disincentives to watershed management, nutrient trading and offsets, and other approaches to optimization. Combinations of both effluent concentration and mass effluent limits for nutrients may constrain the development of trades, or increase the complexity in accounting for trades. Watershed permits formulated with loading exchanges and optimization in mind may facilitate the implementation of water quality trading. Effluent limits based on total mass loadings combined with long averaging periods, such as seasonal or annual limits, facilitate compliance and provide an opportunity for optimal combinations of advanced treatment and water quality offsets and trading.

When the relationship between nutrient loadings and water quality responses is not well defined, it is advisable to avoid overly restrictive effluent limits at the outset, since they may later prove unnecessary to meeting actual receiving water needs when they eventually become better understood. Preserving an opportunity for adaptive management approaches to guide the process of nutrient management over time may improve water quality incrementally, without overly restrictive discharge permits that result in over investment in advanced treatment. Permits structured around no net increase in existing loadings, or simple seasonal or annual loading reductions, may provide a foundation for adaptive management.

7.4 Constrained Sites Influence Technology Selection

Conventional nutrient removal technologies can require significant plant real estate. Unfortunately, many of the SF Bay plants are located on constrained sites. Not only is space required for new treatment basins and equipment, but allowances must be made to sustain operations during construction, while also setting aside construction staging areas. Constrained sites can also require more complex and costly construction techniques.

Site constraints result from several factors. Plants in densely populated areas such as San Francisco and San Mateo, have little open space available. Other plant sites, such as CMSA or Millbrae, are bounded by major roadways and natural features.

With limited space to add treatment processes, compact technologies such as an MBR become more attractive. While an MBR provides a smaller footprint than conventional nutrient removal techniques, it also has higher capital and operating costs. Some emerging technologies have a small footprint, but their performance is yet to be proven in large scale applications.

An example of a constrained site is illustrated in Figure 32 for the City of Millbrae.

Figure 32. Constrained Site, Millbrae Example

Note: New facilities to achieve the Level 3 water quality benchmarks would include: (1) optimization of ferric addition for phosphorus removal, (2) new polymer chemical feed facilities, (3) conversion of the activated sludge to an MBR by converting secondary clarifiers to membrane tanks, (4) expansion of the aeration basins to create a third train (requires moving the blower building), (5) new alkalinity chemical feed facilities, (6) new external carbon source chemical feed facilities, (7) decommissioning of the chlorination disinfection system and use this footprint for additional aeration basin volume, and (8) add an ultraviolet disinfection system.

The only viable treatment solution for nutrient removal on the Millbrae site was to rearrange existing facilities and convert to a compact MBR process. As shown, the plant is located within a triangular parcel of land bounded by Highway 101 to the southwest, the on-ramp to the north, and the Millbrae Avenue overpass to the southeast. In addition, there is a buried 24-inch gas pipeline, owned by PG&E, which runs adjacent to the existing aeration basin. These site constraints severely limit the options available for adding new facilities. To achieve the Level 3 effluent water quality benchmarks, the space currently occupied by the existing chlorine contact basin would be used to expand the biological reactor and a new, compact ultraviolet (UV) system is proposed for disinfection. In addition, the blower building would be relocated to make site space available.

Overall, MBRs were recommended for eight plants due to site constraints.

7.5 Technology Selection Influences Effluent Quality, Footprint, GHGs, and Costs

As previously described, conventional nutrient removal technologies were used as the basis of analysis in this study because the costs, space requirements, and performance are well established. However, emerging technologies have the potential to significantly reduce capital and/or operating costs in comparison to the well-established technologies that were used as the basis of this study. In addition, some emerging technologies could also reduce the plant site space footprint required for nutrient removal.

The following subsections describe some of the emerging technologies that may be useful to reduce nutrient discharges to SF Bay.

7.5.1 Shortcut Nitrogen Removal

Shortcut nitrogen removal refers to a range of processes that reduce the operating cost, footprint, and carbon needs for total nitrogen reduction. This group of processes aims to halt the nitrification reactions at nitrite, and then denitrify the nitrite directly to nitrogen gas by nitrite reducing heterotrophs using carbon, or by anammox bacteria that produce nitrogen gas from ammonia and nitrite. In other cases, simultaneous nitrification and denitrification (SND) can be achieved by operating at reduced dissolved oxygen (DO) concentrations.

Even though the design to achieve shortcut nitrogen removal is still evolving, the use of shortcut nitrogen removal has been demonstrated at many pilot-scale and some full-scale treatment plants. It offers a modest reduction in footprint, but could significantly improve total nitrogen reduction and reduce both aeration requirements and the need for supplemental carbon.

7.5.2 Granular Activated Sludge

The ability to grow activated sludge bacteria to form granules is a significant improvement in the activated sludge process. By growth and waste selection, the activated sludge form granules and each granule has an anaerobic core, an anoxic inner zone, and aerobic outer shell to achieve BOD removal, nitrification/denitrification, and phosphorus removal. Research is ongoing (led by Professor McSwain Sturm at the University of Kansas) to investigate the process requirements, selection mechanisms, and design features needed for mainstream granular activated sludge. This research is still in the emerging stage, but granules have been detected in full-scale applications.

The emerging AquaNereda® process is the only commercially available, full-scale proven granular activated sludge technology. It operates in a sequencing batch reactor (SBR) mode at a mixed liquor concentration of about three times a conventional BNR and requires no additional clarifiers for solids separation. Additional flow buffering tanks may be required to accommodate continuous treatment. As a result of these reduced reactor requirements, the footprint for an AquaNereda® process could be less than 40 percent of a conventional process. The Aqua Nereda® process can achieve the Level 2 water quality benchmarks, but requires additional process elements to meet Level 3 benchmarks.

7.5.3 Zeolite Anammox

Zeolite/Anammox is an emerging technology that was developed in Northern California by Dr. Robert Collison. It is a hybrid technology that leverages the benefits of zeolite and Anammox bacteria. The technology performs nitrogen removal with applications for sidestream treatment, liquid stream treatment, and water reuse.

Zeolite (clinoptilolite) is a microporous, aluminosilicate mineral that has a high cation exchange capacity (CEC). This high CEC preferentially adsorbs ammonium which is immobilized on the ion exchange sites. The immobilization step also concentrates ammonium for advantageous growth of a bacterial biofilm.

The use of zeolite for ammonium removal from wastewater using CEC has been in practice for decades. Truckee Meadows Water Reclamation Facility used zeolite to remove ammonium following secondary treatment for approximately 30 years. While effective, zeolite media has to be regenerated (i.e., ammonium removed) once all the zeolite ion exchange sites are saturated. Typically, regeneration uses high strength brine which has its own challenges.

The Zeolite/Anammox Technology avoids the disadvantages of earlier zeolite-based ammonium removal systems by using continuous biological regeneration of the zeolite media. The technology relies on zeolite serving as a medium to adsorb ammonium and biofilm growth. A biofilm rich with anammox and ammonia-oxidizing bacteria (AOB) coats the zeolite, and as the zeolite adsorbs ammonium, the biofilm continuously regenerates the zeolite by converting the adsorbed ammonium to nitrogen gas. The end products in the process are nitrogen gas and water.

7.5.4 Membrane Aerated Biofilm Reactors (MABR)

The Membrane Aerated Biofilm Reactor (MABR) is a fixed film process that uses a hollow fiber membrane as a surface to grow biofilm on the outside of the fiber while also providing aeration from the inside of the fiber. By supplying aeration to the inside of the biofilm and placing the wastewater on the outside of the biofilm, the resulting biology provides nitrification on the inside of the film and denitrification on the outside of the biofilm. This arrangement allows for highly efficient aeration, a small footprint, and effective nitrification and denitrification.

There are no full-scale MABR plants in the US at this time; however, several pilot studies are ongoing, including a study at Hayward. The results from these studies can further define the design requirements, facility needs, and potential performance of the process.

7.5.5 BioMag® Activated Sludge

The BioMag® activated sludge process introduces magnetite into the biological process to serve as a nucleus for biological growth. Small magnetite particles are introduced to impregnate the biological flocs, making them heavier and easy to separate by gravity in a secondary clarifier. The rapid settling floc facilitates a higher mixed liquor concentration in the biological reactor, which reduces the footprint of the reactor and also accommodates higher peak flows through the process. The magnetite is recovered from the waste sludge and returned to the main biological process. Due to the heavy floc, mixing energy is increased in this process to keep the solids in suspension.

The BioMag® process has been proven in several facilities, mainly smaller plants (e.g., less than 5 mgd). The biological process can be designed as a classic BNR process with similar performance expectations, but with the advantage of a smaller footprint.

7.5.6 High Rate Primary Treatment

Primary treatment is not required for nutrient removal but does reduce the loading to the biological process, resulting in lower biological growth, smaller reactors, but potentially insufficient carbon to achieve nitrogen removal. Primary treatment also diverts organics to solids processing where anaerobic digestion can produce methane that can be used to reduce energy demand or other beneficial uses.

High rate primary treatment options include microscreens (e.g., Salsnes filter), cloth media filters (e.g., AquaPrime), Densadeg® ballasted sedimentation, or CEPT. The first two processes are emerging, whereas the latter two have been used in full-scale plants. The benefit of high rate primary treatment would be to free up site space or improve particulate BOD removal in the primary treatment process.

7.5.7 Sidestream Treatment

As previously described, the sidestream generated from anaerobic digested sludge dewatering is nutrient rich. By eliminating the nitrogen and phosphorus from these streams, the effluent from the plant nutrient load can be reduced accordingly. There are several technologies available to reduce sidestream loading.

Nitrogen can be removed through physical and biological processes. Biological ammonia removal using a deammonification (Anammox®) process such as DEMON®, AnitaMox™, or Paques®, has been proven to be about 85 to 90 percent efficient and cost effective to reduce the ammonia recycle load. Recovery of ammonia (e.g., ammonium sulfate) via stripping and condensation is an emerging technology that is gaining traction. Most of the current full-scale installations are located outside of the US and typically focus on industrial loads. Nonetheless, this market is anticipated to grow in upcoming years and should be monitored.

Phosphorus can be harvested from the sidestream by precipitating struvite into granules (using Ostara, Phospaques, Airprex or similar technologies) and beneficially used as a fertilizer. The high phosphorus recycle can also be arrested by adding a metal salt (alum or ferric) before dewatering to precipitate the phosphorus and capture it in the dewatered cake.

7.5.8 Summary of Emerging Technologies

Many other new technologies are still emerging and it is likely that many more will come. It takes a long time for a new technology to enter full-scale treatment at a substantial (e.g., over 5 mgd) capacity (granular sludge took about 15 years to come to full-scale and remains unproven in the United States). A longer period is needed to “work out the kinks” in the technology and improve the control and efficiency of the process.

The risks associated with a new technology can be substantial. Unforeseen process problems can emerge, process control needs time to mature, and performance may be highly variable until the process has been in full-scale operation for a number of years. For example, while enhanced biological phosphorus removal was discovered and implemented in the early 1970’s, the process performance remained variable with substantial improvements in early 2000’s. Even after 30 years, there remains new discoveries to further improve the process stability, particularly to achieve low effluent phosphorus concentrations.

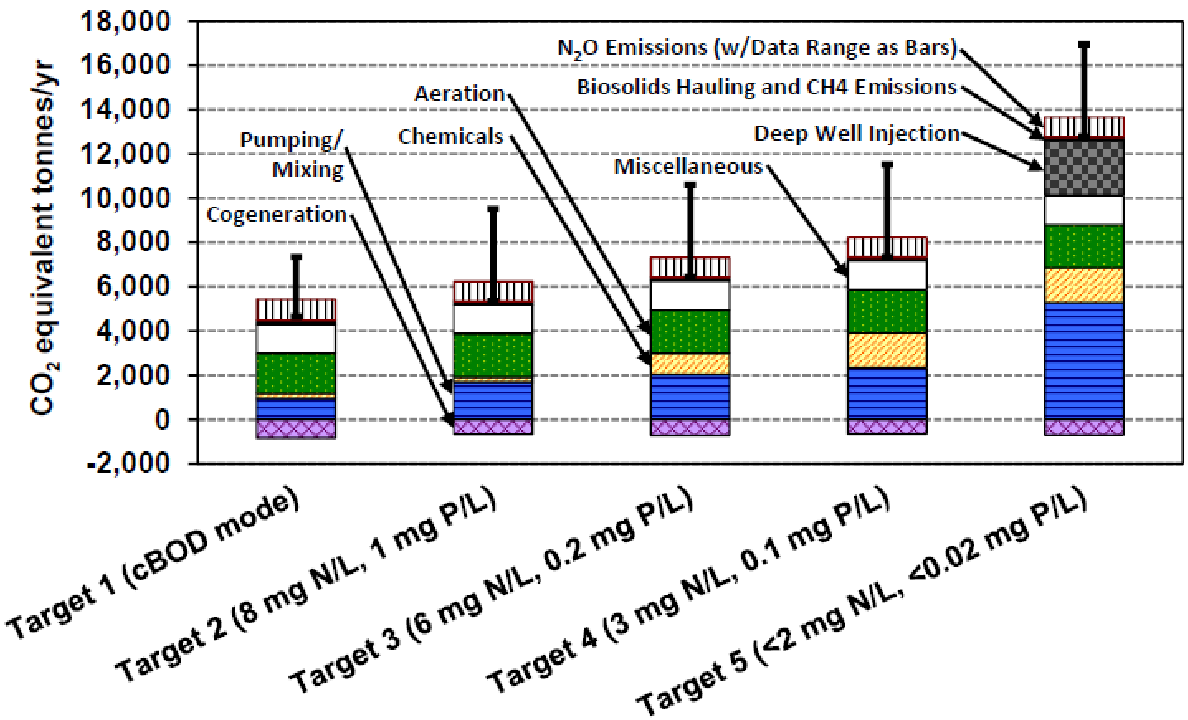
Utilities should remain active in evaluating and potentially pilot testing and even demonstration scale testing promising technologies. Regulatory cooperation could further accelerate implementation of new technologies by allowing full-scale testing and time to optimize the technology.

7.6 GHG Emissions Impacted By Water Quality Objectives

More stringent water quality objectives will result in an increase in GHG emissions with the transition from secondary treatment to advanced treatment with nutrient removal. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, and chemical demands for alkalinity and phosphorus precipitation, among others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient removal is plant specific due to varying water characteristics, technology selection, chemical type, electrical power generation, fuel type (e.g., coal versus natural gas), and location. Research by Falk et al. (2013) is presented in Figure 33 that illustrates the potential plant wide increase in GHG emissions for various nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment, while Targets 2 through 5 represent nutrient targets with Target 5 being the most stringent. The Level 2 target established for this Nutrient Reduction Study is between Falk’s Targets 1 and 2, while the Level 3 target is comparable to Falk’s Target 3.

Figure 33. GHG Emissions for a Nominal 10 mgd Plant for Various Treatment Targets[30]



The gradual increase in GHG emissions demonstrated in Figure 33 from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study revealed that a point of diminishing return is reached as nutrient removal objectives approach the limit of technology where GHG emissions and the cost of treatment both increase rapidly, while the potential for algal growth in the receiving water is only marginally reduced. Note, the point of diminishing returns is watershed specific.

The increased energy demands are assumed to be satisfied with imported electricity; therefore, the GHG emissions associated with the imported electricity would not impact plant-wide anthropogenic greenhouse gas emissions counted towards the California Air Resources Board (CARB) Cap and Trade Threshold (i.e. these would be emissions associated with the electric utility provider).

Similarly, the increase in GHG emissions from chemicals is associated with the production of those chemicals and would not impact plant-wide anthropogenic greenhouse gas emissions counted towards the CARB Cap and Trade Threshold (i.e. these would be emissions associated with the chemical manufacturer/supplier).

[30] Falk, M.W.; Reardon, D.J.; Neethling, J.B.; Clark, D.L.; Pramanik, A. (2013) Striking the Balance between Nutrient Removal, GHG Emissions, Receiving Water Quality, and Costs. Wat. Environ. Res., 85(12):2307-2316.

Although fugitive N_2O emissions can be significant while performing nitrification/denitrification, these emissions are not currently reportable to CARB and are not part of the anthropogenic emissions total that determines Cap and Trade inclusion applicability.

7.7 Capital Costs are Substantial

Capital costs make up approximately 60 to 70 percent of the total present value costs for facilities required to meet the Level 2 and 3 benchmarks. It is notable that construction costs for large infrastructure projects in the SF Bay region, as measured by the CCI, have been escalating at a rate of 3 to 4 percent in recent years. If this trend continues, the construction cost for future projects could be significantly impacted. Moreover, the recent trade tariffs on steel and other items, announced in late March 2018, have created volatility in construction costs, which could have further impacts on future construction costs.

Another factor that could impact future costs is the relative timing of projects. That is, if each of the 37 POTWs were to undergo a major upgrade simultaneously, there could be significant cost impacts due to constraints in construction capacity in the local Bay Area marketplace.

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8. Summary and Next Steps

The purpose of this Nutrient Reduction Study is to evaluate opportunities to reduce effluent nutrient loading to SF Bay through treatment optimization, sidestream treatment, and treatment upgrades. In addition, this study considers opportunities to reduce effluent nutrient loading through other, non-treatment means.

Table 17 summarizes the potential nutrient load reductions for treatment optimization, sidestream treatment, and treatment upgrades. The associated costs are also presented. For comparison, the estimated total nitrogen reduction that is anticipated through planned recycled water use is approximately 8,900 lb N/d by 2040, which is most comparable to the load reductions achievable through treatment optimization.

Table 17. Summary of Nutrient Load Reduction and Associated Costs, Year Round Design and Operation

Parameter	Unit	Projected Discharge Load, without Opt.[1]	Projected Discharge Load, without Sidestream or Upgrades[1]	Treatment Strategy			
				Optimization[2]	Sidestream[2]	Level 2[2]	Level 3[2]
Design Flow	mgd	--	--	546	869	869	869
Load Reduction[4]							
Ammonia	lb N/d	87,900	114,700	12,300	27,400	106,900	106,900
TN	lb N/d	129,700	166,300	8,600	32,000	95,000	136,300
TP	lb P/d	9,200	11,900	3,100	1,400	7,000	10,500
Load Reduction							
Ammonia	%	--	--	14%	24%	93%	93%
TN	%	--	--	7%	19%	57%	82%
TP	%	--	--	34%	12%	59%	88%
Costs[4,5]							
Capital	$M	--	--	119	391	6,976	8,517
O&M PV	$M	--	--	147	345	2,443	3,888
Total PV	$M	--	--	266	736	9,420	12,405
Average Unit Costs							
Per gpd[6]	$/gpd	--	--	0.5	0.8	10.8	14.3
Per lb N[7]	$/lb N	--	--	5.6	2.0	8.7	7.7
Per lb P[7]	$/lb P	--	--	8.6	2.8	44	59

1. The projected discharge loads are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015) and projected to the midpoint of the respective planning period. The reported flows and loads for optimization, upgrades, and sidestream represent average projected load reduction for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream). Sidestream design flow reflects only the candidate plants.
2. Facilities were sized for year round loads and operated year round. The results for each treatment strategy are stand alone.

3. Load values are rounded to the nearest hundred.
4. Costs are referenced to the ENR SF CCI for January 2018 at 12,015. Costs are not additive for scenarios (e.g., the Level 3 costs shown are inclusive of facilities needed to meet Level 2). Costs do not account for changes in any other process, including solids handling or associated energy requirements.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. Unit cost ($/gpd) was calculated by dividing the total present value by the design flow.
7. Unit cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the projection duration (e.g., for upgrades: Total PV for TN Removal facilities divided by (Average Annual TN Removed times 30-years)).

Overall, load reductions increase with increasing degrees of treatment, from optimization through Level 3. Implementation of the optimization strategies could result in a load reduction of approximately seven percent for total nitrogen for a short term (approximately 10 years) capital investment of approximately $120M, whereas implementation of sidestream treatment could result in a total nitrogen load reduction of nearly 20 percent for a longer period (approximately 30 years) at a capital cost of approximately $390M. On the whole, the cost per pound of nitrogen removed is lower for sidestream treatment than that for optimization. However, there may be site-specific optimization opportunities that are more cost-effective and/or would warrant consideration for other reasons. For example, an agency may wish to first pursue optimization if it is the quickest and easiest way to meet a near term no net load increase requirement or if it addresses other process issues or results in a more stable overall process.

Sidestream treatment is the most cost-effective means of reducing both total nitrogen and total phosphorus, when comparing the cost per pound removed. However, sidestream treatment is not feasible at all plants. Of the 37 participating plants, only 23 facilities are candidates for total nitrogen reduction and 15 facilities for total phosphorus reduction. A total load reduction of nearly 20 percent for total nitrogen and over 10 percent for total phosphorus could be achieved with the implementation of sidestream treatment at all the feasible plants.

Ultimately, the costs to upgrade treatment plants to achieve the Level 2 and 3 effluent quality benchmarks are substantial. As a result, it is recommended that the other ongoing scientific studies be further developed or completed to provide a better understanding of nutrient processing and confirm whether or not the SF Bay is impaired, and if so, to determine the specific nutrients (and speciation) causing impairment. As that is better understood, appropriate water quality objectives can be established.

It is important to emphasize the impact that permit limits can have on technology selection and facility sizing, and their associated costs, footprint requirements, and GHG emissions. Traditional permit structures for POTWs generally include both monthly and weekly limits on both a concentration and mass basis. This may inadvertently eliminate the most effective watershed solutions to nutrient management by creating disincentives to wastewater dischargers to explore combinations of advanced wastewater treatment and other watershed management practices, such as reuse and nutrient trading. Flexible permits, with longer averaging periods and mass-based limits (as opposed to concentration-based limits) will foster innovation and create opportunities for the most creative and economical approaches to managing nutrients.

When the relationship between nutrient loadings and water quality responses is not well defined, it is advisable to avoid overly restrictive effluent limits at the outset, since they may later prove unnecessary to meeting actual receiving water needs when they eventually become better understood. Preserving an opportunity for adaptive management approaches to guide the process of nutrient management over time may improve water quality incrementally, without overly restrictive discharge permits that result in over investment in advanced treatment. Permits structured around no net increase in existing loadings, or simple seasonal or annual loading reductions, may provide a foundation for adaptive management.

Once permit requirements are defined, and for the avoidance of doubt, each agency should conduct a thorough facilities planning study to determine the best way to achieve the limits at their respective facility prior to initiating preliminary design, design, and construction. As previously described, the findings presented in this study were based on well-established technologies for the purpose of providing reasonable costs and space requirements for long-term planning. There are many emerging technologies that could be more cost-effective and/or have other benefits that should also be considered.

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Scoping and Evaluation Plan

Brown AND Caldwell

BACWA

Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades

Scoping and Evaluation Plan

San Francisco Regional Water Quality Control Board Comments Incorporated

February 25, 2015

BACWA BAY AREA CLEAN WATER AGENCIES

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Scoping and Evaluation Plan

On April 9, 2014, the San Francisco Regional Water Quality Control Board (Water Board) issued Order No. R2-2014-0014, *Waste Discharge Requirements for Nutrients from Municipal Wastewater Discharges to San Francisco Bay* (Watershed Permit). The Watershed Permit sets forth a regional framework to facilitate collaboration on studies that will inform future management decisions and regulatory strategies. A component of the permit is to conduct treatment plant optimization and upgrade studies for nutrient removal. These studies will increase the understanding of external nutrient loads, improve the accuracy of the inputs used in load response models, and identify potential load reductions and costs for different dischargers to the Bay. Thirty seven plants (see Appendix A) will conduct the nutrient reduction studies collectively as members of Bay Area Clean Water Agencies (BACWA).

The Watershed Permit requires a Scoping and Evaluation Plan that describes the approach and schedule for completing the nutrient reduction studies by plant optimization and plant upgrade, as well as by other means. Nutrients of interest are ammonia, total nitrogen, and total phosphorus. The evaluation considers current flows for plant optimization/sidestream treatment but uses the permitted design capacity flows for plant upgrades. The effort comprises the following steps:

- Establish a range of nutrient removal levels
- Collect data for each plant and conduct a preliminary assessment based on this data
- Evaluate nutrient reductions achievable through plant optimization and sidestream treatment for each plant
- Evaluate nutrient reductions through plant upgrades for each plant
- Compile existing information to identify options for reducing nutrient loads by other means, such as water recycling, wetlands, etc.

The sections below describe the schedule and work necessary for completing the aforementioned steps.

Schedule

The optimization/sidestream treatment study and the plant upgrades study will be performed in parallel. The plants are required to submit a status report for each study by July 1, 2016 and again by July 1, 2017. The final reports are due for both studies the following year on July 1, 2018. In addition the Annual Group Nutrients Report showing trends in nutrient loadings will be submitted by October 1st of each year starting in 2015 and continuing until 2018.

A schedule is proposed that performs the two studies in parallel. An overview of the schedule along with descriptions for the tasks and completion dates is presented in Table 1. The project schedule has been designed to efficiently execute the study ahead of the deadlines specified in the Watershed Permit.

Table 1. Schedule by Tasks

Task	Description	Permit Deadline	BACWA End Date	Comment
1.) Project Management and QA/QC	Scheduled meetings, status updates, and QA/QC		12/2017	Manage the overall project and provide QA/QC of all deliverables
2.) Scoping and Evaluation Plans	Prepare documents for BACWA and RWQCB	12/1/2014 (Scoping) and 7/1/2015 (Evaluation)	12/2014	Documents that define the project approach and schedule
3.) Data Collection, Data Synthesis, and Site Visits	Disseminate questionnaire and compile data		10/2015	Collect plant data, compile data, and conduct site visits to produce site specific solutions
4.) Plant Optimization and Sidestream Treatment	Evaluate optimization and sidestream treatment strategies at each plant	7/1/2018	10/2015	Discuss the beneficial and adverse ancillary impacts for selected strategies; develop capital and operating costs
5.) Plant Upgrades	Evaluate plant upgrades for each plant	7/1/2018	10/2015	Discuss the beneficial and adverse ancillary impacts for each upgrade; develop capital and operating costs
6.) Nutrient Reduction By Other Means	Compile previous reports to identify attractive strategies	7/1/2018	10/2015	Discuss the beneficial and adverse ancillary impacts for any strategies; discuss institutional barriers to water recycling along with proposals for overcoming such barriers
7.) Group Annual Report	Assist BACWA with preparing the Annual Reports to RWQCB	10/1/2015, 10/1/2016, 10/1/2017, and 10/1/2018	10/1/2015, 10/1/2016, 10/1/2017, and 10/1/2018	
8.) Report Submittal	Submittal to RWQCB for the two studies	7/1/2018	6/2016	

Nutrient Removal Levels

The Watershed Permit does not explicitly state nutrient removal goals. As a result, nutrient removal levels for treatment plants were developed for the purposes of this study. As shown in Table 2, three seasonal nutrient levels were identified.

Table 2. Nutrient Removal Targets for Seasonal Averaging Periods*

Treatment Level	Study	Ammonia	Total Nitrogen	Total Phosphorus	Comment
Level 1	Optimization	--	--	--	Removal potential to be determined
Level 2	Upgrades	2 mg N/L	15 mg N/L	1.0 mg P/L	Without filters and external carbon **
Level 3	Upgrades	2 mg N/L	6 mg N/L	0.3 mg P/L	Filters and external carbon source required ***

*   The seasonal impacts will be considered for all three treatment levels.

** Achievable by conventional nutrient removal processes without effluent filtration and without adding an external carbon source. Certain participating plant configurations and technologies will require chemicals.

*** An external carbon source will not be required for certain plant configurations and technologies.

Level 1 consists of optimization efforts where nutrient loads are reduced as much as possible with little or no capital investment. As such, there are no defined numeric targets identified in Level 1. Capital investment(s) (e.g., excess tank volume) that were constructed with the intent to serve the projected growth in a facility's service area may be used in the near term to optimize nutrient removal, but may not be available in perpetuity as growth occurs in the service area. Thus, any strategies identified under Level 1 may not be viable in the long term if the facilities are needed to meet capacity requirements to accommodate planned growth.

The removal goals for plant upgrades are referred to as Levels 2 and 3. These levels were selected based on the typical tipping point for treatment technologies to achieve the respective effluent levels. For most plant configurations, the less stringent Level 2 can be achieved with conventional nutrient removal processes without adding an external carbon source (e.g., methanol) and without adding effluent filtration. The more stringent Level 3 requires an external carbon source for nitrogen removal and metal salt addition with filtration for most plant configurations. These factors contribute to a tipping point due to the well documented increase in cost, operational and safety burdens, energy demand, and greenhouse gas (GHG) emissions. Ammonia levels are selected to provide stable ammonia reduction (typically nitrification). The results for both Treatment Levels are beneficial for making informed future management decisions.

The Plan proposed to set a target of 6 mg/L TN as the lowest level for effluent nitrogen concentration from an upgraded plant. This target was selected based on an assessment of the capabilities of conventional nitrogen reduction technologies in a Northern California climate. To target a level wherein lower effluent nitrogen concentrations could be reliably met (i.e. 3-4 mg/L TN) would require additional levels of treatment (i.e. carbon addition, filtration, etc.) such that implementation costs would be significantly increased. Given the current uncertainty associated with the scientific studies analyzing impacts to the Bay from a wide variety of loadings, and the few plants that currently treat for nutrients, it seemed reasonable, for an initial assessment to set a target level for nutrient reduction consistent with what could be achieved by convention treatment applied at all plants around the Bay.

Innovative technologies that are emerging offer the hope of achieving even lower levels of nutrient discharges from treatment plants in a cost effective manner. As part of the assessment of innovative technologies applicable to specific plants, the consultant will provide what lower levels of nutrient reductions might possibly be achieved should the innovative technology prove to be feasible for full scale implementation.

Nitrogen and phosphorus typically have seasonal impacts on receiving waters. Thus, targets for total nitrogen and phosphorus removal should be based on long averaging periods linked to the specific waterbody response to nutrient enrichment. Short averaging periods based on guidance applicable to toxics constituents[1] will would result in overly conservative designs for nutrient removal facilities in order to provide the required reliability to meet the targets, but would provide little, or no, additional water quality benefit. As a result, seasonal averaging periods for total nitrogen and phosphorus discharges are proposed.

In order to capture seasonality variations, both wet season and dry season discharges will be evaluated. A dry season average was considered because it excludes sizing treatment facilities for peak wet weather events and low temperatures. Biological process kinetics are more rapid at warmer temperatures and thus result in a reduced footprint if sized for the dry season. During a significant precipitation event, plants are subjected to peak flows with subsequently less hydraulic residence time within the plant. Wet and dry season nutrient impacts on the estuary may differ as well.

The dry season, assumed to be from May 1 to September 30, will have different temperature and loading conditions. For example, the effluent temperature from a plant in Northern California is presented in Figure 1. For this facility, the design low temperature for a year round average monthly discharge is 15 degrees C, while the dry season low temperature is 21 degrees C. The design loads also will change by season.

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[1] Brown and Caldwell (2014) Review of USEPA Methods for Setting Water Quality-Based Effluent Limits for Nutrients. Prepared for the National Association of Clean Water Agencies, Washington D.C.

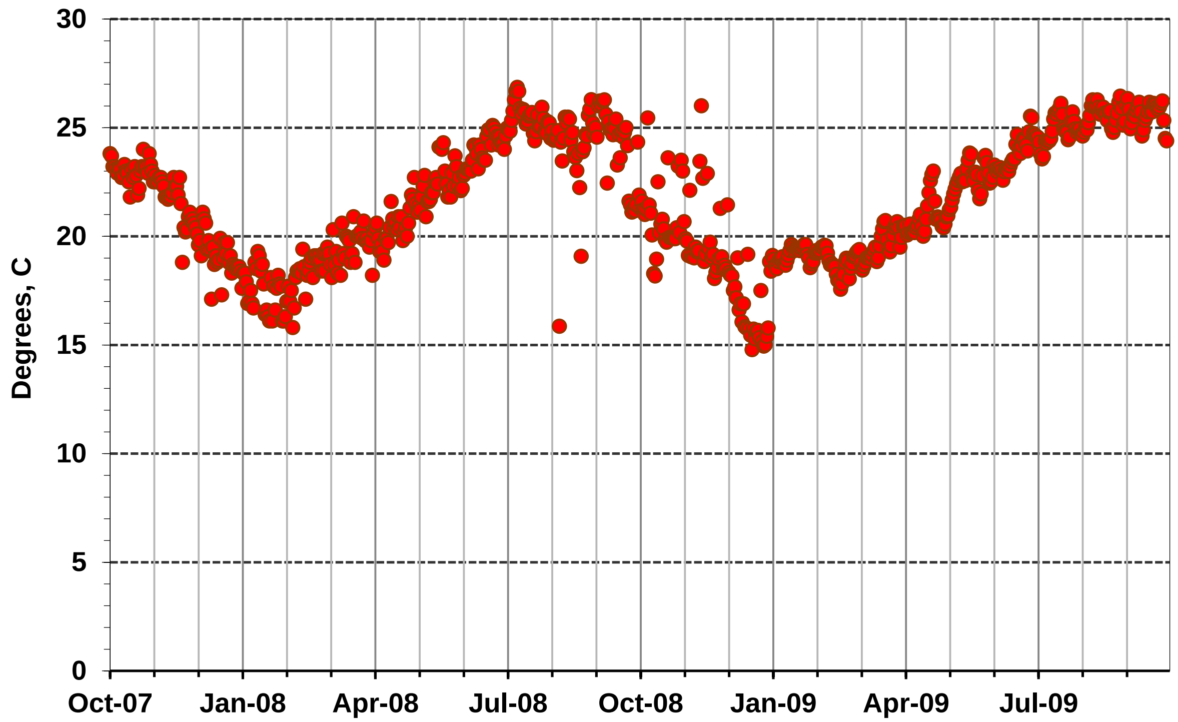

Figure 1. Effluent Temperature Data from a Plant

Data from each plant will be collected as flows and concentrations. The treatment levels are based on concentration. However, the potential nutrient reductions will be presented as load reductions. Using loads is beneficial because they are independent of the impact on flows (e.g., water conservation) while also providing nutrient removal credit for plants that divert flows (e.g., recycled water). The base case for identifying load reductions is the 2013 load calculated from the data set compiled in response to the 13267 Letter (March 2, 2012), which required the municipal dischargers listed in Appendix A to submit information on nutrients in wastewater discharges.

Data Collection and Preliminary Assessment

A questionnaire and site visit will be used to collect plant data. The questionnaire requests plant specific information, such as historical plant flows and loads, performance, treatment assets, etc. The questionnaire will provide an electronic workbook for each plant to submit its historical data. Based on the information received from the questionnaire, the team will perform a preliminary assessment to identify potential optimization strategies and plant upgrades for each plant. Following the preliminary assessment, a site visit of each plant will occur to confirm the preliminary assessment and identify additional nutrient reduction strategies.

A description of the questionnaire, preliminary assessment, and site visit is provided in the sub-sections below.

Data Collection

The questionnaire will be disseminated to each participating plant during the fall of 2014. This detailed request will create a high level understanding of how each plant operates. Plant performance data will be collected. A questionnaire most efficiently gathers data and collects the essential information needed for producing plant-specific results. The questionnaire will seek the following information:

- Plant process and service area description
- Site layout
- Major unit process dimensions and information on number of units in service
- Annual energy and chemical usage
- Future upgrade plans/expansion plans
- Identification of site constraints (e.g., space constraints, poor soils requiring piles, off-limits spaces, odor constraints, etc.)
- Prior reports and technical memoranda on existing facilities/nutrient removal plans
- Prior reports documenting nutrient reductions by other means. For example, plans for recycled water, wetlands treatment, etc.
- Background on regulatory drivers
- Others

The questionnaire responses will be broken out into two categories: data related to sidestream treatment and data related to the total plant performance. The first questionnaire will include influent, effluent, and sidestream data (if available). Information gathered from the responses pursuant to the first questionnaire will be used for the on-going United States Environmental Protection Agency (USEPA) sponsored Sidestream Treatment Grant being led by East Bay Municipal Utility District (EBMUD). The second questionnaire will include remaining information, including major unit process dimensions, site constraints, prior reports, historical plant data, etc. Both questionnaire responses will be due in early 2015.

Preliminary Assessment

Upon receiving all the questionnaire responses, the data will be organized and compiled for each participating plant. Any data gaps will be documented per plant and disseminated to each plant via email with a request for additional data and, if necessary, to perform additional sampling. The request will include:

- Constituents of interest (example BOD, TKN, TP, alkalinity)
- Sampling location (example: raw influent, primary effluent, secondary effluent)
- Sampling frequency (example: daily, weekly)
- Sample method (example: daily composite, hand composite, grab)
- Analytical methodology and laboratory reporting limits

The sampling campaigns will be short in duration by design (e.g., two weeks), designed to provide general guidance. In situations where additional sampling is not practical within the time-frame of the optimization effort, reasonable assumptions will be made for missing information.

The initial step in validating the dataset is to remove any outliers or questionable data. Such data will be removed with values noted.

Following the data screening, the organized data will be used to perform a preliminary assessment of each plant. The approach is to plot performance trends and calculate loading rates for the major unit processes (e.g., primary clarifiers). The values for each plant will be compared against typical design criteria to identify opportunities for optimization. For example, if a plant with activated sludge has historical data that suggests there is sufficient capacity to increase the solids residence time (SRT) and remove ammonia during the lowest flow summer months, then this will be documented.

The data questionnaire will also request information from each utility on planned future optimization/upgrades or expansion at their plant. The preliminary assessment will address how these optimization/upgrade projects will impact discharge nutrient loads. For example, a plant that plans to import organic waste would most likely increase its nutrient discharge load.

Site Visits

The third component is to visit each participating plant. Two-person teams that include a process engineer and an operations expert will visit each participating plant.

The site visits will confirm our understanding of how the plant operates, validate chemical use, and identify “no capital cost” and “low capital cost” optimization strategies. For example, they may look for any unused tanks for additional treatment, or examine operational practices such as the dissolved oxygen set-point. An example list of information that will be generated during the site visit is as follows:

- Validate and confirm facility mode of operation
- Validate and confirm whether the plant is a candidate for sidestream treatment
- Validate and confirm the historical performance trends, number of units in service, etc.
- Generate a list of optimization strategies and their implications, such as:
  - Flow routing
  - Chemical dosing strategy
  - Pumping strategy
  - Aeration strategy
  - Impact to plant capacity
  - Non-economic impacts (e.g., biosolids yield)
  - Impacts on sustainability (e.g., energy demand and GHG emissions)
- Confirm the on-going optimization/upgrade projects and summarize their potential impacts on nutrient discharge loads

A memo will be crafted for each plant that summarizes the site visit. Each plant will have the opportunity to review the memo and provide comments. The memo will include the following:

- Description of the plant and the current discharge requirements
- Description of the potential impact on nutrient discharge loads from on-going optimization/upgrade projects
- Check-list confirming the preliminary assessment findings
- List of potential optimization strategies
- Quantification of nutrient removal benefits
- Impacts on plant capacity, chemicals, biosolids yield, energy, GHG emissions, etc.
- Facility upgrade requirements
- Summary and conclusions

Nutrient Reduction through Plant Optimization

This first study focuses on plant optimization and sidestream treatment. The effort will generate a list of optimization strategies and sidestream treatment opportunities and develop costs for the most attractive option. Details for these two elements are provided in the sub-sections below.

Plant Optimization

Optimization of existing facilities is a potential first step toward nutrient reduction. Nutrient removal is possible at existing facilities due to operating below design load and thus unused available “capacity” might be devoted for nutrient reduction on an interim basis. It takes advantage of unused tankage, new process approaches, instrumentation improvements, and, without a permit limit with potential enforcement penalties, gets as much nutrient reductions as possible in the short term.

Any proposed optimization strategies are viewed as interim solutions as most strategies will take advantage of unused capacity (i.e., facilities not needed to meet the current load but may be required to treat the design load). In rare cases, facilities may be available that is not required to meet future loads and may be available for long term nutrient reduction. The unused capacity was typically constructed using fees to accommodate future growth so it may not be available for nutrient reduction in the future as that growth occurs or as stepping stones for either Level 2 or Level 3 technology changes in the plant.

The plant optimization strategies are based on each individual plant’s documented plans for future growth and record existing flows and BOD/nutrient loadings in 2015 and also what they are projected to be in 2025. For plants where no documentation exists, a 15% increase in BOD/nutrient loadings will be assumed for the 10 year period, and no increase in flows. This data will be provided in a table for all of the major plants identified in the Nutrient Watershed Permit. It is expected that some plants plan for more growth than other plants and that some plants will be projecting little or no growth during the 10 year period.

Each plant will be made aware of the fact that, at some point in the future, regulations may require no net increases in discharges of nutrients to the Bay or individual subembayments of the Bay. If this regulatory mandate occurs, individual plants will need to decide how best to meet those regulations. Capacity set aside for future growth will subtract from capacity available for future nutrient reductions utilizing existing facilities (i.e. optimization) and thus future growth allowances could lead to sooner than anticipated upgrades to plants. The estimated amount of nutrient reductions through optimization and the associated costs for the optimization for each plant will be documented in the report.

It is important to stress that implementing some of the strategies will likely impact overall treatment capacity and operational complexity in the long term. The plant might need to revert back to the prior mode of operation or add new facilities as flows and loads increase over time.

A list of the most common optimization strategies for each treatment category will be generated during the preliminary assessment effort. For example, a plant could implement chemically enhanced primary treatment (CEPT) as a means to remove total phosphorus and increase aeration basin capacity for ammonia removal. This list will serve as the starting point during each site visit. The strategies will be simple, low cost improvements that can be implemented quickly. The strategies will be grouped into “no capital cost” and “low capital cost” strategies. Examples are provided below:

- No Capital Cost Strategies:
  - Use offline tankage to provide additional treatment
  - Modify operational mode, such as raising the solids residence time
  - Modify blower operating set points
  - Operate in split treatment mode
  - Change to simultaneous nitrification/denitrification operation
  - Shut down aeration to create anoxic zones
- Low Capital Cost Strategies
  - Add instruments for nutrient removal in ammonia based aeration control mode
  - Add chemicals for phosphorus removal
  - Add chemicals to reduce load, unlock capacity
  - Add anoxic and/or anaerobic zones for biological nutrient removal
  - Add internal recycle for denitrification
  - Add mixers for unaerated zones

During the site visits, the optimization strategies from our preliminary assessment will be confirmed. Additionally, the two-person process and operations experts will walk the plant to identify additional optimization strategies. This two-person team will visit with operations staff to confirm the findings and ask for any additional input from operations.

Because the strategies are intended to reduce nutrient loads where possible, the solutions will be aggressive as the plant can always revert back to the prior mode of operation. However, the recommended strategies will be intended to maintain stable operation.

The optimization section under the memo produced for each site visit will consist of the following:

- Listing of optimization strategies

- Summary of adverse and ancillary impacts (e.g., greenhouse gas impacts)
- Capital and operations and maintenance (O&M) cost estimates per strategy (if pertinent). The O&M cost will discuss the impacts on energy, chemicals, and labor.
- Estimates of nutrient reduction and unit costs per optimization strategy (e.g., $/lb nutrient; lb GHG/lb nutrient)
- Discussion of seasonal nutrient reduction as some of the optimization strategies might only apply during the dry season and vice versa
- Discuss reduced capacity, process residuals, operational complexity and/or potential regulatory compliance issues that would be created as result of these modifications

Sidestream Treatment

The sidestream refers to the return streams from biosolids processing. Despite their small flows (typically <5 percent of raw plant flow), the sidestream represents about 15 to 40 percent of the discharge nutrient load as shown in Figure 2.

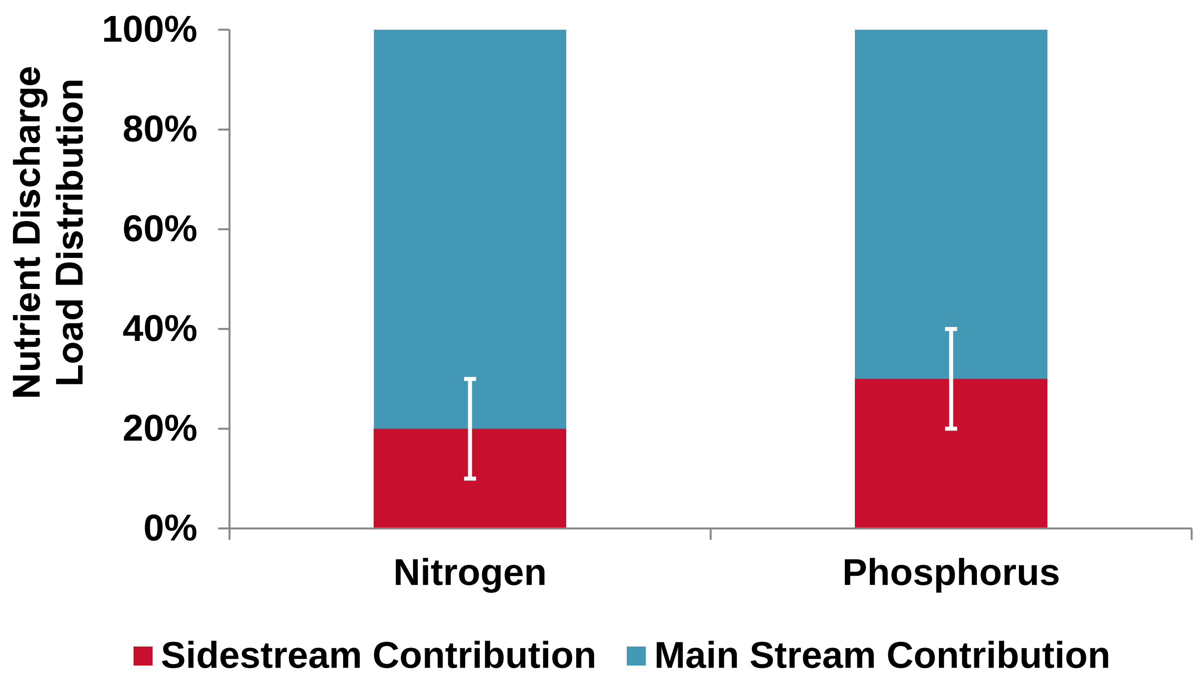

Figure 2. Nutrient Discharge Load Contribution

The benefits of removing nutrients in the sidestream are as follows:

- Warm water (favorable kinetics; small footprint)
- Concentrated nutrients (favorable kinetics; small footprint)
- Low flows (ability to equalize)
- More cost-effective as $/lb nutrient removed than complete liquid stream treatment conversion

- Less aeration and chemicals than liquid stream treatment (limited to nitrogen removal)
- Easier to phase construction than liquid stream treatment
- The sidestream process can remain operational to provide additional reliability and reduce the overall nutrient removal cost if Levels 2 and 3 are required in the future.

Not all plants are candidates for sidestream treatment. The approach for identifying candidate plants is described by the type of nutrient removal in the sub-sections below.

AMMONIA REMOVAL AND RECOVERY

Sidestream ammonia and total nitrogen removal technologies are more numerous that total phosphorus recovery choices. A graphic illustrating a decision tree to identify candidate plants for sidestream nitrogen removal is provided in Figure 3. The questionnaire will include the appropriate questions to identify candidate plants. For plants deemed non-candidates, the report will provide the basis for this decision.

There are dozens of technologies to consider. For candidate plants, the evaluation will consider either conventional nitrification or a deammonification technology, depending on the agency's questionnaire response.

PHOSPHORUS REMOVAL AND RECOVERY

The sidestream treatment of phosphorus typically relies on either chemical precipitation using metal salts or phosphorus recovery via struvite precipitation.

There are two commonly used phosphorus removal and recovery technologies for sidestream phosphorus reduction. For candidate plants, the evaluation will consider either conventional phosphorus removal by metal salts and settling, or phosphorus recovery (typically struvite precipitation technology) for plants using biological phosphorus removal.

SIDESTREAM TREATMENT DELIVERABLE

The memo for each plant will identify candidates for sidestream treatment. For candidate plants, the facilities and unit cost for removing ammonia or nitrogen and phosphorus will be presented. For plants deemed non-candidates, the report will provide the basis for this decision.

Nutrient Reduction with Plant Upgrades

Each facility will be evaluated to determine capital improvements necessary to provide nutrient removal to meet the Level 2 and Level 3 targets described in Table 2. Situations where dischargers have already upgraded existing treatment systems or implemented pilot studies for nutrient removal will be identified and incorporated into the analysis.

Established treatment technologies will be used to determine cost estimates (both capital and operating) and to determine site footprint requirements. However, innovative and/or emerging technologies will be identified for future consideration where they may be appropriate at individual facilities. As part of the evaluation, both beneficial and adverse ancillary impacts associated with plant upgrades will be identified for each facility and will be incorporated into the cost estimates.

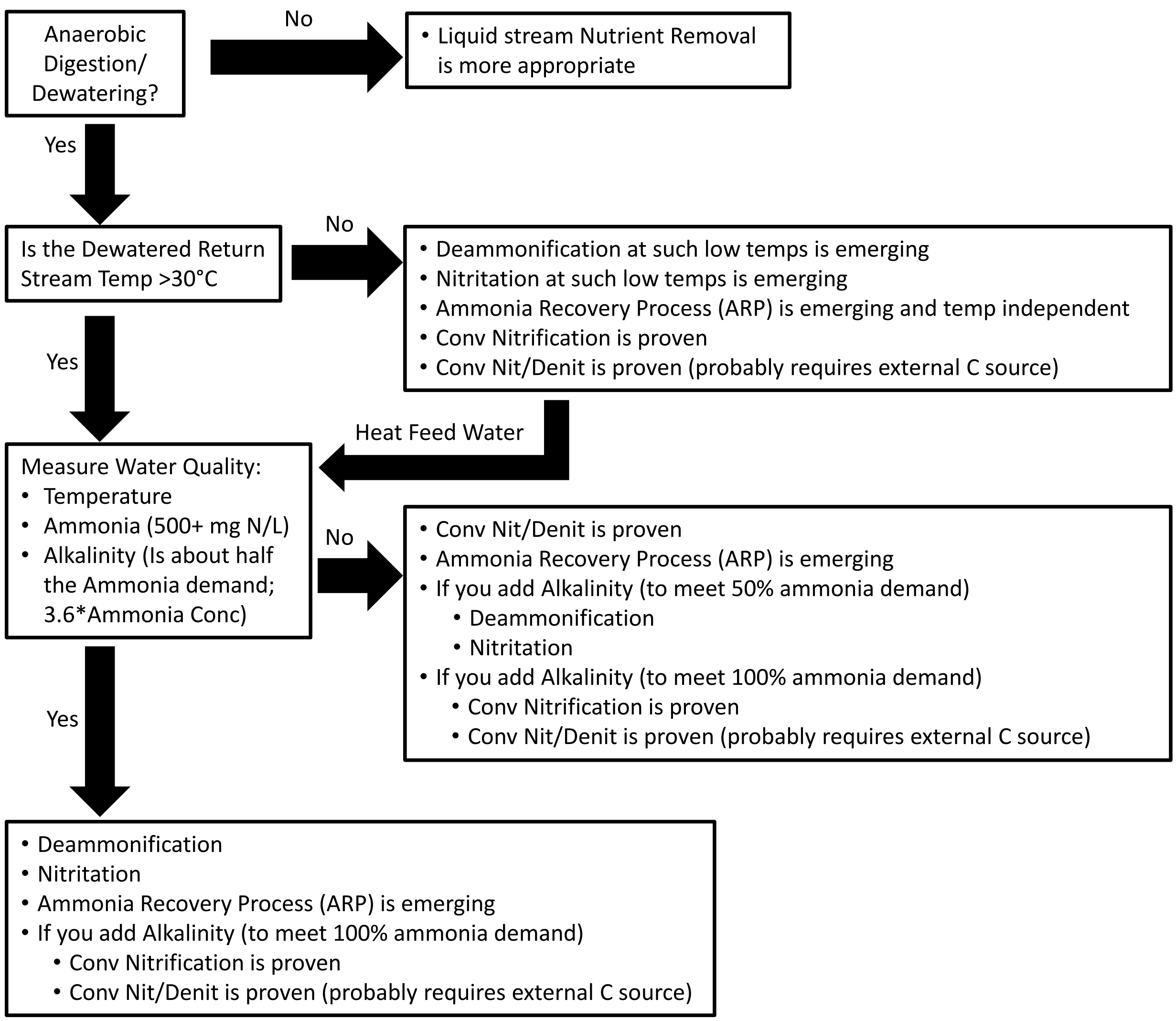

Figure 3. Decision Tree to Identify Candidates for Sidestream Nitrogen Removal

Technology Plant Groupings

The first step in determining the plant upgrades necessary to meet the different nutrient removal levels is to classify each plant. Table 3 provides a list of all 37 plants and their classifications with respect to nutrient removal. Currently, none of these plants have been designed for deliberate phosphorus removal and some have nitrification or partial nitrogen removal.

Table 3. Summary of Current Secondary Processes for BACWA Facilities

Current Secondary Process	Discharger	Facility
Conventional Activated Sludge	Central Contra Costa Sanitary District	Central Contra Costa Sanitary District Wastewater Treatment Plant
	City of Burlingame	Burlingame Wastewater Treatment Plant
	Dublin San Ramon Services District	Dublin San Ramon Services District Wastewater Treatment Plant
	City of Livermore	City of Livermore Reclamation Plant
	City of Benicia	Wastewater Treatment Plant
	City of Millbrae	Water Pollution Control Plant
	Oro Loma/Castro Valley Sanitary District	Oro Loma/Castro Valley Sanitary Districts Water Pollution Control Plant
	City of Pinole	Pinole-Hercules Water Pollution Plant
	City of Richmond Municipal Sewer District	West County Agency Combined Outfall
	Rodeo Sanitary District	Rodeo Sanitary District Water Pollution Control Facility
	City of San Mateo	City of San Mateo Wastewater Treatment Plant
	City and County of San Francisco (San Francisco International Airport)	Mel Leong Treatment plant, Sanitary Plant
	Cities of South San Francisco and San Bruno	South San Francisco and San Bruno Water Quality Control Plant
	Union Sanitary District	Raymond A. Boege Alvarado Wastewater Treatment Plant
Activated Sludge with Seasonal Nitrification	Novato Sanitation District	Novato Sanitary District Wastewater Treatment Plant
Biological Nutrient Removal (BNR)	City of San Jose/Santa Clara	San Jose/Santa Clara Water Pollution Control Plant
	City of Petaluma	Ellis Creek Water Recycling Facility
High Purity Oxygen Activated Sludge	East Bay Municipal Utility District	East Bay Municipal Utility District, Special District No. 1 Wastewater Treatment Plant
	City and County of San Francisco (Southeast Plant)	Southeast Water Pollution Control Plant
Nitrifying Activated Sludge	Sonoma Valley County Sanitary District	Municipal Wastewater Treatment Plant
Nitrifying MBR	City of American Canyon	Wastewater Treatment and Reclamation Facility
Pond System and partial nitrifying activated sludge	Napa Sanitation District	Soscol Water Recycling Facility
Pond with nitrifying trickling filter	City of Sunnyvale	Sunnyvale Water Pollution Control Plant
Trickling Filter	Sausalito-Marin City Sanitary District	Sausalito-Marin City Sanitary District Wastewater Treatment Plant
	Sewage Agency of Southern Marin	Wastewater Treatment Plant
	U.S. Department of Navy (Treasure Island)	Wastewater Treatment Plant
Trickling filter and nitrifying trickling filter	Mt. View Sanitary District	Mt. View Sanitary District Wastewater Treatment Plant
	Las Gallinas Valley Sanitary District	Las Gallinas Valley Sanitary District Sewage Treatment Plant
Trickling Filter/Activated Sludge	Central Marin Sanitation Agency	Central Marin Sanitation Agency Wastewater Treatment Plant
	Silicon Valley Clean Water	Silicon Valley Clean Water Wastewater Treatment Plant
	City of San Leandro	San Leandro Water Pollution Control Plant
	West County Agency	West County Wastewater District Treatment Plant

Table 3. Summary of Current Secondary Processes for BACWA Facilities

Current Secondary Process	Discharger	Facility
	Vallejo Sanitation and Flood Control District	Vallejo Sanitation and Flood Control District Wastewater Treatment Plant
Trickling Filter/Solids Contact	Delta Diablo	Wastewater Treatment Plant
	City of Hayward	Hayward Water Pollution Control Facility
Trickling filters with nitrifying activated sludge	Fairfield-Suisun Sewer District	Fairfield-Suisun Wastewater Treatment Plant
	City of Palo Alto	Palo Alto Regional Water Quality Control Plant

Determining Upgrade Requirements

For nutrient removal upgrades, the general approach will be to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where a Level 2 scenario requires the construction of facilities that would be stranded in a Level 3 scenario.

In determining upgrade requirements, each facility will be evaluated based on existing infrastructure and space constraints. Existing infrastructure will be included in future upgrades as much as possible, especially if facilities are less than 10 years old. Space constraints will determine which technologies will be considered for implementation. For instance, a facility with limited footprint may consider membrane bioreactor and a facility with ample footprint could consider a 5-stage Bardenpho process for meeting Level 3 requirements. In cases of severely constrained sites, removal and replacement of existing facilities may be required.

Several technologies will be considered that represent well established technologies for cost and footprint estimates. Table 4 lists the established technologies that will be considered for upgrades.

Innovative technologies will also be evaluated for each plant. The two most promising innovative technologies for each individual plant will be identified. The pros and cons of using those technologies at a specific plant will also be discussed. The discussion will include the potential for achieving lower nutrient loadings, via enhanced treatment, to receiving waters should the innovative technology prove to be reliable and cost effective. In addition, there will be recommendations for specific steps a utility could take as the innovative technologies become better understood and begin to be implemented at similar plants across the country and around the world. These steps may include additional testing (i.e. bench and pilot testing) and other activities that would be needed to prove the feasibility of an innovative technology at a particular plant and to develop design criteria and costs for implementing the technologies.

Costs for pursing the additional steps, including testing, will be identified in the report. It is premature at this point to speculate on the costs for full scale implementation of innovative technologies due to their on-going development and given the lack of feasibility testing. Individual plans will need to undertake development of design data when the innovative technologies have progressed to the point of beginning to be more broadly implemented.

Table 4. Established Technologies for Ammonia, Nitrogen and Phosphorus Removal

Level 2 Technologies	Level 3 Technologies[1]
Nitrifying Technologies	
Nitrifying air activated sludge Integrated fixed film activated sludge (IFAS) Membrane bioreactor (MBR) Nitrifying trickling filter (NTF) Biological aerated filter (BAF) Oxidation ditch	Level 2 meets Level 3 ammonia limits
Nitrogen Removal Technologies	
Modified Ludzack-Ettinger (MLE) Denitrification filter[2] Moving bed biofilm reactor (MBBR)[2] Step feed activated sludge Oxidation ditch	4-stage Bardenpho[2] Denitrification filter[2] MBBR[2] Oxidation ditch
Phosphorus Removal Technologies	
Oxidation ditch 2-stage Phoredox (P only) 3-stage Phoredox 5-stage Bardenpho (both N and P) Chemical[3] addition to primary clarifiers Chemical[3] addition to aeration basin Tertiary chemical[3] addition/solids removal	Direct filtration[3] Sedimentation/filtration[3] Membrane filtration[3]

Notes:

1. In addition to or expansion of Level 2
2. Carbon source may be required (e.g. methanol)
3. Metal salt or other chemical added

Facility Upgrades

The analysis will first determine plant upgrades that are necessary to meet the Level 3 requirements. For less stringent conditions, the unit processes will be removed to determine Level 2 and nitrification only scenarios. This approach avoids the situation where Level 2 upgrades would result in upgrades becoming obsolete for Level 3.

Figure 4 shows a progression of how technologies could be selected to meet nitrification requirements as well as Level 2 and Level 3 nitrogen removal requirements. This approach illustrates the progression of unit processes to meet Level 2 and later Level 3 requirements. For instance, Figure 4 shows that if a facility were upgraded to a membrane bioreactor (MBR) facility to meet Level 3 nitrogen limits, then a MBR process would also be used for Level 2 nitrogen removal and nitrification.

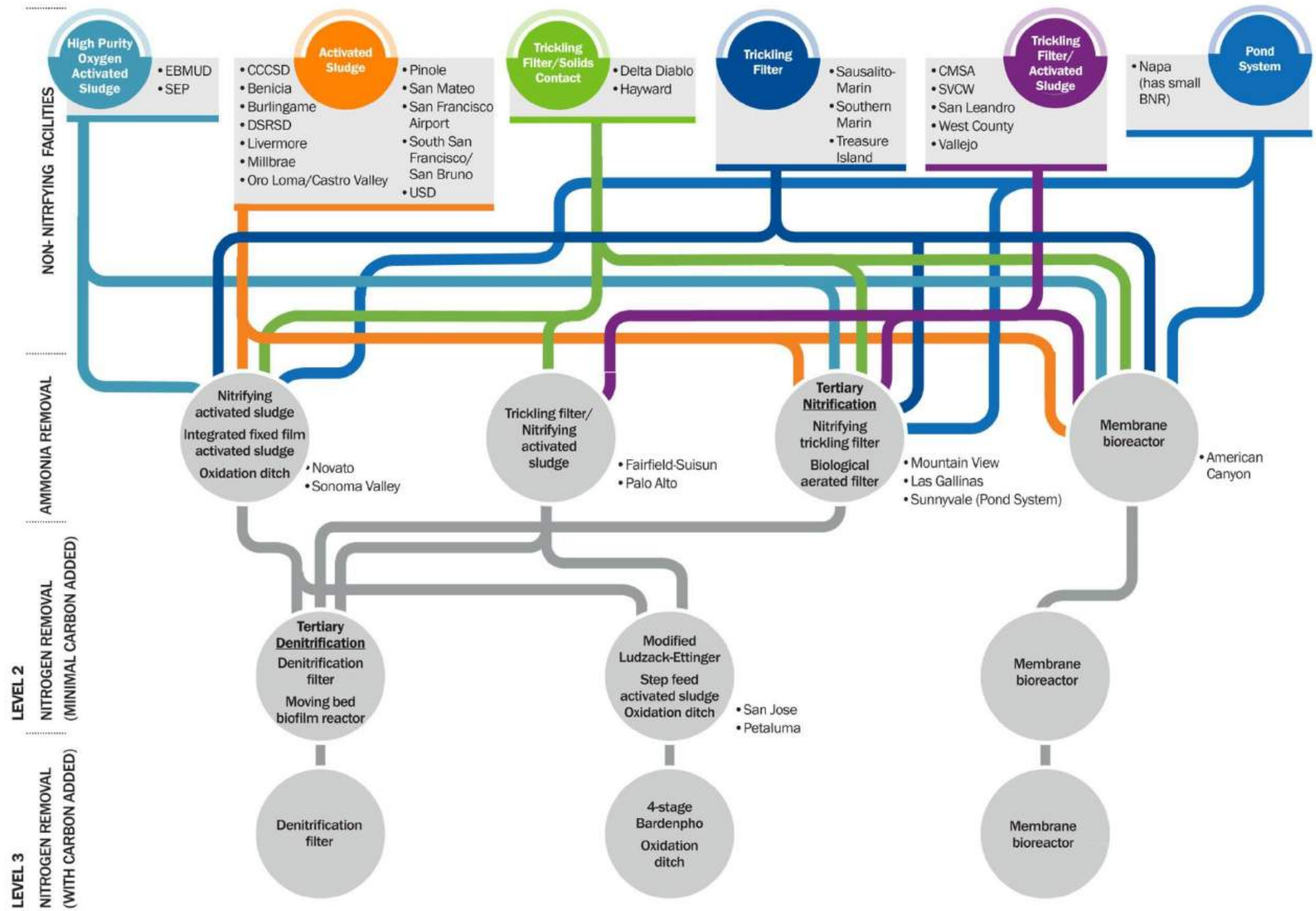

Figure 4. Existing Treatment Categories and the Nitrogen Removal Technologies Progression

Figure 5 shows a similar approach for phosphorus removal technologies. Certain facilities are well positioned to be upgraded to enhanced biological phosphorus removal (e.g. 5-stage Bardenpho or oxidation ditch) to meet Level 2 requirements. For all facilities, Level 3 phosphorus requirements would be met by chemical addition and filtration regardless of the technology implemented for Level 2 removal.

Figure 4 and Figure 5 provide guidance for the overall selection process for plant upgrades. However, the actual selection process will be driven by several factors including existing infrastructure, space constraints and existing solids processing technologies. Therefore, plant upgrades will be tailored to each facility based on these factors.

Once a representative technology that will comply with Level 3 nitrogen and phosphorus requirements has been selected for each facility, conceptual cost estimates will be prepared to determine capital and operating costs for the most attractive option. Operating costs will represent the change in cost due to nutrient removal. For instance, upgrading from a conventional activated sludge process to a membrane bioreactor will increase electrical, chemical, and labor costs and only that increase will be quantified. Cost estimates will be presented so that unit processes are line items that can be removed to evaluate other scenarios. For instance, change from a Level 2 nitrogen removal scenario to a nitrification-only scenario by eliminating anoxic zones.

Changes in GHG emissions from additional energy and chemical demands will be estimated. Expected changes in sludge production will be identified where appropriate. A qualitative estimate of changes in pharmaceuticals removal will be provided.

Impacts of Sea Level Rise

Participating agencies that are vulnerable to the impacts of sea level rise will be identified. The analysis will be based on publically available data from the United States Army Corps of Engineers, the Federal Emergency Management Agency, and publically available topography data. Participating agencies will provide key plant elevation data in the data collection template.

The impacts of sea level rise with respect to potential for inundation of facilities needed to achieve nutrient reduction will be determined for each of those identified agencies. Results will be presented in a map format, illustrating location of the participating plants and areas of inundation. The costs associated with sea level rise mitigation will not be determined as these additional costs are highly site specific.

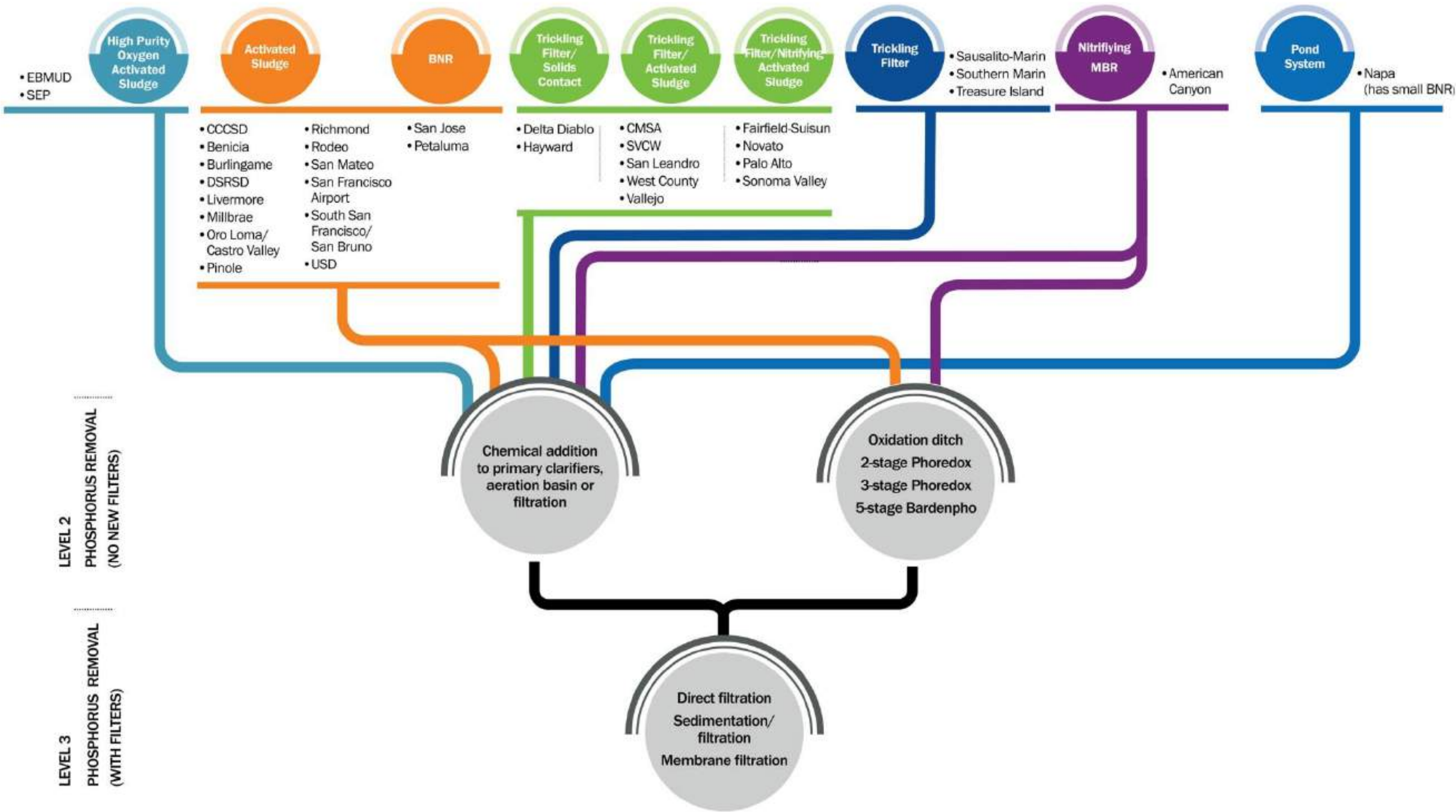

Figure 5. Existing Treatment Categories and the Phosphorus Removal Technologies Progression

Nutrient Reduction by Other Means

Strategies that reduce nutrient loadings to San Francisco Bay are not limited to options inside the plant fence. The optimization and plant upgrades sections focus on concepts that would be implemented inside the plant fence. This section serves as a first step in considering outside the plant fence concepts by compiling previous reports for each plant. Potential nutrient reduction by other means options are listed below:

- Effluent Management: Nutrient trading, water recycling and reuse
- Effluent Polishing: Wetlands treatment (e.g., Hayward Marsh)
- Solids Management: Biosolids export (un-stabilized) to a joint facility
- Source Control: Septic source abatement, urine separation, phosphorus dish detergent ban, etc.
- Non-Point Sources: Non-point source reduction program

The effort associated with this task is to compile any previous reports or documents prepared for each plant that addresses nutrient reduction by other means. Inclusion of such information into the evaluation might identify cost-effective and innovative solutions for nutrient load reductions. The ancillary benefits and adverse impacts for those identified strategies will be discussed. Additionally, the compiled report will identify institutional barriers to water recycling along with approaches for overcoming such barriers.

Economic Impacts Approach

The economic impacts for capital, operations and maintenance (O&M), and life-cycle analysis will be estimated for each plant. The O&M component includes the cost for energy, chemicals, and labor. The cost estimates will be based on best professional judgment of probable construction costs and not an official bid document. The estimates are considered planning level values. A more detailed analysis for each plant would be needed to refine these costs.

Approach

The capital cost estimates will be consistent with the American Association of Cost Engineers, Recommended Practice No. 17R-97, Class 4 and the American National Standards Institute definition of a “budget estimate.” The estimates will be accurate within a range of +40 percent to -20 percent. The life-cycle costs will be prepared using the Net Present Value (NPV) method.

The O&M cost estimates will be calculated using the HDR Water Cost Model. Energy and chemical costs will be confirmed based on preliminary process calculations.

Unit Cost

Unit costs will be developed in coordination with BACWA, such that they represent typical costs for the participating agencies in the San Francisco Bay Area. One set of unit costs will be used for all agencies, such that the results are directly comparable from one plant to another. An example of the unit cost parameters is presented in Table 5 (values will be developed at a later date).

Table 5. Unit Economics Sample Table

Parameter	Unit	Value
Engineering News and Review Cost Index		--
Construction Cost Index		--
Nominal Discount Rate	%	--
Inflation Rate:		
General	%	--
Energy	%	--
Chemicals	%	--
Base Year		--
Project Life	Years	--
Energy	$/kWh	--
Chemicals:		--
Ferric	$/ton	--
Alum	$/ton	--
Methanol	$/gal	--
Alkalinity	$/gal	--
Labor	$/FTE	--

Greenhouse Gas Emissions Accounting

The impact of process changes on GHG emissions will be included in the analysis for both studies. This includes increases in GHG emissions associated with recommended plant optimization and/or upgrade strategies. The analysis will not include the current GHG emissions at each plant.

The GHG emissions accounting will focus on the operating energy and chemical demand for any recommended plant optimization and/or upgrade strategies. The GHG emissions accounting will not include nitrous oxide emissions. The state of the science for nitrous oxide emissions is uncertain at this stage and thus difficult to confidently quantify.

The approach relies on the USEPA eGRID values[2] for each plant's regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on an initial conversion to electrical demand, followed by a conversion to GHG emissions.

The plant questionnaire will include questions to determine fuel type and consumption at each plant, as well as chemical demands.

[2] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Appendix A – Participating Facilities

Discharger	Facility Name	Facility Address
American Canyon, City of	Wastewater Treatment and Reclamation Facility	151 Mezzetta Court American Canyon, CA 94503 Napa County
Benicia, City of	Benicia Wastewater Treatment Plant	614 East Fifth Street Benicia, CA 94510 Solano County
Burlingame, City of	Burlingame Wastewater Treatment Plant	1103 Airport Boulevard Burlingame, CA 94010 San Mateo County
Central Contra Costa Sanitary District	Central Contra Costa Sanitary District Wastewater Treatment Plant	5019 Imhoff Place Martinez, CA 94553 Contra Costa County
Central Marin Sanitation Agency	Central Marin Sanitation Agency Wastewater Treatment Plant	1301 Andersen Drive San Rafael, CA 94901 Marin County
Delta Diablo	Wastewater Treatment Plant	2500 Pittsburg-Antioch Hwy Antioch, CA 94509 Contra Costa County
East Bay Dischargers Authority (EBDA), City of Hayward, City of San Leandro, Oro Loma Sanitary District, Castro Valley Sanitary District, Union Sanitary District, Livermore-Amador Valley Water Management Agency, Dublin San Ramon Services District, and City of Livermore	*EBDA Common Outfall*[A]	EBDA Common Outfall 14150 Monarch Bay Drive San Leandro, CA 94577 Alameda County
	Hayward Water Pollution Control Facility	
	San Leandro Water Pollution Control Plant	
	Oro Loma/Castro Valley Sanitary Districts Water Pollution Control Plant	
	Union Sanitary District, Raymond A. Boege Alvarado Wastewater Treatment Plant	
	Livermore-Amador Valley Water Management Agency Export and Storage Facilities[A]	
	Dublin San Ramon Services District Wastewater Treatment Plant (LAVMA)	
	City of Livermore Water Reclamation Plant (LAVMA)	

Discharger	Facility Name	Facility Address
East Bay Municipal Utility District	East Bay Municipal Utility District, Special District No. 1 Wastewater Treatment Plant	2020 Wake Avenue Oakland, CA 94607 Alameda County
Fairfield-Suisun Sewer District	Fairfield-Suisun Wastewater Treatment Plant	1010 Chadbourne Road Fairfield, CA 94534 Solano County
Las Gallinas Valley Sanitary District	Las Gallinas Valley Sanitary District Sewage Treatment Plant	300 Smith Ranch Road San Rafael, CA 94903 Marin County
Millbrae, City of	Water Pollution Control Plant	400 East Millbrae Avenue Millbrae, CA 94030 San Mateo County
Mt. View Sanitary District	Mt. View Sanitary District Wastewater Treatment Plant	3800 Arthur Road Martinez, CA 94553 Contra Costa County
Napa Sanitation District	Soscol Water Recycling Facility	1515 Soscol Ferry Road Napa, CA 94558 Napa County
Novato Sanitary District	Novato Sanitary District Wastewater Treatment Plant	500 Davidson Street Novato, CA 94945 Marin County
Palo Alto, City of	Palo Alto Regional Water Quality Control Plant	2501 Embarcadero Way Palo Alto, CA 94303 Santa Clara County
Petaluma, City of	Ellis Creek Water Recycling Facility	3890 Cypress Drive Petaluma, CA 94954 Sonoma County
Pinole, City of	Pinole-Hercules Water Pollution Control Plant	11 Tennent Avenue Pinole, CA, 94564 Contra Costa County
Rodeo Sanitary District	Rodeo Sanitary District Water Pollution Control Facility	800 San Pablo Avenue Rodeo, CA 94572 Contra Costa County
San Francisco (San Francisco International Airport), City and County of	Mel Leong Treatment Plant, Sanitary Plant	918 Clearwater Drive San Francisco International Airport San Francisco, CA 94128 San Mateo County
San Francisco (Southeast Plant), City and County of	Southeast Water Pollution Control Plant	750 Phelps Street San Francisco, CA 94124 San Francisco County
San Jose/Santa Clara Water Pollution Control Plant and Cities of San Jose and Santa Clara	San Jose/Santa Clara Water Pollution Control Plant	4245 Zanker Road San Jose, CA 95134 Santa Clara County
San Mateo, City of	City of San Mateo Wastewater Treatment Plant	2050 Detroit Drive San Mateo, CA 94404 San Mateo County
Sausalito-Marin City Sanitary District	Sausalito-Marin City Sanitary District Wastewater Treatment Plant	#1 Fort Baker Road Sausalito, CA 94965 Marin County
Sewerage Agency of Southern Marin	Wastewater Treatment Plant	450 Sycamore Avenue Mill Valley, CA 94941 Marin County
Silicon Valley Clean Water	Silicon Valley Clean Water Water Treatment Plant	1400 Radio Road Redwood City, CA 94065 San Mateo County
Sonoma Valley County Sanitary District	Municipal Wastewater Treatment Plant	22675 8th Street East Sonoma, CA 95476 Sonoma County
South San Francisco and San Bruno, Cities of	South San Francisco and San Bruno Water Quality Control Plant	195 Belle Air Road South San Francisco, CA 94080 San Mateo

Discharger	Facility Name	Facility Address
		County
Sunnyvale, City of	Sunnyvale Water Pollution Control Plant	1444 Borregas Avenue Sunnyvale, CA 94089 Santa Clara County
U.S. Department of Navy (Treasure Island)	Wastewater Treatment Plant	681 Avenue M, Treasure island San Francisco, CA 94130-1807 San Francisco County
Vallejo Sanitation and Flood Control District	Vallejo Sanitation and Flood Control District Wastewater Treatment Plant	450 Ryder Street Vallejo, CA 94590 Solano County
West County Agency (West County Wastewater District and City of Richmond Municipal Sewer District)	Richmond Municipal Sewer District No.1 (RMSD) Water Pollution Control Plant West County Wastewater District (WCWD) Treatment Plant West County Agency Combined Outfall	601 Canal Blvd. Richmond, CA 94804 Contra Costa County 2377 Garden Tract Road Richmond, CA 94801 Contra Costa County

Note:

A. Conveyance; not treatment facility.

B

Basis of Cost Estimates

Basis of Cost Estimates

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Table 1 presents the various allowances that were included to estimate the capital cost. An additional 15 percent contingency was added to the capital cost to reflect the current bidding climate in the SF Bay Area.

These are planning level cost curves. This level of estimate is considered a Class 5 level estimate and is considered accurate within a range of -25 percent to +50 percent. Any opinions of probable construction cost or cost estimates provided by HDR, Inc. are made on the basis of information available to HDR, Inc. and on the basis of cost estimator's experience and qualifications, and represents its judgment as an experienced and qualified professional engineer. However, since HDR, Inc. has no control over the cost of labor, materials, equipment or services furnished by others, or over the contractor(s') methods of determining prices, or over competitive bidding or market conditions, HDR, Inc. does not guarantee that proposals, bids or actual project or construction cost will not vary from opinions of probable cost or cost estimates prepared by HDR, Inc.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. The unit costs used in developing the cost opinions are shown in Table 2.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for January 2018 at 12,014.72. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs are also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the present value (capital and O&M over the project duration) divided by the average nutrient load reduction over the period. Table 3 shows the discount rate and period used for the different scenarios.

Table 1. Allowances used in developing the Opinions of Probable Cost

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Additional Project Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

Table 3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

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C

Sea Level Rise Methodology

Memorandum

Date: Tuesday, April 17, 2018

Project: Bay Area Clean Water Agencies, Nutrient Optimization and Upgrade Project

From: Libby Mesbah, PE

Subject: Methodology and Results of the Sea Level Rise Assessment

Purpose and Scope

HDR has evaluated each of the participating publicly owned treatment works (POTWs) locations to determine the flood impacts associated with sea level rise (SLR) over the next 100 years. The purpose of this memorandum is to summarize the assessment performed. This analysis utilized publically available data from the United States Army Corps of Engineers (USACE), the Federal Emergency Management Agency (FEMA), and publically available topography data to make an assessment of the current and future impacts associated with sea level rise.

The SLR flood risk assessment included the following steps:

1. Identify a point ground elevation representative of each POTW location to compare against water surface elevations.
2. Evaluate FEMA's Flood Insurance Rate Maps (FIRMs) to determine if the POTW site is already within the 1-percent annual chance (100-year) floodplain.
3. Utilize the USACE's Sea Level Change Curve Calculator (2017.55), http://www.corpsclimate.us/ccaceslcurves.cfm, to determine the projected SLR depths over the next 30, 50, and 100 years.
4. Generate tabular and graphical map to display the results.

The following sections describe additional details for each of the assessment steps.

Topographic Data

The United States Geological Survey (USGS) National Elevation Dataset (NED), dated 2013, was utilized to determine a point ground elevation to represent each POTW location. Elevations are provided in the North American Vertical Datum of 1988 (NAVD88) with 1/3 arc-second (approximately 10 meters) resolution. This elevation data was utilized to compare water surface elevations and SLR depths against each other to determine if, and in what timeframe, the POTW could become vulnerable to flooding due to sea level rise (in the absence of mitigation).

FEMA's Flood Insurance Rate Maps

FEMA's FIRMs were utilized to determine if each POTW is currently mapped within the 1-percent annual chance (100-year) floodplain. The term "100-year flood" is used to simplify the definition of a flood that statistically has a 1-percent chance of occurring in any given year. The SLR depth is added on top of the 100-year water surface elevation. The 100-year floodplain is typically designated on the FEMA FIRM as a Zone VE or AE. If the location is identified as already being mapped within the floodplain, sea level rise will only worsen the flooding at the particular location in the future (in the absence of mitigation).

USACE’s Sea Level Change Curve Calculator

Projected SLR estimates over the next 100 years were identified using the USACE’s Sea Level Change Curve Calculator (2017.55), http://www.corpsclimate.us/ccaceslcurves.cfm. The USACE’s calculator tool was selected for this analysis since the USACE is a highly recognized agency, currently designing flood control structures throughout the San Francisco Bay.

The USACE Sea Level Change Curve Calculator computes three curves: USACE Low Curve[1], USACE Intermediate Curve[2], and the USACE High Curve[3]. For this flood risk assessment, each of the three USACE Curves were used to determine projected SLR values at each facility. SLR values were calculated starting from year 2020.

Figure 1 below provides an example of the projected sea level change curves generated at an existing gauge utilized for this analysis. The gauge shown in Figure 1 is located in Suisun Bay.

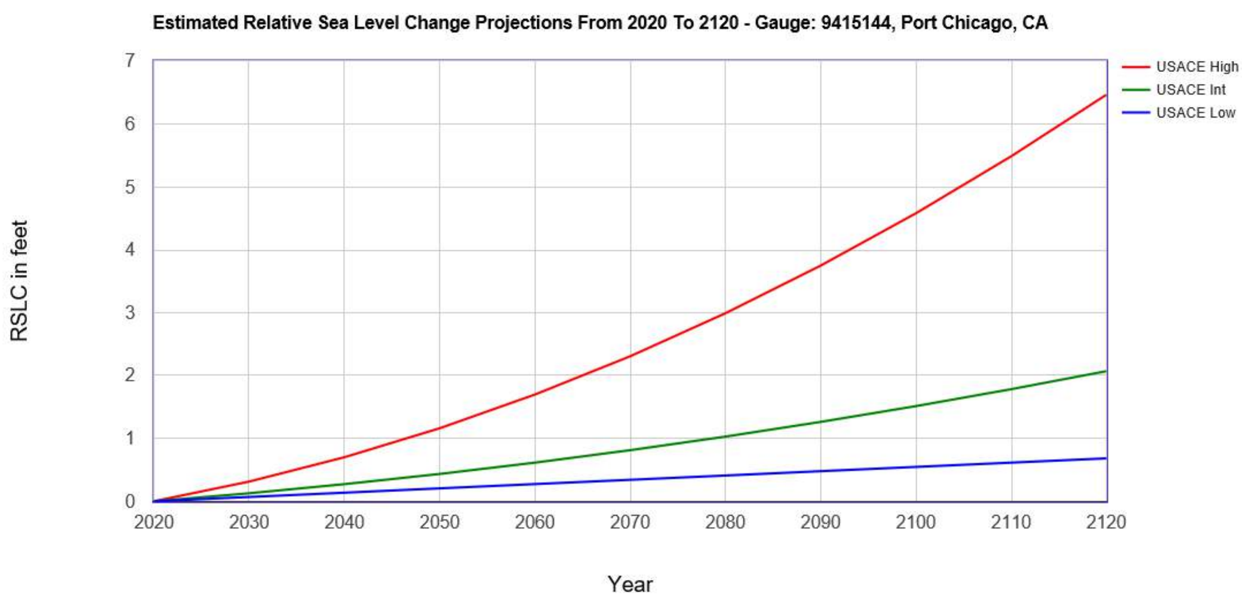

Figure 1 - USACE's Estimated Relative Sea Level Change Projections from 2020 to 2120 - Gauge: 9415144, Port Chicago, CA

[1] The rate for the USACE Low Curve is the historical rate of sea level change.
[2] The rate for the USACE Intermediate Curve is computed from the modified National Research Council (NRC) Curve I considering both the most recent Intergovernmental Panel on Climate Change (IPCC) projections and modified NRC projections with the local rate of vertical land movement added.
[3] The rate for the USACE High Curve is computed from the modified NRC Curve III considering both the most recent IPCC projections and modified NRC projections with the local rate of vertical land movement added.

Example Evaluation

An example of the analysis performed at each location is provided below for the Central Marin Sanitation Agency (CMSA):

Step 1: A point elevation of 7.6 ft NAVD88 was selected to represent the CMSA site.

Step 2: The FEMA FIRM 06041C0478E was evaluated to determine if portions or all of the site are currently within the 1-percent annual chance floodplain. The map below, in Figure 2, shows that the majority of the site is within the floodplain with a Zone AE base flood elevation of 10 ft NAVD88. Thus, portions of the site are 10 ft – 7.6 ft = 2.4 ft under water during a 1-percent annual chance storm event even before SLR occurs.

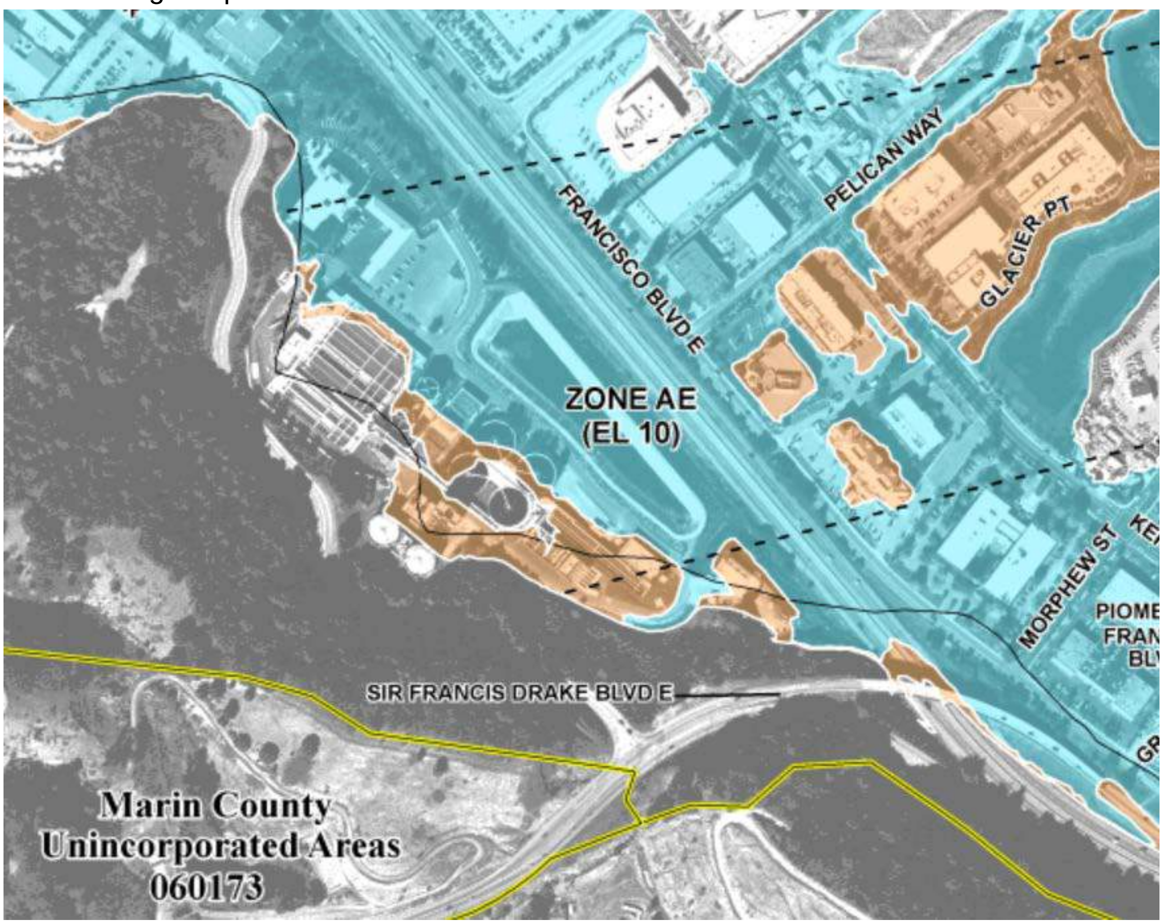

Figure 2 – FEMA's Flood Insurance Rate Map for CMSA

Step 3: The USACE Sea Level Change Curve Calculator (2017.55), was then used to generate the future projected SLR curves for low, intermediate, and high conditions. The San Francisco gauge, shown in Figure 3, is the closest gauge to CMSA. SLR predictions for the high condition were extracted from the curve and are listed below Figure 3.

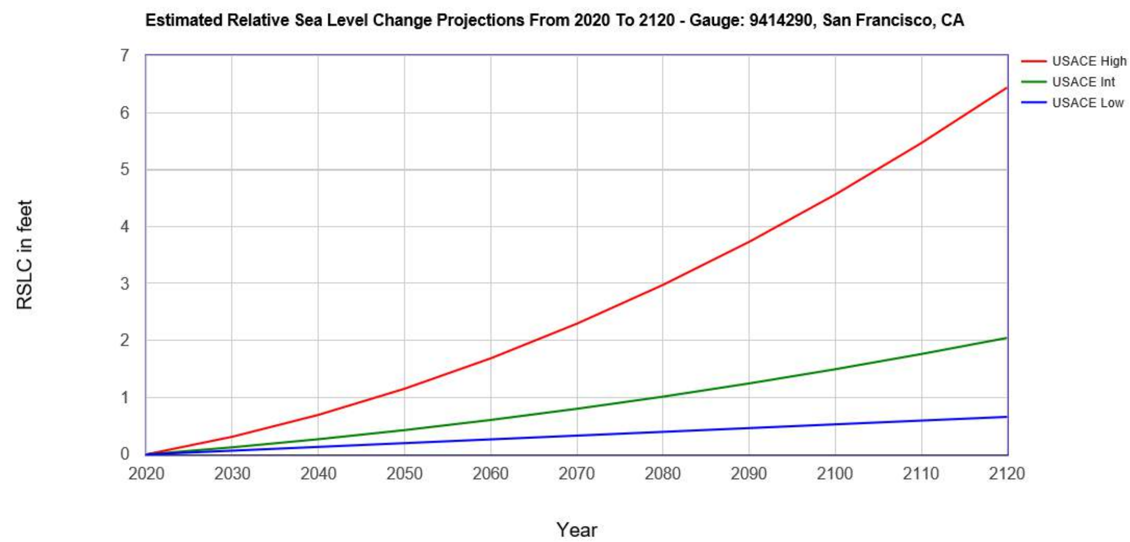

Figure 3 - USACE's Estimated Relative Sea Level Change Projections from 2020 to 2120 - Gauge: 9414290, San Francisco, CA

SLR predictions for the San Francisco gauge:

- Year 2050 (30 years) = +1.2 ft
- Year 2070 (50 years) = +2.3 ft
- Year 2120 (100 years) = +6.4 ft

Step 4: These SLR predictions are then added to the 1-percent annual chance floodplain elevation to determine the future water surface elevation including SLR for planning consideration. For CMSA, the results for the 30-, 50-, and 100-year planning horizon are:

- Predicted Water Surface Elevation in Year 2050 (30 years) = +1.2 ft + 10 ft = 11.2 ft
- Predicted Water Surface Elevation in Year 2070 (50 years) = +2.3 ft + 10 ft = 12.3 ft
- Predicted Water Surface Elevation in Year 2020 (100 years) = +6.4 ft + 10 ft = 16.4 ft

Evaluation Results

The impact of sea level rise at each POTW site was evaluated. The results of the analysis are illustrated in Figures 4 and 5, which show the status of flooding for each of the facilities for each curve and for each time horizon. Attachment A presents tables of results for all locations included in the study.

As shown in Figures 4 and 5, 16 plants are currently within the FEMA 100-yr flood hazard, which indicates that they are currently vulnerable to sea level rise and other flooding conditions. Nine plants are not vulnerable to sea level rise under the low, medium, or high rate of rise conditions. Two plants are protected by existing FEMA accredited levees. The remaining ten plants are vulnerable to the effects of future sea level rise, particularly under the high level of rise condition.

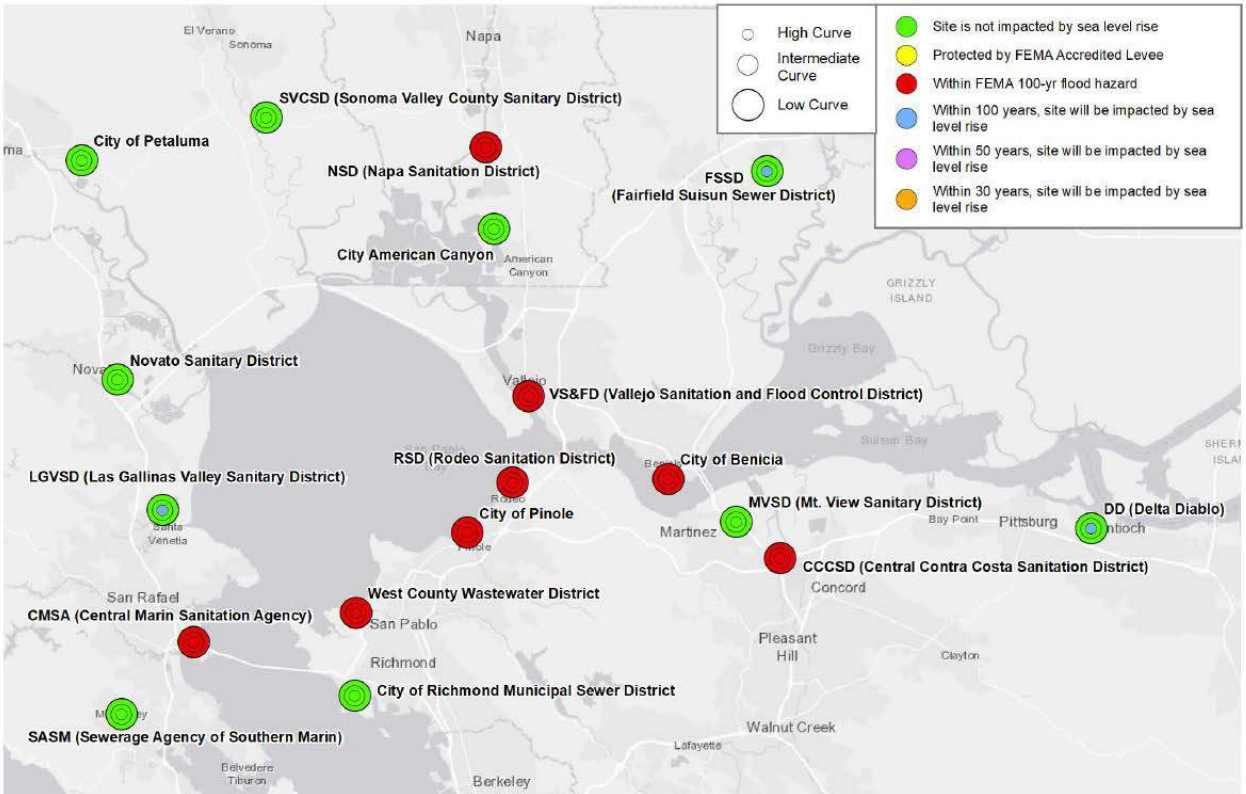

Figure 4 – Sea Level Rise Evaluation Results, North Bay

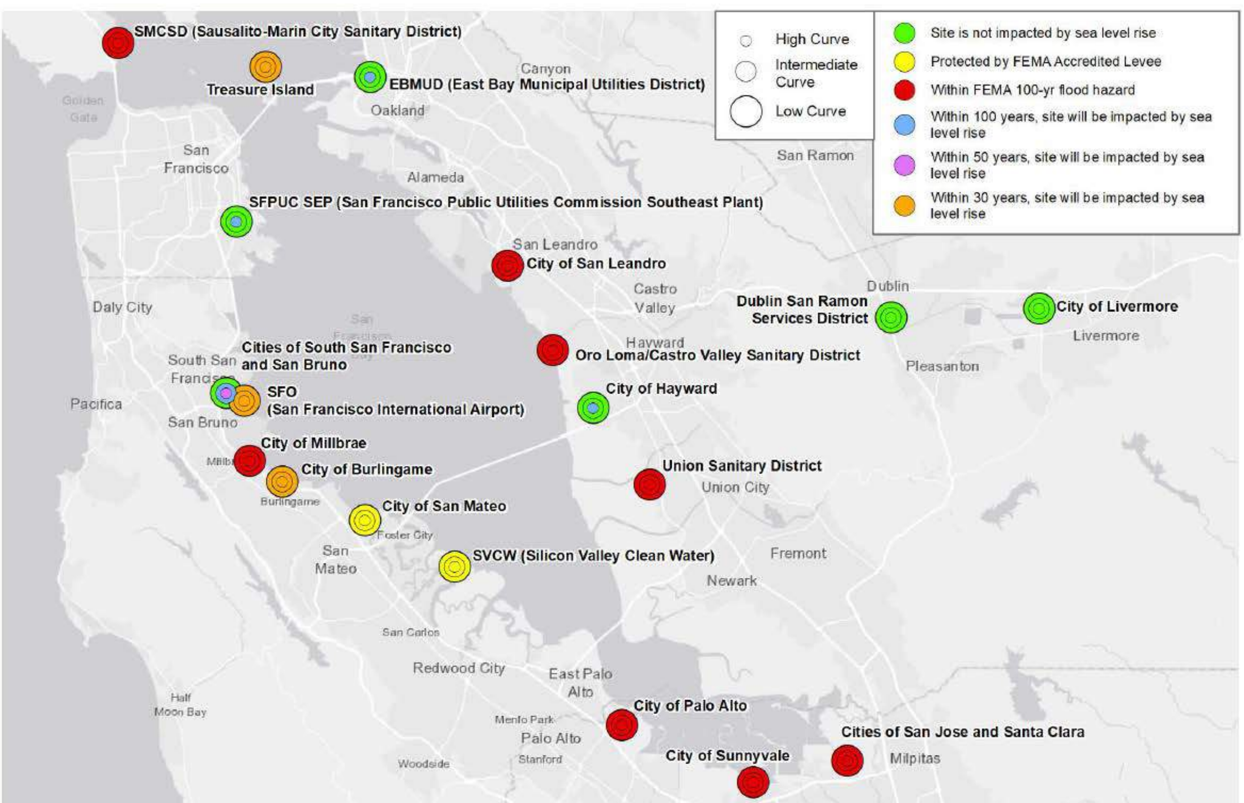

Figure 5 – Sea Level Rise Evaluation Results, South Bay

Study Limitations and Assumptions

The impact of sea level rise at each facility was evaluated using a simplistic approach. Below are the assumptions and the limitations to this approach.

Elevation at each Facility

An elevation for each facility was used as a reference to determine if the site may be impacted by estimated future SLR. Since the elevation is one point at the site, portions of the site may sit higher or lower than the estimated future water surface elevation.

FEMA 100-Year Water Surface Elevations

The FEMA 100-year water surface elevations were used as a base water surface elevation for this assessment. SLR depths estimated from the USACE's Sea Level Change Calculator were then added to the FEMA 100-year water surface elevations. This assessment is limited on the accuracy of the FEMA 100-year water surface elevations.

USACE's Sea Level Change Curve Calculator

The USACE's Sea Level Calculator provides localized estimates in sea level change. It is assumed that the calculator provides accurate sea level change estimates. For more information on the methodology used by the calculator, see the USACE's Engineer Regulation (ER) 1100-2-8162 – Incorporating Sea Level Changes in Civil Works Programs (USACE 2013a).

Existing Structures

This approach does not take into account other physical barriers that may deter the rise of sea levels such as coastal dikes, embankments, buildings and any other structures or natural barriers unless shown on the FEMA FIRMs as an accredited levee.

Future Planning Coastal Protection Measures

Although many agencies have identified future projects to mitigate the impacts of future sea level rise, the approach employed herein only reflects existing flood protection measures (i.e.., FEMA accredited levees and flood walls). There are several coastal protection projects throughout the SF Bay that are in the planning and design stages, which, if constructed, could provide mitigation for future sea level rise.

Future Water Surface Elevations

The estimated future water surface elevations to assess which facilities may be impacted by future SLR are approximate. The probability for each assessed SLR scenario is not provided by the USACE's Sea Level Change Calculator.

Inland Facilities

Inland facilities not impacted by tidal action were not evaluated for SLR.

Collection and Discharge Facilities

This evaluation focused solely on potential flooding due to SLR for the individual treatment plant sites. There are many other wastewater-related facilities that could be impacted by sea level rise, such as piping and sewage lift stations within the collection system (particularly those in low lying areas which could become more susceptible to sea water intrusion) and effluent discharge facilities. With respect to the latter, sea level rise could impact the hydraulics and capacity of effluent discharge pump stations and pipelines. Sea level rise could potentially result in additional pumping requirements to discharge effluent, increasing both energy requirements and associated costs.

Regional Collaboration

This assessment is a simplistic approach in determining which facilities may be impacted by future SLR. There are many on-going regional collaboration efforts addressing sea level rise within the Bay Area that are more comprehensive. Below are a few sources.

- *Rising Seas in California - An Update on Sea level Rise Science, April 2017* by the California Ocean Protection Council. This document is a good source in providing the probabilities of occurrence of future SLR.

  http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

- San Francisco Bay Conservation & Development Commission (BCDC) - Adapting to Rising Tides (ART) Program. The ART program is leading an effort to understand the risks from SLR and how to adapt. As part of the ART program, map products of regional shoreline and studies are available for several communities.

  http://www.adaptingtorisingtides.org/project/regional-sea-level-rise-mapping-and-shoreline-analysis/

- Other sources that address the threat of SLR and the latest data and tools:

  http://www.bcdc.ca.gov/slr.html

Attachment A, Summary of Sea Level Rise Evaluation Results

Table 1 - Summary of Sea Level Rise Impact

POTW Name	USACE Low Curve SLR Impact	USACE Intermediate Curve SLR Impact	USACE High Curve SLR Impact
CCCSD	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
San Jose	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
Sout SF	Site is not impacted by SLR	Impacted within 100 years	Impacted within 50 years
American Canyon	Site is not impacted by SLR	Site is not impacted by SLR	Site is not impacted by SLR
Benicia	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
Burlingame	Impacted within 30 years	Impacted within 30 years	Impacted within 30 years
Hayward	Site is not impacted by SLR	Site is not impacted by SLR	Impacted within 100 years
Livermore	Site is not impacted by SLR	Site is not impacted by SLR	Site is not impacted by SLR
Millbrae	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
Palo Alto	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
Petaluma	Site is not impacted by SLR	Site is not impacted by SLR	Site is not impacted by SLR
Pinole	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
Richmond	Site is not impacted by SLR	Site is not impacted by SLR	Site is not impacted by SLR
San Leandro	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
San Mateo	Protected by FEMA Accredited Levee	Protected by FEMA Accredited Levee	Protected by FEMA Accredited Levee
Sunnyvale	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
CMSA	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
Delta Diablo	Site is not impacted by SLR	Site is not impacted by SLR	Impacted within 100 years
DSRSD	Site is not impacted by SLR	Site is not impacted by SLR	Site is not impacted by SLR
EBMUD	Site is not impacted by SLR	Site is not impacted by SLR	Impacted within 100 years
FSSD	Site is not impacted by SLR	Site is not impacted by SLR	Impacted within 100 years
LGVSD	Site is not impacted by SLR	Site is not impacted by SLR	Impacted within 100 years
MVSD	Site is not impacted by SLR	Site is not impacted by SLR	Site is not impacted by SLR
Novato	Site is not impacted by SLR	Site is not impacted by SLR	Site is not impacted by SLR
Napa	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
Oro Loma	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
Rodeo	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
SASM	Site is not impacted by SLR	Site is not impacted by SLR	Site is not impacted by SLR
SFO Airport	Impacted within 30 years	Impacted within 30 years	Impacted within 30 years
SFPUC SEP	Site is not impacted by SLR	Site is not impacted by SLR	Impacted within 100 years
SMCSD	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
SVCSD	Site is not impacted by SLR	Site is not impacted by SLR	Site is not impacted by SLR
SVCW	Protected by FEMA Accredited Levee	Protected by FEMA Accredited Levee	Protected by FEMA Accredited Levee
Treasure Island	Impacted within 30 years	Impacted within 30 years	Impacted within 30 years
Union San	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
Vallejo	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard
West County	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard	Within FEMA 100-yr flood hazard

[1] Data Source: FEMA's National Flood Hazard Layer Website and Effective/Preliminary DFIRMs

[2] Data from Sea-Level Change Curve Calculator (2017.55) with Project Start Date of 2020

Table 2 - Sea Level Rise Impact based on USACE's Low Curve

POTW Name	Year 2050 (30yr) USACE Low Curve[2] (ft)	Year 2070 (50yr) USACE Low Curve[2] (ft)	Year 2120 (100yr) USACE Low Curve[2] (ft)	FEMA_Zone	Current FEMA WSE[1] (ft)	USACE Low Curve FEMA WSE + 30yr SLR (ft)	USACE Low Curve FEMA WSE + 50yr SLR (ft)	USACE Low Curve FEMA WSE + 100yr SLR (ft)	Average Ground Elev at Facility (ft)	SLR Impact
CCCSD	0.21	0.34	0.68	Riverine Zone A	NA	NA	NA	NA	25.6	Within FEMA 100-yr flood hazard
San Jose	0.20	0.34	0.68	AE	11.0	11.2	11.3	11.7	9.6	Within FEMA 100-yr flood hazard
Sout SF	0.1	0.14	0.27	AE	10.0	10.1	10.1	10.3	11.7	Site is not impacted by SLR
American Canyon	0.21	0.34	0.68	AE	10.0	10.2	10.3	10.7	18.0	Site is not impacted by SLR
Benicia	0.21	0.34	0.68	AE	10.0	10.2	10.3	10.7	12.5	Within FEMA 100-yr flood hazard
Burlingame	0.20	0.34	0.68	AE	11.0	11.2	11.3	11.7	11.2	Within 30 years, site will be impacted by SLR
Hayward	0.20	0.34	0.68	AE	11.0	11.2	11.3	11.7	14.8	Site is not impacted by SLR
Livermore	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	410.0	Site is not impacted by SLR
Millbrae	0.1	0.14	0.27	AE	10.0	10.1	10.1	10.3	6.2	Within FEMA 100-yr flood hazard
Palo Alto	0.20	0.34	0.68	AE	11.0	11.2	11.3	11.7	11.5	Within FEMA 100-yr flood hazard
Petaluma	0.20	0.33	0.66	AE	10.0	10.2	10.3	10.7	16.8	Site is not impacted by SLR
Pinole	0.20	0.33	0.66	AE	11.0	11.2	11.3	11.7	11.0	Within FEMA 100-yr flood hazard
Richmond	0.20	0.33	0.66	AE	12.0	12.2	12.3	12.7	26.3	Site is not impacted by SLR
San Leandro	0.20	0.34	0.68	AE	10.0	10.2	10.3	10.7	8.3	Within FEMA 100-yr flood hazard
San Mateo	0.20	0.34	0.68	AE	11.0	11.2	11.3	11.7	6.3	Protected by FEMA Accredited Levee
Sunnyvale	0.20	0.34	0.68	AE	11.0	11.2	11.3	11.7	9.9	Within FEMA 100-yr flood hazard
CMSA	0.20	0.33	0.66	AE	10.0	10.2	10.3	10.7	7.6	Within FEMA 100-yr flood hazard
Delta Diablo	0.21	0.34	0.68	Zone A	11.0	11.2	11.3	11.7	16.7	Site is not impacted by SLR
DSRSD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	327.0	Site is not impacted by SLR
EBMUD	0.1	0.14	0.27	AE	10.0	10.1	10.1	10.3	13.0	Site is not impacted by SLR
FSSD	0.21	0.34	0.68	AE	10.0	10.2	10.3	10.7	15.1	Site is not impacted by SLR
LGVSD	0.20	0.33	0.66	AE	10.0	10.2	10.3	10.7	15.2	Site is not impacted by SLR
MVSD	0.21	0.34	0.68	Riverine A	NA	NA	NA	NA	13.3	Site is not impacted by SLR
Novato	0.20	0.33	0.66	AE	10.0	10.2	10.3	10.7	18.5	Site is not impacted by SLR
Napa	0.21	0.34	0.68	AE	11.0	11.2	11.3	11.7	6.1	Within FEMA 100-yr flood hazard
Oro Loma	0.20	0.34	0.68	AE	10.0	10.2	10.3	10.7	7.2	Within FEMA 100-yr flood hazard
Rodeo	0.21	0.34	0.68	AE	13.0	13.2	13.3	13.7	9.4	Within FEMA 100-yr flood hazard
SASM	0.20	0.33	0.66	Riverine AE	NA	NA	NA	NA	74.7	Site is not impacted by SLR
SFO Airport	0.1	0.14	0.27	VE	14.0	14.1	14.1	14.3	11.0	Within 30 years, site will be impacted by SLR
SFPUC SEP	0.1	0.14	0.27	AE	10.0	10.1	10.1	10.3	15.9	Site is not impacted by SLR
SMCSD	0.20	0.33	0.66	VE	9.0	9.2	9.3	9.7	12.9	Within FEMA 100-yr flood hazard
SVCSD	0.20	0.33	0.66	Riverine AO	NA	NA	NA	NA	24.8	Site is not impacted by SLR
SVCW	0.20	0.34	0.68	AE	11.0	11.2	11.3	11.7	6.6	Protected by FEMA Accredited Levee
Treasure Island	0.20	0.33	0.66	VE	11.0	11.2	11.3	11.7	9.8	Within 30 years, site will be impacted by SLR
Union San	0.20	0.34	0.68	AE	11.0	11.2	11.3	11.7	9.0	Within FEMA 100-yr flood hazard
Vallejo	0.21	0.34	0.68	AE	10.0	10.2	10.3	10.7	7.5	Within FEMA 100-yr flood hazard
West County	0.20	0.33	0.66	AE	10.0	10.2	10.3	10.7	7.7	Within FEMA 100-yr flood hazard

[1] Data Source: FEMA's National Flood Hazard Layer Website and Effective/Preliminary DFIRMs

[2] Data from Sea-Level Change Curve Calculator (2017.55) with Project Start Date of 2020

Table 3 - Sea Level Rise Impact based on USACE's Intermediate Curve

POTW Name	Year 2050 (30yr) USACE Intermediate Curve[2] (ft)	Year 2070 (50yr) USACE Intermediate Curve[2] (ft)	Year 2120 (100yr) USACE Intermediate Curve[2] (ft)	FEMA_Zone	Current FEMA WSE[1] (ft)	USACE Intermediate Curve FEMA WSE + 30yr SLR (ft)	USACE Intermediate Curve FEMA WSE + 50yr SLR (ft)	USACE Intermediate Curve FEMA WSE + 100yr SLR (ft)	Average Ground Elev at Facility (ft)	SLR Impact
CCCSD	0.43	0.81	2.07	Riverine Zone A	NA	NA	NA	NA	25.6	Within FEMA 100-yr flood hazard
San Jose	0.43	0.81	2.06	AE	11.0	11.4	11.8	13.1	9.6	Within FEMA 100-yr flood hazard
Sout SF	0.31	0.61	1.66	AE	10.0	10.3	10.6	11.7	11.7	Within 100 years, site will be impacted by SLR
American Canyon	0.43	0.81	2.07	AE	10.0	10.4	10.8	12.1	18.0	Site is not impacted by SLR
Benicia	0.43	0.81	2.07	AE	10.0	10.4	10.8	12.1	12.5	Within FEMA 100-yr flood hazard
Burlingame	0.43	0.81	2.06	AE	11.0	11.4	11.8	13.1	11.2	Within 30 years, site will be impacted by SLR
Hayward	0.43	0.81	2.06	AE	11.0	11.4	11.8	13.1	14.8	Site is not impacted by SLR
Livermore	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	410.0	Site is not impacted by SLR
Millbrae	0.31	0.61	1.66	AE	10.0	10.3	10.6	11.7	6.2	Within FEMA 100-yr flood hazard
Palo Alto	0.43	0.81	2.06	AE	11.0	11.4	11.8	13.1	11.5	Within FEMA 100-yr flood hazard
Petaluma	0.43	0.80	2.05	AE	10.0	10.4	10.8	12.1	16.8	Site is not impacted by SLR
Pinole	0.43	0.80	2.05	AE	11.0	11.4	11.8	13.1	11.0	Within FEMA 100-yr flood hazard
Richmond	0.43	0.80	2.05	AE	12.0	12.4	12.8	14.1	26.3	Site is not impacted by SLR
San Leandro	0.43	0.81	2.06	AE	10.0	10.4	10.8	12.1	8.3	Within FEMA 100-yr flood hazard
San Mateo	0.43	0.81	2.06	AE	11.0	11.4	11.8	13.1	6.3	Protected by FEMA Accredited Levee
Sunnyvale	0.43	0.81	2.06	AE	11.0	11.4	11.8	13.1	9.9	Within FEMA 100-yr flood hazard
CMSA	0.43	0.80	2.05	AE	10.0	10.4	10.8	12.1	7.6	Within FEMA 100-yr flood hazard
Delta Diablo	0.43	0.81	2.07	Zone A	11.0	11.4	11.8	13.1	16.7	Site is not impacted by SLR
DSRSD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	327.0	Site is not impacted by SLR
EBMUD	0.31	0.61	1.66	AE	10.0	10.3	10.6	11.7	13.0	Site is not impacted by SLR
FSSD	0.43	0.81	2.07	AE	10.0	10.4	10.8	12.1	15.1	Site is not impacted by SLR
LGVSD	0.43	0.80	2.05	AE	10.0	10.4	10.8	12.1	15.2	Site is not impacted by SLR
MVSD	0.43	0.81	2.07	Riverine AE	NA	NA	NA	NA	13.3	Site is not impacted by SLR
Novato	0.43	0.80	2.05	AE	10.0	10.4	10.8	12.1	18.5	Site is not impacted by SLR
Napa	0.43	0.81	2.07	AE	11.0	11.4	11.8	13.1	6.1	Within FEMA 100-yr flood hazard
Oro Loma	0.43	0.81	2.06	AE	10.0	10.4	10.8	12.1	7.2	Within FEMA 100-yr flood hazard
Rodeo	0.43	0.81	2.07	AE	13.0	13.4	13.8	15.1	9.4	Within FEMA 100-yr flood hazard
SASM	0.43	0.80	2.05	Riverine AE	NA	NA	NA	NA	74.7	Site is not impacted by SLR
SFO Airport	0.31	0.61	1.66	VE	14.0	14.3	14.6	15.7	11.0	Within 30 years, site will be impacted by SLR
SFPUC SEP	0.31	0.61	1.66	AE	10.0	10.3	10.6	11.7	15.9	Site is not impacted by SLR
SMCSD	0.43	0.80	2.05	VE	9.0	9.4	9.8	11.1	12.9	Within FEMA 100-yr flood hazard
SVCSD	0.43	0.80	2.05	Riverine AO	NA	NA	NA	NA	24.8	Site is not impacted by SLR
SVCW	0.43	0.81	2.06	AE	11.0	11.4	11.8	13.1	6.6	Protected by FEMA Accredited Levee
Treasure Island	0.43	0.80	2.05	VE	11.0	11.4	11.8	13.1	9.8	Within 30 years, site will be impacted by SLR
Union San	0.43	0.81	2.06	AE	11.0	11.4	11.8	13.1	9.0	Within FEMA 100-yr flood hazard
Vallejo	0.43	0.81	2.07	AE	10.0	10.4	10.8	12.1	7.5	Within FEMA 100-yr flood hazard
West County	0.43	0.80	2.05	AE	10.0	10.4	10.8	12.1	7.7	Within FEMA 100-yr flood hazard

[1] Data Source: FEMA's National Flood Hazard Layer Website and Effective/Preliminary DFIRMs

[2] Data from Sea-Level Change Curve Calculator (2017.55) with Project Start Date of 2020

Table 4 - Sea Level Rise Impact based on USACE's High Curve

POTW Name	Year 2050 (30yr) USACE High Curve[2] (ft)	Year 2070 (50yr) USACE High Curve[2] (ft)	Year 2120 (100yr) USACE High Curve[2] (ft)	FEMA_Zone	Current FEMA WSE[1] (ft)	USACE High Curve FEMA WSE + 30yr SLR (ft)	USACE High Curve FEMA WSE + 50yr SLR (ft)	USACE High Curve FEMA WSE + 100yr SLR (ft)	Average Ground Elev at Facility (ft)	SLR Impact
CCCSD	1.16	2.31	6.47	Riverine Zone A	NA	NA	NA	NA	25.6	Within FEMA 100-yr flood hazard
San Jose	1.16	2.30	6.46	AE	11.0	12.2	13.3	17.5	9.6	Within FEMA 100-yr flood hazard
Sout SF	1.04	2.10	6.05	AE	10.0	11.0	12.1	16.1	11.7	Within 50 years, site will be impacted by SLR
American Canyon	1.16	2.31	6.47	AE	10.0	11.2	12.3	16.5	18.0	Site is not impacted by SLR
Benicia	1.16	2.31	6.47	AE	10.0	11.2	12.3	16.5	12.5	Within FEMA 100-yr flood hazard
Burlingame	1.2	2.3	6.5	AE	11.0	12.2	13.3	17.5	11.2	Within 30 years, site will be impacted by SLR
Hayward	1.2	2.3	6.5	AE	11.0	12.2	13.3	17.5	14.8	Within 100 years, site will be impacted by SLR
Livermore	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	410.0	Site is not impacted by SLR
Millbrae	1.04	2.10	6.05	AE	10.0	11.0	12.1	16.1	6.2	Within FEMA 100-yr flood hazard
Palo Alto	1.16	2.30	6.46	AE	11.0	12.2	13.3	17.5	11.5	Within FEMA 100-yr flood hazard
Petaluma	1.2	2.3	6.4	AE	10.0	11.2	12.3	16.4	16.8	Site is not impacted by SLR
Pinole	1.2	2.3	6.4	AE	11.0	12.2	13.3	17.4	11.0	Within FEMA 100-yr flood hazard
Richmond	1.2	2.3	6.4	AE	12.0	13.2	14.3	18.4	26.3	Site is not impacted by SLR
San Leandro	1.2	2.3	6.5	AE	10.0	11.2	12.3	16.5	8.3	Within FEMA 100-yr flood hazard
San Mateo	1.2	2.3	6.5	AE	11.0	12.2	13.3	17.5	6.3	Protected by FEMA Accredited Levee
Sunnyvale	1.16	2.30	6.46	AE	11.0	12.2	13.3	17.5	9.9	Within FEMA 100-yr flood hazard
CMSA	1.2	2.3	6.4	AE	10.0	11.2	12.3	16.4	7.6	Within FEMA 100-yr flood hazard
Delta Diablo	1.16	2.31	6.47	Zone A	11.0	12.2	13.3	17.5	16.7	Within 100 years, site will be impacted by SLR
DSRSD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	327.0	Site is not impacted by SLR
EBMUD	1.04	2.10	6.05	AE	10.0	11.0	12.1	16.1	13.0	Within 100 years, site will be impacted by SLR
FSSD	1.16	2.31	6.47	AE	10.0	11.2	12.3	16.5	15.1	Within 100 years, site will be impacted by SLR
LGVSD	1.2	2.3	6.4	AE	10.0	11.2	12.3	16.4	15.2	Within 100 years, site will be impacted by SLR
MVSD	1.16	2.31	6.47	Riverine AE	11.0	NA	NA	NA	13.3	Site is not impacted by SLR
Novato	1.2	2.3	6.4	AE	10.0	11.2	12.3	16.4	18.5	Site is not impacted by SLR
Napa	1.16	2.31	6.47	AE	11.0	12.2	13.3	17.5	6.1	Within FEMA 100-yr flood hazard
Oro Loma	1.2	2.3	6.5	AE	10.0	11.2	12.3	16.5	7.2	Within FEMA 100-yr flood hazard
Rodeo	1.16	2.31	6.47	AE	13.0	14.2	15.3	19.5	9.4	Within FEMA 100-yr flood hazard
SASM	1.2	2.3	6.4	Riverine AE	NA	NA	NA	NA	74.7	Site is not impacted by SLR
SFO Airport	1.04	2.10	6.05	VE	14.0	15.0	16.1	20.1	11.0	Within 30 years, site will be impacted by SLR
SFPUC SEP	1.04	2.10	6.05	AE	10.0	11.0	12.1	16.1	15.9	Within 100 years, site will be impacted by SLR
SMCSD	1.2	2.3	6.4	VE	9.0	10.2	11.3	15.4	12.9	Within FEMA 100-yr flood hazard
SVCSD	1.2	2.3	6.4	Riverine AO	NA	NA	NA	NA	24.8	Site is not impacted by SLR
SVCW	1.2	2.3	6.5	AE	11.0	12.2	13.3	17.5	6.6	Protected by FEMA Accredited Levee
Treasure Island	1.2	2.3	6.4	VE	11.0	12.2	13.3	17.4	9.8	Within 30 years, site will be impacted by SLR
Union San	1.2	2.3	6.5	AE	11.0	12.2	13.3	17.5	9.0	Within FEMA 100-yr flood hazard
Vallejo	1.16	2.31	6.47	AE	10.0	11.2	12.3	16.5	7.5	Within FEMA 100-yr flood hazard
West County	1.2	2.3	6.4	AE	10.0	11.2	12.3	16.4	7.7	Within FEMA 100-yr flood hazard

[1] Data Source: FEMA's National Flood Hazard Layer Website and Effective/Preliminary DFIRMs

[2] Data from Sea-Level Change Curve Calculator (2017.55) with Project Start Date of 2020

D

Individual Plant Reports

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D.1

City of American Canyon Water Reclamation Facility

Bay Area Clean Water Agencies
Nutrient Reduction Study

City of American Canyon Water Reclamation Facility

American Canyon, CA

April 5, 2018
Final Report

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Executive Summary

The City of American Canyon owns and operates the American Canyon Water Reclamation Facility (American Canyon) located in American Canyon, CA and discharges treated effluent to North Slough during the wet season. During the dry season, treated effluent that is not used for reclamation is discharged to freshwater wetland ponds. The plant has an average dry weather flow (ADWF) permitted capacity of 2.5 million gallons per day (mgd) and a peak permitted wet weather flow of 5.0 mgd.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3,7]
Design Flow[9]	mgd	--	--	1.5	1.7	2.5	2.9	2.5	2.9	--
Flow to Bay[2,8]	mgd	1.4	1.4	1.4	1.4	2.0	2.0	2.0	2.0	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	7	7	8	8	10	10	10	10	--
TN	lb N/d	130	130	140	140	190	190	170	100	--
TP	lb P/d	58	58	12	11	15	14	13	5	--
Costs[4,5]										
Capital	$ Mil	--	--	0.54	0.58	0.56	0.58	24	24	--
O&M PV	$ Mil	--	--	0.24	0.24	0.75	0.75	5	12	--
Total PV	$ Mil	--	--	0.78	0.82	1.32	1.33	29	36	--
Unit Costs[6]										
Capital	$/gpd	--	--	0.4	0.3	0.2	0.2	9.7	8.4	--
Total PV	$/gpd	--	--	0.5	0.5	0.5	0.5	11.9	12.6	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2016 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2016). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. American Canyon was not considered for sidestream treatment.
8. Assumes recycled water delivery of 0.3 mgd during the dry season.
9. Design flow shown for year round is the wet season average influent flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Chemical precipitation of phosphate to reduce TP loads.

American Canyon is a nitrifying membrane bioreactor (MBR) facility and the final effluent currently meets the Level 2 and Level 3 ammonia concentrations. It should be noted that several improvements have been implemented at the plant such that the final effluent currently meets the Level 2 TN concentrations. These improvements were implemented after June 2015.

American Canyon is not considered a candidate for sidestream treatment. Waste activated sludge (WAS) is the only solids stream at the plant (there are no primary clarifiers) and WAS has historically been pumped to a solids lagoon. The lagoon decant is intermittently routed to the front of the plant for treatment. During the site visit, staff indicated that a screw press will be installed for dewatering of WAS. The filtrate will be routed to the front of the plant and dewatered cake will be hauled offsite for disposal. In the future, the sludge lagoon will only be used for emergency storage. The filtrate stream is not expected to have a significant nutrient load and therefore American Canyon would not be a candidate for sidestream treatment.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Construction of alum storage and metering facilities for phosphorus removal. Since the plant currently meets Level 2 TN concentrations, no improvements are included for TN.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Construction of one 4-stage Bardenpho-MBR trains.
    c. Conversion of the existing nitrifying MBR trains into 4-stage Bardenpho configuration.
    d. Construction of methanol storage and metering facilities.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $0.8 Mil for dry season optimization up to $36 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The American Canyon Water Reclamation Facility (American Canyon) discharges treated effluent to North Slough during the wet season. During the dry season, treated effluent is used for reclamation and is discharged to freshwater wetland ponds. It is located at 151 Mezzetta Court in American Canyon, CA. The facility serves the city of American Canyon, which has a population of approximately 16,800 (from Appendix F of NPDES Permit No. CA 0038768). The plant receives both domestic and industrial wastewater. The two wastewaters are conveyed separately to the treatment facility and can remain segregated during treatment or can be combined at the plant, upstream of treatment. Industrial dischargers to the plant include a food processing facility, winery and beverage bottling facilities. The plant has an average dry weather flow (ADWF) permitted capacity of 2.5 million gallons per day (mgd) and a peak permitted wet weather flow of 5.0 mgd.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

American Canyon holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2011-0046; CA0038768. Table 2-1 provides a summary of the permit limitations that are specific to American Canyon and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit. Currently, there are no TN or TP discharge limitations.

Table 2-1. NPDES Permit Limitations (Order No. R2-2011-0046; CA0038768)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	2.5	-	-	-
BOD	mg/L	-	10	15	-
TSS	mg/L	-	10	15	-
Total Ammonia, as N	mg/L	-	2.0	-	3.0

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for American Canyon. Both liquids processes and solids processes are shown. Primary treatment is not provided at the plant. Both industrial and domestic inflows are treated using nitrifying membrane bioreactors (MBRs). The plant has both chlorine and UV disinfection facilities; chlorine disinfection is used for the disinfection of recycled water and UV disinfection is used for the disinfection of effluent that is discharged to North Slough.

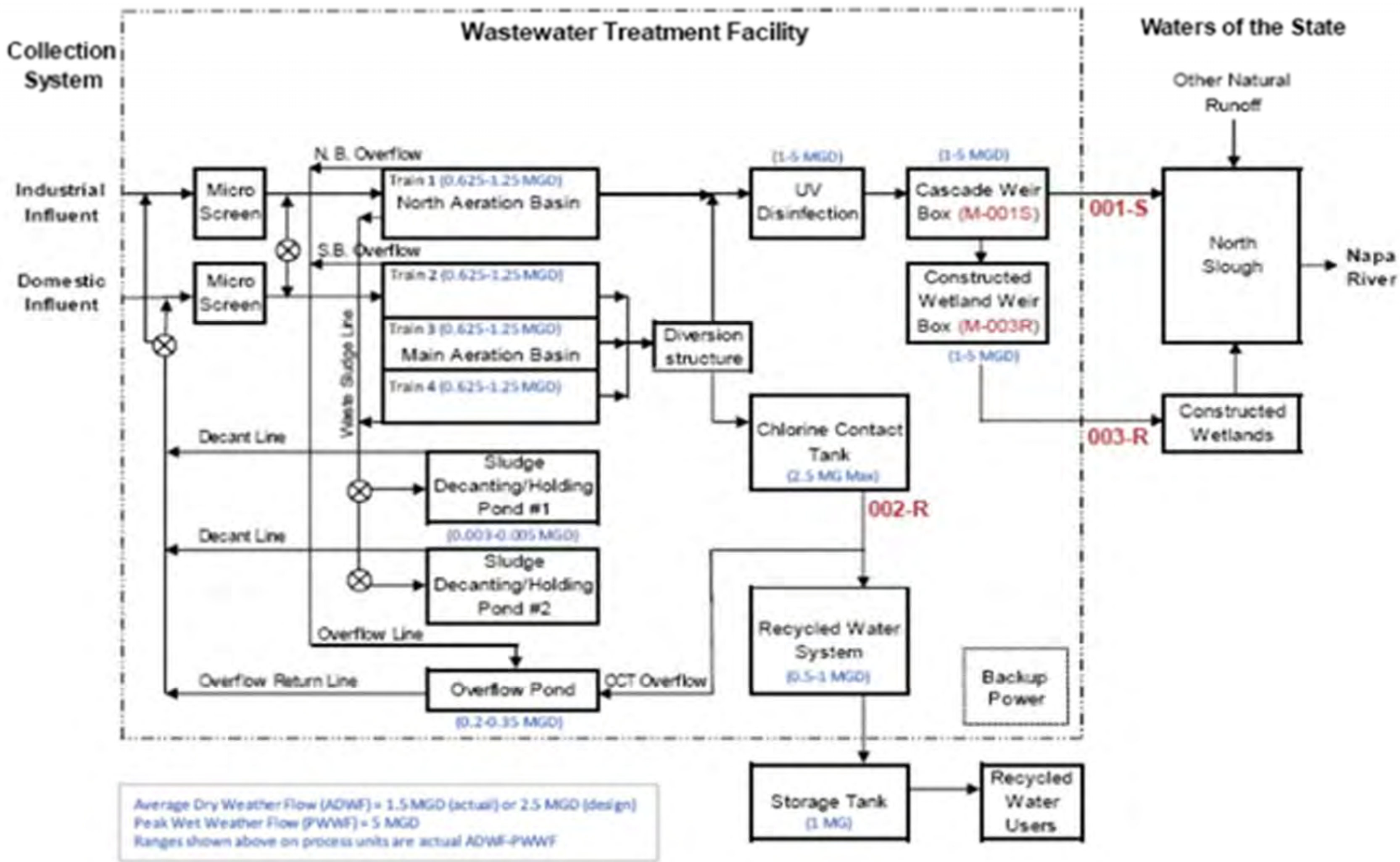

Figure 2-1. Process Flow Diagram for American Canyon

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. American Canyon receives industrial wastewater and domestic wastewater via two segregated influent lines. Recent modifications were made at the plant and the two wastewaters are combined at the front and then treated together. Composite samples of both influent wastewaters are collected. A summary of the historical influent flows and loads for American Canyon is shown in Table 2-2. The table provides the characteristics of the combined domestic and industrial wastewater streams.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2,4]	Average Annual[4]	Dry Season MM (May 1 – Sept 30)[1,3,4]	Year Round MM[1,3,4]
Flow	mgd	1.5	1.6	1.6	2.3
BOD	lb/d	3,150	3,130	3,300	3,420
TSS	lb/d	2,210	2,250	2,420	2,720
Ammonia	lb N/d	385	396	420	440
Total Kjeldahl Nitrogen (TKN)[5,7]	lb N/d	530	399	560	580
Total Phosphorus (TP)[6,7]	lb P/d	46	57	46	82
Alkalinity	lb $CaCO_3$/d	No data	No data	No data	No data
BOD	mg/L	255	235	242	181
TSS	mg/L	179	169	177	144
Ammonia	mg N/L	31	30	31	23
TKN[5,7]	mg N/L	43	40	41	31
TP[6,7]	mg P/L	3.7	4.2	3.4	4.3
Alkalinity	mg CaCO3/L	No data	No data	No data	No data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. The values presented are the combined raw industrial and domestic wastewater flows and loads.
5. TKN data was not available during July 2011 through June 2012 and July 2012 through January 2013. The TKN loads are based upon available data collected from July 2012 through June 2014.
6. TP data was not available during July 2011 through June 2012. The TP loads are based upon available data collected from July 2012 through June 2014.
7. Due to limited TKN and TP data, the calculated BOD peaking factors for the various averaging periods were applied to TKN and TP.

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed, are in progress, or are planned for at American Canyon:

- Modifications to the nitrifying MBR trains to improve operations; the modifications have resulted in improved TN removal.
- Membrane replacement in November 2015.
- Installation of a new dewatering screw press for WAS was completed in 2015 and will be operated on a regular basis.
- Conversion of one sludge holding pond into an equalization basin for industrial influent wastewater. The driver for the modification is that industrial wastewater has a high salt content and impacts recycled water production for agricultural customers. Providing equalization of industrial wastewaters will facilitate/simplify recycled water production. No timeline has been established for this project.
- Construction of a recycled water storage tank to increase recycled water deliveries.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at American Canyon.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for American Canyon are presented in Table 3-1. The projected flow and load for American Canyon in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.5	1.6	1.6	2.3
BOD	lb/d	3,600	3,600	3,800	3,900
TSS	lb/d	2,600	2,600	2,800	3,100
Ammonia	lb N/d	450	470	480	510
TKN[4]	lb N/d	610	610	650	670
TP[4]	lb P/d	50	80	50	95
Alkalinity	lb/d as $CaCO_3$	No data	No data	No data	No data
BOD	mg/L	300	270	280	210
TSS	mg/L	200	200	200	170
Ammonia	mg N/L	40	40	35	30
TKN[4]	mg N/L	50	50	50	35
TP[4]	mg P/L	4.3	5.8	3.9	5.0
Alkalinity	mg/L as $CaCO_3$	No data	No data	No data	No data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Due to limited TKN and TP data, the calculated BOD peaking factors for the various averaging periods were applied to TKN and TP.

3.2 Flow and Loading for Sidestream Treatment

American Canyon is not considered a candidate for sidestream treatment. Historically, WAS has been pumped to a solids lagoon. Decant is intermittently routed to the front of the plant for treatment. During the site visit, Staff indicated that a screw press was going to be installed in August of 2015. The intent is to regularly use the screw press for WAS dewatering and to rely on the lagoon for emergency solids storage only. Dewatered cake will be hauled offsite for disposal and screw press filtrate will be routed to the front of the plant. The filtrate stream is not expected to have a significant nutrient load; therefore, American Canyon was not considered as a candidate for sidestream treatment.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

The following modifications and assumptions were made:

- BOD peaking factors for TKN and TP were used for ADW, MM, and MD conditions
- Future peak hour flows to the treatment system will stay at 5 mgd. Equalization at the plant is currently used for influent flows greater than 5 mgd.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.5	2.70	2.8	3.8
BOD	lb/d	5,310	5,300	5,600	5,800
TSS	lb/d	3,700	3,800	4,100	4,600
Ammonia	lb N/d	650	670	710	750
TKN[4]	lb N/d	900	900	950	980
TP[4]	lb P/d	80	100	80	140
Alkalinity	lb/d as $CaCO_3$	No data	No data	No data	No data
BOD	mg/L	260	240	240	180
TSS	mg/L	180	170	180	140
Ammonia	mg N/L	30	30	30	20
TKN[4]	mg N/L	40	40	40	30
TP[4]	mg P/L	3.7	4.2	3.4	4.3
Alkalinity	mg/L as $CaCO_3$	No data	No data	No data	No data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Due to limited TKN and TP data, the calculated BOD peaking factors for the various averaging periods were applied to TKN and TP

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.

- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Four optimization strategies were identified during the American Canyon visit (Appendix B). These were analyzed following the site visit to screen and select the most attractive strategy. The results of the screening are described below.

- **Optimization Strategy 1:** Addition of ferric chloride or alum to the nitrifying MBR to precipitate phosphorus and reduce P effluent loads.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increases P removal
  - ***Result from analysis:*** Ferric chloride or alum storage and metering facilities could be constructed at the plant. The improvements would include: (a) construction of a chemical storage facility with chemical metering pumps, and (b) construction of chemical feed piping from the storage facility to the nitrifying MBR influent channel. Alum is the preferred chemical because of the potential for ferric chloride to interfere with downstream UV disinfection.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Operate existing equalization pond as an anaerobic selector for enhanced biological phosphorus removal (EBPR).
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** The strategy would include the following upgrades: (a) yard piping modifications to route RAS to the equalization pond, (b) upgrades to the ponds to provide mixing of influent and RAS. In addition to upgrades, this strategy would have operational considerations because the equalization pond is currently used to provide diurnal and wet weather equalization. If implemented, this strategy would likely consist of using the equalization pond as an anaerobic selector during dry weather months only. During dry weather months the pond would serve as an anaerobic selector and diurnal flow equalization would not be performed. This strategy was not carried forward due to scope of the improvements (considered to be capital improvements) and the associated operational challenges of flow management.
  - ***Recommendation:*** Do not carry forward

- **Optimization Strategy 3:** Add mixers to unaerated zones and IMLR for denitrification.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase TN removal
  - ***Result from analysis:*** Recent improvements at the plant included installing anoxic mixers into unaerated zones and reconfiguring the RAS return to optimize denitrification. These improvements have resulted in the final effluent meeting the Level 2 TN concentrations.
  - ***Recommendation:*** This improvement has already been implemented at the plant.

- **Optimization Strategy 4:** Modify blower setpoints.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase ammonia and TN removal
  - ***Result from analysis:*** This improvement was recently made at the plant. Ammonia probes were installed in the aeration basins and a new blower control strategy was implemented. When ammonia reaches a high setpoint, the DO setpoint increases and the blower speed is adjusted.
  - ***Recommendation:*** This improvement has already been implemented at the plant.

As noted above, recent improvements at the plant have resulted in increased TN removal. During the site visit, Staff shared recent average month final effluent data from January 2015 through May 2015. The final effluent TN concentrations ranged from 8 to 9 mg-N/L, demonstrating that with the recent improvements, the plant can meet Level 2 TN concentration limits today.

The recommended strategy to optimize P removal is shown with the process flowsheet presented in Figure 4-1. TN optimization strategies that were identified have already been implemented at the plant and the plant is able to meet Level 2 TN limits. Therefore, additional TN optimization strategies were not identified for implementation. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

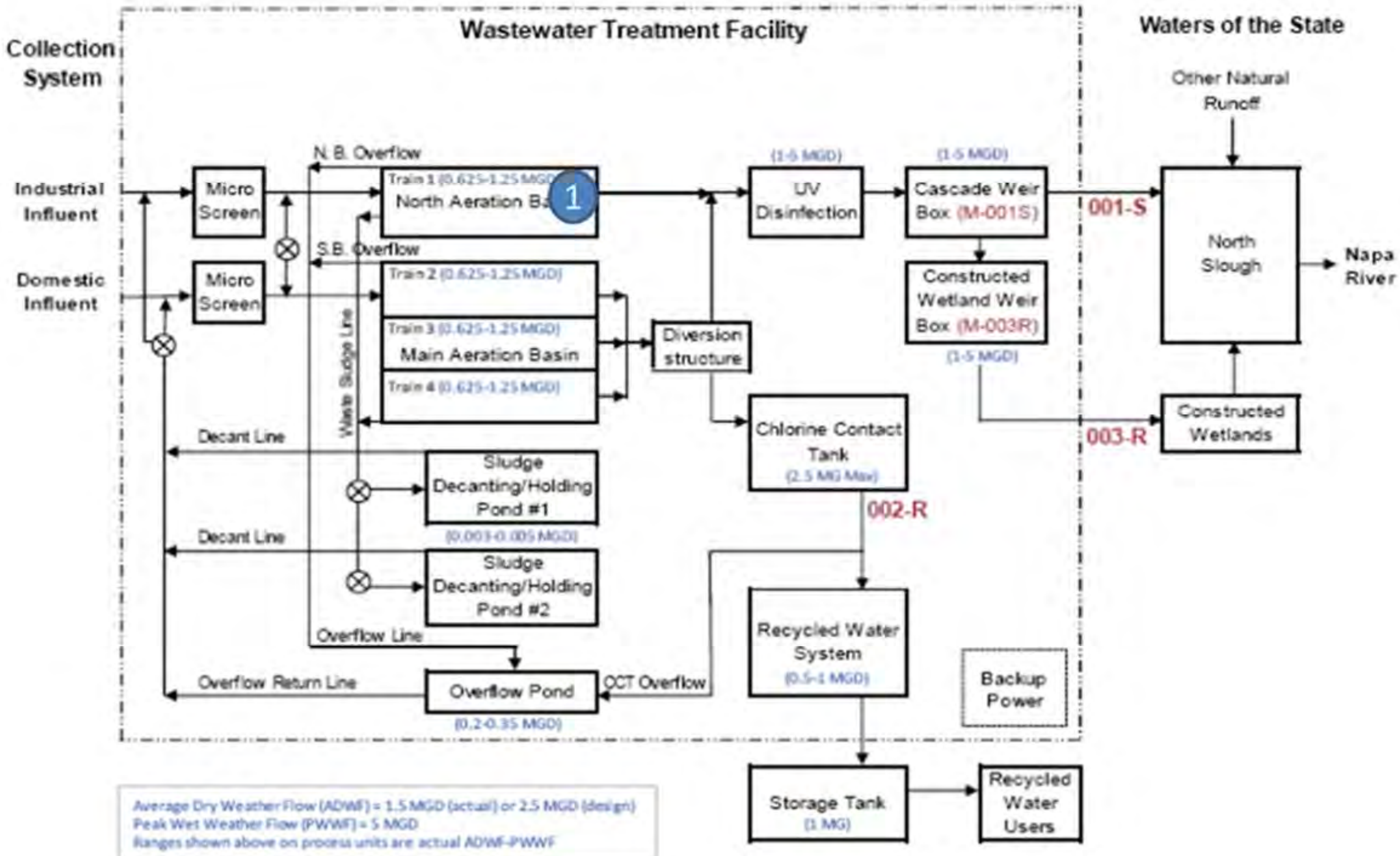

Figure 4-1. Optimization Concepts Considered for American Canyon

(1) add alum for P removal.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
• Construct alum storage and metering facilities near the nitrifying MBR basins.	• Dose alum to the nitrifying MBR influent channel.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. As previously noted, because American Canyon currently achieves the Level 2 ammonia and TN limits, there is no net load reduction for ammonia and TN.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	7	7	140	140	63	63
Discharge with Opt. Strategy[1]	lb N or P/d	8	8	140	140	12	11
Load Reduction[2,3]	lb N or P/d	0	0	0	0	51	52
Load Reduction[2,3]	%	0%	0%	0%	0%	80%	80%
Annual Load Reduction	lb N or P/yr	0	0	0	0	18,500	18,800

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since American Canyon meets Level 2 TN concentration limits today.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively. The costs do not account for operating costs associated with handling and disposal of the additional solids generated from the upgraded process (e.g., chemical precipitation from alum addition).

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	1.5	1.7
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.54	0.58
Annual O&M	$ Mil/yr	0.03	0.03
Present Value O&M[3]	$ Mil	0.24	0.24
Present Value Total[3]	$ Mil	0.78	0.82
Unit Capital Cost[8]	$/gpd	0.4	0.3
Unit Total PV Cost[8]	$/gpd	0.5	0.5
TN Removal			
Capital[2,4]	$ Mil	0	0
Annual O&M[4]	$ Mil/yr	0	0
O&M PV[3,4]	$ Mil	0	0
Total PV[3,4]	$ Mil	0	0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0.54	0.58
Annual O&M[5]	$ Mil/yr	0.03	0.03
O&M PV[3,5]	$ Mil	0.24	0.24
Total PV[3,5]	$ Mil	0.78	0.82
TP Removed (Ave.)[6]	lb P/d	51	52
Annual TP Removed (Ave.)[7]	lb P/yr	18,500	18,800
TP Cost[5,9]	$/lb P	4.2	4.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since American Canyon meets Level 2 TN concentration limits today.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• Phosphorus reliably removed	• Dependency on chemicals • Increased sludge production

5 Sidestream Treatment

Sidestream treatment is not considered a viable option for American Canyon as previously described and thus was not evaluated further.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at American Canyon to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. American Canyon should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The plant is currently able to meet Level 2 TN limits. The plant was constructed and is operated in the MLE configuration; prior to initiating the BACWA study, several improvements were made to the aeration and anoxic basins that have improved denitrification performance. At the time of the site visit, the plant provided recent TN data that demonstrated the ability of the plant to meet ammonia levels less than 2 mg-N/L and TN levels less than 15 mg-N/L. Plant improvements have also included combining industrial and domestic influent flows at the front of the plant. The plant no longer segregates these flows and/or needs the ability to treat industrial flows separately from municipal flows; this means that all of the existing MBR trains are available for treatment capacity.

The Level 2 improvements identified in this section are necessary to provide TP removal for the permitted ADWF. TP removal was assumed to be met with chemical addition to the MBR trains. Alum was assumed over ferric chloride to avoid potential interference with downstream UV disinfection.

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1.

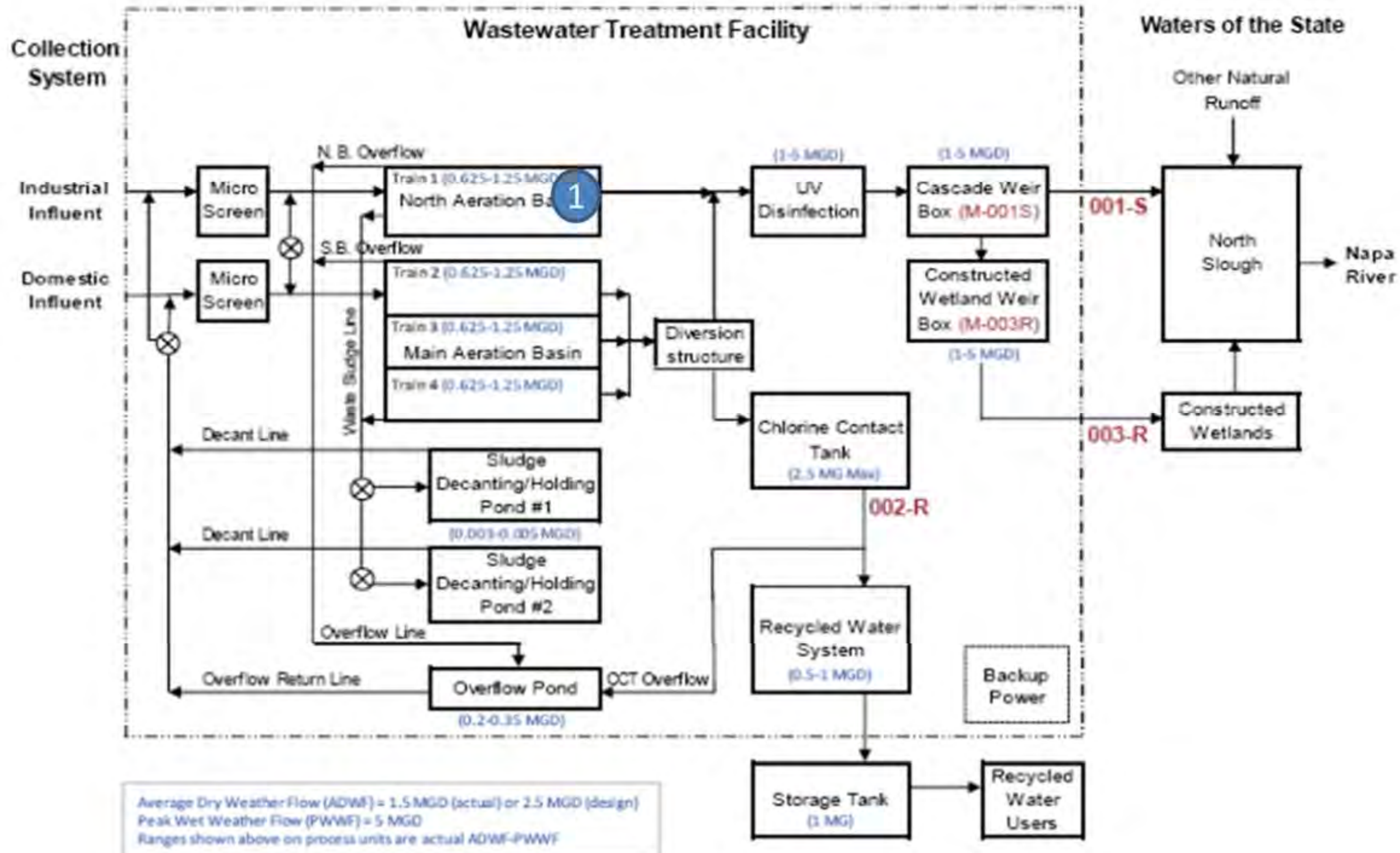

Figure 6-1. Level 2 Upgrade Concept for American Canyon

(1) add alum for P removal.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 would entail reconfiguration of the existing MLE-MBR trains to 4-stage Bardenpho trains. To maintain a reasonable MLSS concentration and to satisfy OUR, one new train was assumed to be constructed to meet Level 3. Provisions for methanol addition for denitrification are included. Alum addition would be increased at the aeration basins to meet the Level 3 TP limit.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Not Applicable	• Not Applicable
Flow Equalization	• Not Applicable	• Not Applicable
Biological	• Alum storage and metering facilities	• 1, 4-stage Bardenpho-MBR trains • Additional 2,300 scfm of process aeration blowers • 62,500 ft^2 of membrane surface area • Alum storage and metering facilities • Methanol storage and metering facilities
Tertiary	--	--
Biosolids or Sidestream	--	--

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

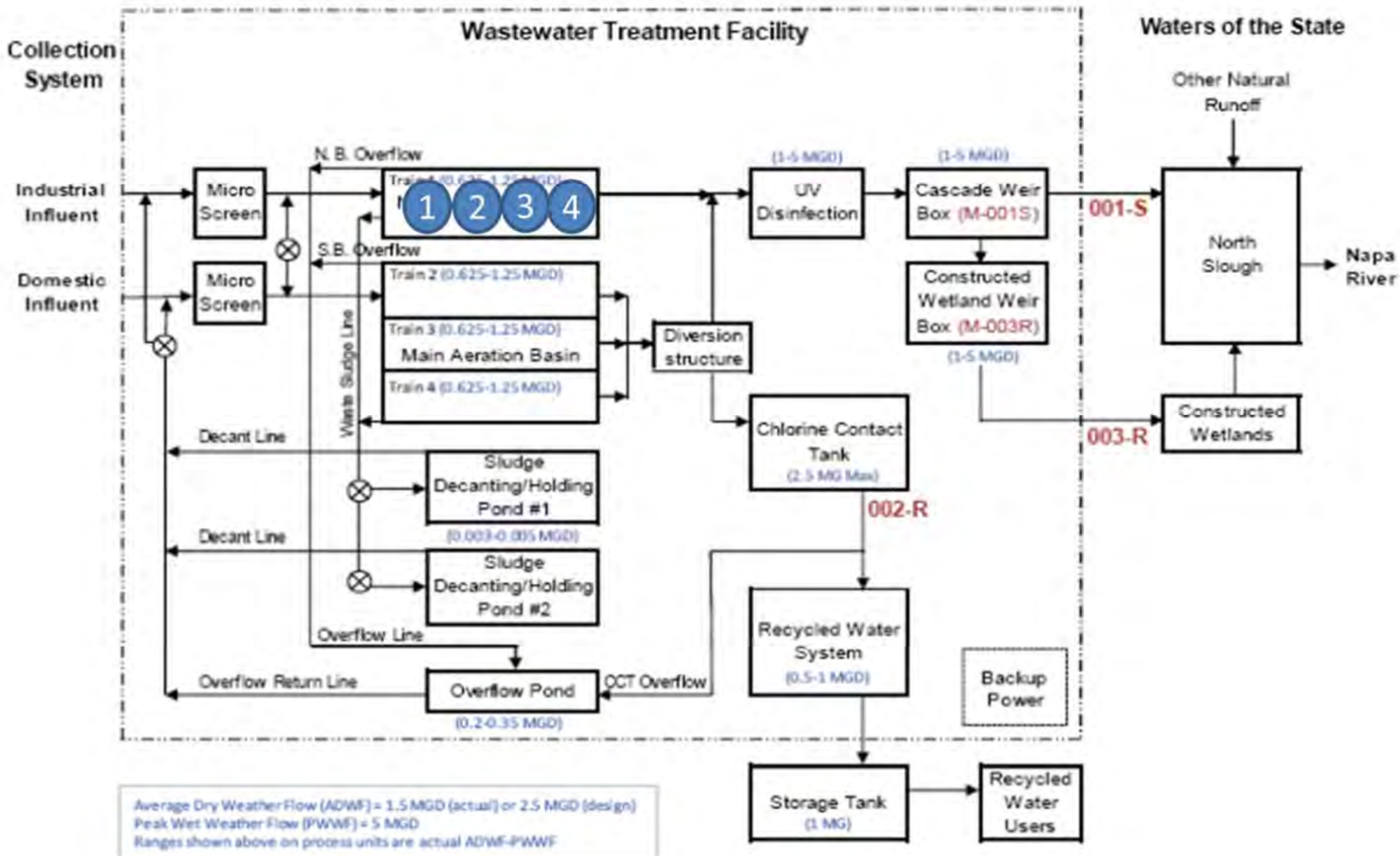

Figure 6-2. Level 3 Upgrade Concept for American Canyon

(1) Include facilities for alum addition (2) Construct one new train in 4-stage Bardenpho configuration (3) Convert existing aeration trains to 4-stage Bardenpho (4) Construct methanol addition facilities to provide a carbon source for denitrification.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) construct facilities for alum addition

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Include facilities for alum addition (2) Construct one new train in 4-stage Bardenpho configuration (3) Convert existing aeration trains to 4-stage Bardenpho (4) Construct methanol addition facilities.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	2.5	2.9	2.5	2.9
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	0.56	0.58	24	24
Annual O&M	$Mil/yr	0.03	0.03	0.24	0.54
O&M PV[3]	$ Mil	0.75	0.75	5	12
Total PV[3]	$ Mil	1.3	1.3	29	36
Unit Capital Cost	$/gpd	0.2	0.2	9.7	8.4
Unit Total PV	$/gpd	0.5	0.5	11.9	12.6
TN Removal					
Capital[2,4]	$ Mil	0	0	24	24
Annual O&M[4]	$ Mil/yr	0	0	0.20	0.48
O&M PV[3,4]	$ Mil	0	0	4	11
Total PV[3,4]	$ Mil	0	0	28	34
TN Removed (Ave.)[6,10]	lb N/d	0	0	10	80
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0	4,300	28,200
TN Cost[4,8]	$/lb N	NA	NA	218.6	40.8
TP Removal					
Capital[2,5]	$ Mil	0.56	0.58	0.63	0.65
Annual O&M[5]	$ Mil/yr	0.03	0.03	0.04	0.06
O&M PV[3,5]	$ Mil	0.75	0.75	0.98	1.34
Total PV[3,5]	$ Mil	1.3	1.3	1.6	2.0
TP Removed (Ave.)[6]	lb P/d	63	64	66	73
Annual TP Removed (Ave.)[7]	lb P/yr	23,000	23,500	24,000	26,800
TP Cost[5,8]	$/lb P	1.9	1.9	2.2	2.5

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.
10. Calculated nutrient reduction is zero, since American Canyon meets Level 2 TN concentration limits today.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing MLE-MBR tankage • Robust technology to absorb variability in flows and loads • Ability to reliably remove ammonia and TN • Ability to reliably reduce TP	• Increased operation costs associated with alum addition
Level 3	• Same as Level 2	• Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use and additional alum use • Safety from external carbon source (if methanol)

7 Nutrient Removal by Other Means

American Canyon has an existing recycled water program that is employed year-round. Recycled water is used for landscape irrigation, agricultural irrigation, commercial use, and internal plant use. This existing program has the effect of reducing nutrients discharged to the Bay. American Canyon currently recycles approximately 150 acre-feet per year (50 million gallons per year) and they are planning to increase recycled water deliveries to 1,300 acre-feet per year (400 million gallons per year) by 2040. The projected recycled water use would primarily be landscape irrigation, which would reduce discharges to the Bay.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most

stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

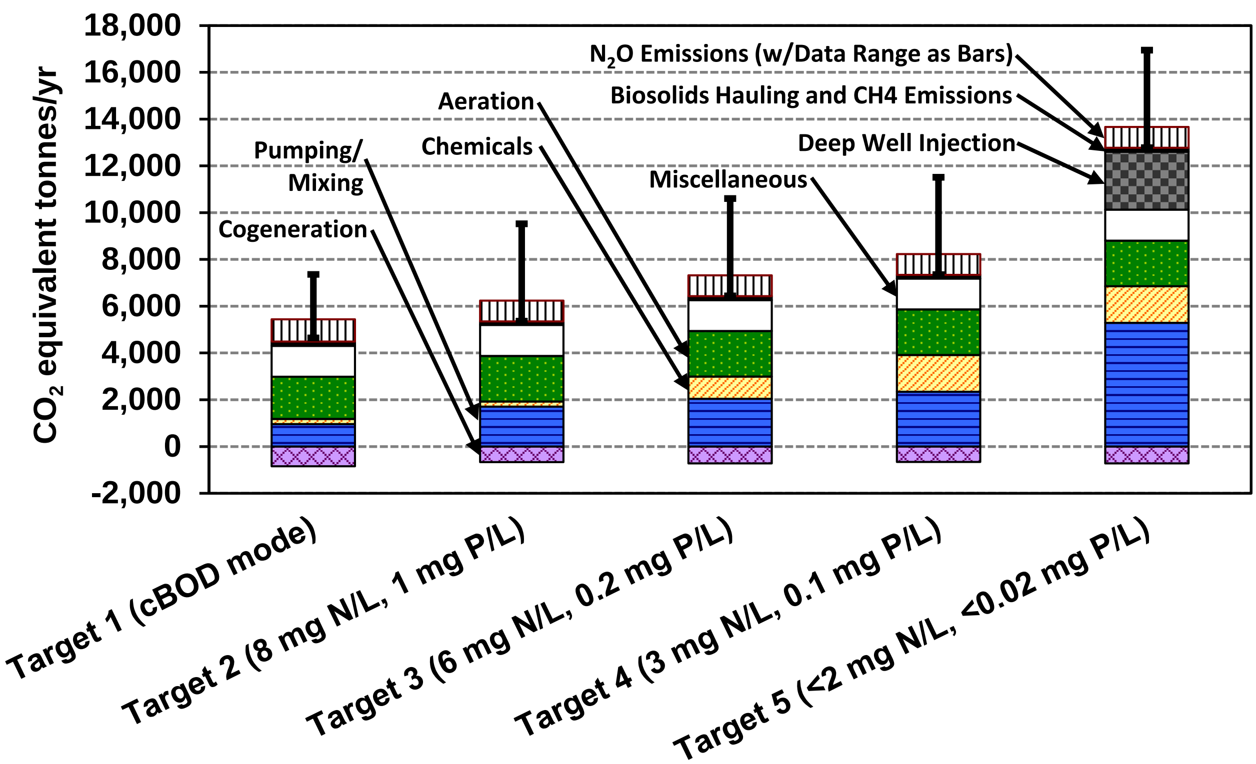

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	2	2	2	2	58	58	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	18	19	30	33	161	176	--
GHG Emissions Increase Total	MT CO_2/yr	20	21	32	35	219	234	--
Unit GHG Emissions[2]	lb CO_2/MG	70	80	70	80	480	520	--
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	--*	--*	--*	--*	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	--*	--*	80	13	--
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	2	2	3	3	6	6	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. American Canyon was not considered for sidestream treatment.

* No removal. Plant already meets Level 2 targets for ammonia and nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at American Canyon. These are:

- Nitrite Shunt – American Canyon BNR basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Simultaneous nitrification/denitrification (SND) –American Canyon aeration basins would be operated at low dissolved oxygen (DO) levels to promote SND. Under this operating scenario, nitrification and denitrification occurs in the same tankage and dedicated anoxic zones are not necessary. As a result, there is a significant reduction in aeration requirements. This requires the installations of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.2

City of Benicia Wastewater Treatment Plant

Bay Area Clean Water Agencies
Nutrient Reduction Study

City of Benicia Wastewater Treatment Plant

Benicia, CA

April 2, 2018
Final Report

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Executive Summary

The City of Benicia (City) owns and operates the Benicia Wastewater Treatment Plant (WWTP) located in Benicia, CA and discharges treated effluent to the Carquinez Strait. The plant has an average dry weather flow (ADWF) permitted capacity of 4.5 million gallons per day (mgd) and a peak permitted one-hour peak wet weather flow of 18 mgd.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow[7]	mgd	--	--	2.1	2.3	4.5	5.1	4.5	5.1	--
Flow to Bay[2]	mgd	2.1	2.1	2.1	2.1	3.5	3.5	3.5	3.5	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	410	410	440	440	60	60	60	60	570
TN	lb N/d	500	500	530	530	460	430	330	170	720
TP	lb P/d	59	59	17	16	31	29	21	9	78
Costs[4,5]										
Capital	$ Mil	--	--	0.6	0.7	30	30	43	45	4.1
O&M PV	$ Mil	--	--	0.3	0.3	15	16	19	24	1.9
Total PV	$ Mil	--	--	0.9	1.0	45	46	62	68	6.0
Unit Costs[6]										
Capital	$/gpd	--	--	0.3	0.3	6.6	5.8	9.5	8.7	--
Total PV	$/gpd	--	--	0.4	0.4	9.9	9.0	13.7	13.4	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Design flow shown for year round is the wet season average influent flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Alum addition upstream of primary sedimentation tanks for phosphorus removal.

The Benicia WWTP is considered a potential candidate for sidestream treatment to reduce nitrogen loads. The recommended sidestream treatment strategy is deammonification for reducing ammonia/nitrogen loads, with metal salts/solids separation facilities for TP load reduction.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

2. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Construct new aeration basins (1.07 MG total volume) in an MLE configuration,
    b. Retrofit the existing basins into an MLE configuration,
    c. Construct 1 new 75-foot diameter secondary clarifier
    d. Construct caustic soda storage and metering facilities,
    e. Construct alum storage and metering facilities,
    f. Demolish the 3, existing RBC trains.
3. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Construct new aeration basins (1.78 MG total volume) in 4-stage Bardenpho configuration,
    b. Retrofit the existing basins as 4-stage Bardenpho,
    c. Construct 1 new 90-foot diameter secondary clarifier,
    d. Construct methanol storage and metering facilities,
    e. Construct caustic soda storage and metering facilities,
    f. Construct alum storage and metering facilities,
    g. Demolish the 3, existing RBC trains, and
    h. Construct tertiary filters and abandon RBC secondary clarifiers

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $0.9 Mil for dry season optimization up to $68 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The City of Benicia's Wastewater Treatment Plant (WWTP) serves a population of about 28,000, which includes the City of Benicia. It is located at 614 East 5th St, Benicia, CA.
The plant has an average dry weather flow (ADWF) permitted capacity of 4.5 million gallons per day (mgd) and a permitted one-hour peak wet weather flow of 18 mgd.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The WWTP currently discharges treated effluent to the Carquinez Strait (latitude of 38.04º N and longitude of -122.15º W) under National Pollutant Discharge Elimination System (NPDES) Permit Order No. R2-2014-0023, NPDES No. CA0038091. Table 2-1 provides a summary of the dry weather permit limitations that are specific to the Benicia WWTP and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2014-0023; CA0038091)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak[1]
Flow	mgd	4.5	--	--	--	18
BOD	mg/L	--	30	45	--	-
TSS	mg/L	--	30	45	--	-
Total Ammonia, as N	mg/L	--	35	--	67	-

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. Permitted one-hour peak wet weather capacity.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the WWTP. Both liquids processes and solids processes are shown. The WWTP consists of screening and grit removal, primary sedimentation, followed by a conventional activated sludge and rotating biological contactors (RBC) for secondary treatment. Secondary effluent is disinfected with sodium hypochlorite and then dechlorinated prior to discharge. The WWTP has equalization basins (approximately 1 MG) for peak wet weather flow management. Solids treatment consists of waste activated sludge (WAS) thickening with a dissolved air flotation thickener (DAFT), anaerobic digestion of primary sludge and WAS and mechanical dewatering with a belt filter press.

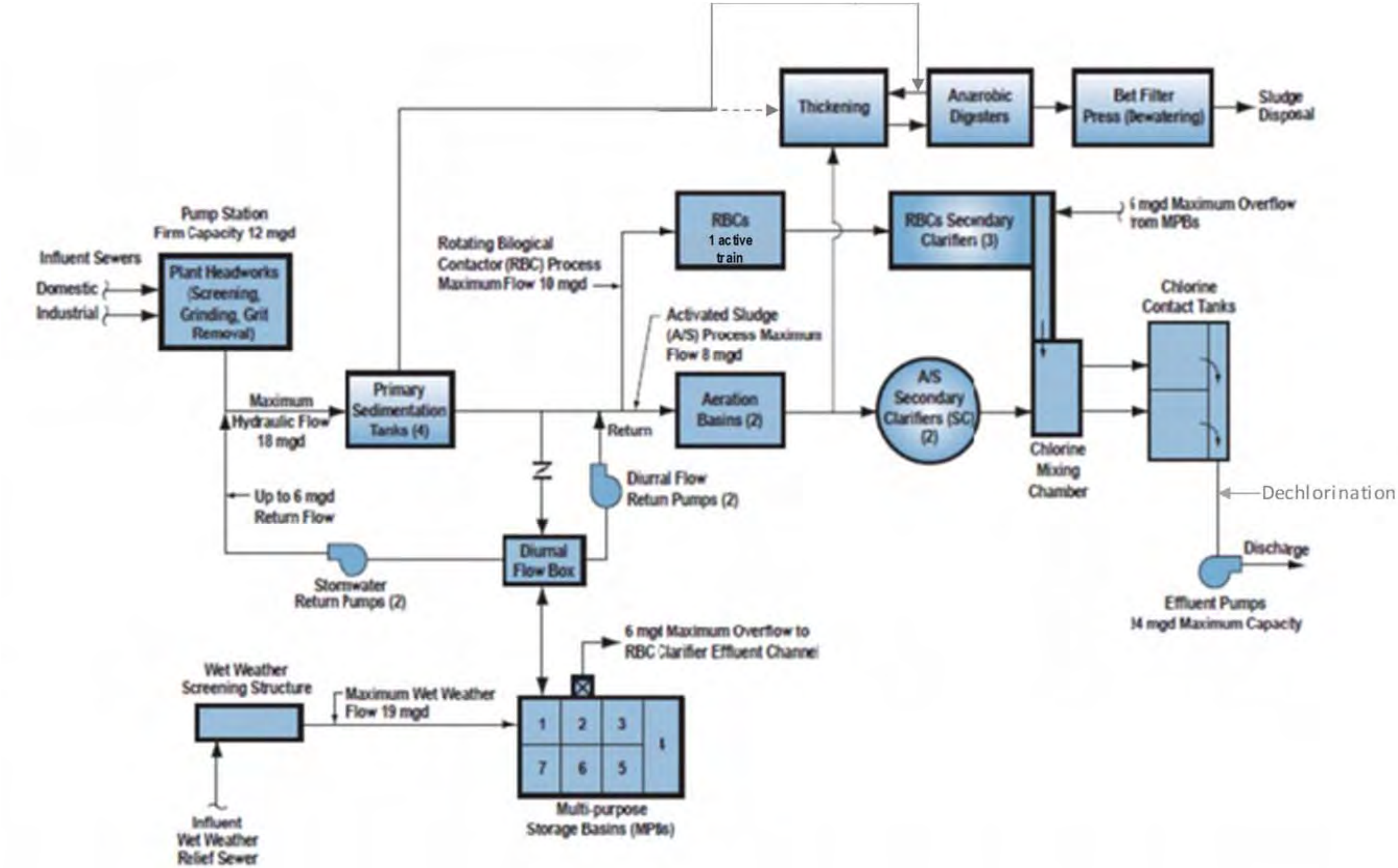

Figure 2-1. Process Flow Diagram for the Benicia WWTP

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Benicia WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.1	2.2	2.31	2.80
BOD	lb/d	5,200	5,400	5,900	6,300
TSS	lb/d	6,600	7,000	7,700	8,700
Ammonia	lb N/d	770	780	850	880
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	940	980	1,070	1,140
Total Phosphorus (TP)[4]	lb P/d	97	100	110	120
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	300	290	310	270
TSS	mg/L	390	380	400	370
Ammonia	mg N/L	45	43	44	38
TKN[4]	mg N/L	55	54	56	49
TP[4]	mg P/L	5.6	5.5	5.7	5.0
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Due to a lack of TKN and TP data, BOD peaking factors were used to develop loads for the various averaging periods.

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the Benicia WWTP:

- In 2017, the City prepared the City of Benicia Water Reuse Project Feasibility Report (Brown and Caldwell, 2017). The recycled water project would produce and deliver up to 2.0 mgd of recycled water to a local refinery. If the project is implemented, ammonia and phosphate removal would be necessary for use at the Refinery. The refinery demand is a year-round demand and if implemented would significantly reduce effluent discharged through the City's outfall.

2.5 Pilot Testing

Testing was performed at the WWTP to see if nitrification could be achieved in the RBC. A sidestream of primary effluent was diverted to the RBC. The testing was shut down due to odor issues, a lack of control with the flow split and a lack of process control.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Benicia WWTP are presented in Table 3-1. The projected flow and load for the WWTP in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by the Benicia WWTP, it was determined that WWTP may be a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the permitted capacity. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.1	2.2	2.3	2.8
BOD	lb/d	5,900	6,200	6,800	7,200
TSS	lb/d	7,600	8,100	8,900	10,000
Ammonia	lb N/d	880	900	980	1,020
TKN[4]	lb N/d	1,080	1,130	1,230	1,310
TP[4]	lb P/d	110	120	130	130
Alkalinity	lb/d as $CaCO_3$	No data	No data	No data	No data
BOD	mg/L	340	340	350	310
TSS	mg/L	440	440	460	430
Ammonia	mg N/L	51	49	51	44
TKN[4]	mg N/L	63	62	64	56
TP[4]	mg P/L	6.5	6.4	6.6	5.8
Alkalinity	mg/L as $CaCO_3$	No data	No data	No data	No data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Due to a lack of TKN and TP data, BOD peaking factors were used to develop loads for the various averaging periods

Table 3-2. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Design Capacity (AA)
Sidestream Flow	mgd	0.012	0.021
Ammonia	lb N/d	70	120
TKN	lb N/d	70	110
TN[1]	lb N/d	70	110
TP	lb P/d	20	34
Ortho P	lb P/d	13	23
Alkalinity	lb CaCO3/d	220	380
Ammonia	mg N/L	680	680
TKN	mg N/L	660	660
TN[1]	mg N/L	660	660
TP	mg P/L	200	200
Ortho P	mg P/L	130	130
Alkalinity	mg CaCO3/L	2,200	2,200

1. It was assumed that TN = TKN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3,4]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	4.5	4.8	5.0	6.1
BOD	lb/d	11,300	11,800	12,900	13,700
TSS	lb/d	14,500	15,300	16,800	19,000
Ammonia	lb N/d	1,680	1,710	1,860	1,930
TKN[5]	lb N/d	2,050	2,140	2,340	2,480
TP[5]	lb P/d	210	220	240	260
Alkalinity	lb/d as $CaCO_3$				
BOD	mg/L	300	290	310	270
TSS	mg/L	390	380	400	370
Ammonia	mg N/L	45	43	44	38
TKN[5]	mg N/L	55	54	56	49
TP[5]	mg P/L	5.6	5.5	5.7	5.0
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Permitted average dry weather flow. Other flows and loads based on current peaking factors unless otherwise noted.
5. BOD peaking factors were used to project loads for the different averaging periods due to the lack of TKN and TP data.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical

Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Four optimization strategies were identified during the WWTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The results of the screening are described below.

- **Optimization Strategy 1:** Ferric chloride or alum addition upstream of the primary sedimentation tanks to precipitate phosphorus.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal
  - ***Result from analysis:*** Alum addition is preferred to ferric chloride addition because if a recycled water project is implemented, alum would not further increase effluent chloride concentrations.
  - ***Recommendation:*** Carry forward

- **Optimization Strategy 2:** Operate in split treatment mode with RBCs.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase ammonia removal
  - ***Result from analysis:*** Split treatment with the RBCs would include the following improvements at the WWTP: (a) construction of a flow split structure and/or yard piping modifications to route a portion and/or all flows to the RBCs, (b) rehabilitation of the two decommissioned RBC trains, including installation of new mechanical equipment, and (c) odor control improvements to address community impacts. The upgrades associated with this strategy were considered to be capital improvements and therefore this strategy was not carried forward as an optimization strategy.
  - ***Recommendation:*** Do Not Carry Forward

- **Optimization Strategy 3:** Raise SRT, add anoxic zones and IMLR in the existing aeration. basins
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase ammonia and N removal
  - ***Result from analysis:*** To achieve nitrification and TN removal in the existing aeration basins the following improvements would be required: (a) installation of new diffuser grids, new blowers, IMLR pumps, anoxic mixers, and baffle walls, (b) aeration piping and valve modifications, and (c) electrical and instrumentation improvements. These improvements would need to be sequenced in a way that enabled treatment in one aeration basin during construction. With these improvements, ammonia and TN removal would be feasible during dry weather conditions; additional tankage would be required to provide ammonia and TN removal of wet weather flows. Due to the extensive improvements associated with this strategy as well as the construction complexity, this strategy is not considered to be an optimization strategy.
  - ***Recommendation:*** Do Not Carry Forward

- **Optimization Strategy 4:** Convert gravity thickener or RBCs to treat sidestream flows.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase ammonia and N removal
  - ***Result from analysis:*** Conversion of the gravity thickener or RBCs would require the following improvements: (a) yard piping modifications to reroute flows to the gravity thickener and/or RBCs, (b) upgrades/improvements to the RBCs to provide reliable nutrient removal of sidestream flows, and (c) demolition of existing mechanical equipment in the gravity thickener and installation of aeration equipment (diffusers and aeration blowers) in the gravity thickener. The scope of this project was considered to be a capital improvement project due to the level of upgrades needed to provide nutrient removal of sidestream flows.
  - ***Recommendation:*** Do Not Carry Forward

Strategy 1 was identified as the best optimization strategy because it was the only strategy that did not require significant upgrades/capital improvements. No feasible alternatives were identified for nitrification or nitrogen removal, because the required improvements are major capital improvements.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

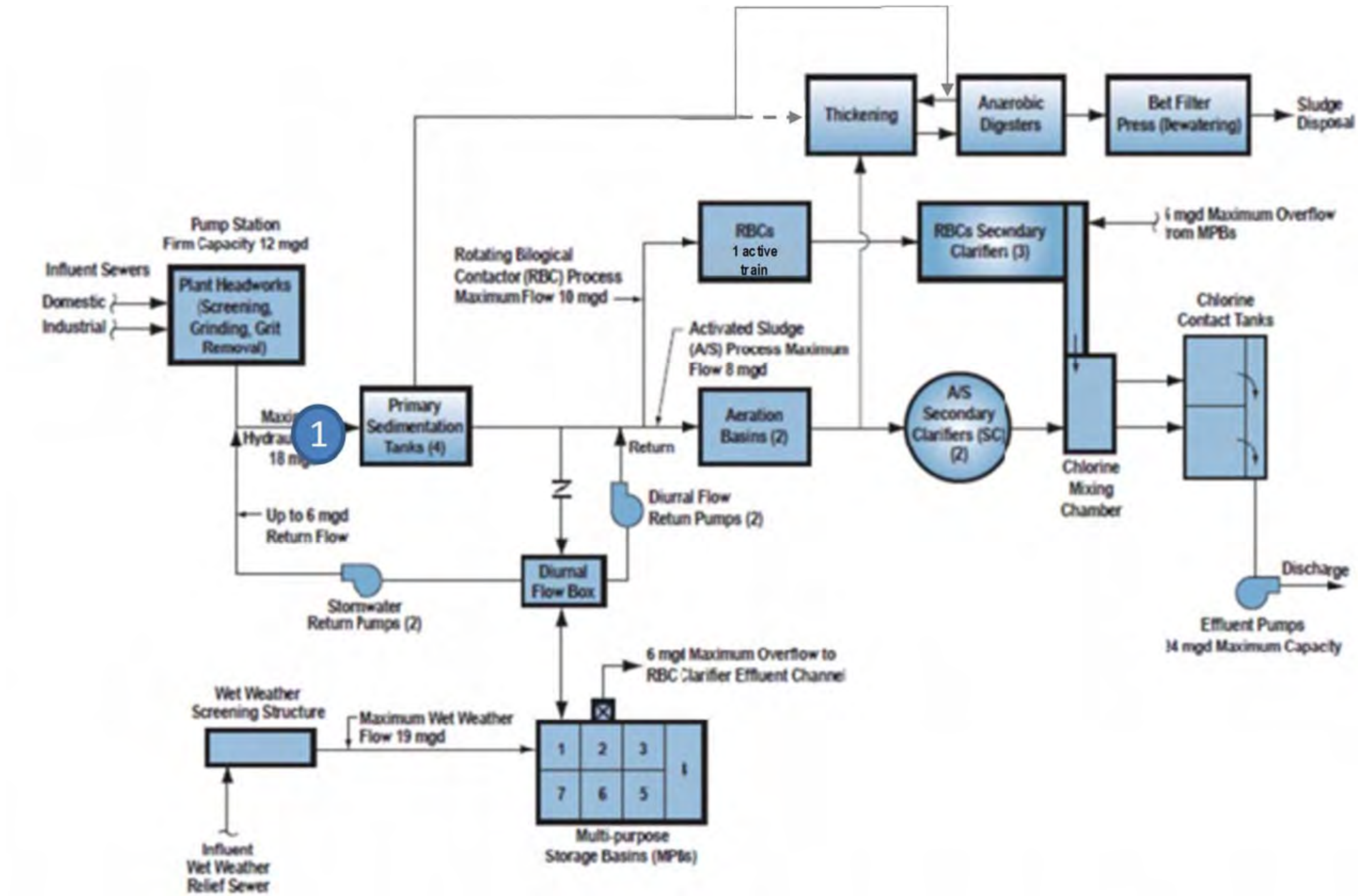

Figure 4-1. Optimization Concepts Considered for the Benicia WWTP

(1) construct alum storage and metering facilities for P removal.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
• Construct alum storage and metering facilities near the flow equalization basins	• Dose alum to the primary clarifier influent

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The optimization at the WWTP would provide TP removal in the dry and wet seasons. Ammonia and TN removal would not be provided with the optimization strategy. Therefore, the ammonia and TN loads would increase from current day due to increased loading into the WWTP.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	440	440	530	530	63	63
Discharge with Opt. Strategy[1]	lb N or P/d	440	440	530	530	17	16
Load Reduction[2,3]	lb N or P/d	0	0	0	0	46	47
Load Reduction[2,3]	%	0%	0%	0%	0%	73%	74%
Annual Load Reduction	lb N or P/yr	0	0	0	0	16,800	17,200

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Optimization only addresses TP loads. As a result, ammonia and TN loads are not reduced and are shown as zero.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	2.1	2.3
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.6	0.7
Annual O&M	$ Mil/yr	0.03	0.03
Present Value O&M[3]	$ Mil	0.3	0.3
Present Value Total[3]	$ Mil	0.9	1.0
Unit Capital Cost[8]	$/gpd	0.3	0.3
Unit Total PV Cost[8]	$/gpd	0.4	0.4
TN Removal			
Capital[2,4]	$ Mil	0	0
Annual O&M[4]	$ Mil/yr	0	0
O&M PV[3,4]	$ Mil	0	0
Total PV[3,4]	$ Mil	0	0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0.6	0.7
Annual O&M[5]	$ Mil/yr	0.03	0.03
O&M PV[3,5]	$ Mil	0.3	0.3
Total PV[3,5]	$ Mil	0.9	1.0
TP Removed (Ave.)[6]	lb P/d	46	47
Annual TP Removed (Ave.)[7]	lb P/yr	16,800	17,200
TP Cost[5,9]	$/lb P	5.2	5.7

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since the recommended optimization strategy does not address ammonia or total nitrogen removal.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• Phosphorus reliably removed	• Dependency on chemicals • Increased sludge production

5 Sidestream Treatment

As previously described, the Benicia WWTP was identified as a potential candidate for sidestream treatment. A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia/TN load reduction and metal salts/solids separation facilities for TP load reduction.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature (common for WWTPs with mechanical dewatering). It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification), such as requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requiring 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for the WWTP.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks). In the case of WWTP, ferric chloride addition ahead of the dewatering is recommended where the precipitated P will be captured with the cake.

Another option to consider for eliminating the phosphorus recycled stream load is recovery via struvite precipitation. This process produces a useful byproduct (struvite crystals) that can be sold economically. Chemical addition is typically simpler and easier for plants to implement. Plants are encouraged to evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant as an alternative to chemical phosphorus recycle load control.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed Facility
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	650	790	94
Discharge with Sidestream Treatment[2]	lb/d	570	720	78
Load Reduction[3]	lb/d	80	70	16
Load Reduction	%	12%	9%	17%
Annual Load Reduction[3]	lb/yr	28,000	24,900	5,800

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	4.0	0.1
Annual O&M	$ Mil/yr	0.1	0.01
Total Present Value[2]	$ Mil	5.6	0.4
NH4-N Load Reduction[3,5]	lb N/yr	28,000	--
TN Load Reduction[3,5]	lb N/yr	24,900	--
TP Load Reduction[4,5]	lb P/yr	--	5,800
NH4-N Cost [3,5,6]	$/lb N	6.7	--
TN Cost [3,5,6]	$/lb N	7.5	--
TP Cost [4,5,6]	$/lb P	--	2.0

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Benicia WWTP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The City should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 assumes that new aeration basins are constructed and the existing RBC trains would be demolished. The sizing of the secondary treatment facilities assumes that the removal across the primary clarifiers is consistent with current day. The new aeration basins will need to be larger than existing trains to get the necessary volume and to locate them adjacent to the existing aeration basins. One new, 75-ft diameter secondary clarifier is needed. The WWTP currently operates in a contact stabilization mode during peak wet weather events. The secondary clarifier sizing assumes that in the future, contact stabilization would remain an option for treatment of peak wet weather flows. New blowers would be needed to provide adequate aeration capacity. It is assumed that the new blowers would replace existing blowers in the existing blower building. The plant does not nitrify now so provisions to add caustic soda for alkalinity addition were assumed.

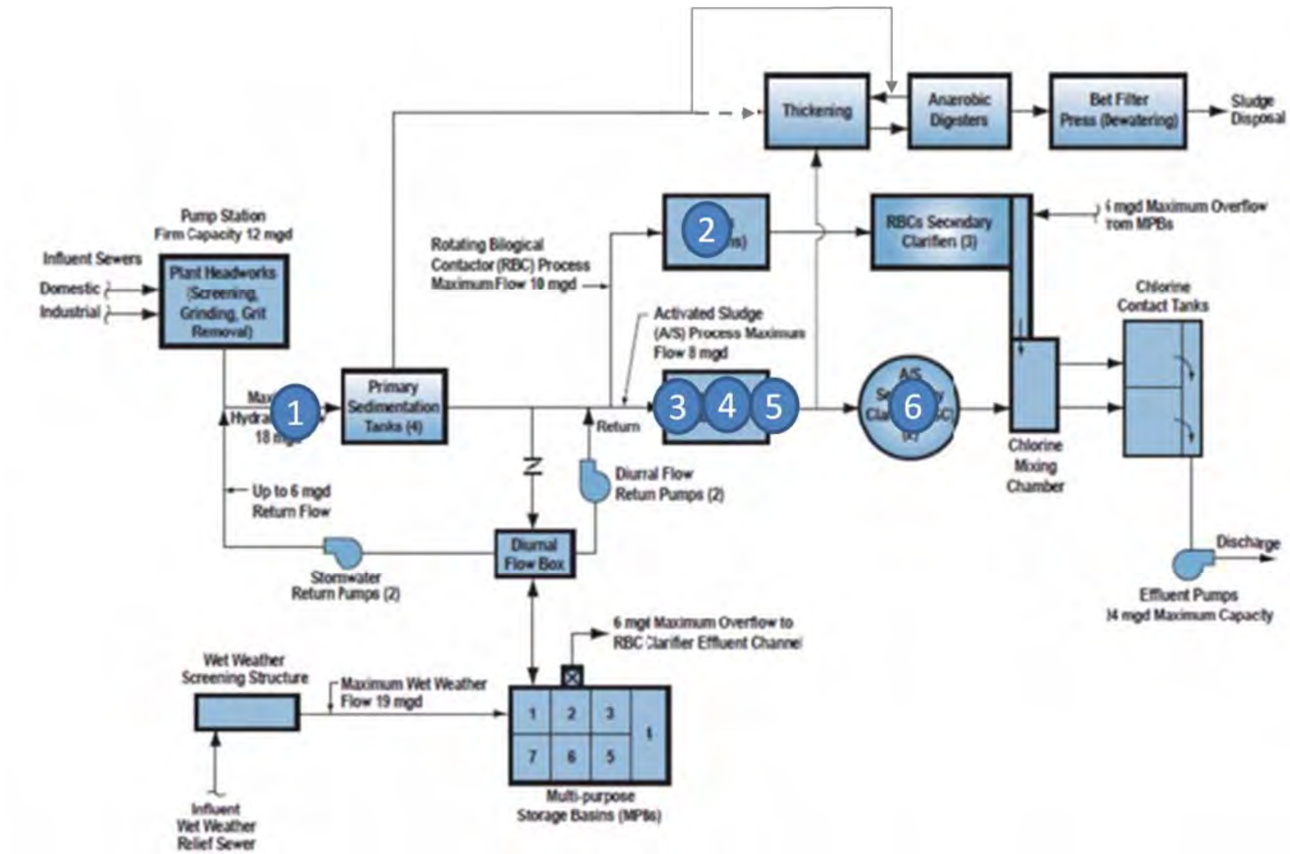

Figure 6-1. Level 2 Upgrade Concept for the Benicia WWTP

(1) construct alum storage and dosing facility, (2) Demolition of existing RBC trains (3) construction of 2, new aeration basins (1.07 MG total volume) in MLE configuration, (4) retrofit existing aeration basins to a MLE configuration (5) construct caustic soda storage and metering facilities, and (6) construct 1, new 75-ft diameter secondary clarifier

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2. Level 3 would require construction of two new aeration basins (total volume of 1.78 MGD) in a 4-stage Bardenpho configuration. The existing aeration basins would be retrofitted into a 4-stage Bardenpho configuration. One new, 90-ft diameter secondary clarifier is needed. The secondary clarifier sizing assumes that in the future, contact stabilization would remain an option for treatment of peak wet weather flows. The storage and addition of methanol would be needed to meet the Level 3 TN limits. Tertiary filtration with a filter feed pump station would also be constructed. Alum addition for phosphorus removal would be needed upstream of the primary clarifiers and the tertiary filters.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Construct alum storage and metering facility	Same as Level 2
Secondary	• Demolish existing RBC trains • Add 2 aeration basins (1.07 MG) as MLE • Retrofit existing aeration basins to MLE • New aeration blowers • Construct caustic soda addition facilities • Construct 1 new 75-ft diameter secondary clarifier • Maintain ability to operate in contact stabilization mode for peak wet weather flows •	• Demolish existing RBC trains • Add 2 aeration basins (1.78 MG) as 4-stage Bardenpho • Retrofit existing aeration basins to 4-stage Bardenpho • New aeration blowers • Construct caustic soda addition facilities • Construct 1 new 90-ft diameter secondary clarifier • Methanol addition facility • Maintain ability to operate in contact stabilization mode for peak wet weather flows
Tertiary	• None	• Construct new tertiary filters with filter feed pump station

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

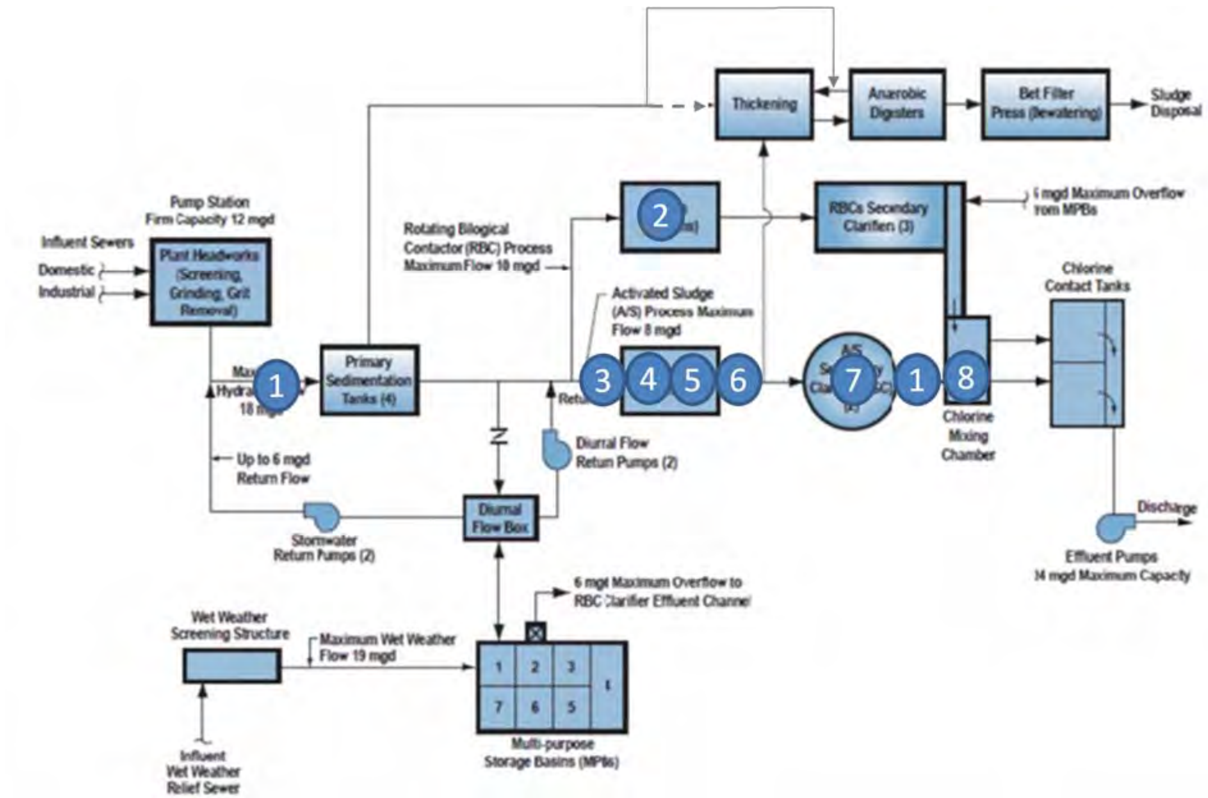

Figure 6-2. Level 3 Upgrade Concept for the Benicia WWTP

(1) add alum storage and metering facilities for P removal (2) Demolition of existing RBC trains (3) construction of 2, new aeration basins (1.78 MG total volume) in 4-stage Bardenpho configuration, (4) retrofit existing aeration basins to a 4-stage Bardenpho configuration (5) construct caustic soda storage and metering facilities, (6) construct methanol storage and metering facilities, (7) construct 1, new 90-ft diameter secondary clarifier and (8) construct tertiary filters.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) construct alum storage and dosing facility, (2) Demolition of existing RBC trains (3) construction of 2, new aeration basins (1.07 MG total volume) in MLE configuration, (4) retrofit existing aeration basins to a MLE configuration (5) construct caustic soda storage and metering facilities, and (6) construct 1, new 75-ft diameter secondary clarifier.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) add alum storage and metering facilities for P removal (2) Demolition of existing RBC trains (3) construction of 2 new aeration basins (1.78 MG total volume) in 4-stage Bardenpho configuration, (4) retrofit existing aeration basins to a 4-stage Bardenpho configuration (5) construct caustic soda storage and metering facilities, (6) construct methanol storage and metering facilities, (7) construct 1, new 90-ft diameter secondary clarifier and (8) tertiary filters for dry weather and (9) additional tertiary filters for wet weather.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	4.5	5.1	4.5	5.1
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	30	30	43	45
Annual O&M	$Mil/yr	0.68	0.72	0.86	1.1
O&M PV[3]	$ Mil	15	16	19	24
Total PV[3]	$ Mil	45	46	62	69
Unit Capital Cost	$/gpd	6.6	5.8	9.5	8.7
Unit Total PV	$/gpd	9.9	9.0	13.7	13.4
TN Removal					
Capital[2,4]	$ Mil	29	29	35	35
Annual O&M[4]	$ Mil/yr	0.63	0.67	0.77	0.91
O&M PV[3,4]	$ Mil	14	15	17	20
Total PV[3,4]	$ Mil	43	44	52	55
TN Removed (Ave.)[6]	lb N/d	330	360	460	620
Annual TN Removed (Ave.)[7]	lb N/yr	120,000	130,000	167,000	225,000
TN Cost[4,8]	$/lb N	12.0	11.3	10.3	8.1
TP Removal					
Capital[2,5]	$ Mil	0.6	0.7	8	9.8
Annual O&M[5]	$ Mil/yr	0.05	0.05	0.09	0.16
O&M PV[3,5]	$ Mil	1	1.1	2.1	3.6
Total PV[3,5]	$ Mil	1.7	1.8	10	13
TP Removed (Ave.)[6]	lb P/d	63	65	73	85
Annual TP Removed (Ave.)[7]	lb P/yr	22,900	23,600	26,500	31,000
TP Cost[5,8]	$/lb P	2.4	2.5	13	14

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing secondary process tankage • Robust technology to absorb variability in flows and loads • Ability to reliably remove ammonia, TN and TP • Reduction in secondary sludge production	• Increased operations costs associated with additional aeration demand • Higher operating cost associated with caustic soda and alum use
Level 3	Same as Level 2	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use • Safety from external carbon source (if methanol) • Additional unit process (tertiary filters) to operate

7 Nutrient Removal by Other Means

The City prepared the City of Benicia Water Reuse Project Feasibility Report in 2017 (Brown and Caldwell, 2017). The recycled water project would produce and deliver up to 2.0 mgd of recycled water to a local refinery. If the project is implemented, ammonia and phosphate removal would be necessary for use at the Refinery. The refinery demand is a year-round demand and if implemented would significantly reduce effluent discharged through the City's outfall.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most

stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

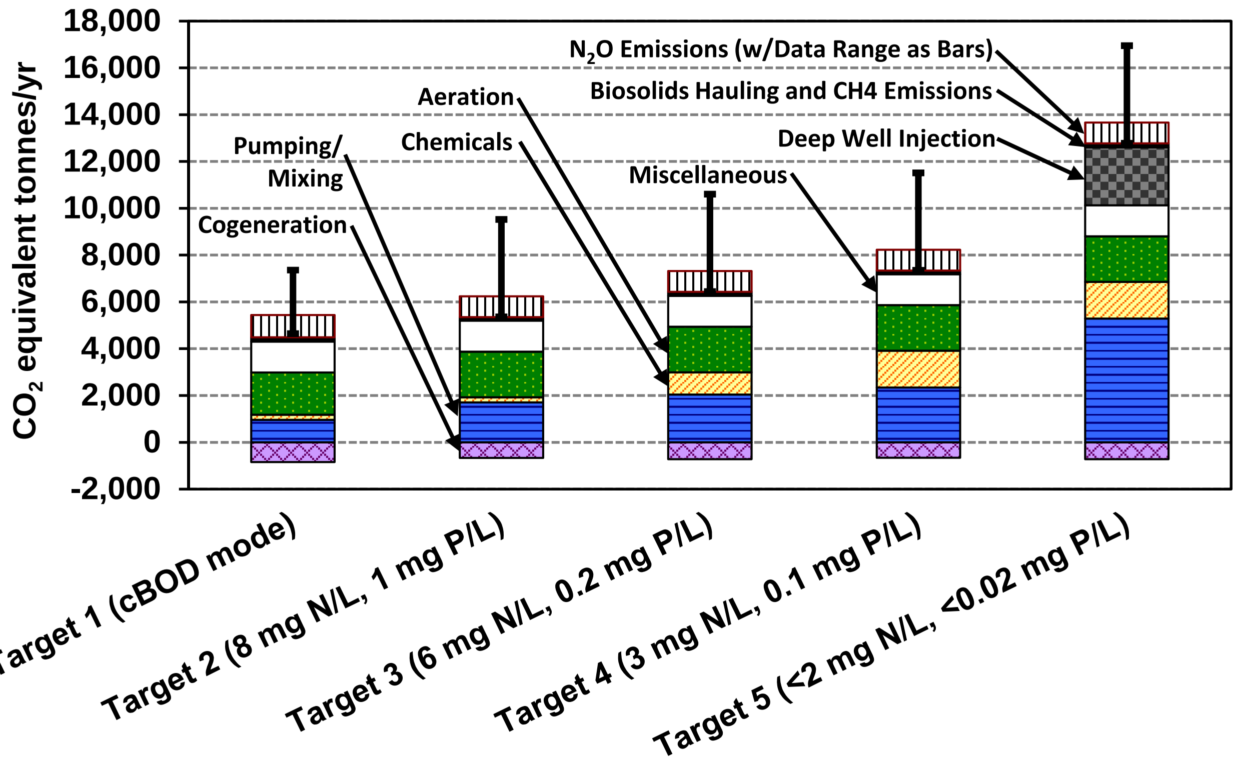

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	2	2	800	900	900	1,000	10
GHG Emissions Increase from Chemicals	MT CO_2/yr	25	27	100	100	300	300	3
GHG Emissions Increase Total	MT CO_2/yr	27	29	900	1,000	1,200	1,300	13
Unit GHG Emissions[2]	lb CO_2/MG	74	77	1,100	1,100	1,500	1,600	39
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	8	9	9	9	1.1
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	15	14	14	11	0.9
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	4	4	5	6	12	12	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Benicia WWTP. These are:

- Nitrite Shunt – WWTP aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Sidestream Nitrogen Removal Using Granular Sludge – Sidestream from dewatering would be directed to a sidestream anammox system that utilizes granular sludge. The application of granular sludge means process tankage requirements are reduced which reduced overall costs. One supplier, Paques, has large full-scale installations overseas of their ANAMMOX® process, however there are none on North America.
  - Advantages: Low footprint requirements, proven technology
  - Disadvantages: No installations in North America
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.3

City of Burlingame Wastewater Treatment Facility

Bay Area Clean Water Agencies
Nutrient Reduction Study

City of Burlingame Wastewater Treatment Facility

Burlingame, CA

March 28, 2018
Final Report

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Executive Summary

The City of Burlingame (City) owns and operates the Burlingame Wastewater Treatment Facility (Burlingame WTF) located in Burlingame, CA and discharges treated effluent along with the North Bayside System Unit (NBSU) to the Lower San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 5.5 million gallons per day (mgd) and a peak permitted wet weather flow of 16 mgd.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow	mgd	--	--	2.8	3.2	5.5	6.3	5.5	6.3	--
Flow to Bay[2]	mgd	3.0	3.0	3.0	3.0	4.5	4.5	4.5	4.5	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	590	590	410	410	80	70	80	70	640
TN	lb N/d	980	980	830	830	600	560	430	220	1,240
TP	lb P/d	180	180	20	20	40	40	30	10	240
Costs[4,5]										
Capital	$ Mil	--	--	1.6	1.6	75	76	91	92	8.2
O&M PV	$ Mil	--	--	0.9	0.9	29	32	37	44	8.0
Total PV	$ Mil	--	--	2.5	2.5	100	110	130	140	16.2
Unit Costs[6]										
Capital	$/gpd	--	--	0.6	0.5	13.6	12.0	16.6	14.5	--
Total PV	$/gpd	--	--	0.9	0.8	18.9	17.0	23.3	21.5	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Add ferric chloride upstream of primary clarifiers for year round phosphorus removal.
2. Increase activated sludge solids retention time (SRT) and install internal mixed liquor recycle for nitrogen removal (summer only).

The Burlingame WTF is considered a candidate for sidestream treatment for ammonia, TN and TP removal. The recommended sidestream treatment strategy is conventional nitrifying sidestream treatment technology for reducing ammonia/nitrogen loads and metal salts/solids separation facilities for TP load reduction.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. 3-mm primary effluent screening facility,
   b. Caustic soda addition facility,
   c. Convert existing secondary system to MBR, and
   d. Ferric chloride addition facility
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Expand MBR system and convert to 4-stage system, and
   c. Methanol addition facility

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $2.5 Mil for dry season optimization up to $140 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The City of Burlingame Wastewater Treatment Facility (Burlingame WTF) serves a population of about 37,000, which includes the City of Burlingame, a portion of the Town of Hillsborough, and the Burlingame Sewer Maintenance District. It is located at 1103 Airport Blvd, Burlingame, CA.
The plant has an average dry weather flow (ADWF) permitted capacity of 5.5 million gallons per day (mgd) and a peak permitted wet weather flow of 16 mgd.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The Burlingame WTF currently discharges treated effluent along with the North Bayside System Unit (NBSU) to the Lower San Francisco Bay. The NBSU is a joint powers authority comprised of the cities of Burlingame, Millbrae, South San Francisco and San Bruno and the San Francisco International Airport. The Burlingame WTF discharge is located at a latitude of 37º39’ 55” N and longitude of 122º21’ 41” W.

The Burlingame WTF holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2013-0015, NPDES Permit No. CA0037788). Table 2-1 provides a summary of the permit limitations that are specific to the Burlingame WTF and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2013-0015; CA0037788)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak
Flow	mgd	5.5	--	--	--	16
BOD	mg/L	--	30	45	--	--
TSS	mg/L	--	30	45	--	--
Total Ammonia, as N	mg/L	--	67	--	130	--

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Burlingame WTF. Both liquids processes and solids processes are shown. The Burlingame WTF consists of screening and grit removal, primary clarification, followed by an activated sludge process. Secondary effluent is disinfected by chlorine disinfection. Solids treatment consists of sludge thickening, anaerobic digestion and mechanical dewatering.

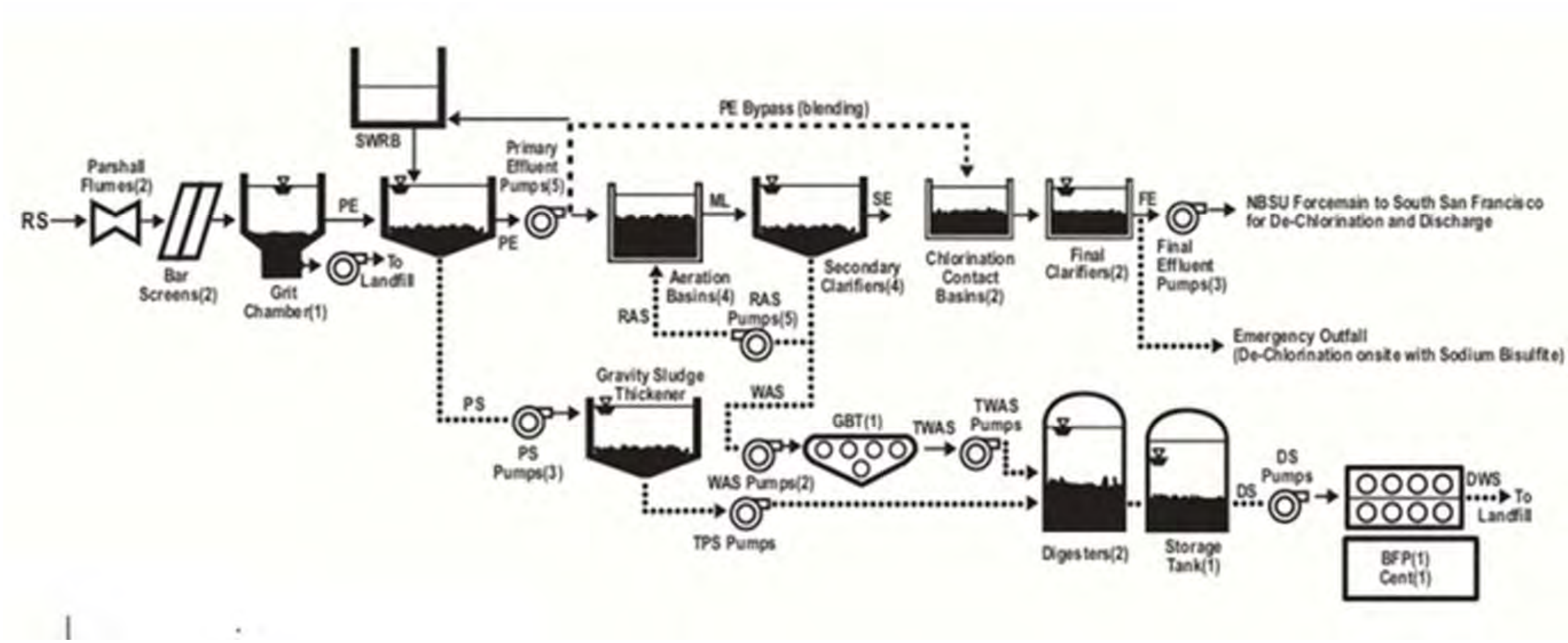

Figure 2-1. Process Flow Diagram for Burlingame WTF

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Burlingame WTF is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.8	3.0	3.0	4.3
BOD	lb/d	7,700	8,000	8,500	9,700
TSS	lb/d	6,800	7,200	7,500	8,700
Ammonia	lb N/d	960	900	1,030	1,010
Total Kjeldahl Nitrogen (TKN)	lb N/d	1,160	1,260	1,310	1,450
Total Phosphorus (TP)	lb P/d	350	350	420	650
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	330	320	340	270
TSS	mg/L	290	290	300	240
Ammonia	mg N/L	41	36	41	28
TKN	mg N/L	50	50	52	40
TP	mg P/L	15.2	13.9	16.8	18.1
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the Burlingame WTF:

- Anoxic swing zones were added to each of the 4 aeration basins in 2006.
- Carollo is currently working on a Master Plan that will address nutrients, reliability and recycled water. Work is expected to be complete in October 2015. Preliminary assessment shows that there should be no issue with TDS in recycled water

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the Burlingame WTF.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Burlingame WTF are presented in Table 3-1. The projected flow and load for the Burlingame WTF in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided, it was determined that the Burlingame WTF is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the permitted capacity. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.8	3.0	3.0	4.3
BOD	lb/d	8,800	9,200	9,700	11,100
TSS	lb/d	7,800	8,200	8,600	10,100
Ammonia	lb N/d	1,110	1,040	1,180	1,170
TKN	lb N/d	1,330	1,450	1,510	1,660
TP	lb P/d	410	400	490	750
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	380	370	390	310
TSS	mg/L	330	330	340	280
Ammonia	mg N/L	48	41	47	32
TKN	mg N/L	57	58	60	46
TP	mg P/L	17.5	15.9	19.3	20.9
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

Table 3-2. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Design Capacity (AA)
Sidestream Flow	mgd	0.10	0.19
Ammonia	lb N/d	180	350
TKN	lb N/d	270	540
TN[1]	lb N/d	270	540
TP	lb P/d	26	52
Ortho P	lb P/d	26	51
Alkalinity	lb CaCO3/d	700	1,400
Ammonia	mg N/L	220	220
TKN	mg N/L	340	340
TN[1]	mg N/L	340	340
TP	mg P/L	32	32
Ortho P	mg P/L	32	32
Alkalinity	mg CaCO3/L	900	900

1. It was assumed that TN = TKN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	5.5	5.9	6.0	8.5
BOD	lb/d	15,100	15,800	16,700	19,100
TSS	lb/d	13,400	14,100	14,700	17,200
Ammonia	lb N/d	1,900	1,780	2,030	2,000
TKN	lb N/d	2,280	2,490	2,580	2,850
TP	lb P/d	700	680	830	1,290
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	330	320	340	270
TSS	mg/L	290	290	300	240
Ammonia	mg N/L	41	36	41	28
TKN	mg N/L	50	50	52	40
TP	mg P/L	15.2	13.9	16.8	18.1
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Permitted average dry weather flow. Other flows and loads are based on current flow and loading characteristics.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Five optimization strategies were identified during the Burlingame WTF site visit (Appendix B). These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The results of the screening are described below.

- **Optimization Strategy 1:** Add ferric chloride or alum addition upstream of the final clarifiers to precipitate phosphorous.
    - ***Is it feasible?*** Yes.
    - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
    - ***Result from analysis:*** Ferric chloride addition will increase P removal.
    - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Operate existing aeration basins at a higher SRT to promote nitrification and install a mixed liquor return pump to return nitrified mixed liquor to the anoxic zone.
    - ***Is it feasible?*** Yes.
    - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
    - ***Result from analysis:*** Implementation of this technology would require installing new mixed liquor return pumping and piping. However, this strategy would only work in summer when flows are low.
    - ***Recommendation:*** Carry forward.

- **Optimization Strategy 3:** Route dewatering streams to the stormwater retention basin and meter back at night to reduce ammonia peaks.
    - ***Is it feasible?*** Yes.
    - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy only addresses ammonia, not total nitrogen.
    - ***Result from analysis:*** This strategy was not carried forward because there is minimal benefit to ammonia removal, and no benefit to nitrogen or phosphorus.
    - ***Recommendation:*** Do not carry forward.

Strategy 1 is the best apparent way to reduce effluent phosphorous load and Strategy 2 is the best apparent way to reduce nitrogen loading.

No feasible alternatives were identified for nitrification or nitrogen removal, because the required improvements are major capital improvements (new aeration system, alkalinity system and carbon feed).

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

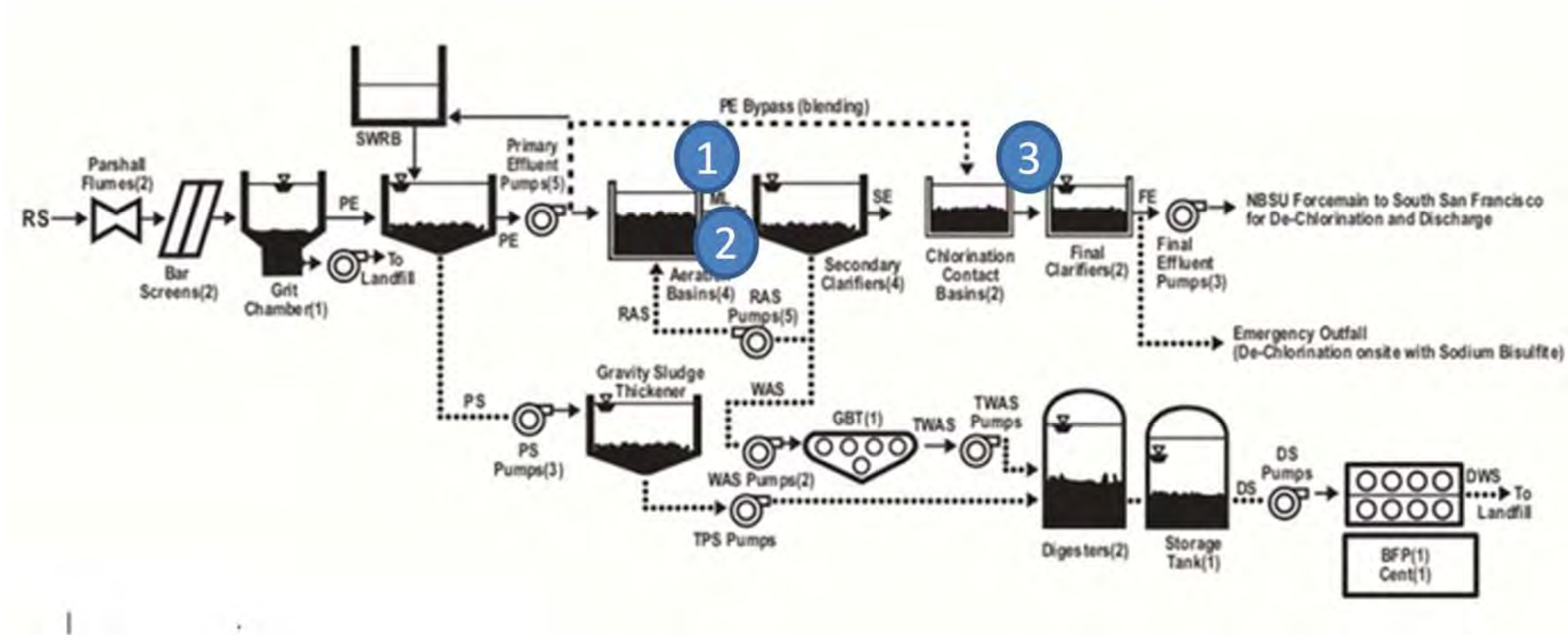

Figure 4-1. Optimization Concepts Considered for the Burlingame WTF

(1) caustic soda addition for alkalinity, (2) install IMLR and piping to operate in MLE mode (operates in dry season only), and (3) add ferric chloride upstream of final clarifiers for P removal.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
• Four mixed liquor return pumps • Mixed liquor return piping • Ferric chloride storage and pumping	• Chemical use for ferric chloride and caustic soda • Energy cost due to mixed liquor return pumping • Higher energy use in secondary process to support nitrification

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The Burlingame WTF plant shows improved ammonia and nitrogen removal during the dry season and TP removal in both the dry season and year round.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season[4]	NH4-N Year Round[4]	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	640	640	1,050	1,050	190	190
Discharge with Opt. Strategy[1]	lb N or P/d	410	410	830	830	20	20
Load Reduction[2,3]	lb N or P/d	230	230	230	230	170	170
Load Reduction[2,3]	%	36%	36%	22%	22%	87%	88%
Annual Load Reduction	lb N or P/yr	84,300	84,300	82,700	82,700	60,800	61,400

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. This table shows the annual discharge loadings for improvements sized for the dry season or sized for the full year. The improvement for NH4-N and TN is assumed to be sized for and operate in the dry season only for both cases.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

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Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	2.8	3.2
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	1.6	1.6
Annual O&M	$ Mil/yr	0.1	0.1
Present Value O&M[3]	$ Mil	0.9	0.9
Present Value Total[3]	$ Mil	2.5	2.5
Unit Capital Cost[8]	$/gpd	0.6	0.5
Unit Total PV Cost[8]	$/gpd	0.9	0.8
TN Removal			
Capital[2,4]	$ Mil	1.0	1.0
Annual O&M[4]	$ Mil/yr	0.01	0.01
O&M PV[3,4]	$ Mil	0.1	0.1
Total PV[3,4]	$ Mil	1.1	1.1
TN Removed (Ave.)[6]	lb N/d	230	230
Annual TN Removed (Ave.)[7]	lb N/yr	82,700	82,700
TN Cost[4,9]	$/lb N	1.3	1.3
TP Removal			
Capital[2,5]	$ Mil	0.6	0.9
Annual O&M[5]	$ Mil/yr	0.09	0.09
O&M PV[3,5]	$ Mil	0.8	0.8
Total PV[3,5]	$ Mil	1.4	1.7
TP Removed (Ave.)[6]	lb P/d	170	170
Annual TP Removed (Ave.)[7]	lb P/yr	60,800	61,400
TP Cost[5,9]	$/lb P	2.3	2.7

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• Total nitrogen removal during summer months • Phosphorous reliably removed under peak flow scenarios • Reduction in secondary sludge production	• Dependency on chemicals • Higher energy costs

5 Sidestream Treatment

As previously described, the Burlingame WTF was identified as a potential candidate for sidestream treatment. A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia/total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction.

Conventional nitrification is recommended at Burlingame WTF as a robust technology is required to address their infrequent dewatering operation (4 to 5 days per week). Plants with similar dewatering operations frequency either produce a nutrient slug of sidestream nitrogen load or equalize the sidestream load and bleed it back over time. The former requires a robust technology such as conventional nitrification that can absorb slug loading. The latter requires a technology that can handle a wide range of temperatures (about 10 to 30 degrees C) as the stored sidestream cools to ambient air temperatures. A conventional nitrification sidestream treatment technology can handle either situation and is thus recommended for Burlingame WTF.

Conventional nitrifying sidestream treatment is an established technology where ammonia is oxidized to nitrate. The nitrate formed in the sidestream is expected to be removed in the main stream process via biological denitrification at either the headworks and/or primary clarifiers. Nitrate removal in the main stream process is easier than sidestream denitrification where organic carbon is not readily available.

The removal of TP from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks). In the case of Burlingame WTF, ferric chloride addition ahead of the dewatering is recommended where the precipitated P will be captured with the cake.

Another option to consider for eliminating the phosphorus recycled stream load is recovery via struvite precipitation. This process produces a useful byproduct (struvite crystals) that can be sold economically. The finances are typically more attractive for larger plants (>40 mgd). It is recommended that the Burlingame WTF evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant if phosphorus load reduction is required in the future.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements[1]
Feed Pumping (if necessary)	Metal Salt Chemical Feed[1]
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	
Alkalinity Supply/Storage	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	880	1,460	270
Discharge with Sidestream Treatment[2]	lb/d	640	1,250	240
Load Reduction[3]	lb/d	240	210	30
Load Reduction	%	27%	15%	11%
Annual Load Reduction[3]	lb/yr	86,900	77,200	10,400

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	8.1	0.1
Annual O&M	$ Mil/yr	0.3	0.02
Total Present Value[2]	$ Mil	15.6	0.6
NH4-N Load Reduction[3,5]	lb N/yr	86,900	--
TN Load Reduction[3,5]	lb N/yr	77,200	--
TP Load Reduction[4,5]	lb P/yr	--	10,440
NH4-N Cost [3,5,6]	$/lb N	6.0	--
TN Cost [3,5,6]	$/lb N	6.7	--
TP Cost [4,5,6]	$/lb P	--	2.0

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Burlingame WTF to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The Burlingame WTF should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 upgrades could be met by converting 3 of the aeration basins and 4 of the secondary clarifiers to a MBR process. In addition, new stand-alone membrane tanks would be constructed. Chemical addition using either ferric chloride or alum would be performed in the membrane tanks to provide for P removal. A new screening facility would be constructed to screen primary effluent prior to secondary treatment.

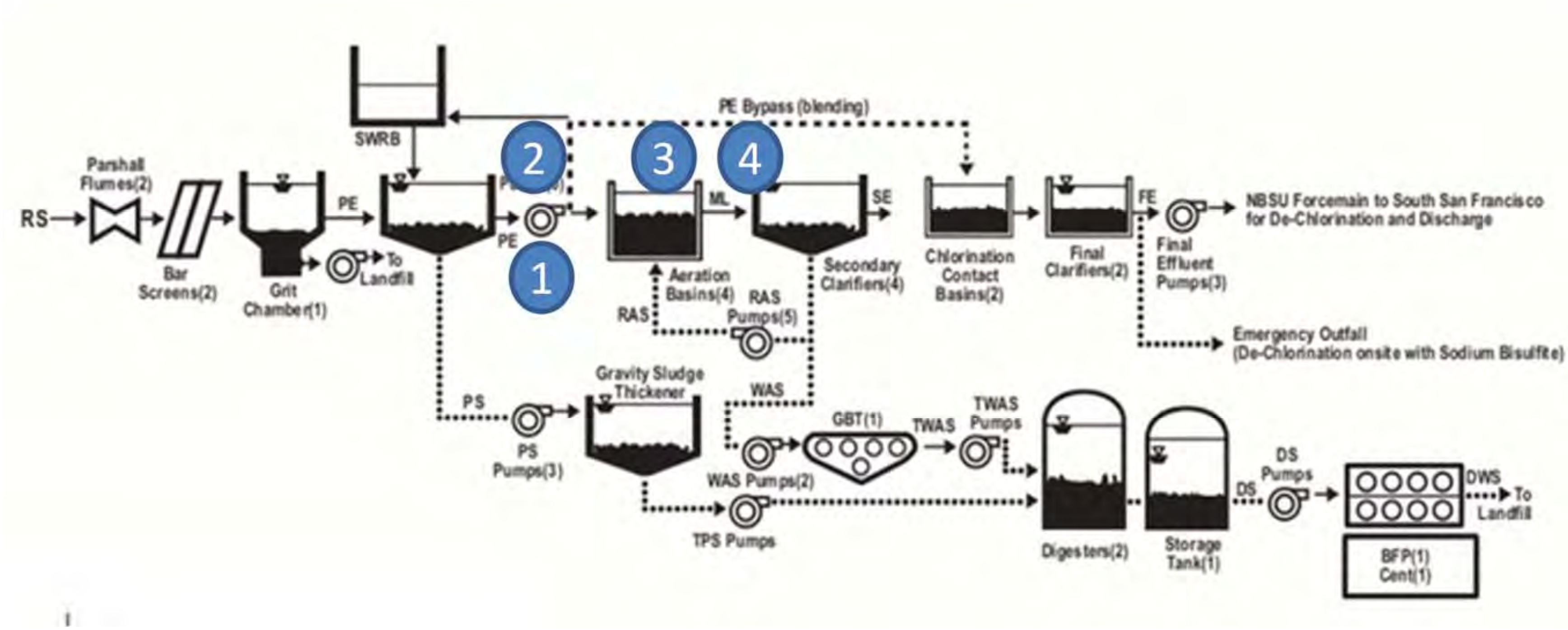

Figure 6-1. Level 2 Upgrade Concept for the Burlingame WTF

(1) caustic soda addition for alkalinity, (2) install 3-mm screen, (3) add ferric chloride to MBR for P removal and (4) convert to MLE MBR.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Level 3 would require an expansion of the MBR process and a conversion to a 4-stage Bardenpho configuration. Additional aeration tanks would be constructed where the existing administration building is located. Therefore, the administration building would need to be relocated. The chemical dose for P removal would also be increased to achieve the lower concentration and methanol would be added to the MBR process to achieve the Level 3 nitrogen removal.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Install 3-mm primary effluent screening	Same as Level 2
Biological/ Tertiary	• Caustic soda addition system • Ferric chloride addition system • Convert aeration tanks and secondary clarifiers to MLE MBR • Construct new membrane tanks for MBR	Same as Level 2, plus: • Convert to 4-stage Bardenpho MBR and expand secondary system • Relocate administration building • Methanol addition facility

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

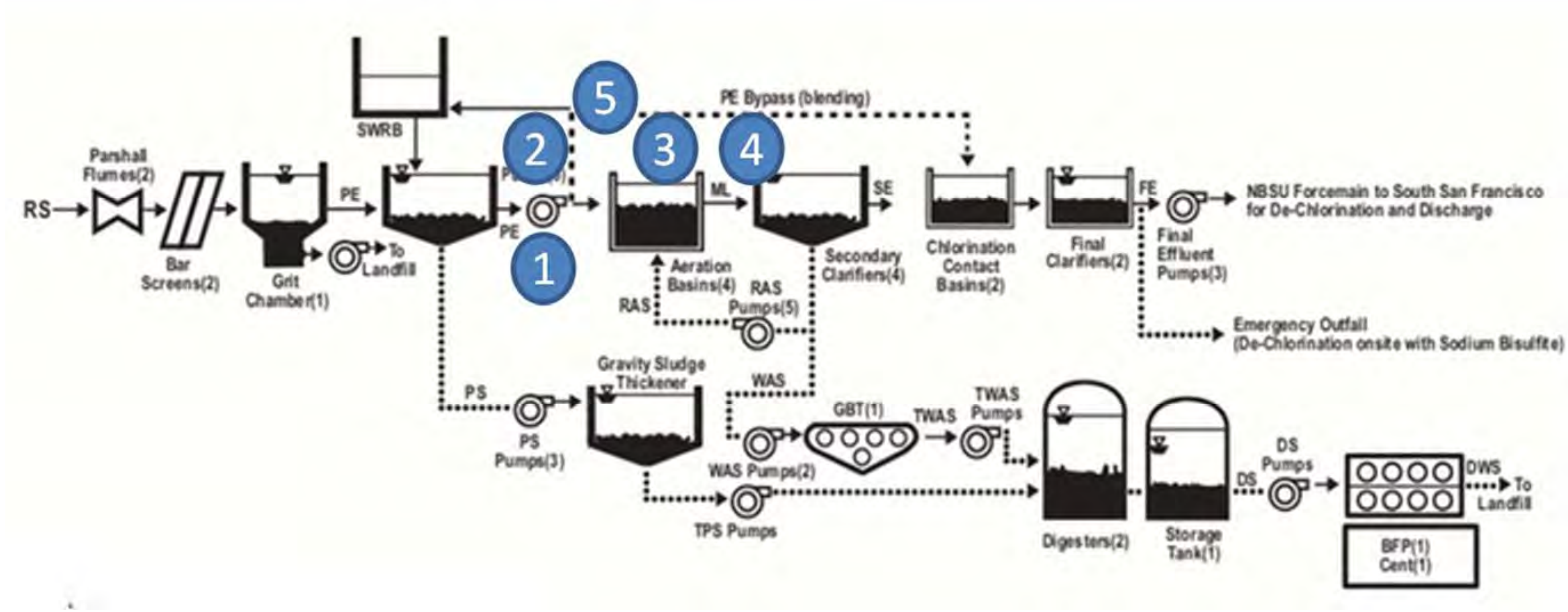

Figure 6-2. Level 3 Upgrade Concept for the Burlingame WTF

(1) caustic soda addition for alkalinity, (2) install 3-mm screen, (3) add ferric chloride to MBR for P removal, (4) convert to 4-stage MBR and (5) add methanol for N removal.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) convert existing tankage to MLE MBR, (2) install chemical storage facilities for ferric chloride and caustic soda, (3) construct new membranes for MBR, and (4) construct primary effluent screening facility.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) convert to 4-stage MBR, (2) install chemical storage facilities for ferric chloride, methanol and caustic soda, (3) construct new membranes for MBR, (4) construct primary effluent screening facility, and (5) new administration building.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	5.5	6.3	5.5	6.3
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	75	76	91	92
Annual O&M	$Mil/yr	1.3	1.4	1.6	2
O&M PV[3]	$ Mil	29	32	37	44
Total PV[3]	$ Mil	100	110	130	140
Unit Capital Cost	$/gpd	13.6	12.0	16.6	14.5
Unit Total PV	$/gpd	18.9	17.0	23.3	21.5
TN Removal					
Capital[2,4]	$ Mil	74	75	90	91
Annual O&M[4]	$ Mil/yr	1.2	1.3	1.5	1.7
O&M PV[3,4]	$ Mil	27	29	33	38
Total PV[3,4]	$ Mil	100	100	120	130
TN Removed (Ave.)[6]	lb N/d	860	890	1,020	1,230
Annual TN Removed (Ave.)[7]	lb N/yr	313,000	327,000	374,000	450,000
TN Cost[4,8]	$/lb N	10.7	10.6	11.0	9.6
TP Removal					
Capital[2,5]	$ Mil	0.8	0.9	60	60
Annual O&M[5]	$ Mil/yr	0.1	0.1	0.6	1.2
O&M PV[3,5]	$ Mil	2.7	2.9	13	27
Total PV[3,5]	$ Mil	3.4	3.7	73	87
TP Removed (Ave.)[6]	lb P/d	220	230	240	250
Annual TP Removed (Ave.)[7]	lb P/yr	82,000	82,900	86,600	92,500
TP Cost[5,8]	$/lb P	1.4	1.5	28	31

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing secondary process tankage • Robust technology to absorb variability in flows and loads • Ability to reliably remove ammonia, TN and TP • Reduction in secondary sludge production	• Increased operations costs associated with membrane operation • Additional unit processes to operate • High cost associated with caustic soda use • Additional screenings generation from screening facility
Level 3	Same as Level 2	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use • Safety from external carbon source (if methanol)

7 Nutrient Removal by Other Means

The Burlingame WTF does not currently produce recycled water. There are no current plans to produce recycled water.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

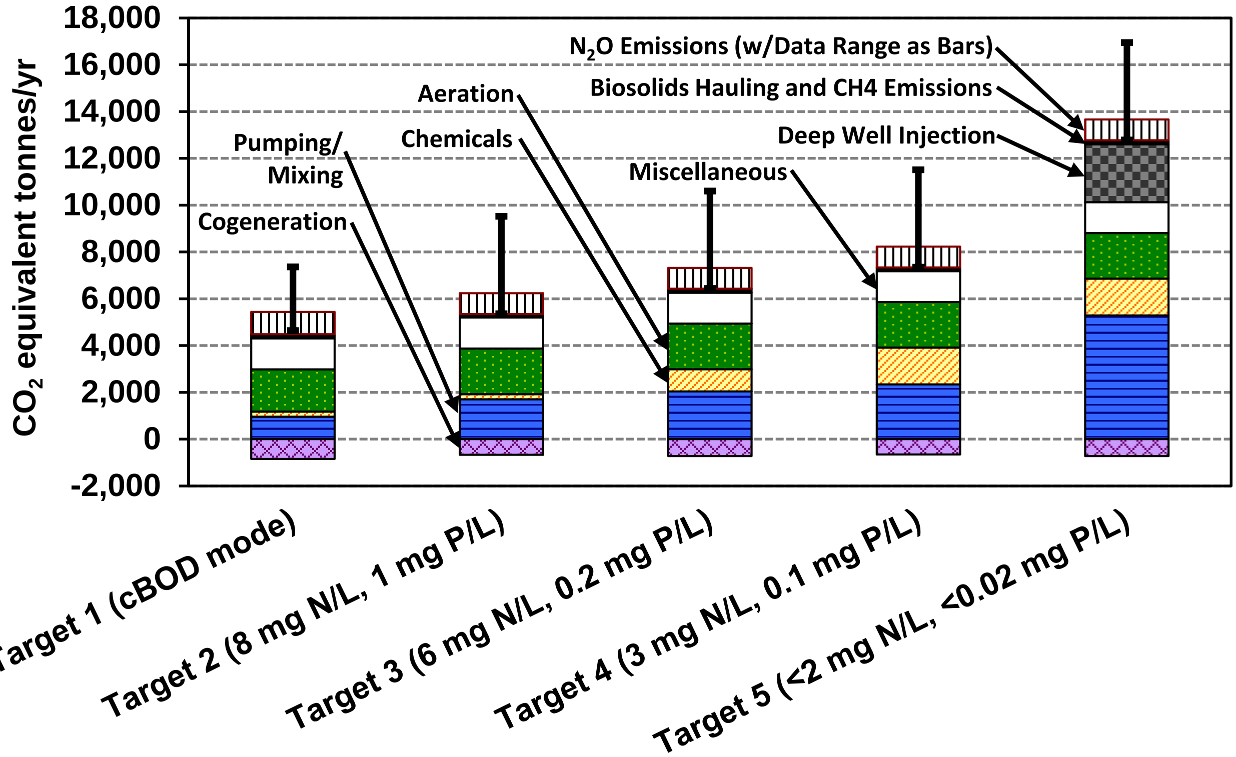

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line

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[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	160	80	960	1,030	1,060	1,130	32
GHG Emissions Increase from Chemicals	MT CO_2/yr	10	11	19	21	260	280	2
GHG Emissions Increase Total	MT CO_2/yr	170	90	980	1,050	1,320	1,410	34
Unit GHG Emissions[2]	lb CO_2/MG	330	170	990	1,060	1,330	1,420	67
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	3.3	1.6	6.6	7.0	7.0	7.4	0.9
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	4.1	1.9	6.7	6.9	7.5	6.7	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	0.5	0.5	0.6	0.7	14	13	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Burlingame WTF. These are:

- Nitrite Shunt – Burlingame WTF aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Ballasted Activated Sludge – Burlingame WTF secondary process would be converted to a ballasted activated sludge process to reduce process tankage requirements. The BioMag® process supplied by Evoqua utilizes magnetite as a ballast. As a result, the secondary process is operated at an elevated mixed liquor suspended solids concentration because secondary clarifiers can tolerate higher solids loading rates due to improved settleability realized with magnetite use.
  - Advantages: Low footprint requirements, proven technology
  - Disadvantages: Increased operations and maintenance costs
  - Potential Next Steps: Determine footprint requirements of full-scale system and consider pilot testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.4

Central Contra Costa Sanitary District

Bay Area Clean Water Agencies
Nutrient Reduction Study

Central Contra Costa Sanitary District

Martinez, CA

April 25, 2018
Final Report

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Executive Summary

The Central Contra Costa Sanitary District (Central San) owns and operates the Central San Wastewater Treatment Plant (WWTP) located in Martinez, CA and discharges treated effluent to Suisun Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 53.8 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs (e.g., $/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Basis of Design Flow for Strategies	mgd	--	--	35.5	40.7	53.8	61.6	53.8	61.6	--
Flow to Bay[2]	mgd	36.3	36.3	36.3	36.3	45.5	45.5	45.5	45.5	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	7,670	7,670	5,650	5,650	820	770	820	770	--
TN	lb N/d	9,050	9,050	8,790	8,790	4,870	4,560	3,680	2,210	--
TP	lb P/d	260	260	280[7]	280[7]	330	330	240	110	--
Costs[4,5]										
Capital	$ Mil	--	--	7.9	7.9	238	264	391	436	--
O&M PV	$ Mil	--	--	32.0	32.0	88	96	191	342	--
Total PV	$ Mil	--	--	40.0	40.0	326	360	582	777	--
Unit Costs[6]										
Capital	$/gpd	--	--	0.2	0.2	4.4	4.3	7.3	7.1	--
Total PV	$/gpd	--	--	1.1	1.0	6.1	5.8	10.8	12.6	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. The unit load reduction cost was calculated by dividing the capital or total present value by the basis of design flow.
7. If effluent phosphorus loads are not a major concern at the time of optimization, CEPT may not be required and the effluent TP load would be higher than shown in this table. (i.e. effluent TP loads will increase if Optimization Strategy 3 only is implemented).

The recommendations included in this report should be considered preliminary and are subject to change. Central San may continue to evaluate potential future nutrient removal alternatives and may further refine the costs and recommendations of this report or may include additional and/or different recommendations than this report. Other potential options being considered by Central San include supporting recycled water opportunities to divert nutrient loads from Suisun Bay, applied research and piloting of nutrient removal technologies that may provide similar or better levels of treatment at lower present value costs, and other methods of nitrification and nutrient removal that may offer a more feasible implementation.

Through secondary process optimization (i.e. implementation of an anaerobic selector) and recycled water use, Central San is already achieving around 85% total phosphorus load reduction of approximately 19,200 lb P/year (~1,600 lb P/day), around 32% total nitrogen load reduction of approximately 53,000 lb N/year (~4,400 lb N/day), and around 9% ammonia load reduction of approximately 9,600 lb Ammonia as N/year (~800 lb Ammonia as N/day) based on 2011-2014 average annual influent and effluent TP, TKN, and Ammonia data.

The current optimization strategies require a significant investment ($40M Total PV) to achieve approximately 25% additional ammonia load reduction and less than 3% additional TN load reduction. Table ES-1 assumes that upon further evaluation the optimization strategies will be feasible; however, the recommended strategies require further investigation before determining whether or not they are feasible.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Seasonal nitrification and partial denitrification during the dry season. Nitrification would be achieved by increasing the solids retention time (SRT) during the dry season in the activated sludge process. This would require additional blower capacity, alkalinity chemical feed facilities (if required). Partial denitrification would occur in the existing anaerobic selector. Denitrification would likely be limited by return activated sludge (RAS) pumping and a lower than desired hydraulic residence time (HRT) in the anaerobic selector. During the dry season, the existing anaerobic selector will be converted to an anoxic selector and the growth of phosphorus accumulating organisms (PAOs) and corresponding phosphorus removal will be inhibited (i.e. effluent phosphorus loads will increase during the dry season). During dry season startup (for possibly a couple weeks), possible foaming issues and nitrite lock are likely to occur, which may create operational challenges related to effluent quality and recycled water disinfectant demands. Additional recycled water facilities may be required (not currently included in the costs) such as an expansion to the existing sodium hypochlorite facilities and/or an ammonia injection facility. It is recommended that this strategy be further modeled and evaluated to determine its feasibility.

2. If phosphorus removal is of concern, coagulant chemical feed facilities can be included for seasonal phosphorus removal in the primary sedimentation tanks. While the plant already achieves the Level 2 phosphorus concentration, 1 mg P/L, the ability to remove phosphorus in the activated sludge process would go away during the dry season if seasonal nitrification and partial denitrification is implemented. This strategy is predicated on implementation of the previously described optimization strategy (seasonal nitrification and partial denitrification) and is not recommended as a standalone strategy. Bench and pilot testing is recommended to confirm feasibility prior to implementation.

Central San is not considered a candidate for sidestream treatment because the plant incinerates solids, which does not produce a return sidestream laden with nutrients.

The upgrade strategies to achieve Levels 2 and 3 include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Additional primary sedimentation tanks to maintain solids and organics capture in the primary sedimentation tanks.
   b. Modifying the aeration basins to an Integrated Fixed-Film Activated Sludge (IFAS) process. This would also require additional basins, additional feed pumping capacity, additional blower capacity, alkalinity chemical feed facilities (if required), mixed liquor return pumping/piping, additional RAS pumping capacity, and air piping modifications.
   c. Relocation of contaminated soils is required to construct the additional IFAS basins required.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L):
   a. Same as Level 2, plus
   b. Add a new denitrifying filter complex to reduce both total nitrogen and total phosphorus loads. This would require a feed pumping station.
   c. External carbon source chemical feed facilities located at the denitrifying filters to assist with further reducing total nitrogen levels.
   d. Metal salt and polymer chemical feed facilities located at the denitrifying filters to assist with further reducing total phosphorus levels.

Capital costs, O&M costs and present value costs were determined for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for changes in solids handling requirements, resulting energy impacts in other unit processes, and any costs that may be incurred due to increased greenhouse gas emissions, which may be significant and should be considered when further evaluating the recommendations.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the total present value costs range from $40 Mil for dry season optimization up to $777 Mil for Level 3 year-round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. With the exception of chemicals for optimization, the GHG emissions showed an increase as the level of treatment and energy demands increase. The increase in GHG emissions are associated with the production and hauling of chemicals, fugitive biogenic emissions, and emissions due to offsite energy generation and increase import of grid electricity. These increases in GHG emissions are not considered on-site anthropogenic emissions and as such, are not expected to impact Central San’s ability to stay below the California Air Resources Board Cap and Trade Threshold.

1 Introduction

The Central Contra Costa Sanitary District (Central San) wastewater treatment plant discharges to Suisun Bay. It is located at 5019 Imhoff Place, Martinez, CA and it serves approximately 115,100 service connections throughout Danville, Lafayette, Martinez, Moraga, Orinda, Pleasant Hill, San Ramon, Walnut Creek, Concord, Clayton, and adjacent unincorporated areas, including Alamo, Blackhawk, Clyde, and Pacheco. The plant has average dry weather flow (ADWF) permitted capacity of 53.8 million gallons per day (mgd).

The recommendations included in this report should be considered preliminary and are subject to change. Central San may continue to evaluate potential future nutrient removal alternatives and may further refine the costs and recommendations of this report or may include additional and/or different recommendations than this report. Other potential options being considered by Central San include supporting recycled water opportunities to divert nutrient loads from Suisun Bay, applied research and piloting of nutrient removal technologies that may provide similar or better levels of treatment at lower present value costs, and other methods of nitrification and nutrient removal that may offer a more feasible implementation.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

Central San holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2017-0009; CA0037648. Table 2–1 provides a summary of select relevant Central San NPDES permit requirements. Currently, there are no TN or TP discharge limitations. Table 2–1 is not a complete list of constituent limitations in the NPDES permit.

Table 2–1. Select NPDES Permit Limitations (Order No. R2-2017-0009; CA0037648)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	53.8	--	--	--
cBOD[1]	mg/L	--	25	40	--
TSS[1]	mg/L	--	30	45	--
Total Ammonia, as N[2]	mg N/L	--	64	--	82

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. The CCCSD NPDES permit also includes 85% $CBOD_5$ and TSS removal calculated on a monthly basis using the arithmetic mean for influent and effluent CBOD5 at 20 degrees C and TSS concentrations.
2. The CCCSD NPDES permit also includes an average monthly effluent limit for Total Ammonia of 5,500 kg per day.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for Central San. Both liquids processes and solids processes are shown. The Central San wastewater treatment consists of screening and grit removal, primary sedimentation, followed by an activated sludge (AS) process with an anaerobic selector. The AS process maintains a low SRT (1.1 to 1.3 days) for secondary treatment. The selector is used to improve activated sludge settling properties. In addition, the selector provides some biological phosphorus removal. Secondary effluent is disinfected by ultraviolet (UV) disinfection prior to discharge. A portion of the secondary effluent is filtered and chlorine disinfected to produce recycled water; the remaining effluent is discharged to Suisun Bay. Solids treatment consists of waste activated sludge (WAS) thickening, centrifuge dewatering of combined primary and thickened WAS sludge and incineration.

2.3 Existing Flows and Loads

A data request was submitted to each POTW in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for Central San is shown in Table 2–2.

Table 2–2. Current Influent Flows and Loads (7/2011-6/2014)[5]

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	35.5	38.1	38.4	47.0
BOD	lb/d	61,600	62,600	71,500	74,700
TSS	lb/d	81,000	81,500	86,400	88,100
Ammonia	lb N/d	9,400	9,300	10,000	10,000
Total Kjeldahl Nitrogen (TKN)	lb N/d	14,100	13,700	14,800	15,500
Total Phosphorus (TP)	lb P/d	1,740	1,860	1940	2,130
Alkalinity[4]	lb $CaCO_3$/d	No Data	76,500	No Data	88,600
BOD	mg/L	208	197	223	191
TSS	mg/L	273	256	270	225
Ammonia	mg N/L	32	29	31	26
TKN	mg N/L	48	43	46	40
TP	mg P/L	5.9	5.9	6.1	5.4
Alkalinity[4]	mg $CaCO_3$/d	No Data	241	No Data	226

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September assuming they are the lowest consecutive three dry weather months.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data was available from July 2013 to June 2014.

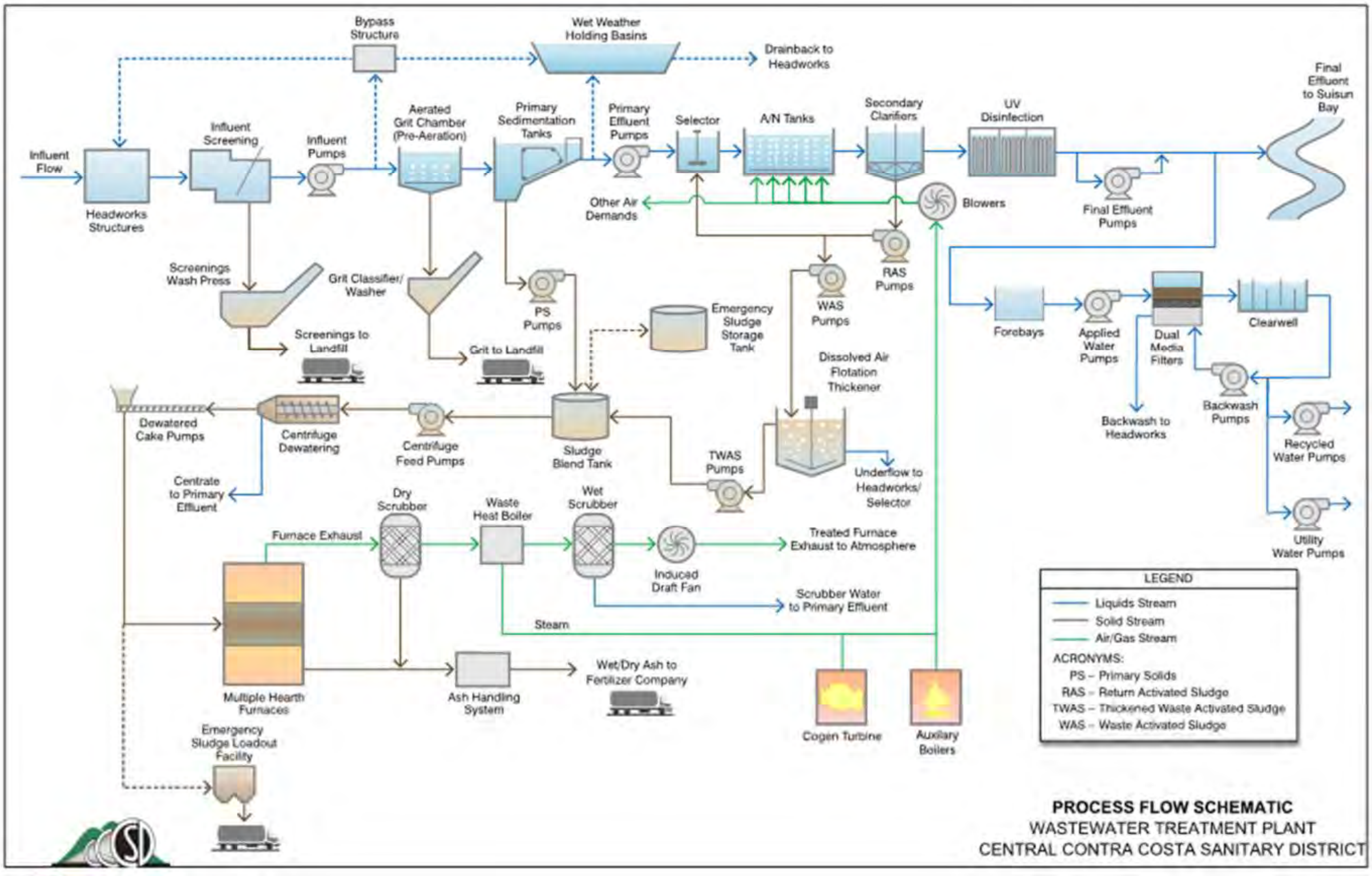

Figure 2-1. Process Flow Diagram for Central San

2.4 Future Nutrient Removal Projects

In 2014, Central San submitted a series of ammonia and nitrogen removal feasibility studies to the Regional Board as part of their NPDES discharge permit requirements. These submittals included the facility needs and corresponding costs for nutrient removal. Implementation of these projects will depend on future nutrient removal requirements.

Central San also completed a Comprehensive Wastewater Master Plan in 2017. The Master Plan also identified possible configurations, siting, and estimated costs for potential future nutrient removal facilities.

2.5 Pilot Testing

Central San has performed a bench-top and pilot-scale test related to ammonia and nitrogen removal. In 2013, CCCSD evaluated the impact of incinerator scrubber water on nitrification growth rates using bench-top reactors. The data suggests that the scrubber water may inhibit nitrifier growth rates resulting in extended treatment that would be required to achieve full nitrification.

In 2015, Central San pilot tested the Zeolite/Anammox technology for removing secondary effluent ammonia and nitrogen. The pilot was discontinued due to challenges with establishing reliable total nitrogen removal and maintaining a reliable anammox population. Information gathered under this effort was shared through the EPA Regional Grant on Sidestream Treatment (led by East Bay Municipal Utility District).

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025 and where that information is unavailable, a 15 percent increase in loadings was assumed for the 10-year period and no increase in flows. Plant upgrade strategies were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for Central San are presented in Table 3–1. The projected flow and load for Central San in 2025 was not available at the time this report was developed; as a result, a 15 percent increase for loads was used with no increase in flow.

Central San later completed flow and load projections as part of their Comprehensive Wastewater Master Plan. The projected flows and loads included in this report using a 15 percent increase to Year 2025 are different than the flows and loads projected as part of Central San's Comprehensive Wastewater Master Plan. The higher flows and loads projected as part of the Comprehensive Wastewater Master Plan would impact the sizing, costs, and feasibility of the optimization alternatives proposed in this report.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3–1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30) [1,3]	Year Round MM[1,3]
Flow	mgd	35.5	38.1	38.4	47.0
BOD	lb/d	70,900	72,000	82,200	86,100
TSS	lb/d	93,000	93,600	99,500	101,400
Ammonia	lb N/d	10,900	10,600	11,400	11,700
TKN	lb N/d	16,400	15,700	17,000	18,000
TP	lb P/d	2,010	2,160	2,250	2,430
Alkalinity	lb/d as $CaCO_3$	No Data	88,100	No Data	101,900
BOD	mg/L	239	227	256	220
TSS	mg/L	314	294	311	259
Ammonia	mg N/L	37	33	36	30
TKN	mg N/L	55	49	53	46
TP	mg P/L	6.8	6.8	7.0	6.2
Alkalinity	mg/L as $CaCO_3$	No Data	277	No Data	260

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September assuming they are the lowest consecutive three dry weather months.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

Central San is not considered a candidate for sidestream treatment because the plant incinerates solids, which does not produce a return sidestream laden with nutrients.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity. The projected flows and loads included in this report for sizing facility upgrades are different than the flows and loads projected as part of Central San's Comprehensive Wastewater Master Plan. The higher flows and loads projected as part of the Comprehensive Wastewater Master Plan would impact the sizing, costs, and feasibility of the upgrade alternatives proposed in this report.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30) [1,3]	Year Round MM[1,3]
Flow	mgd	53.8	57.7	58.2	71.2
BOD	lb/d	93,300	94,800	108,200	113,400
TSS	lb/d	122,500	123,200	131,000	133,600
Ammonia	lb N/d	14,400	14,000	15,000	15,400
TKN	lb N/d	21,500	20,700	22,300	23,700
TP	lb P/d	2,650	2,840	2,960	3,210
Alkalinity	lb/d as $CaCO_3$	No Data	116,000	No Data	134,100
BOD	mg/L	208	197	223	191
TSS	mg/L	273	256	270	225
Ammonia	mg N/L	32	29	31	26
TKN	mg N/L	48	43	46	40
TP	mg P/L	5.9	5.9	6.1	5.4
Alkalinity	mg/L as $CaCO_3$	No Data	241	No Data	226

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September assuming they are the lowest consecutive three dry weather months.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs included in this report do not include any increased costs associated with solids handling, energy management, and greenhouse gas emissions. These potential additional costs and potential additional capital improvements can be significant depending on each individual POTWs configuration, energy and greenhouse gas management goals, and should be considered to confirm the recommended nutrient removal improvements prior to implementation.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over that same project duration. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (years)
Optimization	2%	10
Sidestream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Four optimization strategies were identified during the Central San site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The results of the screening are as follows:

- **Optimization Strategy 1:** Coagulant chemical feed facilities (e.g., ferric chloride) for seasonal phosphorus removal in the primary sedimentation tanks. This strategy is predicated on implementation of Optimization Strategy 3 (seasonal nitrification and partial denitrification). Bench and pilot testing is recommended to confirm feasibility prior to implementation. This strategy is not considered a standalone strategy and would only be considered if increased effluent phosphorus loads (as a result of implementing Optimization Strategy 3) become a regulatory concern.
    - ***Is it feasible?*** Yes. There is concern on the impact of a coagulant on the incinerator capacity and on the performance of the ultraviolet disinfection system (i.e. the coagulant may trigger

operational changes or improvements needed in the UV disinfection system). This would require further investigation and piloting.

- ***Potential impact on ability to reduce nutrient discharge loads?*** The plant already achieves the Level 2 phosphorus concentration, 1 mg P/L. However, the current removal of phosphorus in the activated sludge process would go away during the dry season if seasonal nitrification and partial denitrification is implemented (see Optimization Strategy 3). Optimization Strategy 1 is not expected to reduce effluent ammonia or total nitrogen loads.
- ***Result from analysis:*** If Optimization Strategy 3 is implemented, coagulant addition would maintain the ability to remove total phosphorus across the plant to levels similar to what Central San currently achieves. No additional credit was taken for solids capture across the primaries as they were recently optimized.
- ***Recommendation:*** Perform lab-scale bench test to assess feasibility. Then, perform full-scale pilot test of at least one primary sedimentation tank. If successful and if phosphorus removal is a regulatory concern, consider carrying forward recommendation for coagulant chemical feed facilities to compliment Optimization Strategy 3. Do not carry for forward as a standalone strategy.

- **Optimization Strategy 2:** Split treatment in the aeration basins by using two out of the four trains for nitrogen removal. Operate in this mode year round. This will require operating two parallel activated sludge plants that operate at different SRTs. The two trains operating under nitrogen removal will increase the SRT and increase RAS recycle to facilitate denitrification (RAS firm pumping capacity is 20 mgd per quad of secondary clarifiers). Basin modifications required to facilitate split treatment include piping/valving modifications as well as conversion/expansion of the existing anaerobic selector to an anoxic selector. The remaining two trains will continue to operate as they currently do and will maintain the anaerobic selector which may be inadvertently performing biological P removal.
  - ***Is it feasible?*** Possibly, although it would be a major shift in operations strategy that will require operating two separate activated sludge systems. Additionally, it may not be feasible to maintain the desired SRT and effluent quality during the wet weather season when Central San experiences large storm events. With existing hydraulic flow split challenges and the fact that each parallel train is limited to operate with one set of four secondary clarifiers, this strategy may not be feasible.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Full ammonia removal in the 2 trains performing nitrogen removal (approximately 40 percent of the flow). The extent of total nitrogen load reduction in these basins is limited by the RAS recycle (anticipate approximately 40 percent in the two trains dedicated for nitrogen load reduction. The more RAS returned translates to more total nitrogen removal. During peak wet weather flows, the ammonia and nitrogen load reduction may be less. The two trains performing nitrogen removal will not perform P removal as the anaerobic selector will operate as an anoxic selector. If increased effluent phosphorus loads are a regulatory concern, implementing CEPT (Strategy 1) would be a way to offset any reduction in P loads from this strategy.
  - ***Result from analysis:*** The plant can treat about 40 percent of the average flow for nitrogen removal. While theoretically feasible during most conditions, the challenges associated with operating two separate activated sludge systems and operating during peak wet weather events are significant and out-weigh the potential gains.
  - ***Recommendation:*** Do not carry forward due to the challenges associated with operating two separate activated sludge systems and wet weather operational concerns.

- **Optimization Strategy 3:** Seasonal nitrification by increasing the SRT during the dry season.
  - ***Is it feasible?*** Yes, although it would be a major shift in operations strategy during the dry season and may result in seasonal transition challenges and significant impacts to solids handling approach, energy management, and greenhouse gas emissions.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy would reduce the majority of the ammonia (>80 percent) and a portion of the nitrogen load (approximately 20 percent) during the dry season only.
  - ***Result from analysis:*** There are challenges while transitioning into nitrification and partial denitrification, such as foam inducing organisms, the ability to switch to a longer SRT in a timely manner without violating discharge requirements, and nitrite lock during the transition to nitrification. The nitrite lock issue is a temporary challenge during nitrification start-up annually (anticipated to last approximately 1-2 weeks) at the recycled water facility (RWF). The strategy in addressing nitrite lock at the RWF is a combination of increased chlorine demand and/or ammonia addition. This may require an expansion of the existing sodium hypochlorite facilities and/or a new ammonia injection facility not currently included in the costs. Additional blower capacity and alkalinity (if required) are included with this strategy and the cost.
  - ***Recommendation:*** Continue to evaluate feasibility due to the complicated nature of transitioning into nitrification and partial denitrification for the dry season. Continue to investigate feasibility and any increased costs associated with solids handling, energy, and greenhouse gas emissions. If feasible, carry forward this recommendation.

- **Optimization Strategy 4:** Remove any nitrite and/or nitrate in the scrubber water.
  - ***Is it feasible?*** No, because it requires sufficient nitrite and/or nitrate (several hundred mg N/L) to make a significant impact.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy could remove a portion of the nitrogen load.
  - ***Result from analysis:*** Further investigation of historical data revealed that nitrite and nitrate scrubber water concentrations are well below the threshold deemed viable for treatment.
  - ***Recommendation:*** Do not carry forward.

Strategy 3 may be the only approach to reduce ammonia and total nitrogen loads; however, there are significant challenges that require further evaluation. The most significant challenge is better understanding the start-up impacts of transitioning into nitrification/partial-denitrification each dry weather season and to determine if this strategy can meet all effluent requirements even during the annual transition periods. In implementing Strategy 3, the effluent phosphorus load would increase due to the removal of the anaerobic zone during the dry season. Strategies 1 and 3 could be implemented in combination. By using seasonal coagulant chemical feed facilities (Strategy 1), the effluent phosphorus load reduction would be maintained similar to current levels. As a result, Strategies 1 and 3 were combined as the preliminary recommended strategy for optimization at the Central San plant. However, as noted, additional investigation is required to confirm the feasibility of either strategy.

The recommended overall optimization strategy is shown with the process flowsheet presented in Figure 4-1. It is noted, however, that recommended modifications for optimization may also impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

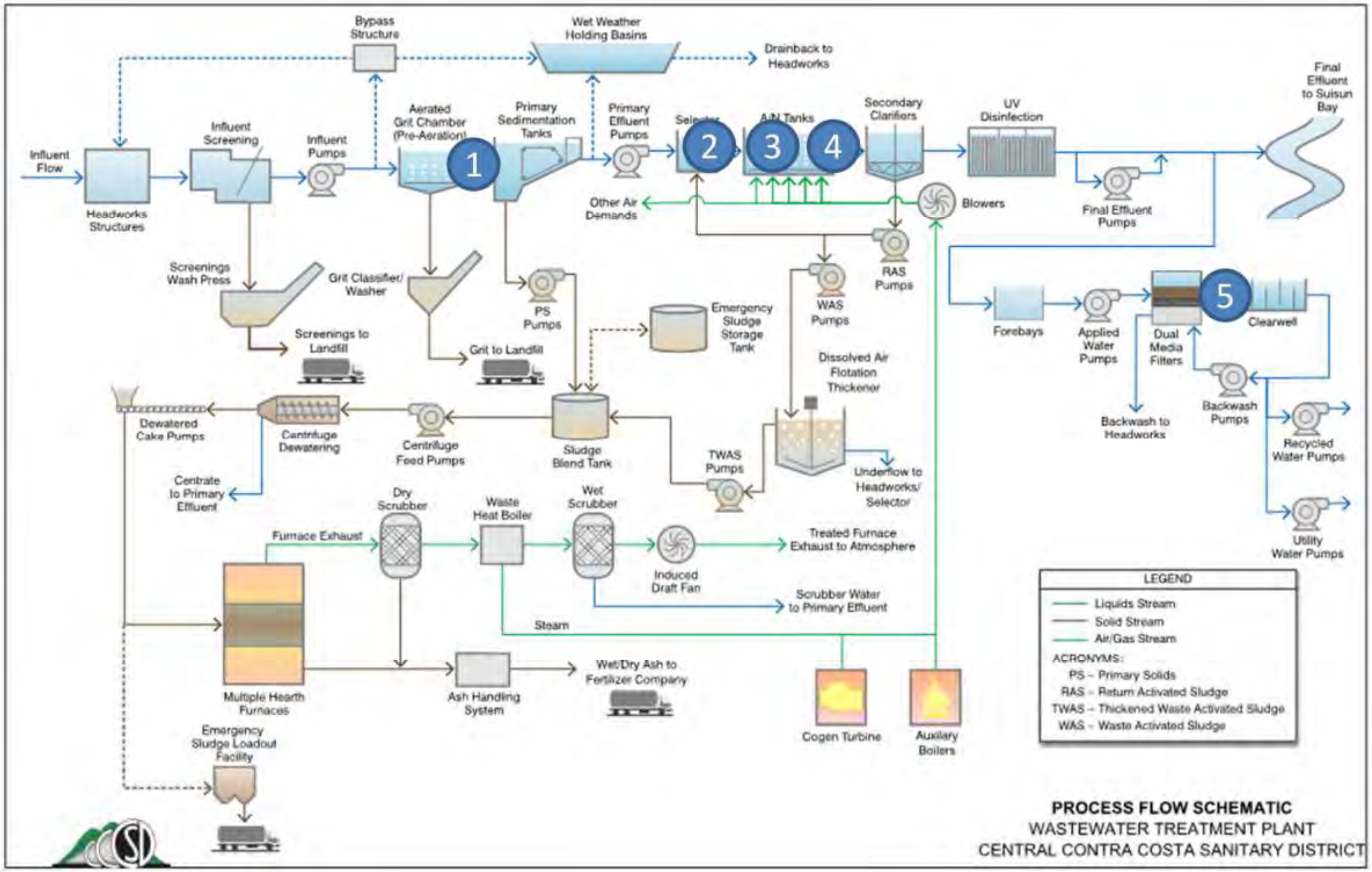

Figure 4-1. Optimization Concepts Considered for the Central Contra Costa Sanitary District

(1) Seasonal coagulant chemical feed facilities, (2) seasonal nitrification with partial denitrification by increasing the SRT, (3) additional blower capacity, (4) alkalinity chemical feed facilities (if required), and (5) temporary (anticipated for 1-2 weeks per year) external ammonia addition and/or increased chlorine demand at the Recycled Water Facility to address nitrite lock concerns

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Coagulant Chemical Feed Facilities for Seasonal P Removal • Add a coagulant chemical feed facility near the primary sedimentation tanks.	• Seasonally dose coagulant into the primary influent channel.
Seasonal Nitrification and Partial Denitrification • Add blower capacity • Add alkalinity chemical feed facilities (if required; cost included in estimate) • Temporary ammonia totes and/or increased chlorine dose at the RWF during nitrification start-up (approximately 1-2 weeks). Expansion of existing chlorine facility may be required and is not currently included in the costs (cost not included in estimate).	• Seasonally increase the aerobic SRT in the aeration basins. • Operate and maintain additional blowers. • Seasonally dose alkalinity upstream of the aeration basins (if required; cost included in estimate). • Dose the temporary ammonia totes at the RWF (approximately 1-2 weeks) during nitrification start-up. • Increase chlorine demand dose at the RWF (approximately 1-2 weeks) during nitrification start-up.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season*	NH4-N Year Round	TN Dry Season*	TN Year Round	TP Dry Season	TP Year Round
Discharge under Current Treatment Mode[1]	lb N or P/d	8,240	8,240	9,730	9,730	280	280
Discharge with Opt. Strategy[1]	lb N or P/d	5,650	5,650	8,790	8,790	280	280
Load Reduction with Opt. Strategy[1,2]	lb N or P/d	2,590	2,590	930	930	0	0
Load Reduction with Opt. Strategy[1,2]	%	31%	31%	10%	10%	0%	0%
Annual Load Reduction with Opt. Strategy1,[3]	lb N or P/yr	944,000	944,000	341,000	341,000	0	0

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
* The ammonia load reduction listed for dry season represent a year round value. It is anticipated that ammonia and total load reduction during the dry season would be approximately 80 percent and 20 percent, respectively.

Table 4-3 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-3. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
Seasonal Coagulant for Maintaining Phosphorus Load Reduction (Strategy 1) • Potentially more organics and solids diverted to the incinerator • Phosphorus maintained during the dry season	• Dependency on chemicals • Chemical costs • Potential impact from coagulant on the incinerator and UV disinfection performance & operational impacts • Potentially more organics and solids diverted to the incinerator reduces available solids handling capacity and increases energy requirements and greenhouse gas emissions
Seasonal Nitrification and Partial Denitrification for Ammonia and Total Nitrogen Load Reduction (Strategy 3) • Maintain settleability in the secondary clarifiers (except during startup) • Increased TSS and BOD load reduction in the secondary clarifiers due to a longer SRT • Reduced waste activated sludge yield • Improved contaminants of emerging concern removal • Potential improvement to UV transmittance of secondary effluent	• Seasonally transition between secondary and nitrogen removal activated sludge treatment operational mode. This can have start-up challenges that last 1-2 weeks (e.g., nitrite lock and secondary clarifier settleability challenges) that may risk not meeting effluent regulatory requirements. • Additional blower demands while in nitrogen removal activated sludge treatment mode • Seasonal foaming concerns while in nitrogen removal activated sludge treatment mode • Might require alkalinity addition while in nitrogen removal activated sludge treatment mode • Potential impacts on solids handling and energy system operation and costs. • Possible triggering of greenhouse gas cap and trade threshold (and associated costs) if additional on-site use of natural gas is required for cogeneration and/or boiler operation. • Increased fugitive N_2O emissions associated with total nitrogen removal.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-4 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-4. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

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Table 4-4. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Basis of Design Flow for Strategies	mgd	35.5	40.7
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	7.9	7.9
Annual O&M	$ Mil/yr	3.6	3.6
Present Value O&M[3]	$ Mil	32.0	32.0
Present Value Total[3]	$ Mil	40.0	40.0
Unit Capital Cost[8]	$/gpd	0.2	0.2
Unit Total PV Cost[8]	$/gpd	1.1	1.0
TN Removal			
Capital[2,4]	$ Mil	6.1	6.1
Annual O&M[4]	$ Mil/yr	3.0	3.0
O&M PV[3,4]	$ Mil	27.2	27.2
Total PV[3,4]	$ Mil	33.3	33.3
TN Removed (Ave.)[6]	lb N/d	930	930
Annual TN Removed (Ave.)[7]	lb N/yr	341,000	341,000
TN Cost[4,9]	$/lb N	9.8	9.8
TP Removal			
Capital[2,5]	$ Mil	0.9	0.9
Annual O&M[5]	$ Mil/yr	0.3	0.3
O&M PV[3,5]	$ Mil	2.6	2.6
Total PV[3,5]	$ Mil	3.5	3.5
TP Removed (Ave.)[6]	lb P/d	--*	--*
Annual TP Removed (Ave.)[7]	lb P/yr	--*	--*
TP Cost[5,9]	$/lb P	--*	--*

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes, or additional costs related to greenhouse gas emissions (if required), or for other possible facility impacts as noted in the report.
3. PV is calculated based on a 2 percent discount rate for 10 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

* The optimization strategy will not reduce total phosphorus loads. Rather, it will maintain current total phosphorus load reduction performance.

5 Sidestream Treatment

Sidestream treatment is not considered a viable option for Central San as previously described and thus was not evaluated further.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Central San plant to meet the Level 2 and Level 3 nutrient removal targets for the plants 53.8 mgd ADWF permitted capacity. The plant modifications for a seasonal nitrification and partial denitrification in the Optimization Section could be used for the Upgrades. In contrast, the metal salt coagulant chemical feed facilities in the Optimization Section are not complimentary in this case to the listed Level 2 and 3 Upgrades. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all upgrade facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. Central San should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements attempt to build on those presented under the Optimization Section. The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. As shown, additional grit removal and primary sedimentation tanks are required and an integrated fixed-film activated sludge (IFAS) process to treat primary effluent is proposed.

IFAS was selected due its inherent ability to leverage existing assets (i.e., aeration basins and secondary clarifiers) while minimizing additional reactors. The existing aeration basins would require converting the anaerobic selector to an anoxic zone coupled with expanding the selector volume. Similar to optimization, alkalinity chemical feed facilities might be required. A new aeration system is assumed that includes air piping modifications for the existing and new basins. New aeration basin volume is required that would need additional feed pumping capacity. The mixed liquor can be returned to the anoxic zone by pumping water through the wall at the end of the basin. Additional RAS pumping capacity is required as well.

Cost is included for the contaminated soil located to the east of the aeration basins to be relocated to Basin A South as currently envisioned under Central San's Master Plan.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

To meet the Level 3 effluent concentrations, a new denitrifying filter complex with a feed pumping station would follow the IFAS facilities. A supplemental carbon source, such as methanol, is required at the denitrifying filters to further reduce total nitrogen levels. A metal salt and polymer chemical feed facilities are also required at the denitrifying filters to further reduce total phosphorus loads. These processes were selected because they are complimentary to the facilities recommended for Level 2, requiring little or no changes to the Level 2 facilities.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Additional Grit Removal Facilities • Additional Primaries (1-2 basins)	Same as Level 2
Biological	• IFAS Media • New Aeration Basins (3 to 4 trains) • New Aeration System • Air Piping Modifications • Additional RAS Pumping Capacity • Alkalinity Chemical Feed facilities (if required) • No New Secondaries • Contaminated Soil Relocation	Same as Level 2 except potentially 1 more aeration basin
Tertiary	--	• New Denitrifying Filter Complex with a Feed Pumping Station • External Carbon Source Chemical Feed Facilities • Metal Salt and Polymer Chemical Feed Facilities • Rapid Mix and Flocculation Tanks

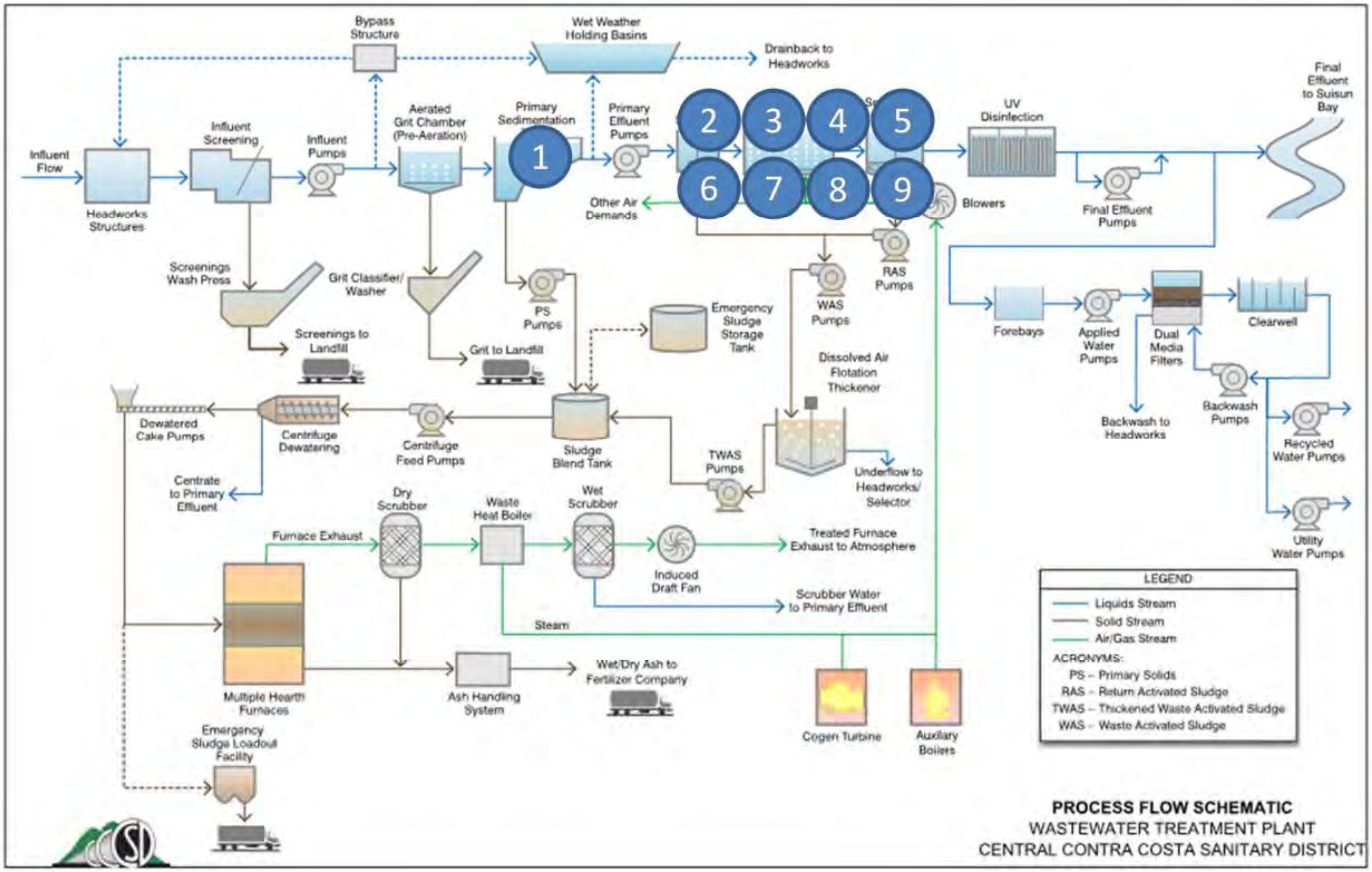

Figure 6-1. Level 2 Upgrade Concept for Central Contra Costa Sanitary District

(1) Additional grit and primary sedimentation tanks, (2) additional aeration basin volume with additional feed pumping capacity, (3) modify aeration basins to an IFAS configuration, (4) additional blower capacity, (5) add alkalinity chemical feed facilities, (6) add mixed liquor return pumps/piping, (7) additional RAS pumping capacity, (8) air piping modifications, (9) contaminated soil re-location

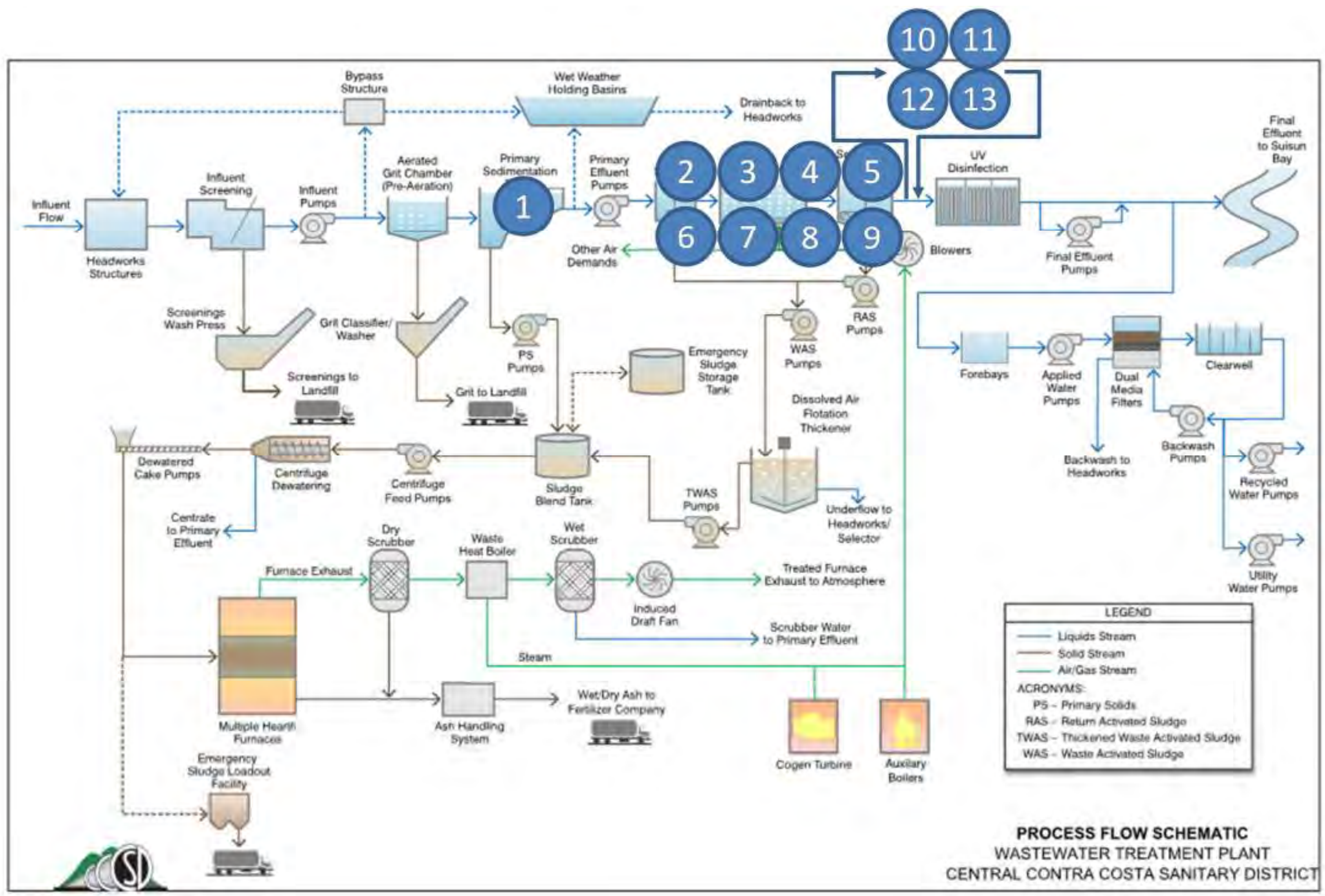

Figure 6-2. Level 3 Upgrade Concept for Central Contra Costa Sanitary District

(1) Additional grit and primary sedimentation tanks, (2) additional aeration basin volume with additional feed pumping capacity, (3) modify aeration basins to an IFAS configuration, (4) additional blower capacity, (5) add alkalinity chemical feed facilities, (6) add mixed liquor return pumps/piping, (7) additional RAS pumping capacity, (8) air piping modifications, (9) contaminated soil clean-up, (10) denitrifying filter feed pumping station, (11) denitrifying filters and ancillary facilities, (12) add metal salt/polymer chemical feed facilities, and (13) add an external carbon source chemical feed facilities

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Additional grit and primary sedimentation tanks, (2) additional aeration basin volume with additional feed pumping capacity, (3) modify aeration basins to an IFAS configuration, (4) additional blower capacity, (5) add alkalinity chemical feed facilities, (6) add mixed liquor return pumps/piping, (7) additional RAS pumping capacity, (8) air piping modifications, (9) contaminated soil clean-up

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Additional grit and primary sedimentation tanks, (2) additional aeration basin volume with additional feed pumping capacity, (3) modify aeration basins to an IFAS configuration, (4) additional blower capacity, (5) add alkalinity chemical feed facilities, (6) add mixed liquor return pumps/piping, (7) additional RAS pumping capacity, (8) air piping modifications, (9) contaminated soil clean-up, (10) denitrifying filter feed pumping station, (11) denitrifying filters and ancillary facilities, (12) add metal salt/polymer chemical feed facilities, and (13) add an external carbon source chemical feed facilities

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Basis of Design Flow for Scenarios	mgd	53.8	61.6	53.8	61.6
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	238	264	391	436
Annual O&M	$Mil/yr	4	4	9	15
O&M PV[3]	$ Mil	88	96	191	342
Total PV[3]	$ Mil	326	360	582	777
Unit Capital Cost	$/gpd	4.4	4.3	7.3	7.1
Unit Total PV	$/gpd	6.1	5.8	10.8	12.6
TN Removal					
Capital[2,4]	$ Mil	200	225	353	397
Annual O&M[4]	$ Mil/yr	4	4	8	15
O&M PV[3,4]	$ Mil	84	92	187	338
Total PV[3,4]	$ Mil	284	317	539	735
TN Removed (Ave.)[6]	lb N/d	6,500	6,800	7,700	9,200
Annual TN Removed (Ave.)[7]	lb N/yr	2,370,000	2,490,000	2,810,000	3,350,000
TN Unit Cost[4,8]	$/lb N	4.0	4.3	6.4	7.3
TP Removal					
Capital[2,5]	$ Mil	16	18	165	187
Annual O&M[5]	$ Mil/yr	0.9	1.0	1.7	2.8
O&M PV[3,5]	$ Mil	21	22	38	64
Total PV[3,5]	$ Mil	37	40	204	251
TP Removed (Ave.)[6]	lb P/d	--*	--*	90	220
Annual TP Removed (Ave.)[7]	lb P/yr	--*	--*	34,300	81,100
TP Unit Cost[5,8]	$/lb P	--*	--*	198	103

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes, or additional costs related to greenhouse gas emissions (if required), or for other possible facility impacts as noted in the report. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

* The existing facilities already meet Level 2 concentrations. This level of performance will be maintained.

Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing aeration basins and secondary clarifiers • Robust technology to absorb variability in flows and loads • Ability to reliably remove ammonia and TN • Reduced solids production • Improved CEC removal in IFAS compared to existing activated sludge	• Energy intensity to keep media in suspension or pass water through media (media dependent) • More complex to operate than existing activated sludge • Headloss across IFAS process may have adverse impacts not yet identified
Level 3	Same as Level 2 plus the following additional benefits: • High quality water as all the water will be filtered via sand filters • Further enhanced CEC removal compared to Level 2 as any particulate bound CECs should be captured in the filters	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Safety from external carbon source (if methanol) • Additional unit process to operate (new biological filter complex) • Additional pumping facilities (requires pumping all plant flow again) • Additional chemicals to handle

7 Nutrient Load Reduction by Other Means

Central San has an existing recycled water program. This existing program has the effect of reducing nutrients discharged to the Bay. The WWTP currently recycles approximately 1,800 acre-feet per year (585 million gallons per year) for treatment plant use, landscape irrigation, and for commercial applications. Central San is planning for a possible increase in recycled water demands from a new development in the City of Concord for an additional 2,749 acre-feet per year (896 million gallons per year). Build-out of the development is expected to be phased over several decades starting in the early 2020s. Central San is also exploring several other recycled water opportunities such as serving up to 22,400 acre-feet per year (7,300 million gallons per year) industrial recycled water to two nearby refineries for cooling tower and/or boiler water use.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in energy and chemical demands and associated greenhouse gas emissions if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant.

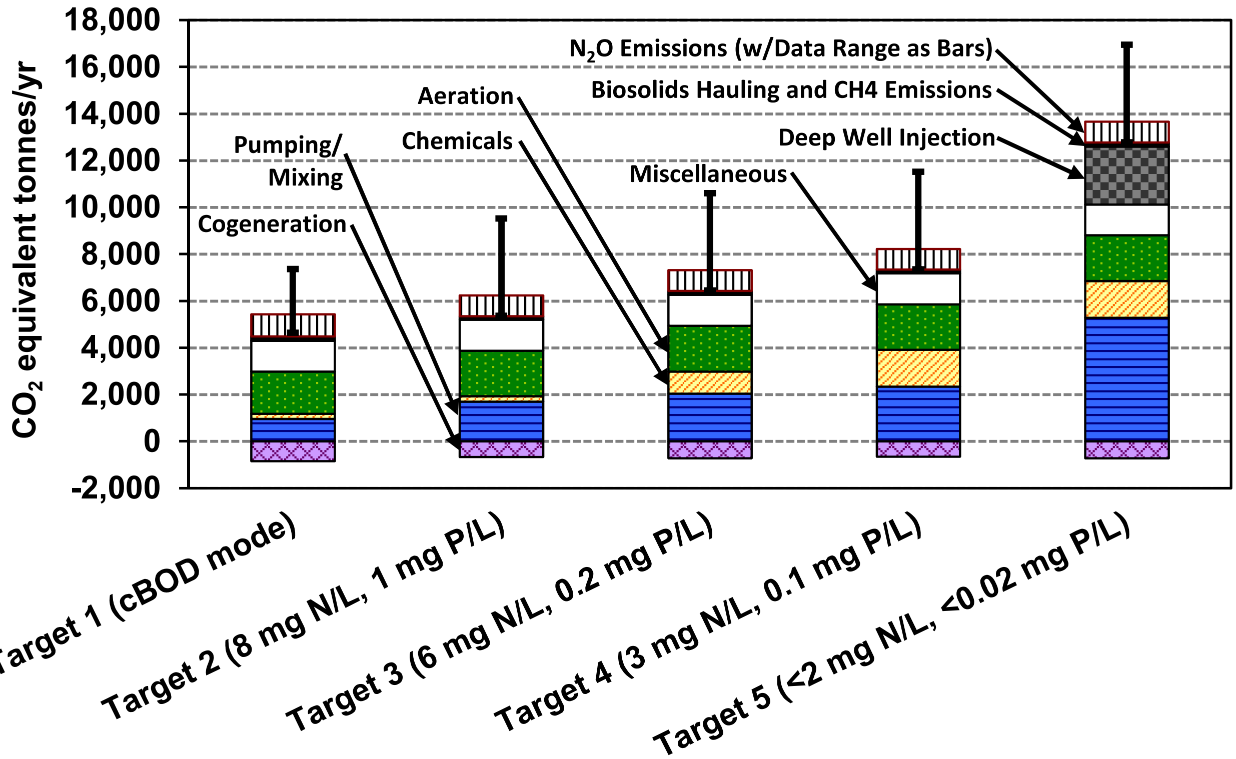

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be a plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values4 for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the anticipated increase in GHG emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

It is important to note that Central San closely monitors plantwide anthropogenic greenhouse gas emissions in order to avoid exceeding the California Air Resources Board's (CARBs) current Cap and Trade Threshold of 25,000 metric tons of CO2-equivalents per year. As improvements require additional use of anthropogenic fuels on site, Central San will most likely exceed the Cap and Trade Threshold (e.g. increased natural gas use in the cogeneration facility to meet new electrical demands or increased natural gas use in boilers to generate steam for increased steam-driven aeration turbine steam demands).

The increased energy demands are assumed to be satisfied with imported electricity and that new electric driven aeration blowers will be in place; therefore, the GHG emissions associated with the imported electricity would not impact plantwide anthropogenic greenhouse gas emissions counted towards the CARB Cap and Trade Threshold for Central San (i.e. these would be emissions associated with PG&E's facilities - Central San's electric utility provider).

Similarly, the increase in GHG emissions from chemicals is associated with the production of those chemicals and would not impact plantwide anthropogenic greenhouse gas emissions counted towards the CARB Cap and Trade Threshold for Central San (i.e. these would be emissions associated with the chemical manufacturer/supplier).

Although fugitive N2O emissions can be significant while performing nitrification/denitrification, these emissions are not currently reportable to CARB and are not part of the anthropogenic emissions total that determines Cap and Trade inclusion applicability.

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[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions*

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy[2]	MT CO_2/yr	6,600	5,500	12,200	12,300	14,200	14,500	--
GHG Emissions Increase from Chemicals[2]	MT CO_2/yr	36,800	15,400	5,400	2,300	16,400	14,200	--
GHG Emissions Increase Total[2]	MT CO_2/yr	43,300	20,900	17,500	14,600	30,600	28,800	--
Unit GHG Emissions[2]	lb CO_2/MG	6,800	3,300	1,800	1,500	3,200	3,000	--
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	100	50	10	8	10	8	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	280	130	16	12	23	18	--
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--**	--**	--**	--**	280	130	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. Central San is not a candidate for sidestream treatment.

* The analysis is based on emissions from imported electricity and chemicals and thus do not count towards Central San's CARB Cap and Trade Threshold.

** The existing facilities already meet Level 2 concentrations. This level of performance will be maintained from Optimization through Level 2.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at Central San:

- Granular Activated Sludge – this could be used to either replace or seed the activated sludge facility. The latter would entail constructing a granular sludge facility in parallel to the existing activated sludge. The wasted solids from the granular sludge facility could potentially be used to seed the existing activated sludge facility for nutrient removal. This would require more detailed analysis to confirm this option. Modifications would need to the existing activated sludge facility for the seeding option. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to treat primary influent or primary effluent, and the ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the existing plenum aeration diffusers within the aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No full-scale installations in North America. It is currently being evaluated at the demonstration scale by the Metropolitan Water Reclamation District of Greater Chicago.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis. As POTWs further evaluate these recommendations, the unit costs and project cost factors may vary and may change the capital and O&M costs included in this report.

Table 1. Allowanced used in developing the Opinion of Probable Cost

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.5

Central Marin Sanitation Agency

Bay Area Clean Water Agencies
Nutrient Reduction Study

Central Marin Sanitation Agency

San Rafael, CA

April 5, 2018
Final Report

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Executive Summary

The Central Marin Sanitation Agency Wastewater Treatment Plant (CMSA WWTP) discharges to Central San Francisco Bay. It is located at 1301 Andersen Drive, San Rafael, CA 94901 and serves about 52,200 service connections throughout the City of Larkspur, the Towns of Corte Madera, Fairfax, Ross, San Anselmo, portions of the City of San Rafael, the unincorporated areas of Ross Valley, San Quentin Village, and San Quentin State Prison. The plant has an average dry weather flow (ADWF) permitted capacity of 10 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs (e.g., $/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	8.4	12.2	10.0	14.5	10.0	14.5	--
Flow to Bay[2]	mgd	8.3	8.3	8.3	8.3	9.1	9.1	9.1	9.1	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	1,900	1,900	1,360	1,270	160	150	160	150	1,300
TN	lb N/d	2,520	2,520	2,580	2,580	1,220	1,140	920	450	1,920
TP	lb P/d	240	240	180	170	80	80	60	20	220
Costs[4,5]										
Capital	$ Mil	--	--	6.6	7.1	190	200	250	260	11.2
O&M PV	$ Mil	--	--	16.4	18.4	120	130	140	150	5.3
Total PV	$ Mil	--	--	23.0	25.4	310	330	390	410	16.5
Unit Costs[6]										
Capital	$/gpd	--	--	0.8	0.6	19	14	25	18	--
Total PV	$/gpd	--	--	2.7	2.1	31	22	39	28	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Use year round chemically enhanced primary treatment (CEPT).
2. Increase the solids retention time (SRT) in the activated sludge system and operate in nitrification mode to remove a portion of the ammonia load. This will require additional blower capacity, additional diffusers (if required), and alkalinity chemical feed facilities (if required).

The CMSA WWTP is considered a candidate for sidestream treatment to reduce ammonia and total nitrogen loads as the plant anaerobically digests biosolids and dewaters digested biosolids. The dewatering return stream is laden with ammonia and total nitrogen. The recommended sidestream treatment strategy is deammonification for reducing ammonia and total nitrogen loads.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Continue optimization concepts that includes year round CEPT, increasing the SRT in the activated sludge system, and alkalinity chemical feed facilities.
    b. Implement split treatment on primary effluent by making the following modifications and additions: i) modify the primary effluent flow split structure to send a portion of flow to new unit processes (approximately 80 percent of flow) while sending the remaining flow to a combination of the existing biotowers and directly to the activated sludge basins (approximately 20 percent of flow), ii) modify the existing biotowers to operate as nitrifying biotowers, iii) modify the existing activated sludge facility for nitrification/denitrification by creating an anoxic zone and sending a portion of primary effluent directly to the activated sludge, and iv) construct and operate a new membrane bioreactor (MBR) facility that treats primary effluent not sent to the existing train. The analysis is based on maintaining the plant's ability to blend primary and secondary treated water as follows exceed 30 mgd.
    c. Add external carbon source chemical feed facilities to reduce total nitrogen loads.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Continue optimization concepts that includes year round CEPT and alkalinity chemical feed facilities.
    b. Decommission the existing secondary treatment facilities.
    c. Modify the primary effluent flow split structure to send all the flow to the new MBR. As previously stated, the analysis is based on maintaining the plant's ability to blend primary and secondary treated water as follows exceed 30 mgd.
    d. The MBR for Level 3 is larger than Level 2 as it treats all the flow and it is sized for meeting lower discharge concentrations.
    e. Add external carbon source chemical feed facilities to the MBR for reducing total nitrogen loads.
    f. Add metal salt chemical feed facilities to the MBR for reducing total phosphorus loads.

Capital costs, O&M costs and present value costs were determined for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for changes in solids handling requirements or energy requirements in other unit processes.

As shown in Table ES-1, and as might be expected, the costs generally increase from sidestream treatment to optimization, and again to Level 2 and Level 3 upgrades, respectively. The costs generally increase for both capital and O&M from the dry season to year round. Overall, the present value costs range from $16 Mil for sidestream treatment up to $410 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. The GHG emissions associated with energy increased with the treatment level. In contrast, the GHG emissions associated with chemicals decreased with treatment level.

1 Introduction

The Central Marin Sanitation Agency Wastewater Treatment Plant (CMSA WWTP) discharges to Central San Francisco Bay. It is located at 1301 Andersen Drive, San Rafael, CA 94901 and serves about 52,200 service connections throughout the City of Larkspur, the Towns of Corte Madera, Fairfax, Ross, San Anselmo, portions of the City of San Rafael, the unincorporated areas of Ross Valley, San Quentin Village, and San Quentin State Prison. The plant has an average dry weather flow (ADWF) permitted capacity of 10 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The CMSA WWTP holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2012-0051; CA0038628. Table 2–1 provides a summary of the permit limitations for CMSA WWTP. Table 2–1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2–1. NPDES Permit Limitations (Order No. R2-2012-0051; CA0038628)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak[1]
Flow	mgd	10	--	--	--	30
BOD	mg/L	--	25	40	--	--
TSS	mg/L	--	30	45	--	--
Total Ammonia, as N	mg/L	--	60	-	120	--

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. Secondary treatment capacity (not permitted capacity). The plant has the ability to blend primary and secondary treated water as follows exceed 30 mgd.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the CMSA WWTP. Both liquids processes and solids processes are shown. Treatment processes consist of screening, grit removal, primary sedimentation, secondary biological treatment (high-rate biofilters and aeration tanks), secondary clarification, chlorination, and dechlorination. No major nutrient removal systems are currently in place. Solids from the secondary clarifiers are processed via rotary drum thickeners, then thickened secondary solids and primary solids are processed via anaerobic digestion and dewatering using high speed centrifuges.

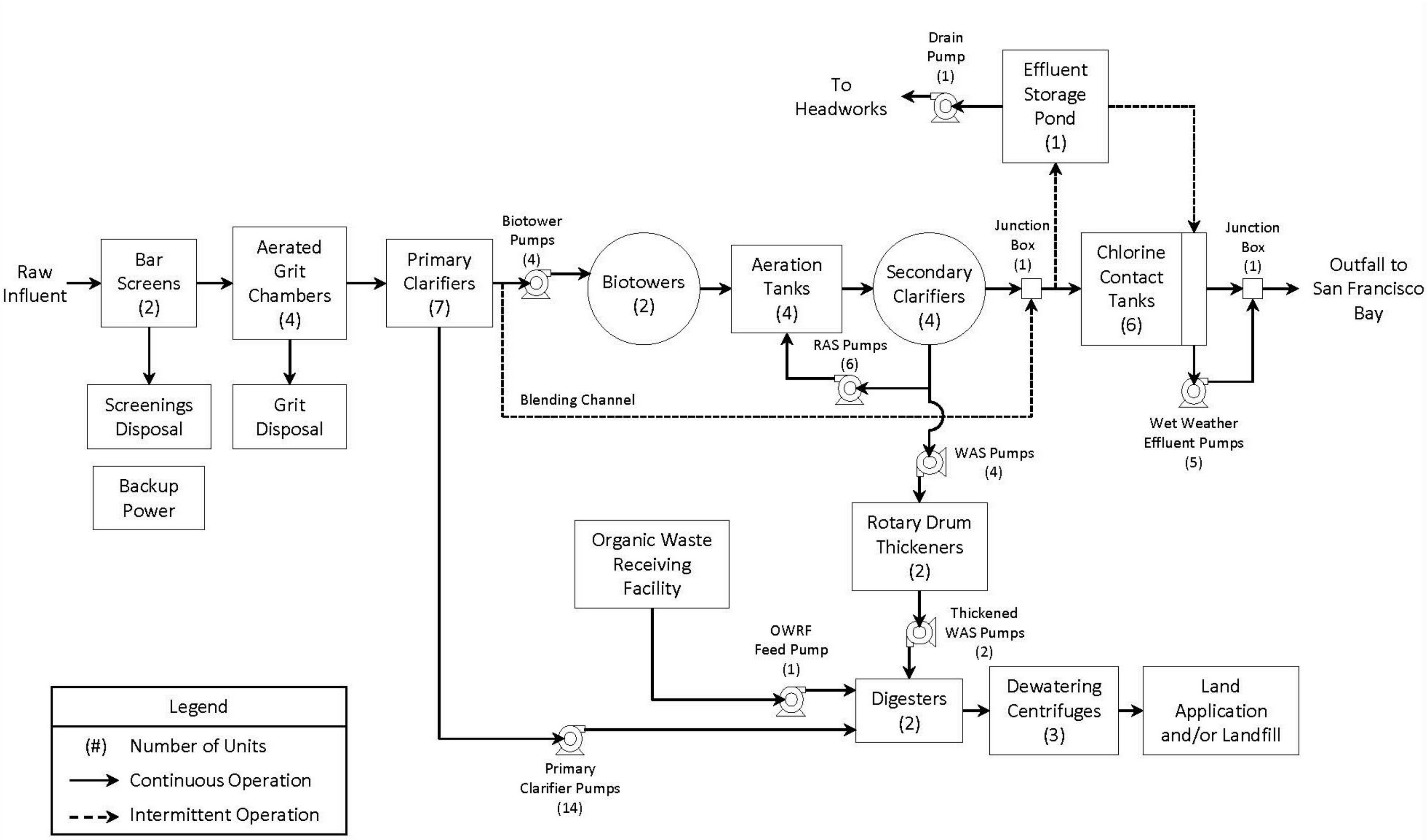

Figure 2-1. Process Flow Diagram for the CMSA WWTP

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the CMSA WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	8.4	10.6	9.6	22.5
BOD	lb/d	19,800	21,400	26,100	30,200
TSS	lb/d	33,800	32,200	44,900	52,600
Ammonia	lb N/d	2,700	2,600	2,900	3,000
Total Kjeldahl Nitrogen (TKN)	lb N/d	4,700	4,600	4,700	4,500
Total Phosphorus (TP)	lb P/d	720	620	720	510
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	282	241	325	161
TSS	mg/L	482	363	560	280
Ammonia	mg N/L	38	29	36	16
TKN	mg N/L	67	52	59	24
TP	mg P/L	10.3	7.0	9.0	2.7
Alkalinity	mg $CaCO_3$/d	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

CMSA is currently preparing a master plan which may identify potential future nutrient removal projects. However, no nutrient removal projects are currently planned.

2.5 Pilot Testing

CMSA has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in

the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for the CMSA WWTP are presented in Table 3-1. The projected flow and load for 2025 were estimated based on a 5 percent increase for loads with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	8.4	10.6	9.6	22.5
BOD	lb/d	20,800	22,400	27,400	31,800
TSS	lb/d	35,500	33,800	47,200	55,300
Ammonia[4]	lb N/d	2,800	2,700	3,000	3,200
TKN[4]	lb N/d	4,900	4,800	5,000	4,700
TP[4]	lb P/d	760	650	760	530
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	296	253	341	169
TSS	mg/L	506	381	588	294
Ammonia[4]	mg N/L	40	30	38	17
TKN[4]	mg N/L	70	55	62	25
TP[4]	mg P/L	10.8	7.4	9.5	2.8
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Nutrient data not available before July 2012.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by CMSA, it was determined that the CMSA WWTP is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July, 2015. The sampling results were projected forward to the permitted capacity for use in the sidestream treatment evaluation. The sidestream flows and loads for the permitted capacity are provided in Table 3–2. The permitted capacity flows and loads were used in the facility sizing.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3–2. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Projected to Permitted Flow Capacity
Sidestream Flow	mgd	0.06	0.07
Ammonia	lb N/d	440	520
TKN	lb N/d	460	550
TN[1]	lb N/d	460	550
TP	lb P/d	3	4
OrthoP	lb P/d	2	3
Alkalinity	lb $CaCO_3$/d	1,300	1,500
Ammonia	mg N/L	930	930
TKN	mg N/L	990	990
TN[1]	mg N/L	990	990
TP	mg P/L	7	7
OrthoP	mg P/L	5	5
Alkalinity	mg/L as CaCO3	2,700	2,700

1. It was assumed that TKN = TN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	10.0	12.6	11.4	26.8
BOD	lb/d	23,500	25,400	31,000	36,000
TSS	lb/d	40,200	38,300	53,400	62,600
Ammonia	lb N/d	3,200	3,100	3,400	3,600
TKN	lb N/d	5,600	5,500	5,600	5,400
TP	lb P/d	860	740	860	600
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	282	241	325	161
TSS	mg/L	482	363	560	280
Ammonia	mg N/L	38	29	36	16
TKN	mg N/L	67	52	59	24
TP	mg P/L	10.3	7.0	9.0	2.7
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy.

Five optimization strategies were identified during the CMSA WWTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The five optimization strategies were screened down to three strategies as follows.

- **Optimization Strategy 1:** Use existing ferric chloride chemical feed facilities and modify the existing polymer chemical feed facilities to turn the primary clarifiers into chemically enhanced primary treatment (CEPT) year round. This strategy would require polymer system chemical feed delivery modifications. Year round CEPT should improve phosphorus removal and provide even more TSS and BOD capture at the primaries.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase phosphorus removal and reduce loading to downstream unit processes. This could enhance the potential to remove ammonia in the existing secondary treatment facilities.
  - ***Result from analysis:*** It would remove phosphorus at the primaries and increase downstream capacity. However, it would most likely remove more carbon than desired which could negatively impact the ability to denitrify downstream (if required in the future). The extent of this impact would require more detailed analysis.
  - ***Recommendation:*** Carry forward. Additional field tests are recommended for dry and wet weather conditions to verify phosphorus removal and overall process improvements.

- **Optimization Strategy 2:** Increase solids retention time (SRT) in the activated sludge system for nitrification mode to reduce ammonia loads.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Improved ammonia load reduction.
  - ***Result from analysis:*** This strategy could successfully reduce the ammonia load. This would require adding additional blower capacity and alkalinity chemical feed facilities. A more detailed analysis would be required to determine whether there is sufficient available diffusers. The alkalinity might not be required, but additional analysis is required.
  - ***Recommendation:*** Carry forward with the understanding that diffuser capacity analysis is recommended if considered for implementation.

- **Optimization Strategy 3:** Split treatment where a portion of the primary effluent is nitrified in the biotowers with subsequent denitrification in the activated sludge process. The remaining portion is nitrified/denitrified in the activated sludge process. This strategy would require modifying the oxidation towers by decreasing flow and increasing the recirculation rate.
  - ***Is it feasible?*** Yes but a drive mechanism would need to be added to one of the towers to maintain movement at low flows.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Remove a portion of the ammonia load in the oxidation towers and the remaining load in the activated sludge system.
  - ***Result from analysis:*** The analysis suggests that the towers do not have sufficient capacity to remove sufficient ammonia and merit consideration.

➢ ***Recommendation:*** Do not carry forward.

Strategies 1 and 2 could be used to improve phosphorus and ammonia load reduction. The optimized process would push the limits of the current facility.

The recommended strategies are shown with the process flow diagram presented in Figure 4-1. A description of each strategy and the evaluation results are presented thereafter. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

The capital and operational elements of the recommended optimization strategies are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
CEPT during dry weather • Modify the existing polymer feed delivery system	• Operate the ferric chloride/ polymer chemical feed facilities
Nitrification in the Activated Sludge Facilities • Add additional blower capacity to meet additional demands • Add alkalinity chemical feed facilities (if required) • Add additional diffusers (if required)	• Change mode of operation and maintain additional blowers • Operate the alkalinity chemical feed facilities

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	1,940	1,940	2,580	2,580	240	240
Discharge with Opt. Strategy[1]	lb N or P/d	1,360	1,270	2,580	2,580	180	170
Load Reduction[2]	lb N or P/d	590	670	0	0	60	80
Load Reduction[2]	%	30%	35%	0%	0%	26%	31%
Annual Load Reduction	lb N or P/yr	214,300	245,800	0	0	22,700	27,800

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

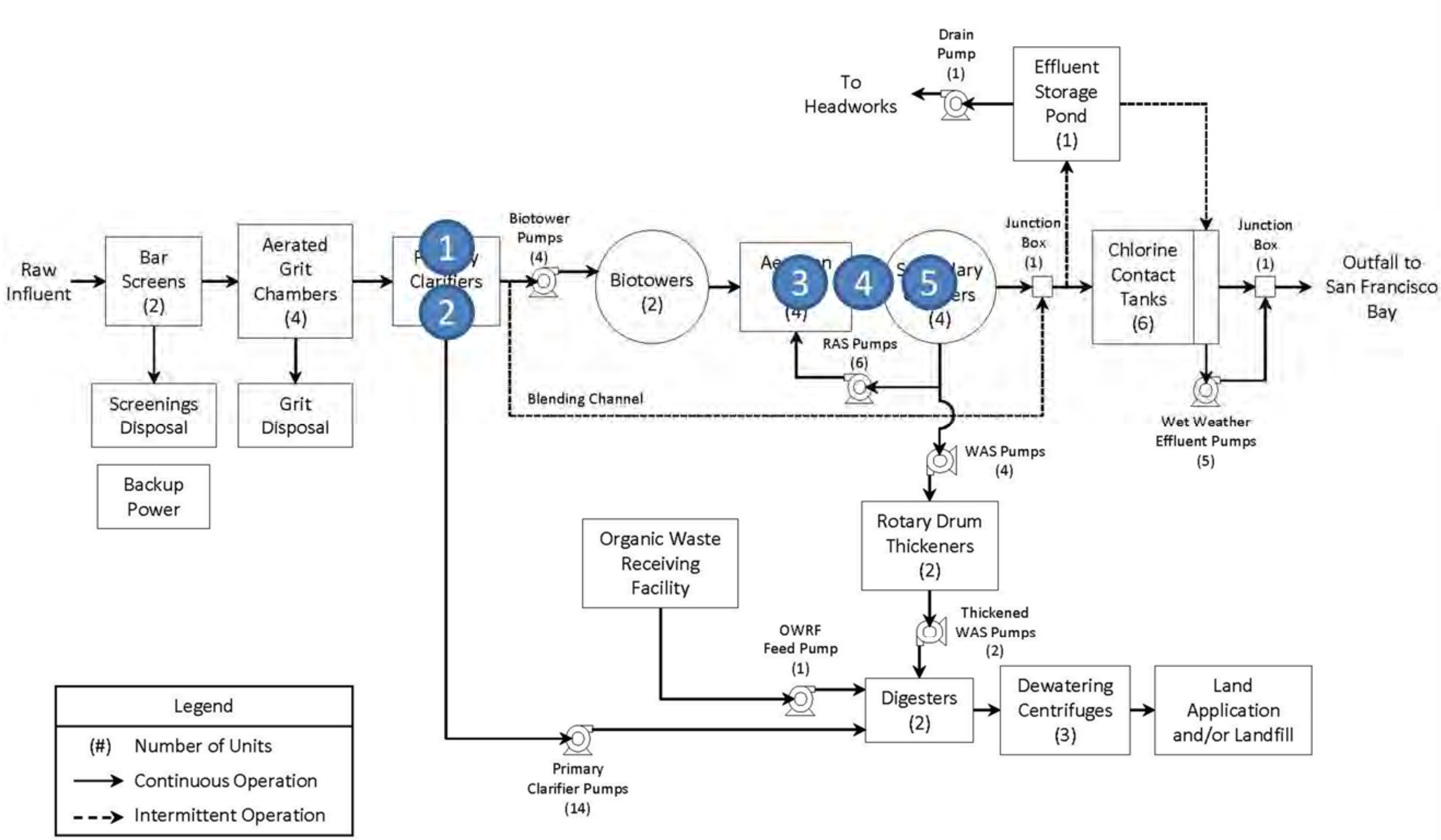

Figure 4-1. Optimization Concepts Considered for CMSA WWTP

(1) Use existing ferric chloride chemical feed facilities to operate in Chemically Enhanced Primary Treatment (CEPT) mode, (2) modify the existing polymer feed delivery system to operate in CEPT mode, (3) increase the SRT in the aeration basins for nitrification mode, (4) add additional blower capacity and diffusers (if required), and (5) add alkalinity chemical feed facilities (if required).

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	8.4	12.2
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	6.6	7.1
Annual O&M	$ Mil/yr	1.8	2.0
Present Value O&M[3]	$ Mil	16.4	18.4
Present Value Total[3]	$ Mil	23.0	25.4
Unit Capital Cost[8]	$/gpd	0.8	0.6
Unit Total PV Cost[8]	$/gpd	2.7	2.1
TN Removal			
Capital[2,4]	$ Mil	5.4	5.8
Annual O&M[4]	$ Mil/yr	1.3	1.5
O&M PV[3,4]	$ Mil	11.5	13.1
Total PV[3,4]	$ Mil	16.9	18.8
TN Removed (Ave.)[6]	lb N/d	--*	--*
Annual TN Removed (Ave.)[7]	lb N/yr	--*	--*
TN Cost[4,9]	$/lb N	--*	--*
TP Removal			
Capital[2,5]	$ Mil	1.3	1.3
Annual O&M[5]	$ Mil/yr	0.5	0.6
O&M PV[3,5]	$ Mil	4.9	5.3
Total PV[3,5]	$ Mil	6.2	6.6
TP Removed (Ave.)[6]	lb P/d	60	80
Annual TP Removed (Ave.)[7]	lb P/yr	22,700	27,800
TP Cost[5,9]	$/lb P	27	24

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 10 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

* The optimization strategy will not reduce total nitrogen loads. Rather, it will improve ammonia load reduction.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at CMSA WWTP.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
CEPT • Ability to reduce phosphorus discharge loads • Additional potential capacity for the primaries • Additional capacity for the downstream unit processes	• Additional solids generation • Additional chemicals to handle
Increase SRT and operate in nitrification mode • Ability to reduce ammonia load • Enhanced removal of chemicals of emerging concern (CECs) • Reduced downstream chlorine dose due to ammonia removal	• Modified process to learn and optimize • More blowers to maintain and operate • Additional chemicals to handle • Potential breakpoint chlorination issues during periods of ammonia bleed through

5 Sidestream Treatment

As previously described, the CMSA WWTP was identified as a potential candidate for sidestream treatment. The WWTP currently has anaerobic digestion and mechanical dewatering. Additionally, the plant accepts organics that are fed into the digesters.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia and total nitrogen load reduction. Total phosphorus load reduction is not recommended as the sidestream P loading values are marginal.

Deammonification is an innovative biological treatment technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification) including requiring 60 percent less oxygen, elimination of supplemental carbon for nitrogen removal, and requires 50 percent less alkalinity. Based on these benefits, deammonification is recommended for CMSA.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements*
Feed Pumping (if necessary)	--
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

* Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)[4]
Current Discharge[1]	lb/d	1,730	2,300	220
Discharge with Sidestream Treatment[2]	lb/d	1,300	1,920	220
Load Reduction[3]	lb/d	430	380	0
Load Reduction	%	25%	17%	0%
Annual Load Reduction	lb/yr	156,950	139,500	0

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP[7]
Capital[1]	$ Mil	11.2	--
Annual O&M	$ Mil/yr	0.24	--
Total Present Value[2]	$ Mil	16.5	--
NH4-N Load Reduction[3,5]	lb N/yr	156,950	--
TN Load Reduction[3,5]	lb N/yr	139,500	--
TP Load Reduction[4,5]	lb P/yr	--	--
NH4-N Cost [3,5,6]	$/lb N	3.5	--
TN Cost [3,5,6]	$/lb N	3.9	--
TP Cost [4,5,6]	$/lb P	--	--

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the CMSA WWTP to meet the Level 2 and Level 3 nutrient removal targets for the plants 10 mgd ADWF permitted capacity. The upgrades would be able to accommodate peak design flows up to 30 mgd. For flows greater than 30 mgd, the plant would maintain the ability to blend primary effluent with secondary treated water, followed by disinfection as currently permitted for the plant.

The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. CMSA should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under the Optimization Section. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, the primaries would operate in CEPT mode (similar to optimization) and a split treatment configuration to treat the primary effluent. The primary effluent flow split structure would be modified to convey a portion of flow to a new membrane bioreactor (MBR) facility (approximately 80 percent of the flow) and the remaining flow to the existing secondary treatment facility (approximately 20 percent). The existing biotower train would be modified to operate as a nitrifying biotower by increasing the internal recirculation rate. The existing activated sludge facility would be modified by increasing the SRT and creating an up-front anoxic zone. A portion of primary effluent conveyed to the existing train would bypass the biotowers and go directly into this anoxic zone. Such a bypass is required to provide carbon for total nitrogen load reduction. The new MBR and its ancillary facilities would have the ability to remove ammonia and total nitrogen loads.

Both the existing and MBR trains would have access to an external carbon source (e.g., methanol) and alkalinity (if required) chemical feed facilities to meet Level 2 nutrient concentrations. The external carbon source is provided to meet the carbon requirements for meeting the total nitrogen discharge concentrations. The alkalinity addition is provided to supplement alkalinity consumed during nitrification.

As previously stated, all primary effluent flows greater than 30 mgd will maintain the ability to blend primary and secondary treated water.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades attempt to expand upon those listed for optimization and Level 2 upgrades where possible. Due to the low level nutrient levels for Level 3, the existing secondary treatment train would need to be decommissioned. The new MBR would treat the primary effluent flow. In addition to the new MBR and its ancillary facilities, external carbon, alkalinity, and ferric chloride chemical feed facilities are required at the new MBR to assist with meeting Level 3 concentrations.

As previously stated, all primary effluent flows greater than 30 mgd will maintain the ability to blend primary and secondary treated water.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Modify the existing polymer feed delivery system to operate under CEPT mode. • Use existing ferric chloride chemical feed facility to assist with CEPT mode.	Same as Level 2
Biological	• Modify the primary effluent flow split structure for split treatment • Modify the existing biotowers to operate as nitrifying biotowers by increasing the internal recirculation rate. • Modify the existing activated sludge facilities by increasing the SRT and adding an up-front anoxic zone. • Add alkalinity chemical feed facilities (if required). • Add MBR facilities and all the associated equipment (e.g., tanks, RAS/WAS pumping, aeration system, membranes, etc.). • Add external carbon source chemical feed facilities.	• Modify the primary effluent flow split structure to send flow to the new MBR. • Decommission the existing secondary treatment facilities. • Add alkalinity chemical feed facilities (if required). • Add MBR facilities and all the associated equipment (e.g., tanks, RAS/WAS pumping, aeration system, membranes, etc.). • Add external carbon source chemical feed facilities. • Add ferric chloride chemical feed facilities.

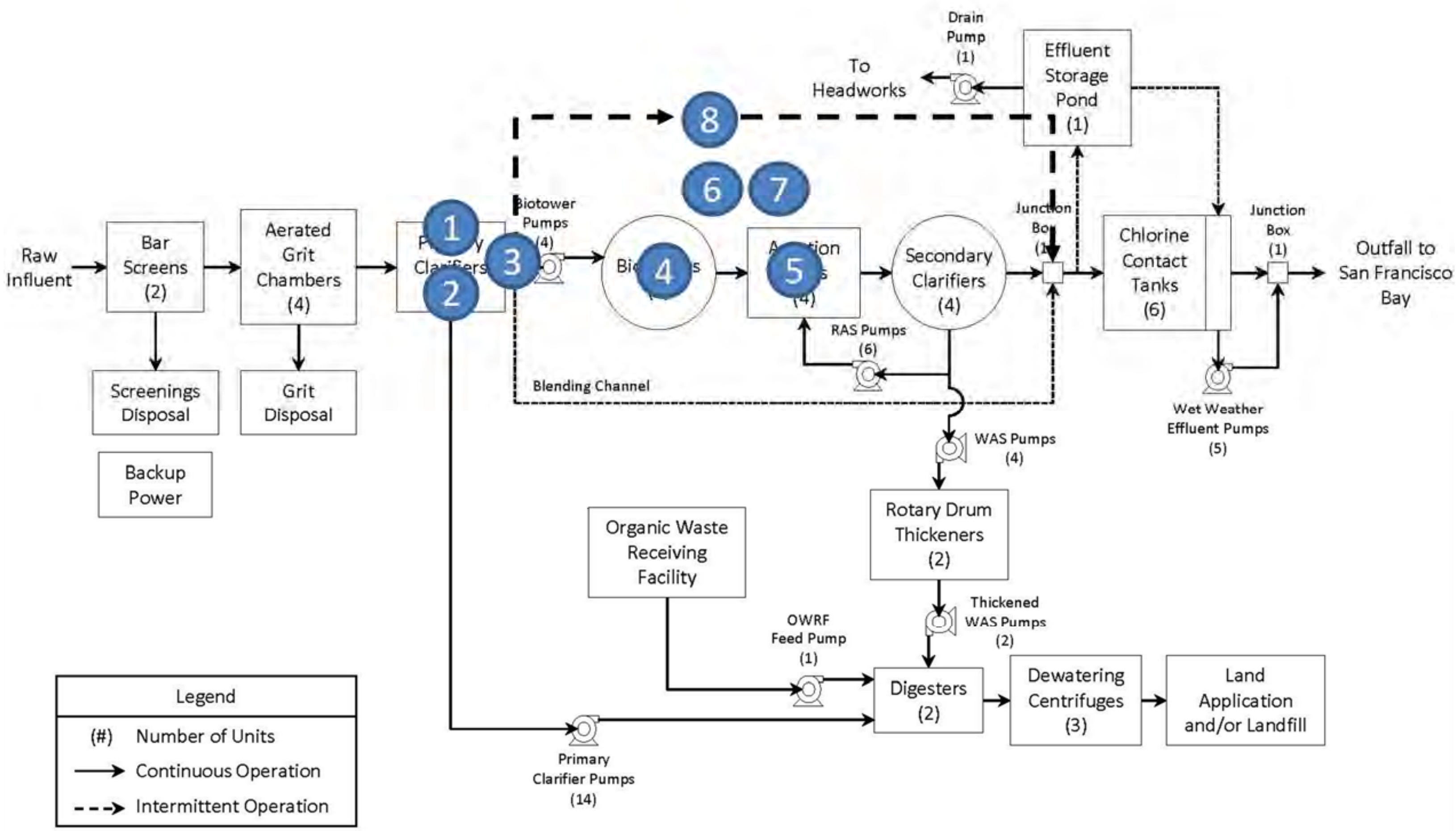

Figure 6-1. Level 2 Upgrade Concepts for CMSA WWTP

(1) Use existing ferric chloride chemical feed facilities to operate in Chemically Enhanced Primary Treatment (CEPT) mode, (2) modify the existing polymer feed delivery system to operate in CEPT mode, (3) modify the primary effluent flow split structure to send a portion of flow to the existing secondary treatment facilities and the remaining to new MBR facilities, (4) modify the biotowers for internal recirculation to facilitate nitrification, (5) increase the SRT in the aeration basins and add an up-front anoxic zone for nitrification/denitrification mode, (6) add alkalinity chemical feed facilities (if required), (7) add external carbon source chemical feed facilities, and (8) add new MBR facilities to treat a portion of flow.

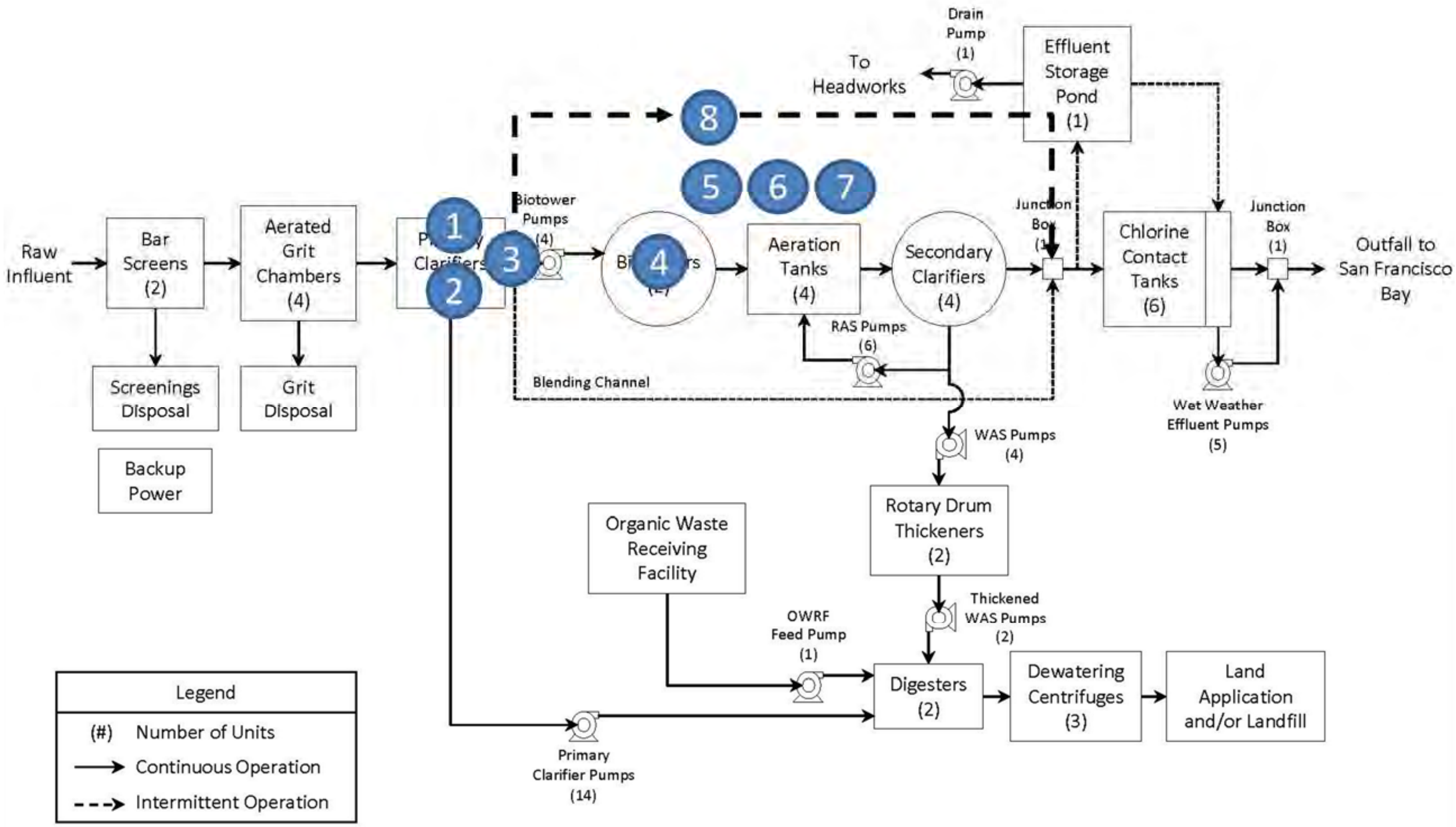

Figure 6-2. Level 3 Upgrade Concepts for CMSA WWTP

(1) Use existing ferric chloride chemical feed facilities to operate in Chemically Enhanced Primary Treatment (CEPT) mode, (2) modify the existing polymer feed delivery system to operate in CEPT mode, (3) modify the primary effluent flow split structure to send all the flow required more than primary treatment to the new MBR facilities, (4) decommission the existing secondary treatment facility, (5) add alkalinity chemical feed facilities (if required), (6) add external carbon source chemical feed facilities, (7) add ferric chloride chemical feed facilities to the MBR, and (8) add new MBR facilities.

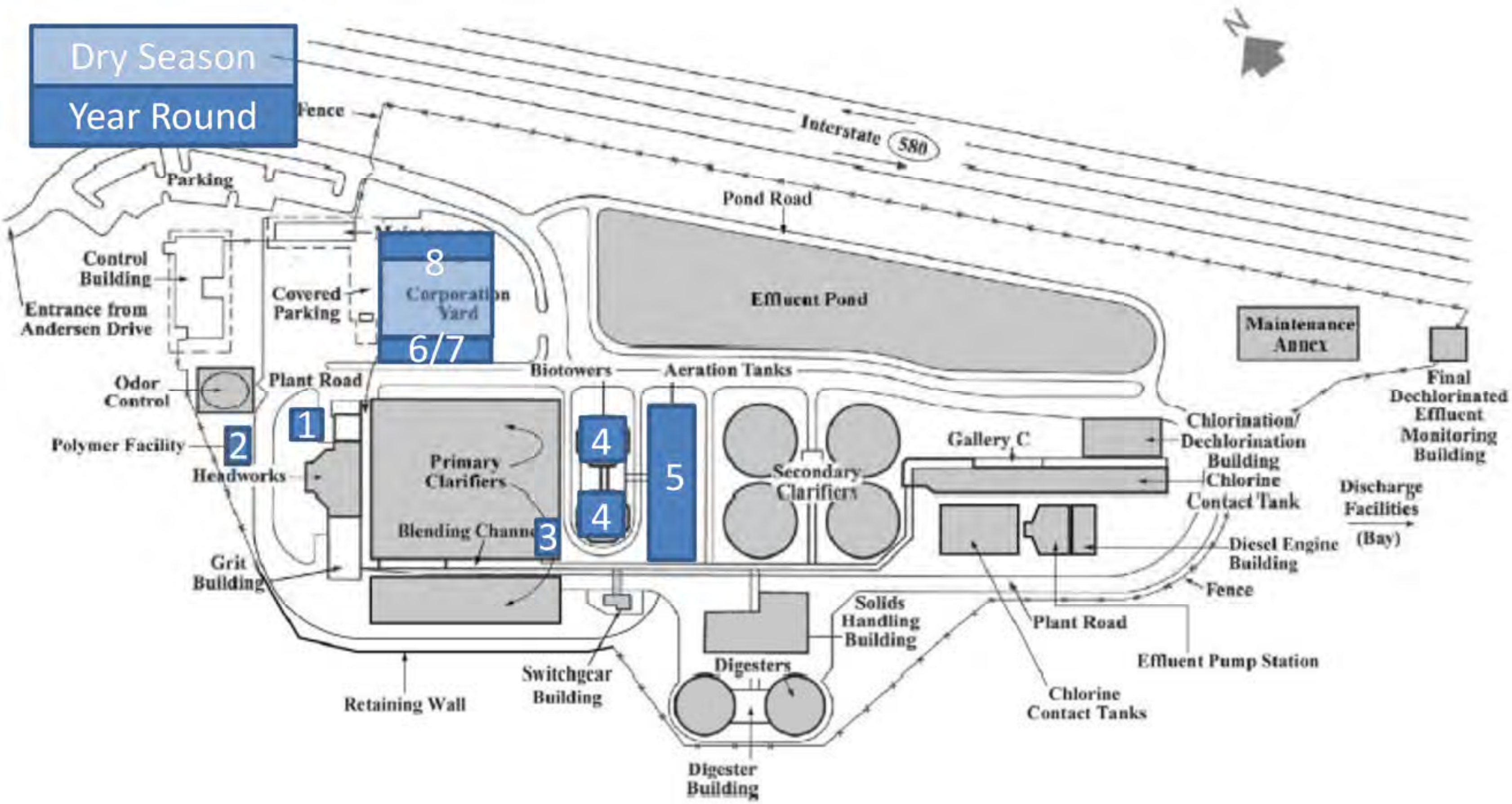

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Use existing ferric chloride chemical feed facilities to operate in Chemically Enhanced Primary Treatment (CEPT) mode, (2) modify the existing polymer feed delivery system to operate in CEPT mode, (3) modify the primary effluent flow split structure to send a portion of flow to the existing secondary treatment facilities and the remaining to new MBR facilities, (4) modify the biotowers for internal recirculation to facilitate nitrification, (5) increase the SRT in the aeration basins and add an up-front anoxic zone for nitrification/denitrification mode, (6) add alkalinity chemical feed facilities (if required), (7) add external carbon source chemical feed facilities, and (8) add new MBR facilities to treat a portion of flow.

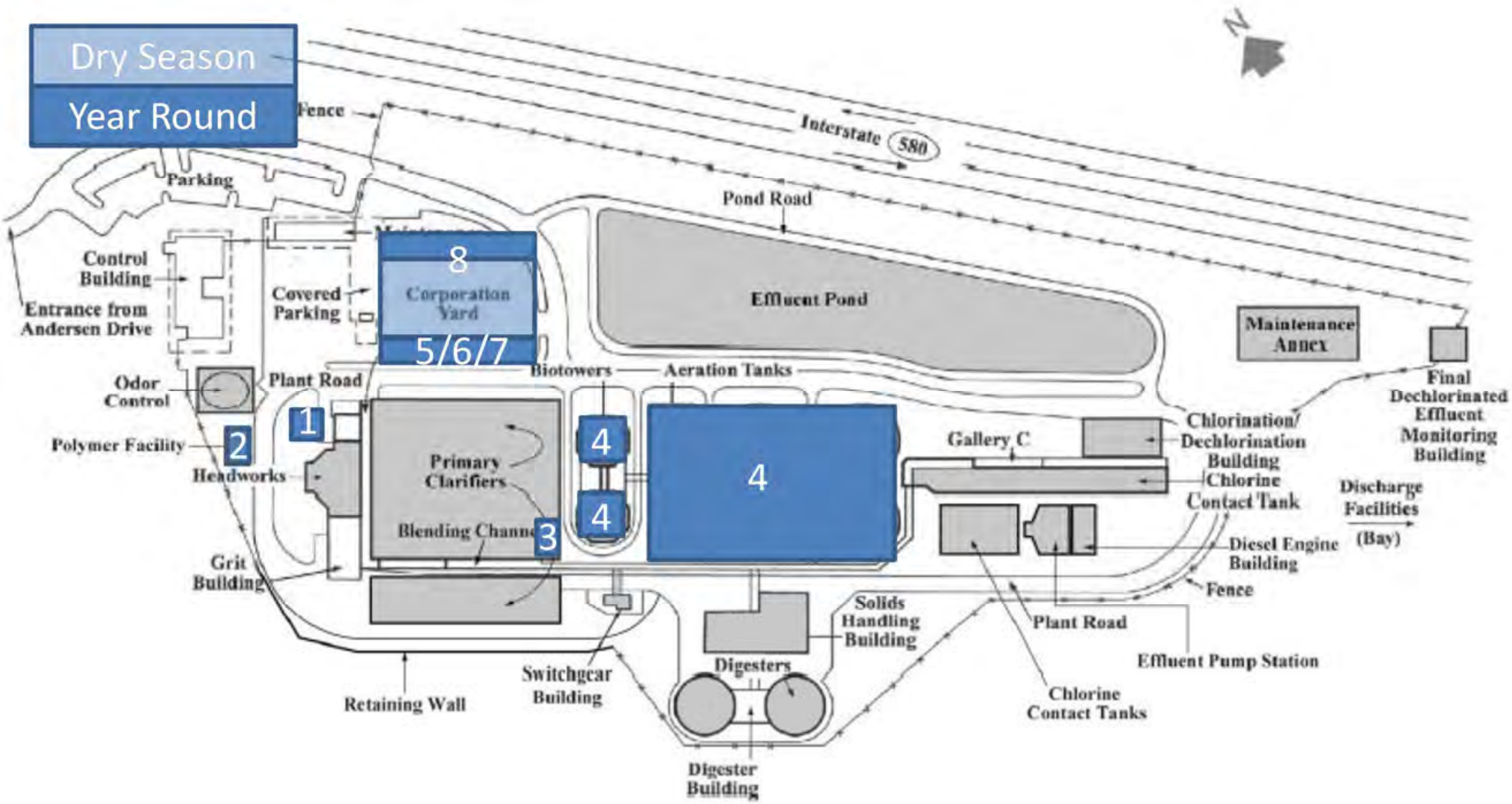

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Use existing ferric chloride chemical feed facilities to operate in Chemically Enhanced Primary Treatment (CEPT) mode, (2) modify the existing polymer feed delivery system to operate in CEPT mode, (3) modify the primary effluent flow split structure to send all the flow required more than primary treatment to the new MBR facilities, (4) decommission the existing secondary treatment facility, (5) add alkalinity chemical feed facilities (if required), (6) add external carbon source chemical feed facilities, (7) add ferric chloride chemical feed facilities to the MBR, and (8) add new MBR facilities.

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	10.0	14.5	10.0	14.5
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	190	200	250	260
Annual O&M	$Mil/yr	5.4	5.8	6.3	6.8
O&M PV[3]	$ Mil	120	130	140	150
Total PV[3]	$ Mil	310	330	390	410
Unit Capital Cost	$/gpd	19	14	25	18
Unit Total PV	$/gpd	31	22	39	28
TN Removal					
Capital[2,4]	$ Mil	190	190	250	260
Annual O&M[4]	$ Mil/yr	4.8	5.2	5.7	6.1
O&M PV[3,4]	$ Mil	110	120	130	140
Total PV[3,4]	$ Mil	290	310	380	390
TN Removed (Ave.)[6]	lb N/d	1,500	1,600	1,800	2,300
Annual TN Removed (Ave.)[7]	lb N/yr	561,000	592,000	673,000	841,000
TN Cost[4,8]	$/lb N	18	18	19	16
TP Removal					
Capital[2,5]	$ Mil	1.3	1.3	1.9	2.1
Annual O&M[5]	$ Mil/yr	0.6	0.6	0.6	0.7
O&M PV[3,5]	$ Mil	12.7	13.8	14.6	16.1
Total PV[3,5]	$ Mil	14.0	15.1	16.5	18.2
TP Removed (Ave.)[6]	lb P/d	180	180	200	240
Annual TP Removed (Ave.)[7]	lb P/yr	65,000	67,000	73,000	87,000
TP Cost[5,8]	$/lb P	7.2	7.5	7.5	7.0

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Better phosphorus and nitrogen removal • Increased chemicals of emerging concern (CECs) removal • High quality product water amenable to recycled water • MBR has a compact footprint compared to existing secondary treatment	• Additional chemicals from CEPT • Increase energy demand from the MBR • Safety from external carbon source • Operate a new process that will require the operators to get accustomed to
Level 3	Same as Level 2 plus the following additional benefits: • Further alkalinity recovery due to more denitrification than the other Levels	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2

7 Nutrient Load Reduction by Other Means

CMSA has an existing recycled water program that is employed year-round. The program includes a recycled water truck fill station, as needed water for pond habitat maintenance (at Remillard Park (City of Larkspur)), and internal water for on-site non-potable applications, such as landscape irrigation, boiler water, engine-generator cooling water, plant heating loop, evaporative cooling, tank wash down, etc. The recycled water truck fill station is primarily used by satellite collection agencies for sewer line flushing and possibly in the future for other recycled water uses (construction site dust control, street/sidewalk cleaning by local municipalities, and median strip irrigation). The internal water program does not necessarily reduce nutrient loads to the Bay. Rather, it reduces potable water demand on the order of 750 acre-feet per year (240 million gallons per year).

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

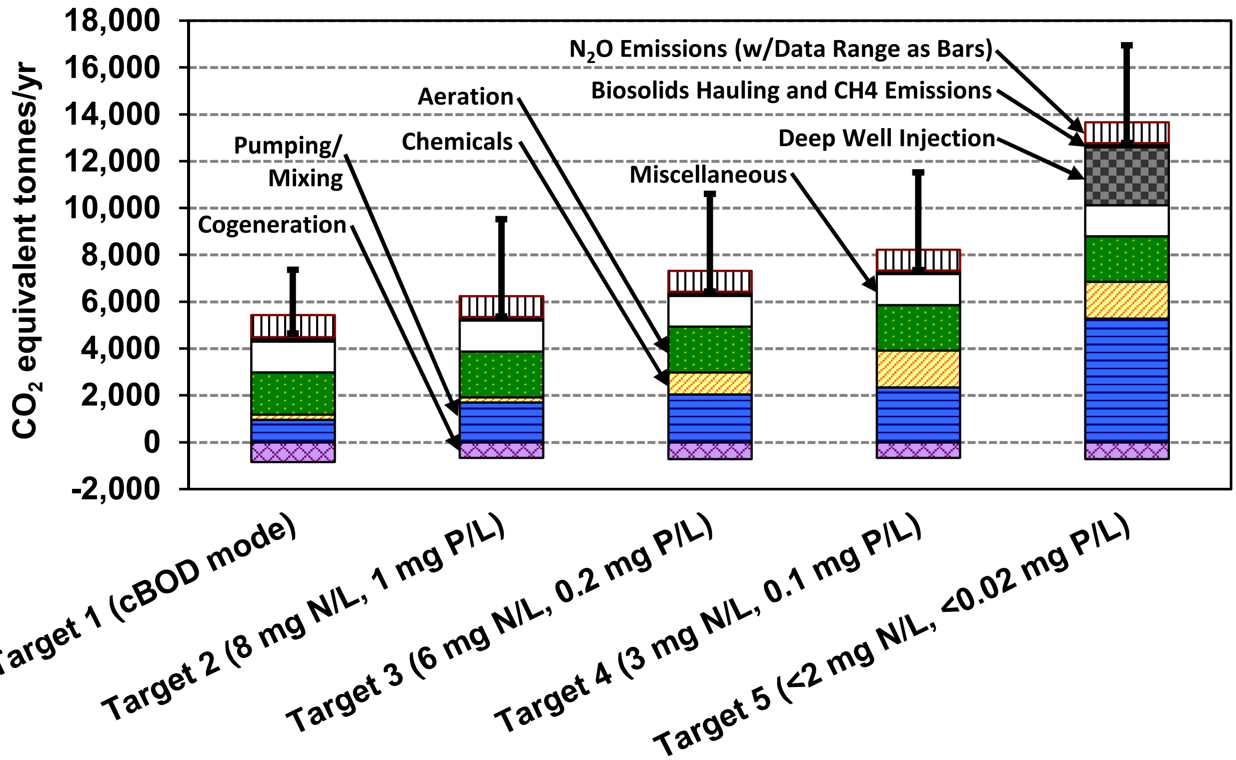

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA

eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	400	700	2,700	3,500	3,700	4,500	58
GHG Emissions Increase from Chemicals	MT CO_2/yr	17,000	19,000	9,700	11,200	9,800	8,600	16
GHG Emissions Increase Total	MT CO_2/yr	17,400	19,700	12,400	14,700	13,500	13,100	74
Unit GHG Emissions[2]	lb CO_2/MG	9,900	11,200	5,900	7,000	6,500	6,200	65
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	180	180	40	50	40	40	1.1
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	-*	50	50	40	30	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	10	10	3	5	6	6	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

* The optimization strategy will not reduce total nitrogen loads. Rather, it will improve ammonia load reduction.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at CMSA:

- Nutrient Removal using Granular Sludge – this could be used to phase out the biotower/activated sludge. In fact, the existing biotower tankage could potentially be repurposed to serve as a granular sludge reactor. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
    - Advantages: Low footprint requirements (opportunity at CMSA to use existing biotower tankage as a granular sludge reactor), energy efficient, ability to remove ammonia, TN, and TP.
    - Disadvantages: No installations in North America.
    - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Emerging Membrane Bioreactor (MBR) – the report considered established MBR technologies. There are emerging MBR technologies (e.g., Anaergia) that provide an even more compact footprint than established MBR technologies. The footprint savings relates to less required membrane area. Such a membrane savings results in a reduced unit energy demand for air scour compared to established MBR technologies. The benefit to CMSA is it has the potential to further save footprint with a reduced energy demand with respect to established MBR technologies. While there are limited installations in North America of such MBR technologies, several plants are evaluating such technologies for upcoming designs.
    - Advantages: Low footprint requirements, more energy efficient than established MBR technologies, high quality product water amenable to reuse, ability to remove ammonia, TN, and TP.
    - Disadvantages: Limited installations in North America.
    - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	9%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.21 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.55/gal for 12.5%
Ferric Chloride	$479/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$6.24/gal which is $0.734/lb

D.6

Delta Diablo Wastewater Treatment Plant

Bay Area Clean Water Agencies
Nutrient Reduction Study

Delta Diablo Wastewater Treatment Plant

Antioch, CA

June 18, 2018
Final Report

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Executive Summary

Delta Diablo (DD) owns and operates the Delta Diablo Wastewater Treatment Plant (DDWWTP) located in Antioch, CA and discharges treated effluent to New York Slough (a tributary to the San Joaquin River which feeds into Suisun Bay). The plant has an average dry weather flow (ADWF) permitted capacity of 19.5 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs (e.g., $/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	13.0	13.1	19.5	19.6	19.5	19.6	--
Flow to Bay[2]	mgd	6.8	6.8	6.8	6.8	10.1	10.1	10.1	10.1	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	3,050*	3,050*	2,700	2,520	180	170	180	170	1,470
TN	lb N/d	3,460	3,460	3,180	2,970	1,350	1,260	960	500	3,640
TP	lb P/d	70	70	60	60	90	80	60	30	90
Costs[4,5]										
Capital	$ Mil	--	--	5.8	6.1	130	134	162	167	14.5
O&M PV	$ Mil	--	--	4.5	5.7	94	103	105	108	8.4
Total PV	$ Mil	--	--	10.3	11.8	224	237	267	275	22.9
Unit Costs[6]										
Capital	$/gpd	--	--	0.4	0.5	6.6	6.8	8.3	8.5	--
Total PV	$/gpd	--	--	0.8	0.9	11.5	12.1	13.7	14.0	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

* The 2015 BACWA Nutrient Reduction Study Group Annual Report ammonia data was adjusted to reflect more recent ammonia:total nitrogen ratios. Prior to 2016, the power plants would intermittently go in and out of nitrification/denitrification in their cooling towers, changing the nitrogen loading/speciation in the blowdown. This operation has since been prohibited and the 2015 data has been adjusted to better represent loadings for the optimization and upgrades analysis.

The recommended optimization concepts to reduce nutrient loads in the plant effluent includes:

1. Optimize metal salt addition to the Pittsburg and Antioch pumping stations, recycled water facility, or somewhere else in the treatment plant. Additionally, a polymer chemical feed facility would be required. This effectively turns the primaries into chemically enhanced primary treatment (CEPT) to increase phosphorus, TSS, and BOD removal.
2. Split treatment at the biotowers for ammonia removal by diverting a portion of the load to biotowers 1 and 2 and sending the remaining flow to biotowers 3 and 4.
3. Additional blower capacity to meet firm capacity demands for ammonia/TN load reduction. The existing blowers provide sufficient total capacity (i.e., no redundancy). The analysis is based on having a redundant unit and maintaining firm blower capacity.
4. Construct a zone in each completely mixed aeration basin that can operate as a seasonal anoxic zone for total nitrogen load reduction (predicated on implementation of split treatment at the biotowers).

DD is a candidate for sidestream treatment to reduce nitrogen loads because the plant anaerobically digests their biosolids and dewaters to produce a return sidestream laden with nitrogen. The recommended sidestream treatment strategy is a deammonification technology for reducing ammonia/nitrogen loads.

DD is not considered a viable candidate for sidestream treatment to reduce phosphorus loads as the plant is already removing phosphorus loads in the primary clarifiers.

The upgrade strategies to achieve Levels 2 and 3 include:

- Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
  - Add a flow split structure to divert a portion of primary influent to a new membrane bioreactor (MBR).
  - Add a new MBR to treat a portion of primary influent.
  - Convert a portion of the aeration basins to an anoxic zone.
  - Add a biological aerated filter (BAF) and a feed pumping station plus the ancillary facilities.
  - Alkalinity chemical feed facilities at the BAF to nitrify ammonia that bleeds through the biotower/activated sludge process.
  - Add denitrifying filters and a feed pumping station plus the ancillary facilities.
  - Chemical feed facilities at the denitrifying filter complex (external carbon source, metal salt, and polymer).
- Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L):
  - Same as Level 2, plus
  - Expansion of the MBR and denitrifying filters.
  - Addition of rapid mix and flocculation tanks.
  - Increased chemical dosing at the denitrifying filters to further reduce total nitrogen and total phosphorus loads.

Capital costs, O&M costs and present value costs were determined for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for changes in solids handling requirements or energy requirements in other unit processes.

As shown in Table ES-1, and as might be expected, the costs generally increase from optimization to sidestream, and again to Level 2 and Level 3 upgrades, respectively. The costs generally increase for both capital and O&M from the dry season to year round. Overall, the present value costs range from $10 Mil for optimization up to $275 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. The GHG emissions associated with energy increased with the treatment level. In contrast, the GHG emissions associated with chemicals decreased with treatment level.

1 Introduction

The Delta Diablo Wastewater Treatment Plant (DDWWTP) discharges to New York Slough (a tributary to the San Joaquin River which feeds into Suisun Bay). It is located at 2500 Pittsburg-Antioch Highway, Antioch, CA 94509, and it serves about 57,700 service connections throughout Pittsburg, Antioch, and the unincorporated community of Bay Point. The plant has an average dry weather flow (ADWF) permitted capacity of 19.5 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

DDWWTP holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2014-0030; CA0038547. Table 2–1 provides a summary of some relevant permit requirements for DDWWTP. Table 2–1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2–1. NPDES Permit Limitations (Order No. R2-2014-0030; CA0038547)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	19.5			
BOD	mg/L		30	45	-
TSS	mg/L		30	45	-
Total Ammonia, as N	mg/L		170	-	220

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for DDWWTP. Both liquids processes and solids processes are shown. The DDWWTP has primary clarifiers, followed by the option to divert flows to flow equalization and a trickling filter/activated sludge (TF/AS) system for secondary treatment. The TF/AS maintains a low SRT (less than 3 days) for secondary treatment. A portion of secondary effluent is conveyed to a water recycling facility and the remaining portion is sent to disinfection prior to discharge. A majority of the recycled water is sent to nearby power plants that return blowdown upstream of disinfection. Solids treatment consists of thickening, anaerobic digestion and dewatering.

Phosphorus is removed in the primary clarifiers as a result of the ferrous chloride added in the collection system coupled with alum in the recycled water facility clarifier sludge that is returned to the headworks of the DDWWTP.

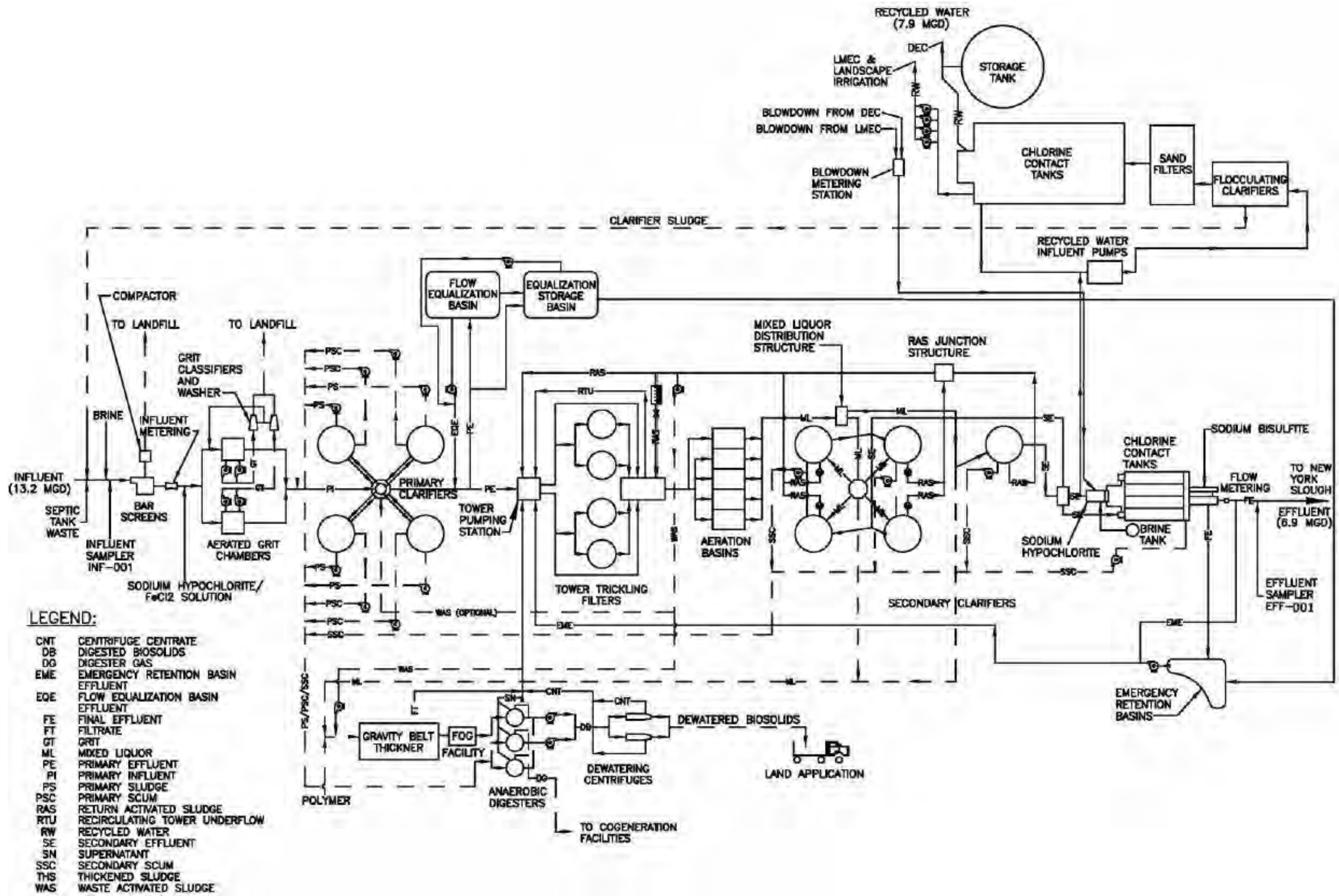

Figure 2-1. Process Flow Diagram for Delta Diablo Wastewater Treatment Plant

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for DDWWTP is shown in Table 2–2.

Table 2–2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	12.5	13.1	13.3	13.7
BOD	lb/d	35,700	37,400	38,700	41,700
TSS	lb/d	38,500	38,900	42,500	43,400
Ammonia	lb N/d	3,500	3,800	3,800	4,100
Total Kjeldahl Nitrogen (TKN)	lb N/d	5,400	5,700	6,000	6,200
Total Phosphorus (TP)	lb P/d	570	760	2,100	1,600
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	329	344	347	364
TSS	mg/L	355	357	382	379
Ammonia	mg N/L	32	35	34	36
TKN	mg N/L	50	52	54	54
TP	mg P/L	5.3	7.0	19.2	13.6
Alkalinity	mg $CaCO_3$/d	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

The 2011 Treatment Plant Master Plan Update identified facility needs to remove nutrients and increase recycled water using various technologies. However, implementation of these projects has been delayed due to slow growth and regulatory uncertainty

Delta Diablo is in the process of evaluating an organics co-digestion project. Such a project would increase nutrient discharge loads in the dewatering return sidestream. As part of the project, Delta Diablo is planning to treat the dewatering return sidestream which would not only decrease the added nitrogen load from the co-digestion of organics, but would also reduce nitrogen discharge to the Bay from wastewater sources.

2.5 Pilot Testing

In partnership with Stanford University, Delta Diablo conducted pilot testing of an embryonic technology known as the Coupled Aerobic-anoxic Nitrous Decomposition Operation (CANDO) for treating their dewatering return stream, known as the sidestream. The CANDO process converts ammonia in the sidestream to nitrous oxide with the eventual intent of recovering the nitrous oxide and blending it with biogas to be used in a cogeneration engine to increase energy production. The current pilot testing involves the conversion of ammonia to nitrous oxide and does not include the nitrous oxide utilization. This pilot testing effort was part of the EPA Regional Grant on Sidestream Treatment that is being led by East Bay Municipal Utility District (EBMUD). The EPA Regional Grant on Sidestream Treatment can be found at: https://bacwa.org/wp-content/uploads/2017/05/EPA-Grant-Sidestream-Nutrient-Removal-Study-Report-04282017.pdf.

Delta Diablo is also pilot testing the Zeolite-Anammox technology in partnership with the power plants that receive recycled water for their cooling towers. The technology has the potential to reduce capital and operating costs as compared to more established technology and is being tested on secondary effluent and centrate.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where information about future projections are unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Plant upgrade strategies were developed based on design capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for the DDWWTP are presented in Table 3–1. The projected flow and load for DDWWTP in 2025 was not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided, it was determined that DDWWTP may be a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the permitted capacity for use in the sidestream treatment evaluation. The sidestream flows and loads for the permitted capacity are provided in Table 3–2. The permitted capacity flows and loads were used in the facility sizing.

The values in Table 3–2 due to not account for any increase in sidestream loads associated with implementation of an organics receiving facility. As previously stated, such a facility would increase nutrient discharge loads. If Delta Diablo moves forward with the organics receiving facility, the sidestream flows and loads would need to be updated to reflect the additional loads associated with organics.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan, San Francisco Regional Water Quality Control Board Comments Incorporated.

Table 3–1. Raw Influent Flow and Load for Optimization (Projected to 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	12.5	13.1	13.3	13.7
BOD	lb/d	41,100	43,000	44,500	48,000
TSS	lb/d	44,300	44,700	48,900	49,900
Ammonia	lb N/d	4,000	4,400	4,400	4,700
TKN	lb N/d	6,200	6,600	6,900	7,100
TP[4]	lb P/d	660	870	2,500	1,800
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	379	394	401	420
TSS	mg/L	409	409	441	437
Ammonia	mg N/L	37	40	40	41
TKN	mg N/L	57	60	62	62
TP[4]	mg P/L	6	8	22	16
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. The TP maximum levels are atypically concentrated due to backwash return from the recycled water facility.

Table 3–2. Feed Flow and Loads for Sidestream Treatment*

Criteria	Unit	Current	Projected to Permitted Flow Capacity
Sidestream Flow[1]	mgd	0.07	0.10
Ammonia	lb N/d	680	1,030
TKN	lb N/d	850	1,270
TN[2]	lb N/d	850	1,270
OrthoP	lb P/d	55	83
TP	lb P/d	30	45
Alkalinity	lb $CaCO_3$/d	2,750	4,110
Ammonia	mg N/L	1,260	1,260
TKN	mg N/L	1,570	1,570
TN[1]	mg N/L	1,570	1,570
OrthoP	mg P/L	100	100
TP	mg P/L	60	60
Alkalinity	mg/L as CaCO3	5,070	5,070

1. Feed flow is the dewatering centrate flow.
2. It was assumed that TKN = TN.

* The sidestream flows and loads do not account for any increase in sidestream loads associated with implementation of an organics co-digestion project. If such a facility is implemented, the flows and loads and corresponding facility needs would need to be updated.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3–3. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3–3. Raw Influent Flow and Load for Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	19.5	19.5	20.0	20.6
BOD	lb/d	53,500	56,100	58,000	62,400
TSS	lb/d	57,600	58,200	63,700	65,000
Ammonia	lb N/d	5,200	5,700	5,700	6,200
TKN	lb N/d	8,100	8,500	9,000	9,300
TP[4]	lb P/d	850	1,140	3,200	2,310
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	329	344	347	364
TSS	mg/L	355	357	382	379
Ammonia	mg N/L	32	35	34	36
TKN	mg N/L	50	52	54	54
TP[4]	mg P/L	5.3	7.0	19.2	13.6
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. The TP maximum levels are atypically concentrated due to clarifier sludge from the recycled water facility.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy.

Four optimization strategies were identified during the DD site visit (Appendix B). These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The results of the screening are as follows:

- **Optimization Strategy 1:** Optimize metal salt addition to the Pittsburg and Antioch pumping stations, recycled water facility, or somewhere else in the treatment plant. Additionally, a polymer chemical feed facility would be required. This effectively turns the primaries into chemically enhanced primary treatment (CEPT) to increase phosphorus, TSS, and BOD removal. While DDWWTP is already adding ferrous and alum chemicals, the dosing could be further optimized along with new polymer chemical feed facilities to meet the current objectives plus phosphorus removal in the primaries.
    - ***Is it feasible?*** Yes, but it will require new polymer chemical feed facilities.

- ➢ ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal and reduce loading to biotowers. This could enhance the potential to remove ammonia in the nitrifying biotowers.
- ➢ ***Result from analysis:*** It will marginally increase P removal because the plant is already removing P. However, it will improve the day to day reliability and thus deemed potentially viable.
- ➢ ***Recommendation:*** Carry forward.

❖ **Optimization Strategy 2:** Seasonal nitrification in the aeration basins by increasing the solids residence time (SRT) in the warmer summer months to remove ammonia.

- ➢ ***Is it feasible?*** No; the mixed liquor levels would increase above industry accepted levels.
- ➢ ***Potential impact on ability to reduce nutrient discharge loads?*** Full ammonia removal in the aeration basins during the dry season. No total nitrogen reduction.
- ➢ ***Result from analysis:*** Mixed liquor in the aeration basins would be too high. The current MLSS is about 2,200 mg/L; the solids would increase to about 6,000 mg/L as the aerobic SRT increases to a marginal 6 days. Furthermore, the oxygen uptake rate would increase above reasonable levels. No nitrogen reduction is achieved without anoxic zones.
- ➢ ***Recommendation:*** Do not carry forward.

❖ **Optimization Strategy 3:** Split treatment with the biotowers (4 in total). Use biotowers 1 and 2 for seasonal nitrification by decreasing the feed flow and send the remaining flow to biotowers 3 and 4. By decreasing the flow and increasing the internal recirculation, the low loading would foster the growth of ammonia oxidizing bacteria and results in nitrification. This strategy can be modified from ammonia to total nitrogen removal by sending a portion of primary effluent to the completely mixed aeration basins modified with up-front anoxic zones for denitrification (see strategy 4 below).

- ➢ ***Is it feasible?*** Yes, but it would require significant pumping, piping valving modifications, and additional blower capacity. Additional blower capacity would be required to maintain firm capacity (i.e., redundant unit). The existing blowers provide sufficient total capacity (i.e., no redundancy). The analysis is based on having a redundant unit.
- ➢ ***Potential impact on ability to reduce nutrient discharge loads?*** Remove a portion of the ammonia load during the dry season.
- ➢ ***Result from analysis:*** Maximum flow that can be base loaded to the nitrifying biotowers 1 and 2 will reduce the ammonia load approximately 15 to 25%.
- ➢ ***Recommendation:*** Carry forward.

❖ **Optimization Strategy 4:** Construct a zone in each completely mixed aeration basin that can operate as a seasonal anoxic zone to facilitate denitrification. This strategy is predicated on implementation of Optimization Strategy 3. A portion of primary effluent would bypass the biotowers to provide carbon to denitrify the effluent from nitrifying biotowers 1 and 2.

- ➢ ***Is it feasible?*** Yes, but requires implementation of Optimization Strategy 3.
- ➢ ***Potential impact on ability to reduce nutrient discharge loads?*** Remove a portion of the nitrogen load during the dry season.
- ➢ ***Result from analysis:*** Maximum flow that can be base loaded to nitrifying biotowers 1 and 2 is 15% of the load. This nitrified ammonia load would be subsequently removed in the anoxic zone within the aeration basins that are created as part of Optimization Strategy 3.
- ➢ ***Recommendation:*** Carry forward.

A combination of Strategies 1, 3 and 4 is the best apparent way to reduce effluent nutrient loads. Strategy 1 is a stand-alone optimization process that focuses on phosphorus. The additional solids and organics removal associated with Strategy 1 will result in additional capacity in the downstream biotowers/activated sludge. This additional capacity would further reduce ammonia/total nitrogen load reduction for Strategies 3 and 4. Split treatment (Strategy 3) would transform biotowers 1 and 2 into nitrifying biotowers by reducing the loading to a few mgd. Strategy 4 is predicated on implementation of Strategy 3 where the ammonia converted to nitrate in Strategy 3 is removed in the aeration basins anoxic zone. Such an anoxic zone would need to be constructed in each completely mixed basin.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of each strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.
The capital and operational elements of the nutrient removal optimization strategies carried forward are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
CEPT for P Removal • Polymer chemical feed facilities	• Optimize the existing ferrous chloride facilities • Operate the new polymer chemical feed facilities
Split Treatment at Biotowers • Modifications to the piping and valving at the biotower flow split structure	• Decrease pumping to biotowers 1 and 2. • Increase biotower recirculation for 1 and 2 to maintain wetting rate.
Blower Capacity • Additional blower capacity would be required to maintain firm capacity (i.e., redundant unit). The existing blowers provide sufficient total capacity (i.e., no redundancy). The analysis is based on having a redundant unit.	• Maintain additional blowers
Construct a zone in each completely mixed aeration basin that can operate as a seasonal anoxic zone • Modifications to send the biotower bypass flow to the appropriate aeration basins. • Construct a zone in each completely mixed aeration basin that operates as an anoxic zone. • Modify the aeration supply to the anoxic zones for seasonal denitrification.	• Control the flow bypass so that a predefined volume of primary effluent is sent to the anoxic zone. • Have the ability to reduce airflow to the first aeration basin zone so that it operates as an anoxic zone.

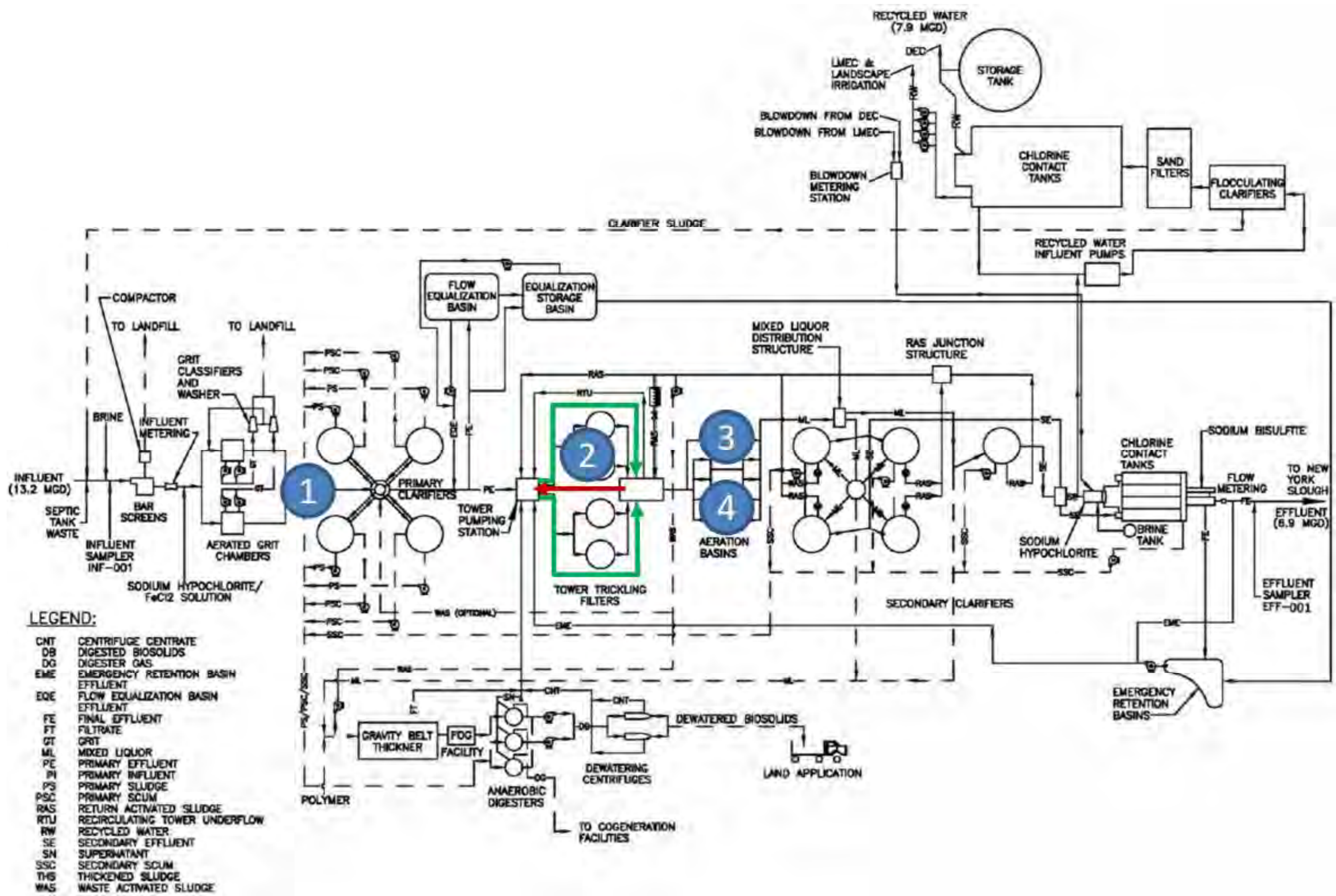

Figure 4-1. Optimization Concepts Considered for the Delta Diablo Wastewater Treatment Plant

(1) Optimize metal salt dosing and add polymer chemical feed facilities for chemically enhanced primary treatment (CEPT) to enhance existing TP load reduction, (2) split treatment at the biotowers for ammonia/TN load reduction, (3) additional blower capacity to meet firm capacity demands for ammonia/TN load reduction (current blowers provide sufficient total capacity; the analysis is based on having a redundant unit), and (4) construct a zone in each completely mixed aeration basin that operates as a seasonal anoxic zone for denitrification. (predicated on implementation of (3)).

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	3,280*	3,280*	3,720	3,720	80	80
Discharge with Opt. Strategy[1]	lb N or P/d	2,700	2,520	3,180	2,970	60	60
Load Reduction[2]	lb N or P/d	580	760	550	750	20	20
Load Reduction[2]	%	18%	23%	15%	20%	21%	26%
Annual Load Reduction[3]	lb N or P/yr	210,600	276,520	199,000	275,000	5,930	7,270

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.

* The 2015 BACWA Nutrient Reduction Study Group Annual Report ammonia data was adjusted to reflect more recent ammonia:total nitrogen ratios. Prior to 2016, the power plants would intermittently go in and out of nitrification/denitrification in their cooling towers, changing the nitrogen loading/speciation in the blowdown. This operation has since been prohibited and the 2015 data has been adjusted to better represent loadings for the optimization and upgrades analysis.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	13.0	13.1
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	5.8	6.1
Annual O&M	$ Mil/yr	0.50	0.6
Present Value O&M[3]	$ Mil	4.5	5.7
Present Value Total[3]	$ Mil	10.3	11.8
Unit Capital Cost[8]	$/gpd	0.4	0.5
Unit Total PV Cost[8]	$/gpd	0.8	0.9
TN Removal			
Capital[2,4]	$ Mil	5.8	6.1
Annual O&M[4]	$ Mil/yr	0.5	0.6
O&M PV[3,4]	$ Mil	4.5	5.7
Total PV[3,4]	$ Mil	10.3	11.8
TN Removed (Ave.)[6]	lb N/d	550	750
Annual TN Removed (Ave.)[7]	lb N/yr	199,000	275,000
TN Cost[4,9]	$/lb N	5.1	4.3
TP Removal			
Capital[2,5]	$ Mil	0.6	0.6
Annual O&M[5]	$ Mil/yr	0.05	0.08
O&M PV[3,5]	$ Mil	0.4	0.7
Total PV[3,5]	$ Mil	1.0	1.3
TP Removed (Ave.)[6]	lb P/d	16	20
Annual TP Removed (Ave.)[7]	lb P/yr	5,930	7,270
TP Cost[5,9]	$/lb P	17.6	17.9

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 10 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at DDWWTP.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
CEPT for P Removal • Ability to optimize P removal • Increase the downstream treatment capacity (biotowers/activated sludge) • Further reduce odors in the collection system • Control struvite related issues (if any exist)	• Increase in operational cost from increased chemical demand
Split Treatment at Biotowers • Ability to reduce seasonal ammonia loads • Reduce waste activated sludge yield	• Need to operate parallel biotowers • Major piping/valving/pumping modifications required • Internal recirculation required for the biotower that is fully nitrifying • Alkalinity lost during nitrification
Blower Capacity • Ability to reduce seasonal ammonia loads	• Additional energy demand • Additional blower capacity required to meet firm capacity demands (current blowers would provide sufficient total capacity; the analysis is based on having a redundant unit)
Construct a zone in each completely mixed aeration basin that can operate as a seasonal anoxic zone • Ability to reduce seasonal total nitrogen loads • Recovery of alkalinity lost during nitrification • Improved settleability in the secondaries • Reduce waste activated sludge yield • Reduce aeration demand from BOD consumption	• Need to operate both anoxic and aerobic zones

5 Sidestream Treatment

As previously described, DDWWTP was identified as a potential candidate for sidestream treatment. A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia/TN load reduction. TP load reduction is not recommended as the plant already removes TP by chemical precipitation. Thus, sidestream treatment for TP load reduction will most likely not decrease TP discharge loads.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification), including a 60 percent reduction oxygen demand as compared to conventional nitrification, elimination of organic carbon demand for nitrogen removal, and a 50 percent reduction in alkalinity as compared to conventional nitrification. Based on these benefits, deammonification is recommended for DDWWTP.

A list of the facility needs for sidestream treatment is provided in Table 5–1.

Table 5–1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements[1]
Feed Pumping (if necessary)	--
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

1. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5–1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge*

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)[4]
Current Discharge[1]	lb/d	2,240	4,330	90
Discharge with Sidestream Treatment[2]	lb/d	1,470	3,640	90
Load Reduction[3]	lb/d	770	690	0
Load Reduction	%	34%	16%	0%
Annual Load Reduction	lb/yr	280,800	249,600	0

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

* The sidestream flows and loads do not account for any increase in sidestream loads associated with implementation of an organics co-digesti project. If such a project is implemented, the flows and loads and corresponding facility needs would need to be updated.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade, as well as the estimated cost per pound of nutrient removed, are presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment*

Parameter	Units	Ammonia/TN	TP[7]
Capital[1]	$ Mil	14.5	--
Annual O&M	$ Mil/yr	0.4	--
Total Present Value[2]	$ Mil	22.9	--
NH4-N Load Reduction[3,5]	lb N/yr	280,800	--
TN Load Reduction[3,5]	lb N/yr	249,600	--
TP Load Reduction[4,5]	lb P/yr	--	--
NH4-N Cost [3,5,6]	$/lb N	2.7	--
TN Cost [3,5,6]	$/lb N	3.1	--
TP Cost [4,5,6]	$/lb P	--	--

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

* The sidestream flows and loads do not account for any increase in sidestream loads associated with implementation of an organics co-digestion project. If such a project is implemented, the flows and loads and corresponding facility needs would need to be updated.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at DDWWTP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities needed to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. Delta Diablo should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flowsheet presented in Figure 6-1. As shown, a parallel membrane bioreactor (MBR) to treat primary influent was selected. This technology selection is in accordance with the Master Plan Update (2011). A flow split structure would be required upstream of the primaries to convey a portion of the flow to the MBR. The MBR waste activated sludge (WAS) would be used to seed the biotower/activated sludge process. Additionally, an anoxic zone to reduce any nitrate produced in the biotowers or aeration basins would be used. This would require an external carbon source unless sufficient carbon is provided through bypassing primary effluent around the biotowers. The analysis is based on the latter.

In order to remove all the ammonia, a biologically aerated filter (BAF) with a feed pumping station is recommended to fully nitrify any ammonia that bleeds through the biotower/activated sludge. The BAF requires alkalinity lost within the BAF. The nitrate that bleeds through the biotower/activated sludge and formed within the BAF will be denitrified with denitrifying filters following the BAF. A feed pumping station would be required at the denitrifying filters. An external carbon source is required to serve as a carbon source at the denitrifying filters. Additionally, metal salt and polymer chemical feed facilities are required to further reduce TP loads in either the BAF or denitrifying filters.

Another strategy is to expend the reuse customer base as a means to divert nutrient loads away from discharging to the Bay.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flowsheet presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Level 3 upgrades would require expansion of the denitrifying filters and rapid mix/flocculating tanks to provide sufficient contact time prior to filtration. This additional step is required for Level 3 in order to meet the more stringent P levels. The external carbon demand at the denitrifying filters would increase to further reduce total nitrogen loads. These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure (i.e. biotower/activated sludge processes). This technology selection is in accordance with the recent Master Plan Update (2011).

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs is provided in Table 6-1.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Flow split structure upstream of the primaries to send portion of primary influent to the new MBR	Same as Level 2
Biological	• New MBR to treat primary influent • New Blowers and Aeration System for MBR • Air Piping for MBR • Construction of anoxic zones in each aeration basin • External carbon source addition to anoxic zone and/or bypass a portion of primary effluent around the biotowers. The analysis is based on the latter.	Same as Level 2 • Expand the MBR basins
Tertiary	• New BAF and feed pumping station plus the ancillary facilities • Alkalinity addition to BAF • New denitrifying filters and feed pumping station plus ancillary facilities • External carbon source addition to denitrifying filters • Metal salt and polymer chemical facilities	• Additional denitrifying filter area • Rapid mix and flocculation tanks

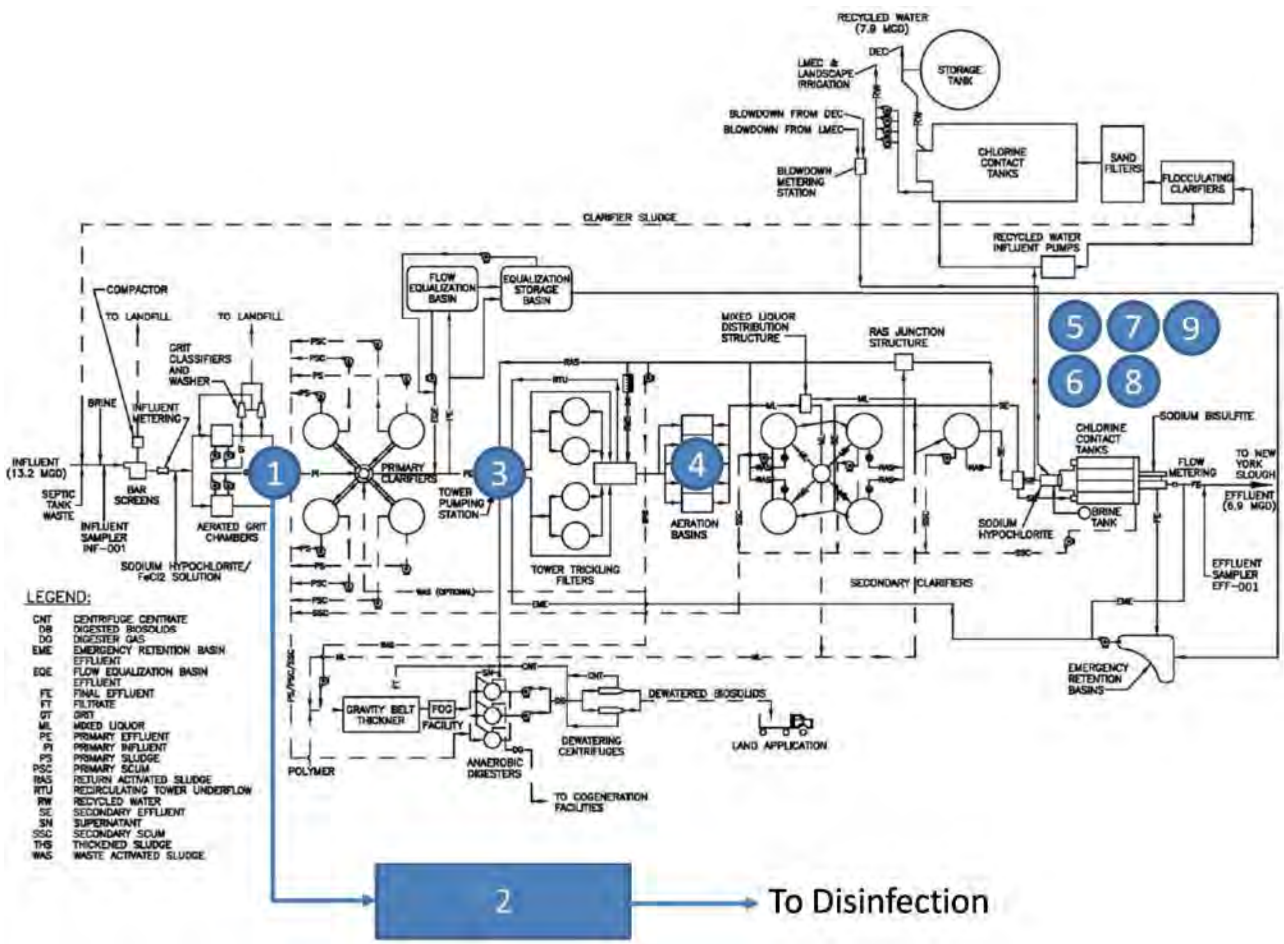

Figure 6-1. Level 2 Upgrade Concepts for Delta Diablo Wastewater Treatment Plant

(1) Flow split structure, (2) New membrane bioreactor, (3) bypass a portion of primary effluent around biotowers to the aeration basins as a means to provide carbon for denitrification, (4) construction of anoxic zones in each aeration basin, (5) new BAF facilities and feed pumping station, (6) alkalinity chemical feed facilities at the BAF, (7) new denitrifying filters and feed pumping station, (8) external carbon source chemical feed facilities for the denitrifying filters, and (9) metal salt/polymer chemical feed facilities

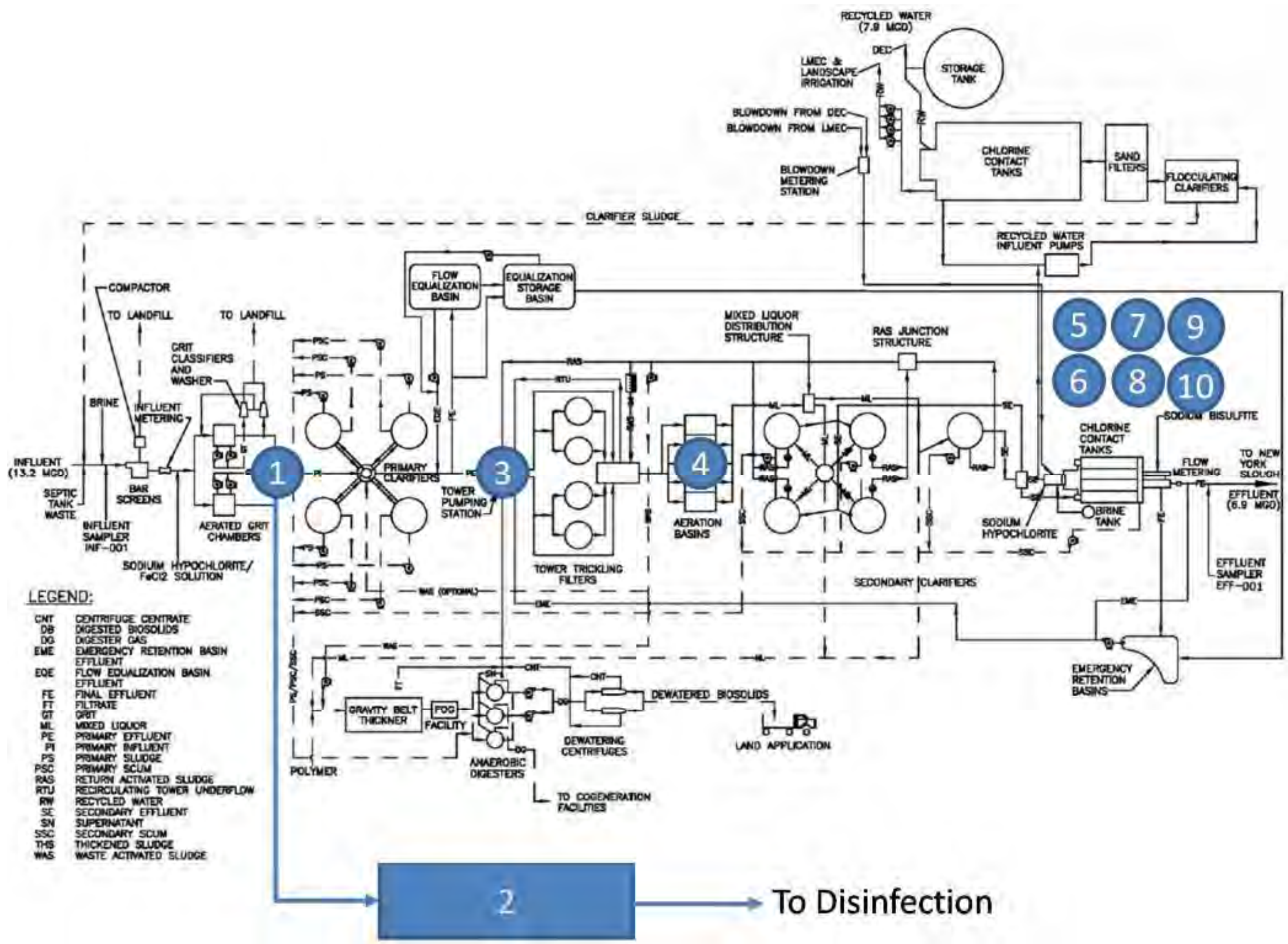

Figure 6-2. Level 3 Upgrade Concepts for Delta Diablo Wastewater Treatment Plant

(1) Flow split structure, (2) New membrane bioreactor, (3) bypass a portion of primary effluent around biotowers to the aeration basins as a means to provide carbon for denitrification, (4) construction of anoxic zones in each aeration basin, (5) new BAF facilities and feed pumping station, (6) alkalinity chemical feed facilities at the BAF, (7) new denitrifying filters and feed pumping station, (8) external carbon source chemical feed facilities for the denitrifying filters, (9) metal salt/polymer chemical feed facilities, and (10) rapid mix/flocculation tanks

Conceptual layouts for the Level 2 and 3 facility upgrades are provided in Figure 6-3 and Figure 6-4, respectively.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Flow split structure, (2) New membrane bioreactor, (3) bypass a portion of primary effluent around biotowers to the aeration basins as a means to provide carbon for denitrification, (4) construction of anoxic zones in each aeration basin, (5) new BAF facilities and feed pumping station, (6) alkalinity chemical feed facilities at the BAF, (7) new denitrifying filters and feed pumping station, (8) external carbon source chemical feed facilities for the denitrifying filters, and (9) metal salt/polymer chemical feed facilities

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Flow split structure, (2) New membrane bioreactor, (3) bypass a portion of primary effluent around biotowers to the aeration basins as a means to provide carbon for denitrification, (4) construction of anoxic zones in each aeration basin, (5) new BAF facilities and feed pumping station, (6) alkalinity chemical feed facilities at the BAF, (7) new denitrifying filters and feed pumping station, (8) external carbon source chemical feed facilities for the denitrifying filters, (9) metal salt/polymer chemical feed facilities, and (10) rapid mix/flocculation tanks

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	19.5	19.6	19.5	19.6
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	130	134	162	167
Annual O&M	$Mil/yr	4.2	4.6	4.7	4.8
O&M PV[3]	$ Mil	94	103	105	108
Total PV[3]	$ Mil	224	237	267	275
Unit Capital Cost	$/gpd	6.6	6.8	8.3	8.5
Unit Total PV	$/gpd	11.5	12.1	13.7	14.0
TN Removal					
Capital[2,4]	$ Mil	130	134	162	167
Annual O&M[4]	$ Mil/yr	4.2	4.6	4.7	4.8
O&M PV[3,4]	$ Mil	94	103	105	108
Total PV[3,4]	$ Mil	224	237	267	275
TN Removed (Ave.)[6]	lb N/d	2,980	3,060	3,360	3,820
Annual TN Removed (Ave.)[7]	lb N/yr	1,090,000	1,120,000	1,230,000	1,390,000
TN Cost[4,8]	$/lb N	6.8	7.0	7.2	6.6
TP Removal					
Capital[2,5]	$ Mil	1.6	1.7	24	24
Annual O&M[5]	$ Mil/yr	--	--	--	--
O&M PV[3,5]	$ Mil	--	--	--	--
Total PV[3,5]	$ Mil	1.6	1.7	24	24
TP Removed (Ave.)[6]	lb P/d	5	5	28	64
Annual TP Removed (Ave.)[7]	lb P/yr	1,800	1,800	10,300	23,300
TP Cost[5,8]	$/lb P	29	30	79	35

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Additional capacity for primary clarifiers by splitting portion of primary influent to MBR • High quality water produced in the MBR • Ability to reliably remove ammonia and TN in MBR • Long-term recycled water flexibility by producing high quality water in MBR • Improved CEC removal in MBR compared to biotower/activated sludge • Highest quality water as all the water will be filtered via filters or MBR • Reduced solids/BOD discharge loading to Suisun Bay	• Energy intensity of MBR • Additional chemicals for MBR and an external carbon source • Safety concerns from external carbon source (if methanol) • Two parallel treatment plants to operate • Additional unit processes to operate • Potential increase in solids production
Level 3	Same as Level 2	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2

7 Nutrient Load Reduction by Other Means

The DDWWTP has an existing recycled water program that is employed year-round. This existing program has the effect of reducing nutrients discharged to the Bay. The WWTP currently recycles approximately 7,400 acre-feet per year (2,400 million gallons per year). There are no existing plans to further expand the recycled water program.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

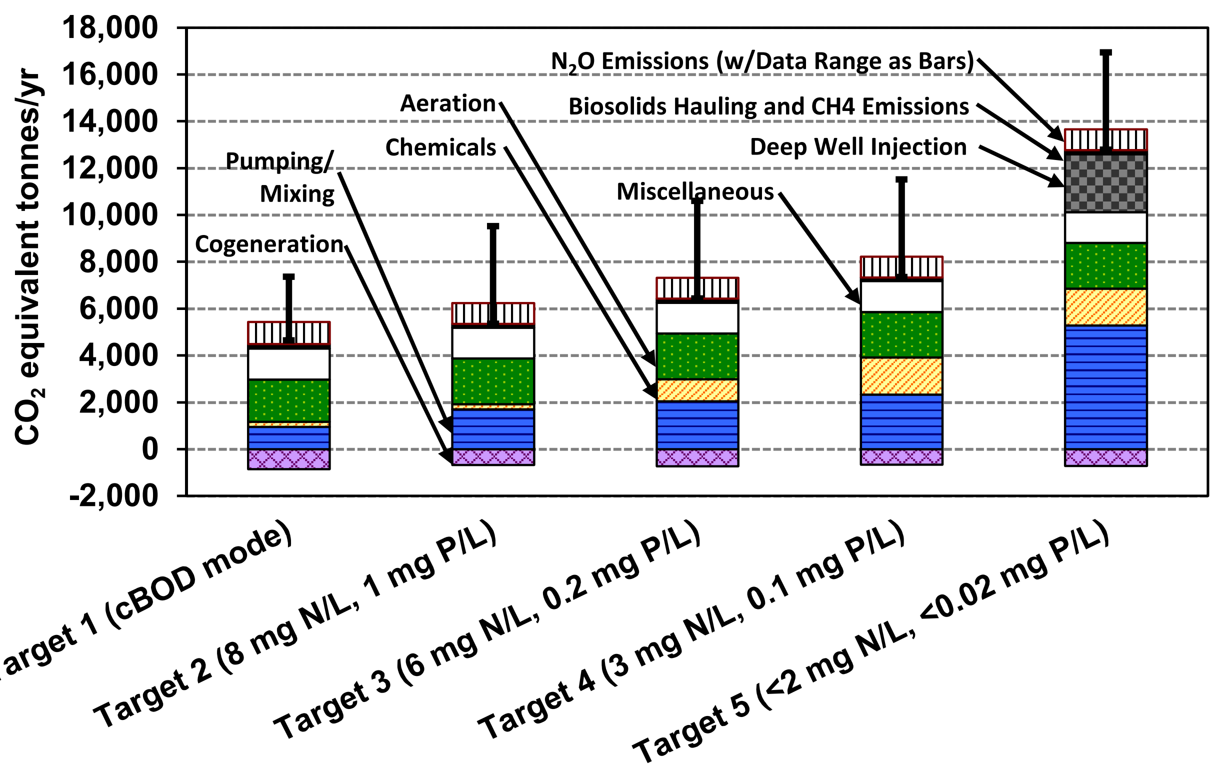

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA

eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	--*	600	3,000	4,700	3,000	4,600	100
GHG Emissions Increase from Chemicals	MT CO_2/yr	100	100	900	1,200	1,100	1,400	--
GHG Emissions Increase Total	MT CO_2/yr	100	700	4,000	5,900	4,100	6,000	100
Unit GHG Emissions[2]	lb CO_2/MG	30	310	1,200	1,800	1,300	1,900	94
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	--*	14	6	9	6	8	0.9
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	4	8	12	7	9	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--*	--*	--*	--*	--*	--*	--[5]

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

* The values are equal or less than the current operating mode.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at DD:

- Granular Activated Sludge – this could be used to phase out the biotower/activated sludge and/or MBR. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.
- High Rate A/B Process – this could be used to increase the downstream treatment capacity by increasing solids/organics capture in the primaries. The application would modify the primary clarifiers to operate as an activated sludge process by placing a small aeration tank (30 min hydraulic residence time) ahead of the primaries and recycling a portion of the solids back to the small aeration tank. This will not remove ammonia, but it will enhance organics capture to unlock downstream treatment capacity for ammonia removal; potentially increasing nitrification in the biotowers. There are over a dozen installations in Europe; however, there are currently no installations in North America.
  - Advantages: Low footprint requirements, energy efficient as more organics are diverted to the digesters, ability to remove ammonia and TN in the downstream processes.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2 below. A common unit cost basis was selected for this analysis.

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.7

Dublin San Ramon Services District Regional Wastewater Facility

Bay Area Clean Water Agencies
Nutrient Reduction Study

Dublin San Ramon Services District Regional Wastewater Facility

Pleasanton, CA

May 23, 2018
Final Report

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Executive Summary

The Dublin San Ramon Sanitary District Wastewater Treatment Plant (DSRSD WWTP) is located in Pleasanton, CA and conveys treated effluent to the Livermore-Amador Valley Water Management Agency (LAVWMA), followed by East Bay Dischargers Authority (EBDA). EBDA dechlorinates and discharges the treated effluent to the South Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 23.9 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs (e.g., $/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	10.5	10.6	17.0	17.0	17.0	17.0	--
Flow to Bay[2]	mgd	7.7	7.7	8.0	8.0	11.0	11.0	11.0	11.0	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	2,530	2,530	440	410	200	180	200	180	--
TN	lb N/d	2,550	2,550	1,920	1,780	1,170	1,100	900	550	--
TP	lb P/d	90	90	70	60	100	90	70	30	--
Costs[4,5]										
Capital[7]	$ Mil	--	--	1.0	4.4	84	88	113	117	--
O&M PV	$ Mil	--	--	3.9	5.4	40	46	58	75	--
Total PV[7]	$ Mil	--	--	4.9	9.8	124	134	171	192	--
Unit Costs[6]										
Capital	$/gpd	--	--	0.1	0.4	5.0	5.2	6.6	6.8	--
Total PV	$/gpd	--	--	0.5	0.9	7.3	7.9	10.0	11.2	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Does not include the costs associated with the on-going primary sedimentation tank optimization and upgrades project.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. New primary clarifiers to improve solids and organics capture. The existing primaries are overloaded with current flows and loads. Note: adding new primaries is not included in the optimization costs but it is a critical element in the overall strategy so it is included in the discussion.
2. Add metal salt to the facultative sludge lagoon supernatant. This strategy will facilitate operating the activated sludge with the anaerobic selector year round.
3. Operate in biological phosphorus removal mode year round by operating the anaerobic selector year round (currently limited to the dry season). This strategy is predicated on implementation of Strategy 2.
4. Increase the solids retention time (SRT) for year-round nitrification. The primary effluent can be step feed to downstream aeration zones to facilitate seasonal TN load reduction. This will require supplemental alkalinity addition for year round limits.

The WWTP is not considered a candidate for sidestream treatment because the plant only produces seasonal facultative sludge lagoon returns.

The upgrade strategies to achieve Levels 2 and 3 include:

- Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
  - Same as Optimization, plus
  - Add a membrane bioreactor (MBR) to treat a portion of the primary effluent.
- Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
  - Same as Optimization and Level 2, plus
  - Modify both the activated sludge and MBR to operate as a 5-stage Bardenpho,
  - Add an additional activated sludge train,
  - Expand the MBR basin,
  - Add an external carbon source to the activated sludge and MBR to further reduce total nitrogen loads, and
  - Expand the filter complex with more chemical facilities and additional filter surface area to further reduce total phosphorus loads.

Capital costs, O&M costs and present value costs were determined for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for changes in solids handling requirements or energy requirements in other unit processes.

As shown in Table ES-1, the costs increase from optimization to upgrades. Overall the present value costs range from $5 Mil for optimization (ammonia, total nitrogen, and total phosphorus load reduction) up to $192 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Dublin San Ramon Sanitary District Wastewater Treatment Plant (DSRSD WWTP) is located at 7399 Johnson Drive Pleasanton, CA 94588 and it serves about 53,500 service connections throughout San Ramon, Dublin and Pleasanton. Treated effluent water is conveyed to the Livermore-Amador Valley Water Management Agency (LAVWMA), followed by East Bay Dischargers Authority (EBDA). EBDA dechlorinates and discharges the treated effluent to the South Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 23.9 million gallons per day (mgd) and a peak permitted flow of 60 mgd.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The DSRSD WWTP discharges treated effluent through a common outfall operated by the East Bay Dischargers Authority (EBDA). EBDA member agencies include the City of Hayward, City of San Leandro, Oro Loma Sanitary District, Castro Valley Sanitary District, Union Sanitary District, and the Livermore-Amador Valley Water Management Agency (LAVWMA). The EBDA discharge is located at latitude 37°41’40” and longitude 122°17’42”.

EBDA holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2017-0017, NPDES No. CA0037613). Table 2-1 provides a summary of the permit limitations that are specific to the DSRSD WWTP, under the EBDA NPDES permit, and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2017-0017; CA0037613)

Criteria[1]	Unit	Average Dry Weather Flow*	Average Monthly	Average Weekly	Maximum Daily	Wet Weather Design Flow
Flow	mgd	23.9	--	--	--	60.7
BOD	mg/L	--	25	40	--	--
TSS	mg/L	--	30	45	--	--
Total Ammonia, as N	mg/L	--	91	--	120	--

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the DSRSD WWTP. Both liquids processes and solids processes are shown. DSRSD provides secondary treatment consisting of screening, grit removal, primary clarification, activated sludge, secondary clarification, and disinfection. Sludge is thickened by dissolved air floatation, anaerobically digested, further conditioned onsite at facultative sludge lagoons for approximately four years, and then injected into the soil at an onsite dedicated land disposal facilities.

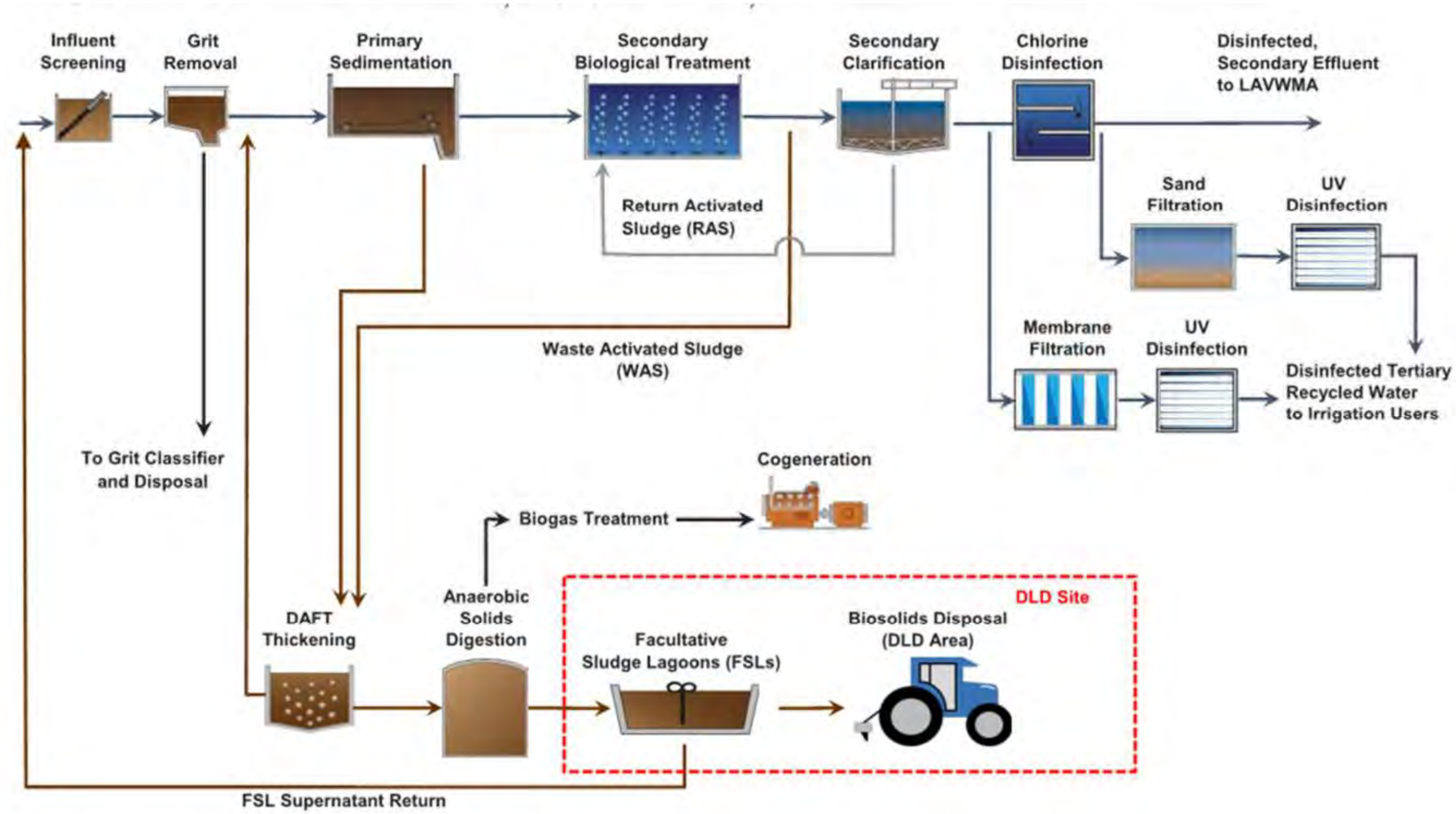

Figure 2-1. Process Flow Diagram for Dublin San Ramon Services District Regional Wastewater Facility

2.3 Existing Flows and Loads

A data request was submitted to each treatment plant included in the Watershed Permit in December 2014 as a means to understand historical plant performance and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for DSRSD is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	10.5	10.5	11.0	12.1
BOD	lb/d	22,200	22,600	26,200	29,700
TSS	lb/d	22,900	24,400	27,700	33,000
Ammonia	lb N/d	2,900	3,400	2,900	4,000
Total Kjeldahl Nitrogen (TKN)	lb N/d	4,400	4,900	4,400	5,400
Total Phosphorus (TP)	lb P/d	490	620	490	740
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	251	257	284	296
TSS	mg/L	260	277	301	328
Ammonia	mg N/L	34	39	32	39
TKN	mg N/L	52	56	49	54
TP	mg P/L	5.8	7.1	5.5	7.4
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. Nutrient data began in July of 2012.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

DSRSD has completed a Master Plan. Nutrient load reduction is an element of the Master Plan. The CIP has a 10-year schedule that was updated at the conclusion of the Master Plan to reflect the findings. However, DSRSD has already started the primary treatment capacity improvements project.

2.5 Pilot Testing

DSRSD has conducted a phosphorus reduction facultative sludge lagoon supernatant pilot study and determined that phosphorus reduction was not economical or feasible due to space limitations.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where information about future projections are unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Plant upgrade strategies were developed based on design capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis for the optimization analysis for DSRSD are presented in Table 3-1. The 2025 projected flow and load for DSRSD were not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	12.1	12.1	12.7	13.9
BOD	lb/d	25,600	26,000	30,200	34,100
TSS	lb/d	26,400	28,000	31,900	37,900
Ammonia	lb N/d	3,300	3,900	3,400	4,600
TKN	lb N/d	5,100	5,700	5,100	6,200
TP	lb P/d	570	710	560	860
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	251	257	284	296
TSS	mg/L	260	277	301	328
Ammonia	mg N/L	34	39	32	39
TKN	mg N/L	52	56	49	54
TP	mg P/L	5.8	7.1	5.5	7.4
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

The request for information included a series of questions to identify plants that are candidates for sidestream treatment. DSRSD is not considered a candidate for sidestream treatment due to having only seasonal sidestream return flows from the facultative sludge lagoons.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's ADWF permitted flow capacity based on existing facilities, 17.0 mgd. Note: the ADWF permitted flow may be increased to 23.9 mgd based on an increase of 3.7 mgd from facility upgrades and 3.2 mgd for Zone 7 Water Agency reject water. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Permitted Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2,4]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	17.0	17.0	17.8	19.5
BOD	lb/d	35,900	36,500	42,300	47,900
TSS	lb/d	37,000	39,300	44,700	53,200
Ammonia	lb N/d	4,700	5,500	4,700	6,500
TKN	lb N/d	7,100	7,900	7,100	8,800
TP	lb P/d	790	990	780	1,200
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	251	257	284	296
TSS	mg/L	260	277	301	328
Ammonia	mg N/L	34	39	32	39
TKN	mg N/L	52	56	49	54
TP	mg P/L	5.8	7.1	5.5	7.4
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Based on existing plant facilities. The ADWF permitted flow may be increased to 23.9 mgd based on an increase of 3.7 mgd from facility upgrades and 3.2 mgd for Zone 7 Water Agency reject water

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Four optimization strategies were identified during the 2015 DSRSD site visit. These were analyzed following the site visit to screen and select the most attractive strategy. The recommended overall optimization strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results follow Figure 4-1. It is noted, however, that recommended modifications for optimization may impact the plant’s treatment capacity. Thus, any changes for optimization should be considered an interim solution. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads.

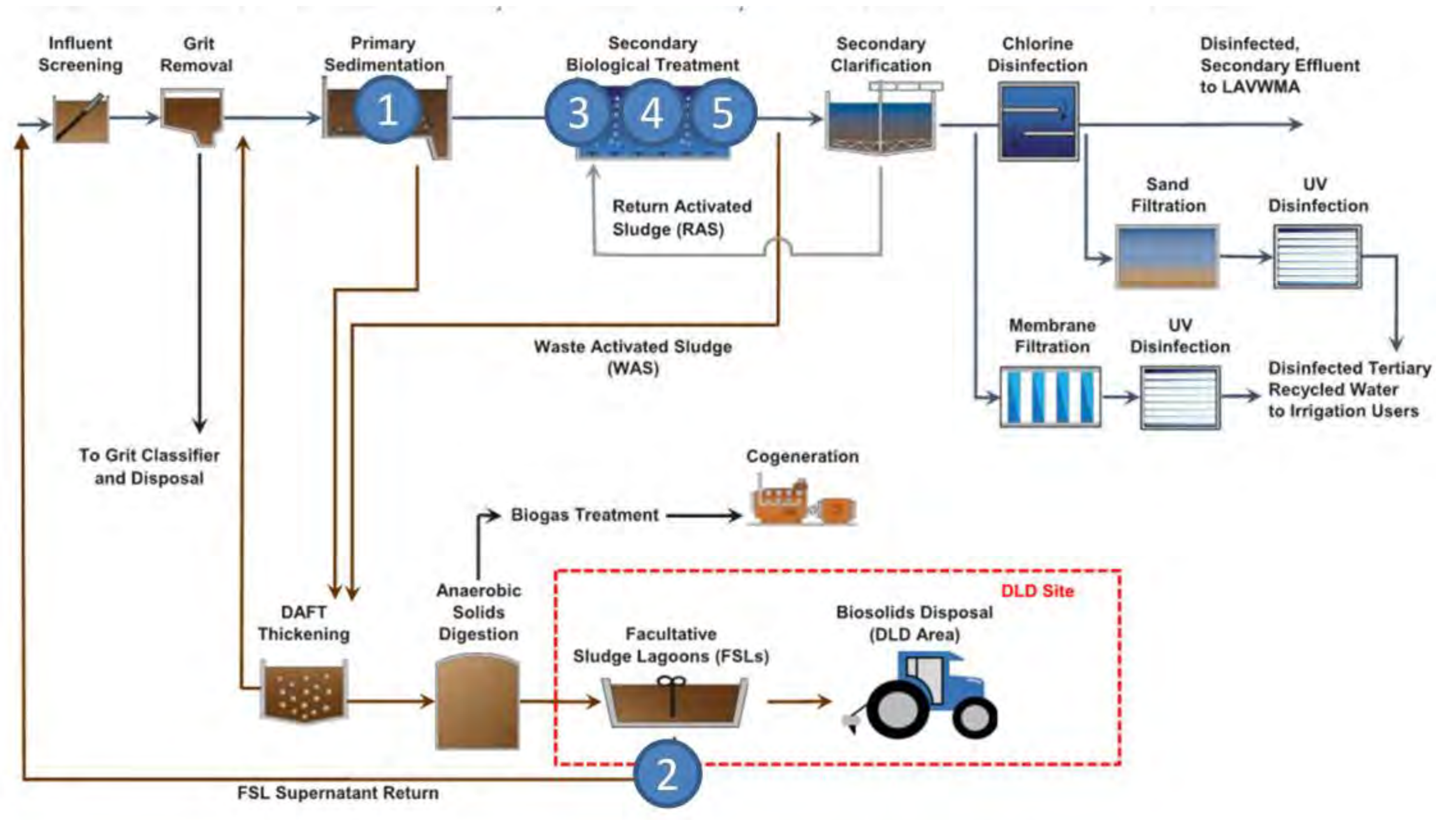

Figure 4-1. Optimization Strategy for DSRSD

(1) Optimize the existing primary sedimentation tanks and add new primary sedimentation tanks, (2) add metal salt coagulant to the facultative sludge lagoon supernatant while returning supernatant, (3) operate activated sludge in biological P removal year round, (4) modify activated sludge for ammonia/TN load reduction by increasing the SRT, and (5) supplemental alkalinity chemical feed facilities (limited to year round limits)

The results of the screening are as follows:

- **<u>Optimization Strategy 1:</u>** Optimize existing primary sedimentation tanks and add new primary sedimentation tanks to improve solids and organics capture. The existing primaries are overloaded with current flows and loads.
  - ***Is it feasible?*** Yes. There is space located to the west of the existing primary clarifiers.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increasing solids and organics capture and the primaries will increase the downstream activated sludge capacity to potentially reduce nutrient loads.
  - ***Result from analysis:*** New primaries should increase the solids capture from about 47 to 60 percent.
  - ***Recommendation:*** Carry forward. Note: DSRSD is in the process of implementing this strategy. It is a critical element in the overall optimization strategy, so it is included in this discussion, but not in the costs.
- **<u>Optimization Strategy 2:</u>** Add metal salt to the facultative sludge lagoon supernatant. This would be limited to when supernatant is returned to the main plant (about 8 months a year during the wet season and shoulder months). The benefit in this strategy is to reduce P loads, provide struvite control, and facilitate using the activated sludge selector year round for biological P removal. The plant currently does not use the selector while facultative sludge lagoon supernatant is returned to the main plant.
  - ***Is it feasible?*** Yes. It would require new chemical feed facilities located at the facultative sludge lagoon supernatant flume.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Maintain P removal whenever the facultative sludge lagoon supernatant is returned to the main plant.
  - ***Result from analysis:*** The plant already removes P during the dry season. This strategy will facilitate year round removal at dry season levels.
  - ***Recommendation:*** Carry forward.
- **<u>Optimization Strategy 3:</u>** Operate the activated sludge in biological P removal year round by operating the anaerobic selector. This strategy is predicated on implementation of Strategy 2. DSRSD currently operates in biological P removal about 4 months a year which would be expanded to year round.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy would operate the anaerobic selector and biological P removal year round to reliably reduce P loads.
  - ***Result from analysis:*** This strategy will ensure year round biological P removal.
  - ***Recommendation:*** Carry forward.
- **<u>Optimization Strategy 4:</u>** Increase the SRT for year-round nitrification. The primary effluent can be step feed to downstream aeration zones to facilitate seasonal TN load reduction.
  - ***Is it feasible?*** Yes, although it would be a major shift in operations strategy and there are foaming concerns.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy would remove a majority of ammonia and a portion of the TN load.
  - ***Result from analysis:*** The results suggest that removing a majority of the ammonia load is possible year-round, where TN load reduction is more limited to the dry season. Supplemental alkalinity addition would be required for a year round limits.
  - ***Recommendation:*** Carry forward.

A combination of Strategies 1, 2, 3, and 4 is the best apparent means to reduce overall effluent nutrient loads. Strategies 2, 3, and 4 are all predicated on expansion of the primary clarifiers (Strategy 1). While Strategy 1 is not included in the cost estimates, it is critical for the other strategies and thus is included for discussion. Strategies 2 and 3 are dependent upon each other and they focus solely on TP load reduction. Strategy 4 is focused on ammonia/TN load reduction. It will have the largest impact on plant operations as it will be a new mode of operation.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Primary Sedimentation Tanks • Optimize the existing primary sedimentation tanks add new primary sedimentation tanks.	• Operate and maintain the new primary sedimentation tanks.
Metal Salt Addition to the Facultative Sludge Lagoon Supernatant • New chemical feed facilities.	• Operate and maintain the chemical feed facilities.
Operate Activated Sludge in Year Round Biological P Removal • No new capital elements as the facility already has an anaerobic selector.	• Operate and maintain the existing anaerobic selector.
Increase the SRT for Ammonia and TN Load Reduction • Modifications to the piping/valving at all the aeration basin feed channels. • Provide step feed to the various aeration basins. • Create anoxic zones within the aeration basins. • Alkalinity chemical feed facilities (limited to year round limits).	• Increase the SRT by reducing mixed liquor wasting. • Provide the ability to reduce airflow to anoxic zones. • Provide the ability to control flow splits between the various basins.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	2,720	2,720	2,750	2,750	100	100
Discharge with Opt. Strategy[1]	lb N or P/d	440	410	1,920	1,780	70	60
Load Reduction[2]	lb N or P/d	2,270	2,310	830	970	30	30
Load Reduction[2]	%	84%	85%	30%	35%	27%	33%
Annual Load Reduction[3]	lb N or P/yr	829,800	843,200	300,000	354,000	9,630	11,430

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy*

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	10.5	10.6
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	1.0	4.4
Annual O&M	$ Mil/yr	0.4	0.6
Present Value O&M[3]	$ Mil	3.9	5.4
Present Value Total[3]	$ Mil	4.9	9.8
Unit Capital Cost[8]	$/gpd	0.1	0.4
Unit Total PV Cost[8]	$/gpd	0.5	0.9
TN Removal			
Capital[2,4]	$ Mil	--	3.3
Annual O&M[4]	$ Mil/yr	0.2	0.3
O&M PV[3,4]	$ Mil	1.7	3.0
Total PV[3,4]	$ Mil	1.7	6.3
TN Removed (Ave.)[6]	lb N/d	820	970
Annual TN Removed (Ave.)[7]	lb N/yr	300,000	354,000
TN Cost[4,9]	$/lb N	0.6	1.8
TP Removal			
Capital[2,5]	$ Mil	1.0	1.1
Annual O&M[5]	$ Mil/yr	0.3	0.3
O&M PV[3,5]	$ Mil	2.3	2.6
Total PV[3,5]	$ Mil	3.3	3.6
TP Removed (Ave.)[6]	lb P/d	30	30
Annual TP Removed (Ave.)[7]	lb P/yr	9,630	11,430
TP Cost[5,9]	$/lb P	30	30

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 10 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

* Does not include the costs associated with the on-going primary sedimentation tank optimization and upgrades project.

The costs in Table 4-3 do not account for any changes in any other process, including solids handling or associated energy requirements. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
Primary Sedimentation Tanks • More organics and solids diverted to unlock downstream treatment capacity • Less oxygen demand on the downstream activated sludge • More biogas production	• More facilities to operate
Metal Salt Addition to the Facultative Sludge Lagoon Supernatant • Struvite control • Potential for improved secondary clarifier settleability	• Safety associated with more chemicals to handle • Chemical feed facilities would be located outside the main plant (at the facultative sludge lagoons)
Operate Activated Sludge in Year Round Biological P Removal • Improved secondary clarifier settleability • Increase filter capacity due to improved secondary clarifier effluent product water • Less chemicals at the filters due to improved secondary clarifier effluent product water • Operate the activated sludge in the same mode year round simplifies operations	• Potential for struvite. The metal salt addition in Strategy 2 should resolve this issue
Increase the SRT for Ammonia and TN Load Reduction • Reduced biosolids yield from activated sludge • Reduction in secondary clarifier effluent particles, TSS, and BOD • Increase filter capacity due to improved secondary clarifier effluent product water • Less chemicals at the filters due to improved secondary clarifier effluent product water • Improved CEC removal	• More complex activated sludge process to operate • Potential for increased energy demand from aeration • Foaming concerns in the activated sludge process • Additional chemical handling with supplemental alkalinity (limited to year round limits)

5 Sidestream Treatment

Sidestream treatment is not considered a viable option for DSRSD as previously described and thus was not further evaluated.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the DSRSD WWTP to meet the listed Level 2 and Level 3 nutrient removal limits. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. DSRSD should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades to meet Level 2 build on the optimization strategies. The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flowsheet presented in Figure 6-1. As shown, existing primary sedimentation tanks will be optimized and new primary sedimentation tanks will be added as they are overloaded under current conditions. In order to operate under biological P removal year round, a metal salt will be added to the facultative sludge lagoon supernatant when flows are returned to the main plant (about 8 months a year). The activated sludge will have the modifications listed in the optimization where the anaerobic selector would be operated year-round for biological P removal. The SRT would be increased to facilitate nitrification and step feed implemented for TN load reduction.

The major expansion from Optimization to Level 2 is adding a parallel membrane bioreactor (MBR) to treat primary effluent. The existing activated sludge basins do not have sufficient capacity at the permitted capacity (as ADWF) with the modifications previously discussed. The parallel MBR will treat a portion of the primary effluent load and the combination of activated sludge and MBR will provide the permitted capacity (as ADWF).

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flowsheet presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Similar to Level 2, supplemental alkalinity would be required for year-round limits in both the activated sludge and MBR facilities. Both the activated sludge and MBR facilities would need to be modified to a 5-stage Bardenpho process for maintaining biological P removal and enhancing total nitrogen load reduction. An additional activated sludge train would be required as well. An external carbon source would be required for both the activated sludge and MBR facilities. The filter complex would need to be expanded for the more stringent Level 3 limits, specifically total phosphorus. The filter complex expansion would require expansion of filter cells and chemical feed facilities.

These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure.

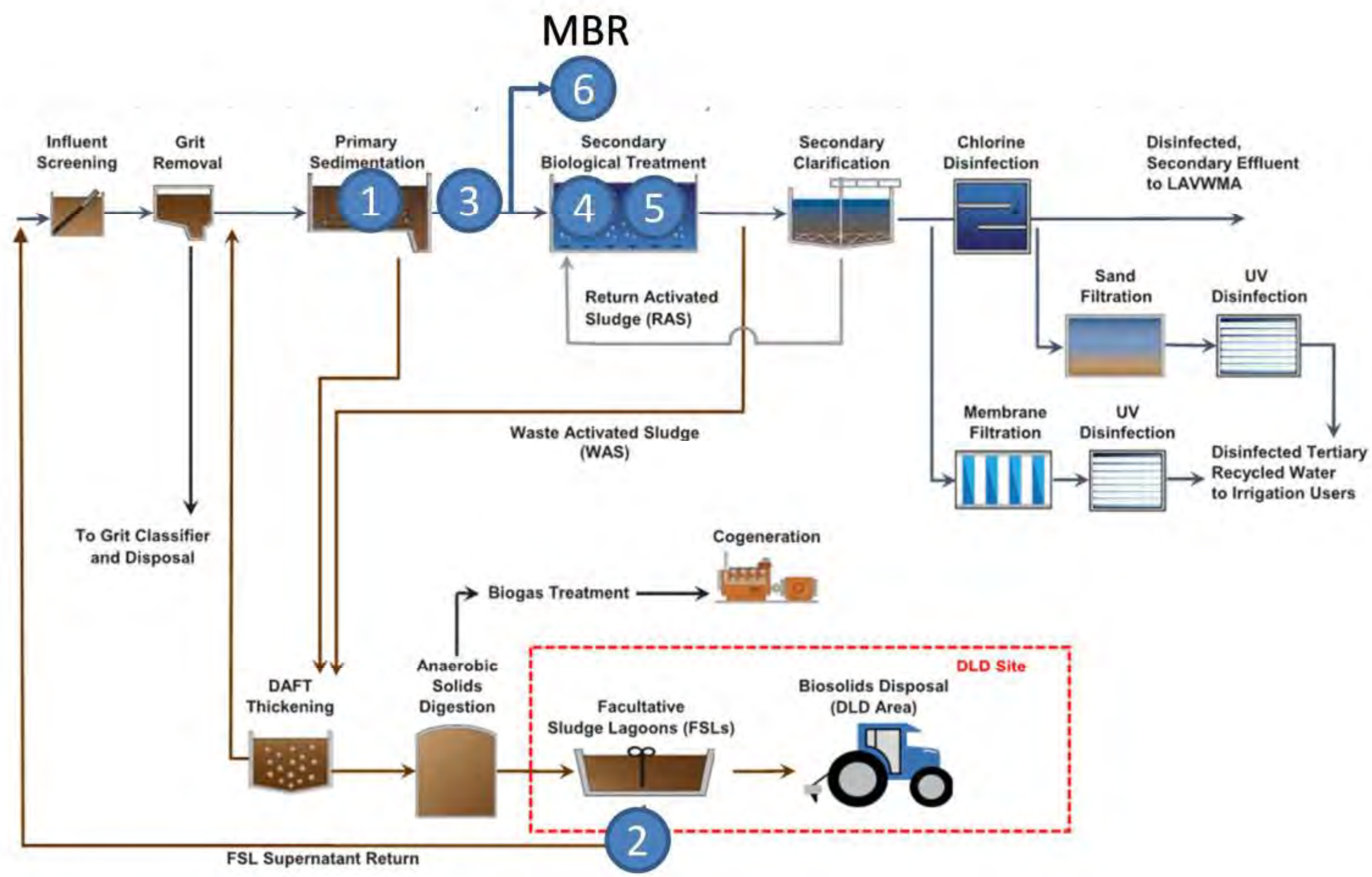

Figure 6-1. Level 2 Upgrade Concepts for DSRSD RWF

(1) Optimize the existing primary sedimentation tanks and add new primary sedimentation tanks, (2) add metal salt coagulant to facultative sludge lagoon supernatant (facilities located at facultative sludge lagoons), (3) supplemental alkalinity chemical feed facilities to feed both MBR and activated sludge (limited to year round limits), (4) operate activated sludge in biological P removal year round, (5) modify activated sludge for ammonia/TN load reduction, and (6) new membrane bioreactor (MBR) and ancillary equipment to treat primary effluent

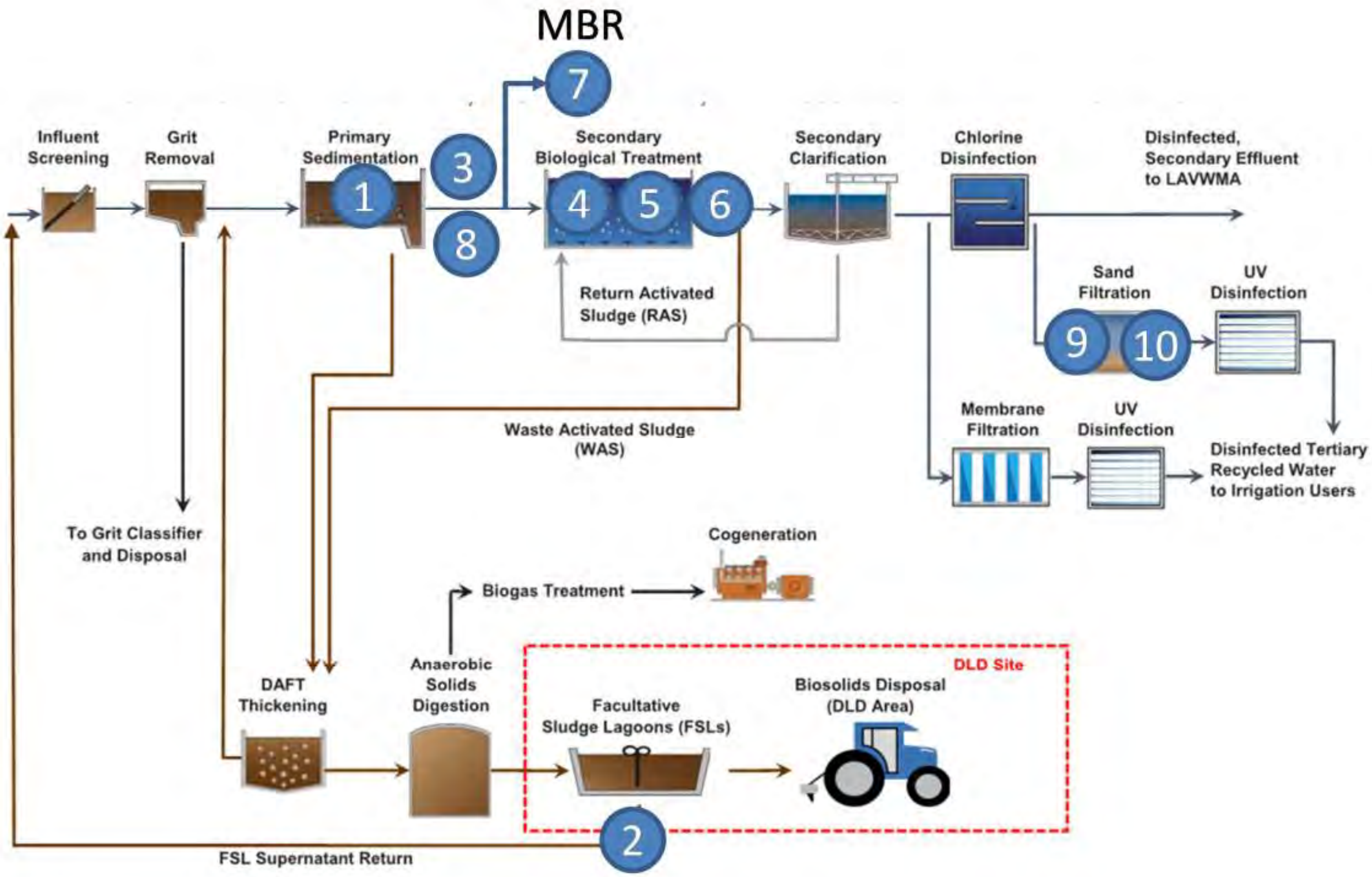

Figure 6-2. Level 3 Upgrade Concepts for DSRSD RWF

(1) Add new primaries, (2) add metal salt facultative sludge lagoon supernatant (facilities located at facultative sludge lagoons), (3) supplemental alkalinity chemical feed facilities to feed both MBR and activated sludge (limited to year round limits), (4) operate activated sludge in biological P removal year round, (5) modify activated sludge for ammonia/TN load reduction, (6) add a new activated sludge train, (7) add new membrane bioreactor (MBR) and ancillary equipment to treat primary effluent, (8) add an external carbon source chemical feed facilities to feed both MBR and activated sludge, (9) expand the filtration facilities, and (10) expand the metal salt/polymer chemical feed facilities

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs is provided in Table 6-1.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Optimize existing primary sedimentation tanks and add new primary sedimentation tanks (as previously identified under optimization)	Same as Level 2
Biological	• Modify aeration basin zone to operate in step feed mode • Primary effluent flow split structure to convey a portion of flow to MBR • New MBR to treat primary effluent and all the associated ancillary equipment (e.g., aeration system, piping, pumping, etc.) • Supplemental alkalinity chemical feed facilities (limited to year round limits)	Same as Level 2 • Modify both the activated sludge and MBR to operate as a 5-stage Bardenpho process • Add an additional activated sludge train • Add an external carbon source to feed both the MBR and activated sludge facilities
Tertiary	--	• Additional filter area • Expansion of chemical feed facilities (alum/polymer)
Biosolids or Sidestream	Metal salt addition to the facultative sludge lagoon supernatant (previously identified under optimization)	Same as Level 2

Conceptual layouts for the Level 2 and 3 facility upgrades are provided in Figure 6-3 and Figure 6-4, respectively.

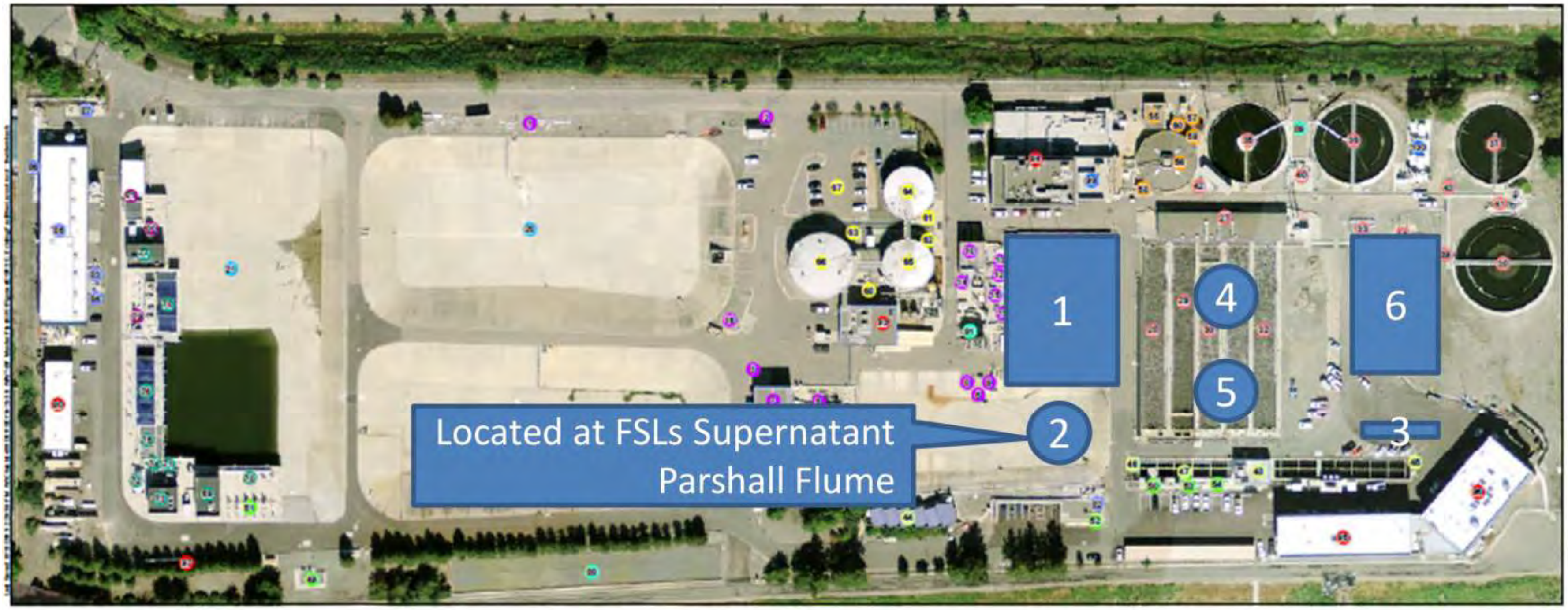

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Optimize the existing primary sedimentation tanks and add new primary sedimentation tanks, (2) add metal salt coagulant to facultative sludge lagoon supernatant (facilities located at facultative sludge lagoons), (3) supplemental alkalinity chemical feed facilities to feed both MBR and activated sludge (limited to year round limits), (4) operate activated sludge in biological P removal year round, (5) modify activated sludge for ammonia/TN load reduction, and (6) new membrane bioreactor (MBR) and ancillary equipment to treat primary effluent

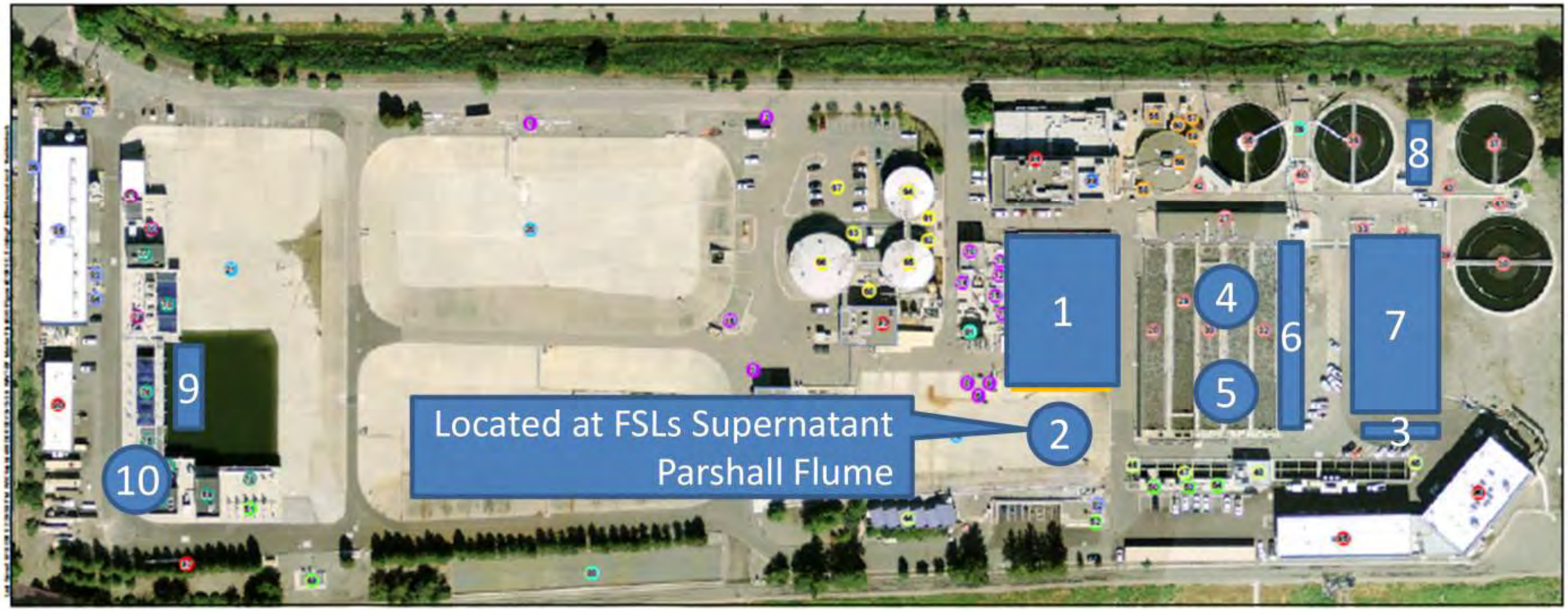

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add new primaries, (2) add metal salt facultative sludge lagoon supernatant (facilities located at facultative sludge lagoons), (3) supplemental alkalinity chemical feed facilities to feed both MBR and activated sludge (limited to year round limits), (4) operate activated sludge in biological P removal year round, (5) modify activated sludge for ammonia/TN load reduction, (6) add a new activated sludge train, (7) add new membrane bioreactor (MBR) and ancillary equipment to treat primary effluent, (8) add an external carbon source chemical feed facilities to feed both MBR and activated sludge, (9) expand the filtration facilities, and (10) expand the metal salt/polymer chemical feed facilities

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades*

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	17.0	17.0	17.0	17.0
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	84	88	113	117
Annual O&M	$Mil/yr	1.8	2.1	2.6	3.3
O&M PV[3]	$ Mil	40	46	58	75
Total PV[3]	$ Mil	124	134	171	192
Unit Capital Cost	$/gpd	5.0	5.2	6.6	6.8
Unit Total PV	$/gpd	7.3	7.9	10.0	11.2
TN Removal					
Capital[2,4]	$ Mil	81	84	98	99
Annual O&M[4]	$ Mil/yr	1.6	1.8	1.9	2.1
O&M PV[3,4]	$ Mil	35	40	42	47
Total PV[3,4]	$ Mil	116	124	140	146
TN Removed (Ave.)[6]	lb N/d	2,200	2,200	2,400	2,800
Annual TN Removed (Ave.)[7]	lb N/yr	790,000	818,000	890,000	1,018,000
TN Cost[4,8]	$/lb N	4.9	5.1	5.3	4.8
TP Removal					
Capital[2,5]	$ Mil	42	43	55	58
Annual O&M[5]	$ Mil/yr	1.4	1.6	2.0	2.5
O&M PV[3,5]	$ Mil	32	35	44	56
Total PV[3,5]	$ Mil	74	78	99	114
TP Removed (Ave.)[6]	lb P/d	20	30	50	90
Annual TP Removed (Ave.)[7]	lb P/yr	6,900	9,300	17,700	32,600
TP Cost[5,8]	$/lb P	360	280	190	120

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

* Does not include the cost associated with optimizing the existing primary sedimentation tanks and adding new primary sedimentation tanks.

Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Addition of primaries should enhance solids and organics capture • Ability to operate activated sludge in biological P removal mode year round • Improved secondary clarifier effluent water which will increase filter capacity and reduce filter chemical demand • Reduced solids production • High quality water produced in the MBR • Ability to reliably remove ammonia and TN in MBR • Long-term recycled water flexibility by producing high quality water in MBR • Improved CEC removal in MBR compared to biotower/activated sludge • Highest quality water as all the water will be filtered via filters or MBR • Reduced solids/BOD discharge loading	• Additional chemicals at the facultative sludge lagoon flume • New mode of operation for the activated sludge • Energy intensity of MBR • Additional chemicals for MBR • Two parallel treatment plants to operate • Additional unit processes to operate
Level 3	Same as Level 2	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Requires an external carbon source, which has potential safety issues (if methanol) • Potential increase in solids production at the filters

7 Nutrient Load Reduction by Other Means

The DSRSD WWTP has an existing recycled water program that is employed year-round, primarily during alternating months (February, April, June, August, October, and December). This existing program has the effect of reducing nutrients discharged to the Bay. The WWTP currently recycles approximately 2,200 acre-feet per year (730 million gallons per year). There are existing plans to further expand the recycled water program by increasing recycled water use for landscape use. There is currently funding to expand recycled water program to approximately 4,120 acre-feet per year (1,340 million gallons per year) by 2025 with a master plan to further expand to approximately 4,200 acre-feet per year (1,370 million gallons per year) by 2030.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

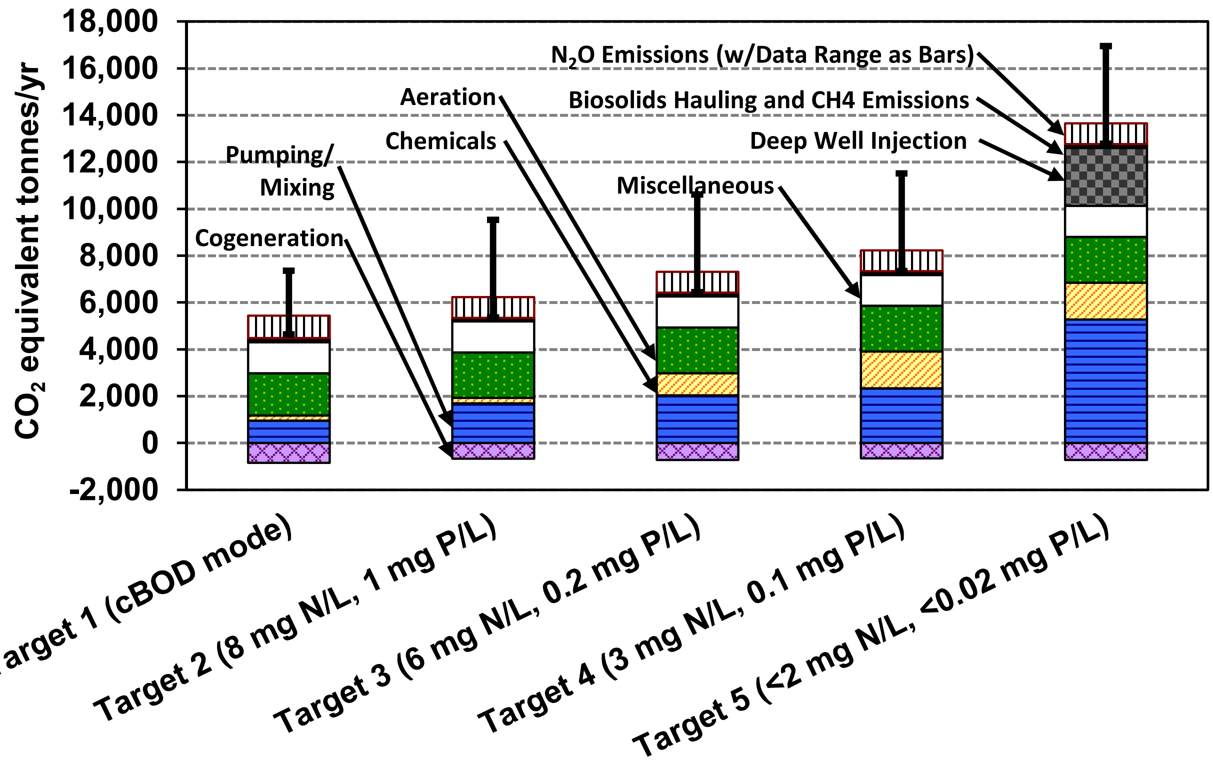

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. The largest contributor to GHG emissions is supplemental alkalinity for year round limits and energy related. The contribution from alkalinity reduces with more stringent limits, which is attributed to more alkalinity recovery with lower TN limits. Outside of alkalinity, energy is the predominant contributor, regardless of treatment level. The increase in GHG emissions from energy in Levels 2 and 3 upgrades is attributed primarily to the MBR facility energy demand.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	400	500	2,200	2,200	2,900	2,800	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	300	4,400	500	4,800	600	1,100	--
GHG Emissions Increase Total	MT CO_2/yr	700	4,900	2,700	7,000	3,500	3,900	--
								--
Unit GHG Emissions[2]	lb CO_2/MG	400	2,800	1,000	2,500	1,300	1,400	--
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	1	12	4	12	4	4	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	3	28	6	17	6	6	--
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	80	70	630	660	310	170	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. The WWTP is not a candidate for sidestream treatment as previously discussed.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the WWTP:

- Granular Activated Sludge – this could be used to operate in split treatment to the activate sludge (similar to MBR concept in the upgrades section) or phase out the activated sludge facilities. The application of granular sludge translates to reduced process tankage requirements and reduced overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration diffusers within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2 below. A common unit cost basis was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.8

East Bay Municipal Utility District

8

Bay Area Clean Water Agencies
Potential Nutrient Reduction Study

East Bay Municipal Utility District

Oakland, CA

May 28, 2018
Final Report

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Executive Summary

The East Bay Municipal Utility District (EBMUD) owns and operates the EBMUD Wastewater Treatment Plant (WWTP) located in Oakland, CA and discharges treated effluent to the San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 120 million gallons per day (mgd). The plant is allowed to blend primary with secondary effluent when secondary influent exceeds 150 mgd.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs (e.g., $/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream[3]
Design Flow	mgd	--	--	--*	--*	120	139	120	139	--
Flow to Bay[2]	mgd	56	56	--*	--*	95	95	95	95	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	18,300	18,300	--*	--*	1,700	1,600	1,700	1,600	15,500
TN	lb N/d	23,200	23,200	--*	--*	12,800	11,900	9,200	4,800	24,900
TP	lb P/d	1,800	1,800	--*	--*	850	800	580	240	2,180
Costs[4,5]										
Capital	$ Mil	--	--	--*	--*	2,250	2,280	2,320	2,400	74.5
O&M PV	$ Mil	--	--	--*	--*	310	340	390	470	89.2
Total PV	$ Mil	--	--	--*	--*	2,560	2,620	2,710	2,870	163.7
Unit Costs[6]										
Capital	$/gpd	--	--	--*	--*	19	16	19	17	--
Total PV	$/gpd	--	--	--*	--*	21	19	23	21	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

* No optimization strategies were deemed viable at EBMUD. It is worth noting that EBMUD has enhanced the total phosphorus load reduction across the plant in recent years due to a combination of biological phosphorus removal and chemical precipitation.

Optimization

No optimization strategies were deemed viable at EBMUD. It is worth noting that EBMUD has enhanced the TP load reduction across the plant since data was collected for this analysis. This increase in TP load reduction is attributed to a combination of optimizing the existing biological phosphorus removal in the high purity oxygen system and metal salt coagulant dosing at the anaerobic digesters. This has resulted in a total phosphorus reduction across the plant of greater than 50 percent (excludes contributions from organic wastes).

Sidestream Treatment

The EBMUD WWTP is considered a candidate for sidestream treatment to reduce ammonia, total nitrogen, and total phosphorus loads as the plant anaerobically digests biosolids and dewaters to produce a return sidestream laden with nutrients. The recommended sidestream treatment strategy is deammonification for reducing ammonia/nitrogen loads.

The EBMUD WWTP is also considered a viable candidate for sidestream treatment to reduce total phosphorus loads. While the plant already removes a portion of phosphorus loads in the sidestream, implementation of chemical precipitation of phosphorus in the sidestream is another opportunity to further reduce phosphorus loads.

Upgrades

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Replace the high purity oxygen system with a membrane bioreactor (MBR) and an aeration system.
   b. Demolish the high purity oxygen system and secondary clarifiers.
   c. Add sidestream treatment reactor (deammonification technology recommended).
   d. Add a fermenter for treating primary solids to produce volatile fatty acids (VFAs) to serve as a carbon source in the MBR.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Expand the aeration basins to trim nitrogen and phosphorus.
   c. Add mixed liquor return pumps in the MBR to trim nitrogen.
   d. Add chemical feed facilities for an external carbon source to trim nitrogen.
   e. Add chemical feed facilities for a metal salt to trim phosphorus.

Summary

Capital costs, O&M costs and present value costs were determined for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for any changes in any other process, including solids handling or associated energy requirements. Costs for relocating and rebuilding some of the demolished facilities are not included either.

As shown in Table ES-1, there are no costs for optimization and the costs increase from sidestream treatment to upgrades required to achieve Level 2 and Level 3 treatment levels. Overall the present value costs range from $164 Mil for sidestream treatment (ammonia, total nitrogen, and total phosphorus load reduction) up to $2,870 Mil for Level 3 upgrades (for year round flows and loads). In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The East Bay Municipal Utility District Special District No.1 Main Wastewater Treatment Plant (EBMUD) discharges to Central San Francisco Bay. It is located at 2020 Wake Avenue, Oakland, CA 94607, and it serves about 685,000 customers throughout Alameda, Albany, Berkeley, Emeryville, Oakland, Piedmont, and the Stege Sanitary District (serving El Cerrito, Kensington, and part of Richmond) via about 160,000 service connections. The plant has an average dry weather flow (ADWF) permitted capacity of 120 million gallons per day (mgd). The plant also accepts non-hazardous trucked wastes for treatment and resource recovery, which is a more environmentally responsible way compared to dispose of wastes.

2 Current Conditions

The subsections below provide information on current conditions, such as flows and loads, permit requirements, plant performance, and on-going efforts for evaluating nutrient load reduction strategies.

2.1 Existing NPDES Permit

EBMUD holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2015-0018 (CA0037702). Table 2–1 provides a summary of the permit limitations but is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2–1. NPDES Permit Limitations (Order No. R2-2015-0013; CA0038024)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	120	-	-	-
BOD	mg/L	-	25	40	-
TSS	mg/L	-	30	45	-
Total Ammonia, as N	mg/L	-	84	-	110

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the existing process flow diagram that includes both liquids processes and solids processes. The wastewater treatment process consists of odor control, grit removal, primary clarification, high purity oxygen activated sludge, secondary clarification, disinfection, and dechlorination. The activated sludge maintains a low SRT for secondary treatment. The plant currently removes over 40 percent of raw influent total phosphorus loads. Such load reduction does not include any total phosphorus added to the digesters by trucked wastes for resource recovery. Sludge is thickened, anaerobically digested and dewatered.

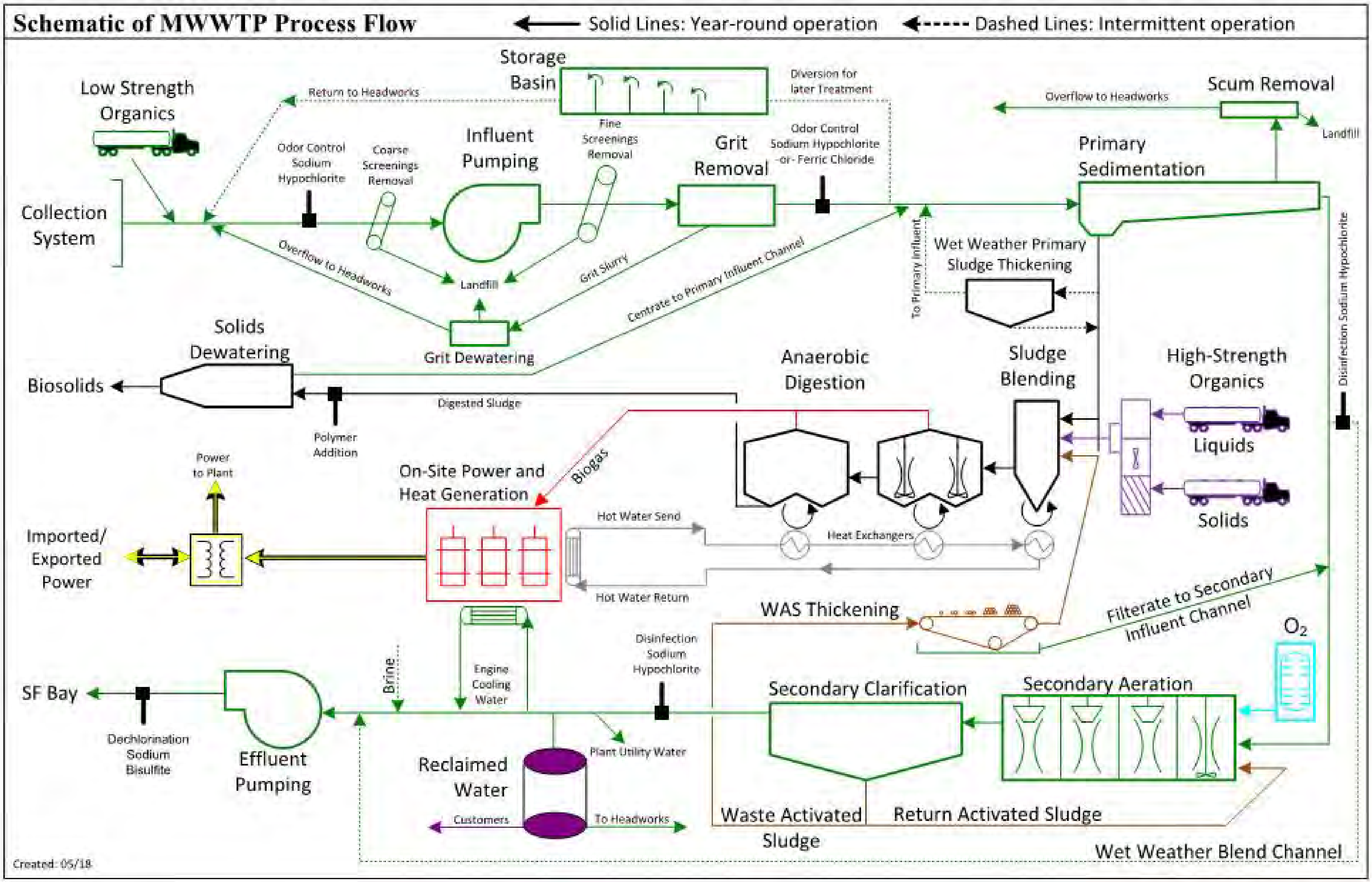

Figure 2-1. Process Flow Diagram for EBMUD WWTP

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for EBMUD is shown in Table 2–2.

Table 2–2. Current Influent Flows and Loads (7/2011-6/2014)[1]

Criteria	Unit	ADWF[2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[2]	Year Round MM[2]
Flow	mgd	54.7	59.7	58.7	92.5
BOD	lb/d	152,200	148,900	171,200	177,000
TSS	lb/d	159,700	177,200	200,200	227,200
Ammonia	lb N/d	14,600	14,800	14,600	15,100
Total Kjeldahl Nitrogen (TKN)	lb N/d	23,400	24,300	23,400	25,200
Total Phosphorus (TP)	lb P/d	3,890	3,860	3,890	3,840
Alkalinity	lb $CaCO_3$/d	120,900	119,600	124,100	121,700
BOD	mg/L	334	299	350	230
TSS	mg/L	350	356	409	295
Ammonia	mg N/L	32	30	30	20
TKN	mg N/L	51	49	48	33
TP	mg P/L	8.5	7.8	7.9	5.0
Alkalinity	mg $CaCO_3$/L	265	240	254	158

1. Based on historical daily average plant data provided by EBMUD to HDR in 2015.
2. ADWF = Average Dry Weather Flow and MM = Maximum Month.
3. ADWF is calculated as the average flow for the months of July, August, and September.

2.4 Future Nutrient Removal Projects

EBMUD began preparing a comprehensive Wastewater Treatment Plant Master Plan in 2018. As part of the master plan, EBMUD will investigate a wide range of nutrient reduction options.

2.5 Pilot Testing

EBMUD has been actively pilot testing various sidestream treatment technologies and led a regional project funded through an EPA Grant titled Nutrient Reduction by Sidestream Treatment (https://bacwa.org/wp-content/uploads/2017/05/EPA-Grant-Sidestream-Nutrient-Removal-Study-Report-04282017.pdf). As part of the grant, EBMUD piloted non-proprietary attached and suspended growth deammonification sidestream technologies and both demonstrated the potential to reduce ammonia and total nitrogen loading to the Bay.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025 and where that information is unavailable, a 15 percent increase in loadings was assumed for the 10 year period and no increase in flows. Sidestream treatment and Levels 2 and 3 upgrades were developed based on permitted capacity.

3.1 Influent Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for the EBMUD WWTP are presented in Table 3–1. The contribution of sidestream generated from anaerobic digestion of sludges and high organic-strength truck wastes was not shown in Table 3–1, but was included in the facility needs analysis. The projected flow and load for 2025 was not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow. EBMUD's Resource Recovery program has the potential to impact these projections significantly.

Table 3–1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	54.7	59.7	58.7	92.5
BOD	lb/d	175,000	171,000	197,000	204,000
TSS	lb/d	184,000	204,000	230,000	262,000
Ammonia	lb N/d	16,800	17,200	16,900	17,700
TKN	lb N/d	26,800	28,100	27,000	29,300
TP	lb P/d	4,460	4,470	4,450	4,430
Alkalinity	lb/d as $CaCO_3$	139,100	137,400	143,000	140,100
BOD	mg/L	384	344	403	265
TSS	mg/L	403	409	470	339
Ammonia	mg N/L	37	35	35	23
TKN	mg N/L	59	56	55	38
TP	mg P/L	9.8	9.0	9.1	5.8
Alkalinity	mg/L as $CaCO_3$	305	276	292	182

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.2 Influent Flow and Loading for Sidestream Treatment

Based on the data provided by EBMUD, it was determined that the EBMUD WWTP is a candidate for sidestream treatment.

The sidestream flows and loads for other BACWA member agency reports are based on sidestream sampling performed in July 2015 under the EPA Regional Grant titled Nutrient Reduction by Sidestream Treatment. While for EBMUD, higher nutrient concentrations, presented in Table 3-2, were assumed based on EBMUD's additional sidestream sampling results and potential future growth of its Resource Recovery Program. The permitted capacity flows and loads were used in the facility sizing. As noted with Optimization, EBMUD's Resource Recovery program has the potential to impact these projections.

Table 3–2. Feed Flow and Load for Sidestream Treatment

Criteria	Unit	Permitted Flow Capacity
Sidestream Flow	mgd	1.00
Ammonia[1]	lb N/d	20,900
TKN[1]	lb N/d	21,300
TN[1,2]	lb N/d	21,300
OrthoP	lb P/d	1,080
TP	lb P/d	1,520
Alkalinity	lb $CaCO_3$/d	64,600
Ammonia[1]	mg N/L	2,500
TKN[1]	mg N/L	2,548
TN[1,2]	mg N/L	2,548
OrthoP	mg P/L	130
TP	mg P/L	182
Alkalinity	mg/L as CaCO3	7,750

1. Higher than actual concentrations were assumed for ammonia and TKN, accounting for potential growth of the Resource Recovery Program.
2. It was assumed that TN = TKN.

3.3 Influent Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3–3. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current ADWF concentrations, current flow peaking factors, and current load peaking factors (PFs) to the ADWF permitted flow capacity. The contribution of sidestream generated from anaerobic digestion of sludges and high organic-strength truck wastes was not shown in Table 3–3, but was included in the facility needs analysis. As noted with Optimization, EBMUD's Resource Recovery program has the potential to impact these projections.

Table 3–3. Raw Influent Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30) [1,3]	Year Round MM[1,3]
Flow	mgd	120	131	129	203
BOD	lb/d	334,000	326,000	376,000	389,000
TSS	lb/d	350,000	389,000	439,000	499,000
Ammonia	lb N/d	32,000	32,800	32,200	33,800
TKN	lb N/d	51,000	53,500	51,500	55,800
TP	lb P/d	8,500	8,500	8,500	8,500
Alkalinity	lb/d as $CaCO_3$	265,000	262,000	273,000	267,000
BOD	mg/L	334	299	350	230
TSS	mg/L	350	356	409	295
Ammonia	mg N/L	32	30	30	20
TKN	mg N/L	51	49	48	33
TP	mg P/L	8.5	7.8	7.9	5.0
Alkalinity	mg/L as $CaCO_3$	265	240	254	158

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to size facilities to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers was identified and the footprint for these facilities was located on the site plan. Land cost are not included in the cost analysis. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Demolition costs were included. Allowances were included for undefined facilities, site conditions, and contractor’s costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. There is no contingency included for O&M costs. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for, TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal. For example, the membrane bioreactor (MBR) facility was included as a cost element for TN reduction, whereas metal salt coagulant to reduce phosphorus loads were not included as a cost element for TN reduction.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Sidestream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy(ies).

Ten optimization strategies were identified during the EBMUD WWTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The ten optimization strategies were screened down to three strategies as follows.

- **Optimization Strategy 1:** Perform split treatment within the existing high purity oxygen system where a portion of the primary effluent is subjected to nitrification/denitrification in modified basins and the remaining portion is subjected to the existing high purity oxygen system. This strategy would require major modifications for those basins retrofitted to operate under nitrification/denitrification.
  - ***Is it feasible?*** Yes, but it would require taking the covers off the basins being retrofitted, modifications to the aeration system, significant pumping, pipe and valve modifications, and would require de-rating the permitted capacity.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** The extent of load reduction is dependent on the portion of flow subjected to nitrification/denitrification. The

analysis assumed that approximately one-quarter of the flow is subjected to nitrification/denitrification using half of the secondary treatment facilities, in which case all of that ammonia would be removed and about half of that total nitrogen load removed.

- ***Result from analysis:*** The challenges associated with modifying the high purity oxygen basins are significant. Specifically, once the covers are removed it would be challenging to re-cover them so it is viewed as a sunken cost. There are concerns over operating two separate biological processes in parallel, as well as concerns over foaming within the modified basins. And lastly, a more detailed evaluation on the hydraulics suggest that the plant would need to be de-rated to carry this forward.
- ***Recommendation:*** Do not carry forward.

◈ **Optimization Strategy 2:** Optimize the existing biological P removal process in the high purity oxygen system and chemical precipitation with ferrous chloride at the anaerobic digesters. This strategy would enhance overall TP load reduction across the plant.

- ***Is it feasible?*** Yes, the existing facility is already performing biological P removal and ferrous chloride has been added historically for odor control.
- ***Potential impact on ability to reduce nutrient discharge loads?*** Potential for enhanced TP load reduction across the plant.
- ***Result from analysis:*** The historical data provided by EBMUD (7/2011-6/2014) suggests an approximate concentration reduction of 40 percent while comparing raw influent against discharge (excludes contributions from high-strength organic wastes). Recent data from August 2016 to April 2018 showed an over 50 percent TP reduction. Given that EBMUD has been actively optimizing TP load reduction since this effort began in 2015, the expected TP load reductions with further optimizing are expected to be negligible.
- ***Recommendation:*** Do not carry forward as the optimization steps for TP load reduction have been made by EBMUD since this effort began in 2015.

◈ **Optimization Strategy 3:** Increase the solids residence time (SRT) to facilitate seasonal nitrification in the activated sludge process. This would require taking the covers off the high purity oxygen basins, modifying the aeration system, and other major pipe and valve modifications.

- ***Is it feasible?*** No, the basins are not large enough to increase the SRT in all the basins and reliably remove ammonia.
- ***Potential impact on ability to reduce nutrient discharge loads?*** The basins are only big enough to treat approximately 25 percent of the flow, and reduce the ammonia discharge load by approximately 25 percent (similar to Strategy 1).
- ***Result from analysis:*** The oxygen demands exceed the high purity oxygen system and the mixed liquor levels would exceed the secondary clarifiers capacity.
- ***Recommendation:*** Do not carry forward.

No optimization strategies are recommended for the reasons stated above. It is worth noting that EBMUD has enhanced the TP load reduction across the plant since data was collected for this analysis. This increase in TP load reduction is attributed to a combination of optimizing the existing biological phosphorus removal in the high purity oxygen system and metal salt coagulant dosing at the anaerobic digesters. This has resulted in a total phosphorus load reduction across the plant of greater than 50 percent (excludes contributions from organic wastes).

5 Sidestream Treatment

As previously described, the EBMUD WWTP was identified as a potential candidate for sidestream treatment.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia/total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction. While the plant already removes a portion of total phosphorus loads, implementation of chemical precipitation of phosphorus in the sidestream is an opportunity to further reduce the total phosphorus loads.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. Deammonification offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification) including requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requires 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for EBMUD.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Note, alum and ferric chloride addition both consume alkalinity (approximately 0.5 lb alkalinity/lb alum and 0.6 lb alkalinity/lb ferric) which might require supplemental alkalinity for the previously described deammonification technology. The impact of alkalinity consumption on other unit processes would need to be considered while evaluating total phosphorus load reduction in the sidestream. The metal salt dosing could occur upstream of the mechanical dewatering or on the centrate line. Dosing upstream of the mechanical dewatering would capture precipitated phosphorus with the cake and it comes with a higher unit chemical demand. A previously completed Struvite Study at EBMUD estimated the ferric dose at approximately 600 mg/L.

A list of the facility needs for sidestream treatment is provided in Table 5–1.

Table 5–1. Sidestream Treatment Facility Needs for Ammonia/TN and TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping	Metal Salt Chemical Feed Facility
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Supplemental Alkalinity (if deemed necessary)	

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5–1.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)[4]
Current Discharge[1]	lb/d	29,200	37,000	2,930
Discharge with Sidestream Treatment[2]	lb/d	15,500	24,900	2,180
Load Reduction[3]	lb/d	13,700	12,100	750
Load Reduction	%	47%	33%	26%
Annual Load Reduction	lb/yr	4,990,000	4,430,000	270,000

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. Based on EBMUD's historical TP load reduction data of approximately 40 percent while comparing raw influent against discharge (excludes contributions from organic wastes). The listed load reductions are based on additional removal with sidestream treatment.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These costs do not account for any changes in any other process, including solids handling or associated energy requirements. The unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP[7]
Capital[1]	$ Mil	73	1.5
Annual O&M	$ Mil/yr	3.1	0.9
Total Present Value[2]	$ Mil	142	21.7
NH4-N Load Reduction[3,5]	lb N/yr	4,990,000	--
TN Load Reduction[3,5]	lb N/yr	4,430,000	--
TP Load Reduction[4,5]	lb P/yr	--	270,000
NH4-N Cost [3,5,6]	$/lb N	0.9	--
TN Cost [3,5,6]	$/lb N	1.1	--
TP Cost [4,5,6]	$/lb P	--	2.6

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. Based on EBMUD's historical TP load reduction data of approximately 40 percent while comparing raw influent against discharge (excludes contributions from organic wastes). The listed load reductions are based on additional removal with sidestream treatment.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the EBMUD WWTP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. EBMUD should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the listed Level 2 discharge limits are independent of those presented under the Optimization Section (i.e., enhance biological P removal in the existing HPO system). The process flow diagram for Level 2 upgrades is presented in Figure 6-1. A new membrane bioreactor (MBR) constructed that includes all the ancillary equipment associated with operating an MBR (e.g., new aeration system, RAS pumps, clean in place chemicals, membranes, etc.). The MBR would be a three-stage biological process that includes anaerobic, anoxic, and aerobic zones. The anaerobic zone is included to facilitate biological phosphorus removal, the anoxic zone is included for total nitrogen load reduction, and aerobic for removing organics and ammonia. Following implementation of the MBR, the existing high purity oxygen reactors, oxygen production facilities, and secondary clarifiers would be demolished. Sidestream treatment with a deammonification technology is recommended to treat the nitrogen load. Additionally, the primary solids would be fermented in available tankage to produce volatile fatty acids (VFAs) required for denitrification in the MBR.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the listed Level 3 discharge limits are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades expand upon those listed for Level 2. Level 3 costs are inclusive of facilities needed to meet Level 2.

In addition to those listed for Level 2, the Level 3 upgrades require further expansion of the aeration basins, an external carbon source chemical feed facility, a metal salt chemical feed facility, and mixed liquor return pumps/piping for denitrification polishing. The basin expansion is to allow an additional anoxic and oxic zone to further reduce the TN load. The external carbon source and mixed liquor pumps/piping are provided to satisfy the carbon requirements for meeting the TN discharge target. And lastly, the metal salt is to further reduce TP within the MBR.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs is provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively. Additionally, due to the significant increase in power demand for Levels 2 and 3 treatment, the need and cost for upgrading the existing power supply system should be investigated.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	Fermentation Tank to Treat Primary Solids to Produce Volatile Fatty Acids (VFAs) for Denitrification in the Biological Process	Same as Level 2
Biological	• New Membrane Bioreactor Facilities to Replace the High Purity Oxygen System, which Includes: o New Aeration Basins o Membrane Tanks o Clean In Place Chemical Facilities o Anoxic and Aerobic Zones for Reducing Ammonia and Total Nitrogen Loads o Anaerobic Zones for Biological Phosphorus Removal • New Aeration System (e.g., Fine-Bubble Diffusers and Blowers) • Demolish High Purity Oxygen Reactors, Oxygen Production Facilities, and Secondary Clarifiers	Same as Level 2, plus: • Additional Aeration Basin Volume for Polishing Zones • External Carbon Source Chemical Feed Facilities in the MBR • Additional Metal Salt chemical feed Facilities in the MBR • Mixed Liquor Return Piping/Pumping
Tertiary	--	--
Biosolids or Sidestream	Sidestream Treatment	Same as Level 2

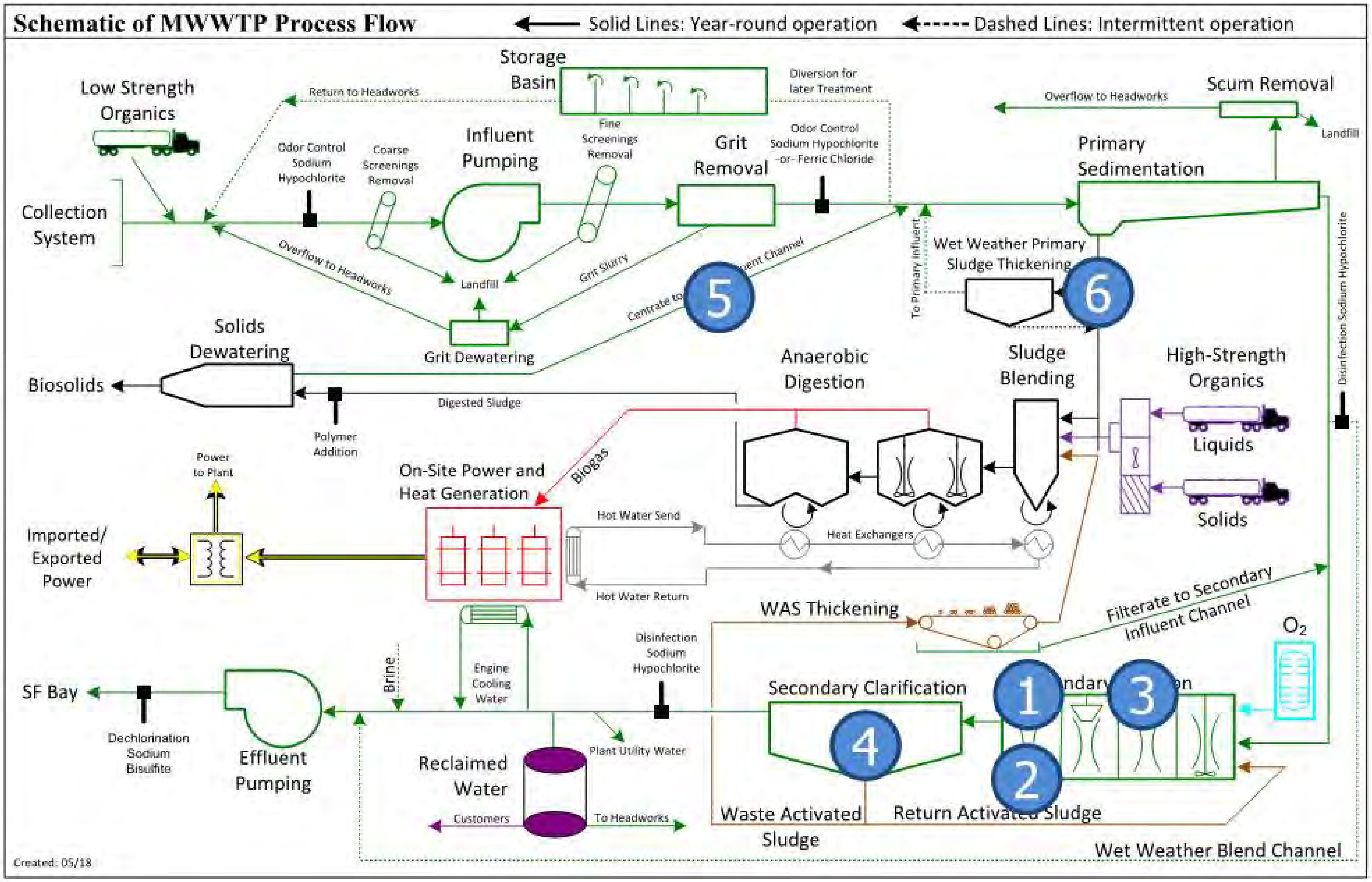

Figure 6-1. Level 2 Upgrade Concepts for EBMUD WWTP

(1) Add new MBR, (2) Add an Aeration System, (3) Demolish the High Purity Oxygen Reactors and Oxygen Production Facilities, (4) Demolish the Secondary Clarifiers, (5) Add a Sidestream Treatment Reactor, and (6) Add a Fermenter to Treat Primary Solids

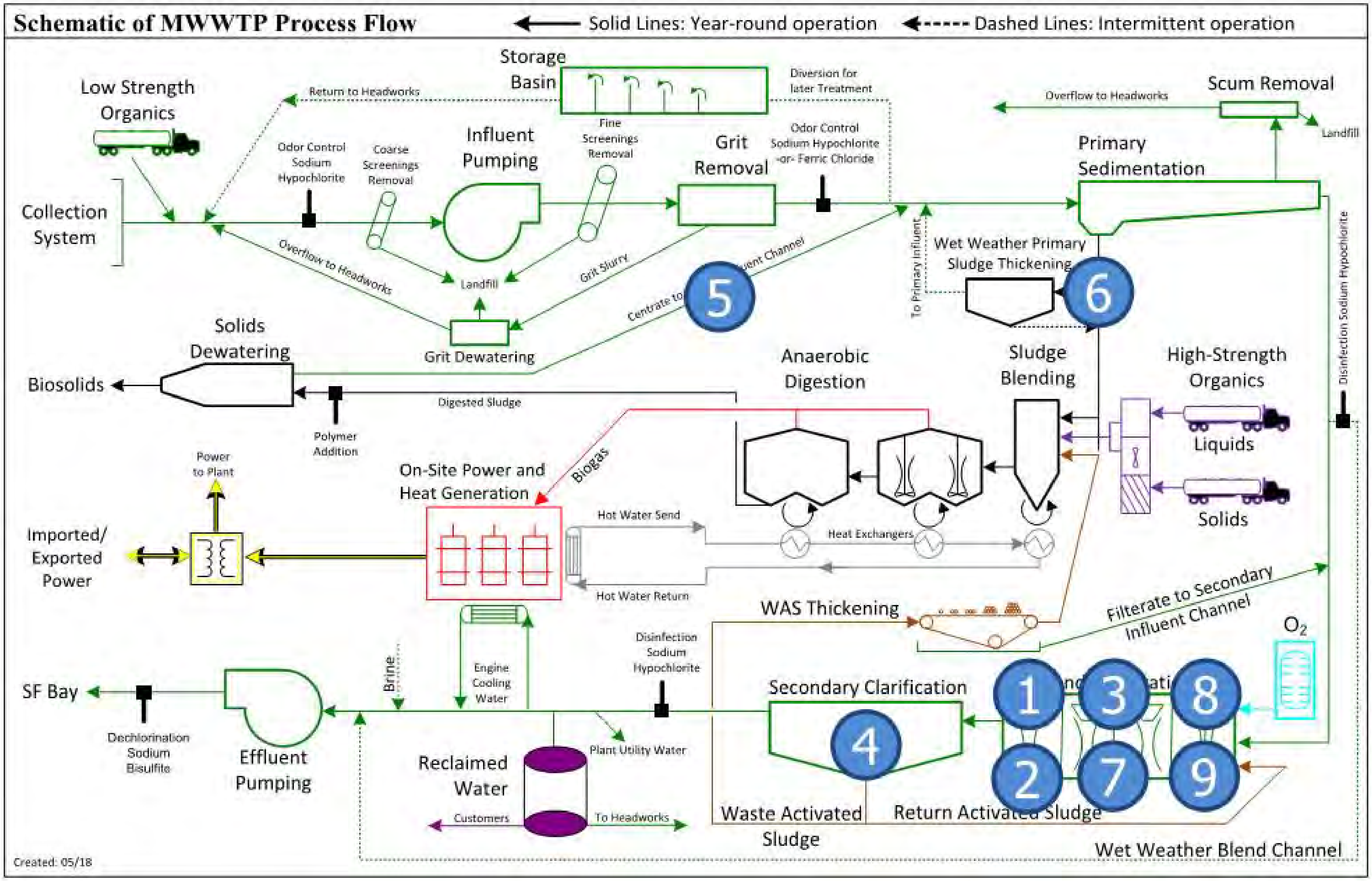

Figure 6-2. Level 3 Upgrade Concepts for EBMUD WWTP

(1) Add new MBR, (2) Add an Aeration System, (3) Demolish the High Purity Oxygen Reactors and Oxygen Production Facilities, (4) Demolish the Secondary Clarifiers, (5) Add a Sidestream Treatment Reactor, (6) Add a Fermenter to Treat Primary Solids, (7) Add an External Carbon Source, (8) Add a Metal Salt, and (9) Add Mixed Liquor Return Piping/Pumping for a 5-Stage Bardenpho MBR Configuration

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add new MBR, (2) Add an Aeration System, (3) Demolish the High Purity Oxygen Reactors and Oxygen Production Facilities, (4) Demolish the Secondary Clarifiers, (5) Add a Sidestream Treatment Reactor, and (6) Add a Fermenter to Treat Primary Solids
Note: the new MBR facility (1) would require relocating the Maintenance Building, parking, and fueling station.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add new MBR, (2) Add an Aeration System, (3) Demolish the High Purity Oxygen Reactors and Oxygen Production Facilities, (4) Demolish the Secondary Clarifiers, (5) Add a Sidestream Treatment Reactor, (6) Add a Fermenter to Treat Primary Solids, (7) Add an External Carbon Source, (8) Add a Metal Salt, and (9) Add Mixed Liquor Return Piping/Pumping for a 5-Stage Bardenpho MBR Configuration

Note: the new MBR facility (1) would require relocating the Maintenance Building, parking, and fueling station.

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for TN and TP Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	120	139	120	139
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	2,250	2,280	2,320	2,400
Annual O&M	$Mil/yr	14	15	17	21
O&M PV[3]	$ Mil	310	340	390	470
Total PV[3]	$ Mil	2,560	2,620	2,710	2,870
Unit Capital Cost	$/gpd	19	16	19	17
Unit Total PV	$/gpd	21	19	23	21
TN Removal					
Capital[2]	$ Mil	2,220	2,250	2,290	2,360
Annual O&M	$ Mil/yr	14	15	17	20
O&M PV[3]	$ Mil	300	330	380	450
Total PV[3]	$ Mil	2,520	2,580	2,670	2,810
TN Removed (Ave.)[4]	lb N/d	24,300	25,100	27,800	32,200
Annual TN Removed	lb N/yr	8,850,000	9,150,000	10,150,000	11,770,000
TN Cost[5]	$/lb N	9.5	9.4	8.7	8.0
TP Removal[6]					
Capital[2]	$ Mil	2,130	2,160	2,170	2,230
Annual O&M	$ Mil/yr	15	16	16	17
O&M PV[3]	$ Mil	330	360	360	380
Total PV[3]	$ Mil	2,460	2,520	2,530	2,610
TP Removed (Ave.)[4]	lb P/d	2,100	2,100	2,400	2,700
Annual TP Removed	lb P/yr	760,000	780,000	858,000	984,000
TP Cost[5]	$/lb P	108	107	98	88

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. The average nutrient load reduction over the 30-year project duration.
5. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
6. Based on EBMUD's historical TP load reduction data of approximately 40 percent while comparing raw influent against discharge (excludes contributions from organic wastes). The listed load reductions are based on additional removal with the Level 2 and 3 upgrades.

Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. These costs do not account for any changes in any other process, including solids handling or associated energy requirements. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Produce a high quality water that is amenable to future recycled water opportunities • Reduced overall solids production due to the longer aerobic SRT associated with the MBR • Reduced solids/BOD discharge loading • Enhanced CEC removal due to a longer SRT and solids separation for removing particulate bound CECs	• Additional chemicals for cleaning the membranes • Increase in overall energy intensity due to replacing efficient high purity oxygen system with energy intensive membrane bioreactor • New aeration system to learn how to operate and maintain • Operate with a completely new biological and solids separation processes. This will require significant operator training • Two separate biological processes to operate (MBR and sidestream treatment) • Less nutrients available in the recycled water (if desired by recycled water customers)
Level 3	Same as Level 2 plus the following additional benefits: • Further alkalinity recovery due to more denitrification than Level 2	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Safety from external carbon source (if methanol) • Additional aeration basin volume to operate • Additional energy demand associated with mixed liquor return pumping

7 Nutrient Load Reduction by Other Means

The EBMUD WWTP has an existing recycled water program that is employed year-round. This existing program has the effect of reducing nutrients discharged to the Bay. The WWTP recycled about 152 acre-feet in 2015 (or approximately 50 million gallons). There are plans to further expand the recycled water program to meet the District's goal of 20 mgd by 2040. These plans are currently under review through the Recycled Water Master Plan Update study.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit required GHG emissions are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be a plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

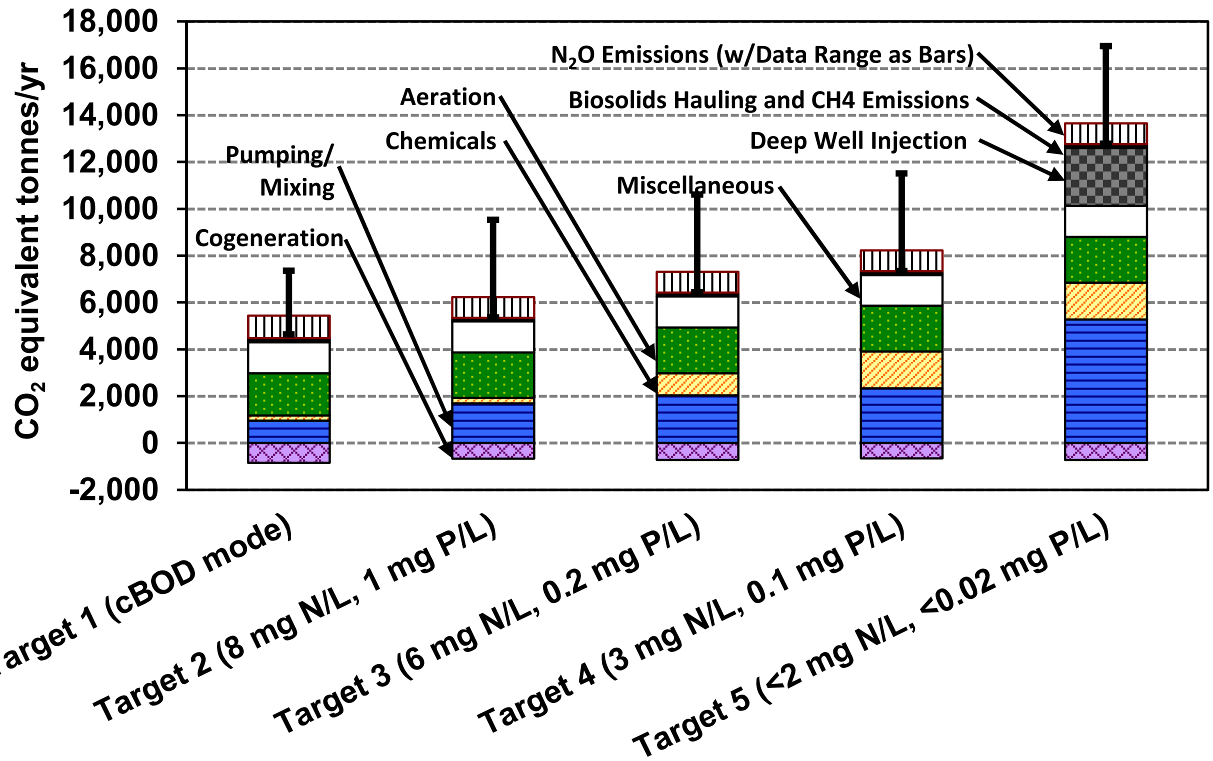

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	--*	--*	23,000	23,100	26,400	27,000	1,830
GHG Emissions Increase from Chemicals	MT CO_2/yr	--*	--*	0	0	6,400	6,900	460
GHG Emissions Increase Total	MT CO_2/yr	--*	--*	23,000	23,100	32,700	33,900	2,290
Unit GHG Emissions[2]	lb CO_2/MG	--*	--*	1,100	1,100	1,500	1,600	250
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	--*	--*	5	5	5	5	1.1
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	5	5	6	6	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--*	--*	90	90	90	80	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
* No optimization strategies were deemed viable at EBMUD.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at EBMUD:

- Granular Activated Sludge – this could be used to phase out the HPO system. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. The key benefits of this technology at EBMUD are the compact footprint and energy efficiency. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America and currently limited to batch process operation.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could serve as an aeration diffuser for any activated sludge configurations to increase aeration capacity and improve energy efficiency. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit of this technology at EBMUD is the potential to use high purity oxygen and inject it directly into the MABR cassettes. This would save EBMUD from having to replace the high purity oxygen system with blowers. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected this analysis.

Table 1. Allowanced used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Value
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.9

Fairfield Suisun Sewer District

Bay Area Clean Water Agencies
Nutrient Reduction Study

Fairfield Suisun Sewer District

Fairfield, CA

April 12, 2018
Final Report

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Appendices

Executive Summary

Fairfield-Suisun Sewer District (FSSD) owns and operates the Fairfield-Suisun Wastewater Treatment Plant (WWTP) located in Fairfield, CA and discharges treated effluent to Boynton Slough, Duck Pond 1, Duck Pond 2, and Ledgewood Creek. The plant has an average dry weather flow (ADWF) permitted capacity of 23.7 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs (e.g., $/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	12.3	13.8	23.7	26.7	23.7	26.7	--
Flow to Bay[2]	mgd	12.8	12.8	13.3	13.3	19.8	19.8	19.8	19.8	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	4	4	4	4	5	5	5	5	5
TN	lb N/d	2,820	2,820	2,190	2,080	2,110	1,980	1,590	990	3,500
TP	lb P/d	440	440	400	370	180	160	120	50	600
Costs[4,5]										
Capital[7]	$ Mil	--	--	18.3	18.4	31	56	79	100	14.7
O&M PV	$ Mil	--	--	0.2	1.6	--	2	16	36	9.2
Total PV	$ Mil	--	--	18.5	19.9	31	58	95	136	23.9
Unit Costs[6]										
Capital	$/gpd	--	--	1.5	1.3	1.3	2.1	3.3	3.7	--
Total PV	$/gpd	--	--	1.5	1.4	1.3	2.2	4.0	5.1	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Optimization and upgrades include the on-going blower replacement total project cost (anticipated total project cost of $11.6 Mil)

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Convert a portion of the first aeration zone to anoxic zones (limited to Trains A and B) for reducing TN discharge loading. This will require at a minimum wall sections and mixers. This strategy includes the on-going blower replacement total project cost as this project directly relates to ammonia and total nitrogen load reduction.
2. Add metal salt chemical feed facility to increase dosing at the filters. This will assist with reducing total phosphorus discharge loads. While potentially viable, there is concern that this might overload the filters with solids. Testing is recommended to confirm whether overloading the filters would fatally flaw this strategy.

The FSSD WWTP is considered a candidate for sidestream treatment to reduce TN and TP loads as the plant anaerobically digests biosolids and dewaters to produce a return sidestream laden with nutrients. The plant already removes a portion of raw influent TN and TP loads. Sidestream treatment would further enhance such nutrient load reductions. For TN load reduction in the sidestream, a potential sidestream treatment strategy is a deammonification technology. For TP load reduction in the sidestream, metal salt coagulant (e.g., ferric chloride) dosing in the sidestream would precipitate phosphorus which could be captured with biosolids and removed from the discharge.

Besides the listed sidestream technologies, FSSD is in partnership with Lystek International Inc. (Lystek) and evaluating a means to eliminate the mechanical dewatering return sidestream. The approach is to deliver non-dewatered WWTP biosolids directly to Lystek for blending with dryer biosolids from other agencies. Such an approach would completely remove the mechanical dewatering sidestream and any nutrient loads associated with a mechanical dewatering return sidestream. The District would want to pursue that option first before utilizing additional resources for a sidestream treatment system.

This evaluation is based on the sidestream deammonification and metal salt coagulant technologies with the understanding that the Lystek partnership would be under consideration.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Convert the first aeration zones to anoxic zones (limited to trains A/B).
   b. Add chemical feed facilities at the primaries and operate as chemically enhanced primary treatment.
   c. Add mixed liquor return pumping for trains A/B/C.
   d. Add additional aeration trains.
   e. Add new blowers per the on-going blower replacement project.
   f. Expand the filter complex.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Expand the aeration trains to provide nutrient removal polishing zones.
   c. Add chemical feed facilities for an external carbon source to further reduce TN loads. Possible carbon sources include, but are not limited to:

i. Established carbon sources commonly used at treatment plants (e.g., methanol, acetic acid, etc.)

ii. Lystek product, LysteCarb, which is currently being tested for use as an external carbon source. This would be located on site and potentially minimize feed facilities.

iii. Candy waste from nearby Jelly Belly as a carbon source rather the current approach of using it to feed the digester for enhanced biogas production.

d. Add a rapid mix/flocculation tank upstream of the filters.

e. Add sidestream treatment (deammonification technology).

Capital costs, O&M costs and present value costs were determined for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for changes in solids handling requirements or energy requirements in other unit processes.

As shown in Table ES-1, and as might be expected, the costs generally increase from optimization to sidestream treatment, and again to Level 2 and Level 3 upgrades, respectively. The costs generally increase for both capital and O&M from the dry season to year round. Overall, the present value costs range from $18.5 Mil for optimization (includes the on-going blower replacement project) up to $136 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. The GHG emissions associated with energy increased with the treatment level. In contrast, the GHG emissions associated with chemicals decreased with treatment level.

1 Introduction

The Fairfield-Suisun Sewer District Wastewater Treatment Plant (FSSD WWTP) discharges to Boynton Slough, Duck Pond 1, Duck Pond 2, and Ledgewood Creek. It is located at 1010 Chadbourne Road, Fairfield, CA 94534, and it serves about 57,700 service connections throughout Fairfield, Suisun City, and Travis Air Force Base. The plant has an average dry weather flow (ADWF) permitted capacity of 23.7 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

FSSD WWTP holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2015-0013. Table 2-1 provides a summary of the permit limitations but is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2015-0013; CA0038024)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly
Flow	mgd	23.7		
BOD	mg/L		10	15
TSS	mg/L		10	15
Total Ammonia, as N	mg/L		2.0	-

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the existing process flow diagram for FSSD WWTP. Both liquids processes and solids processes are shown. The FSSD WWTP has headworks, primary clarifiers, oxidation towers, an activated sludge system that fully nitrifies and partially denitrifies, filtration, and ultraviolet (UV) disinfection. There is the ability to bypass the oxidation towers to the aeration trains. The activated sludge maintains a high SRT for full nitrification and it partially denitrifies in one of the three trains (receives approximately 40 to 45 percent of the feed flow). The tertiary treated effluent is conveyed to a combination of marsh and other water recycling users.

Solids treatment consists of thickening, anaerobic digestion and dewatering. The biosolids cake diverted to an on-site organic material recovery facility, operated by Lystek International. This facility began receiving FSSD biosolids in August 2016.

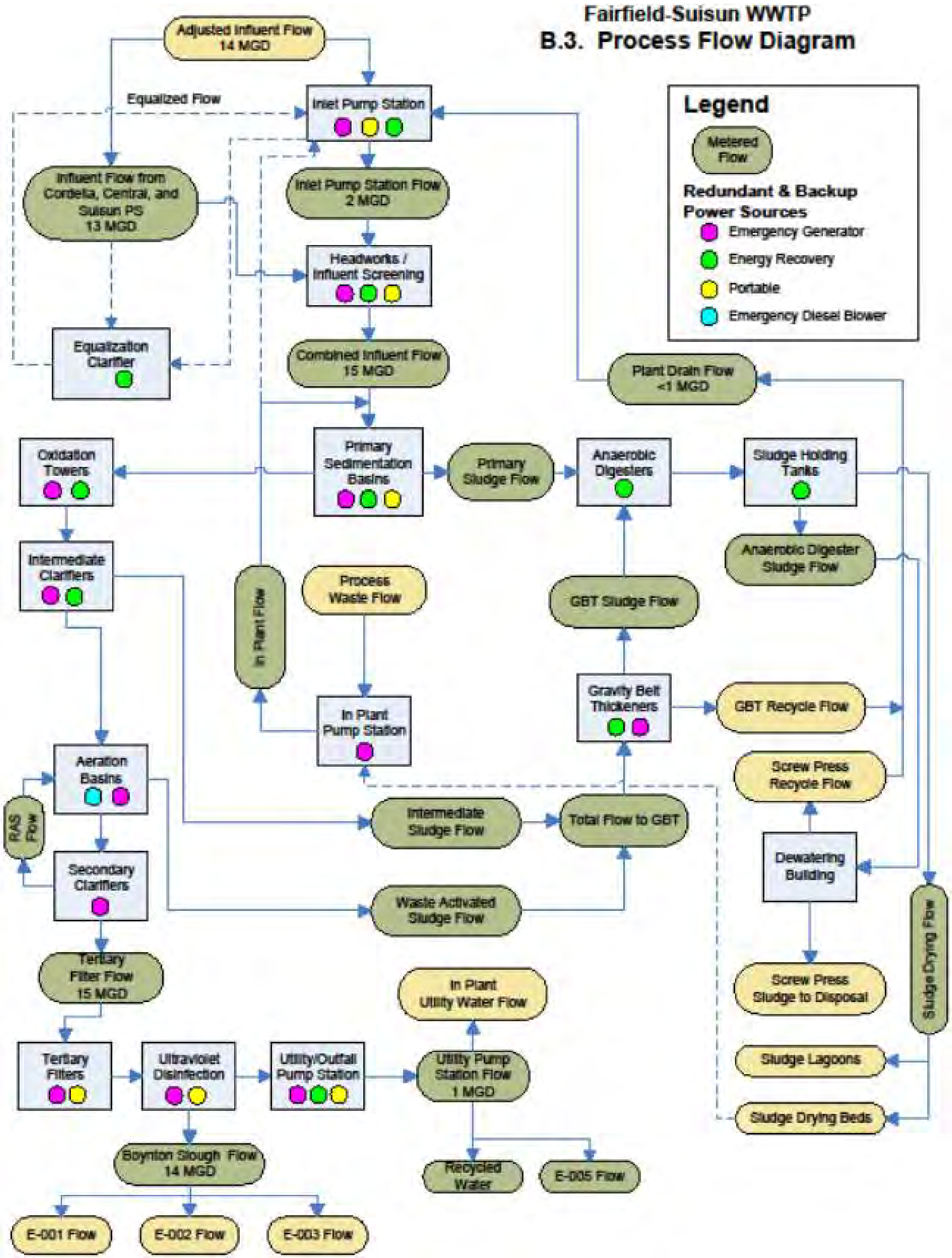

Figure 2-1. Process Flow Diagram for Fairfield Suisun Sewer District

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the FSSD WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	12.3	13.2	13.8	18.6
BOD	lb/d	31,000	31,500	35,300	36,100
TSS	lb/d	27,000	26,900	30,500	30,800
Ammonia	lb N/d	3,400	3,300	3,900	3,600
Total Kjeldahl Nitrogen (TKN)	lb N/d	5,600	4,800	5,900	6,100
Total Phosphorus (TP)	lb P/d	790	780	900	1220
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	303	286	308	232
TSS	mg/L	264	245	266	198
Ammonia	mg N/L	33	30	34	23
TKN	mg N/L	55	44	51	39
TP	mg P/L	7.7	7.1	7.8	7.9
Alkalinity	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

FSSD is already providing full nitrification and partial denitrification. The WWTP has three on-going projects that relate to nutrient removal:

1. The plant is in contract with Lystek®, a private biosolids processor to treat digested biosolids and produce an agricultural fertilizer. The goal is that this process will eventually eliminate filtrate return to the process, but that will likely take some time to establish and there may continue to be some return sidestream flow.
2. A capital project is currently underway to replace the existing blowers with high-speed turbo blowers capable of producing 22,500 scfm. Provisions are being made to expand this to 37,500 scfm.

2.5 Pilot Testing

FSSD has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for the FSSD WWTP are presented in Table 3-1. The projected flow and load for 2025 was not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	12.3	13.2	13.8	18.6
BOD	lb/d	35,700	36,200	40,600	41,500
TSS	lb/d	31,100	31,000	35,100	35,400
Ammonia	lb N/d	3,900	3,800	4,500	4,100
TKN	lb N/d	6,500	5,600	6,700	7,000
TP	lb P/d	910	900	1,030	1,410
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	348	329	354	267
TSS	mg/L	304	282	306	228
Ammonia	mg N/L	38	35	39	26
TKN	mg N/L	63	51	59	45
TP	mg P/L	8.9	8.2	9.0	9.1
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by FSSD, it was determined that the FSSD WWTP is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July, 2015. The sampling results were projected forward to the permitted capacity. The flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-2. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Permitted Flow Capacity
Sidestream Flow	mgd	0.07	0.10
Ammonia	lb N/d	700	1,000
TKN	lb N/d	850	1,300
TN[1]	lb N/d	850	1,300
OrthoP	lb P/d	30	45
TP	lb P/d	55	83
Alkalinity	lb $CaCO_3$/d	2,750	4,110
Ammonia	mg N/L	1,300	1,300
TKN	mg N/L	1,600	1,600
TN[1]	mg N/L	1,600	1,600
OrthoP	mg P/L	55	55
TP	mg P/L	100	100
Alkalinity	mg/L as CaCO3	5,100	5,100

1. It was assumed that TN = TKN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	23.7	25.5	26.6	36.0
BOD	lb/d	59,900	60,800	68,200	69,600
TSS	lb/d	52,200	52,000	58,900	59,400
Ammonia	lb N/d	6,500	6,400	7,500	6,900
TKN	lb N/d	10,900	9,300	11,300	11,700
TP	lb P/d	1,520	1,510	1,730	2,370
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	303	286	308	232
TSS	mg/L	264	245	266	198
Ammonia	mg N/L	33	30	34	23
TKN	mg N/L	55	44	51	39
TP	mg P/L	7.7	7.1	7.8	7.9
Alkalinity	mg/L as CaCO3	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for, TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period.

Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy.

Eight optimization strategies were identified during the FSSD WWTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The eight optimization strategies were screened down to four strategies as follows.

- **Optimization Strategy 1:** Add ferric chloride chemical feed facilities at the primary clarifiers to turn them into chemically enhanced primary treatment (CEPT). CEPT will remove phosphorus and increase the TSS and BOD capture at the primaries.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase phosphorus removal and reduce loading to downstream unit processes. This could enhance the potential to remove ammonia in the biotowers (if converted to nitrifying biotowers) and increase downstream capacity for nitrification/denitrification.
  - ***Result from analysis:*** It will remove phosphorus at the primaries and increase downstream capacity. However, it will most likely remove more carbon than desired which will negatively impact the ability to denitrify downstream (if required in the future). The extent of this impact would require more detailed analysis.
  - ***Recommendation:*** Do not carry forward.
- **Optimization Strategy 2:** Increase chemical addition at the filters. This will require adding an additional alum chemical feed facility (one already exists).
  - ***Is it feasible?*** Yes, but there are concerns about overloading the filters. Testing is recommended to confirm the ability of the filter units to handle the elevated solids loading associated with additional alum dose.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Total phosphorus load reduction.
  - ***Result from analysis:*** Additional alum at the filters will remove phosphorus. However, the filters might not able to handle the additional solids loading as previously stated.
  - ***Recommendation:*** Carry forward for this analysis. It would require field testing to confirm that the filters can handle the additional solids loading.
- **Optimization Strategy 3:** Split treatment where a portion of the primary effluent is nitrified in the oxidation towers with subsequent denitrification in the activated sludge process. The remaining portion is nitrified/denitrified in the activated sludge process. This strategy would require modifying the oxidation towers by decreasing flow and increasing the recirculation rate.
  - ***Is it feasible?*** Yes, but it would require significant pumping, piping and valve modifications at the oxidation towers.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Remove a portion of the ammonia load in the oxidation towers and the remaining load in the activated sludge system.
  - ***Result from analysis:*** The challenges associated with converting the oxidation towers to nitrifying oxidation towers outweigh the benefits as the WWTP is already fully nitrifying and it has the potential to denitrify with less significant changes to the aeration trains (see Strategy 4).
  - ***Recommendation:*** Do not carry forward.

- **Optimization Strategy 4:** Convert the first aeration zone in trains A and B to an anoxic zone to facilitate denitrification. Train C already has an anoxic zone so it would require little or no modifications to that train. Depending on the plant load, the oxidation towers have the option of shutting off so all carbon passes directly to the aeration trains. Also, the new blowers currently being installed will nearly double the firm aeration capacity. The on-going blower replacement total project cost is included with this strategy.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Remove a portion of the nitrogen load year round.
  - ***Result from analysis:*** This strategy can successfully reduce the nitrogen load. The extent of nitrogen load reduction is predicated on three variables: i) the amount of aeration train capacity to reliably oxidize the ammonia load to nitrate, ii) the amount of carbon available for denitrification (increases as more primary effluent bypasses the oxidation towers), and iii) the amount of return activated sludge that can be returned to the anoxic zones.
  - ***Recommendation:*** Carry forward.

Strategies 2 and 4 could independently reduce phosphorus and nitrogen, respectively. Strategy 4 is the best apparent way to reduce discharge nitrogen loads. Increasing alum addition to the filters (Strategy 2) would reduce the discharge phosphorus loads.

The recommended strategies are shown with the process flow diagram presented in Figure 4-1. A description of each strategy and the evaluation results are presented thereafter. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

The capital and operational elements of the recommended optimization strategies are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Convert First Aeration Zones to Anoxic Zones • Modifications to send the oxidation tower bypass flow to the appropriate aeration trains or potentially bypass oxidation towers altogether with additional blower capacity that will be installed by 2018. This strategy Includes the on-going blower replacement total project cost. • Convert a portion of the first zone in the appropriate aeration trains to anoxic zones (Trains A and B). This will require at a minimum wall sections and mixers. • Modify the aeration supply grid for nitrification/denitrification in trains A and B.	• Have the ability to control how much primary effluent bypasses the oxidation towers so that there is sufficient aeration capacity to oxidize ammonia to nitrate in the aeration zones. • Have the ability to turn off airflow to the created anoxic zone and operate the mixers so that it operates as an anoxic zone.
Increase Chemical Addition at the Filters • Add an additional alum chemical feed facility	• Operate the alum chemical feed facilities

Figure 4-1. Optimization Concepts Considered for FSSD WWTP

(1) Convert the first aeration zones to anoxic zones (limited to Trains A/B) and (2) add metal salt chemical feed facility to increase dosing at the filters.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season[4]	NH4-N Year Round[4]	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	4	4	3,030	3,030	470	470
Discharge with Opt. Strategy[1]	lb N or P/d	4	4	2,190	2,080	400	370
Load Reduction[2]	lb N or P/d	0	0	840	950	70	100
Load Reduction[2]	%	0%	0%	28%	31%	16%	21%
Annual Load Reduction[3]	lb N or P/yr	0	0	305,000	346,000	27,100	35,700

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
4. The plant already fully nitrifies so any optimization concept will not further reduce ammonia discharge loads.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy*

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	12.3	13.8
Ammonia, TN and TP Removal			
Capital[2,**]	$ Mil	18.3	18.4
Annual O&M	$ Mil/yr	0.02	0.18
Present Value O&M[3]	$ Mil	0.2	1.6
Present Value Total[3]	$ Mil	18.5	19.9
Unit Capital Cost[8]	$/gpd	1.5	1.3
Unit Total PV Cost[8]	$/gpd	1.5	1.4
TN Removal			
Capital[2,4,**]	$ Mil	17.4	17.4
Annual O&M[4]	$ Mil/yr	--	--
O&M PV[3,4]	$ Mil	--	--
Total PV[3,4]	$ Mil	17.4	17.4
TN Removed (Ave.)[6]	lb N/d	840	950
Annual TN Removed (Ave.)[7]	lb N/yr	305,000	346,000
TN Cost[4,9]	$/lb N	5.7	5.0
TP Removal			
Capital[2,5]	$ Mil	0.9	0.9
Annual O&M[5]	$ Mil/yr	0.3	0.4
O&M PV[3,5]	$ Mil	3.1	3.6
Total PV[3,5]	$ Mil	4.0	4.5
TP Removed (Ave.)[6]	lb P/d	74	98
Annual TP Removed (Ave.)[7]	lb P/yr	27,100	35,700
TP Cost[5,9]	$/lb P	14.7	12.6

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 10 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

* The plant already fully nitrifies so any optimization concept will not further reduce ammonia discharge loads.
** Includes the on-going blower replacement project (anticipated total project cost of $11.6 Mil)

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at FSSD WWTP.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
Convert Portion of First Aeration Zones to Anoxic Zones (Limited to Trains A/B) • Ability to reduce total nitrogen discharge loads • Recovery of alkalinity lost during nitrification • Improved settleability in the secondaries • Reduced biosolids handling yield due to BOD used towards denitrification instead of oxidation towers • Increase in blower capacity from the on-going blower replacement project	• Need to operate both aerobic and anoxic zones (Limited to Trains A/B)
Increase Chemical Addition at the Filters • Ability to reduce total phosphorus loads	• Additional chemical handling • Reduced filtration capacity due to additional solids loading from chemical addition • Additional solids in the liquid stream process to handle from filter backwash • Additional energy demand to backwash filters more regularly • Negative impact on UV disinfection transmittance from additional alum addition. This is unclear but warrants additional bench-scale testing to verify

5 Sidestream Treatment

As previously described, the FSSD WWTP was identified as a potential candidate for sidestream treatment. The WWTP currently uses drying beds on a seasonal basis. In the near future, the WWTP is moving towards year-round dewatering which was assumed in the analysis.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for TN load reduction and metal salts/solids separation facilities for TP load reduction. The WWTP already removes ammonia in the main plant so sidestream treatment to reduce ammonia discharge loads to the Bay is not recommended.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification) including requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requires 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for FSSD.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks). In the case of FSSD, ferric chloride addition ahead of the dewatering is recommended where the precipitated P will be captured with the cake.

Besides the listed sidestream technologies, FSSD is in partnership with Lystek International Inc. (Lystek) and evaluating a means to eliminate the mechanical dewatering return sidestream by delivering non-dewatered biosolids directly to Lystek for blending with dryer biosolids from other agencies. Such an approach would completely remove the mechanical dewatering sidestream and in turn any nutrient loads associated with a mechanical dewatering return sidestream. The District would want to pursue that option first before utilizing additional resources for a sidestream treatment system.

This evaluation is based on the sidestream deammonification and metal salt coagulant technologies with the understanding that the Lystek partnership is under consideration. A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Nutrient Load Reduction*

Total Nitrogen Load Reduction Elements[1]	Total Phosphorus Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Coagulant
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

1. The plant already fully nitrifies so any optimization concept will not further reduce ammonia discharge loads.
* Note: FSSD is evaluating a means to eliminate mechanical dewatering which would nullify any sidestream treatment recommendations.

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge*

Parameter	Units	NH4-N (lb N/d)[4]	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	5	4,100	640
Discharge with Sidestream Treatment[2]	lb/d	5	3,500	600
Load Reduction[3]	lb/d	0	600	40
Load Reduction	%	0%	15%	6%
Annual Load Reduction	lb/yr	0	228,700	13,400

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. The plant already fully nitrifies so any optimization concept will not further reduce ammonia discharge loads.
* Note: FSSD is evaluating a means to eliminate mechanical dewatering which would nullify any sidestream treatment recommendations.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/Total Nitrogen[7]	Total Phosphorus
Capital[1]	$ Mil	14.5	0.2
Annual O&M	$ Mil/yr	0.4	0.04
Total Present Value[2]	$ Mil	22.9	1.0
NH4-N Load Reduction[3,5]	lb N/yr	--[7]	--
TN Load Reduction[3,5]	lb N/yr	228,700	--
TP Load Reduction[4,5]	lb P/yr	--	13,400
NH4-N Cost [3,5,6]	$/lb N	--[7]	--
TN Cost [3,5,6]	$/lb N	3.3	--
TP Cost [4,5,6]	$/lb P	--	2.0

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. The plant already fully nitrifies so any optimization concept will not further reduce ammonia discharge loads.

* Note: FSSD is evaluating a means to eliminate mechanical dewatering which would nullify any sidestream treatment recommendations.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the FSSD WWTP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. FSSD should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under the Optimization Section. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, ferric chloride chemical feed facilities would be added just upstream of the primary clarifiers. This effectively turns the primaries into chemically enhanced primary treatment (CEPT) to increase phosphorus, TSS, and BOD removal. An additional aeration train would be required that operates in parallel with the existing trains. This train is required for capacity purposes due to a combination of nitrification/denitrification and sending primary effluent directly to the aeration trains. The plant is currently implementing new blowers that should satisfy requirements for Levels 2 and 3. The estimated cost of the blowers is included in this analysis as the new blowers are not currently installed. All of the trains will require mixed liquor return pumps to return nitrate laden mixed liquor to the anoxic zones for denitrification. The existing step feed channels can be modified to return the mixed liquor and it will require mixed liquor return pumps. The existing filter complex will be expanded to reduce hydraulic loading.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

In addition to those listed for Level 2, Level 3 upgrades requires further expansion of the aeration trains, an external carbon source chemical feed facility, alum/polymer chemical feed facilities at the filters, a rapid mix/flocculation tank upstream of the filters, and sidestream treatment. The train expansion is to allow an additional anoxic and oxic zone to further reduce the TN load down to the target. The external carbon source is provided to meet the carbon requirements for meeting the TN discharge target. Possible carbon sources include, but are not limited to:

- Established carbon sources commonly used at WWTPs (e.g., methanol, acetic acid, etc.)
- Lystek product, LysteCarb, which is currently being tested for use as an external carbon source. This would be located on site and potentially minimize feed facilities.
- Candy waste from nearby Jelly Belly as a carbon source rather the current approach of using it to feed the digester for enhanced biogas production.

This analysis was based on use of methanol as it is the most common external carbon source used at WWTPs. FSSD should consider the other listed carbon sources if Level 3 upgrades are required in the future. The chemical feed facilities and the rapid mix/flocculation step prior to the filters is in place to remove solids loading associated with chemical precipitation upstream of the filters. The additional chemical feed facilities would operate on a daily basis to meet the TP discharge target. The sidestream treatment is recommended to reduce the activated sludge footprint, reduce overall energy, and reduce chemical demands (specifically an external carbon source).

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Ferric Chloride facility to operate as a CEPT	Same as Level 2
Biological	• Add Anoxic Zones in Trains A/B • Add a New Train • Mixed Liquor Return Pumping and Modifications to the Step Feed Channel • New Blowers (Currently Being Implemented) • Aeration System Modifications to Air Piping, Headers, Air Valves, and Distribution	Same as Level 2, plus: • Expand the trains with nutrient polishing zones • Further Modifications to the Aeration System Piping/Distribution • External Carbon Source Chemical Feed Facility.
Tertiary	• Expand the Filter Complex to Reduce Loading	Same as Level 2, plus: • Daily Use of Alum Chemical Feed Facilities Added under Optimization • Polymer Chemical Feed Facilities • Rapid Mix and Flocculation Tanks
Biosolids or Sidestream	--	Sidestream Treatment

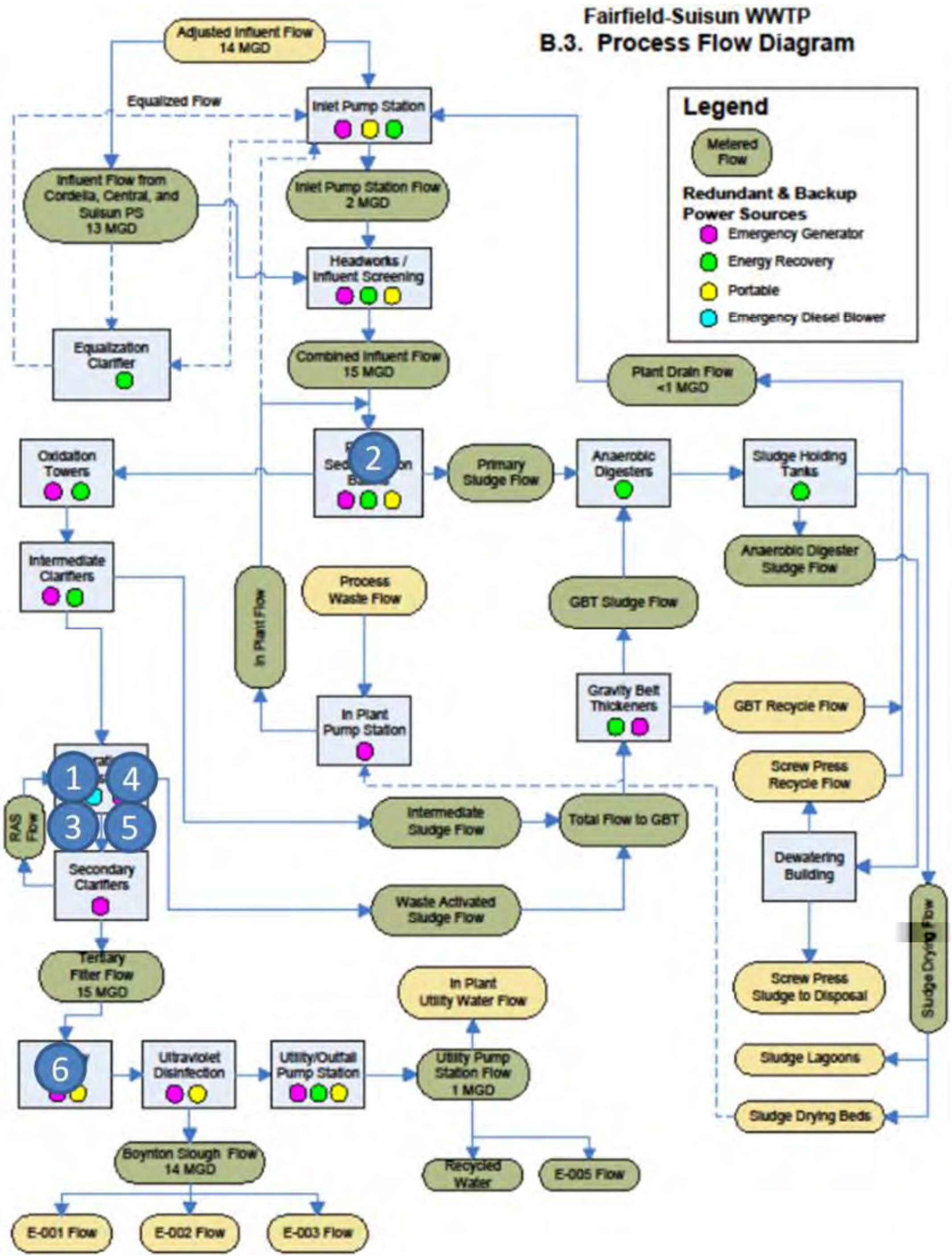

Figure 6-1. Level 2 Upgrade Concepts for FSSD WWTP

(1) Convert a portion of the first aeration zones to anoxic zones (limited to A/B Trains), (2) add chemical feed facilities at the primary sedimentation basins and operate as chemically enhanced primary treatment (3) add mixed liquor return pumping for A/B/C Trains, (4) add additional aeration train, (5) add new blowers and other aeration system modifications (currently being implemented), and (6) expand the filter complex

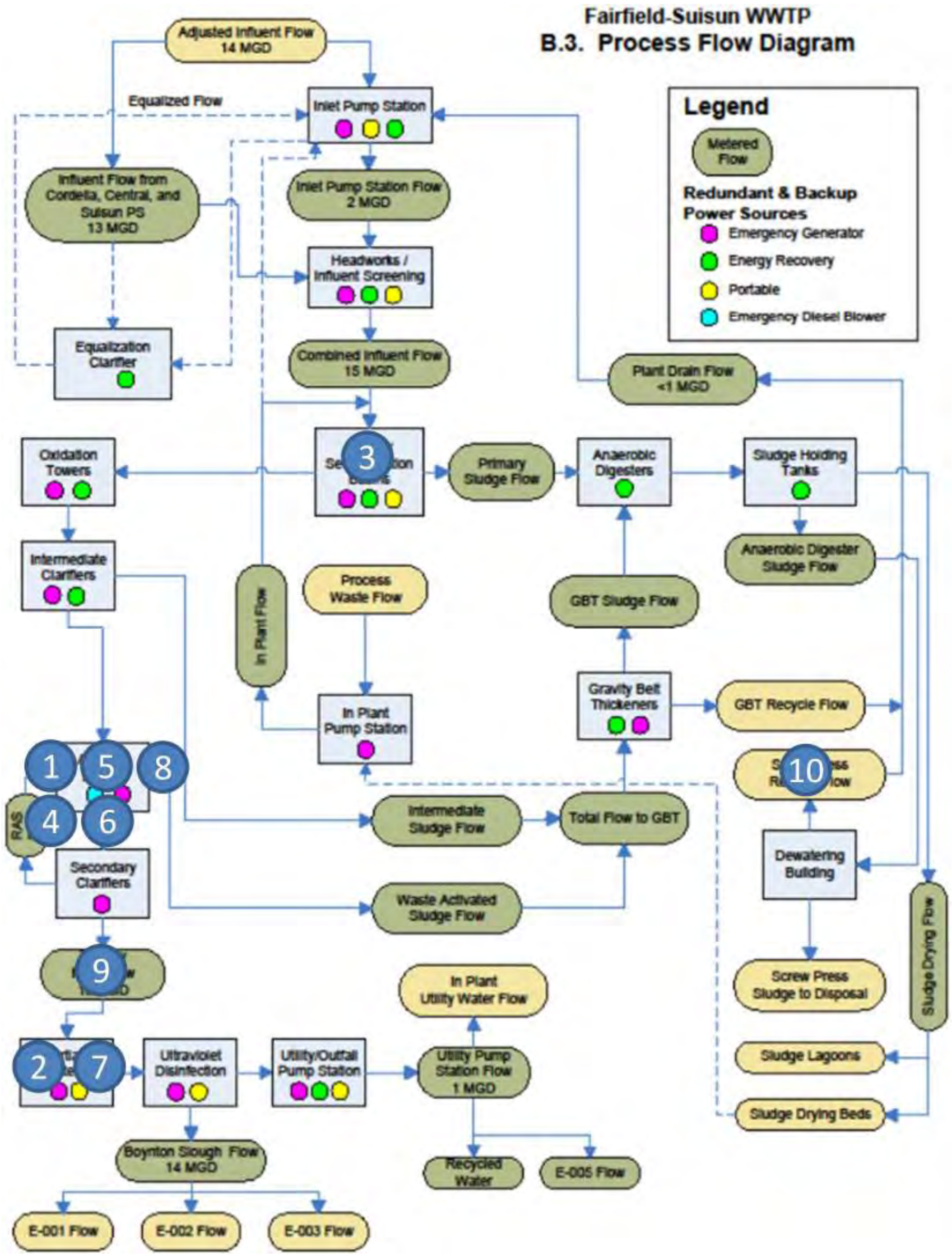

Figure 6-2. Level 3 Upgrade Concepts for FSSD WWTP

(1) Convert a portion of the first aeration zones to anoxic zones (limited to A/B Trains), (2) add metal salt chemical feed facility to increase dosing at the filters, (3) add chemical feed facilities at the primary sedimentation basins and operate as chemically enhanced primary treatment (4) add mixed liquor return pumping for A/B/C Trains, (5) add additional aeration train and expand all the trains with nutrient polishing zones, (6) add new blowers and other aeration system modifications (currently being implemented), (7) expand the filter complex, (8) add external carbon source chemical feed facilities, (9) add a rapid mix/flocculation tank upstream of the filters, and (10) sidestream treatment (deammonification technology)

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Convert a portion of the first aeration zones to anoxic zones (limited to A/B Trains), (2) add chemical feed facilities at the primary sedimentation basins and operate as chemically enhanced primary treatment (3) add mixed liquor return pumping for A/B/C Trains, (4) add additional aeration train, (5) add new blowers and other aeration system modifications (currently being implemented), and (6) expand the filter complex

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Convert a portion of the first aeration zones to anoxic zones (limited to A/B Trains), (2) add metal salt chemical feed facility to increase dosing at the filters, (3) add chemical feed facilities at the primary sedimentation basins and operate as chemically enhanced primary treatment (4) add mixed liquor return pumping for A/B/C Trains, (5) add additional aeration train and expand all the trains with nutrient polishing zones, (6) add new blowers and other aeration system modifications (currently being implemented), (7) expand the filter complex, (8) add external carbon source chemical feed facilities, (9) add a rapid mix/flocculation tank upstream of the filters, and (10) sidestream treatment (deammonification technology)

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	23.7	26.7	23.7	26.7
Cost for Ammonia, TN, and TP Removal					
Capital[2,9]	$ Mil	31	56	79	100
Annual O&M	$Mil/yr	--	0.1	0.7	1.6
O&M PV[3]	$ Mil	--	2	16	36
Total PV[3]	$ Mil	31	58	95	136
Unit Capital Cost	$/gpd	1.3	2.1	3.3	3.7
Unit Total PV	$/gpd	1.3	2.2	4.0	5.1
TN Removal					
Capital[2,4,9]	$ Mil	27	46	74	89
Annual O&M[4]	$ Mil/yr	--	--	--	0.4
O&M PV[3,4]	$ Mil	--	--	--	8
Total PV[3,4]	$ Mil	27	46	74	97
TN Removed (Ave.)[6]	lb N/d	2,000	2,100	2,500	3,100
Annual TN Removed (Ave.)[7]	lb N/yr	740,000	780,000	930,000	1,150,000
TN Cost[4,8]	$/lb N	1.2	1.9	2.7	2.8
TP Removal					
Capital[2,5]	$ Mil	4.4	9.8	5.1	10.8
Annual O&M[5]	$ Mil/yr	1.0	1.1	1.2	1.3
O&M PV[3,5]	$ Mil	22	25	26	28
Total PV[3,5]	$ Mil	27	34	31	39
TP Removed (Ave.)[6]	lb P/d	460	480	520	590
Annual TP Removed (Ave.)[7]	lb P/yr	169,000	173,000	190,000	216,000
TP Cost[5,8]	$/lb P	5.2	6.6	5.5	6.1

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Includes the on-going blower replacement total project cost (anticipated total project cost of $11.6 Mil)

Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Additional capacity for primary clarifiers • Improved settleability in the secondary clarifiers • Additional filtration capacity due to improved secondary clarifier effluent (the extent is unclear and would require verification testing) • Reduced solids/BOD discharge loading • Alkalinity recovery associated with the denitrification step • Similar or better CEC removal than the existing plant	• Additional chemicals from CEPT • Increase in overall energy intensity due to removing oxidation towers from the process • Additional aeration basin to operate • Operate in a new mode that will require the operators to get accustomed to
Level 3	Same as Level 2 plus the following additional benefits: • Further alkalinity recovery due to more denitrification than the other Levels	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Additional solids • Safety from external carbon source (if methanol) • Additional aeration basin volume to operate • Operating an additional biological process (i.e., sidestream treatment)

7 Nutrient Load Reduction by Other Means

The FSSD WWTP has an existing recycled water program that is employed year-round. This existing program has the effect of reducing nutrients discharged to the Bay. The WWTP currently recycles approximately 9,500 acre-feet per year (3,100 million gallons per year). There are no existing plans to further expand the recycled water program.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG

emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

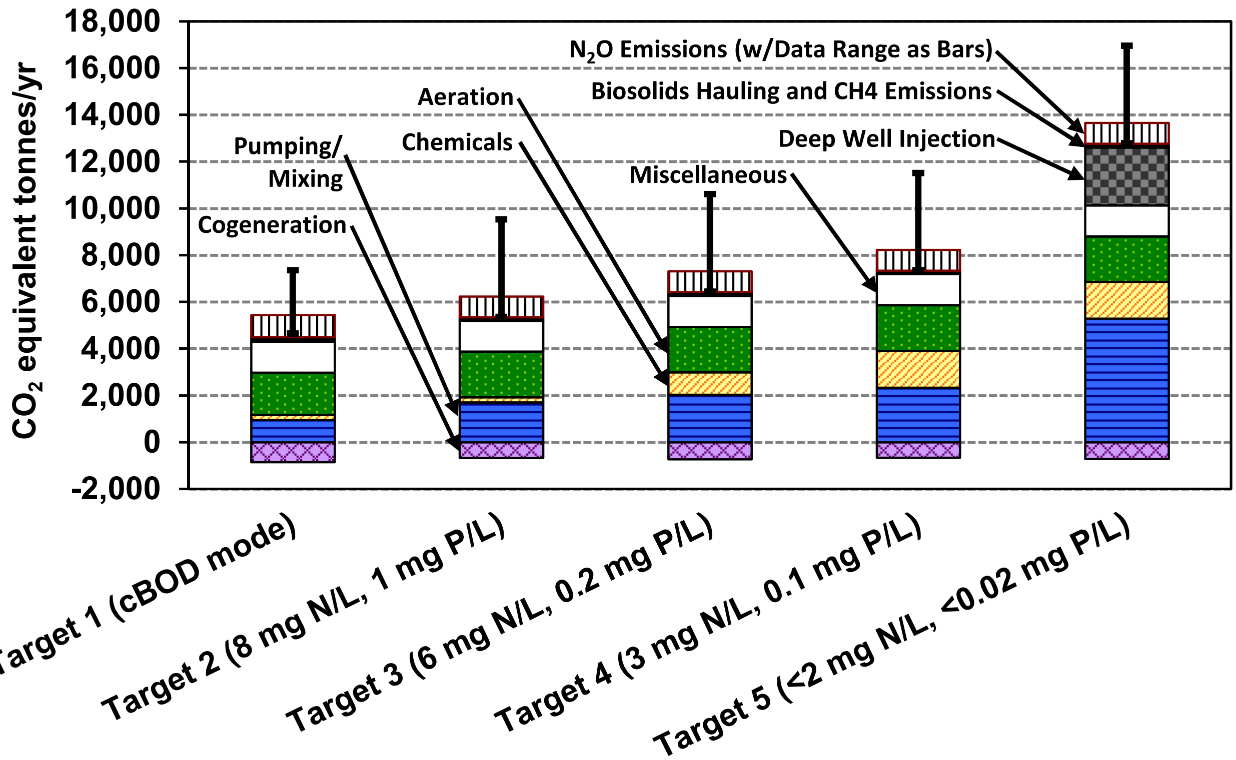

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Ave. Annual
GHG Emissions Increase from Energy	MT CO_2/yr	180	190	100	200	200	300	90
GHG Emissions Increase from Chemicals	MT CO_2/yr	10	10	200	200	1,000	1,100	10
GHG Emissions Increase Total	MT CO_2/yr	190	200	300	400	1,200	1,400	100
Unit GHG Emissions[2]	lb CO_2/MG	90	90	70	90	300	340	50
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	--*	--*	--*	--*	--*	--*	--*
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--**	--**	--**	--**	1.1	1.1	1.0
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	29	23	10	10	9	9	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only
4. Based on phosphorus removal only

* The plant already fully nitrifies so any optimization concept will not further reduce ammonia discharge loads.

** Values are less than the current GHG emissions.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at FSSD:

- Granular Activated Sludge – this could be used to phase out the biotower/activated sludge. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit to FSSD is it has the potential to not require basin expansion for Levels 2 or 3. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Value
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.10

Hayward Water Pollution Control Facility

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Hayward Water Pollution Control Facility

Hayward, CA

March 28, 2018
Final Report

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Executive Summary

The City of Hayward (City) owns and operates the Hayward Water Pollution Control Facility located in Hayward, CA and discharges treated effluent through a common outfall under the Joint Exercise of Power Agency (JEPA) of the East Bay Dischargers Authority (EBDA). The plant has an average dry weather flow (ADWF) permitted capacity of 18.5 million gallons per day (mgd) and a peak permitted wet weather flow of 35 mgd.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow	mgd	--	--	11.2	11.8	18.5	19.6	18.5	19.6	--
Flow to Bay[2,9]	mgd	9.2	9.2	9.2	9.2	13.1	13.1	13.1	13.1	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	1,890	1,890	2,040	2,040	230	220	230	220	1,790
TN[7]	lb N/d	2,360	2,360	2,540	2,540	1,750	1,640	1,240	660	2,500
TP	lb P/d	217	217	77	72	120	110	80	30	280
Costs[4,5,8]										
Capital	$ Mil	--	--	1.0	1.2	190	200	230	250	13.9
O&M PV	$ Mil	--	--	2.5	2.5	90	100	110	130	19.5
Total PV	$ Mil	--	--	3.5	3.8	280	300	340	380	33.4
Unit Costs[6]										
Capital	$/gpd	--	--	0.1	0.1	10.0	10.1	12.5	12.6	--
Total PV	$/gpd	--	--	0.3	0.3	15.2	15.2	18.6	19.3	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 3-year average (2011 through 2014), based on the data provided by Hayward. The 2015 BACWA Nutrient Reduction Study Group Annual Report data was not used, since values were only provided for the combined EBDA discharge. The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7.
8. Level 3 costs include costs associated with Level 2.
9. Assume average flow of 2.5 mgd to power plant.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Increase ferric chloride addition at the primary clarifiers to remove total phosphorus. This is expected to meet Level 2 phosphorus loads. No optimization strategies were identified for nitrogen removal since removal would require the construction of new process tankage. Existing infrastructure could not be repurposed for nitrogen removal.

Hayward WPCF is considered a candidate for sidestream treatment to reduce ammonia and nitrogen loads. The recommended sidestream treatment strategy is conventional nitrifying sidestream treatment for reducing ammonia/nitrogen loads.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

2. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Ferric chloride addition upstream of primary clarifiers,
    b. Construct four nitrifying trickling filters, and
    c. Construct denitrification filters (15 for summer, 17 for winter).
3. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Additional denitrification filters (eight additional for summer, nine additional for winter).

Capital costs, O&M costs and NPV were determine for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $3.5 Mil for dry season optimization up to $380 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Hayward Water Pollution Control Facility (WPCF) serves a population of about 153,000 (2012), which includes the majority of the City of Hayward, with the exception of a small portion of the northern part of city. It is located at 3700 Enterprise Avenue in Hayward, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 18.5 million gallons per day (mgd) and a peak permitted wet weather flow of 35 mgd.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The Hayward WPCF discharges treated effluent through a common outfall under the Joint Exercise of Power Agency (JEPA) of the East Bay Dischargers Authority (EBDA). EBDA member agencies include the City of Hayward, City of San Leandro, Oro Loma Sanitary District, Castro Valley Sanitary District, Union Sanitary District, and the Livermore-Amador Valley Water Management Agency (LAVWMA). The EBDA discharge is located at latitude 37°41’40” and longitude 122°17’42”.

EBDA holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2012-0004, NPDES No. CA0037869). Table 2-1 provides a summary of the dry weather permit limitations that are specific to the City of Hayward, under the EBDA NPDES permit, and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2012-0004; CA0037869)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	18.5	-	-	35.0
cBOD	mg/L	-	25	40	-
TSS	mg/L	-	30	45	-
Total Ammonia, as N	mg/L	-	93	-	130

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Hayward WPCF. Both liquids processes and solids processes are shown. The Hayward WPCF consists of screening and grit removal, vacuators, primary clarification, followed by a trickling filter/solids contact process. Secondary effluent is disinfected by chlorine disinfection. Solids treatment consists of secondary sludge thickening, anaerobic digestion and drying bed.

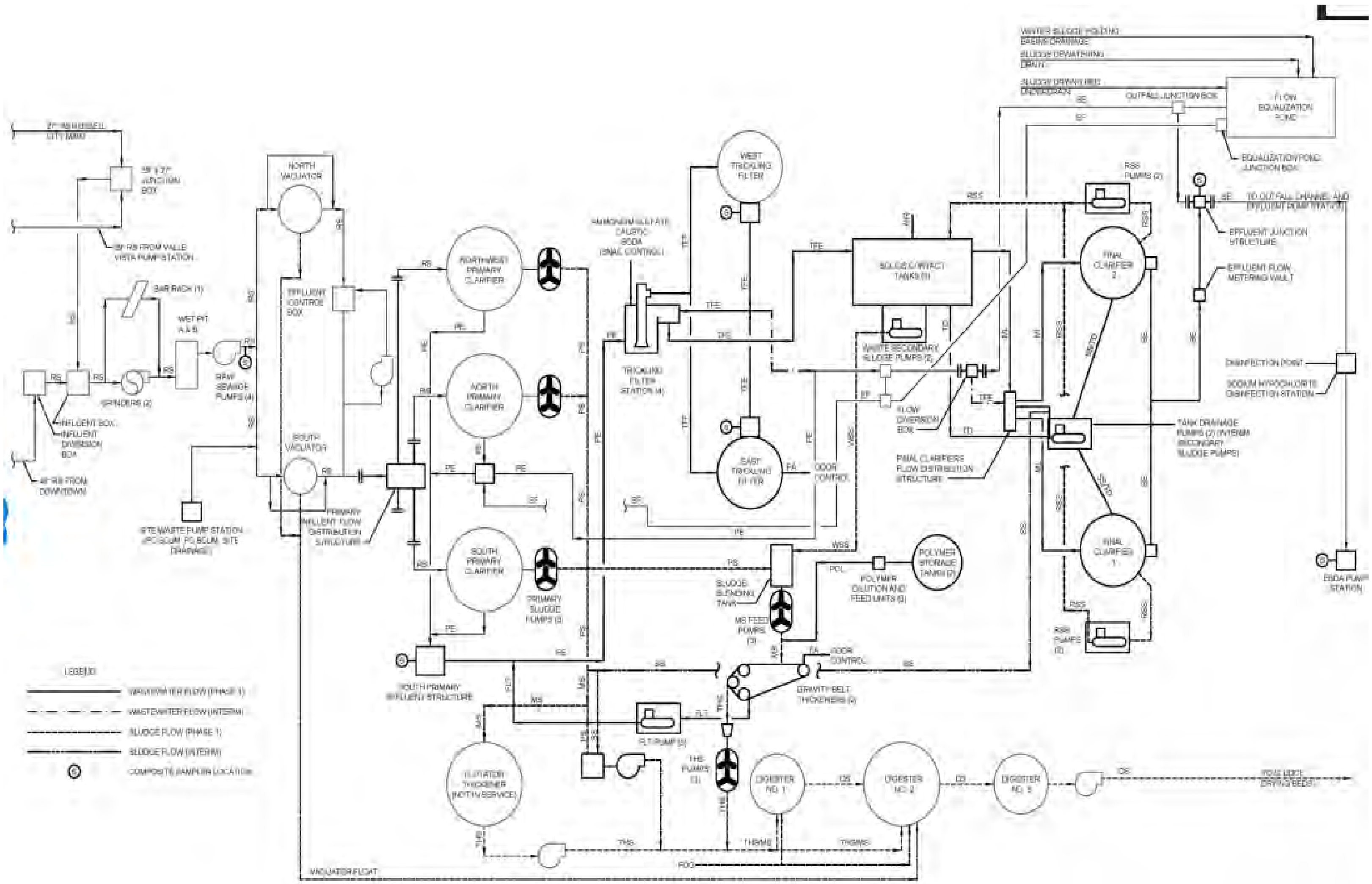

Figure 2-1. Process Flow Diagram for Hayward WPCF

Source: 2014 Master Plan Update.
Note: The flotator thickener has been converted to a fourth primary clarifier.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Hayward WPCF is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	11.2	11.5	13.2	19.6
cBOD	lb/d	37,500	39,500	42,600	45,400
TSS	lb/d	28,000	29,200	31,500	34,700
Ammonia[4]	lb N/d	3,070	3,000	3,180	3,590
Total Kjeldahl Nitrogen (TKN)[5]	lb N/d	4,650	4,550	4,820	5,430
Total Phosphorus (TP)[6]	lb P/d	460	530	530	710
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
cBOD	mg/L	400	410	430	410
TSS	mg/L	300	300	320	310
Ammonia[4]	mg N/L	33	31	32	32
TKN[5]	mg N/L	50	47	49	49
TP[6]	mg P/L	5.0	5.5	5.3	6.4
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Dry weather and peak ammonia data only available for July 2012 – June 2014.
5. TKN data is not routinely collected; therefore, TKN was calculated assuming TKN:ammonia ratio of 1:0.66.
6. TP data is not routinely collected; therefore, TP was calculated assuming TP:ortho P ratio of 1:0.5.

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the Hayward WPCF:

- On-line ammonia probe has been installed on secondary effluent to provide real time data on effluent ammonia. The probe could be used with dissolved oxygen for aeration control in the future.
- Snail kill procedure for TFs has been modified to reduce ammonia release. This is achieved by recycling ammonia solution through the TF for three days before placing TF back in service. This results in oxidation of ammonia to nitrate.

- A portion of secondary effluent is sent to RCEC (power plant) where ferric sulfate is added. As a result, the phosphorus is chemically precipitated. The chemical sludge is returned to Hayward, but the phosphorus is likely bound in to the chemical sludge and eventually end up in biosolids sent to the drying beds.
- There are plans to increase recycled water production by 0.5 mgd for irrigation

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the Hayward WPCF.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Hayward WPCF are presented in Table 3-1. The projected flow and load for the Hayward WPCF in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided, it was determined that the Hayward WPCF is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the permitted capacity. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	11.2	11.5	11.8	13.2
cBOD	lb/d	43,100	45,400	49,000	52,200
TSS	lb/d	32,200	33,600	36,300	40,000
Ammonia	lb N/d	3,530	3,450	3,660	4,120
TKN	lb N/d	5,350	5,230	5,540	6,250
TP	lb P/d	530	610	610	810
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
cBOD	mg/L	460	470	490	470
TSS	mg/L	350	350	370	360
Ammonia	mg N/L	38	36	37	37
TKN	mg N/L	58	55	56	57
TP	mg P/L	5.7	6.4	6.1	7.4
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

Table 3-2. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Design Capacity (AA)
Sidestream Flow	mgd	0.13	0.20
Ammonia	lb N/d	640	1,010
TKN	lb N/d	890	1,390
TN[1]	lb N/d	890	1,390
TP	lb P/d	12	18
Ortho P	lb P/d	4	6
Alkalinity	lb CaCO3/d	2,880	4,530
Ammonia	mg N/L	610	610
TKN	mg N/L	850	850
TN[1]	mg N/L	850	850
TP	mg P/L	11	11
Ortho P	mg P/L	4	4
Alkalinity	mg CaCO3/L	2,800	2,800

1. It was assumed that TN = TKN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	18.5	19.1	19.6	21.9
cBOD	lb/d	62,200	65,500	70,700	75,300
TSS	lb/d	46,500	48,400	52,300	57,600
Ammonia	lb N/d	5,090	4,980	5,280	5,950
TKN	lb N/d	7,720	7,550	8,000	9,010
TP	lb P/d	770	880	870	1,170
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
cBOD	mg/L	400	410	430	410
TSS	mg/L	300	300	320	310
Ammonia	mg N/L	33	31	32	32
TKN	mg N/L	50	47	49	49
TP	mg P/L	5.0	5.5	5.3	6.4
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Permitted average dry weather flow. Other flows and loads are based on current flow and loading characteristics.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.

- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Eleven optimization strategies were identified during the Hayward WPCF site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The eleven optimization strategies were screened down to four strategies described below.

- **Optimization Strategy 1:** Increase ferric chloride addition at headworks to increase phosphorus removal.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Ferric chloride addition will increase P removal.
  - ***Recommendation:*** Carry forward.
- **Optimization Strategy 2:** Precipitate phosphorus from drying bed return using chemical addition
  - ***Is it feasible?*** Yes, but this would require new facilities to provide adequate performance.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Minimal impact since the drying bed return has minimal phosphorus.
  - ***Result from analysis:*** Implementation of this technology would have minimal benefit.
  - ***Recommendation:*** Do not carry forward.

- **Optimization Strategy 3:** Implement CEPT to reduce loading to TF to allow for nitrification in TF and in SC tanks (possibly summer only).
  - ***Is it feasible?*** No, partial nitrification in the trickling filters would seed the solids contact tank with nitrifiers. The solids contact tanks are not designed to support additional nitrification and would require replacement of existing aeration diffusers, diffuser grids and blowers.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy only addresses ammonia, not total nitrogen.
  - ***Result from analysis:*** This strategy was not carried forward because the existing secondary process is not designed for nitrification. The solids contact tanks are not designed to support additional nitrification and would require replacement of existing aeration diffusers, diffuser grids and blowers.
  - ***Recommendation:*** Do not carry forward.
- **Optimization Strategy 4:** Potential to increase DO setpoint in solids contact tank and achieve nitrification.
  - ***Is it feasible?*** Yes, but it would require an increase in SRT in the solids contact tanks.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy only addresses ammonia, not total nitrogen.
  - ***Result from analysis:*** This strategy was not carried forward because the existing secondary process is not designed for nitrification. The solids contact tanks are not designed to support additional nitrification and would require replacement of existing aeration diffusers, diffuser grids and blowers.
  - ***Recommendation:*** Do not carry forward.

Strategy 1 is the best apparent way to reduce effluent phosphorus loads; no feasible strategies were determined to reduce ammonia or increase nitrogen removal.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

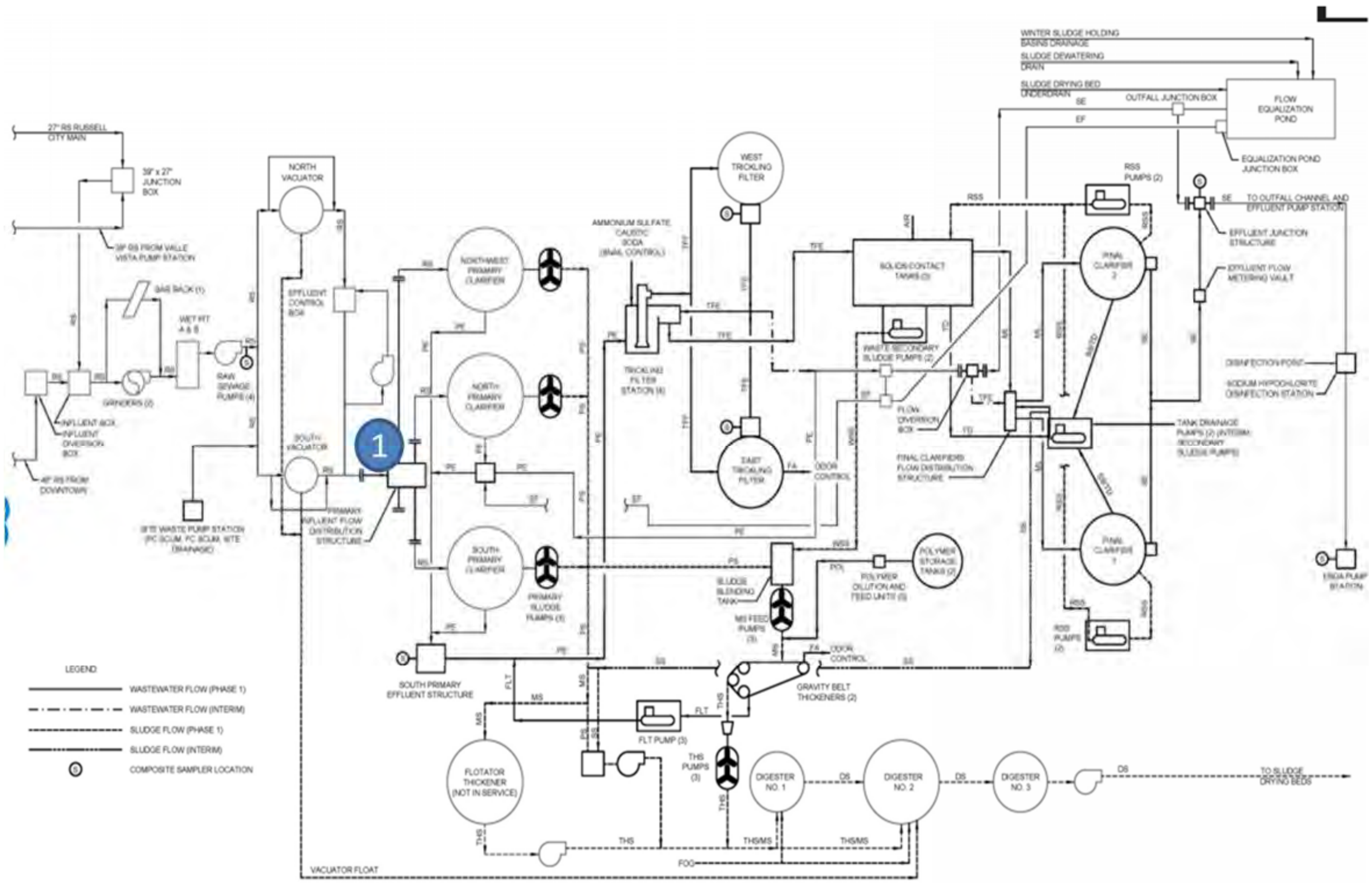

Figure 4-1. Optimization Concepts Considered for the Hayward WPCF

(1) increase ferric chloride addition at the headworks for P removal.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
None	Increase existing ferric chloride use.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The Hayward WPCF plant shows improved phosphorus removal but no change in ammonia or nitrogen removal

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	2,040	2,040	2,540	2,540	233	233
Discharge with Opt. Strategy[1]	lb N or P/d	2,040	2,040	2,540	2,540	77	72
Load Reduction[2,3]	lb N or P/d	0	0	0	0	157	161
Load Reduction[2,3]	%	0%	0%	0%	0%	67%	69%
Annual Load Reduction	lb N or P/yr	0	0	0	0	57,200	58,900

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce phosphorus; no optimization strategy was identified for nitrogen.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	11.2	11.8
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	1.0	1.2
Annual O&M	$ Mil/yr	0.3	0.3
Present Value O&M[3]	$ Mil	2.5	2.5
Present Value Total[3]	$ Mil	3.5	3.8
Unit Capital Cost[8]	$/gpd	0.1	0.1
Unit Total PV Cost[8]	$/gpd	0.3	0.3
TN Removal			
Capital[2,4]	$ Mil	0.0	0.0
Annual O&M[4]	$ Mil/yr	0.0	0.0
O&M PV[3,4]	$ Mil	0.0	0.0
Total PV[3,4]	$ Mil	0.0	0.0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	1.0	1.2
Annual O&M[5]	$ Mil/yr	0.3	0.3
O&M PV[3,5]	$ Mil	2.5	2.5
Total PV[3,5]	$ Mil	3.5	3.8
TP Removed (Ave.)[6]	lb P/d	157	161
Annual TP Removed (Ave.)[7]	lb P/yr	57,200	58,900
TP Cost[5,9]	$/lb P	6.2	6.4

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• More organics and solids diverted to fuel the digester • Phosphorus reliably removed under peak flow scenarios	• Dependency on chemicals • Chemical costs • CEPT would reduce the organic loading to the trickling filters. As a result, the trickling filters could begin to nitrify which would seed the solids contact tank with nitrifiers. The solids contact tanks cannot support nitrification.

5 Sidestream Treatment

As previously described, the Hayward WPCF was identified as a potential candidate for sidestream treatment. The WPCF already removes TP by chemical precipitation. As a result, sidestream TP load reduction is not recommended as the phosphorus is already captured in the biosolids chemical sludge.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a conventional nitrifying sidestream treatment technology is recommended for ammonia/TN load reduction.

Conventional nitrification is recommended as the WPCF uses drying beds instead of mechanical dewatering equipment. The drying beds return sidestream reaches ambient air temperature that requires a technology, such as conventional nitrification, that can reliably treat a wide range of temperatures (about 10 to 25 degrees C).

Conventional nitrifying sidestream treatment is an established technology where ammonia is oxidized to nitrate. The nitrate formed in the sidestream is expected to be removed in the main stream process via biological denitrification at either the headworks and/or primary clarifiers. Nitrate removal in the main stream process is easier than sidestream denitrification where organic carbon is not readily available.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements[1]
Feed Pumping (if necessary)	--
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--
Alkalinity Supply	--

1. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)[4]
Current Discharge[1]	lb/d	2,520	3,140	290
Discharge with Sidestream Treatment[2]	lb/d	1,790	2,500	290
Load Reduction[3]	lb/d	730	640	0
Load Reduction	%	29%	21%	0%
Annual Load Reduction[3]	lb/yr	265,100	235,680	0

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP[7]
Capital[1]	$ Mil	13.9	--
Annual O&M	$ Mil/yr	0.9	--
Total Present Value[2]	$ Mil	33.4	--
NH4-N Load Reduction[3,5]	lb N/yr	265,100	--
TN Load Reduction[3,5]	lb N/yr	235,680	--
TP Load Reduction[4,5]	lb P/yr	--	--
NH4-N Cost [3,5,6]	$/lb N	4.2	--
TN Cost [3,5,6]	$/lb N	4.7	--
TP Cost [4,5,6]	$/lb P	--	--

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Hayward WPCF to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The Hayward WPCF should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 upgrades could be met by constructing nitrifying trickling filters (NTF) and denitrification filters downstream of the existing secondary process for nitrogen removal and implementing ferric chloride addition to the primary clarifiers for phosphorus removal. Since complete denitrification is not necessary for Level 2, a portion of the NTF effluent flow would be routed around the denitrification filter combined with the denitrification filter effluent. These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure (i.e. TF/SC processes). This technology selection is in accordance with the recent Master Plan Update (2014).

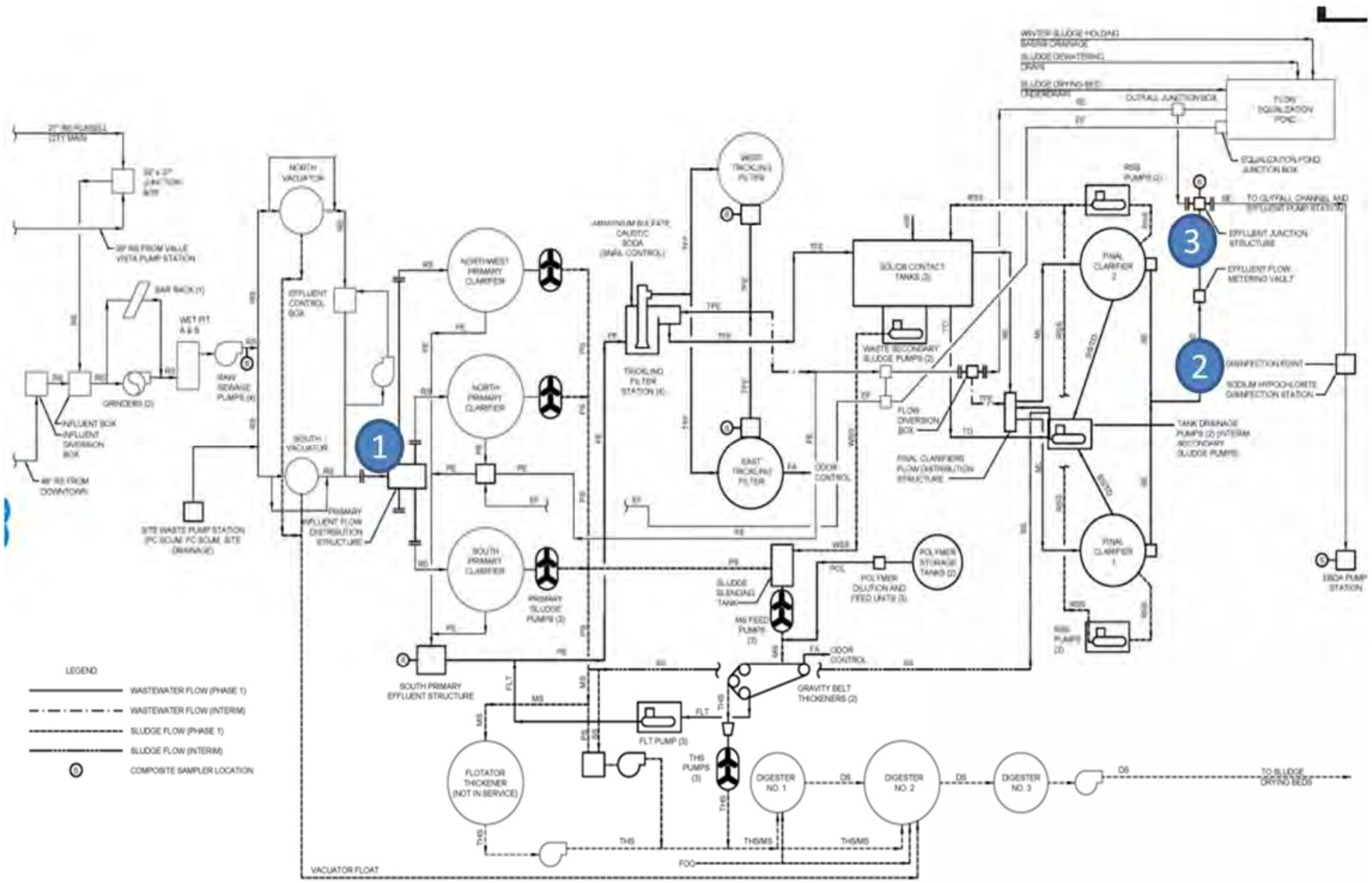

Figure 6-1. Level 2 Upgrade Concept for the Hayward WPCF

(1) add ferric chloride and polymer for P removal as well as alkalinity addition to support nitrification, (2) construct new nitrifying trickling filters, and (3) construct new denitrification filters.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2. Level 3 upgrades would require additional chemical addition immediately upstream of denitrification filters since chemical addition upstream of filtration would be required to meet phosphorus levels. Additional methanol use would be necessary at the denitrification filters to achieve Level 3 nitrogen levels. These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure (i.e. TF/SC processes). This technology selection is in accordance with the recent Master Plan Update (2014).

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Ferric Chloride and Polymer Chemical Feed • Alkalinity addition	Same as Level 2
Secondary and Tertiary	• Nitrifying Trickling Filters • Nitrifying Trickling Filter Pump Station • Denitrification Filters • Denitrification Filter Pump Station • Caustic Soda Addition Facilities • External Carbon Source Chemical Feed	Same as Level 2 plus: • Additional Denitrification Filters • Additional External Carbon Source Chemical Feed • Ferric Chloride Chemical Feed

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

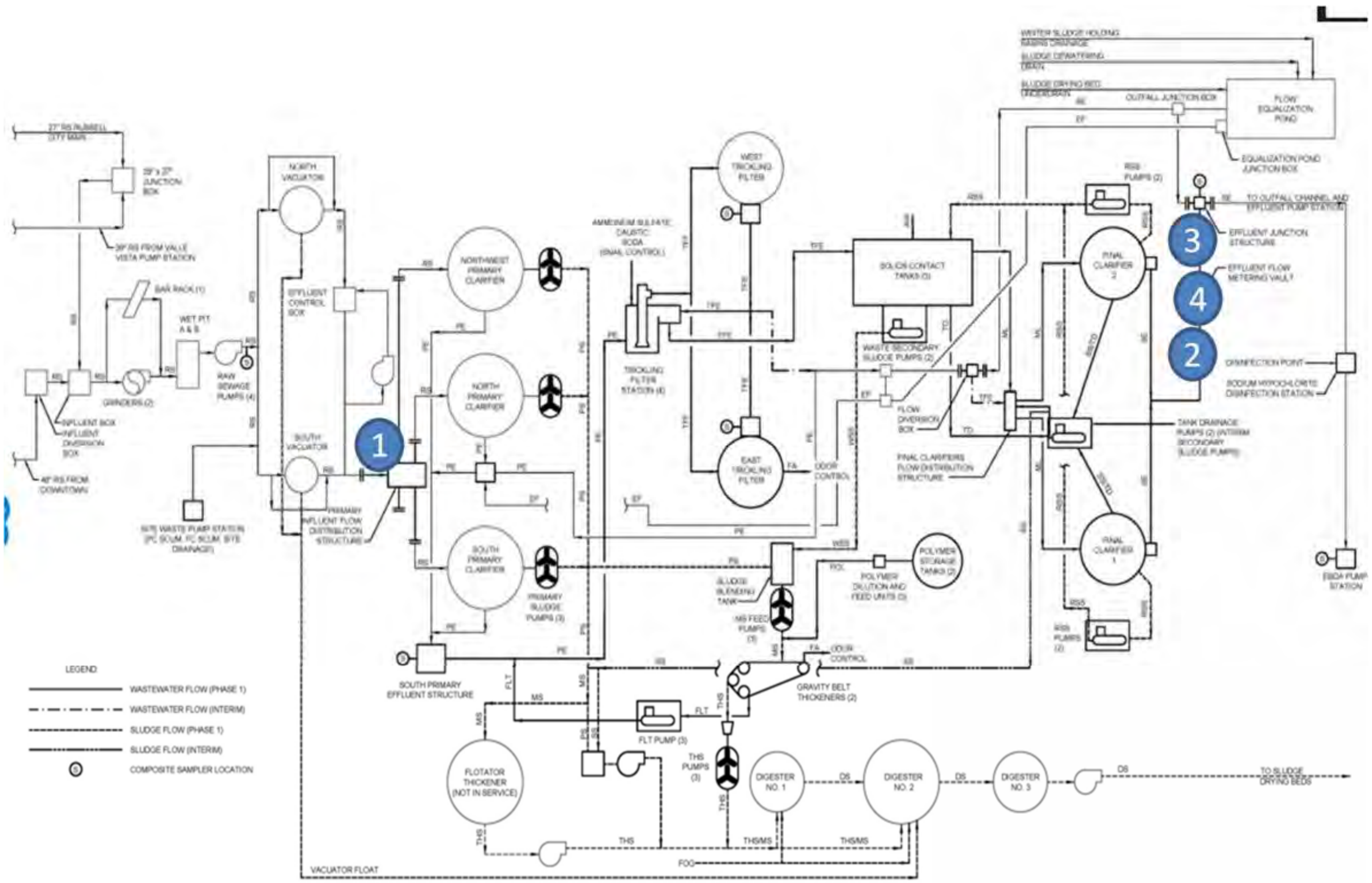

Figure 6-2. Level 3 Upgrade Concept for the Hayward WPCF

(1) add ferric chloride and polymer for P removal as well as alkalinity to support nitrification, (2) construct new nitrifying trickling filters, (3) construct new denitrification filters with methanol addition, and (4) add ferric chloride for P removal.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) chemical addition facilities, (2) new nitrifying trickling filters, (3) chemical addition facilities, (4) nitrifying trickling filter and denitrification filter pumping stations, and (5) denitrification filters and ancillary equipment and (6) and denitrification filter for year round.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) chemical addition facilities, (2) new nitrifying trickling filters, (3) chemical addition facilities, (4) nitrifying trickling filter and denitrification filter pumping stations, and (5) denitrification filters and ancillary equipment and (6) and denitrification filter for year round.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	18.5	19.6	18.5	19.6
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	190	200	230	250
Annual O&M	$Mil/yr	4.2	4.5	5.1	5.9
O&M PV[3]	$ Mil	90	100	110	130
Total PV[3]	$ Mil	280	300	340	380
Unit Capital Cost	$/gpd	10.0	10.1	12.5	12.6
Unit Total PV	$/gpd	15.2	15.2	18.6	19.3
TN Removal					
Capital[2,4]	$ Mil	180	200	230	250
Annual O&M[4]	$ Mil/yr	3.9	4.1	4.5	5.1
O&M PV[3,4]	$ Mil	90	90	100	110
Total PV[3,4]	$ Mil	270	290	330	360
TN Removed (Ave.)[6]	lb N/d	1,390	1,500	1,900	2,490
Annual TN Removed (Ave.)[7]	lb N/yr	509,000	549,000	693,000	908,000
TN Cost[4,8]	$/lb N	17.8	17.5	15.9	13.2
TP Removal					
Capital[2,5]	$ Mil	1.2	1.2	160	180
Annual O&M[5]	$ Mil/yr	0.4	0.4	0.8	1.5
O&M PV[3,5]	$ Mil	8	9	19	33
Total PV[3,5]	$ Mil	9	10	180	210
TP Removed (Ave.)[6]	lb P/d	170	180	210	260
Annual TP Removed (Ave.)[7]	lb P/yr	62,700	65,400	76,600	93,300
TP Cost[5,8]	$/lb P	5	5	78	75

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing secondary process • Robust technology to absorb variability in flows and loads • Ability to reliably remove TN and TP	• Increased energy from NTF pumping and tertiary filter pumping • Additional unit processes to operate • Safety from external carbon source (if methanol) • High cost associated with methanol use • Increase sludge production
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use

7 Nutrient Removal by Other Means

The Hayward WPCF has an existing recycled water program that is employed year-round. Recycled water is used for industrial use. This existing program has the effect of reducing nutrients discharged to the Bay. The Hayward WPCF currently recycles approximately 1,700 acre-feet per year (550 million gallons per year) and they are planning to increase recycling to 3,100 acre-feet per year (1,000 million gallons per year).

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy

and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

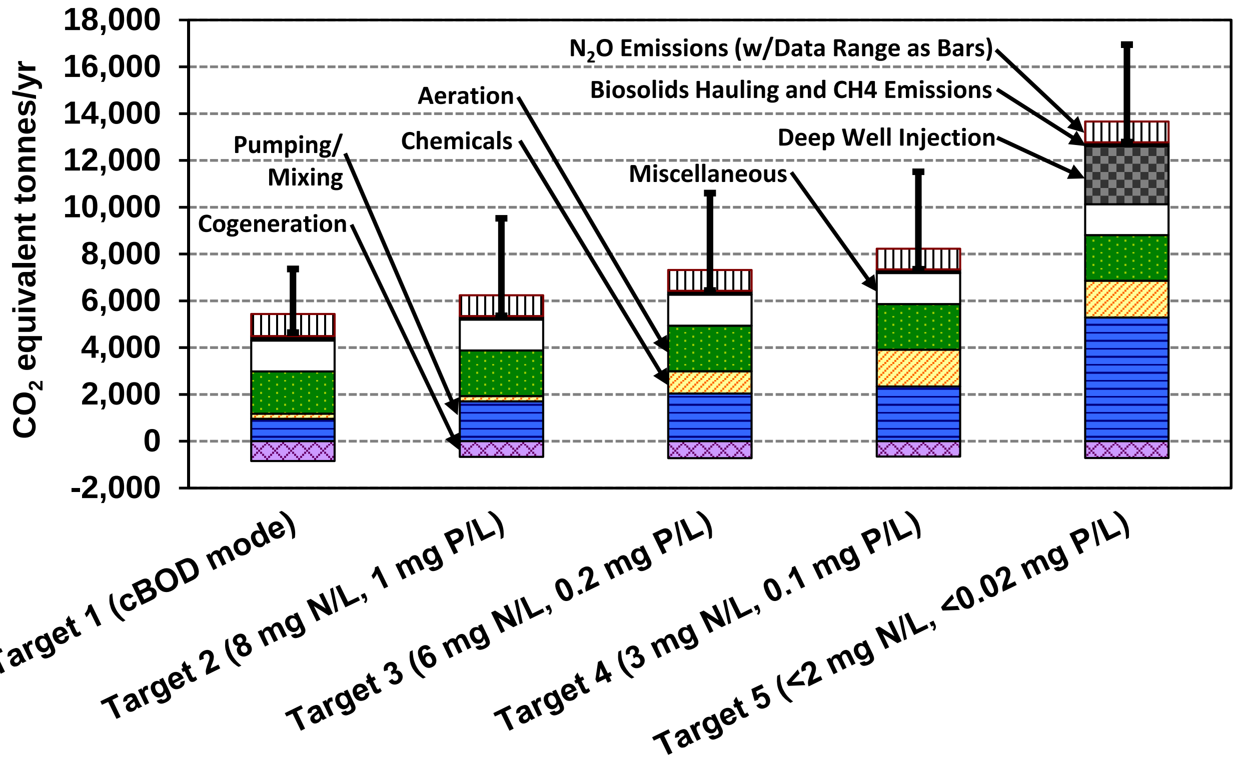

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

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[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	6	6	1,800	1,900	2,300	2,400	97
GHG Emissions Increase from Chemicals	MT CO_2/yr	37	38	30,300	31,300	31,500	32,400	1
GHG Emissions Increase Total	MT CO_2/yr	43	44	32,200	33,200	33,800	34,800	98
Unit GHG Emissions[2]	lb CO_2/MG	22	23	10,100	10,500	10,600	10,900	49
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	80	80	80	80	0.9
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	140	130	110	80	0.9
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	2	2	2	2	38	33	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Hayward WCPF. These are:

- Zeolite-Anammox – Hayward WPCF final effluent would be subsequently treated by a zeolite-anammox process where ammonia sorbs to a zeolite bed and is subsequently removed through a deammonification process.
  - Advantages: Low energy process, minimal operational requirements, minimal instrumentation.
  - Disadvantages: Large footprint, no full-scale installations
  - Potential Next Steps: Determine footprint requirements based on previous studies. If appropriate, consider pilot testing the zeolite-annamox process to determine benefits.
- Treatment Wetland – Hayward WPCF final effluent would be subsequently treated through a constructed wetland where algae and aquatic plants take up nutrients and nitrogen removal is performed by biofilms.
  - Advantages: Low operations and maintenance, mature technology
  - Disadvantages: Large footprint
  - Potential Next Steps: Determine footprint requirements based on typical wetlands design. Consider pilot testing a small-scale constructed wetland to determine benefits.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.11

Las Gallinas Valley Sanitary District Sewage Treatment Plant

8

Brown AND Caldwell

Bay Area Clean Water Agencies
Nutrient Reduction Study

Las Gallinas Valley Sanitary District Sewage Treatment Plant

San Rafael, CA

March 30, 2018
Final Report

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Executive Summary

Las Gallinas Valley Sanitary District owns and operates the Las Gallinas Valley Sanitary District Sewage Treatment Plant (LGVSD STP) located in San Rafael, CA and discharges treated effluent to Miller Creek, which drains to San Pablo Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 2.92 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season[7]	Current Year Round	Opt. Dry Season[3,7]	Opt. Year Round[3]	Level 2 Dry Season[3,7]	Level 2 Year Round[3]	Level 3 Dry Season[3,7]	Level 3 Year Round[3]	Side-Stream[3,8]
Design Flow	mgd	--	--	2.3	2.8	2.9	3.8	2.9	3.8	--
Flow to Bay[2]	mgd	--	1.3	--	1.3	--	1.5	--	1.5	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	0	27	0	28	0	25	0	25	--
TN	lb N/d	0	260	0	280	0	190	0	80	--
TP	lb P/d	0	37	0	11	0	13	0	4	--
Costs[4,5]										
Capital	$ Mil	--	--	0	0	0	60	0	80	--
O&M PV	$ Mil	--	--	0	0.23	0	10	0	15	--
Total PV	$ Mil	--	--	0	0.23	0	70	0	95	--
Unit Costs[6]										
Capital	$/gpd	--	--	0	0	0	15.6	0	20.8	--
Total PV	$/gpd	--	--	0	0.1	0	18.2	0	24.8	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. No discharge during the dry season.
8. LGVSD STP was not considered for sidestream treatment since the facility already nitrifies and is limited to seasonal discharge.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Add chemical (alum or PACl) upstream of the primary clarifiers to remove phosphorus. Chemical addition is expected to meet Level 2 phosphorus concentrations. Optimization strategies to reduce ammonia or nitrogen were not feasible, although planned plant improvements will reduce nitrogen.

LGVSD STP is not considered a candidate for sidestream treatment due to them already fully nitrifying and being limited to seasonal discharge.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Construct an integrated fixed film activated sludge (IFAS) process using the STM-Aerotor, the process planned in the current upgrade. Configure the system as a 3-stage BNR with both anaerobic and anoxic selectors for both biological phosphorus removal and denitrification.
    b. Construct methanol addition facilities, in case sufficient carbon is not available for both biological phosphorus removal and denitrification.
    c. Construct two additional secondary clarifiers, and upgrade the existing clarifier.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Construct additional BNR tank volume in the 5-stage BNR configuration to meet low nitrogen limits.
    c. Construct additional filters with alum addition for phosphorus polishing.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $0 Mil for dry season optimization up to $95 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Las Gallinas Valley Sanitary District Sewage Treatment Plant (LGVSD STP) serves a population of about 30,000, which includes the domestic wastewater for the northern area of the City of San Rafael and unincorporated portions of Marin County. It is located at 300 Smith Ranch Rd., San Rafael, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 2.92 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The LGVSD STP holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2015-0021, NPDES No. CA0037851). The treated wastewater is discharged to Miller Creek, which drains to San Pablo Bay. Two Miller Creek discharge locations exist; the upstream one being used primarily during higher flow conditions and both being used evenly during normal conditions. The upstream discharge location is at latitude 38.23718° N and longitude 122.43186° W, and the downstream discharge location is at latitude 38.21834° N and longitude 122.38325° W respectively. During the dry season, chlorinated effluent is discharged to two unlined storage ponds, from which effluent is used for reclamation (irrigation of the 200-acre on-site pasture). Surplus water remaining in the storage ponds at the end of the dry season is returned to the plant during the wet season.

Table 2-1 provides a summary of the permit limitations that are specific to the LGVSD STP and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2015-0021; CA0037851)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak
Effluent Limitations – November through April						
Flow[1]	mgd	2.92	-	-	-	-
BOD	mg/L	-	30	45	-	-
TSS	mg/L	-	30	45	-	-
Total Ammonia, as N	mg/L	-	10	-	18	-
Effluent Limitations – May through October[2]						
Flow[1,2]	mgd	2.92	-	-	-	-
BOD	mg/L	-	20	25	30	-
TSS	mg/L	-	15	18	20	-
Total Ammonia, as N	mg/L	-	6	-	-	-

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. The facility is designed to provide secondary treatment for 8 mgd. When influent flow exceeds 8 mgd, excess primary effluent receives separate disinfection and then combines with secondary treatment prior to dechlorination and disposal. Peak wet weather hydraulic capacity of the plant is 25 mgd.
2. Discharge is prohibited from June 1 to October 31, except when the facility inflow exceeds the capacity of the influent storage and the capacity of the recycled water distribution and storage system due to wet weather.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the LGVSD STP during normal operation. Both liquids processes and solids processes are shown. The LGVSD STP consists of screening, grit removal, flow equalization, primary clarification, trickling filters, a secondary clarifier, a nitrifying trickling filter, deep-bed filters, and chlorine disinfection. Solids treatment consists of gravity thickening, anaerobic digestion, sludge storage lagoons, and onsite land disposal.

Due to high inflow and infiltration during wet weather, LGVSD STP sometimes blends primary treated wastewater with secondary treated wastewater prior to discharge. Flows up to 6.9 mgd receive secondary treatment, nitrification, and filtration, and flows between 6.9 mgd and 8 mgd receive secondary treatment and disinfection. Flows above 8 mgd receive primary treatment, partial filtration, and disinfection.

LGVSD STP is in the process of implementing a secondary treatment plant improvement project to reduce blending during wet weather.

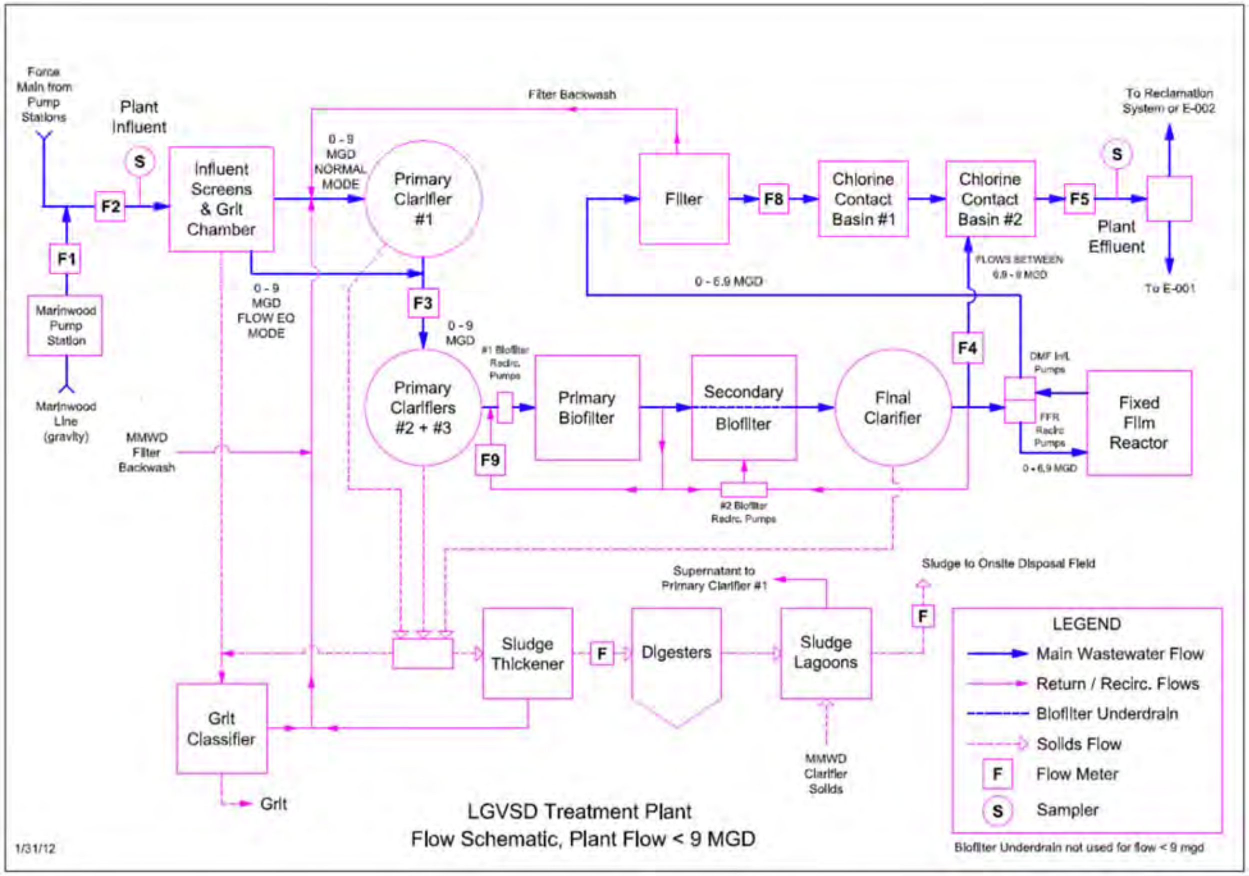

Figure 2-1. Process Flow Diagram for LGVSD STP

Source: Provided by LGVSD STP

Note: Wet weather flow routing is not shown on this figure. At high flows, primary effluent is routed to either the filters or chlorine contact tanks.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the LGVSD STP is shown in Table 2-2.

Based on data from the Group Annual Report, LGVSD STP had no discharge during the dry season between July 2012 and June 2015, so only wet season conditions are considered in this evaluation.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2,4]	Average Annual[5]	Dry Season MM (May 1 – Sept 30)[1,3,4]	Year Round MM[1,3]
Flow	mgd	2.11[1]	2.8	No Data	4.3
BOD	lb/d	No Data	5,600	No Data	6,900
TSS	lb/d	No Data	6,000	No Data	7,500
Ammonia	lb N/d	No Data	440	No Data	630
Total Kjeldahl Nitrogen (TKN)[6]	lb N/d	No Data	840	No Data	1,220
Total Phosphorus (TP)[6]	lb P/d	No Data	110	No Data	170
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	No Data	240	No Data	190
TSS	mg/L	No Data	260	No Data	210
Ammonia	mg N/L	No Data	19	No Data	18
TKN[6]	mg N/L	No Data	36	No Data	34
TP[6]	mg P/L	No Data	4.9	No Data	4.7
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Dry season influent data was not provided by LGVSD, except for May 2012. LGVSD stated that current ADWF is 2.11 mgd.
5. Average value shown is for the data provided (wet season only). The plant has no discharge to receiving water during the dry season. Concentrations are calculated from flows and loadings.
6. TKN and TP based on two samples collected between July 2012 and June 2014. Year round maximum month was calculated using the ammonia peaking factor.

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the LGVSD STP:

- Planned secondary improvements to reduce blending at LGVSD STP include construction of integrated fixed film activated sludge reactors (Westech's STM Aerotor) to provide nitrification and some level of denitrification. Two new secondary clarifiers would also be constructed. Trickling filters and nitrifying trickling filters would be replaced.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the LGVSD STP.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the LGVSD STP are presented in Table 3-1. The projected BOD load for the LGVSD STP in 2025 was assumed to equal the design BOD loading for the secondary improvements, which is equivalent to an 11 percent increase. The same increase was used for other constituents.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average[4]	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.3	3.1	---	4.7
BOD	lb/d	---	6,300	---	7,600
TSS	lb/d	---	6,600	---	8,300
Ammonia	lb N/d	---	490	---	700
TKN	lb N/d	---	930	---	1,350
TP	lb P/d	---	130	---	180
Alkalinity	lb/d as $CaCO_3$	---	---	---	---
BOD	mg/L	---	240	---	190
TSS	mg/L	---	260	---	210
Ammonia	mg N/L	---	19	---	18
TKN	mg N/L	---	36	---	34
TP	mg P/L	---	4.9	---	4.7
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Average values shown are for the wet season only. Concentrations are calculated from flows and loadings.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.2 Flow and Loading for Sidestream Treatment

LGVSD is not considered a candidate for sidestream treatment due to them already fully nitrifying and being limited to seasonal discharge.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Build-Out Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3,4]	Average Annual[5]	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.9	3.8	---	5.9
BOD	lb/d	---	7,800	---	9,500
TSS	lb/d	---	8,300	---	10,400
Ammonia	lb N/d	---	610	---	880
TKN	lb N/d	---	1,160	---	1,680
TP	lb P/d	---	160	---	230
Alkalinity	lb/d as $CaCO_3$	---	---	---	---
BOD	mg/L	---	240	---	190
TSS	mg/L	---	260	---	210
Ammonia	mg N/L	---	19	---	18
TKN	mg N/L	---	36	---	34
TP	mg P/L	---	4.9	---	4.7
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Projected buildout ADWF. Other flows and loads are based on current flow and loading characteristics.
5. Average value is for the wet season only.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Based on data from the Group Annual Report, LGVSD STP had no discharge during the dry season. Optimizations were only evaluated for the wet season.

Two optimization strategies were identified during the LGVSD STP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The two optimization strategies are described below.

- **Optimization Strategy 1:** Add chemical (alum or PACl) upstream of the primary clarifiers to increase phosphorus removal.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Plant already has facilities for chemical addition, and chemical is added during high flow events. This strategy would involve adding chemical throughout the wet season to increase P removal.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Add chemical (alum) upstream of the tertiary filters to increase phosphorus removal.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** An alternative to Strategy 1 is to add chemicals before filtration for phosphorus removal. Since filter plugging is an issue during wet weather, addition to the primary clarifiers is preferred.
  - ***Recommendation:*** Do not carry forward at this time.

Strategy 1 is the best apparent way to reduce effluent phosphorus loads. No feasible strategies were determined to reduce ammonia or increase nitrogen removal, although the planned plant improvements will reduce nitrogen. The plant currently nitrifies, although effluent ammonia concentrations (average 2.5 mg/L) are higher than Level 2 criteria.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

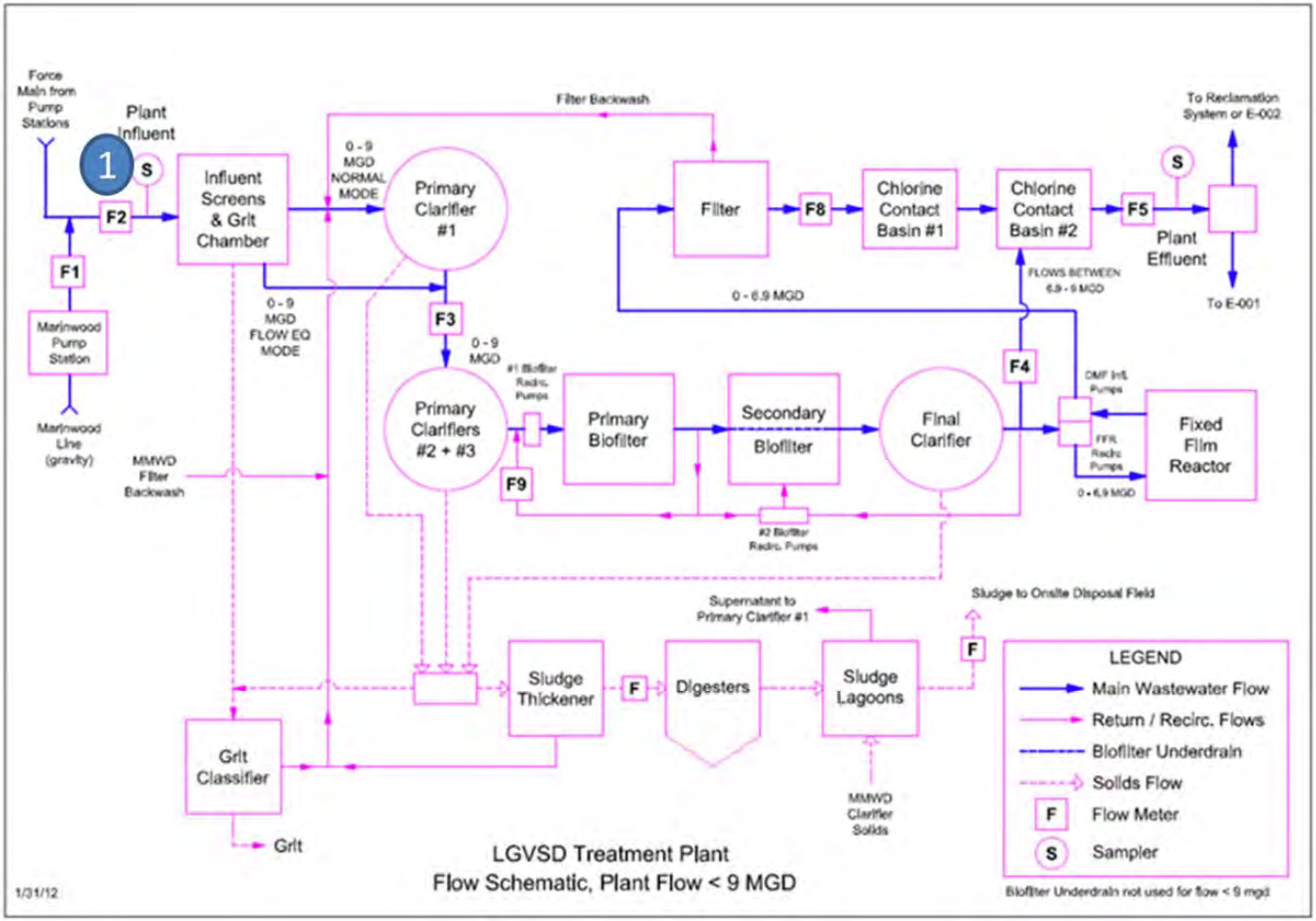

Figure 4-1. Optimization Concepts Considered for the LGVSD STP

(1) Add chemicals (alum or PACl) for P removal in primary clarifiers.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
None	Dose chemical upstream of the primary clarifiers using existing facilities.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The LGVSD STP plant shows improved phosphorus removal, but no change in ammonia or removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season[4]	NH4-N Year Round	TN Dry Season[4]	TN Year Round	TP Dry Season[4]	TP Year Round
Current Discharge[1]	lb N or P/d	0	28	0	280	0	39
Discharge with Opt. Strategy[1]	lb N or P/d	0	28	0	280	0	11
Load Reduction[2,3]	lb N or P/d	0	0	0	0	0	28
Load Reduction[2,3]	%	0	0%	0	0%	0	71%
Annual Load Reduction	lb N or P/yr	0	0	0	0	0	10,200

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.
4. No discharge during the dry season.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes, although the planned digester improvements will be needed before this strategy can be implemented. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1,11]	Year Round[1]
Design Flow	mgd	2.3	2.8
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0	0.0
Annual O&M	$ Mil/yr	0	0.03
Present Value O&M[3]	$ Mil	0	0.23
Present Value Total[3]	$ Mil	0	0.23
Unit Capital Cost[8]	$/gpd	0	0
Unit Total PV Cost[8]	$/gpd	0	0.1
TN Removal			
Capital[2,4]	$ Mil	0	0
Annual O&M[4]	$ Mil/yr	0	0
O&M PV[3,4]	$ Mil	0	0
Total PV[3,4]	$ Mil	0	0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0	0.0
Annual O&M[5]	$ Mil/yr	0	0.03
O&M PV[3,5]	$ Mil	0	0.23
Total PV[3,5]	$ Mil	0	0.23
TP Removed (Ave.)[6]	lb P/d	0	30
Annual TP Removed (Ave.)[7]	lb P/yr	0	10,200
TP Cost[5,9]	$/lb P	NA	2.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen.
11. No discharge during the dry season.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• More organics and solids diverted to fuel the digester	• Dependency on chemicals • Chemical costs • Increased sludge production • Additional alkalinity addition may be needed

5 Sidestream Treatment

Sidestream treatment is not considered a viable option for LGVSD as previously described and thus was not further evaluated.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the LGVSD STP plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

Planned secondary improvements to reduce blending at LGVSD STP include construction of integrated fixed film activated sludge reactors (Westech's STM Aerotor) to provide nitrification and denitrification to Level 2 limits. Two new secondary clarifiers will also be constructed, and the existing secondary clarifier would be modified. Trickling filters and nitrifying trickling filters will be replaced, and tertiary filters will be removed since they are at the end of their useful life and are not compatible with the hydraulic gradeline of new facilities. This technology was used as the basis for determining planning level costs and space requirements.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 nitrogen limits are assumed using an integrated fixed film activated sludge (IFAS) process (STM-Aerotor), configured as a 3-stage BNR with both anaerobic and anoxic selectors for both biological phosphorus removal and denitrification. Facilities for methanol addition are included, since sufficient carbon may not be available for both biological phosphorus removal and denitrification. Two additional secondary clarifiers are included, and the existing secondary clarifier is modified.

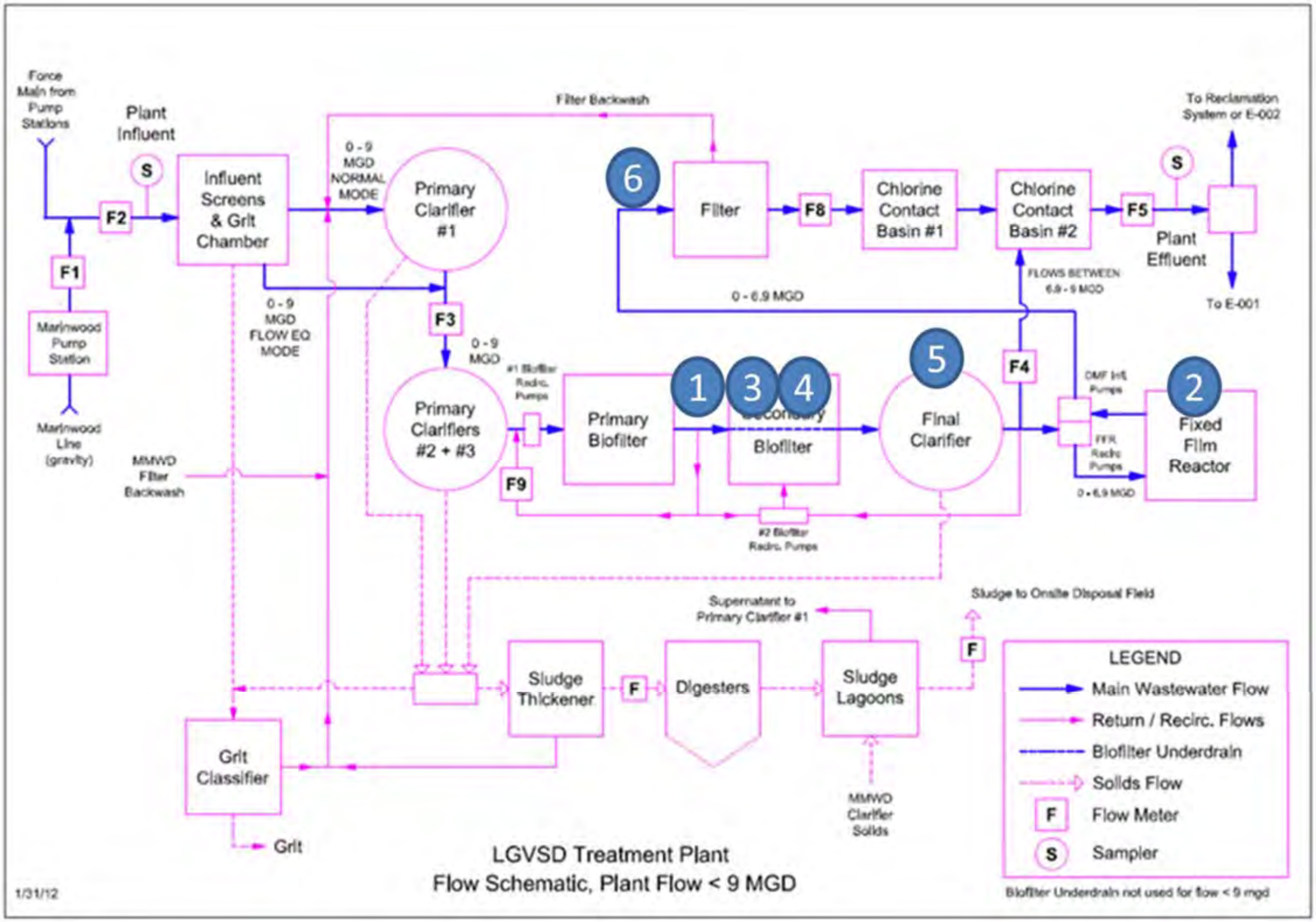

Figure 6-1. Level 2 Upgrade Concept for LGVSD STP

(1) demolish primary and secondary biofilters and nitrifying fixed film reactor, (2) construct new primary effluent equalization and secondary influent pumping, (3) construct new 3-stage BNR IFAS basins, (4) construct carbon addition facilities (methanol) to support biological phosphorus removal and denitrification if needed, (5) construct two additional secondary clarifiers and modify existing secondary clarifier, and (6) remove tertiary filters (included as part of planned secondary improvements, but not included in costs for nutrient upgrades).

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2. Additional BNR tank volume is needed for a 5-stage BNR configuration to meet low nitrogen limits. New filters with alum addition are shown for phosphorus polishing. New filters will be compatible with the hydraulic gradeline of the new secondary treatment facilities. Filtration of flows up to 12 mgd (four times the design ADWF) is assumed. During peak flow events, flows above 12 mgd would not receive filtration.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Secondary	• Demolish biofilters and nitrifying fixed film reactor • New secondary influent equalization and pumping • New 3-stage BNR IFAS basins using STM Aerotor system • Two new secondary clarifiers and modifications to existing secondary clarifier • External carbon source addition facilities	Same as Level 2 plus: • Construct additional BNR volume for 5-stage BNR.
Tertiary	--	Same as Level 2 plus: • New filters, including alum addition for phosphorus polishing

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

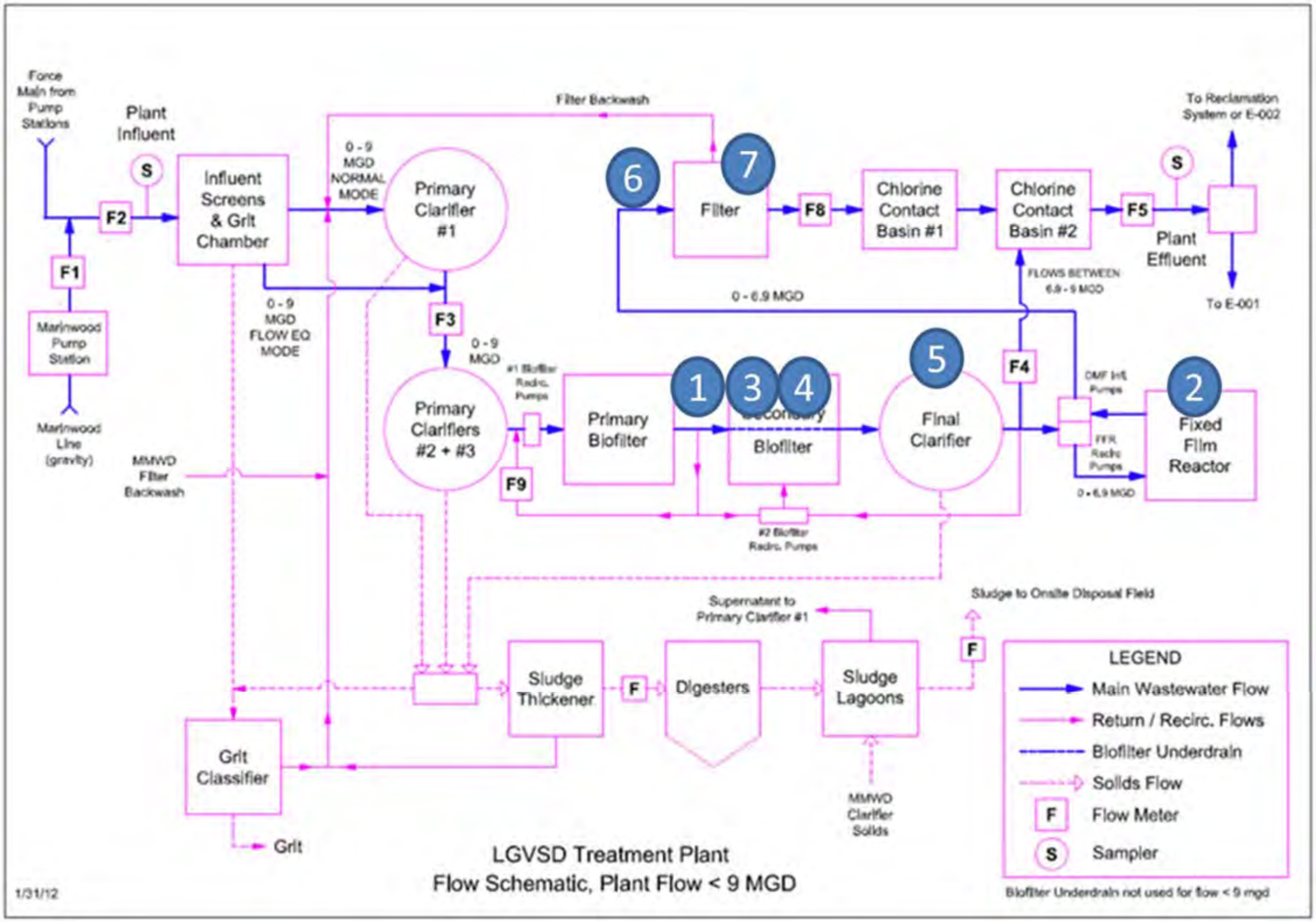

Figure 6-2. Level 3 Upgrade Concept for LGVSD STP

(1) demolish primary and secondary biofilters and nitrifying fixed film reactor, (2) construct new primary effluent equalization and secondary influent pumping, (3) construct new 5-stage BNR IFAS basins, (4) construct carbon addition facilities (methanol) to support biological phosphorus removal and denitrification, (5) construct two additional secondary clarifiers and modify existing secondary clarifier, (6) add chemicals (alum) before filtration for phosphorus polishing, and (7) construct new filters to treat up to four times the design ADWF.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Wet Season

(1) Demolish existing biofilters, (2) construct deep equalization, (3) construct secondary influent pumping, (4) construct anaerobic zone of BNR basins, (5) construct MLE BNR IFAS basins, (6) modifications to existing secondary clarifier (increase diameter), (7) construct new secondary clarifier, (8) demolish nitrifying fixed film reactor and construct new secondary clarifier, and (9) chemical storage (methanol).

Figure 6-4. Level 3 Upgrade Aerial Layouts for Wet Season

(1) Demolish existing biofilters, (2) construct deep equalization, (3) construct secondary influent pumping, (4) construct anaerobic zone of BNR basins, (5) construct MLE BNR IFAS basins, (6) construct new post-anoxic zone for nitrogen polishing, (7) modifications to existing secondary clarifier (increase diameter), (8) construct new secondary clarifier, (9) demolish nitrifying fixed film reactor and construct new secondary clarifier, (10) new filters for phosphorus polishing of up to three times the ADWF, and (11) chemical storage (alum, methanol).

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1,10]	Level 2 Year Round[1]	Level 3 Dry Season[1,9,10]	Level 3 Year Round[1,9]
Design Flow	mgd	2.9	3.8	2.9	3.8
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	0	60	0	80
Annual O&M	$Mil/yr	0	0.5	0	0.7
O&M PV[3]	$ Mil	0	10	0	15
Total PV[3]	$ Mil	0	70	0	95
Unit Capital Cost	$/gpd	0	15.6	0	20.8
Unit Total PV	$/gpd	0	18.2	0	24.8
TN Removal					
Capital[2,4]	$ Mil	0	53	0	64
Annual O&M[4]	$ Mil/yr	0	0.4	0	0.5
O&M PV[3,4]	$ Mil	0	8	0	12
Total PV[3,4]	$ Mil	0	62	0	75
TN Removed (Ave.)[6]	lb N/d	0	120	0	240
Annual TN Removed (Ave.)[7]	lb N/yr	0	44,700	0	86,400
TN Cost[4,8]	$/lb N	0	45.9	0	29.0
TP Removal					
Capital[2,5]	$ Mil	0	6.5	0	14
Annual O&M[5]	$ Mil/yr	0	0.07	0	0.13
O&M PV[3,5]	$ Mil	0	1.7	0	2.8
Total PV[3,5]	$ Mil	0	8	0	17
TP Removed (Ave.)[6]	lb P/d	0	30	0	40
Annual TP Removed (Ave.)[7]	lb P/yr	0	11,500	0	14,800
TP Cost[5,8]	$/lb P	0	23.8	0	37.2

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.
10. No discharge during the dry season.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Ability to reliably remove TN and TP	• Carbon addition may be needed for a 3-stage BNR with both phosphorus and nitrogen removal. • Safety from external carbon source (if methanol) • Biological phosphorus removal sludge can be difficult to dewater
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher operational costs associated with methanol and alum use

7 Nutrient Removal by Other Means

The LGVSD STP has an existing recycled water program that is employed year-round. LGVSD has no Bay discharge during the dry season. Recycled water is used for landscape irrigation, golf course irrigation, and commercial and industrial uses. Water is also irrigated on District pasture land. The existing program has the effect of reducing nutrients discharged to the Bay. LGVSD currently recycles approximately 660 acre-feet per year (220 million gallons per year) not including District pasture land. There are no existing plans to further expand the recycled water program.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA

Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

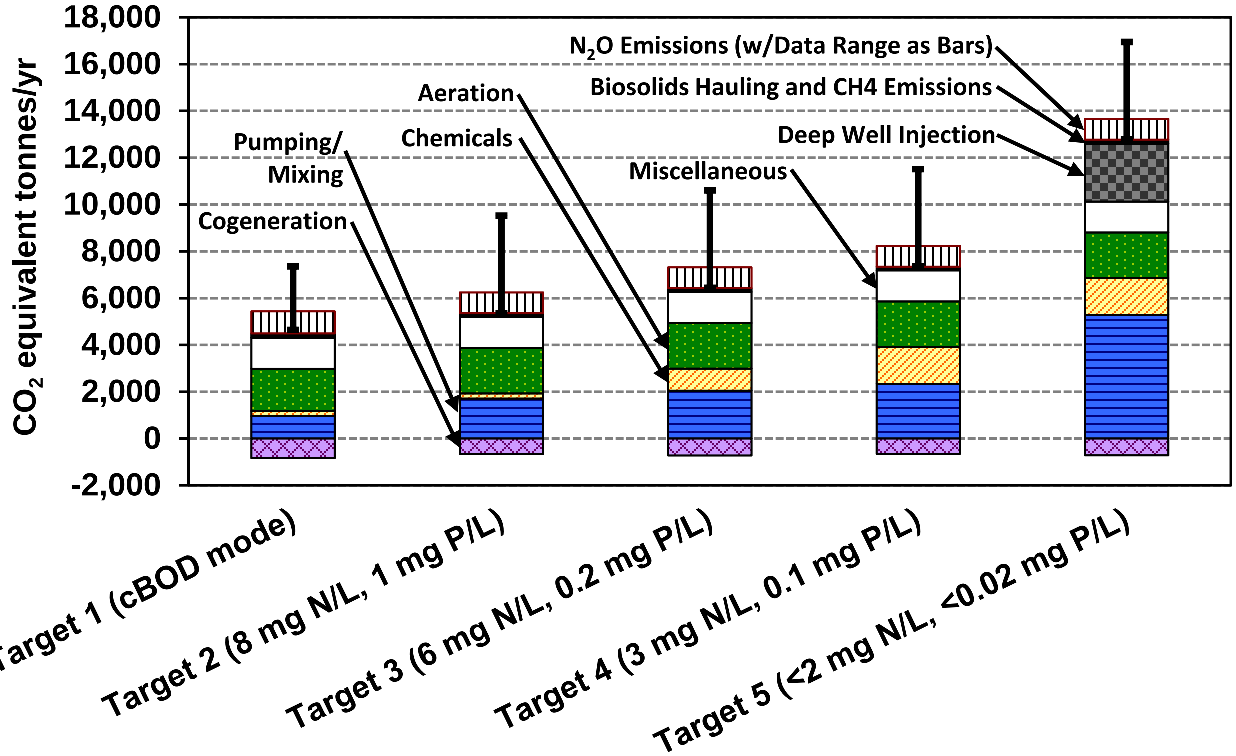

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1,6]	Optimization Year Round[1]	Level 2 Dry Season[1,6]	Level 2 Year Round[1]	Level 3 Dry Season[1,6]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy[5]	MT CO_2/yr	--	0	--	500	--	580	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	--	20	--	0	--	120	--
GHG Emissions Increase Total	MT CO_2/yr	--	20	--	500	--	700	--
Unit GHG Emissions[2]	lb CO_2/MG	--	100	--	900	--	1,200	--
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--	--*	--	426	--	469	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--	--*	--	23	--	15	--
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	--	5	--	5	--	11	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. LGVSD STP was not considered for sidestream treatment since the facility already nitrifies and is limited to seasonal discharge.
6. No discharge during the dry season

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the LGVSD STP. These are:

- Nitrite Shunt – LGVSD STP BNR would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Simultaneous nitrification/denitrification (SND) – LGVSD STP BNR would be operated at low dissolved oxygen (DO) levels to promote SND. Under this operating scenario, nitrification and denitrification occurs in the same tankage and dedicated anoxic zones are not necessary. As a result, there is a significant reduction in aeration requirements. This requires the installations of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.12

City of Livermore Water Reclamation Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

City of Livermore Water Reclamation Plant

Livermore, CA

March 30, 2018
Final Report

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Executive Summary

The City of Livermore owns and operates the Livermore Water Reclamation Plant (WRP) located in Livermore, CA and discharges treated effluent to Lower San Francisco Bay through a common outfall operated by the East Bay Dischargers Association (EBDA). The plant has an average dry weather flow (ADWF) permitted capacity of 8.5 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow	mgd	--	--	6.8	6.7	9.5	9.3	9.5	9.3	--
Flow to Bay[2]	mgd	4.9	4.9	4.9	4.9	5.9	5.9	5.9	5.9	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	1,810	1,810	1,940	1,940	110	100	110	100	1,670
TN	lb N/d	1,810	1,810	1,950	1,950	790	740	580	300	1,730
TP	lb P/d	47	47	34	34	45	41	37	15	60
Costs[4,5,7]										
Capital	$ Mil	--	--	0	0	26	26	36	38	11.0
O&M PV	$ Mil	--	--	0	0	20	21	28	37	6.0
Total PV	$ Mil	--	--	0	0	46	47	64	75	17.0
Unit Costs[6]										
Capital	$/gpd	--	--	0	0	2.7	2.8	3.8	4.1	--
Total PV	$/gpd	--	--	0	0	4.8	5.1	6.7	8.1	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the 3-year average (July 2011 through June 2014), based on the data provided by Livermore. The 2015 BACWA Nutrient Reduction Study Group Annual Report data was not used, since values were only provided for the combined EBDA discharge. The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Level 3 costs include costs associated with Level 2.

The recommended optimization strategy to reduce nutrient loads in the plant effluent is to operate anaerobic selectors using both aeration tanks, including the recently upgraded tank, to improve biological phosphorus removal. Since the plant is already operating in the optimized mode, no costs are associated with this optimization. Optimization strategies to reduce ammonia or nitrogen were not feasible, due to insufficient aeration tank volume.

Livermore WRP is considered a candidate for sidestream treatment for ammonia and TN removal. Livermore WRP already removes TP by a combination of chemical precipitation and biological phosphorus removal. As a result, sidestream TP load reduction is not recommended.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Upgrade to a 3-stage BNR facility. This would require additional aeration basins. To achieve both phosphorus and nitrogen removal biologically, carbon (e.g. methanol) addition may be necessary. Facilities to add alkalinity and an external carbon source are assumed.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Upgrade to a 5-stage BNR facility. This would require additional aeration basins. An external carbon source is needed for nitrate reduction.
    c. Phosphorus polishing in tertiary filters, with additional filter cells required. Metal salt/polymer chemical feed facilities would be located at the filters to trim phosphorus.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $0 Mil for optimization up to $75 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The City of Livermore Water Reclamation Plant (WRP) serves a population of about 83,600, which includes the industrial, commercial, and domestic wastewater for the City of Livermore. It is located at 101 West Jack London Blvd, Livermore, CA 94551. The Livermore WRP discharges treated effluent to Lower San Francisco Bay through a common outfall operated by the East Bay Dischargers Association (EBDA). The plant has an average dry weather flow (ADWF) permitted capacity of 8.5 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The City of Livermore discharges treated effluent through a common outfall operated by the EBDA. EBDA dischargers include the City of Hayward, City of San Leandro, Oro Loma Sanitary District, Castro Valley Sanitary District, Union Sanitary District, and the Livermore-Amador Valley Water Management Agency (LAVWMA) plants, which include the City of Livermore, City of Pleasanton, and Dublin San Ramon Services District (DSRSD). LAVWMA also receives Zone 7 reverse osmosis reject water.

The City of Livermore Water Reclamation Plant currently discharges under Order No. R2-2017-0018, NPDES Permit No. CA0038008. Table 2-1 provides a summary of the dry weather permit limitations that are specific to Livermore and are specific to nutrients. Currently, there are no TN or TP discharge limitations Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2017-0018; CA0038008)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow[1]	mgd	8.5			
cBOD[2]	mg/L		25	40	-
TSS[2]	mg/L		30	45	-
Total Ammonia, as N	mg/L		91	-	120

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. Current permitted capacity. Permit includes a proposed ADWF capacity for 11.1 MGD.
2. BOD and TSS include a minimum percent removal of 85% through the WRP.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Livermore WRP. Both liquids processes and solids processes are shown. Livermore currently has four primary clarifiers, followed by two aeration basins (only one is in service) and three secondary clarifiers for secondary treatment. A low SRT is maintained in the activated sludge system to prevent nitrification. The operating aeration basin includes an anaerobic selector that may perform some phosphorus removal. Ferric chloride is added at the headworks for hydrogen sulfide control. Ferric chloride addition may remove some phosphorus in the primary clarifiers. Livermore provides tertiary treatment for use as recycled water with four anthracite media filters. The facility also has two flocculation tanks to improve filtration. Solids treatment consists of waste activated sludge (WAS) thickening, anaerobic digestion, and belt filter press dewatering.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Livermore WRP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	6.8	6.8	7.0	7.1
BOD	lb/d	13,100	13,200	14,700	15,400
TSS	lb/d	17,600	18,800	19,200	23,100
Ammonia[4]	lb N/d	2,260	2,280	2,540	2,660
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	2,860	2,890	3,220	3,370
Total Phosphorus (TP)[4]	lb P/d	370	370	420	440
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	230	230	250	260
TSS	mg/L	310	330	330	390
Ammonia[4]	mg N/L	40	40	44	45
TKN[4]	mg N/L	50	51	55	57
TP[4]	mg P/L	6.5	6.6	7.2	7.4
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Average TKN, ammonia and TP are based on four samples collected between July 2012 – January 2014. Peak TKN, ammonia and TP calculated assuming same peaking factors as BOD.

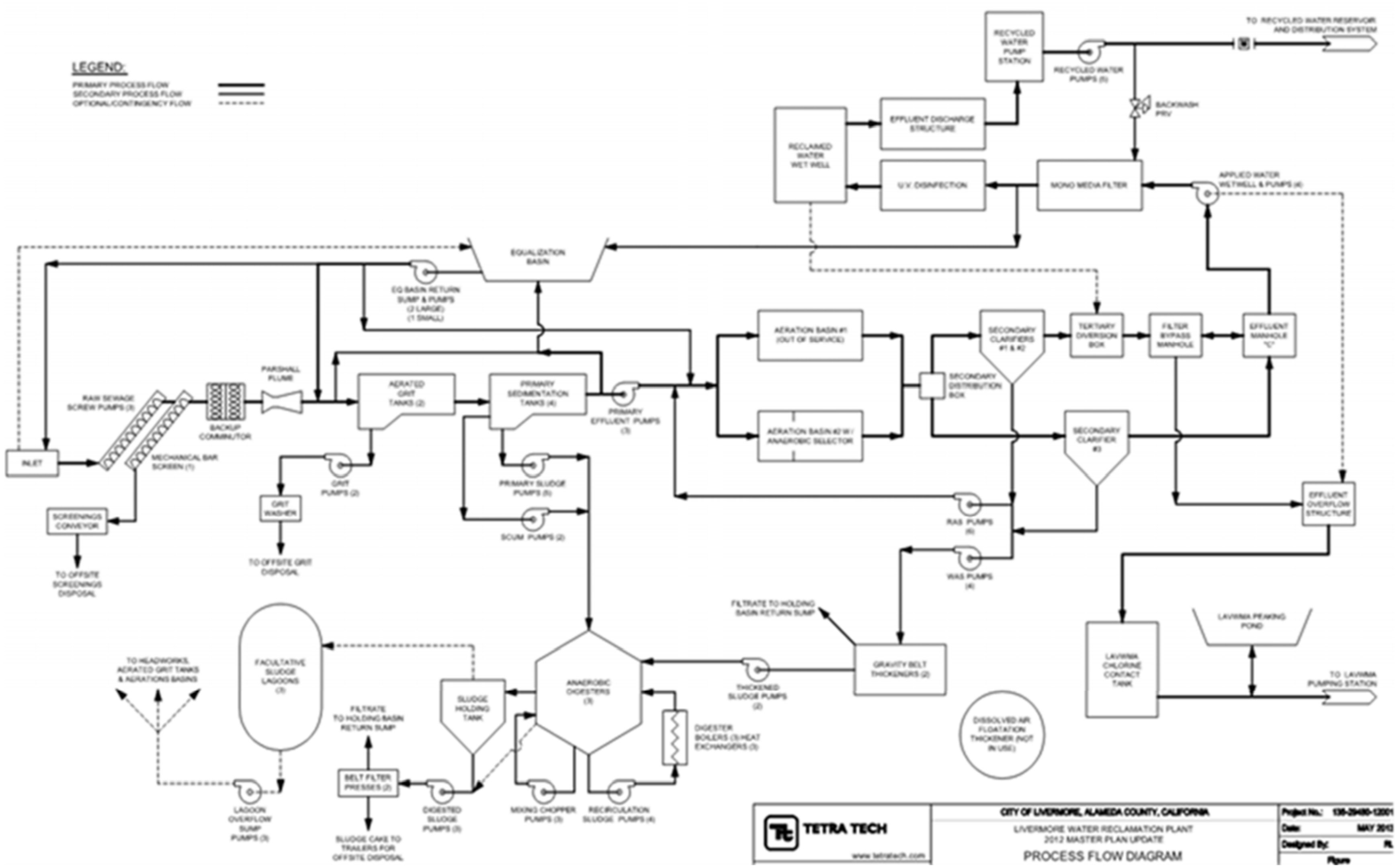

Figure 2-1. Process Flow Diagram for Livermore WRP

Source: 2012 Water Reclamation Plant Master Plan Update.

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the Livermore WRP:

- The plant recently upgraded the second aeration basin with an anaerobic selector, and intends to operate both basins in the future.
- The facility is considering expanding the recycled water system treatment from 6 MGD to 8 MGD.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the Livermore WRP.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Livermore WRP are presented in Table 3-1. The projected flow and load for the Livermore WRP in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by the Livermore WRP, it was determined that the WRP is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the permitted capacity. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	6.8	6.8	7.0	7.1
BOD	lb/d	15,000	15,200	16,900	17,700
TSS	lb/d	20,200	21,700	22,000	26,500
Ammonia	lb N/d	2,600	2,630	2,930	3,060
TKN	lb N/d	3,280	3,320	3,700	3,880
TP	lb P/d	420	430	480	500
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	260	270	290	300
TSS	mg/L	350	380	380	450
Ammonia	mg N/L	46	47	50	52
TKN	mg N/L	58	59	64	66
TP	mg P/L	7.5	7.6	8.2	8.5
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

Table 3-2. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Design Capacity (AA)
Sidestream Flow	mgd	0.06	0.08
Ammonia	lb N/d	450	630
TKN	lb N/d	890	1,230
TN[1]	lb N/d	890	1,230
TP	lb P/d	355	492
Ortho P	lb P/d	78	109
Alkalinity	lb CaCO3/d	2,000	2,700
Ammonia	mg N/L	990	990
TKN	mg N/L	1,930	1,930
TN[1]	mg N/L	1,930	1,930
TP	mg P/L	770	770
Ortho P	mg P/L	170	170
Alkalinity	mg CaCO3/L	4,300	4,300

1. It was assumed that TN = TKN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. For most plants, these values are based on the plant's permitted flow capacity as ADWF. However, the Livermore WRP permit shows a current ADWF capacity of 8.5 mgd and a proposed capacity of 11.1 mgd. The utility provided an ADWF projection of 9.5 mgd, which was used as the basis for plant upgrades. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	9.5	9.4	9.7	9.8
BOD	lb/d	18,100	18,300	20,400	21,400
TSS	lb/d	24,400	26,100	26,600	32,000
Ammonia	lb N/d	3,130	3,170	3,530	3,690
TKN	lb N/d	3,960	4,010	4,460	4,670
TP	lb P/d	510	520	580	600
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	230	230	250	260
TSS	mg/L	310	330	330	390
Ammonia	mg N/L	40	40	44	45
TKN	mg N/L	50	51	55	57
TP	mg P/L	6.5	6.6	7.2	7.4
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Based on utility-provided average dry weather flow projection. Other flows and loads are based on current flow and loading characteristics.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical

Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Three optimization strategies were identified during the Livermore site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The results of the screening are described below.

- **Optimization Strategy 1:** Operate anaerobic selector in both aeration tanks to improve biological phosphorus removal. Maintain a solids retention time (SRT) low enough to prevent nitrification but high enough to maintain biological phosphorus removal. The plant recently upgraded the second aeration basin with an anaerobic selector, and intends to operate both basins in the future.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** The plant already removes P, but operation with both aeration basins should improve removal reliability.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Increase ferric chloride addition at the headworks to remove P chemically instead of through biological P removal.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** If there is no biological phosphorus removal, chemical addition could be increased to remove P. This strategy is not recommended unless Optimization Strategy 1 (biological phosphorus removal) is halted.
  - ***Result from analysis:*** Biological phosphorus removal will achieve similar performance without chemical addition, so chemical addition is not recommended.
  - ***Recommendation:*** Do not carry forward.

- **Optimization Strategy 3:** The proposed strategy would remove ammonia and N by nitrifying in the existing aeration basins. Use CEPT to remove phosphorus and reduce organic loading to the secondary process. Increase the SRT to nitrify in the existing aeration basins, with mixed liquor recycle for nitrogen removal and alkalinity recovery. Evaluation of this proposed strategy found that the tank volume at Livermore is not sufficient to nitrify, so this strategy is not feasible.
  - ***Is it feasible?*** No. Two tanks do not provide sufficient volume for nitrification during summer or winter, and aeration capacity is not sufficient.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Not feasible.
  - ***Result from analysis:*** Not feasible.
  - ***Recommendation:*** Do not carry forward.

Strategy 1 is the best apparent way to reduce effluent phosphorus loads. The strategy identified to reduce nitrogen loads was not feasible due to insufficient tank volume.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

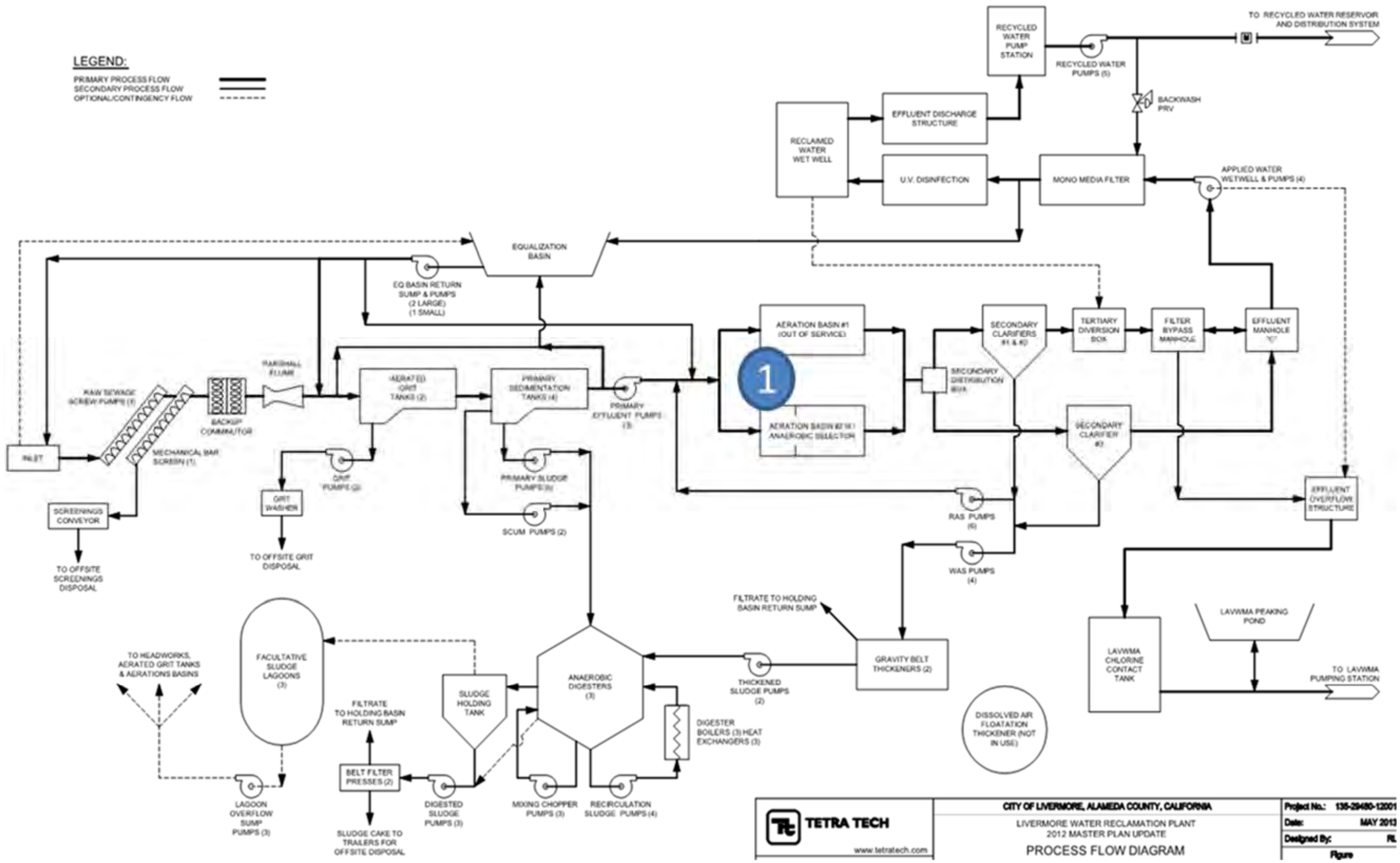

Figure 4-1. Optimization Concepts Considered for the Livermore WRP

(1) Operate A/O process in both tanks for biological phosphorus removal.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
None.	Use existing anaerobic zone mixers.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	1,940	1,940	1,950	1,950	50	50
Discharge with Opt. Strategy[1]	lb N or P/d	1,940	1,940	1,950	1,950	34	34
Load Reduction[2,3]	lb N or P/d	0	0	0	0	17	17
Load Reduction[2,3]	%	0%	0%	0%	0%	33%	33%
Annual Load Reduction	lb N or P/yr	0	0	0	0	6,030	6,030

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. Since the plant is already operating in the optimized mode, the costs are zero. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	6.8	6.7
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0	0
Annual O&M	$ Mil/yr	0	0
Present Value O&M[3]	$ Mil	0	0
Present Value Total[3]	$ Mil	0	0
Unit Capital Cost[8]	$/gpd	0	0
Unit Total PV Cost[8]	$/gpd	0	0
TN Removal			
Capital[2,4]	$ Mil	0	0
Annual O&M[4]	$ Mil/yr	0	0
O&M PV[3,4]	$ Mil	0	0
Total PV[3,4]	$ Mil	0	0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5,11]	$ Mil	0	0
Annual O&M[5,11]	$ Mil/yr	0	0
O&M PV[3,5,11]	$ Mil	0	0
Total PV[3,5,11]	$ Mil	0	0
TP Removed (Ave.)[6]	lb P/d	17	17
Annual TP Removed (Ave.)[7]	lb P/yr	6,030	6,030
TP Cost[5,9,11]	$/lb P	0	0

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen.
11. No costs are included for phosphorus removal, since the plant recently upgraded the anaerobic zones which will promote phosphorus removal.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
Biological Phosphorus Removal • Phosphorus reliably removed • Potential for improved settleability in the secondary clarifiers • An increase in SRT to improve biological phosphorus removal would reduce sludge production	• Biological phosphorus removal sludge can be difficult to dewater

5 Sidestream Treatment

As previously described, the Livermore WRP was identified as a potential candidate for sidestream treatment.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia/TN load reduction. Livermore WRP already removes TP by a combination of chemical precipitation and biological phosphorus removal. As a result, sidestream TP load reduction is not recommended.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature (common for treatment plants with mechanical dewatering). It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification), such as requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requiring 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for the Livermore WRP.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements[1]
Feed Pumping (if necessary)	--
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

1. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)[4]
Current Discharge[1]	lb/d	2,150	2,160	60
Discharge with Sidestream Treatment[2]	lb/d	1,670	1,730	60
Load Reduction[3]	lb/d	480	430	0
Load Reduction	%	23%	20%	0%
Annual Load Reduction[3]	lb/yr	177,800	158,100	0

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP[7]
Capital[1]	$ Mil	11.0	--
Annual O&M	$ Mil/yr	0.3	--
Total Present Value[2]	$ Mil	17.0	--
NH4-N Load Reduction[3,5]	lb N/yr	177,800	--
TN Load Reduction[3,5]	lb N/yr	158,100	--
TP Load Reduction[4,5]	lb P/yr	--	--
NH4-N Cost [3,5,6]	$/lb N	3.2	--
TN Cost [3,5,6]	$/lb N	3.6	--
TP Cost [4,5,6]	$/lb P	--	--

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Livermore WRP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. Livermore should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. As shown, a 3-stage BNR facility treating primary effluent is proposed.

A 3-stage BNR facility could include two additional activated sludge tanks with anaerobic and anoxic selector zones and internal mixed liquor recycle. The selector zones in the existing tanks would be reconfigured to match the new tanks, and internal mixed liquor recycle would be added to the existing tanks. This technology selection is in consistent with the Master Plan Update (2012). To achieve both phosphorus and nitrogen removal biologically, as in a 3-stage BNR, carbon (e.g. methanol) addition may be necessary. For this evaluation, the capital for methanol addition is included, but no methanol is included in the operating costs. Facilities for alkalinity addition are also included in the capital costs.

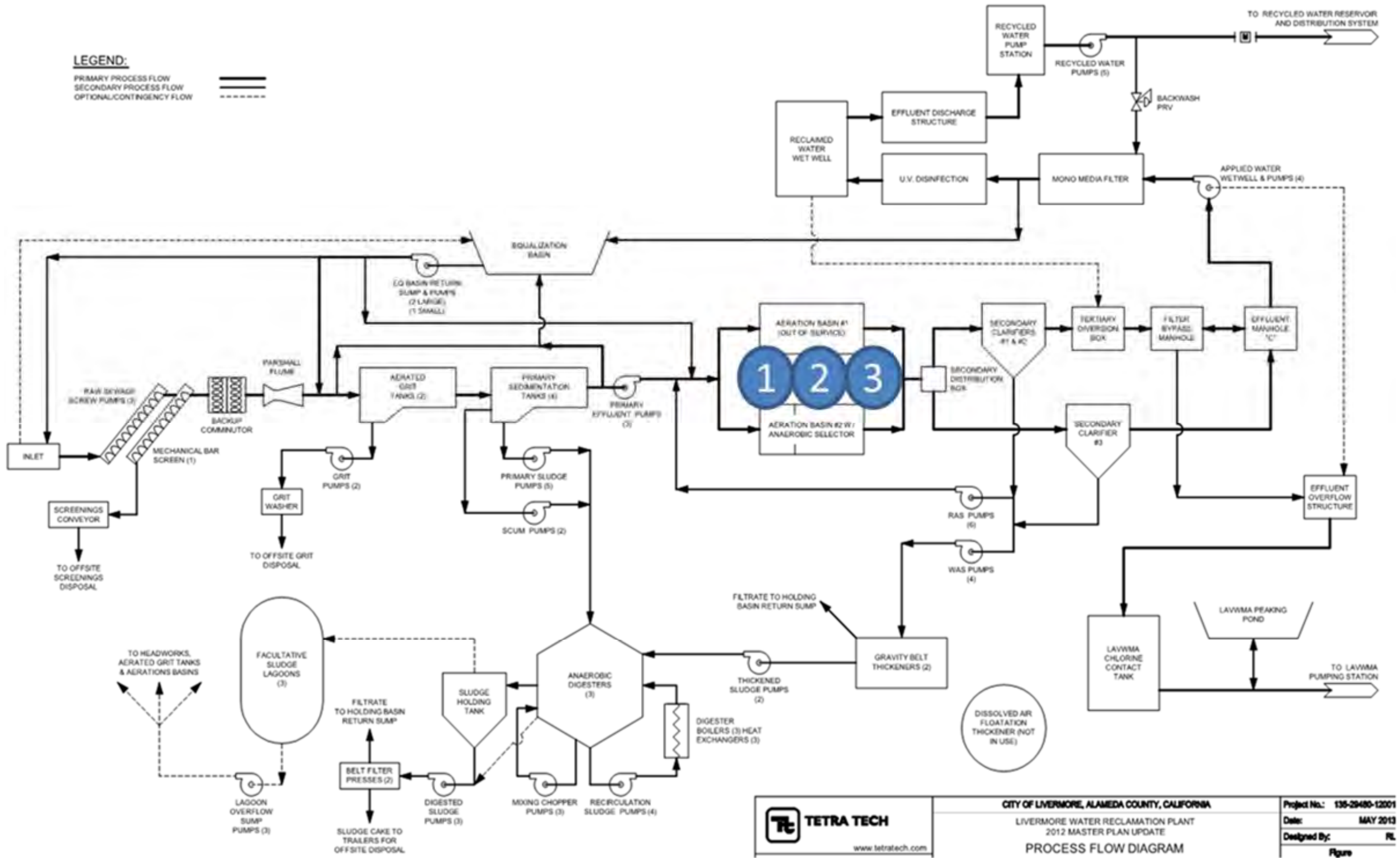

Figure 6-1. Level 2 Upgrade Concept for Livermore WRP

(1) 3-stage BNR with 2 additional tanks (4 total) with selectors and IMLR. Add IMLR to existing tanks. (2) Include facilities for alkalinity addition, and (3) include facilities to add methanol (or other carbon source).

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Level 3 upgrades could be met using a 5-stage BNR facility using a total of five activated sludge tanks (one tank more than Level 2) with a different configuration of selector zones including a post anoxic selector zone. Methanol addition is needed as a carbon source for denitrification. The selector zones in the existing tanks would be reconfigured to match the new tanks. Alum is added before filtration for phosphorus polishing, and four additional tertiary filter cells are included. This technology selection is in consistent with the Master Plan Update (2012).

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	--	--
Flow Equalization	--	--
Biological	• New Aeration Basins (2 new basins, 4 total), including diffusers, mixers, IMLR pumps and baffles • Retrofit of existing aeration basins to 3-stage BNR (diffusers, mixers, IMLR pumps and baffles • New Aeration System • Alkalinity addition facilities • Methanol addition facilities • No new secondary clarifiers	• Same as Level 2 plus one additional aeration basin (5 basins total), including diffusers, mixers, IMLR pumps and baffles, configured for 5-stage BNR
Tertiary	--	• Additional Filters • Alum and Polymer Chemical Feed • Rapid Mix and Flocculation Tanks

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

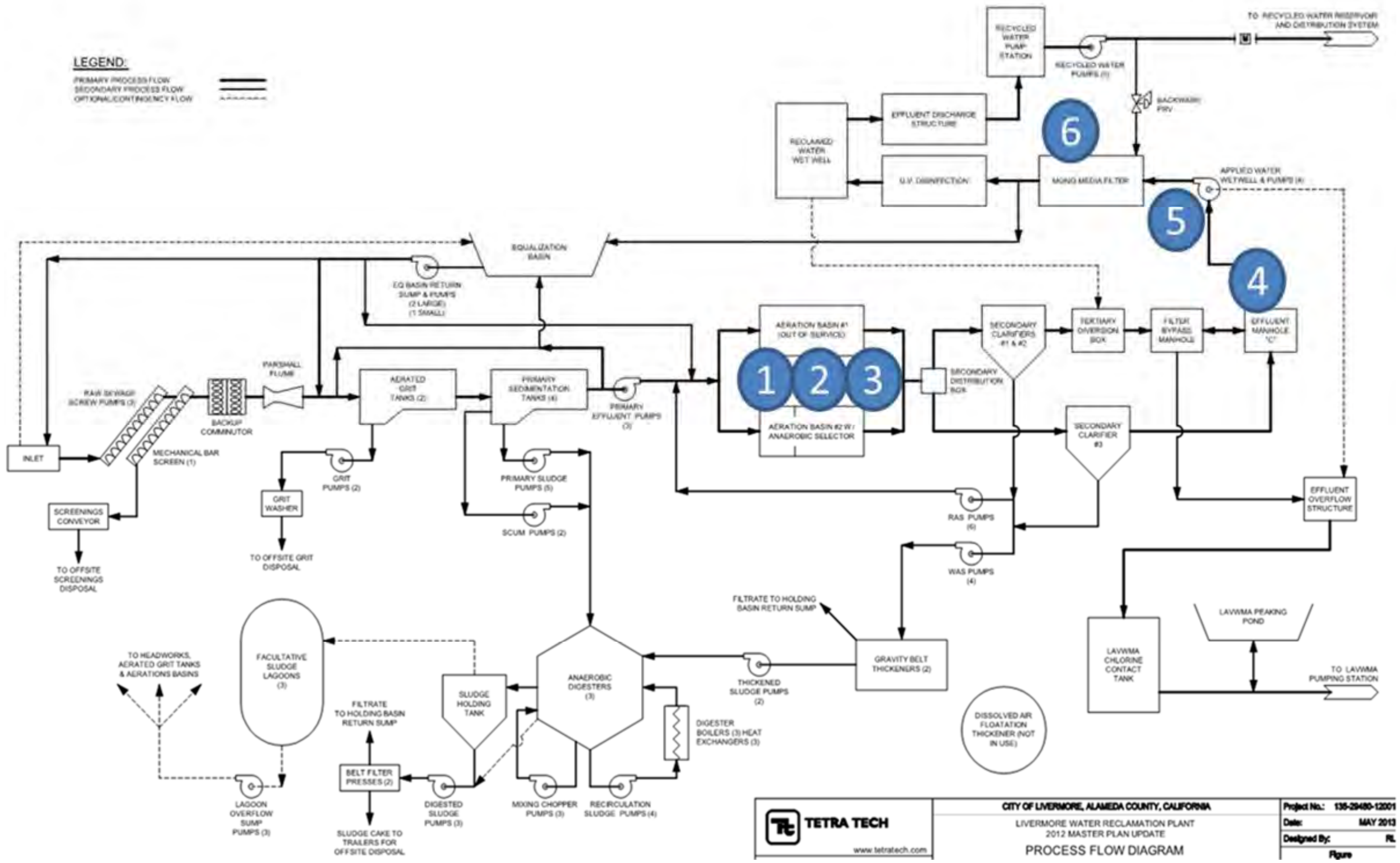

Figure 6-2. Level 3 Upgrade Concept for Livermore WRP

(1) 5-stage BNR with 3 additional tanks (5 total) with selectors and IMLR. Reconfigure baffles and add IMLR to existing tanks. (2) Include facilities for alkalinity addition, (3) add methanol (or other carbon source), (4) modify piping so all secondary effluent is filtered, and only recycled water flows to UV, (5) add alum for phosphorus polishing, and (6) add 4 additional filter cells (8 total).

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Additional BNR tanks (3-stage), and (2) chemical addition facilities (methanol and caustic).

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Additional BNR tanks (5-stage), (2) chemical addition facilities (methanol, caustic, alum), and (3) additional filters.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	9.5	9.3	9.5	9.3
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	26	26	36	38
Annual O&M	$Mil/yr	0.9	1.0	1.2	1.6
O&M PV[3]	$ Mil	20	21	28	37
Total PV[3]	$ Mil	46	47	64	75
Unit Capital Cost	$/gpd	2.7	2.8	3.8	4.1
Unit Total PV	$/gpd	4.8	5.1	6.7	8.1
TN Removal					
Capital[2,4]	$ Mil	26	26	32	32
Annual O&M[4]	$ Mil/yr	0.9	1.0	1.1	1.3
O&M PV[3,4]	$ Mil	20	21	25	30
Total PV[3,4]	$ Mil	46	47	57	62
TN Removed (Ave.)[6]	lb N/d	1,370	1,430	1,580	1,870
Annual TN Removed (Ave.)[7]	lb N/yr	501,100	520,500	577,200	682,100
TN Cost[4,8]	$/lb N	3.0	3.0	3.3	3.0
TP Removal					
Capital[2,5,10]	$ Mil	0	0	3.7	6.1
Annual O&M[5,10]	$ Mil/yr	0.0	0.0	0.1	0.3
O&M PV[3,5,10]	$ Mil	0	0	2.7	6.8
Total PV[3,5,10]	$ Mil	0	0	6.4	12.9
TP Removed (Ave.)[6]	lb P/d	11	14	18	41
Annual TP Removed (Ave.)[7]	lb P/yr	3,880	5,180	6,750	14,910
TP Cost[5,8,10]	$/lb P	0	0	32	29

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.
10. No costs are included for phosphorus removal for Level 2, since the plant recently upgraded the anaerobic zones which will promote phosphorus removal.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing aeration basins and secondary clarifiers • Ability to reliably remove ammonia and TN • Reduced solids production • Improved CEC removal compared to existing activated sludge	• Increased aeration demand compared to existing activated sludge • More complex to operate than existing activated sludge • Carbon addition may be needed for a 3-stage BNR with both phosphorus and nitrogen removal. • Safety from external carbon source (if methanol) • Alkalinity may be needed for nitrification. • Biological phosphorus removal sludge can be difficult to dewater
Level 3	Same as Level 2 plus the following additional benefits: • Highest quality water as all the water will be filtered via sand filters • Further enhanced CEC removal compared to Level 2 as any particulate bound CECs should be captured in the filters Leverage and expand existing filter facility	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 (alum for phosphorus removal and increased methanol demand) • Safety from external carbon source (if methanol)

7 Nutrient Removal by Other Means

The Livermore WRP has an existing recycled water program that is employed year-round. Recycled water is used for golf course irrigation, landscape irrigation, commercial use, and other non-potable reuse. This existing program has the effect of reducing nutrients discharged to the Bay. Livermore currently recycles approximately 2,300 acre-feet per year (760 million gallons per year) and they are planning to increase recycling to 3,600 acre-feet per year (1,100 million gallons per year) by 2030.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology

selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

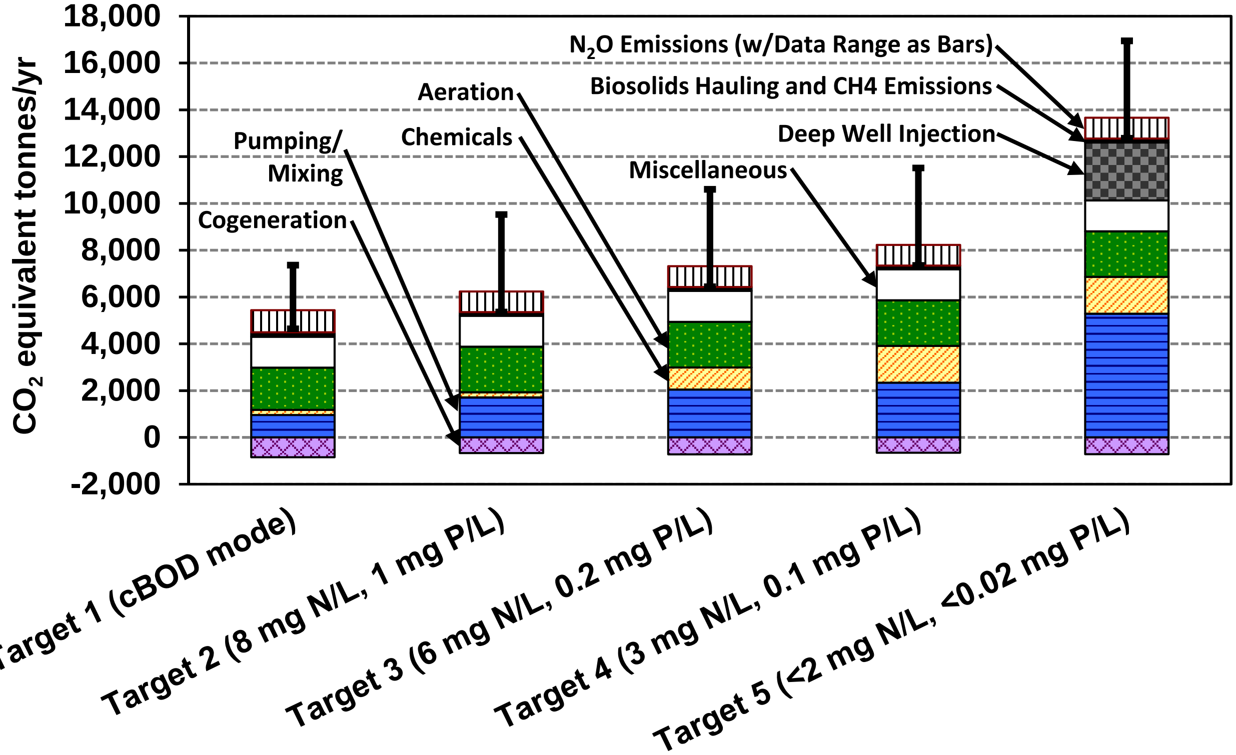

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA

eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	0	0	1,500	1,600	1,700	1,700	65
GHG Emissions Increase from Chemicals	MT CO_2/yr	0	0	0	0	500	500	5
GHG Emissions Increase Total	MT CO_2/yr	0	0	1,500	1,600	2,200	2,200	70
Unit GHG Emissions[2]	lb CO_2/MG	0	0	990	1,000	1,400	1,400	85
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	4	4	4	4	0.9
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	7	7	8	6	0.9
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	0	0	0	0	68	32	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Livermore WRP. These are:

- Nitrite Shunt – Livermore WRP aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes
- Ballasted Activated Sludge – Livermore WRP secondary process would be converted to a ballasted activated sludge process to reduce process tankage requirements. The BioMag® process supplied by Evoqua utilizes magnetite as a ballast. As a result, the secondary process is operated at an elevated mixed liquor suspended solids concentration because secondary clarifiers can tolerate higher solids loading rates due to improved settleability realized with magnetite use.
  - Advantages: Low footprint requirements, proven technology
  - Disadvantages: Increased operations and maintenance costs
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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City of Millbrae Water Pollution Control Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

City of Millbrae Water Pollution Control Plant

Millbrae, CA

May 21, 2018
Final Report

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Executive Summary

The City of Millbrae Water Pollution Control Plant (WPCP) discharges to the South Bay. It is located at 400 East Millbrae Avenue, Millbrae, CA 94030, and it serves approximately 6,550 service connections throughout the City of Millbrae. The plant has an average dry weather flow (ADWF) permitted capacity of 3 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	1.5	1.6	3.0	3.2	3.0	3.2	--
Flow to Bay[2]	mgd	1.5	1.5	1.5	1.5	2.3	2.3	2.3	2.3	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	510	510	230	220	40	40	40	40	660
TN	lb N/d	590	590	510	480	310	290	220	120	790
TP	lb P/d	30	30	10	10	20	20	10	10	41
Costs[4,5]										
Capital	$ Mil	--	--	1.4	1.4	60	63	66	70	5.9
O&M PV	$ Mil	--	--	0.7	1.0	28	31	33	37	2.6
Total PV	$ Mil	--	--	2.1	2.4	88	94	99	107	8.5
Unit Costs[6]										
Capital	$/gpd	--	--	0.9	0.9	20	20	22	22	--
Total PV	$/gpd	--	--	1.4	1.5	29	29	33	34	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Optimize ferric addition at the headworks for phosphorus removal in the primary clarifiers.
2. Optimize biological phosphorus removal in the activated sludge process.
3. Raise the solids residence time (SRT) in the activated sludge, lower dissolved oxygen in the aeration basins and add alkalinity to the aeration basins to improve ammonia and total nitrogen load reduction.

The Millbrae WPCP is considered a potential candidate for sidestream treatment. Conventional nitrifying sidestream treatment is recommended for ammonia/total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Optimize ferric addition in the headworks for phosphorus removal in the primary clarifiers.
    b. Optimize biological phosphorus removal.
    c. Convert the activated sludge process to a membrane bioreactor (MBR) process by converting the existing secondary clarifiers to membrane tanks.
    d. Add additional aeration basin volume to meet MBR volume requirements.
    e. Add new return activated sludge (RAS) pumps to meet MBR pumping demands.
    f. Add new blowers to satisfy MBR blower demands.
    g. Add an alkalinity chemical feed facility for demand associated with ammonia load reduction.
    h. Add an external carbon source chemical feed facility to reduce total nitrogen loads.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus:
    b. Expand the aeration basins further by using the existing chlorine contact tank volume.
    c. Add an ultraviolet disinfection facility to accommodate for the lost chlorination facility.
    d. Add internal mixed liquor pumping for the MBR.
    e. Increase the ferric chloride at the primaries to further reduce total phosphorus loads in the MBR.

As shown in Table ES-1, and as might be expected, the costs generally increase from optimization to sidestream treatment, and again to Level 2 and Level 3 upgrades, respectively. The costs generally increase for both capital and O&M from the dry season to year round. Overall the present value costs range from approximately $2 Mil for dry season optimization up to $107 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The City of Millbrae Water Pollution Control Plant (WPCP) discharges to the South Bay. It is located at 400 East Millbrae Avenue, Millbrae, CA 94030, and it serves approximately 6,550 service connections throughout the City of Millbrae. The plant has an average dry weather flow (ADWF) permitted capacity of 3 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The WPCP holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2013-0037; CA0037532. Table 2-1 provides a summary of the permit limitations for the Millbrae WPCP. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2015-0013; CA0038024)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Peak Daily Wet Weather Design Flow
Flow	mgd	3	--	--	9
BOD	mg/L	--	25	40	--
TSS	mg/L	--	30	45	--
Total Ammonia, as N	mg/L	--	110	--	160

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Millbrae WPCP. Both liquids processes and solids processes are shown. The treatment processes include screens and grit removal, flow equalization, primary sedimentation, biological activated sludge treatment, secondary clarification, disinfection with sodium hypochlorite, and final effluent skimming. Sludge from primary and secondary clarifiers is thickened, anaerobically digested and dewatered with belt filters.

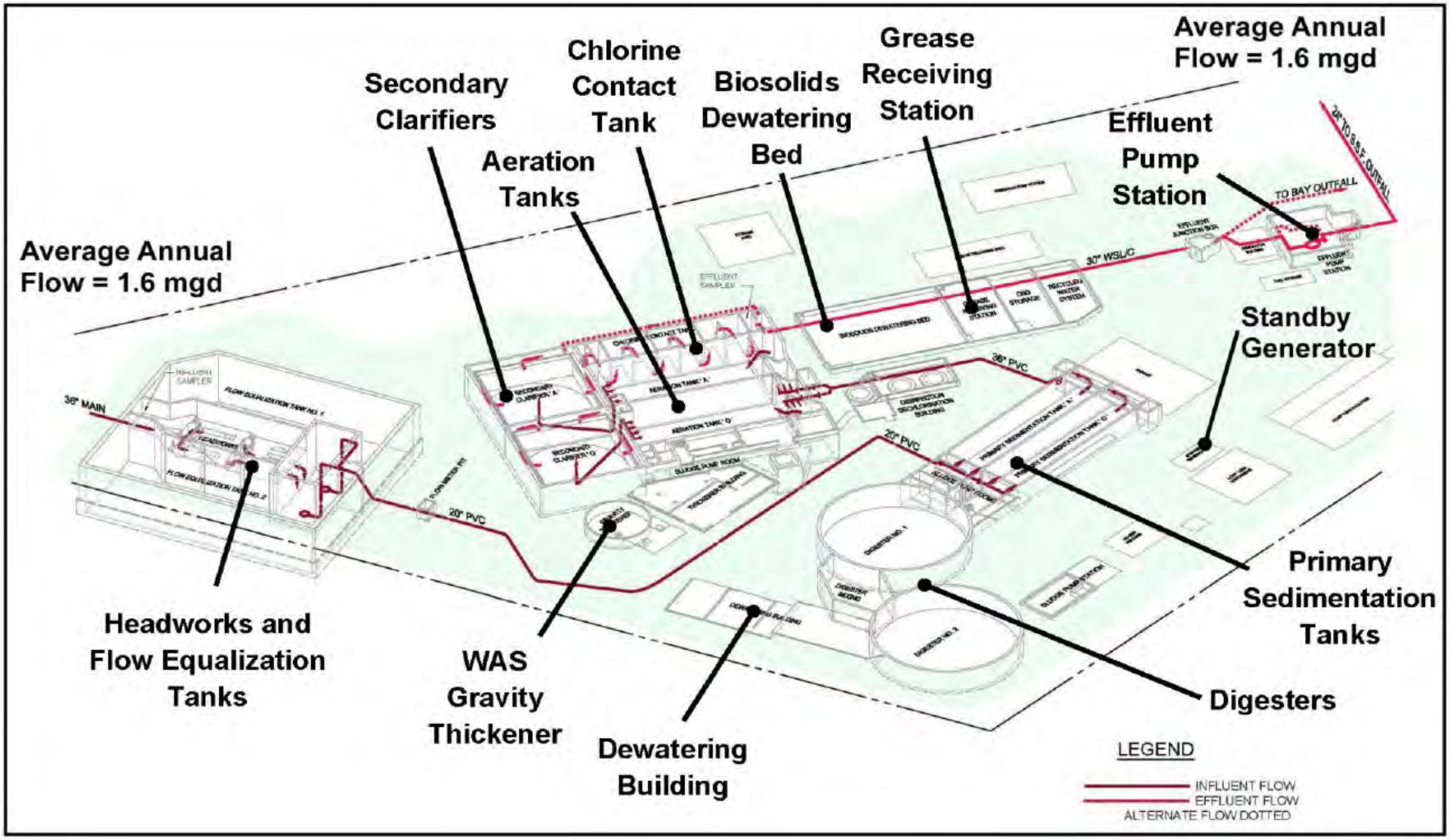

Figure 2-1 Process Flow Diagram for the City of Millbrae WPCP

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Millbrae WPCP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.5	1.5	1.5	2.2
BOD	lb/d	4,400	4,500	4,900	5,100
TSS	lb/d	4,000	4,300	5,000	5,400
Ammonia	lb N/d	400	500	400	500
Total Kjeldahl Nitrogen (TKN)	lb N/d	700	700	700	900
Total Phosphorus (TP)	lb P/d	80	110	80	150
Alkalinity[4]	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	360	354	386	283
TSS	mg/L	327	338	394	300
Ammonia	mg N/L	33	39	32	28
TKN	mg N/L	57	55	55	50
TP	mg P/L	6.5	8.6	6.3	8.3
Alkalinity[4]	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

2.4 Future Nutrient Removal Projects

The Millbrae WPCP recently completed major plant upgrades to improve the overall plant performance. The follow components impact the secondary treatment train and potentially nutrient removal:

- New blowers and diffusers were installed.
- New secondary clarifier mechanisms were installed.
- Bypasses were removed to stop the ability to blend flows.
- The anaerobic selector was made a permanent facility.

The City of Millbrae WPCP does not have any additional projects currently planned related to the removal of nutrients.

2.5 Pilot Testing

The City has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for the Millbrae WPCP are presented in Table 3-1. The projected flow and load for 2025 was not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.5	1.5	1.5	2.2
BOD	lb/d	5,100	5,200	5,600	5,900
TSS	lb/d	4,600	4,900	5,800	6,200
Ammonia	lb N/d	500	600	500	600
TKN	lb N/d	800	800	800	1,000
TP	lb P/d	90	130	90	170
Alkalinity[4]	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	414	407	444	325
TSS	mg/L	376	389	453	345
Ammonia	mg N/L	38	45	37	32
TKN	mg N/L	66	63	63	58
TP	mg P/L	7.5	9.9	7.2	9.5
Alkalinity[4]	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by the Millbrae WPCP, it was determined that the facility is a candidate for sidestream treatment. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

Table 3-2. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Permitted Flow Capacity
Sidestream Flow	mgd	0.014	0.028
Ammonia	lb N/d	88	180
TKN	lb N/d	90	185
TN[1]	lb N/d	90	185
TP	lb P/d	7	15
OrthoP	lb P/d	5	11
Alkalinity	lb $CaCO_3$/d	310	630
Ammonia	mg N/L	770	770
TKN	mg N/L	790	790
TN[1]	mg N/L	790	790
TP	mg P/L	65	65
OrthoP	mg P/L	48	48
Alkalinity	mg/L as CaCO3	2,700	2,700

1. It was assumed that TN = TKN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	3.0	3.1	3.1	4.4
BOD	lb/d	9,000	9,200	10,000	10,400
TSS	lb/d	8,200	8,800	10,200	11,100
Ammonia	lb N/d	800	1,000	800	1,000
TKN	lb N/d	1,400	1,400	1,400	1,800
TP	lb P/d	160	220	160	310
Alkalinity[4]	lb/d as $CaCO_3$	--	--	--	--
BOD	mg/L	360	354	386	283
TSS	mg/L	327	338	394	300
Ammonia	mg N/L	33	39	32	28
TKN	mg N/L	57	55	55	50
TP	mg P/L	6.5	8.6	6.3	8.3
Alkalinity[4]	mg/L as CaCO3	--	--	--	--

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.

- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy.

Several optimization strategies were identified during the Millbrae WPCP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The optimization strategies were screened down to three strategies as follows.

- **Optimization Strategy 1:** Optimize the current ferric chloride chemical feed facilities at the headworks for phosphorus removal in the primaries. Adding more ferric chloride will increase phosphorus removal and TSS and BOD capture at the primaries.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase phosphorus removal and reduce loading to the downstream activated sludge process.
  - ***Result from analysis:*** It will remove phosphorus at the primaries and increase downstream capacity.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Optimize biological phosphorus removal in the permanent anaerobic selector.
  - ***Is it feasible?*** Yes.

- ***Potential impact on ability to reduce nutrient discharge loads?*** Total phosphorus load reduction.
- ***Result from analysis:*** This strategy could effectively reduce phosphorus load. Other Bay Area facilities with anaerobic selectors typically discharge between 1 to 3 mg P/L.
- ***Recommendation:*** Carry forward for this analysis.

- **Optimization Strategy 3:** Raise the SRT and operate at low dissolved oxygen to get partial denitrification.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Total nitrogen load reduction.
  - ***Result from analysis:*** Would require alkalinity addition to maintain nitrification.
  - ***Recommendation:*** Carry forward.

Strategies 1 and 2 could reduce phosphorus loads. Strategy 3 is the best apparent way to reduce nitrogen loads. The recommended strategies are shown with the process flow diagram presented in Figure 4-1. A description of each strategy and the evaluation results are presented thereafter. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

The capital and operational elements of the recommended optimization strategies are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Optimize ferric chloride addition for phosphorus removal at the primaries • None	• Operate the alum chemical feed facilities
Optimize Biological Phosphorus Removal • None	• Operate the anaerobic zone as an anaerobic zone.
Raise SRT, lower DO and add alkalinity • Add alkalinity chemical feed facilities	• Operate the alkalinity chemical feed facility • Learn a new operational mode

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

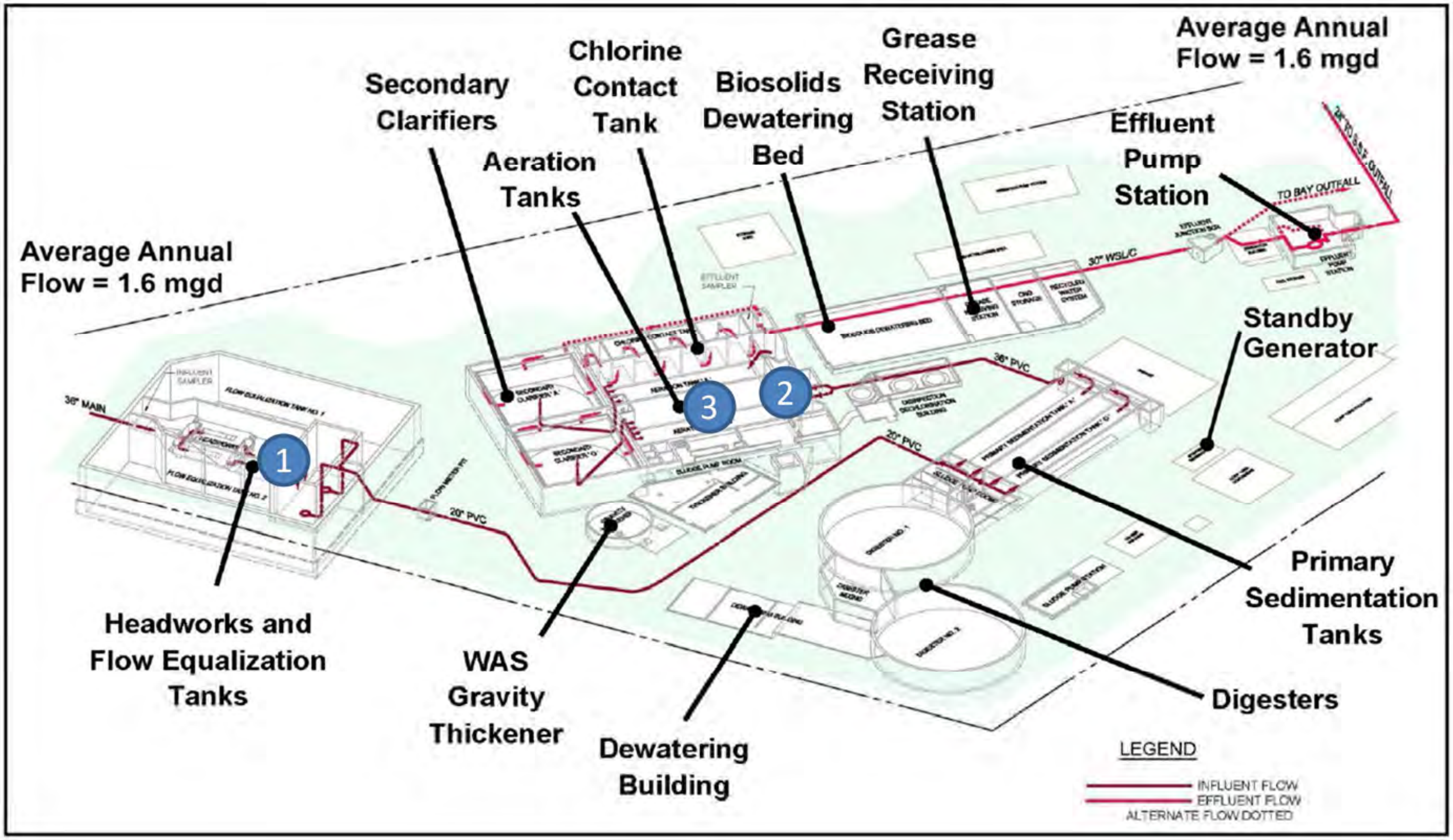

Figure 4-1. Optimization Concepts Considered for the Millbrae WPCP

(1) Optimize existing ferric chloride addition for phosphorus removal, (2) optimize biological phosphorus removal in the activated sludge process, and (3) raise the SRT for nitrification, lower dissolved oxygen and add alkalinity.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	550	550	630	630	30	30
Discharge with Opt. Strategy[1]	lb N or P/d	230	220	510	480	10	10
Load Reduction[2]	lb N or P/d	320	340	120	150	20	20
Load Reduction[2]	%	58%	61%	19%	24%	61%	64%
Annual Load Reduction	lb/yr	117,700	123,100	43,500	55,600	7,770	8,070

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	1.5	1.6
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	1.4	1.4
Annual O&M	$ Mil/yr	0.1	0.1
Present Value O&M[3]	$ Mil	0.7	1.0
Present Value Total[3]	$ Mil	2.1	2.4
Unit Capital Cost[8]	$/gpd	0.9	0.9
Unit Total PV Cost[8]	$/gpd	1.4	1.5
TN Removal			
Capital[2,4]	$ Mil	0.8	0.8
Annual O&M[4]	$ Mil/yr	0.1	0.1
O&M PV[3,4]	$ Mil	0.6	0.9
Total PV[3,4]	$ Mil	1.4	1.7
TN Removed (Ave.)[6]	lb N/d	120	150
Annual TN Removed (Ave.)[7]	lb N/yr	43,500	55,600
TN Cost[4,9]	$/lb N	3.1	3.0
TP Removal			
Capital[2,5]	$ Mil	0.60	0.60
Annual O&M[5]	$ Mil/yr	--*	0.002
O&M PV[3,5]	$ Mil	--*	0.02
Total PV[3,5]	$ Mil	0.60	0.62
TP Removed (Ave.)[6]	lb P/d	21	22
Annual TP Removed (Ave.)[7]	lb P/yr	7,770	8,070
TP Cost[5,9]	$/lb P	7.7	7.6

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

* The O&M costs are anticipated to be similar to current.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at the Millbrae WPCP.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
Optimize ferric chloride addition for phosphorus removal at the primaries • Ability to reduce phosphorus loads • Increase capacity in downstream activated sludge process	• Additional chemical handling • Potential increase in solids handling
Optimize Biological Phosphorus Removal • Ability to reduce phosphorus loads • Improved settleability and sludge volume index in the secondary clarifiers	• More complicated process to operate.
Raise SRT, lower DO and add alkalinity • Ability to reduce nitrogen loads • Enhanced removal of chemicals of emerging concern (CECs) • Reduced TSS and BOD discharge loads	• More complicated process to operate

5 Sidestream Treatment

As previously described, the Millbrae WPCP was identified as a potential candidate for sidestream treatment. A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). The WPCP currently uses anaerobic digesters, followed by belt filter presses. Based on the questionnaire and sampling results, a conventional nitrifying sidestream treatment technology is recommended for ammonia/total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction.

Conventional nitrification is recommended for the WPCP over the innovative deammonification technologies due to concerns over low sidestream treatment design temperatures. The WPCP typically dewaters about 4.5 days per week. A flow equalization feed tank would be required to balance flows for periods when dewatering is off-line. During such periods, the water in the flow equalization tanks would cool down to ambient temperatures. Additionally, this temperature concern is exacerbated with the presence of ambient washwater required to operate their belt filter presses. Given the potentially wide range of operating temperatures (about 15 to 30 degrees C), the robust conventional nitrification technology is recommended.

Conventional nitrifying sidestream treatment is an established technology where ammonia is oxidized to nitrate. The nitrate formed in the sidestream is expected to be removed in the main stream process via biological denitrification at either the headworks and/or primary clarifiers. Nitrate removal in the main stream process is easier than sidestream denitrification where organic carbon is not readily available.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. The WPCP might be able to leverage the existing ferric chloride and polymer chemical feed facilities that feed upstream of the primary clarifiers. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks).

Another option to consider for eliminating the phosphorus recycled stream load is recovery via struvite precipitation. This process produces a useful byproduct (struvite crystals) that can be sold economically. The finances are typically more attractive for larger plants (>40 mgd). It is recommended that the WPCP evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant if phosphorus load reduction is required in the future.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed Facility
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	780	900	49
Discharge with Sidestream Treatment[2]	lb/d	660	790	41
Load Reduction[3]	lb/d	120	110	8
Load Reduction	%	15%	12%	16%
Annual Load Reduction	lb/yr	44,200	39,100	2,880

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	5.9	0.03
Annual O&M	$ Mil/yr	0.1	0.01
Total Present Value[2]	$ Mil	8.3	0.17
NH4-N Load Reduction[3,5]	lb N/yr	44,200	--
TN Load Reduction[3,5]	lb N/yr	39,100	--
TP Load Reduction[4,5]	lb P/yr	--	2,880
NH4-N Cost [3,5,6]	$/lb N	6.3	--
TN Cost [3,5,6]	$/lb N	7.1	--
TP Cost [4,5,6]	$/lb P	--	2.0

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Millbrae WPCP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. Millbrae should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under optimization, Section 4. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. For phosphorus load reduction, optimize ferric chloride addition facilities at the headworks (similar to optimization) and add polymer chemical feed facilities at the primaries to further enhance solids capture.

For ammonia and nitrogen load reduction, convert the existing activated sludge to a membrane bioreactor (MBR). The secondary clarifiers would be converted to membrane tanks (it may require making the tanks deeper depending on the membrane type). Additional aeration basin volume would be required to meet Level 2 upgrades. This additional volume could be achieved by using the existing blower building located adjacent to the aeration basins. Similar to the membrane tanks, it may require deepening the basins to provide the additional volume requirements. Additional facilities for the MBR include increased blower capacity, increased return activated sludge (RAS) pumping capacity, an external carbon source chemical feed facility, and an alkalinity chemical feed facility.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would build upon those listed for Level 2. In addition to those listed for Level 2, Level 3 upgrades require additional aeration basin volume, which is based on using the existing chlorine contact basin due to land constraints. A new UV system was assumed to replace the chlorine disinfection facilities. This is the only plant out of 37 that required such a move of facilities, which is attributed to the limited footprint. The MBR process would require the addition of an internal mixed return pumping and piping system. With the exception of alkalinity, all the pumping and chemical feed facilities would operate at increased pumping/dosing compared to Level 2 upgrades.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Metal salt chemical feed facilities at the headworks • Polymer chemical feed facilities	Same as Level 2, but at a higher dose for both chemicals
Biological	Convert the Activated Sludge to an MBR • Convert secondaries to membrane tanks • Move the existing blower building to another location and use this footprint to create a third aeration basin train. • Operate the anaerobic zone as an anoxic zone • Additional blower capacity • Aeration system modifications to air piping/distribution • Alkalinity chemical feed facilities • External carbon source chemical feed facilities	Same as Level 2, plus • Additional aeration basin volume (use the chlorine contact tank) • Add internal mixed liquor return pumping
Tertiary	--	• Replace the chlorine disinfection system with an ultraviolet disinfection system. Conversion of the existing chlorine contact tank to a bioreactor is based on limited land availability.

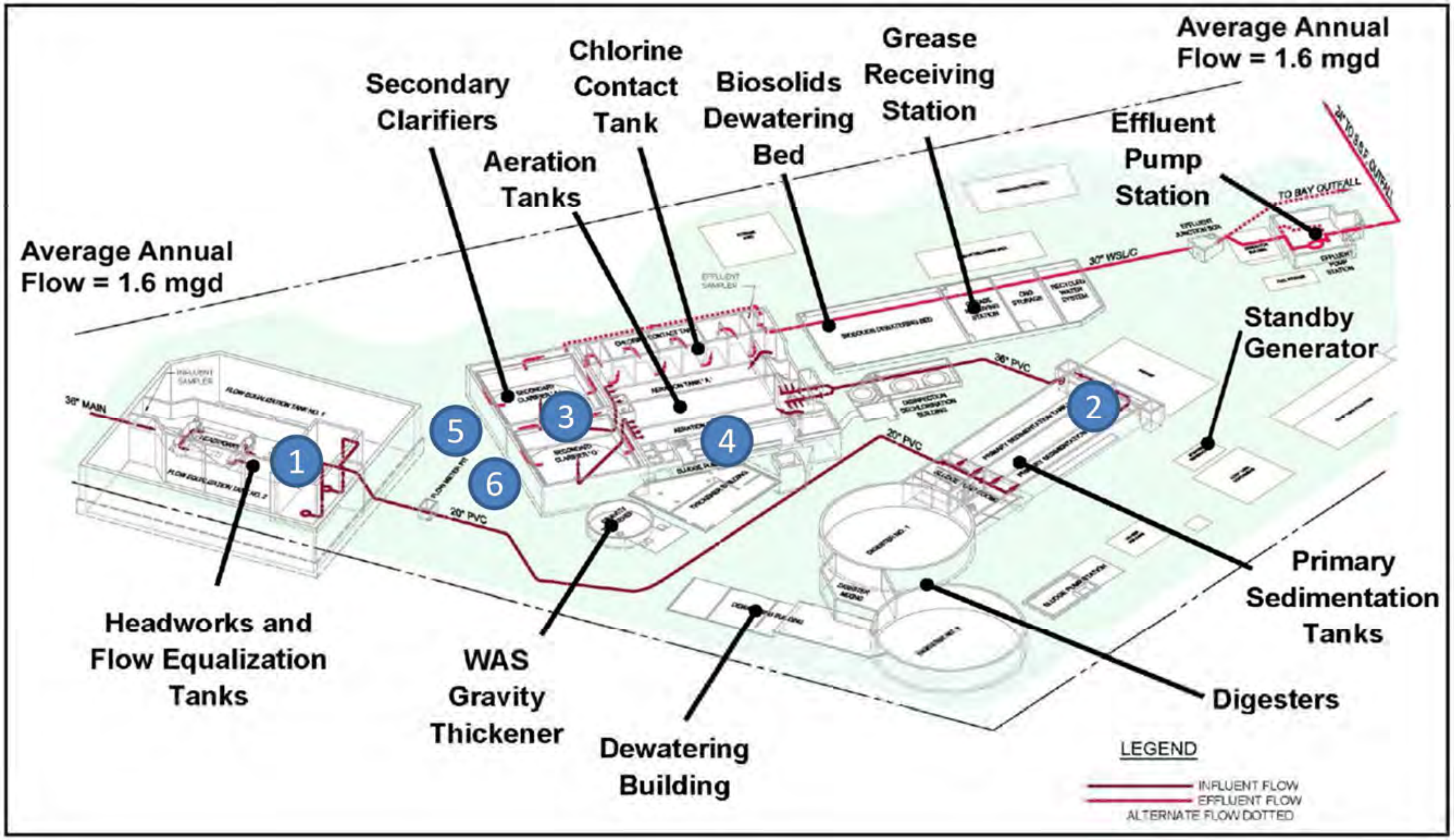

Figure 6-1. Level 2 Upgrade Concepts for the Millbrae WPCP

(1) Optimize ferric addition for phosphorus removal, (2) add polymer chemical feed facilities, (3) convert the activated sludge to MBR by converting secondary clarifiers to membrane tanks, (4) expand the aeration basins to create a third train (requires moving the blower building), (5) add alkalinity chemical feed facilities, and (6) add external carbon source chemical feed facilities.

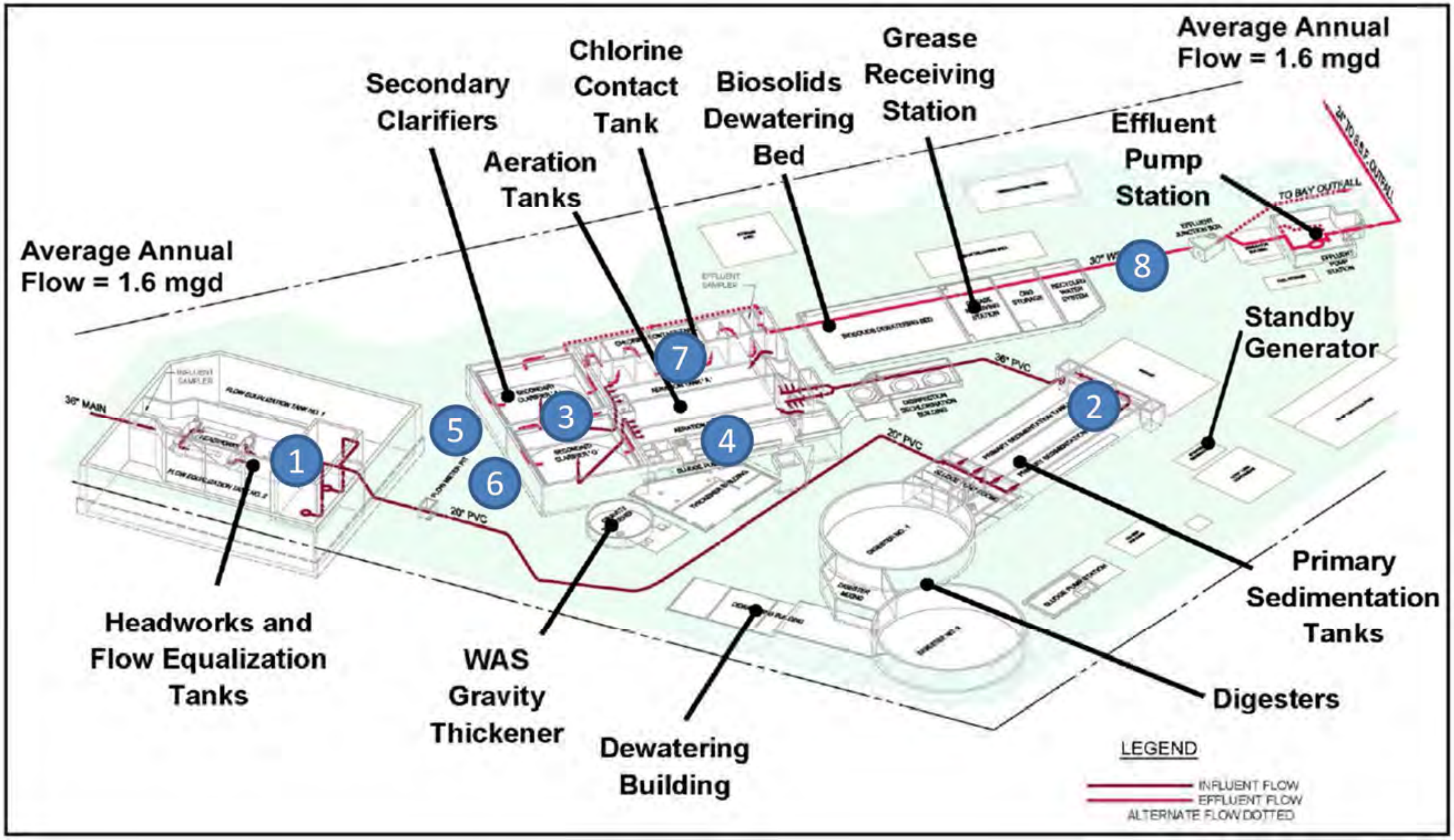

Figure 6-2. Level 3 Upgrade Concepts for the Millbrae WPCP

(1) Optimize ferric addition for phosphorus removal, (2) add polymer chemical feed facilities, (3) convert the activated sludge to MBR by converting secondary clarifiers to membrane tanks, (4) expand the aeration basins to create a third train (requires moving the blower building), (5) add alkalinity chemical feed facilities, (6) add external carbon source chemical feed facilities, (7) decommission the chlorination disinfection system and use this footprint for additional aeration basin volume, and (8) add an ultraviolet disinfection system.

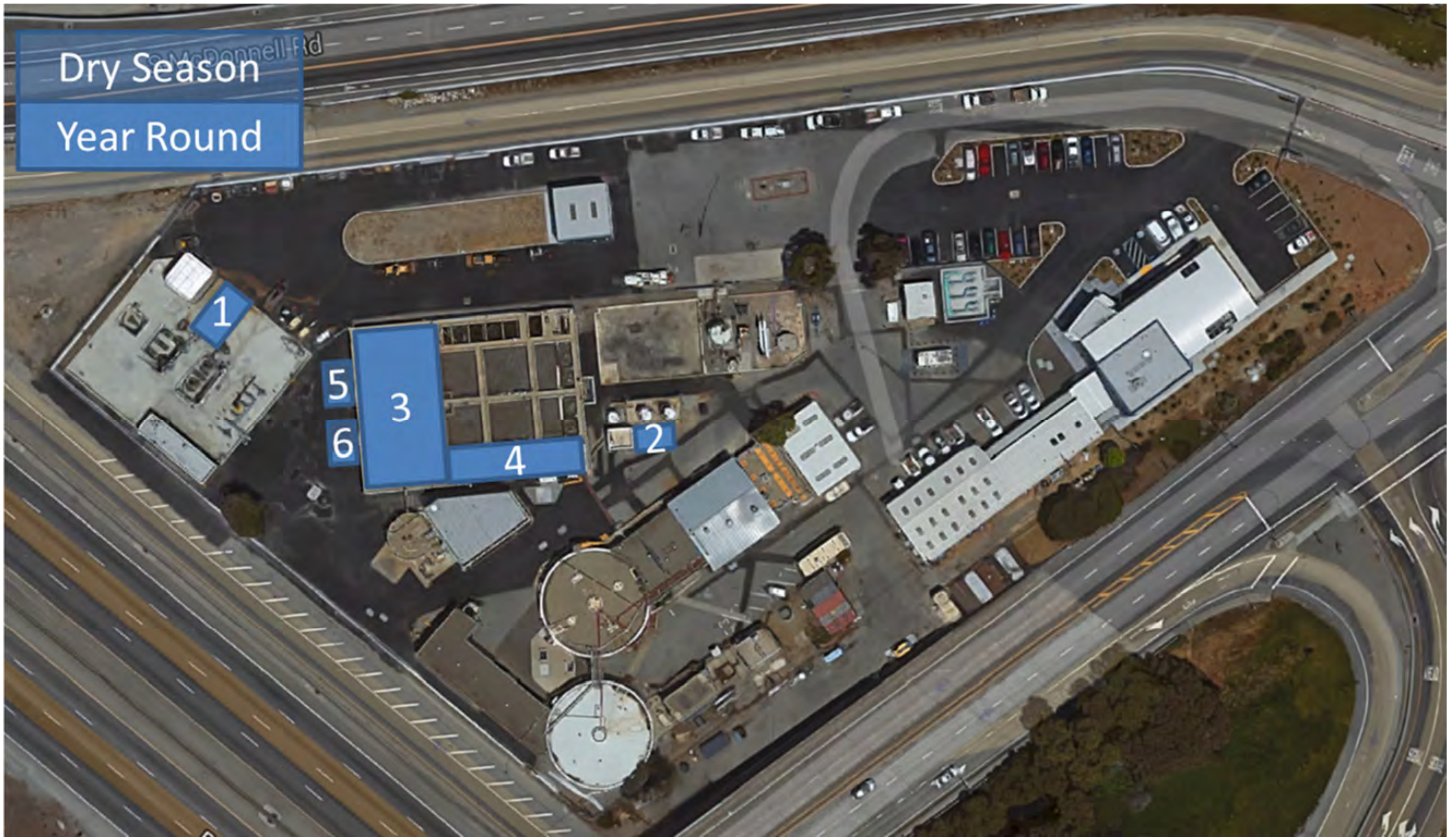

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Optimize ferric addition for phosphorus removal, (2) add polymer chemical feed facilities, (3) convert the activated sludge to MBR by converting secondary clarifiers to membrane tanks, (4) expand the aeration basins to create a third train (requires moving the blower building), (5) add alkalinity chemical feed facilities, and (6) add external carbon source chemical feed facilities.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Optimize ferric addition for phosphorus removal, (2) add polymer chemical feed facilities, (3) convert the activated sludge to MBR by converting secondary clarifiers to membrane tanks, (4) expand the aeration basins to create a third train (requires moving the blower building), (5) add alkalinity chemical feed facilities, (6) add external carbon source chemical feed facilities, (7) decommission the chlorination disinfection system and use this footprint for additional aeration basin volume, and (8) add an ultraviolet disinfection system.

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	3.0	3.2	3.0	3.2
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	60	63	66	70
Annual O&M	$Mil/yr	1.3	1.4	1.5	1.7
O&M PV[3]	$ Mil	28	31	33	37
Total PV[3]	$ Mil	88	94	99	107
Unit Capital Cost	$/gpd	20	20	22	22
Unit Total PV	$/gpd	29	29	33	34
TN Removal					
Capital[2,4]	$ Mil	58	61	64	69
Annual O&M[4]	$ Mil/yr	1.2	1.3	1.4	1.6
O&M PV[3,4]	$ Mil	27	30	32	36
Total PV[3,4]	$ Mil	85	91	96	105
TN Removed (Ave.)[6]	lb N/d	590	600	680	780
Annual TN Removed (Ave.)[7]	lb N/yr	214,000	221,000	246,000	285,000
TN Cost[4,8]	$/lb N	13	14	13	12
TP Removal					
Capital[2,5]	$ Mil	29	30	31	33
Annual O&M[5]	$ Mil/yr	0.5	0.5	0.6	0.6
O&M PV[3,5]	$ Mil	11	12	13	14
Total PV[3,5]	$ Mil	40	42	44	47
TP Removed (Ave.)[6]	lb P/d	28	30	35	43
Annual TP Removed (Ave.)[7]	lb P/yr	10,400	10,900	12,900	15,800
TP Cost[5,8]	$/lb P	126	127	112	98

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Additional capacity for primary clarifiers • Reduced solids/BOD discharge loading • Alkalinity recovery associated with the denitrification step • Enhanced CECs removal compared to the existing aeration basins • Higher quality product water amenable to reuse due to membrane filtration step • Reduced biosolids yield	• Additional chemicals to primary clarifiers and MBR • Increase in overall energy use with larger blowers and pumps • Additional pumping stations to operate • Operate with higher MLSS that will require the operators to get accustomed to • Safety associated with external carbon source (e.g., methanol)
Level 3	Same as Level 2 plus the following additional benefits: • Further alkalinity recovery due to more denitrification than the other Levels	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Additional solids • Additional aeration basin volume to operate • New disinfection system to learn and operate

7 Nutrient Load Reduction by Other Means

The Millbrae WPCP has an existing recycled water program that is employed year-round. The program uses internal water to serve primarily as washwater at the belt filter press. This program does not necessarily reduce nutrient loads to the Bay. Rather, it reduces potable water demand on the order of 60 acre-feet per year (20 million gallons per year). There are no plans to further expand the recycled water program at this time.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

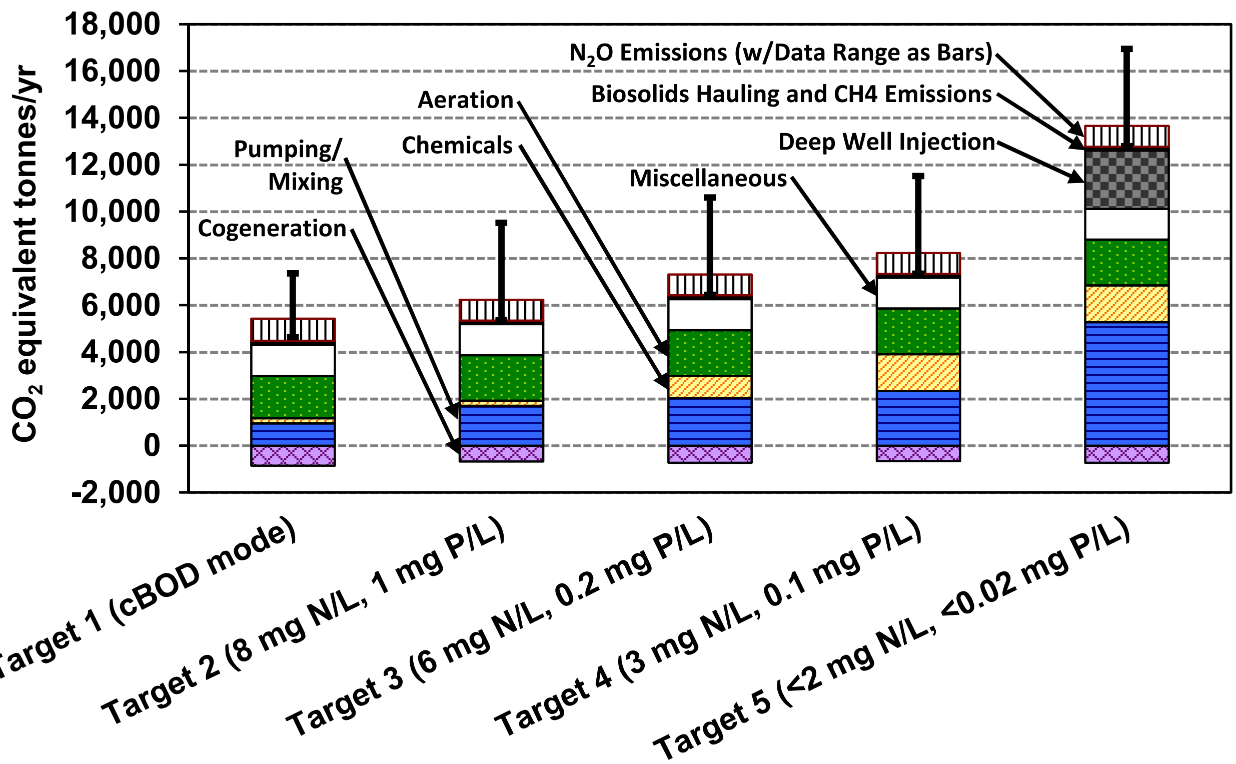

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	60	70	700	800	800	1,000	16.2
GHG Emissions Increase from Chemicals	MT CO_2/yr	1,090	1,470	2,500	3,300	1,100	1,700	1.4
GHG Emissions Increase Total	MT CO_2/yr	1,150	1,540	3,200	4,100	1,900	2,700	17.6
Unit GHG Emissions[2]	lb CO_2/MG	4,600	6,100	6,200	7,900	3,700	5,100	69
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	20	30	20	30	10	20	1.0
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	60	60	30	40	20	20	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	0.6	0.3	40	50	50	50	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the Millbrae WPCP:

- Granular Sludge Activated Sludge – this could be used to phase out the biotower/activated sludge. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit to the Millbrae WPCP is it has the potential to maximize existing aeration basins at this land limited site. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.14

Mt. View Sanitary District Wastewater Treatment Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Mt. View Sanitary District Wastewater Treatment Plant

Martinez, CA

April 23, 2018
Final Report

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Executive Summary

The Mt. View Sanitary District (District) owns and operates the Mt. View Wastewater Treatment Plant (Mt. View WTP) located in Martinez, CA and discharges treated effluent to the Peyton Slough, a tributary to Carquinez Strait. The plant has an average dry weather flow (ADWF) permitted capacity of 3.2 million gallons per day (mgd) and a peak permitted wet weather flow of 10.9 mgd.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3,7]
Design Flow	mgd	--	--	1.4	1.4	1.5	1.5	1.5	1.5	--
Flow to Bay[2]	mgd	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	3.5	3.5	3.6	3.6	3.6	3.6	3.6	3.6	--
TN	lb N/d	280	280	170	160	180	170	130	70	--
TP	lb P/d	38.4	38.4	11.3	10.6	12.2	11.4	8.3	3.4	--
Costs[4,5]										
Capital	$ Mil	--	--	2.4	2.4	36	36	36	36	--
O&M PV	$ Mil	--	--	1.3	1.4	11	12	12	13	--
Total PV	$ Mil	--	--	3.7	3.8	47	48	48	49	--
Unit Costs[6]										
Capital	$/gpd	--	--	1.7	1.7	24.3	24.1	24.3	24.1	--
Total PV	$/gpd	--	--	2.7	2.7	31.7	31.8	32.6	32.7	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Mt. View WTP was not considered for sidestream treatment.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Implement chemically enhanced primary treatment (CEPT) to reduce TP.
2. Increase waste activated sludge (WAS) pumping back to the primary clarifier to realize some denitrification.

The Mt. View WTP is not considered a candidate for sidestream treatment to reduce nitrogen or phosphorus loads since dewatering is infrequent.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Add chemical feed facilities at the primaries and operate as CEPT
   b. Construct denitrification filters
   c. Construct denitrification filter pumping station
   d. Construct methanol addition facility
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Expand denitrification filters
   c. Add chemical feed facilities to remove TP upstream of filters

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round . Overall the present value costs range from $3.7 Mil for dry season optimization up to $49 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

Mt. View Sanitary District Wastewater Treatment Plant (Mt. View WTP) services a population of about 21,900, which includes unincorporated areas of Martinez and portions of the City of Martinez. It is located at 3800 Arthur Road, Martinez, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 3.2 million gallons per day (mgd) and a peak permitted wet weather flow of 10.9 mgd.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

Mt. View WTP holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2016-0023, NPDES Permit No. CA0037770). Treated wastewater is discharged to the Peyton Slough, a tributary to Carquinez Strait at latitude 38.021111 and longitude -122.103611. Table 2-1 provides a summary of the permit limitations that are specific to the Mt. View WTP NPDES permit, and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2016-0023, CA0037770)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	3.2	---	---	---
BOD	mg/L	---	15	25	---
TSS	mg/L	---	15	25	---
Total Ammonia, as N	mg/L	---	1.6	---	4.7

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Mt. View WTP. Both liquids processes and solids processes are shown. The Mt. View WTP consists of pretreatment, primary clarification, trickling filter, secondary clarification, filtration and UV disinfection. Solids treatment consists of sludge thickening, anaerobic digestion, centrifuge dewatering and drying beds.

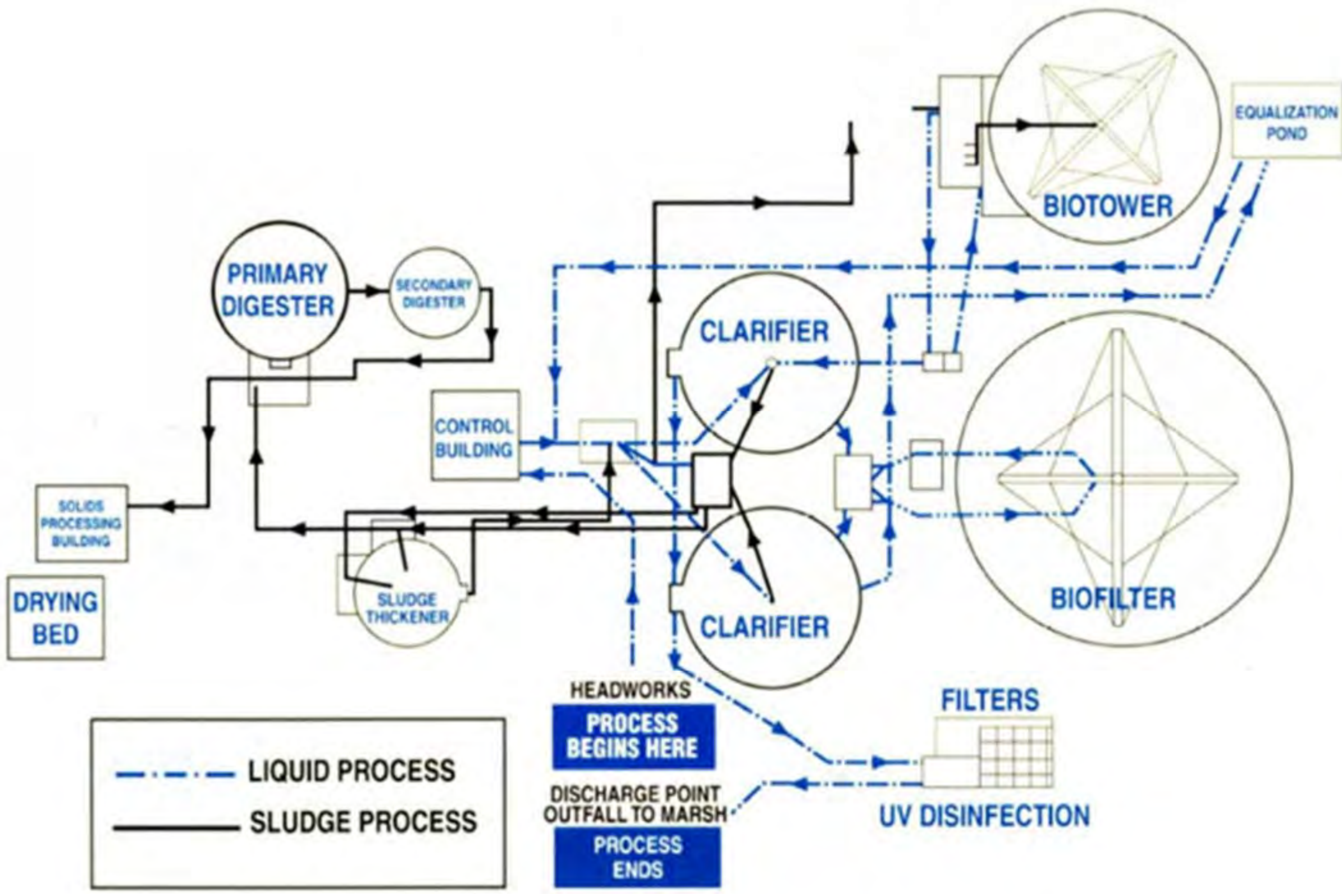

Figure 2-1. Process Flow Diagram for Mt. View WTP

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Mt. View WTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.4	1.4	1.5	1.8
BOD	lb/d	3,300	3,100	4,300	4,200
TSS	lb/d	4,000	3,600	5,500	5,200
Ammonia	lb N/d	470	550	580	1,510
Total Kjeldahl Nitrogen (TKN)	lb N/d	600	620	850	810
Total Phosphorus (TP)	lb P/d	180	210	180	330
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	290	270	330	280
TSS	mg/L	350	310	430	350
Ammonia	mg N/L	41	48	45	101
TKN	mg N/L	52	53	67	55
TP	mg P/L	15.7	18.1	14.1	22.3
Alkalinity	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

There are no current nutrient removal projects at the Mt. View WTP.

2.5 Pilot Testing

Mt. View WTP is currently working toward an enhanced primary clarification nutrient removal pilot test.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in

the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Mt. View WTP are presented in Table 3-1. The projected flow and load for the Mt. View WTP in 2025 was not available; as a result, the buildout flows were used since these represent less than a 15 percent increase in loading.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.5	1.5	1.6	1.9
BOD	lb/d	3,600	3,400	4,600	4,500
TSS	lb/d	4,300	3,800	5,900	5,600
Ammonia	lb N/d	500	600	620	1,620
TKN	lb N/d	650	660	920	880
TP	lb P/d	190	230	190	360
Alkalinity	lb/d as $CaCO_3$	---	---	---	---
BOD	mg/L	290	270	330	280
TSS	mg/L	350	310	430	350
Ammonia	mg N/L	41	48	45	101
TKN	mg N/L	52	53	67	55
TP	mg P/L	15.7	18.1	14.1	22.3
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

Mt. View is not considered a candidate for sidestream treatment due to infrequent dewatering.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's projected buildout flow capacity. The other averaging period

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Buildout Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.5	1.5	1.6	1.9
BOD	lb/d	3,600	3,400	4,600	4,500
TSS	lb/d	4,300	3,800	5,900	5,600
Ammonia	lb N/d	500	600	620	1,620
TKN	lb N/d	650	660	920	880
TP	lb P/d	190	230	190	360
Alkalinity	lb/d as $CaCO_3$	---	---	---	---
BOD	mg/L	290	270	330	280
TSS	mg/L	350	310	430	350
Ammonia	mg N/L	41	48	45	101
TKN	mg N/L	52	53	67	55
TP	mg P/L	15.7	18.1	14.1	22.3
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor’s costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy. Three optimization strategies were identified during the Mt. View WTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The three optimization strategies identified were:

- **Optimization Strategy 1:** Add chemicals upstream of primary clarifier for phosphorus removal (chemically enhanced primary treatment [CEPT])
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Alum removal would increase phosphorus removal in primary clarifiers. Alum is preferred over ferric chloride since UV disinfection is used.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Use alum upstream of filters for phosphorus removal
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Would provide additional phosphorus removal
  - ***Result from analysis:*** Chemical addition upstream of filters could reduce filter run times. Addition to the primary clarifiers (Optimization Strategy 1) is preferred.
  - ***Recommendation:*** Do not carry forward.

- **Optimization Strategy 3:** Increase secondary clarifier waste sludge pumping to remove additional nitrate in the trickling filter.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy could reduce final effluent TN levels.
  - ***Result from analysis:*** This strategy was determined to be feasible and possibly beneficial.
  - ***Recommendation:*** Carry forward.

Strategy 1 and 3 are the best apparent way to reduce effluent TP loads and TN loads.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant’s treatment capacity. Thus, any changes for optimization should be considered an interim solution.

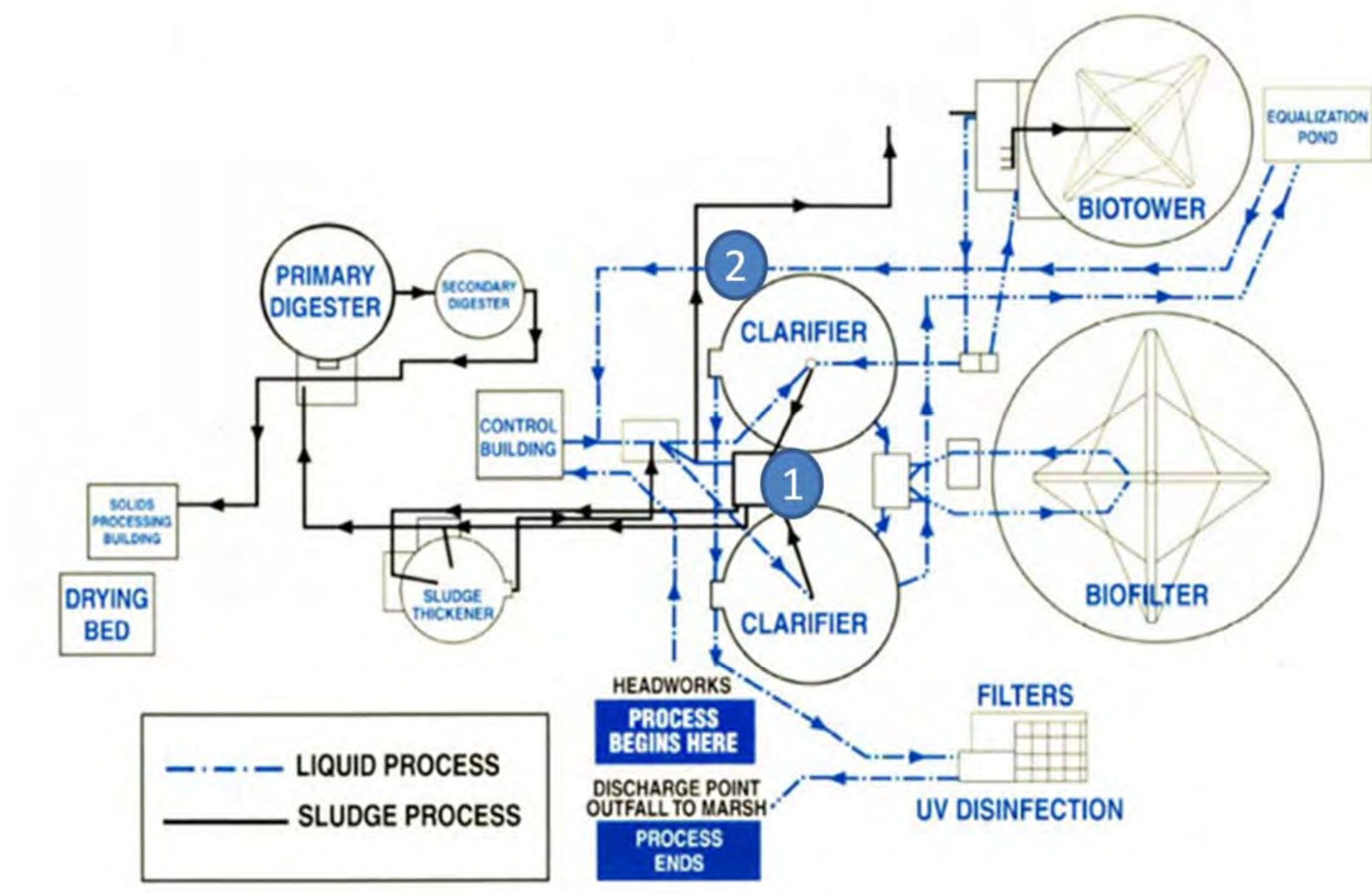

Figure 4-1. Optimization Concepts Considered for the Mt. View WTP

(1) construct CEPT for P removal and (2) increase secondary sludge pumping to primary clarifier.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Install chemical addition upstream of primary clarifiers	Chemical use
Install larger secondary clarifier sludge pump	Pumping costs

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The Mt. View WTP plant shows improved phosphorus removal but no change in ammonia or nitrogen removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	3.6	3.6	290	290	39.8	39.8
Discharge with Opt. Strategy[1]	lb N or P/d	3.6	3.6	170	160	11.3	10.6
Load Reduction[2,3]	lb N or P/d	0	0	120	130	28.5	29.3
Load Reduction[2,3]	%	0	0	41%	45%	72%	73%
Annual Load Reduction	lb N or P/yr	0%	0%	43,300	47,300	10,400	10,700

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	1.4	1.4
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	2.4	2.4
Annual O&M	$ Mil/yr	0.15	0.16
Present Value O&M[3]	$ Mil	1.3	1.4
Present Value Total[3]	$ Mil	3.7	3.8
Unit Capital Cost[8]	$/gpd	1.7	1.7
Unit Total PV Cost[8]	$/gpd	2.7	2.7
TN Removal			
Capital[2,4]	$ Mil	1.9	1.9
Annual O&M[4]	$ Mil/yr	0.13	0.13
O&M PV[3,4]	$ Mil	1.1	1.2
Total PV[3,4]	$ Mil	3.0	3.1
TN Removed (Ave.)[6]	lb N/d	120	130
Annual TN Removed (Ave.)[7]	lb N/yr	43,300	47,300
TN Cost[4,9]	$/lb N	6.9	6.5
TP Removal			
Capital[2,5]	$ Mil	0.5	0.6
Annual O&M[5]	$ Mil/yr	0.02	0.02
O&M PV[3,5]	$ Mil	0.2	0.2
Total PV[3,5]	$ Mil	0.7	0.8
TP Removed (Ave.)[6]	lb P/d	29	29
Annual TP Removed (Ave.)[7]	lb P/yr	10,400	10,700
TP Cost[5,9]	$/lb P	7.1	7.2

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• More organics and solids diverted to fuel the digester • Phosphorus reliably removed under peak flow scenarios • Potential for higher TN removal	• Dependency on chemicals • Chemical costs

5 Sidestream Treatment

Sidestream treatment is not considered a viable option for Mt. View as previously described and thus was not further evaluated.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Mt. View WTP plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The Mt. View WTP should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 upgrades could be met by constructing denitrification filters downstream of the existing secondary process for nitrogen removal and implementing alum addition to the primary clarifiers for phosphorus removal. These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure.

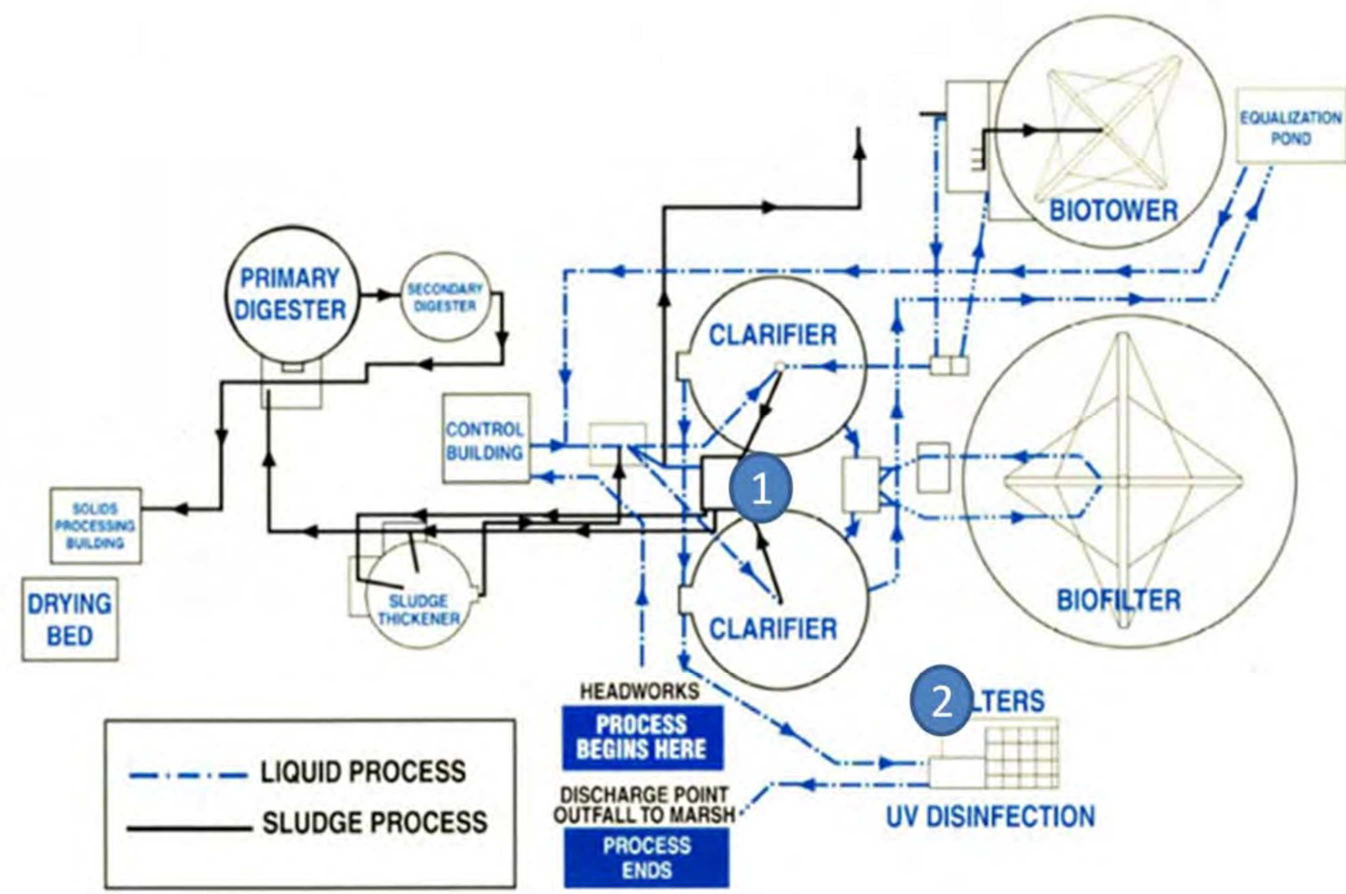

Figure 6-1. Level 2 Upgrade Concept for Mt. View WTP

(1) construct CEPT for P removal and (2) construct new denitrification filters.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Level 3 upgrades would require additional chemical addition immediately upstream of denitrification filters since chemical addition upstream of filtration would be required to meet phosphorus levels. Additional methanol use would be necessary at the denitrification filters to achieve Level 3 nitrogen levels. These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Alum and Polymer Chemical Feed	Same as Level 2
Secondary	--	--
Tertiary	• Denitrification Filters • Denitrification Filter Pump Station • External Carbon Source Chemical Feed	Same as Level 2 plus: • Additional Denitrification Filters • Additional External Carbon Source Chemical Feed • Alum Chemical Feed

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

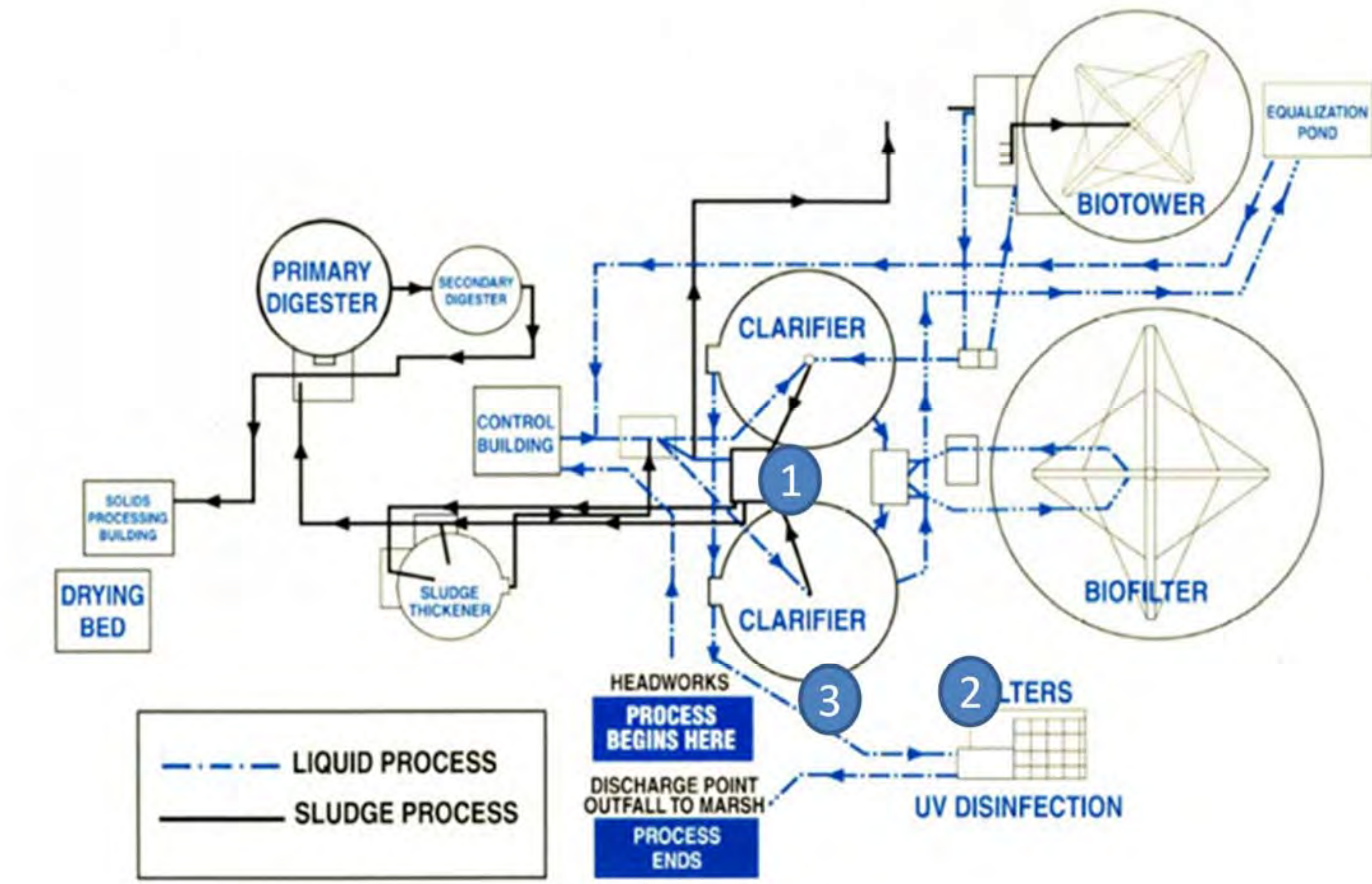

Figure 6-2. Level 3 Upgrade Concept for Mt. View WTP

(1) construct CEPT for P removal and (2) construct new denitrification filters, and (3) construct chemical addition upstream of filters.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) construct CEPT for P removal, (2) construct new denitrification filters and (3) construct methanol facilities.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) construct CEPT for P removal and (2) construct new denitrification filters, and (3) methanol and alum facilities addition upstream of filters.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	1.5	1.5	1.5	1.5
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	36	36	36	37
Annual O&M	$Mil/yr	0.5	0.5	0.5	0.6
O&M PV[3]	$ Mil	11	12	12	13
Total PV[3]	$ Mil	47	48	48	49
Unit Capital Cost	$/gpd	24.3	24.1	24.3	24.1
Unit Total PV	$/gpd	31.7	31.8	32.6	32.7
TN Removal					
Capital[2,4]	$ Mil	35	36	35	36
Annual O&M[4]	$ Mil/yr	0.5	0.5	0.5	0.5
O&M PV[3,4]	$ Mil	11	11	12	12
Total PV[3,4]	$ Mil	46	47	47	48
TN Removed (Ave.)[6]	lb N/d	110	120	160	220
Annual TN Removed (Ave.)[7]	lb N/yr	38,700	42,900	57,200	80,300
TN Cost[4,8]	$/lb N	39.5	36.5	27.2	19.8
TP Removal					
Capital[2,5]	$ Mil	0.5	0.6	35	35
Annual O&M[5]	$ Mil/yr	0.02	0.03	0.1	0.3
O&M PV[3,5]	$ Mil	0.5	0.6	3	6
Total PV[3,5]	$ Mil	1.1	1.2	38	41
TP Removed (Ave.)[6]	lb P/d	28	28	32	36
Annual TP Removed (Ave.)[7]	lb P/yr	10,100	10,400	11,500	13,300
TP Cost[5,8]	$/lb P	4	4	109	104

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing secondary process • Robust technology to absorb variability in flows and loads • Ability to reliably remove TN and TP	• Increased energy from denitrification filter pumping • Additional unit processes to operate • Safety from external carbon source (if methanol) • High cost associated with methanol use • Increase sludge production
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use

7 Nutrient Removal by Other Means

The Mt. View WTP has an existing recycled water program that is employed year-round. Recycled water is used for environmental enhancement. The recycled water sustains a 20-acre constructed marsh for wastewater treatment, Moorhen marsh, which also provides high quality wildlife habitat for indigenous and migrating birds and animal species. This existing program has the effect of reducing nutrients discharged to the Bay. The Mt. View WTP currently recycles approximately 1,200 acre-feet per year (400 million gallons per year) and they are planning to increase recycling to 1,500 acre-feet per year (500 million gallons per year) by 2045. The District is pursuing a partnership with CCWD to recover the discharge after the environmental enhancement of Moorhen Marsh to further treat for cooling tower water at Shell Refinery.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by

Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

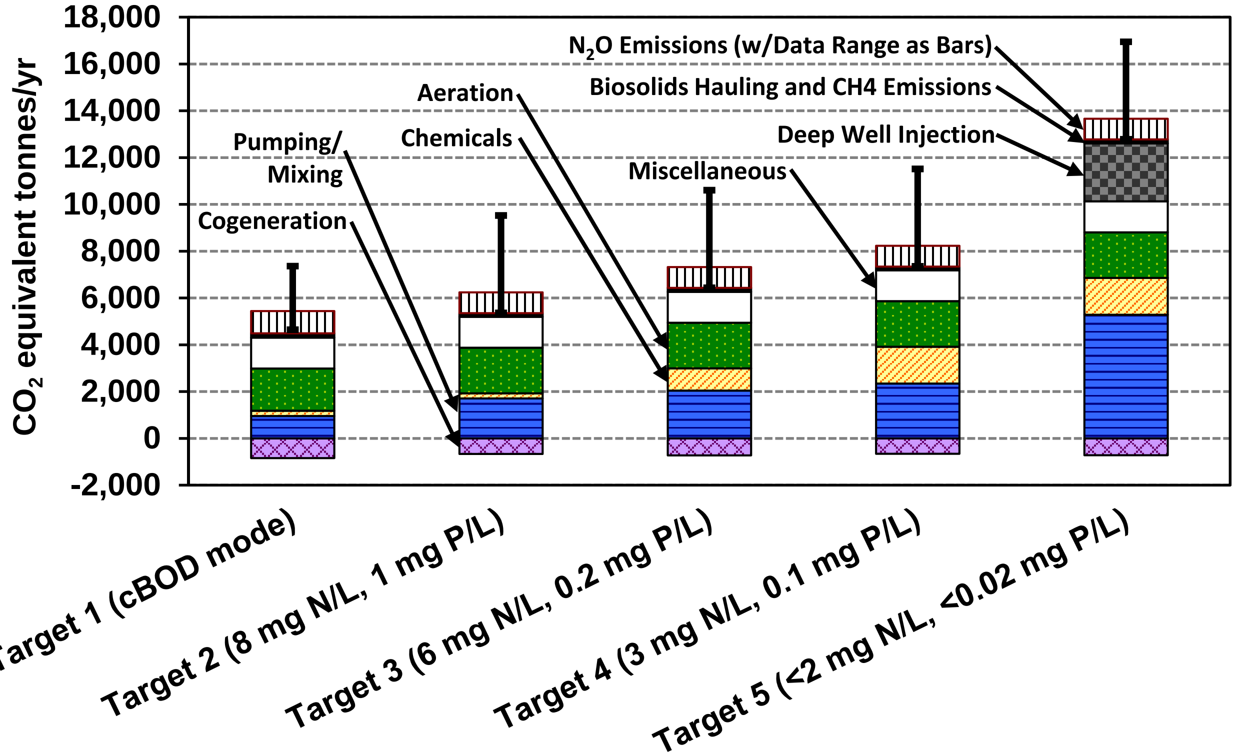

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	200	200	100	100	100	100	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	0	0	300	300	300	300	--
GHG Emissions Increase Total	MT CO_2/yr	200	200	400	400	500	500	--
Unit GHG Emissions[2]	lb CO_2/MG	800	900	1,600	1,700	1,800	1,900	--
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	--*	--*	--*	--*	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	9	8	22	21	16	12	--
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	4	4	4	4	30	26	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. Not applicable because Mt. View is not a candidate for sidestream treatment.

* The plant already fully nitrifies so any optimizations or upgrades will not further reduce ammonia discharge loads.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Mt. View WTP. These are:

- Zeolite-Anammox – Mt. View WTP final effluent would be subsequently treated by a zeolite-anammox process where ammonia sorbs to a zeolite bed and is subsequently removed through a deammonification process.
  - Advantages: Low energy process, minimal operational requirements, minimal instrumentation
  - Disadvantages: Large footprint, no full-scale installations
  - Potential Next Steps: Determine footprint requirements based on previous studies and identify potential location. If appropriate, consider pilot testing the zeolite-anammox process to determine benefits.
- Treatment Wetland – Mt. View WTP final effluent would be subsequently treated through a constructed wetland where algae and aquatic plants take up nutrients and nitrogen removal is performed by biofilms. The District already uses a constructed wetland (Moorhen Marsh) for polishing prior to discharge to Peyton Slough.
  - Advantages: Low operations and maintenance, mature technology
  - Disadvantages: Large footprint
  - Potential Next Steps: Total N and P analysis can be performed at discharge point to the slough (EFF-002) to confirm nutrient removal.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost. See Table 1 below.

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2 below. A common unit cost basis for all plants in the study was selected this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.15

Napa Sanitation District Wastewater Treatment Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Napa Sanitation District Wastewater Treatment Plant

Napa, CA

March 23, 2018
Final Report

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Executive Summary

Napa Sanitation District owns and operates the Soscol Water Recycling Facility located in Napa, CA and discharges treated effluent to the Napa River (part of the San Pablo Bay watershed). The plant has an average dry weather flow (ADWF) permitted capacity of 15.4 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3,7]	Opt. Year Round[3]	Level 2 Dry Season[3,7]	Level 2 Year Round[3,9]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow	mgd	--	--	8.0	9.0	8.6	11.2	8.6	11.2	--
Flow to Bay[2]	mgd	5.0	5.0	5.4	5.4	5.6	5.6	5.6	5.6	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	49	49	54	54	57	55	57	55	--
TN	lb N/d	470	470	520	520	540	540	420	280	--
TP	lb P/d	46	46	50	44	52	46	46	14	--
Costs[4,5]										
Capital	$ Mil	--	--	0	1.1	0	40	34	73	--
O&M PV	$ Mil	--	--	0	0.6	0	15	29	111	--
Total PV	$ Mil	--	--	0	1.7	0	55	64	184	--
Unit Costs[6]										
Capital	$/gpd	--	--	0	0.1	0	3.5	4.0	6.5	--
Total PV	$/gpd	--	--	0	0.2	0	4.9	7.4	16.4	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Current performance meets Level 2 criteria for the dry season.
8. Not Applicable. Napa was not considered for sidestream treatment since the facility already nitrifies, does not dewater daily, and is limited to seasonal discharge.
9. Costs for Level 2 year round TN removal are associated with reliable nitrification of pond effluent. Although the recent data met Level 2 nitrogen limits, ammonia did not consistently meet Level 2 limits.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Increase ferric chloride dose upstream of the primary clarifiers in the wet season to increase phosphorus removal. Since chemical addition to the primary clarifiers may remove a portion of the carbon currently used for denitrification, methanol addition storage and metering facilities are included.

Napa is not considered a candidate for sidestream treatment since the facility already nitrifies, does not dewater daily, and is limited to seasonal discharge.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Increase ferric chloride dose upstream of the primary clarifiers in the wet season to increase phosphorus removal.
   b. Construct two new aeration basins and one new secondary clarifier to be used for nitrification and denitrification of DAF clarifier effluent so the facility can reliably meet Level 2 ammonia limits. Note that a BNR system downstream of a pond system is uncommon and includes inherent risks in predicting actual performance.
   c. Construct external carbon facilities (methanol) for carbon addition for the pond treatment train and to maintain denitrification, since a portion of the carbon currently used for denitrification may be removed with the ferric chloride addition.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Convert the activated sludge process to a 4-stage BNR, and add two additional aeration basins. Increase methanol addition to meet Level 3 nitrogen limits.
   c. Add chemicals (ferric chloride) before filtration for phosphorus polishing. Outfit the sixth filter cell with media and equipment to accommodate peak flows.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $0 Mil for dry season optimization (since Napa meets Level 2 in the dry season) up to $184 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Napa Sanitation District operates the Soscol Water Recycling Facility (Napa WRF), which serves a population of about 82,700, which includes the City of Napa and adjacent areas in southern Napa County. It is located at 1515 Soscol Ferry Road, Napa, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 15.4 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The Napa WRF holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2016-0035, NPDES No. CA0037575). The treated wastewater is discharged to the Napa River (part of the San Pablo Bay watershed) at latitude of 38.23583 and longitude of -122.28611.

Table 2-1 provides a summary of the permit limitations that are specific to the Napa WRF and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2016-0035; CA0037575)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Effluent Limitations – October 1 through June 30					
Flow[1]	mgd	15.4	-	-	-
BOD	mg/L	-	30	45	-
TSS	mg/L	-	30	45	-
Total Ammonia, as N	mg/L	-	21	-	49
Effluent Limitations – July 1 through September 30					
Flow	mgd	Note 2	-	-	-
BOD	mg/L	-	10	20	-
TSS	mg/L	-	20	30	-
Total Ammonia, as N	mg/L	-	21	-	49

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. The facility is designed for a peak discharge capacity of 23 mgd.
2. Discharge is prohibited from July 1 through September 30, except when storage capacity is exceeded and effluent volume exceeds reclamation water demand.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Napa WRF. Both liquids processes and solids processes are shown. The Napa WRF consists of screening and grit removal, primary clarification, followed by a split secondary treatment system. A step-feed BNR activated sludge process including anoxic zones removes nitrogen from a portion of the flow, followed by secondary clarifiers. Caustic is added to the step-feed BNR to provide alkalinity for nitrification. Primary effluent not treated in the step-feed BNR is routed to facultative ponds, which also provide seasonal storage. Nutrient removal through the facultative ponds varies through the year, with high pond effluent ammonia concentrations possible during the winter season. Water returned from the facultative ponds is treated with coagulant and polymer before either a DAF clarifier or a flocculating clarifier. Secondary effluent is combined and chlorinated before discharge. Continuous backwash upflow filters followed by chlorination are used for Title 22 unrestricted reuse. Solids treatment consists of secondary sludge thickening, anaerobic digestion and dewatering.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Napa WRF is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	6.8	7.9	7.8	15.3
BOD	lb/d	17,100	17,400	19,500	22,600
TSS	lb/d	16,100	17,500	18,100	24,000
Ammonia	lb N/d	1,890	1,900	2,030	2,450
Total Kjeldahl Nitrogen (TKN)	lb N/d	2,620	2,770	3,030	4,740
Total Phosphorus (TP)	lb P/d	450	400	530	560
Alkalinity[4]	lb $CaCO_3$/d	14,600	14,200	15,700	16,900
BOD	mg/L	300	260	300	180
TSS	mg/L	280	260	280	190
Ammonia	mg N/L	33	29	31	19
TKN	mg N/L	46	42	47	37
TP	mg P/L	7.9	6.0	8.2	4.4
Alkalinity[4]	mg CaCO3/L	260	220	240	130

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity is based on primary effluent data.

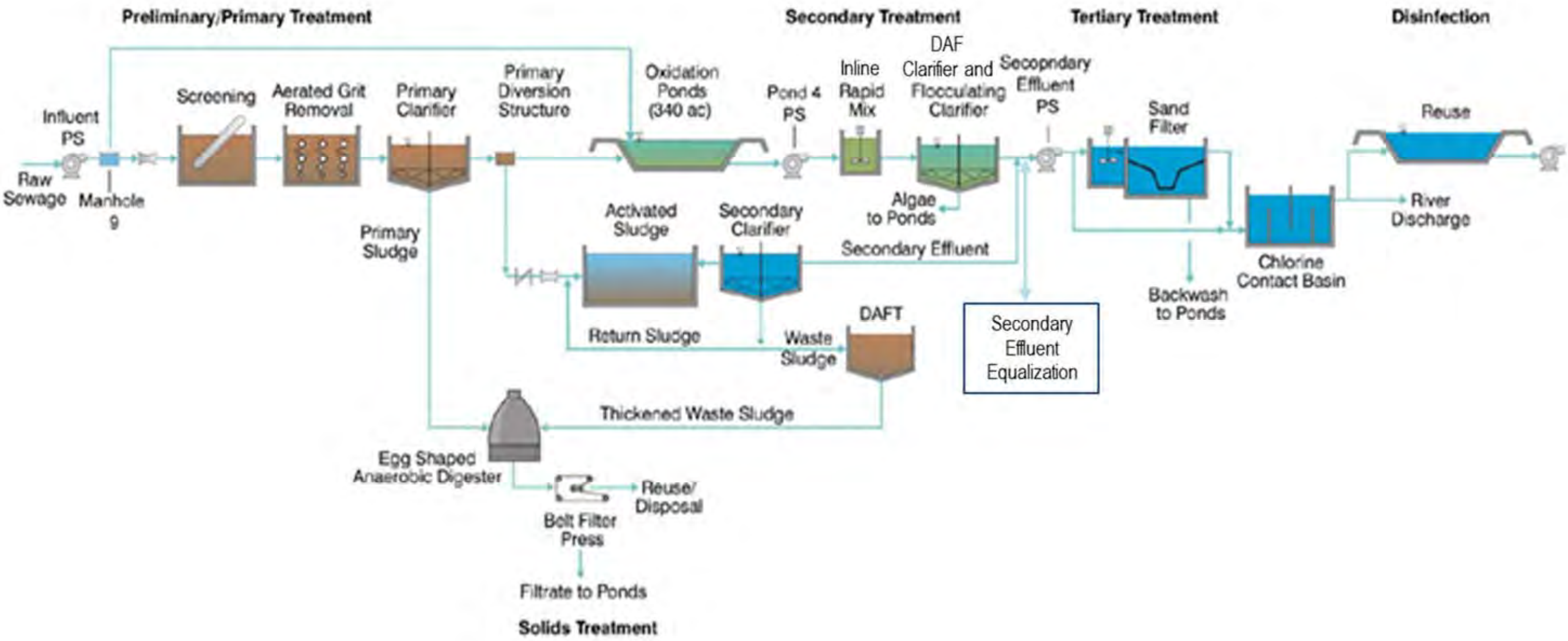

Figure 2-1. Process Flow Diagram for Napa WRF

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the Napa WRF:

- Plant currently recycles 1,800 ac-ft/yr, resulting in a significant decrease in nutrient loading to the Napa River. Expansion of recycled water treatment and distribution is expected to increase recycling to 3,700 ac-ft/yr (starting in 2016).
- Discharge is prohibited from July 1 through September 30
- Ferric chloride addition at the headworks for digester sulfide control may also remove phosphorus.
- Activated sludge treatment includes selector zones that consistently nitrify and remove nitrogen, but pond effluent ammonia and nitrogen concentrations vary through the year. During the dry season, Napa WRF discharge typically meets level 2 limits for all constituents. Winter discharge typically meets level 2 nitrogen concentrations (15 mg/L TN). Ammonia discharges exceed 2 mg/L at times during the winter season.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the Napa WRF.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Napa WRF are presented in Table 3-1. The projected flow and load for the Napa WRF in 2025 was provided in the Wastewater Treatment Plant Master Plan.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	8.0	9.2	9.0	17.8
BOD[5]	lb/d	20,600	21,000	23,500	27,200
TSS[5]	lb/d	19,400	21,000	21,900	29,000
Ammonia[5]	lb N/d	2,280	2,300	2,440	2,960
TKN[5]	lb N/d	3,150	3,340	3,660	5,710
TP[5]	lb P/d	540	480	640	670
Alkalinity[6]	lb/d as $CaCO_3$	17,000	16,500	18,300	19,700
BOD	mg/L	310	270	310	180
TSS	mg/L	290	270	290	190
Ammonia	mg N/L	34	30	32	20
TKN	mg N/L	48	44	48	38
TP	mg P/L	8.2	6.2	8.5	4.5
Alkalinity[6]	mg/L as $CaCO_3$	260	220	240	130

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. ADWF is based on Master Plan 2025 projection. Other flows are based on current flow characteristics.
5. ADWF BOD is based on Master Plan 2025 projection. Other loadings are based on current loading characteristics.
6. Alkalinity concentration was assumed to equal current concentration.

3.2 Flow and Loading for Sidestream Treatment

Napa WRF is not considered a candidate for sidestream treatment since the facility already nitrifies, does not dewater daily, and is limited to seasonal discharge.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's buildout flow and BOD loading provided by the district. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Buildout Flow Capacity)

Parameter	Unit	Buildout Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	8.6	9.9	9.7	19.2
BOD[5]	lb/d	22,100	22,500	25,300	29,200
TSS[5]	lb/d	20,800	22,600	23,500	31,100
Ammonia[5]	lb N/d	2,440	2,460	2,620	3,170
TKN[5]	lb N/d	3,380	3,580	3,920	6,130
TP[5]	lb P/d	580	510	680	720
Alkalinity[6]	lb/d as $CaCO_3$	18,300	17,700	19,700	21,200
BOD[5]	mg/L	310	270	310	180
TSS[5]	mg/L	290	270	290	190
Ammonia[5]	mg N/L	34	30	32	20
TKN[5]	mg N/L	47	43	48	38
TP[5]	mg P/L	8.1	6.2	8.4	4.5
Alkalinity[6]	mg/L as $CaCO_3$	260	220	240	130

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. ADWF is based on Master Plan 2030 projection, which is less than the permitted dry weather flow of 15.4 mgd. Other flows are based on current flow characteristics.
5. ADWF BOD is based on Master Plan 2030 projection. Other loadings are based on current loading characteristics.
6. Alkalinity concentration was assumed to equal current concentration.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor’s costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,0155. In order to understand the relative costs for each of the 37 POTWs, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Eleven optimization strategies were identified during the Napa WRF site visit. Some strategies reflect current plant operation. The plant operates in split treatment mode, with flow split between activated sludge and facultative ponds. The activated sludge system removes nitrogen by operating as a step-feed BNR with unaerated zones. Biological phosphorus removal may be occurring in the first unaerated zone, and ferric chloride added to the headworks may remove some phosphorus. The remaining strategies were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The eleven optimization strategies were screened down to six strategies described below.

Based on recent performance, the plant already meets Level 2 nitrogen criteria (15 mg/L TN) on a seasonal basis, but does not meet Level 2 criteria for phosphorus during the wet season. The plant also does not consistently meet Level 2 criteria for ammonia, with some wet seasons showing average concentrations above the Level 2 criteria.

- **Optimization Strategy 1:** Increase ferric chloride dose upstream of the primary clarifiers to increase phosphorus removal using chemically enhanced primary treatment (CEPT).
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal during wet season, when plant does not meet Level 2 phosphorus criteria.
  - ***Result from analysis:*** The plant already adds ferric chloride to the headworks for digester sulfide control. Phosphorus removal could be increased by increasing the ferric chloride dose. Chemical addition to the primary clarifiers for phosphorus removal may remove a portion of the carbon currently used for denitrification, so external carbon facilities are included to ensure nitrogen removal.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Add ferric chloride upstream of filtration for phosphorus polishing.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Potential to further reduce phosphorus.
  - ***Result from analysis:*** To implement this strategy, additional ferric chloride feed pumps and piping would be needed. Since the plant already has chemical feed facilities for Strategy 1, do not carry forward at this time.
  - ***Recommendation:*** Do not carry forward at this time.

- **Optimization Strategy 3:** Improve dissolved oxygen control in activated sludge to prevent over aeration and improve denitrification performance. Add a mixer to compartment one to optimize performance (current mixing is with coarse bubble aeration).
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Reduce nitrogen and phosphorus concentrations.
  - ***Result from analysis:*** Based on recent performance, the plant already meets Level 2 nitrogen criteria (15 mg/L TN) on a seasonal basis. These improvements could reduce nitrogen and phosphorus concentrations further, but nutrient reduction is expected to be minor. The plant may wish to consider these improvements to save energy.
  - ***Recommendation:*** Do not carry forward at this time, since plant already meets Level 2 nitrogen criteria.

- **Optimization Strategy 4:** Use CEPT to improve primary clarifier removals and increase capacity of activated sludge system. Maximize flow to activated sludge, since activated sludge consistently nitrifies and removes nitrogen.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Improve nitrification and nitrogen removal performance by discharging less pond effluent.
  - ***Result from analysis:*** The facultative ponds do not consistently nitrify, so pond effluent discharged during the wet season increases the effluent ammonia. Primary clarifier BOD removals average 43 percent in winter, so only a minor reduction in primary effluent loading is expected with CEPT. Since the plant is already running both aeration tanks during the wet season, the reduction in ammonia is expected to be minor.
  - ***Recommendation:*** Do not carry forward at this time, since improvements are expected to be minor.

- **Optimization Strategy 5:** Evaluate adding mixed liquor recycle and/or increasing selector volume to improve nitrogen removal in activated sludge. Improve control of step-feed to balance flow split.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Improve nitrogen removal performance.
  - ***Result from analysis:*** Since the seasonal average already meets Level 2 nitrogen limits using a step-feed configuration, this strategy is not recommended at this time.
  - ***Recommendation:*** Do not carry forward at this time.

- **Optimization Strategy 6:** Route belt filter press filtrate to the aeration basins for nitrification and denitrification, instead of to the facultative ponds.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Improve nitrification and nitrogen removal performance.
  - ***Result from analysis:*** Since aeration basins capacity is limited by aeration capacity, adding additional ammonia is not recommended at this time.
  - ***Recommendation:*** Do not carry forward at this time.

Strategy 1 is the best apparent way to reduce effluent phosphorus loads; no optimizations are recommended for nitrogen since the facility already meets Level 2 nitrogen criteria.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

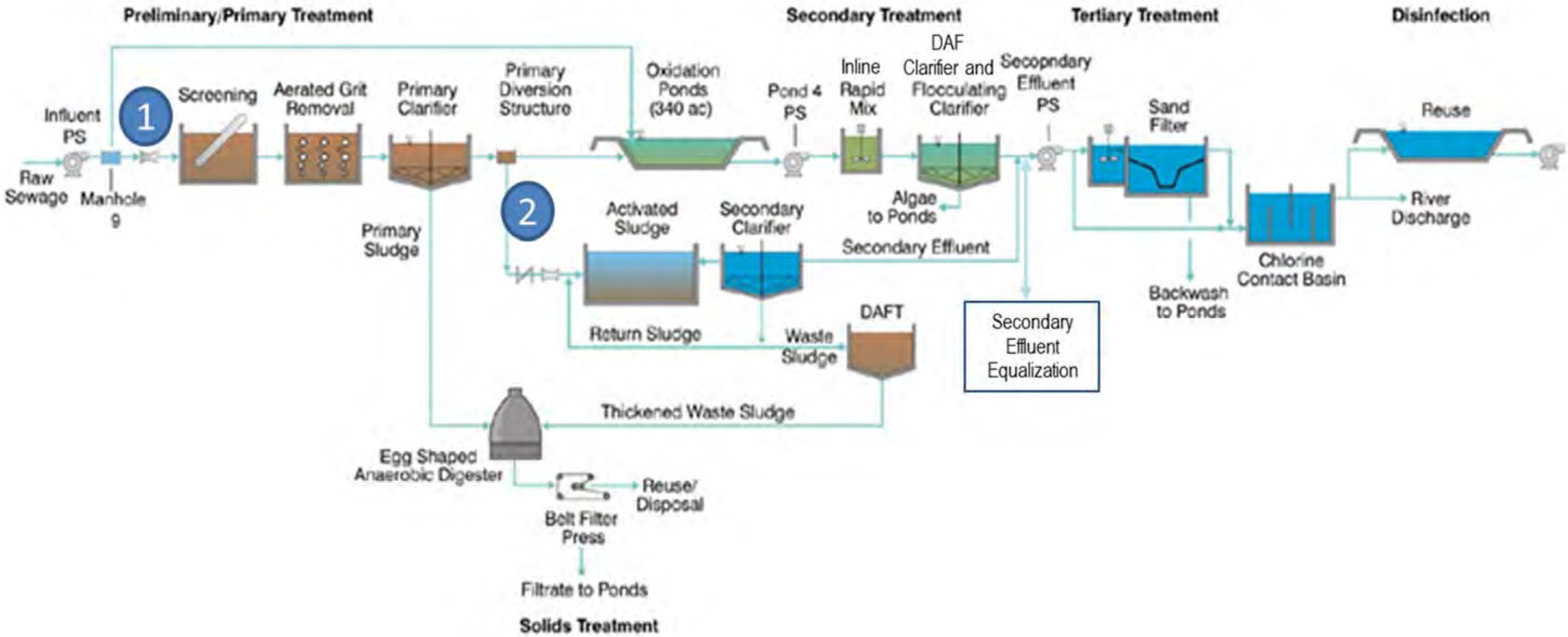

Figure 4-1. Optimization Concepts Considered for the Napa WRF

(1) add ferric chloride during wet season using existing chemical addition facilities for P removal, and (2) include facilities to add methanol (or other carbon source) if needed during wet season.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Use existing ferric chloride addition facilities	Dose ferric chloride upstream of the primary clarifiers.
Methanol storage, chemical metering pump, chemical injection, in case CEPT impacts nitrogen removal	Since the plant currently meets Level 2 nitrogen limits seasonally, assume carbon addition is not needed on a regular basis.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The Napa WRF plant shows improved phosphorus removal, but no change in nitrogen removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	54	54	520	520	50	50
Discharge with Opt. Strategy[1]	lb N or P/d	54	54	520	520	50	44
Load Reduction[2,3]	lb N or P/d	0	0	0	0	0	6
Load Reduction[2,3]	%	0%	0%	0%	0%	0%	12%
Annual Load Reduction	lb N or P/yr	0	0	0	0	0	2,210

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified and plant already meets Level 2 discharge limits for TN. Calculated nutrient reduction for dry season TP is zero since plant already meets Level 2 discharge limits in the dry season.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	8.0	9.0
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0	1.1
Annual O&M	$ Mil/yr	0	0.07
Present Value O&M[3]	$ Mil	0	0.6
Present Value Total[3]	$ Mil	0	1.7
Unit Capital Cost[8]	$/gpd	0	0.1
Unit Total PV Cost[8]	$/gpd	0	0.2
TN Removal			
Capital[2,4]	$ Mil	0	0
Annual O&M[4]	$ Mil/yr	0	0
O&M PV[3,4]	$ Mil	0	0
Total PV[3,4]	$ Mil	0	0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0	1.1
Annual O&M[5]	$ Mil/yr	0	0.07
O&M PV[3,5]	$ Mil	0	0.6
Total PV[3,5]	$ Mil	0	1.7
TP Removed (Ave.)[6,10]	lb P/d	0	6
Annual TP Removed (Ave.)[7]	lb P/yr	0	2,210
TP Cost[5,9,10]	$/lb P	NA	78.7

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since current performance meets Level 2 criteria for nitrogen (dry season and year round) and phosphorus (dry season).

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• More organics and solids diverted to fuel the digester • Phosphorus reliably removed under peak flow scenarios	• Dependency on chemicals • CEPT (ferric chloride) would reduce the organic loading to the step-feed BNR, and could cause a carbon limitation and reduce nitrogen removal. Methanol facilities are included to mitigate this impact.

5 Sidestream Treatment

Sidestream treatment is not considered a viable option for the Napa WRF as previously described and thus was not further evaluated.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Napa WRF plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The Napa WRF should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 phosphorus limits in the wet season could be met by implementing ferric chloride addition to the primary clarifiers for phosphorus removal. Based on recent performance, the plant already meets Level 2 phosphorus criteria during the dry season. Chemical addition to the primary clarifiers for phosphorus removal may remove a portion of the carbon currently used for denitrification, so external carbon addition facilities are included to provide carbon if needed for nitrogen removal.

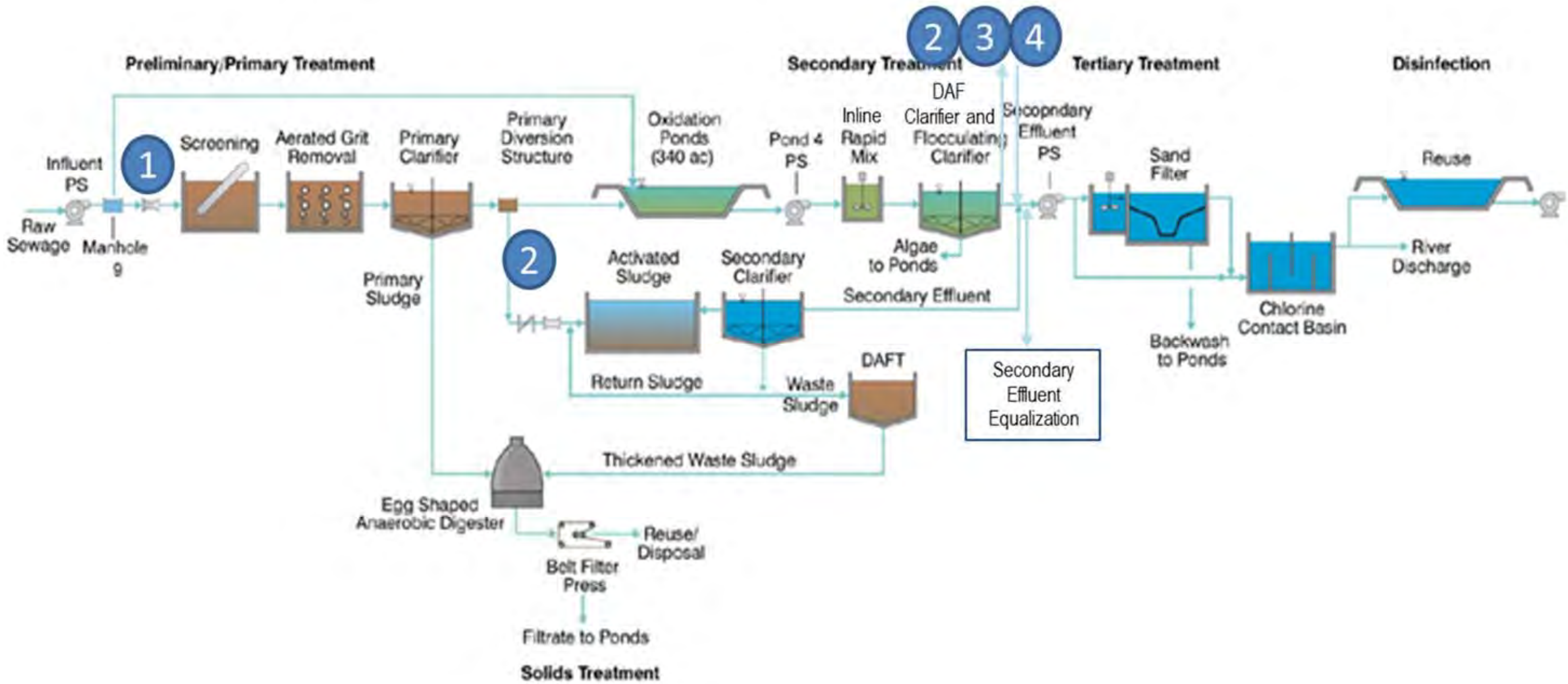

Figure 6-1. Level 2 Upgrade Concept for Napa WRF

(1) add ferric chloride using existing chemical addition facilities for P removal (wet season only), (2) include facilities to add methanol (or other carbon source) (wet season only), (3) add two additional aeration basins (flexible configuration with anoxic zones) for nitrification of DAF clarifier effluent (wet season only), and (4) add one additional secondary clarifier for the DAF clarifier effluent nitrification/denitrification train (wet season only).

The Napa WRF step-feed BNR process nitrifies completely, but the facultative pond treatment does not consistently remove ammonia, and effluent discharges do not consistently meet Level 2 ammonia criteria in the wet season. Treatment of the seasonally-varying ammonia concentrations leaving the ponds is challenging. One option for nitrification and nitrogen removal from the pond treatment train is to add two new aeration basins and one new secondary clarifier that can be used for nitrification and denitrification of the DAF clarifier effluent during the wet season when high flows are discharged. Note that a BNR system downstream of a pond system is uncommon and includes inherent risks in predicting actual performance. The plant staff are concerned that residual polymer and algae may cause problems, so the flexibility to operate as a separate activated sludge train treating DAF clarifier effluent is desired. With flexible design, including swing zones, the new basins could also be used for treatment of primary effluent when needed, and the plant could experiment with feeding combined primary effluent and DAF clarifier effluent to activated sludge. Since the DAF clarifier effluent will have little available carbon, external carbon addition is required. The existing processes could continue operating in step-feed BNR mode. The plant already adds alkalinity to activated sludge, and no change in dose is assumed.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Chemical addition and tertiary filtration could be used to meet Level 3 phosphorus limits. Ferric chloride addition before both primary clarification and filtration is assumed. Filtration is necessary for phosphorus polishing. To meet the estimated peak discharge flows, based on past historical discharge flow variations, the sixth filter cell must be outfitted with media and equipment (structure is existing).

The activated sludge process could be converted to 4-stage BNR to meet Level 3 nitrogen limits, with two additional aeration basins required. External carbon source addition will be required in activated sludge. Pond effluent (following the DAF clarifier) would be treated similarly to Level 2, with two new aeration basins and one new secondary clarifier used for nitrification and denitrification of the DAF clarifier effluent during the wet season when high flows are discharged. Additional methanol would be needed to further reduce effluent nitrogen.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Ferric chloride chemical feed using existing facilities	Same as Level 2
Secondary	• External carbon source addition facilities • Add two aeration basin with flexible configuration for nitrification and denitrification of DAF clarifier effluent during wet season • Add one additional secondary clarifier	Same as Level 2 plus: • Convert existing aeration basins to 4-stage BNR • Add two additional 4-stage BNR basins
Tertiary	---	Same as Level 2 plus: • Ferric chloride addition to filters for phosphorus polishing • Add media and equipment to the sixth filter cell (structure is in place).

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

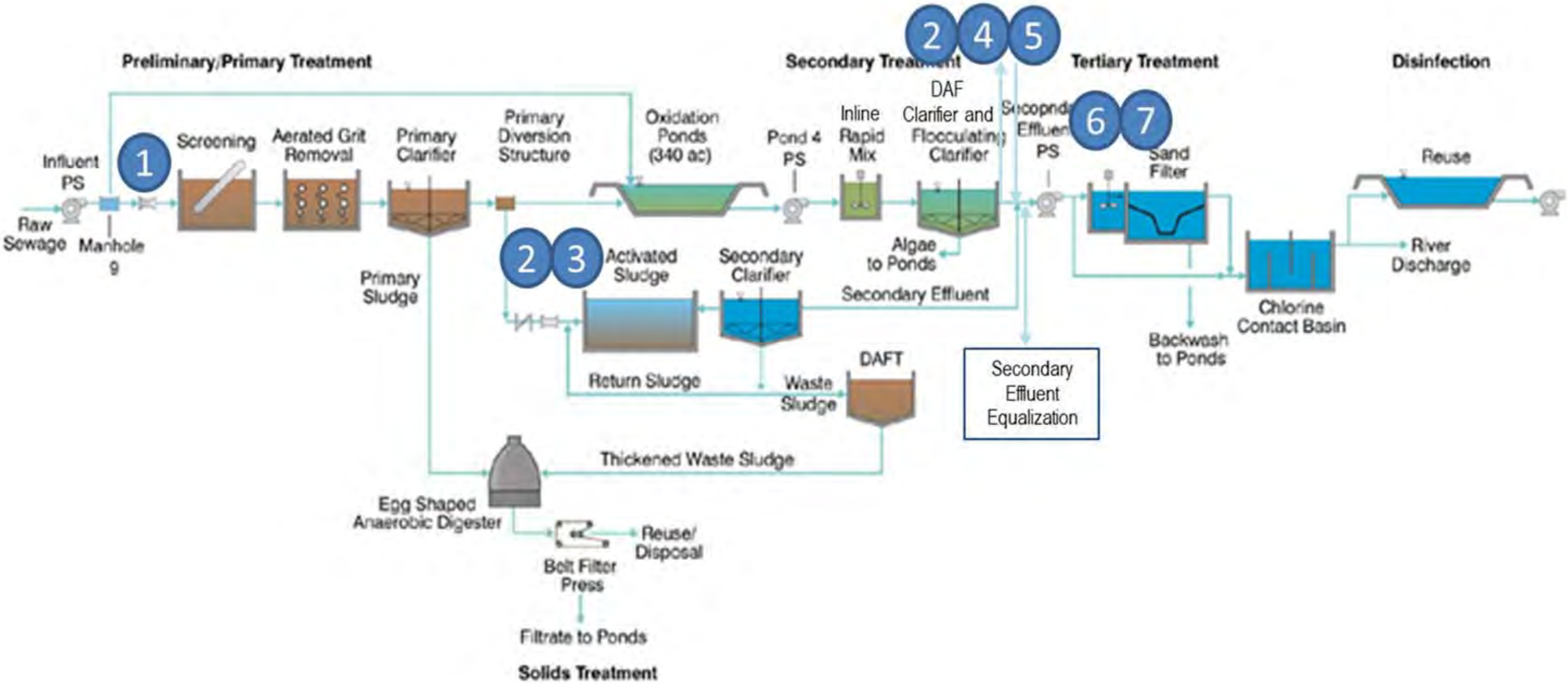

Figure 6-2. Level 3 Upgrade Concept for Napa WRF

(1) add ferric chloride using existing chemical addition facilities for P removal, (2) add methanol (or other carbon source), (3) convert BNR basins to 4-stage BNR and add two additional BNR basins, (4) add two additional aeration basins (flexible configuration with anoxic zones) for nitrification and denitrification of DAF clarifier effluent (wet season only), (5) add one additional secondary clarifier for the DAF clarifier effluent nitrification train (wet season only), (6) add ferric chloride before filters for phosphorus polishing, and (7) add media to the sixth filter cell (structure is in place).

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) add two additional aeration basins (flexible configuration with anoxic zones) for nitrification and denitrification of DAF clarifier effluent (wet season only), (2) add one additional secondary clarifier for the DAF clarifier effluent nitrification train (wet season only), and (3) facilities to add methanol (or other carbon source). Use existing ferric chloride facilities (not shown).

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) convert existing BNR basins to 4-stage BNR, (2) add two additional 4-stage BNR basins, (3) add two additional aeration basins (flexible configuration with anoxic zones) for nitrification and denitrification of DAF clarifier effluent (wet season only), (4) add one additional secondary clarifier for the DAF clarifier effluent nitrification train (wet season only), (5) add ferric chloride before filters for phosphorus polishing, and add media to the sixth filter cell (structure is in place), and (6) add methanol (or other carbon source). Use existing ferric chloride facilities (not shown).

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1,11]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	8.6	11.2	8.6	11.2
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	0	40	34	73
Annual O&M	$Mil/yr	0	0.7	1.3	4.9
O&M PV[3]	$ Mil	0	15	30	111
Total PV[3]	$ Mil	0	55	64	184
Unit Capital Cost	$/gpd	0	3.5	4.0	6.5
Unit Total PV	$/gpd	0	4.9	7.4	16.4
TN Removal					
Capital[2,4]	$ Mil	0	40	33	72
Annual O&M[4]	$ Mil/yr	0	0.6	1.1	1.9
O&M PV[3,4]	$ Mil	0	13	25	42
Total PV[3,4]	$ Mil	0	53	58	114
TN Removed (Ave.)[6,10]	lb N/d	0	0	110	260
Annual TN Removed (Ave.)[7]	lb N/yr	0	0	41,500	94,900
TN Cost[4,8,10]	$/lb N	NA	NA	46.9	40.1
TP Removal					
Capital[2,5]	$ Mil	0	0	1.0	1.1
Annual O&M[5]	$ Mil/yr	0	0.07	0.2	3.1
O&M PV[3,5]	$ Mil	0	1.6	4.4	69
Total PV[3,5]	$ Mil	0	1.6	5.4	70
TP Removed (Ave.)[6,10]	lb P/d	0	6	6	38
Annual TP Removed (Ave.)[7]	lb P/yr	0	2,300	2,400	14,000
TP Cost[5,8,10]	$/lb P	NA	23	76	166

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.
10. Calculated nutrient reduction is zero, since current performance meets Level 2 criteria for nitrogen (dry season and year round) and phosphorus (dry season).
11. Costs for Level 2 year round TN removal are associated with reliable nitrification of pond effluent. Although the recent data met Level 2 nitrogen limits, ammonia did not consistently meet Level 2 limits.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing step-feed BNR process • Robust technology to absorb variability in flows and loads • New aeration basins with flexible configuration could be used for primary effluent or DAF clarifier effluent. • Ability to reliably remove TN and TP • More organics and solids diverted to fuel the digester	• Increased operation costs associated with ferric chloride and methanol addition • Dependency on chemicals • Increased sludge production • Significant capital expenditure may be needed to reliably meet ammonia limits when pond effluent ammonia is elevated.
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use and additional ferric chloride use

7 Nutrient Removal by Other Means

The Napa WRF has an existing recycled water program that is employed year-round with no Bay discharge during the dry season. Recycled water is mostly used for irrigation. This existing program has the effect of reducing nutrients discharged to the Bay. Napa currently recycles approximately 1,800 acre-feet per year (600 million gallons per year) and they are planning to increase recycling to 5,400 acre-feet per year (1,800 million gallons per year) by 2040.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA

Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

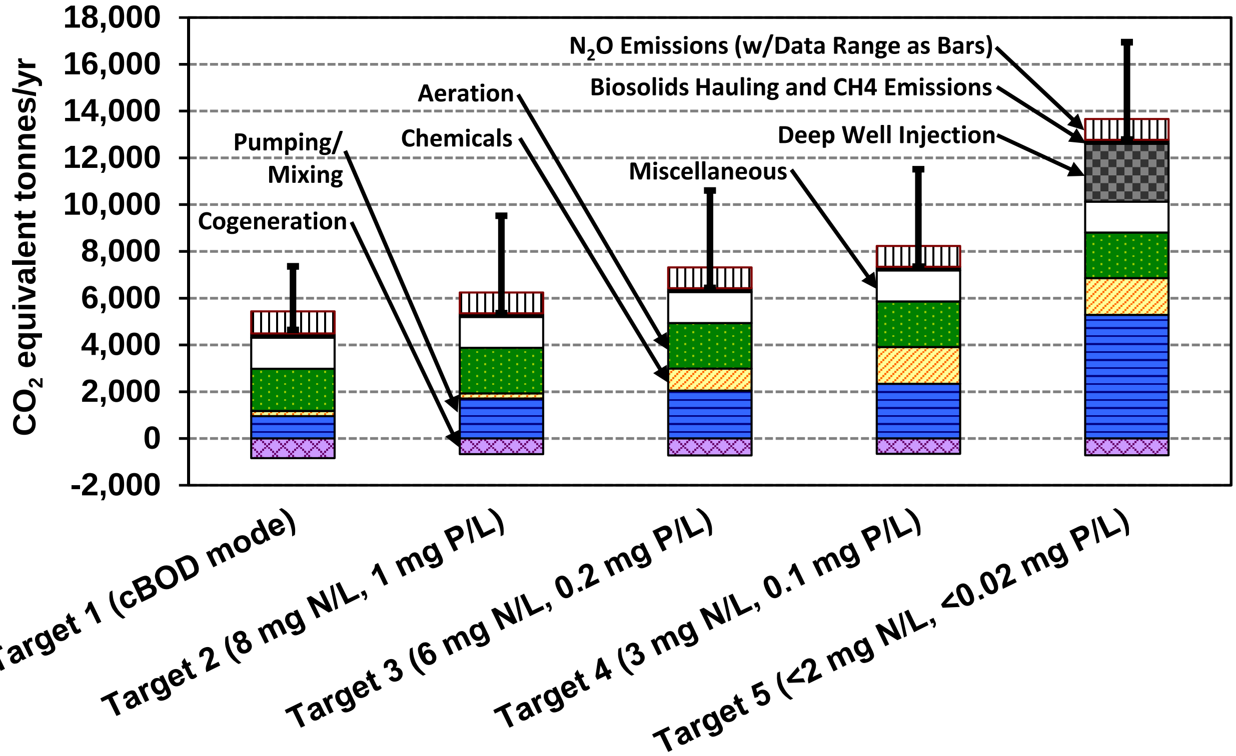

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	0	1	0	300	400	700	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	0	10	0	100	400	600	--
GHG Emissions Increase Total	MT CO_2/yr	0	11	0	400	800	1,200	--
								--
Unit GHG Emissions[2]	lb CO_2/MG	0	8	0	200	500	700	--
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	--*	1,000	--*	1,000	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	--*	--*	38	27	--
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	--*	11	--*	11	45	9	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. Napa WRF was not considered for sidestream treatment since the facility already nitrifies, does not dewater daily, and is limited to seasonal discharge.

* Calculated nutrient reduction is zero, since current performance meets Level 2 and Level 3 criteria for ammonia (dry season), Level 2 criteria for nitrogen (dry season and year round) and Level 2 criteria for phosphorus (dry season).

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Napa WRF. These are:

- Nitrite Shunt – Napa WRF aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Treatment Wetland – Napa WRF facultative pond effluent or final effluent would be subsequently treated through a constructed wetland where algae and aquatic plants take up nutrients and nitrogen removal is performed by biofilms.
  - Advantages: Low operations and maintenance, mature technology
  - Disadvantages: Large footprint
  - Potential Next Steps: Determine footprint requirements based on typical wetlands design. Consider pilot testing a small-scale constructed wetland to determine benefits.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.16

Novato Sanitary District Wastewater Treatment Plant

Bay Area Clean Water Agencies
Nutrient Reduction Study

Novato Sanitary District Wastewater Treatment Plant

Novato, CA

March 22, 2018
Final Report

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Executive Summary

Novato Sanitary District owns and operates the Novato Sanitary District Wastewater Treatment Plant located in Novato, CA and discharges treated effluent to San Pablo Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 7 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3,7]	Opt. Year Round[3]	Level 2 Dry Season[3,7]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3,8]
Design Flow	mgd	--	--	4.1	5.0	7.0	8.7	7.0	8.7	--
Flow to Bay[2,9]	mgd	3.1	3.1	3.1	3.1	4.3	4.3	4.3	4.3	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	26	26	27	27	35	35	35	35	--
TN	lb N/d	350	350	370	370	480	480	370	220	--
TP	lb P/d	33	33	36	23	46	34	33	11	--
Costs[4,5]										
Capital	$ Mil	--	--	0	2.3	0	2.3	36	60	--
O&M PV	$ Mil	--	--	0	0.3	0	1.2	7	16	--
Total PV	$ Mil	--	--	0	2.7	0	3.5	43	76	--
Unit Costs[6]										
Capital	$/gpd	--	--	0	0.5	0	0.3	5.1	6.9	--
Total PV	$/gpd	--	--	0	0.5	0	0.4	6.1	8.8	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value; Opt. = optimization.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream). The values account for days with no discharge. Future flows and loadings were estimated assuming no discharge from June 1 through September 30, consistent with data from 7/2012-6/2015. The District's NPDES permit prohibits discharge from June 1 to August 31 from the current outfall. However, in the future the District may discharge year round to a restored marsh.
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Current performance meets Level 2 criteria for the dry season.
8. Sidestream treatment was not evaluated due to the variability of sidestream return flows from the sludge lagoons.
9. The District's NPDES permit prohibits discharge from June 1 to August 31 from the current outfall. However, in the future the District may discharge year round to a restored marsh.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Add alum upstream of the primary clarifiers to increase phosphorus removal. Alum addition is expected to meet Level 2 phosphorus loads. Seasonal average performance of the existing facility meets Level 2 nitrogen criteria. Since chemical addition to the primary clarifiers may remove a portion of the carbon currently used for denitrification, methanol addition facilities are included. Storage and metering facilities for both alum and methanol would be constructed.

Sidestream treatment was not evaluated due to the variability of sidestream return flows from the sludge lagoons.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Construct chemical facilities for alum addition upstream of primary clarifiers,
   b. Construct external carbon facilities (methanol) for carbon addition to maintain denitrification, since a portion of the carbon currently used for denitrification will be removed with the alum addition.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Construct denitrification filters for a portion of the flow to reduce nitrogen to Level 3 criteria, including external carbon dosing for denitrification and alum dosing for phosphorus polishing.
   c. Construct conventional filters for the remaining flow (up to flows where plant operates in contact stabilization) to remove phosphorus, including alum dosing for phosphorus polishing. Flows higher than 24 mgd, when the plant is operating in contact stabilization mode, will not receive filtration.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $0 Mil for dry season optimization (since Novato meets Level 2 in the dry season) up to $76 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Novato Sanitary District Wastewater Treatment Plant (WTP) serves a population of about 60,000, which includes the City of Novato and adjacent unincorporated Marin County. It is located at 500 Davidson Street, Novato, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 7.0 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The Novato WTP holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2015-0034, NPDES No. CA0037958). The treated wastewater is discharged to the San Pablo Bay at latitude of 38.060001 and longitude of -122.489995.

Table 2-1 provides a summary of the permit limitations that are specific to the Novato WTP and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2015-0034; CA0037958)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak
Effluent Limitations – November through April						
Flow	mgd	7.0[1]	-	-	-	-
BOD	mg/L	-	30	45	-	-
TSS	mg/L	-	30	45	-	-
Total Ammonia, as N	mg/L	-	5.9	-	21	-
Effluent Limitations – May through October						
Flow	mgd	7.0[2]	-	-	-	-
BOD	mg/L	-	15	30	-	-
TSS	mg/L	-	10	20	-	-
Total Ammonia, as N	mg/L	-	5.9	-	21	-

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. The facility is designed to provide secondary treatment for a sustained 3-hour flow of 47 MGD during wet weather.
2. Discharge is prohibited from June 1 to August 31, except when effluent volume exceeds reclamation water demand. In the future, the District may discharge year round to a restored marsh.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Novato WTP. Both liquids processes and solids processes are shown. The Novato WTP consists of screening and grit removal, primary clarification, followed by a Modified Ludzack-Ettinger (MLE) activated sludge process including anoxic zones and mixed liquor recycle for secondary treatment. Contact stabilization mode is used when flow exceeds 20 to 24 mgd. The plant includes continuous backwash upflow filters (1.7 mgd capacity) for Title 22 unrestricted reuse. Secondary effluent is disinfected by ultraviolet disinfection. Solids treatment consists of secondary sludge thickening, anaerobic digestion and sludge lagoons.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Novato WTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	4.1	4.6	4.4	7.5
BOD	lb/d	9,300	9,400	10,500	11,400
TSS	lb/d	12,700	12,800	14,700	17,700
Ammonia	lb N/d	1,170	1,200	1,260	1,860
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	1,600	1,640	1,720	2,550
Total Phosphorus (TP)[5]	lb P/d	220	220	250	270
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	270	250	280	180
TSS	mg/L	380	340	400	280
Ammonia	mg N/L	34	31	34	30
TKN[4]	mg N/L	47	43	47	41
TP[5]	mg P/L	6.4	5.8	6.7	4.3
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. TKN based on seven samples collected between July 2012 and June 2014. Dry season maximum month and year round maximum month were calculated using the ammonia peaking factors.
5. TP based on seven samples collected between July 2012 and June 2014. Dry season maximum month and year round maximum month were calculated using the BOD peaking factors.

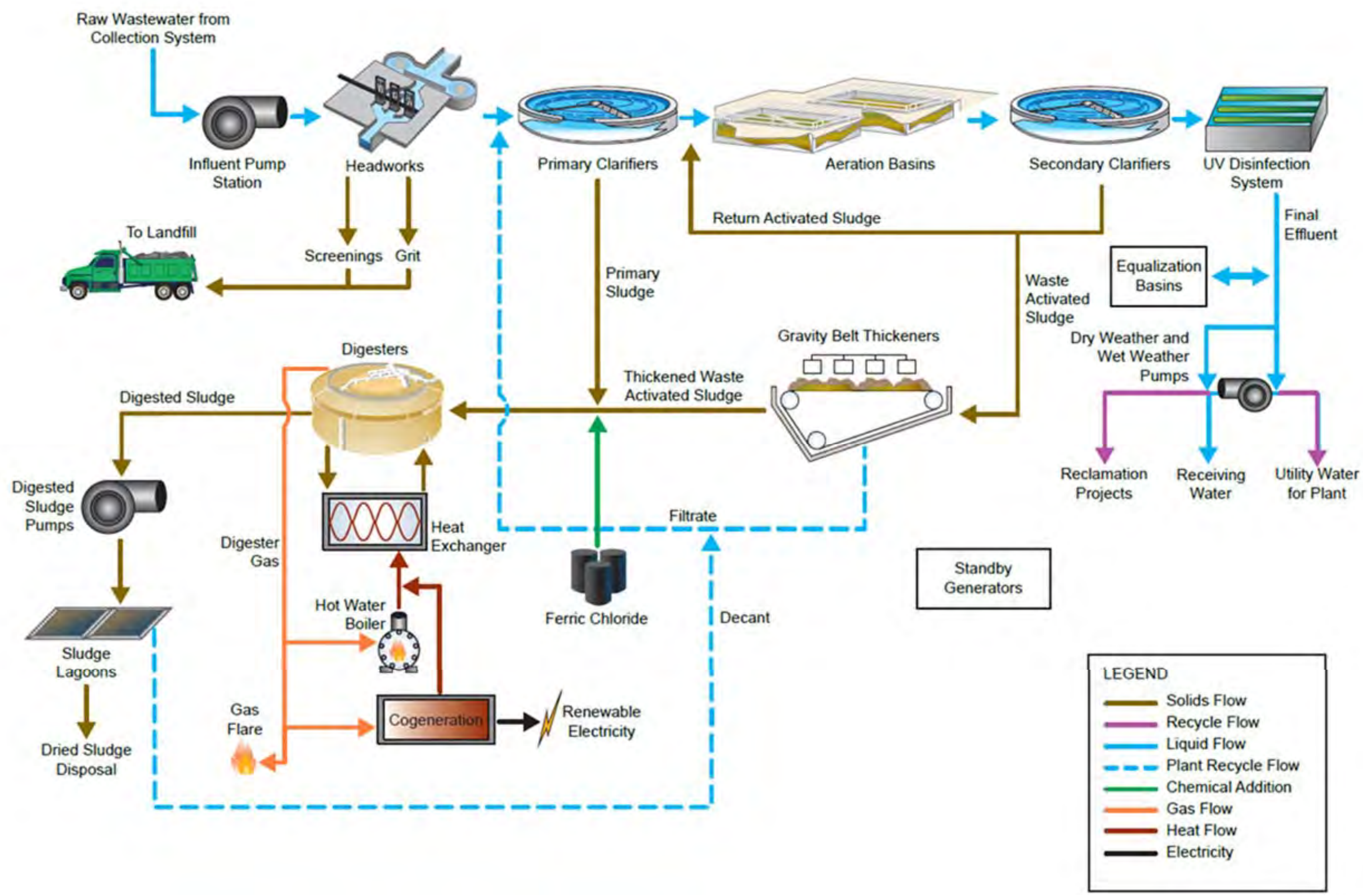

Figure 2-1. Process Flow Diagram for Novato WTP

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the Novato WTP:

- Plant was recently upgraded to the MLE process. Monthly average nitrogen values from July 2012 to June 2015 were reliably less than 20 mg/L. Seasonal average performance meets Level 2 nitrogen criteria (15 mg/L TN). Overall average meets the Level 2 ammonia criteria (2 mg-N/L), but some monthly averages are higher.
- Plant typically does not discharge between May 1 and September 30 or October 31, thus keeping nutrients from the Bay. Water is recycled either for golf course / industrial / school irrigation (Title 22 unrestricted) or on District pasture land (restricted use).
- Plant plans to expand capacity of the Title 22 filtration in three increments of 0.85 mgd, from 1.7 mgd now to a future capacity of 4.25 mgd.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the Novato WTP.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Novato WTP are presented in Table 3-1. The projected flow and load for the Novato WTP in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	4.1	4.6	4.4	7.5
BOD	lb/d	10,700	10,800	12,100	13,100
TSS	lb/d	14,700	14,700	16,900	20,400
Ammonia	lb N/d	1,340	1,380	1,440	2,140
TKN	lb N/d	1,840	1,890	1,980	2,930
TP	lb P/d	250	250	290	310
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	310	280	330	210
TSS	mg/L	430	390	460	330
Ammonia	mg N/L	40	36	39	34
TKN	mg N/L	54	50	54	47
TP	mg P/L	7.4	6.7	7.7	5.0
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

Sidestream treatment was not evaluated due to the variability of sidestream return flows from the sludge lagoons.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's permitted flow capacity as ADWF and the design average loading provided by the district. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3,4]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	7.0[1]	7.8	7.6	12.9
BOD[5]	lb/d	14,400	14,600	16,400	17,800
TSS[5]	lb/d	17,600	17,600	20,300	24,400
Ammonia[6]	lb N/d	1,820	1,870	1,960	2,900
TKN[6]	lb N/d	2,500	2,560	2,690	3,980
TP[6]	lb P/d	340	350	390	420
Alkalinity	lb/d as $CaCO_3$	---	---	---	---
BOD[5]	mg/L	250	220	260	170
TSS[5]	mg/L	300	270	320	230
Ammonia[6]	mg N/L	31	29	31	27
TKN[6]	mg N/L	43	39	42	37
TP[6]	mg P/L	5.9	5.3	6.1	3.9
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Permitted average dry weather flow. Other flows and loads are based on current flow and loading characteristics.
5. BOD and TSS loadings based on design annual average loading.
6. Ammonia, TKN, and TP loading increase is proportional to BOD loading increase

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.

- Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Five optimization strategies were identified during the Novato WTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The five optimization strategies were screened down to four strategies described below. The plant already meets Level 2 criteria for nitrogen, and meets Level 2 phosphorus criteria during the dry season.

- **Optimization Strategy 1:** Add alum upstream of the primary clarifiers to increase phosphorus removal using chemically enhanced primary treatment (CEPT). Chemical addition to the primary clarifiers for phosphorus removal may remove a portion of the carbon currently used for denitrification, so methanol facilities are included to ensure nitrogen removal.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Alum storage and metering facilities could be constructed at the plant. The improvements would include: (a) construction of a chemical storage facility with chemical metering pumps, and (b) construction of chemical feed piping from the storage facility to the plant influent. Alum is the preferred chemical because of the potential for ferric chloride to interfere with downstream UV disinfection. To ensure that nitrogen removal is not negatively impacted, include methanol facilities to supplement carbon if needed. Optimization is only needed during the wet season.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Increase solids retention time (SRT) to improve nitrification and reduce ammonia concentrations. Use offline aeration tank if needed.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Reduce ammonia concentrations.
  - ***Result from analysis:*** Analysis indicates that the current MLE volume is sufficient for full nitrification, and no physical improvements are required. Since the plant has met Level 2 criteria for ammonia and TN, no optimization is needed.
  - ***Recommendation:*** No change from current operation, since plant has met Level 2 criteria for ammonia and TN.

- **Optimization Strategy 3:** Study ways to further optimize nitrogen removal performance (increase internal mixed liquor recycle (IMLR), modify RAS flow, modify DO setpoints, operate one additional tank).
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Improve nitrogen removal performance to consistently meet Level 2.
  - ***Result from analysis:*** The seasonal average performance already meets Level 2 nitrogen criteria (15 mg/L TN), and improvements are likely to be minor. IMLR is typically 100 percent of influent, with a capacity up to 200 percent. Plant could also increase RAS flows, modify DO setpoints, and operate an additional tank.
  - ***Recommendation:*** Do not carry forward at this time, since improvements are expected to be minor.

- **Optimization Strategy 4:** Add instruments for ammonia based aeration control.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Improve nitrification and nitrogen removal performance.
  - ***Result from analysis:*** Plant may be able to save energy and improve nitrification, but improvements are likely to be minor and further study would be needed. Since the seasonal average already meets Level 2 nitrogen limits, this strategy is not recommended at this time.
  - ***Recommendation:*** Do not carry forward at this time.

Strategy 1 is the best apparent way to reduce effluent phosphorus loads. Since the plant already meets Level 2 criteria during the dry season, optimizations are assumed for wet season only. The plant already meets Level 2 criteria for ammonia and nitrogen.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

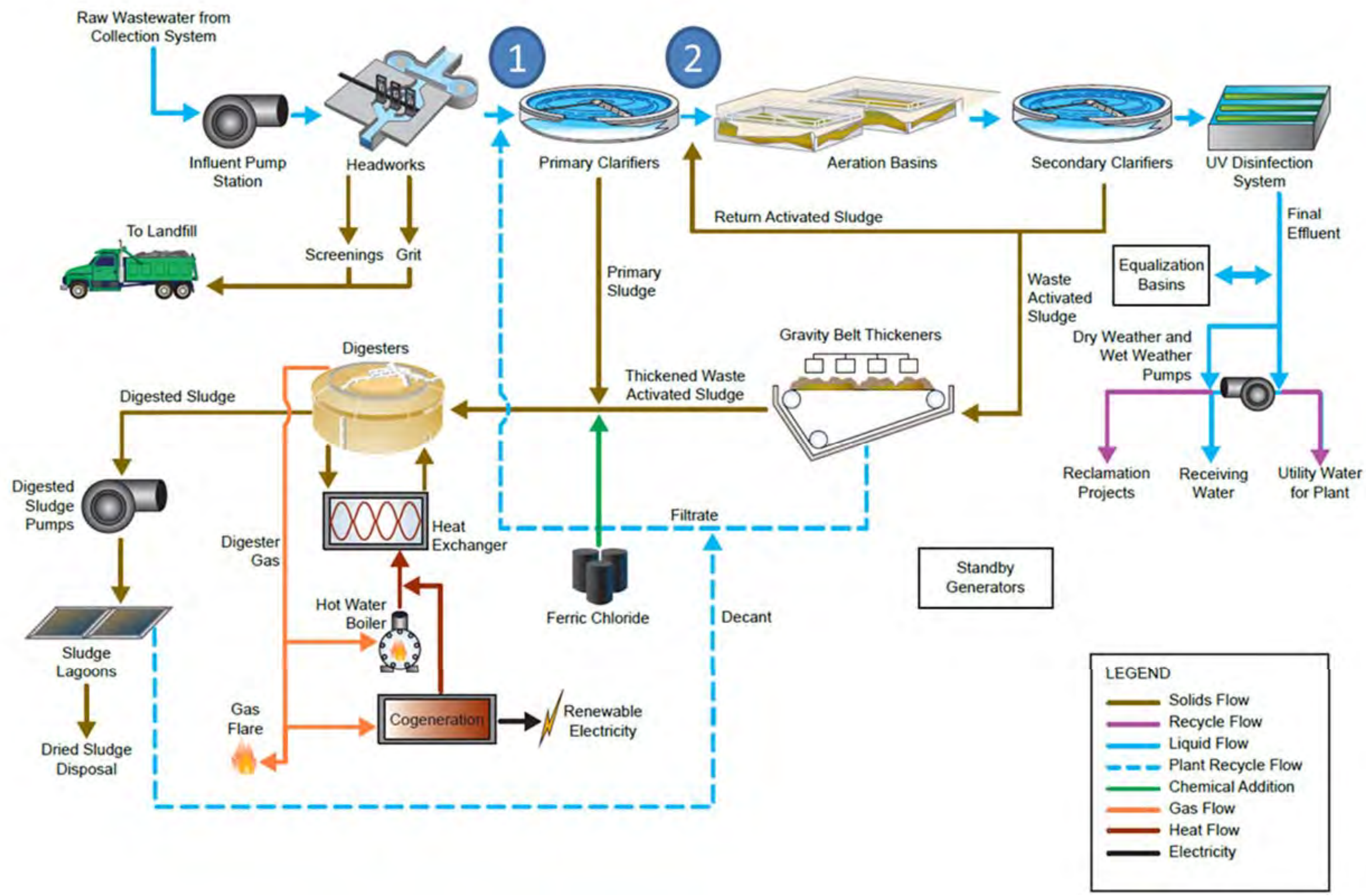

Figure 4-1. Optimization Concepts Considered for the Novato WTP

(1) alum addition upstream of the primary clarifiers for P removal during the wet season, including chemical storage and metering, and (2) include facilities to add methanol (or other carbon source) to supplement carbon if needed (wet season only).

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Alum storage, chemical metering pump, chemical injection (flash mixer) (wet season only)	Dose alum upstream of the primary clarifiers.
Methanol storage, chemical metering pump, chemical injection (wet season only)	Since the plant currently meets Level 2 nitrogen limits seasonally, assume carbon addition is not needed on a regular basis.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The Novato WTP plant shows improved phosphorus removal, but no change in ammonia or nitrogen removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	27	27	370	370	36	36
Discharge with Opt. Strategy[1]	lb N or P/d	27	27	370	370	36	23
Load Reduction[2,3]	lb N or P/d	0	0	0	0	0	13
Load Reduction[2,3]	%	0%	0%	0%	0%	0%	36%
Annual Load Reduction	lb N or P/yr	0	0	0	0	0	4,630

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization). The values account for days with no discharge.
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified and plant already meets Level 2 discharge limits. Calculated nutrient reduction for dry season TP is zero since plant already meets Level 2 discharge limits in the dry season.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	4.1	5.0
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0	2.3
Annual O&M	$ Mil/yr	0	0.04
Present Value O&M[3]	$ Mil	0	0.3
Present Value Total[3]	$ Mil	0	2.7
Unit Capital Cost[8]	$/gpd	0	0.5
Unit Total PV Cost[8]	$/gpd	0	0.5
TN Removal			
Capital[2,4]	$ Mil	0	0
Annual O&M[4]	$ Mil/yr	0	0
O&M PV[3,4]	$ Mil	0	0
Total PV[3,4]	$ Mil	0	0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0	2.3
Annual O&M[5]	$ Mil/yr	0	0.04
O&M PV[3,5]	$ Mil	0	0.3
Total PV[3,5]	$ Mil	0	2.7
TP Removed (Ave.)[6]	lb P/d	0	13
Annual TP Removed (Ave.)[7]	lb P/yr	0	4,630
TP Cost[5,9,10]	$/lb P	NA	57.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since current performance meets Level 2 criteria for nitrogen (dry season and year round) and phosphorus (dry season).

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• More organics and solids diverted to fuel the digester • Phosphorus reliably removed under peak flow scenarios	• Dependency on chemicals • Chemical costs • CEPT (alum) would reduce the organic loading to the MLE, and could cause a carbon limitation and reduce nitrogen removal. Methanol facilities are included to mitigate this impact.

5 Sidestream Treatment

Sidestream treatment is not evaluated for Novato as previously described.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Novato WTP plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The Novato WTP should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 phosphorus limits could be met by implementing alum addition to the primary clarifiers for phosphorus removal. As designed, the Novato MLE process meets Level 2 nitrogen limits and no upgrades are assumed. Since the plant already meets Level 2 nitrogen limits without alkalinity addition, those alkalinity addition facilities are not included. Chemical addition to the primary clarifiers for phosphorus removal may remove a portion of the carbon currently used for denitrification, so methanol storage facilities are included.

Note that internal mixed liquor recycle capacity (14 mgd total) is approximately 100 percent of the max month winter flow, which is lower than typically seen. The design also assumes contact stabilization mode at flows greater than 24 mgd. In contact stabilization mode, nitrification and denitrification will be reduced, but these events are rare so seasonal average nitrogen limits can probably still be achieved. An additional secondary clarifier (not included) would be needed to eliminate contact stabilization mode.

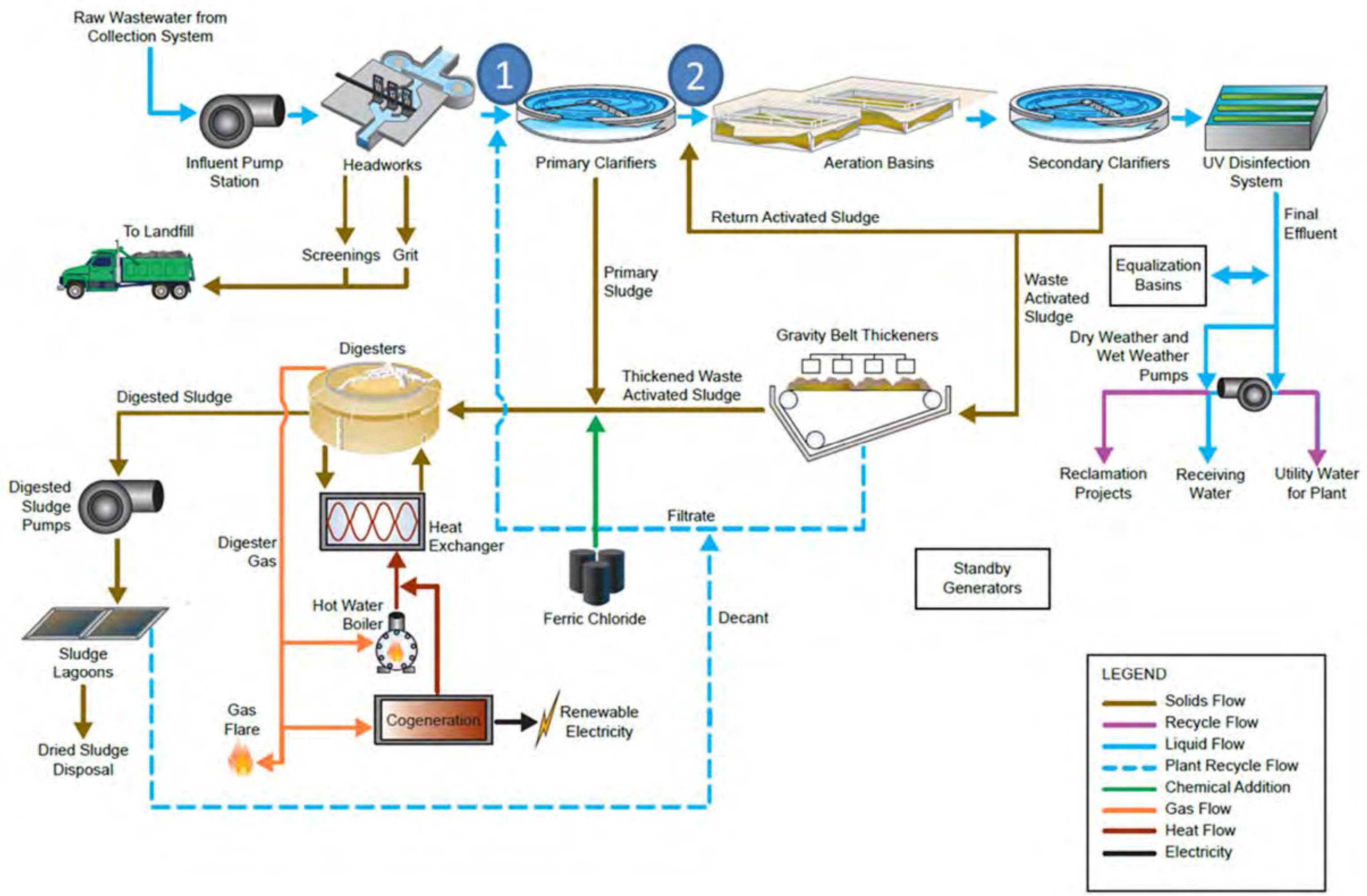

Figure 6-1. Level 2 Upgrade Concept for Novato WTP

(1) alum addition upstream of the primary clarifiers for P removal (wet season only), including chemical storage and metering, and (2) include facilities to add methanol (or other carbon source) to supplement carbon if needed.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Denitrification filters following the existing MLE process could be used for Level 3 nitrogen limits. To reduce nitrogen to Level 3 limits, denitrification filters with methanol addition would treat 85 percent of the maximum month flow.

Chemical addition and tertiary filtration could be used to meet Level 3 phosphorus limits. Alum addition before both primary clarification and filtration is assumed. Filtration with either denitrification filters or conventional filters is necessary for phosphorus polishing. Conventional filters are shown for flows that exceed the denitrification filter capacity. For this analysis, it is assumed that during peak flow events, the plant will continue to operate in contact stabilization mode. Similar to contact stabilization mode, filtration of flows up to 24 mgd is assumed. During peak flow events, flows above 24 mgd would not receive filtration. It may be feasible to meet phosphorus limits while filtering a lower flow. If Level 3 treatment is required, the Novato WTP should further evaluate the filter flows required to meet the phosphorus limits. Chemical addition to the primary clarifiers for phosphorus removal may remove a portion of the carbon currently used for denitrification, so facilities to add methanol to activated sludge are included.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Alum Chemical Feed	Same as Level 2
Secondary	• External carbon source addition facilities	Same as Level 2
Tertiary	---	Same as Level 2 plus: • Denitrification Filters for 6.8 mgd (dry season only) or 11.5 mgd (year round) (85 percent of maximum month flow) • Conventional Filters for flows up to 24 mgd (a lower flow may be sufficient and should be evaluated further if phosphorus removal is required). • Additional External Carbon Source Chemical Feed • Alum feed to filters

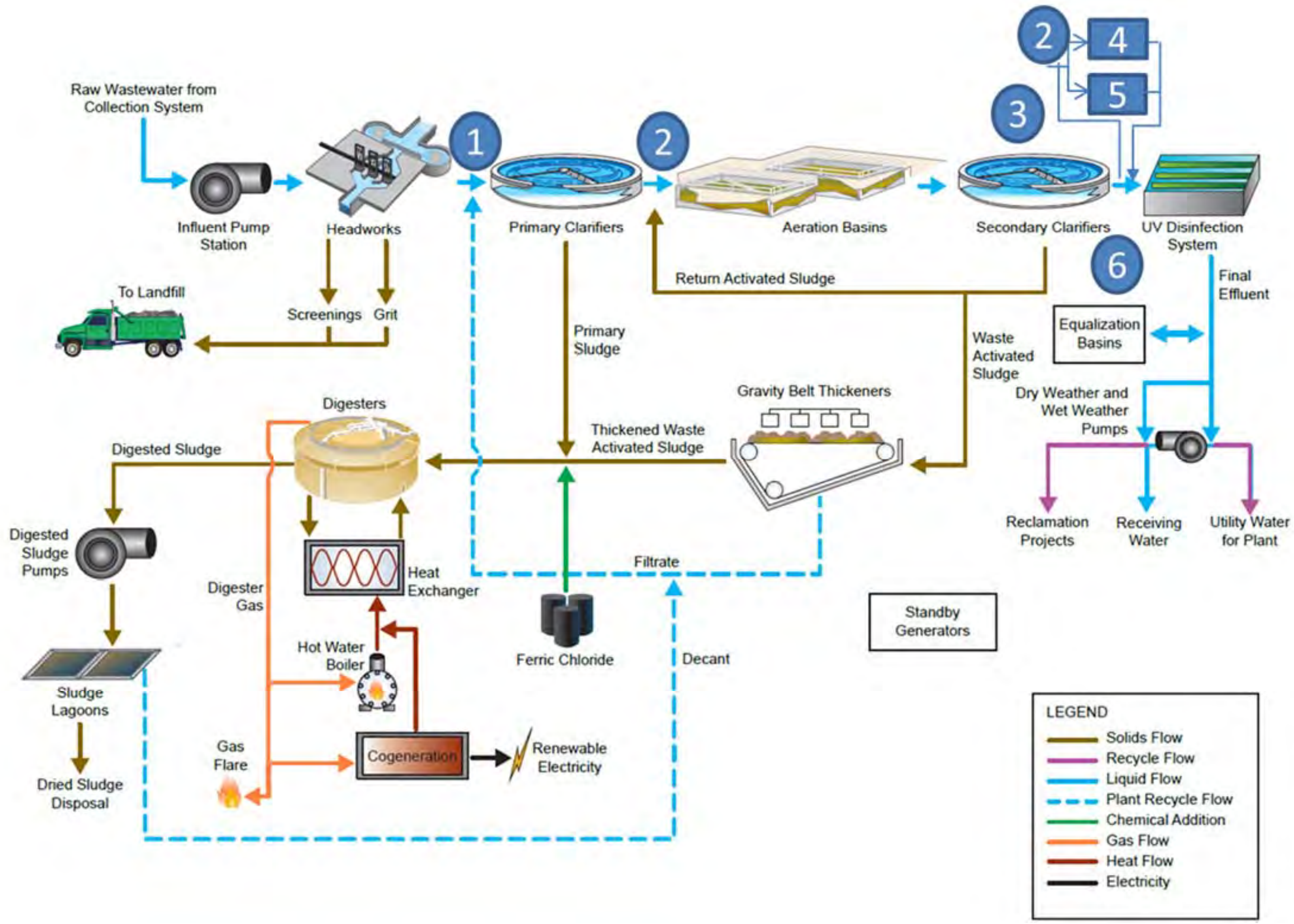

Figure 6-2. Level 3 Upgrade Concept for Novato WTP

(1) alum addition upstream of the primary clarifiers for P removal, including chemical storage and metering, (2) facilities to add methanol for denitrification in aeration basins and denitrification filters, (3) add alum for phosphorus polishing in filters, (4) denitrification filters for 85 percent of max month flow, (5) granular media filters for flows up to 24 mgd (a lower flow may be sufficient and should be further evaluated if phosphorus removal is required), and (6) no filtration above 24 mgd (greater than max day flow).

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) chemical addition facilities (alum and methanol).

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) chemical addition facilities (alum and methanol), (2) denite filters for dry season (assumed to treat 6.8 mgd), (3) additional denite filters for year round (assumed to treat 11.5 mgd total with denite filters), (4) granular media filters for dry season (assumed to treat 2.4 mgd), and (5) additional granular media filters for wet weather season (assumed to treat 12.5 mgd total with conventional filters).

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	7.0	8.7	7.0	8.7
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	0	2.3	36	60
Annual O&M	$Mil/yr	0	0.1	0.3	0.7
O&M PV[3]	$ Mil	0	1.2	7	16
Total PV[3]	$ Mil	0	3.5	43	76
Unit Capital Cost	$/gpd	0	0.3	5.1	6.9
Unit Total PV	$/gpd	0	0.4	6.1	8.8
TN Removal					
Capital[2,4]	$ Mil	0	0	33	50
Annual O&M[4]	$ Mil/yr	0	0	0.2	0.5
O&M PV[3,4]	$ Mil	0	0	4	10
Total PV[3,4]	$ Mil	0	0	37	61
TN Removed (Ave.)[6,10]	lb N/d	0	0	80	230
Annual TN Removed (Ave.)[7]	lb N/yr	0	0	28,500	83,300
TN Cost[4,8,10]	$/lb N	NA	NA	43.0	24.3
TP Removal					
Capital[2,5]	$ Mil	0	2.3	35	59
Annual O&M[5]	$ Mil/yr	0	0.1	0.2	0.5
O&M PV[3,5]	$ Mil	0	1.2	5	11
Total PV[3,5]	$ Mil	0	3.5	40	70
TP Removed (Ave.)[6,10]	lb P/d	0	8.8	9.2	32
Annual TP Removed (Ave.)[7]	lb P/yr	0	3,200	3,400	11,500
TP Cost[5,10]	$/lb P	NA	36	392	202

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.
10. Calculated nutrient reduction is zero, since current performance meets Level 2 criteria for nitrogen (dry season and year round) and phosphorus (dry season).

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing MLE process • Robust technology to absorb variability in flows and loads	• Increased operation costs associated with alum addition • Increased sludge production
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use and additional alum use • Higher energy costs for filter feed pumping

7 Nutrient Removal by Other Means

The Novato WTP has an existing recycled water program that is employed during the dry season. Novato has no Bay discharge during the dry season, with water recycled either for golf course / industrial / school irrigation (Title 22 unrestricted) or on District pasture land (restricted use). This existing program has the effect of reducing nutrients discharged to the Bay. Novato currently recycles approximately 300 acre-feet per year (100 million gallons per year) not including District pasture land, and they are planning to increase recycling to 500 acre-feet per year (160 million gallons per year) by 2020.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy

and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

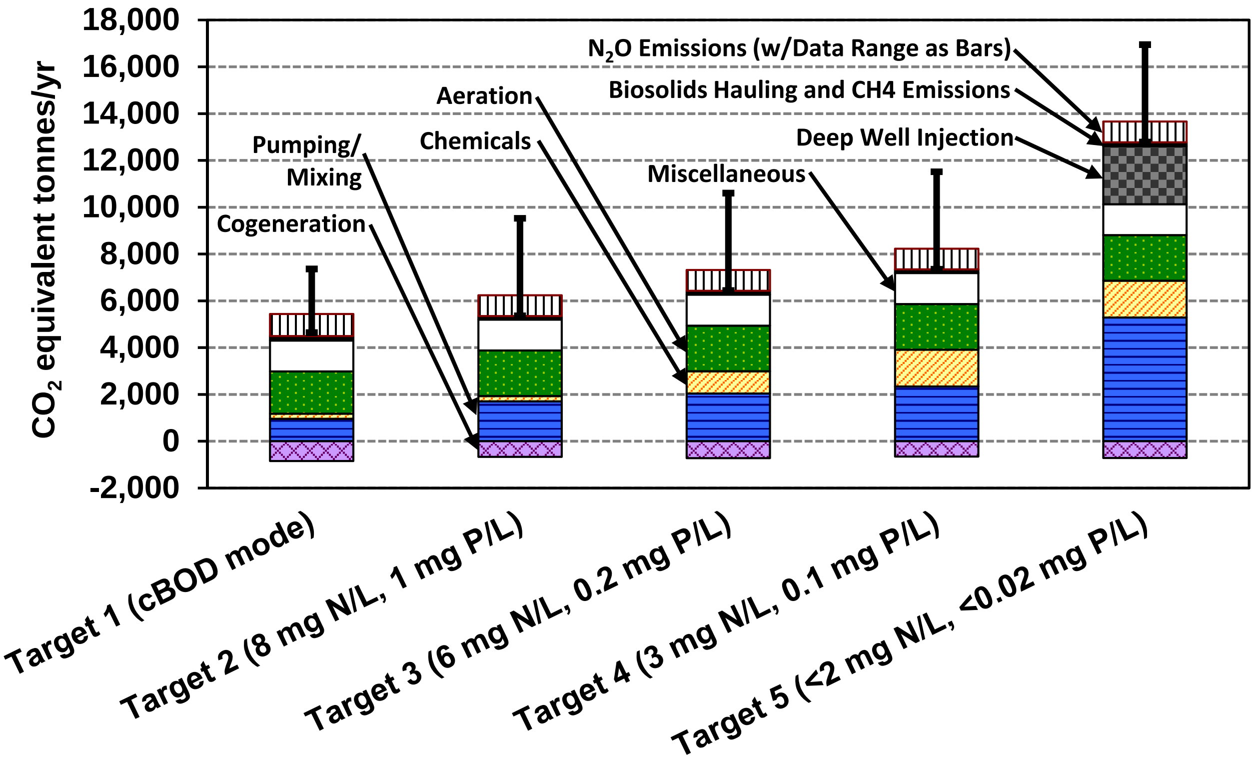

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

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[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	0	2	0	2	260	310	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	0	35	0	61	350	430	--
GHG Emissions Increase Total	MT CO_2/yr	0	37	0	63	610	740	--
								--
Unit GHG Emissions[2]	lb CO_2/MG	0	48	0	47	460	560	--
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	--*	--*	--*	--*	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	--*	--*	40	10	--
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	--*	18	--*	43	220	90	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. Novato was not evaluated for sidestream treatment.

* Calculated nutrient reduction is zero, since current performance meets Level 2 and Level 3 criteria for ammonia, Level 2 criteria for nitrogen (dry season and year round) and Level 2 criteria for phosphorus (dry season).

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Novato WTP. These are:

- Nitrite Shunt – Novato WTP aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Simultaneous nitrification/denitrification (SND) –Novato aeration basins would be operated at low dissolved oxygen (DO) levels to promote SND. Under this operating scenario, nitrification and denitrification occurs in the same tankage and dedicated anoxic zones are not necessary. As a result, there is a significant reduction in aeration requirements. This requires the installations of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.17

Oro Loma/Castro Valley Wastewater Treatment Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Oro Loma/Castro Valley Wastewater Treatment Plant

San Lorenzo, CA

February 9, 2018
Final Report

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Executive Summary

The Oro Loma Sanitary District (OLSD) operates the Oro Loma/Castro Valley Wastewater Treatment Plant (OLSD WWTP) discharges to South San Francisco Bay. The plant has average dry weather flow (ADWF) permitted capacity of 20 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	12.0	13.5	20.0	22.5	20.0	22.5	--
Flow to Bay[2]	mgd	12.0	12.8	12.0	12.8	16.0	17.1	16.0	17.1	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	3,240	3,240	670	620	310	290	310	290	3,200
TN	lb N/d	3,450	3,450	2,370	2,220	2,290	2,140	1,640	860	3,600
TP	lb P/d	150	150	30	30	150	140	100	40	200
Costs[4,5]										
Capital	$ Mil	--	--	8.1	8.5	43	48	77	96	19
O&M PV	$ Mil	--	--	1.4	2.7	3	7	21	44	11
Total PV	$ Mil	--	--	9.5	11.2	45	55	98	140	30
Unit Costs[6]										
Capital	$/gpd	--	--	0.7	0.6	2.1	2.1	3.8	4.3	--
Total PV	$/gpd	--	--	0.8	0.8	2.3	2.4	4.9	6.2	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Chemically Enhanced Primary Treatment (CEPT) to increase solids and organics capture in the primary clarifiers and in turn increase the downstream activated sludge process capacity. This will also remove TP loads. It should be noted that the plant nearly achieves the Level 2 phosphorus loads (1 mg P/L) with an average value of about 1.4 mg P/L.
2. Increase the solids residence time (SRT) and modify the aeration basins by replacing the mechanical aerators with fine-bubble aeration system that includes blowers.
3. Increase the return activated sludge (RAS) rate to maximize the amount of total nitrogen reduced. This strategy is predicated on implementation of strategy 2.This would simply increase the RAS pumping rate and not require addition of new pumps.

OLSD is considered a candidate for sidestream treatment because the plant digests biosolids and dewaters the digested biosolids. The recommended sidestream treatment technology is a deammonification technology to treat the ammonia laden dewatering return stream.

The upgrade strategies to achieve Levels 2 and 3 include:

- Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
  - Same as Optimization, plus
  - Expand the flow equalization basin,
  - Expand the aeration basins, and
  - Sidestream treatment.
- Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L):
  - Same as Optimization and Level 2, plus
  - Expanding the aeration basins,
  - Adding an external carbon source, and
  - Adding a filter complex and metal salt/polymer at the filters to trim phosphorus.

Capital costs, O&M costs and present value costs were determined for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for changes in solids handling requirements or energy requirements in other unit processes.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the total present value costs range from $9.5 Mil for dry season optimization up to $140 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Oro Loma Sanitary District (OLSD) operates the Oro Loma/Castro Valley Wastewater Treatment Plant (OLSD WWTP) that discharges to the South Bay. It is located at 2655 Grant Ave San Lorenzo, CA 94580, and it serves approximately 47,000 service connections throughout the cities of San Lorenzo, Ashland, Cherryland, Fairview, and portions of Castro Valley and the communities of San Leandro and Hayward. The plant has average dry weather flow (ADWF) permitted capacity of 20 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

OLSD WWTP discharges treated effluent through a common outfall operated by the East Bay Dischargers Authority (EBDA). EBDA member agencies include the City of Hayward, City of San Leandro, Oro Loma Sanitary District, Castro Valley Sanitary District, Union Sanitary District, and the Livermore-Amador Valley Water Management Agency (LAVWMA). The EBDA discharge is located at latitude 37°41’40” and longitude 122°17’42”.

EBDA holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2012-0004, NPDES No. CA0037869). Table 2-1 provides a summary of the permit limitations that are specific to OLSD, under the EBDA NPDES permit, and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2012-0004; CA0037869)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	20	--	--	--
BOD	mg/L	--	25	40	--
TSS	mg/L	--	30	45	--
Total Ammonia, as N	mg/L	--	93	--	130

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for OLSD WWTP. Liquid stream treatment consists of a headworks, primary sedimentation, activated sludge with an anaerobic selector, secondary clarification, chlorination, and then conveyed to EBDA for dechlorination/discharge. The activated sludge anaerobic selector assists with settleability and provides biological phosphorus removal. No major ammonia/nitrogen removal systems are currently in place.

Solids treatment includes thickening, anaerobic digesters, dewatering using a belt filter press followed by drying beds.

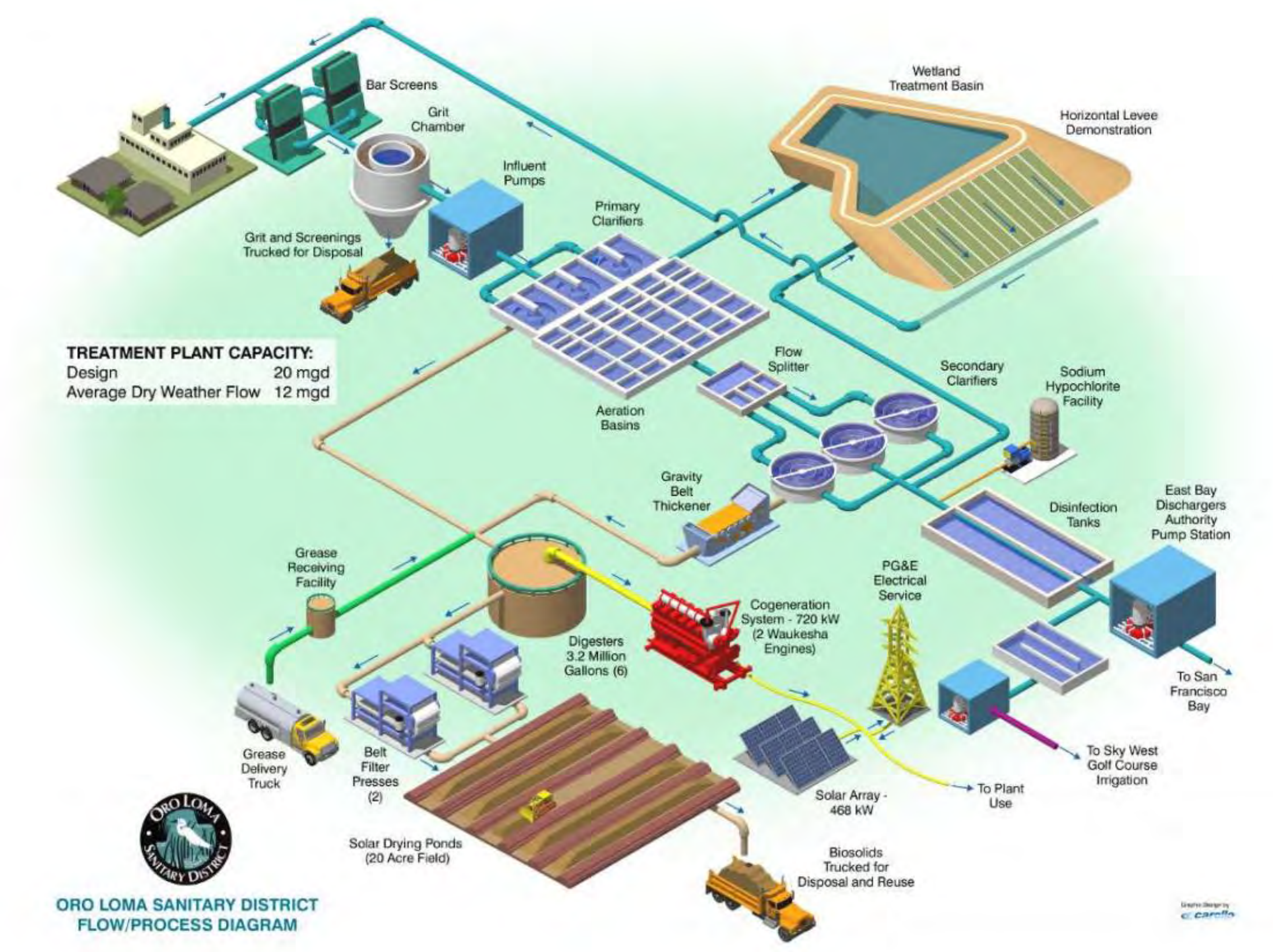

Figure 2-1. Process Flow Diagram for Oro Loma/Castro Valley Wastewater Treatment Plant

(Source: http://www.oroloma.org/sewer/treatment/diagram/index.html)

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical plant performance and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for OLSD WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	12.0	12.8	13.3	17.5
BOD	lb/d	25,500	26,300	28,600	30,600
TSS	lb/d	39,500	40,600	46,200	46,100
Ammonia	lb N/d	2,200	2,300	2,200	2,800
Total Kjeldahl Nitrogen (TKN)	lb N/d	4,200	4,500	4,400	5,200
Total Phosphorus (TP)	lb P/d	490	550	530	600
Alkalinity[4]	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	256	246	257	210
TSS	mg/L	396	379	416	316
Ammonia	mg N/L	22	21	20	19
TKN	mg N/L	42	42	40	36
TP	mg P/L	4.9	5.1	4.8	4.1
Alkalinity[4]	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

2.4 Future Nutrient Removal Projects

OLSD has evaluated and implemented numerous nutrient removal technologies as follows:

- Developed a Nutrients Removal Report in 2012 that identified facility needs to reduce nutrients using various technologies.
- Performed pilot and demonstration testing on sidestream treatment technologies (see Section 2.5).
- Recently constructed a horizontal levee, known as the Ecotone Project that will provide critical wetland habitat and nutrient removal. This concept is the first of its kind in the Bay Area. The anticipated benefits of the Ecotone Project (see Section 7) will be verified while in operation.
- In the pre-design phase for the optimization concept developed under this effort (see Section 4).

2.5 Pilot Testing

OLSD has piloted and performed demonstration testing on the Zeolite/Anammox technology for treating their dewatering return stream. The Zeolite/Anammox process sorbs the ammonia in the sidestream onto the zeolite. The zeolite is subsequently recharged by converting the sorbed ammonia to nitrogen gas which is released to the atmosphere. The pilot and demonstration testing effort is a part of the EPA Regional Grant on Sidestream Treatment that was led by East Bay Municipal Utility District (EBMUD).

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where information about future projections are unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Plant upgrade strategies were developed based on design capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for OLSD are presented in Table 3-1. The projected flow and load for OLSD in 2025 was not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided, it was determined that OLSD WWTP may be a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July, 2015. The sampling results were projected forward to the permitted capacity for use in the sidestream treatment evaluation. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30) [1,3]	Year Round MM [1,3]
Flow	mgd	12.0	12.8	13.4	17.5
BOD	lb/d	29,000	30,000	33,000	35,000
TSS	lb/d	46,000	47,000	53,000	53,000
Ammonia[4]	lb N/d	2,000	3,000	3,000	3,000
TKN[4]	lb N/d	4,800	5,200	5,100	5,900
TP[4]	lb P/d	570	630	600	690
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	293	282	294	241
TSS	mg/L	456	436	476	363
Ammonia[4]	mg N/L	25	25	23	22
TKN[4]	mg N/L	48	48	45	41
TP[4]	mg P/L	5.7	5.9	5.4	4.8
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Nutrient data not available before July 2012.

Table 3-2. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Projected to Permitted Flow Capacity
Sidestream Flow	mgd	0.13	0.21
Ammonia	lb N/d	940	1,580
TKN	lb N/d	2,000	3,400
TN [1]	lb N/d	2,000	3,400
OrthoP	lb P/d	660	1,100
TP	lb P/d	130	230
Alkalinity	lb $CaCO_3$/d	4,000	6,700
Ammonia	mg N/L	910	910
TKN	mg N/L	1,930	1,930
TN [1]	mg N/L	1,930	1,930
OrthoP	mg P/L	630	630
TP	mg P/L	130	130
Alkalinity	mg/L as CaCO3	3,900	3,900

1. It was assumed that TKN = TN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period

values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30) [1,3]	Year Round MM[1,3]
Flow	mgd	20.0	21.4	24.0	35.0
BOD	lb/d	43,000	44,000	51,000	61,000
TSS	lb/d	66,000	68,000	83,000	92,000
Ammonia	lb N/d	4,000	4,000	4,000	6,000
TKN	lb N/d	7,000	7,500	7,900	10,300
TP	lb P/d	830	920	940	1,210
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	255	246	256	210
TSS	mg/L	397	379	414	316
Ammonia	mg N/L	22	22	20	19
TKN	mg N/L	42	42	39	35
TP	mg P/L	5.0	5.2	4.7	4.1
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was based on a uniform approach for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortia (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Sidestream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs and greenhouse gas (GHG) emissions.

Four optimization strategies were identified during the OLSD site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The results of the screening are as follows:

- **Optimization Strategy 1:** Optimize existing ferric chloride addition to the existing chemical feed facilities at the primary clarifiers. This effectively turns the primaries into chemically enhanced primary treatment (CEPT) to increase phosphorus, TSS, and BOD removal. The plant already adds ferric chloride to primary solids which helps with odors/corrosion at the digesters but not on the listed CEPT benefits on capture.
  - ***Is it feasible?*** Yes. The facilities already exist.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal and reduce loading to the downstream activated sludge process. This could enhance the potential to remove ammonia in the downstream activated sludge.

- ***Result from analysis:*** It will marginally increase P removal because the plant is already removing P in the downstream activated sludge. However, it will improve the day to day reliability for P removal, unlock downstream treatment capacity, and is thus deemed potentially viable.
- ***Recommendation:*** Carry forward.

◈ Optimization Strategy 2: Increase the SRT in the aeration basins for full nitrification.

- ***Is it feasible?*** Yes. The facilities will require replacing the mechanical aerators with a fine bubble aeration system.
- ***Potential impact on ability to reduce nutrient discharge loads?*** Full ammonia removal in the aeration basins. Marginal nitrogen load reduction governed by how much RAS is returned to the aeration basins.
- ***Result from analysis:*** The aeration basins have sufficient interim capacity to fully nitrify. The extent of nitrogen load reduction is dependent on how much RAS can be returned to the aeration basins. The expected nitrogen load reduction is about 40 to 50 percent with respect to the current discharge load.
- ***Recommendation:*** Carry forward.

◈ Optimization Strategy 3: Increase the RAS pumping to return more nitrate to the activated sludge process. This strategy is predicated on implementation of Optimization Strategy 2.

- ***Is it feasible?*** Yes, but it would require additional pumping.
- ***Potential impact on ability to reduce nutrient discharge loads?*** Remove a portion of the total nitrogen load year round.
- ***Result from analysis:*** The existing RAS has the ability to pump between 5 to 30 mgd. Matching the RAS pumping with the influent feed flow translates to a nitrogen load reduction of about 50 percent as all the nitrate returned with the RAS should be removed (as long as there is sufficient carbon). There should be sufficient carbon to reduce the load at least 50 percent with respect to the current discharge load.
- ***Recommendation:*** Carry forward.

A combination of all 3 Strategies is the best apparent way to reduce effluent nutrient loads. Strategy 1 is a stand-alone optimization strategy that will contribute to P discharge load reduction. The additional solids and organics removal associated with Strategy 1 will result in additional capacity in the downstream activated sludge. This additional capacity would further reduce ammonia/total nitrogen load reduction for Strategies 2 and 3. Strategy 2 requires the most significant plant and operational modifications. Strategy 3 is predicated on implementation of Strategy 2 where a portion of ammonia converted to nitrate in Strategy 2 is removed.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of each strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

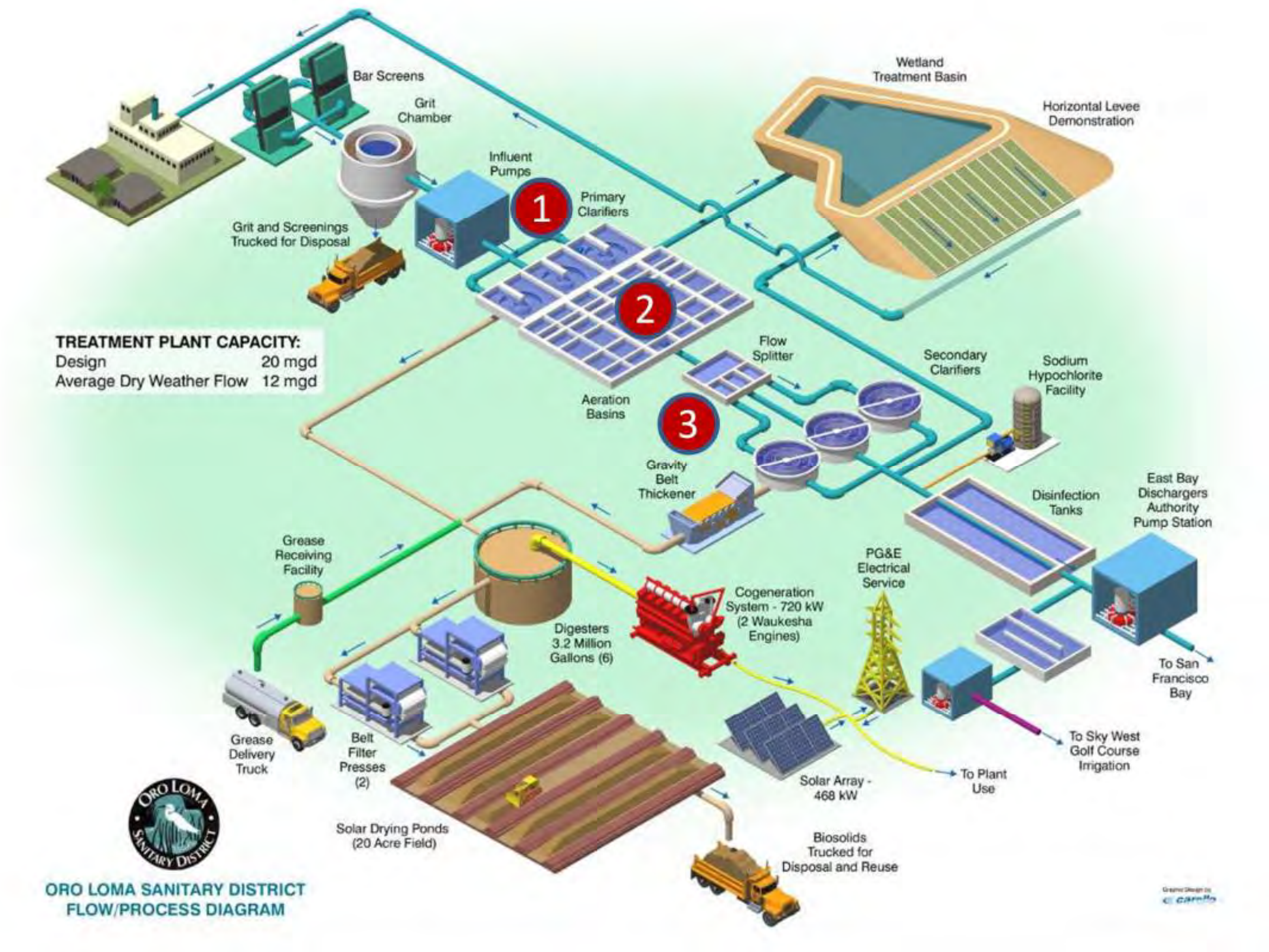

Figure 4-1. Optimization Concepts Considered for OLSD

(1) Optimize metal salt dosing to enhance P removal, (2) increase the SRT for nitrification, and (3) increase the return activated sludge return for nitrogen reduction (predicated on implementation of (2)).

The capital and operational impacts of these nutrient removal optimization strategies are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
CEPT for P Removal • No additional chemical facilities	• Optimize the existing facilities
Increase the SRT and Use Old Secondaries • No capital elements to increase the SRT • Replace the mechanical aeration system with fine bubble aeration system with blowers •	• Decrease the WAS pumping rate to increase SRT sufficient for nitrification •
Increase the RAS Return Rate • No additional pumping capacity	• Optimize the existing facilities

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	3,480	3,480	3,710	3,710	160	160
Discharge with Opt. Strategy[1]	lb N or P/d	670	620	2,370	2,220	30	30
Load Reduction[2]	lb N or P/d	2,820	2,860	1,340	1,490	130	130
Load Reduction[2]	%	81%	82%	36%	40%	80%	81%
Annual Load Reduction	lb/yr	1,030,000	1,040,000	489,000	544,000	47,000	48,000

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	12.0	13.5
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	8.1	8.5
Annual O&M	$ Mil/yr	0.2	0.3
Present Value O&M[3]	$ Mil	1.4	2.7
Present Value Total[3]	$ Mil	9.5	11.2
Unit Capital Cost[8]	$/gpd	0.7	0.6
Unit Total PV Cost[8]	$/gpd	0.8	0.8
TN Removal			
Capital[2,4]	$ Mil	8.1	8.5
Annual O&M[4]	$ Mil/yr	0.2	0.3
O&M PV[3,4]	$ Mil	1.6	2.9
Total PV[3,4]	$ Mil	9.6	11.3
TN Removed (Ave.)[6]	lb N/d	1,340	1,490
Annual TN Removed (Ave.)[7]	lb N/yr	489,000	544,000
TN Cost[4,9]	$/lb N	2.0	2.1
TP Removal			
Capital[2,5]	$ Mil	0.6	0.6
Annual O&M[5]	$ Mil/yr	0.3	0.3
O&M PV[3,5]	$ Mil	2.7	3.0
Total PV[3,5]	$ Mil	3.3	3.6
TP Removed (Ave.)[6]	lb P/d	130	130
Annual TP Removed (Ave.)[7]	lb P/yr	47,000	48,000
TP Cost[5,9]	$/lb P	7.1	7.6

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
CEPT for P Removal • More organics and solids diverted to the digesters for additional biogas production • Less oxygen demand on the downstream activated sludge • Phosphorus reliably removed under peak flow scenarios	• Dependency on chemicals • Chemical costs
Increase the SRT • Improved secondary clarifier settleability due to longer SRT • Increased oxygen transfer efficiency with the fine-bubble diffuser • Increased TSS and BOD load reduction in the Secondary Clarifiers due to longer SRT • Reduced waste activated sludge yield • Improved contaminants of emerging concern removal	• Operating a more complex process • Additional energy demand • Foaming concerns • Might require alkalinity addition
Increase the RAS Return Rate • Alkalinity recovery from nitrogen reduction	• Additional energy demand by pumping more RAS

5 Sidestream Treatment

As previously described, OLSD WWTP was identified as a candidate for sidestream treatment. A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia/TN load reduction. TP load reduction is not recommended as the plant already removes TP by biological phosphorus removal. Thus, sidestream treatment for TP load reduction will most likely not decrease TP discharge loads.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification) including requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requires 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for OLSD.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements*
Feed Pumping (if necessary)	--
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--

* Sidestream treatment for TP discharge load reduction not recommended as previously discussed

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The nutrient loads under the 2015 Group Annual Report are used to illustrate the potential load reduction. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)[4]
Current Discharge[1]	lb/d	4,490	4,990	200
Discharge with Sidestream Treatment[2]	lb/d	3,420	3,920	200
Load Reduction[3]	lb/d	1,070	1,070	0
Load Reduction	%	24%	21%	0%
Annual Load Reduction	lb/yr	415,000	369,000	0

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. The plant already removes phosphorus so sidestream treatment will not further reduce P discharge loads.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP[7]
Capital[1]	$ Mil	19	--
Annual O&M	$ Mil/yr	0.5	--
Total Present Value[2]	$ Mil	30	--
NH4-N Load Reduction[3,5]	lb N/yr	415,000	--
TN Load Reduction[3,5]	lb N/yr	369,000	--
TP Load Reduction[4,5]	lb P/yr	--	--
NH4-N Cost [3,5,6]	$/lb N	2.4	--
TN Cost [3,5,6]	$/lb N	2.7	--
TP Cost [4,5,6]	$/lb P	--	--

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (TN load Removed (Ave.) times 365 days times 30-years))
7. The plant already removes phosphorus so sidestream treatment will not further reduce P discharge loads.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the OLSD plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. OLSD should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. The Level 2 treatment concept builds upon the optimization strategy with the addition of a Modified Ludzack-Ettinger (MLE) activated sludge process to treat primary effluent, expansion of the flow equalization (for wet weather events), and sidestream treatment using a deammonification technology as previously described in Section 5.

MLE was selected due its inherent ability to expand upon the optimization concept coupled with the ease to replace the mechanical aeration system with a fine-bubble aeration system (with blowers). The existing aeration basins would require converting the anaerobic selector to an anoxic zone coupled with expanding the selector volume. No carbon addition is required to meet the Level 2 effluent target of 15 mg/L TN.

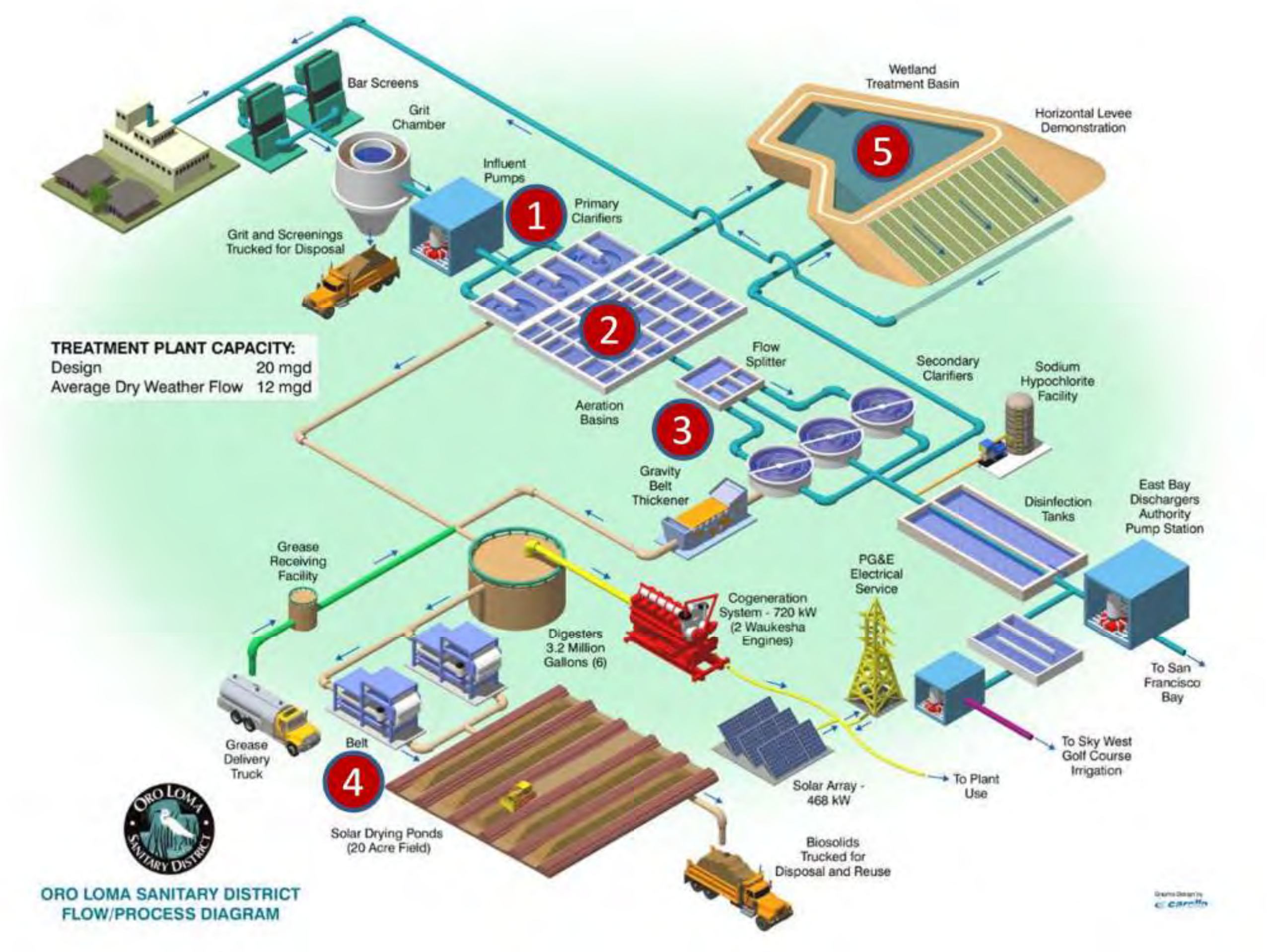

Figure 6-1. Level 2 Upgrade Concept for OLSD

(1) optimize metal salt dosing to enhance P removal, (2) increase the SRT, expand the basin volume, new fine-bubble aeration system, (3) mixed liquor pumping/piping, (4) sidestream treatment to reduce N, and (5) expand the flow equalization.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for optimization and Level 2. The additional facilities are expansion of the basins, converting the MLE to a 4-stage Bardenpho process, adding an external carbon source, and adding polishing filters and chemical feed facilities.

To meet the Level 3 effluent limits, the MLE would be expanded to a 4-stage Bardenpho process that has additional aerobic/anoxic zones to meet the lower TN limits. An additional carbon source, such as methanol, is required for the 4-stage Bardenpho to achieve the Level 3 nitrogen levels.

Polishing filters with chemical feed facilities are required to achieve the Level 3 phosphorus levels. These processes were selected because they are complimentary to the facilities recommended for Level 2, requiring modifications to the Level 2 facilities.

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs is provided in Table 6-1.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	--	--
Flow Equalization	Expand the existing flow equalization basins with additional volume beyond the Ecotone Project	Same as Level 2
Biological	• Modification to MLE • Replace mechanical aeration with fine-bubble aeration system (same as optimization but with more aeration capacity) • Air Piping • Alkalinity • No new secondaries	Same as Level 2 plus: • Expansion of aeration basin volumes • Convert the MLE to a 4-stage Bardenpho • External carbon source
Tertiary	--	• New Filters • Ferric Chloride and Polymer Chemical Feed • Rapid Mix and Flocculation Tanks
Biosolids or Sidestream	Deammonification Sidestream Treatment	Same as Level 2 plus: • Chemicals between digesters and dewatering to trim phosphorus

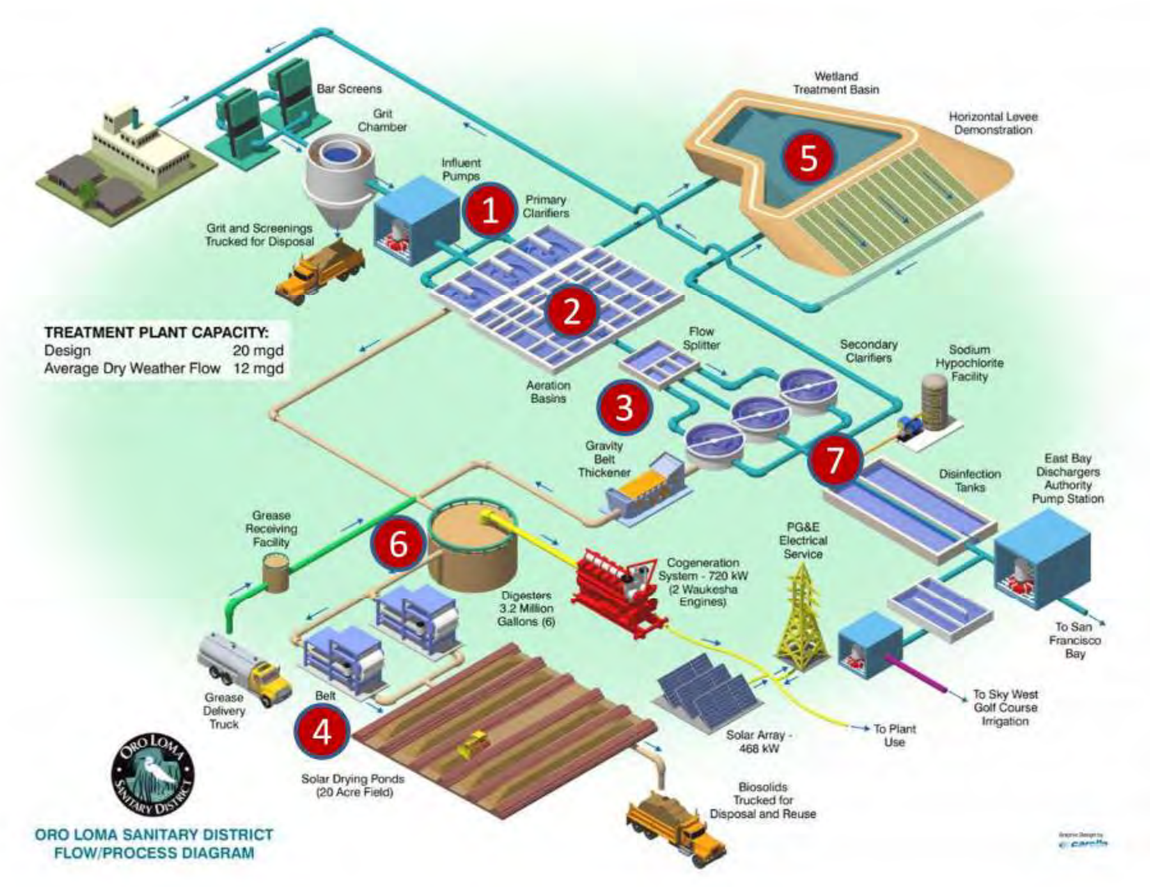

Figure 6-2. Level 3 Upgrade Concept for OLSD

(1) optimize metal salt dosing to enhance P removal, (2) increase the SRT, expand the basin volume, and fine-bubble aeration system, (3) mixed liquor pumping/piping, (4) sidestream treatment to reduce N, (5) expand the flow equalization, (6) add metal salt to dewatering return stream to remove P, and (7) tertiary filtration and chemical feed facilities to trim P.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) optimize metal salt dosing to enhance P removal, (2) increase the SRT, expand the basin volume, add fine-bubble aeration system, (3) mixed liquor pumping/piping, and (4) sidestream treatment to reduce N, and (5) expand flow equalization.

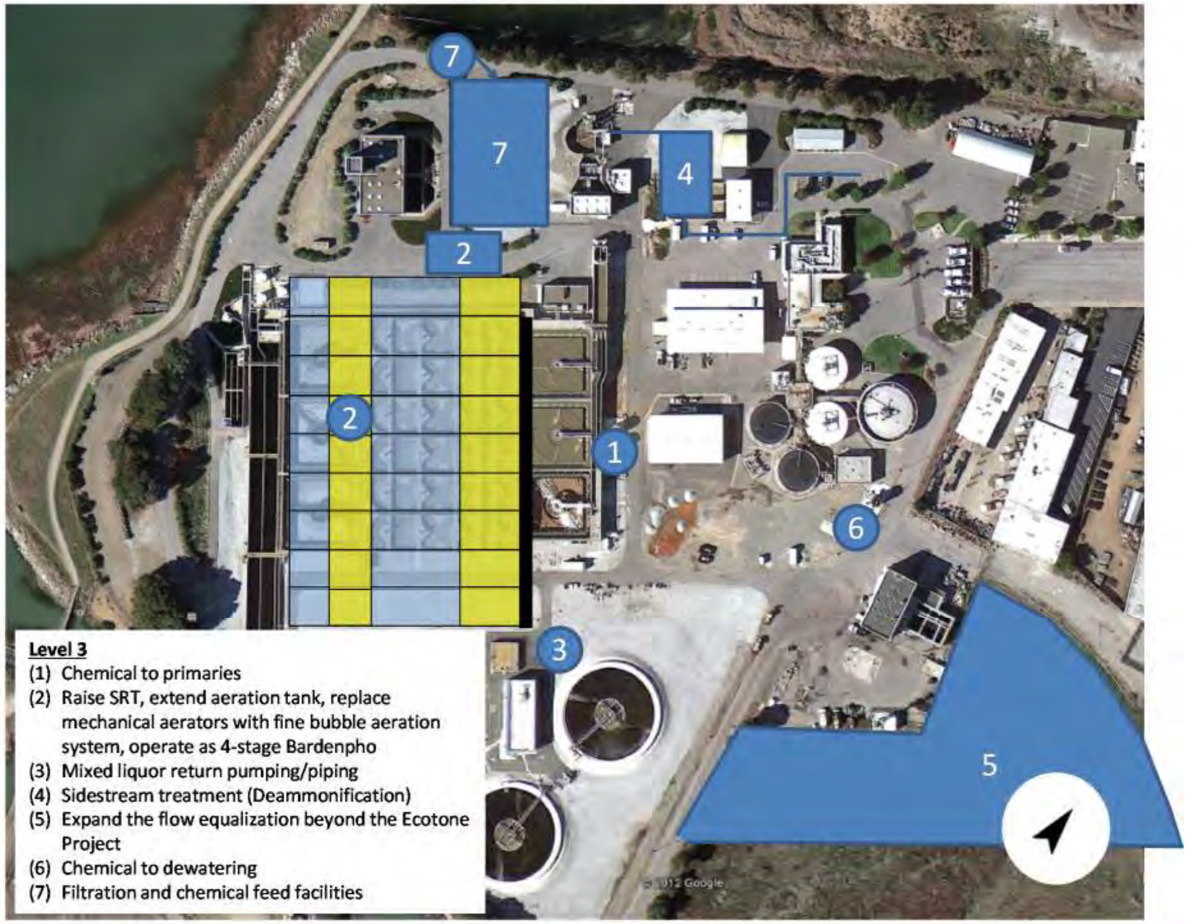

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) optimize metal salt dosing to enhance P removal, (2) increase the SRT, expand the basin volume, fine-bubble aeration system, (3) mixed liquor pumping/piping, (4) sidestream treatment to reduce N, (5) expand the flow equalization, (6) add metal salt to dewatering return stream to remove P, and (7) tertiary filtration and chemical feed facilities to trim P.

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	20.0	22.5	20.0	22.5
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	43	48	77	96
Annual O&M	$Mil/yr	0.1	0.3	0.9	2.0
O&M PV[3]	$ Mil	3	7	21	44
Total PV[3]	$ Mil	45	55	98	140
Unit Capital Cost	$/gpd	2.1	2.1	3.8	4.3
Unit Total PV	$/gpd	2.3	2.4	4.9	6.2
TN Removal					
Capital[2,4]	$ Mil	43	48	67	73
Annual O&M[4]	$ Mil/yr	0.2	0.4	0.9	1.7
O&M PV[3,4]	$ Mil	4	8	19	37
Total PV[3,4]	$ Mil	47	56	86	110
TN Removed (Ave.)[6]	lb N/d	2,320	2,460	2,970	3,750
Annual TN Removed (Ave.)[7]	lb N/yr	846,000	899,000	1,083,000	1,368,000
TN Cost[4,8]	$/lb N	1.8	2.1	2.7	2.7
TP Removal					
Capital[2,5]	$ Mil	0.6	0.6	11	23
Annual O&M[5]	$ Mil/yr	0.4	0.4	0.5	0.8
O&M PV[3,5]	$ Mil	8.4	9.2	12	17
Total PV[3,5]	$ Mil	9.0	9.8	23	40
TP Removed (Ave.)[6]	lb P/d	50	60	100	160
Annual TP Removed (Ave.)[7]	lb P/yr	17,300	20,900	35,100	57,400
TP Cost[5,8]	$/lb P	17	16	22	23

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing aeration basins and secondary clarifiers • Robust technology to absorb variability in flows and loads • Ability to reliably remove ammonia and TN • Reduced solids production • Reduced TSS and BOD discharge loading • Improved CEC removal compared to existing activated sludge	• New aeration system to learn, operate, and maintain (same system as optimization recommendation) • More complex to operate than existing activated sludge • New sidestream treatment facility to operate and maintain • More chemicals than current
Level 3	Same as Level 2 plus the following additional benefits: • Further enhanced CEC removal compared to Level 2 as any particulate bound CECs should be captured in the filters • Leverage and expand existing filter facility	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Safety from external carbon source (if methanol) • Additional unit process to operate (filters and sedimentation)

7 Nutrient Load Reduction by Other Means

The OLSD WWTP has an existing recycled water program that is employed year-round. This existing program has the effect of reducing nutrients discharged to the Bay. The WWTP currently recycles approximately 5,475 acre-feet per year (1,780 million gallons per year). There are no plans to further expand the recycled water program.

OLSD recently constructed a horizontal levee, known as the Ecotone Project. It is the first of its kind in the Bay Area. The horizontal levee has several anticipated benefits to the OLSD WWTP:

- Protection against sea level rise
- Reduces nutrient loads to the Bay by polishing in the levees wetland system
- Provides wet weather flow equalization
- Protects against flooding and habitat loss

The Ecotone Project performance will provide valuable information to assist other agencies in determining whether such a project is appropriate for them.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant.

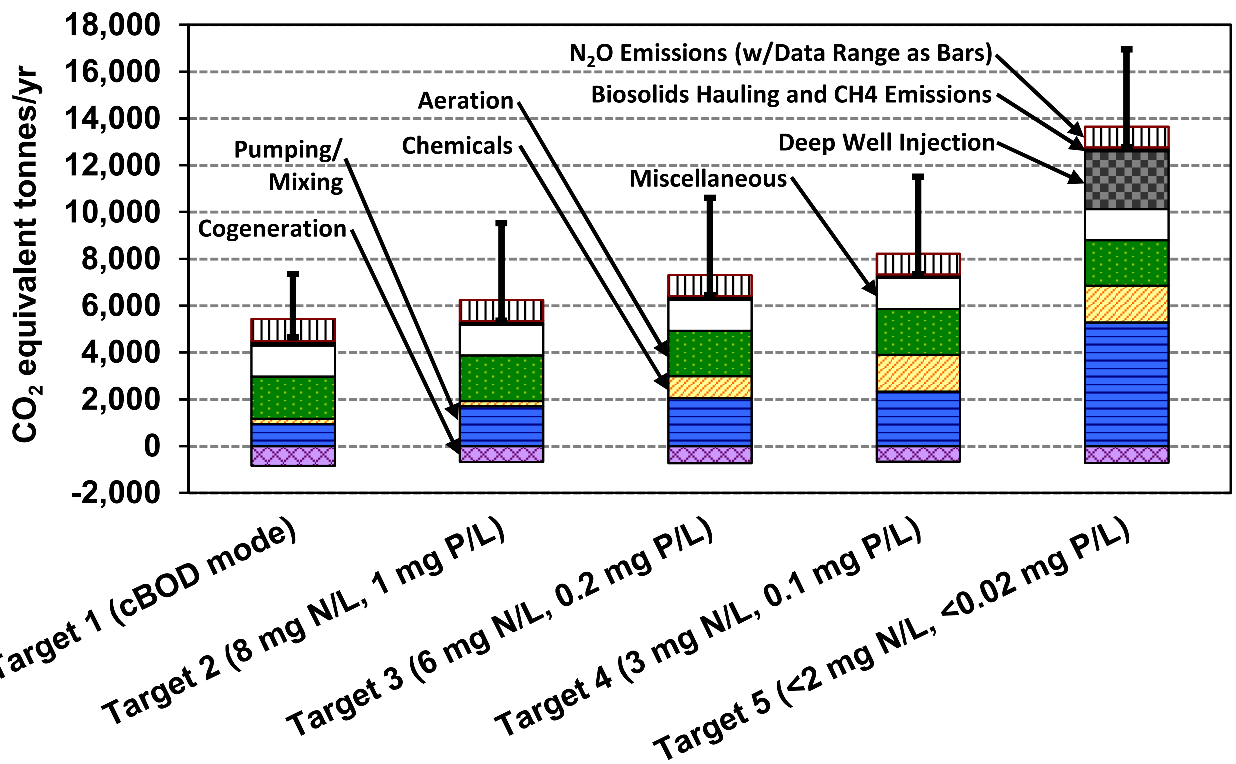

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

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[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	180	200	580	650	1,400	1,500	150
GHG Emissions Increase from Chemicals	MT CO_2/yr	60	60	100	110	1,200	1,300	10
GHG Emissions Increase Total	MT CO_2/yr	240	270	680	760	2,600	2,900	160
Unit GHG Emissions[2]	lb CO_2/MG	110	130	190	210	740	810	60
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	1	1	1	1	3	3	0.9
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	1	1	2	2	5	4	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	3	3	11	10	13	10	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at OLSD:

- Nutrient Removal using Granular Sludge – this could be used to phase out the biotower/activated sludge and/or MBR. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
    - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
    - Disadvantages: No installations in North America.
    - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the mechanical aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
    - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
    - Disadvantages: No installations in North America.
    - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.18

Palo Alto Regional Water Quality Control Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Palo Alto Regional Water Quality Control Plant

Palo Alto, CA

March 30, 2018
Final Report

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Executive Summary

The City of Palo Alto (Palo Alto) owns and operates the Palo Alto Regional Water Quality Control Plant located in Palo Alto, CA and discharges treated effluent to the South San Francisco Bay under a National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2009-0032, NPDES No. CA0037834). The plant has an average dry weather flow (ADWF) permitted capacity of 39 million gallons per day (mgd) and a peak permitted wet weather flow of 80 mgd.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[9]
Design Flow[11]	mgd	--	--	20.6	21.4	34.0	35.4	34.0	35.4	--
Flow to Bay[2,8]	mgd	20.5	20.5	20.5	20.5	27.2	27.2	27.2	27.2	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	30	30	40	40	40	40	40	40	--
TN[7]	lb N/d	5,200	5,200	5,590	5,590	3,620	3,400	2,540	1,360	--
TP	lb P/d	820	820	170	160	240	230	160	70	--
Costs[4,5]										
Capital	$ Mil	--	--	0.8	0.8	145	146	172	174	--
O&M PV	$ Mil	--	--	1.2	1.2	105	114	131	156	--
Total PV	$ Mil	--	--	2.0	2.0	250	260	303	330	--
Unit Costs[6]										
Capital	$/gpd	--	--	0.04	0.04	4.2	4.1	5.1	4.9	--
Total PV	$/gpd	--	--	0.1	0.1	7.3	7.3	8.9	9.3	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2016 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2016). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Assume 2 mg/L of dissolved organic nitrogen.
8. Level 2 and Level 3 effluent flows were projected by applying the current ratio of influent to effluent flows for dry season and year round. Influent flows were based build-out projections presented in the Long Range Facilities Plan (Carollo, 2012).
9. Not Applicable. The Palo Alto RWQCP was not considered for sidestream treatment because the plant currently incinerates solids. Sidestream flows do not have a high nutrient load.
10. Design flow shown for year round is the wet season average influent flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Add aluminum sulfate (alum) upstream of the primary clarifiers to remove total phosphorus. This is expected to meet Level 2 phosphorus loads. No optimization strategies were identified for nitrogen removal since removal would require significant capital improvements and/or construction of new structures. The existing infrastructure could not be repurposed for nitrogen removal.

The plant was not considered a candidate for sidestream treatment because solids are currently incinerated and sidestream flows at the plant do not contain high nutrient loads.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow follow the strategies identified in the City's Long-Range Facilities Plan (Carollo, 2012) and include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Alum and polymer addition upstream of primary clarifiers,
    b. Construct denitrification filters for treatment of approximately 70 percent of the secondary effluent (the remaining effluent bypasses the denitrification filters), and
    c. Construct storage and metering of an external carbon source.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Construction of additional denitrification filters.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $2.0 Mil for dry season optimization up to $330 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Palo Alto Regional Water Quality Control Plant (Palo Alto RWQCP) serves a population of about 220,000, which includes the Cities of Los Altos, Los Altos Hills, Palo Alto, Mountain View, and East Palo Alto Sanitary District. It is located at 2501 Embarcadero Way, Palo Alto, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 39 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The Palo Alto RWQCP currently discharges about 95% of the treated wastewater to South San Francisco Bay at latitude of 37º27' 30" N and longitude of 122º06' 37" W. About 5% of the treated wastewater is discharged through Renzel Marsh to the Matadero Creek at latitude of 37º26' 30" N and longitude of 122º06' 45" W. A small portion of flow is reused as Title 22 recycled water.

The Palo Alto RWQCP holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2014-0024, NPDES No. CA0037834). Table 2-1 provides a summary of the permit limitations that are specific to Palo Alto RWQCP under the NPDES permit, and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2014-0024; CA0037834)

Criteria	Unit	Average Dry Weather[1]	Average Monthly	Average Weekly	Maximum Daily	Peak
Flow	mgd	39[a]	---	---	---	80
cBOD	mg/L	---	10	---	20	---
TSS	mg/L	---	10	---	20	---
Total Ammonia, as N	mg/L	---	2.7	---	9.5	---

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

1. Current permitted capacity.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Palo Alto RWQCP. Both liquids processes and solids processes are shown. The Palo Alto RWQCP has primary clarifiers followed by trickling filters, nitrifying activated sludge for secondary treatment and dual media filtration for tertiary treatment. The facility currently meets the Level 2 and Level 3 ammonia objectives.

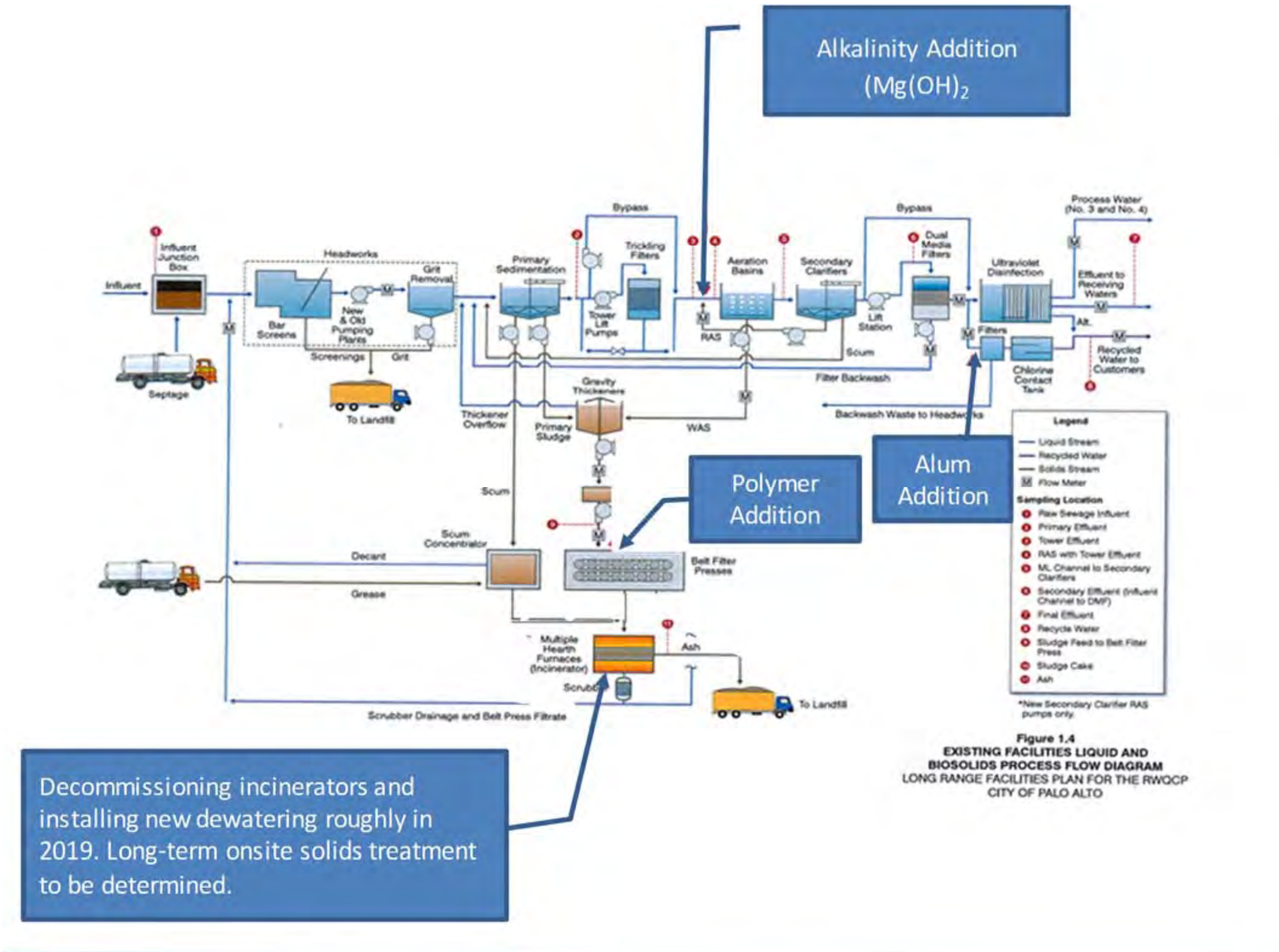

Figure 2-1. Process Flow Diagram for Palo Alto RWQCP

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Palo Alto RWQCP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	20.6	21.0	21.7	23.6
BOD	lb/d	48,200	49,700	52,400	53,700
TSS	lb/d	45,500	44,700	48,500	52,900
Ammonia	lb N/d	5,950	5,900	6,260	6,370
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	10,400	7,530	10,400	8,180
Total Phosphorus (TP)[4]	lb P/d	1,110	1,000	1,160	1,040
Alkalinity	lb $CaCO_3$/d	49,300	53,800	55,500	73,500
BOD	mg/L	280	290	290	280
TSS	mg/L	270	260	270	270
Ammonia	mg N/L	35	34	35	33
TKN[4]	mg N/L	61	44	58	43
TP[4]	mg P/L	6.5	6.1	6.5	6.0
Alkalinity	mg $CaCO_3$/L	290	310	310	370

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. TKN and TP data only available for July 2012 – June 2014.

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the Palo Alto RWQCP:

- The Facility's incinerators will be decommissioned by 2019. Raw sludge will be dewatered and hauled offsite. The City will reevaluate solids processing again in the future.
- Based on the findings and recommendations in the City's Long Range Facilities Plan (prepared in 2012), the City plans to rehabilitate the existing trickling filters.
- The Biosolids Facility Plan identified sidestream treatment to be constructed if digestion facilities are constructed.
- The City plans to increase recycled water deliveries from about 600/700 AFY to 950 AFY. However, the exact timing for increased recycled water deliveries is uncertain because the project is still in the planning stages. The City is also looking at the feasibility of doubling the

amount of treated effluent that is discharged to the Renzel Marsh Pond (and ultimately to Matadero Creek).

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the Palo Alto RWQCP.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Palo Alto RWQCP are presented in Table 3-1. The projected flow and load for the Palo Alto RWQCP in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow. The assumed 2025 values in Table 3-1 were compared to the 2020 load projections in the Palo Alto RWQCP Long Range Facilities Master Plan (October 2012) to confirm that the assumed values are appropriate.

3.2 Flow and Loading for Sidestream Treatment

The request for information included a series of questions to identify plants that are candidates for sidestream treatment. Palo Alto RWQCP is currently not a candidate for sidestream treatment because the facility incinerates primary and waste activated sludges. The solids return streams currently produced at the plant do not contain a high level of nutrients.

In the future, the facility intends to decommission their incinerators and possibly construct a dewatering and haul off facility. Long-term solids stabilization and handling is yet to be determined.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	20.6	21.0	21.8	23.5
BOD[4]	lb/d	55,400	57,100	60,500	61,700
TSS[4]	lb/d	52,400	51,300	56,000	60,600
Ammonia[4]	lb N/d	6,850	6,780	7,190	7,330
TKN[4,5]	lb N/d	8,400	8,660	9,180	9,360
TP[4]	lb P/d	1,280	1,150	1,340	1,200
Alkalinity	lb/d as $CaCO_3$	49,300	53,800	55,500	73,500
BOD	mg/L	320	330	330	310
TSS	mg/L	310	290	310	310
Ammonia	mg N/L	40	39	39	37
TKN[5]	mg N/L	49	49	50	48
TP	mg P/L	7.4	6.6	7.3	6.1
Alkalinity	mg/L as $CaCO_3$	290	310	310	370

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Load projections assume a 15 percent increase from current day conditions. No increase in flows was assumed.
5. There was limited TKN data; therefore, BOD peaking factors were used to estimate TKN loading for the different averaging periods

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. The ADW values are based on the 2062 flow and load projections from Palo Alto RWQCP's Long Range Facilities Plan (October 2012). The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the projected ADW conditions.

Table 3-2. Flow and Load for Facility Upgrades (Projected to 2062 ADW Conditions)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3,4]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	34.0	34.7	36.1	38.9
BOD	lb/d	69,100	71,200	87,000	88,600
TSS	lb/d	62,500	61,200	80,400	87,000
Ammonia	lb N/d	7,900	7,800	10,300	10,500
TKN[5]	lb N/d	12,100	12,400	13,200	13,400
TP	lb P/d	1,800	1,700	1,900	1,700
Alkalinity	lb/d as $CaCO_3$	81,500	88,900	91,700	121,400
BOD	mg/L	240	250	290	270
TSS	mg/L	220	210	270	270
Ammonia	mg N/L	28	27	34	32
TKN[5]	mg N/L	43	43	44	41
TP	mg P/L	6.5	5.7	6.4	5.3
Alkalinity	mg/L as $CaCO_3$	300	310	310	380

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. ADW conditions presented are based on the 2062 projections in the Long Range Facilities Plan (October 2012).
5. There was limited TKN data; therefore, BOD peaking factors were used to estimate TKN loading for the different averaging periods.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

The Palo Alto RWQCP currently nitrifies and already meets Level 2 and Level 3 ammonia levels. Three optimization strategies were identified during the Palo Alto RWQCP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. The three optimization strategies are described below.

- **Optimization Strategy 1:** Internal recycle of secondary effluent to the front of the plant.
  - ***Is it feasible?*** Yes, but significant capital improvements would be needed to implement this.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase N removal.
  - ***Result from analysis:*** There is uncertainty that returning secondary effluent to the front of the plant could be implemented without significant capital improvements at the facility.
  - ***Recommendation:*** Do not carry forward.

- **<u>Optimization Strategy 2:</u>** Increase effluent diversion to Renzel Marsh to achieve nitrogen removal.
  - ***Is it feasible?*** Uncertain, Palo Alto is currently reviewing the technical feasibility of increasing diversions to Renzel Marsh using the existing conveyance system.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Reduces discharges by diverting flows to the marsh and potentially achieving a reduction in total nitrogen.
  - ***Result from analysis:*** It is anticipated that significant capital expenses would be needed to implement this in addition to permitting efforts.
  - ***Recommendation:*** Do not carry forward.

- **<u>Optimization Strategy 3:</u>** Precipitate phosphorus with the addition of alum upstream of the primary clarifiers.
  - ***Is it feasible?*** Yes, alum could be added to influent wastewater upstream of the primary clarifiers to precipitate phosphorus and remove it in the primary clarifiers.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy only reduces phosphorus in the discharge.
  - ***Result from analysis:*** This strategy will be carried forward because it is an optimization that can be implemented to reduce total phosphorus in the effluent.
  - ***Recommendation:*** Carry forward

Strategy 3 is the best apparent way to reduce effluent phosphorus loads; no feasible strategies were identified to increase total nitrogen removal. The Palo Alto RWQCP already meets the Level 2 and Level 3 ammonia levels.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

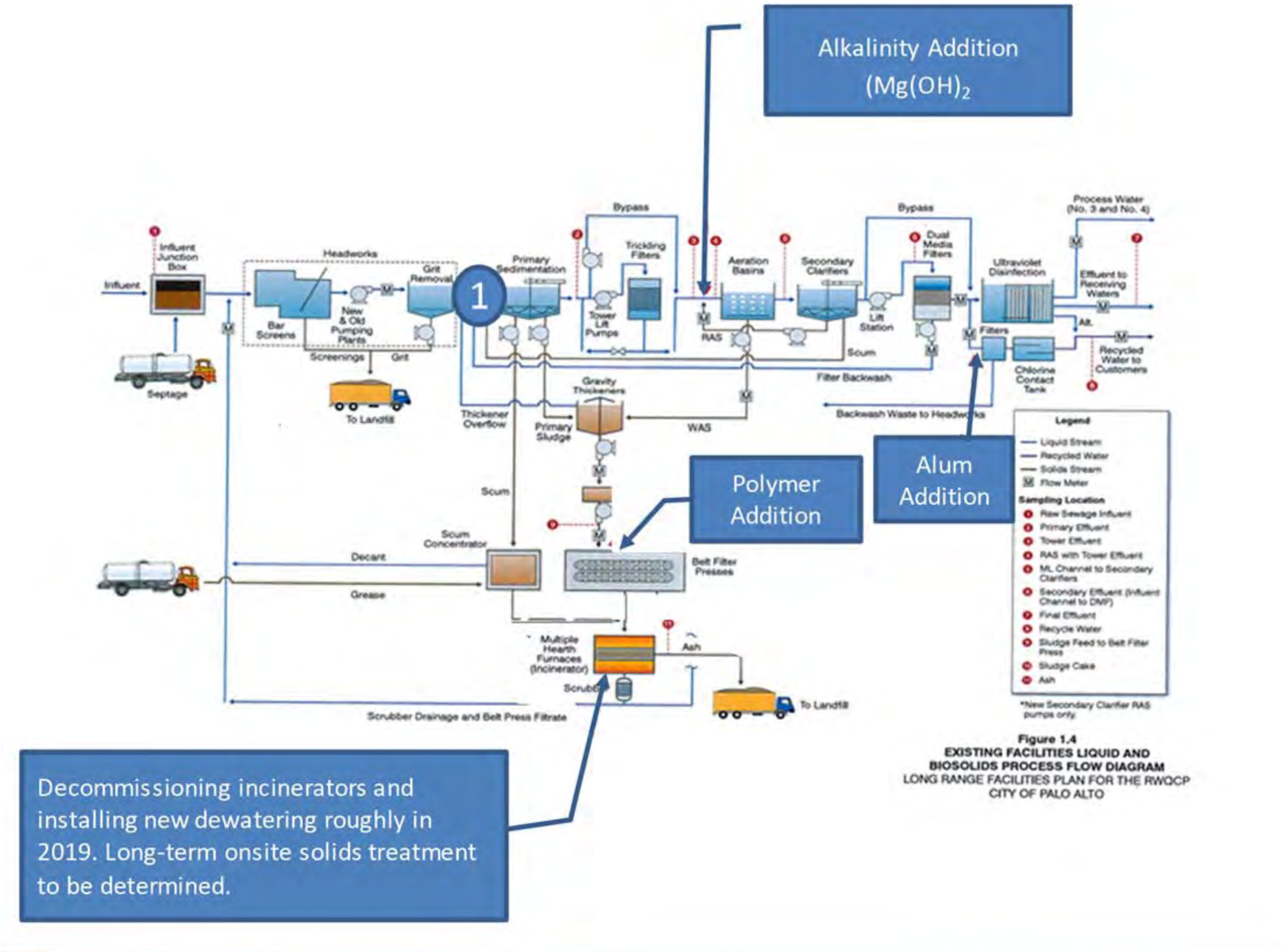

Figure 4-1. Optimization Concepts for the Palo Alto RWQCP

(1) provide alum addition upstream of primary clarifiers for P removal.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements (Increase alum addition upstream of the primary clarifiers to increase phosphorus removal)

Capital Elements	Operating Elements
Construct additional alum storage and chemical metering and piping facilities for chemical addition upstream of the primary clarifiers	Increase existing alum use at the plant; increased storage and metering facilities and extend piping to the headworks area.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The Palo Alto RWQCP shows improved phosphorus removal but no change in nitrogen removal. Ammonia removal would be consistent with current operation.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	40	40	5,590	5,590	880	880
Discharge with Opt. Strategy[1]	lb N or P/d	40	40	5,590	5,590	170	160
Load Reduction[2,3]	lb N or P/d	0	0	0	0	710	720
Load Reduction[2,3]	%	0%	0%	0%	0%	81%	82%
Annual Load Reduction	lb N or P/yr	0	0	0	0	258,000	262,000

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The plant currently fully nitrifies so optimization strategies would not further reduce ammonia discharge loads. Calculated nutrient reduction is zero for TN since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. The optimization strategy utilizes chemical addition upstream of the primary clarifiers for TP reduction. The addition of alum upstream of the primary clarifiers provides an additional benefit of reducing the organic load of the primary effluent. Therefore, the projected energy savings of the reduced organic load offsets the increased annual costs associated with alum addition. The costs in Table 4-3 do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce phosphorus; no optimization strategy was identified for nitrogen.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow[11]	mgd	20.6	21.4
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.8	0.8
Annual O&M	$ Mil/yr	0.1	0.1
Present Value O&M[3]	$ Mil	1.2	1.2
Present Value Total[3]	$ Mil	2.0	2.0
Unit Capital Cost[8]	$/gpd	0.04	0.04
Unit Total PV Cost[8]	$/gpd	0.1	0.1
TN Removal			
Capital[2,4]	$ Mil	0.0	0.0
Annual O&M[4]	$ Mil/yr	0.0	0.0
O&M PV[3,4]	$ Mil	0.0	0.0
Total PV[3,4]	$ Mil	0.0	0.0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0.8	0.8
Annual O&M[5]	$ Mil/yr	0.1	0.1
O&M PV[3,5]	$ Mil	1.2	1.2
Total PV[3,5]	$ Mil	2.0	2.0
TP Removed (Ave.)[6]	lb P/d	710	720
Annual TP Removed (Ave.)[7]	lb P/yr	258,000	262,000
TP Cost[5,9]	$/lb P	0.8	0.8

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen. The identified optimization strategy provides TP removal only.
11. Design flow shown for year round is the wet season average influent flow.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• More organics and solids are removed at the primary clarifiers and diverted to fuel the future solids handling facility. • Phosphorus reliably removed under peak flow scenarios • CEPT would reduce the organic loading to the trickling filters. As a result, the trickling filters could begin to nitrify which would seed the solids contact tank with nitrifiers and could reduce the oxygen demand in the activated sludge tanks.	• Dependency on chemicals • Chemical costs

5 Sidestream Treatment

As previously described, the RWQCP was not identified as a candidate for sidestream treatment because solids are currently incinerated and return streams at the plant do not contain high nutrient loads. The RWQCP was identified as a potential future candidate for sidestream treatment depending on the future solids handling processing.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Palo Alto RWQCP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The City recently prepared the Long-Range Facilities Plan (Carollo, 2012) which identified technologies for performing nutrient removal at the RWQCP. The RWQCP currently nitrifies and meets the Level 2 and Level 3 ammonia limits. The Long-Range Facilities Plan identified denitrification filters for total nitrogen removal. Based on discussions with the City, total nitrogen removal presented in this report is based on the findings and recommendations identified in the Long-Range Facilities Plan. The Palo Alto RWQCP could evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future. The Level 2 and Level 3 facility needs assume that the solids handling process is modified in the future to include anaerobic digesters and sludge dewatering.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 upgrades could be met by constructing denitrification filters downstream of the existing secondary process for nitrogen removal and implementing alum addition upstream of the primary clarifiers for phosphorus removal. Since complete denitrification is not necessary for Level 2, a portion of the nitrified effluent would be routed around the dentrification filters to the existing dual media filters and combined with the denitrification filter effluent. These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure (i.e. TF/AS processes). This technology selection is in accordance with the Long Range Facilities Plan (Carollo, 2012).

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Level 3 upgrades would require additional alum addition immediately upstream of denitrification filters since chemical addition upstream of filtration would be required to meet phosphorus levels. Additional denitrification filters and methanol use would be necessary to achieve Level 3 nitrogen levels. Because the media depth of the denitrification filters would be greater than the depth of the dual media filters, it was assumed that the existing dual media filters would be demolished and denitrification filters would be constructed at this location.

These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure (i.e. TF/AS processes). This technology selection is in accordance with the recent Long Range Facilities Plan (2012).

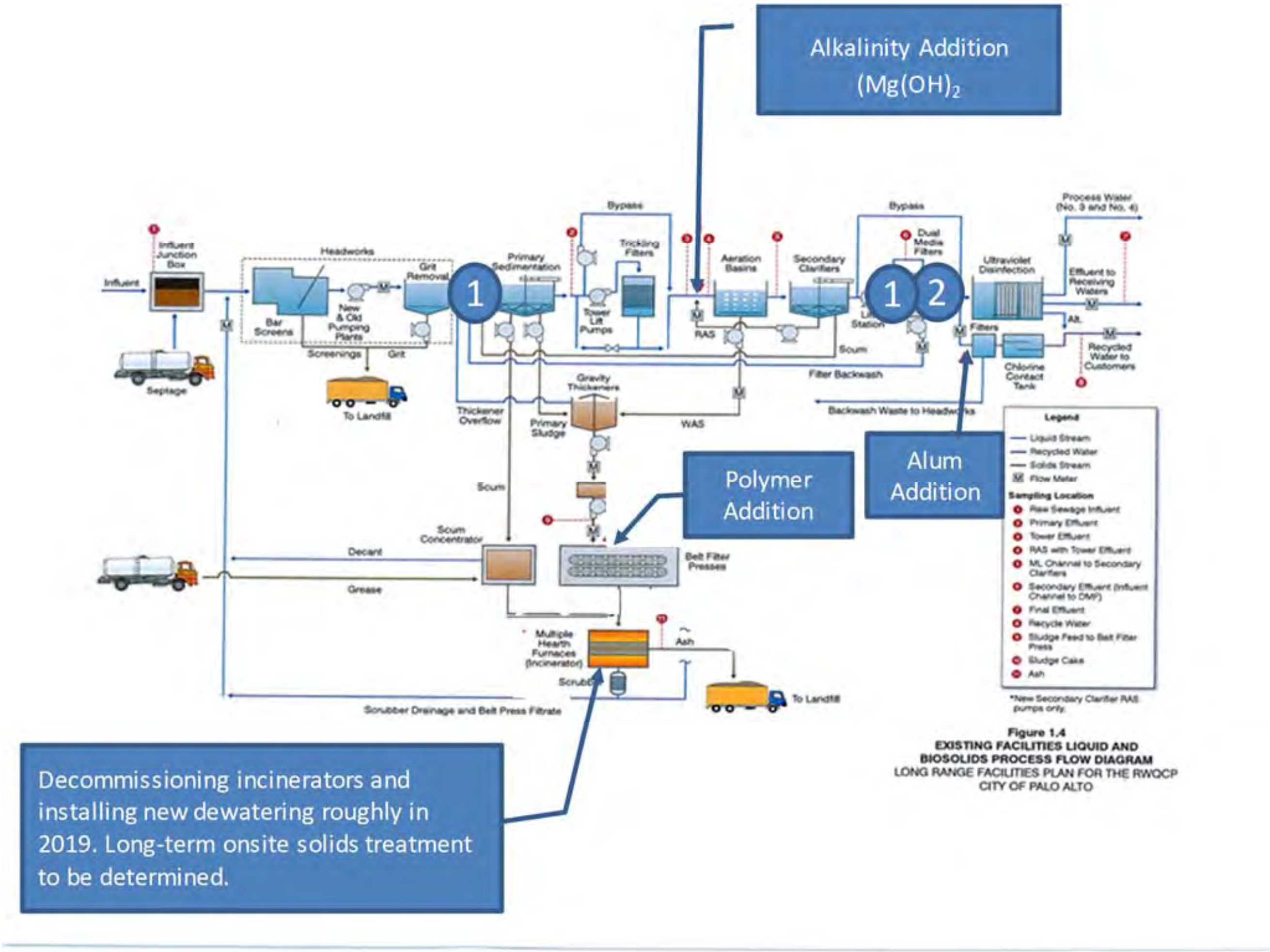

Figure 6-1. Level 2 Upgrade Concept for Palo Alto Regional Water Quality Control Plant

(1) add alum and polymer for P removal (2) construct new denitrification filters, and route approximately 30 percent of flow around denitrification filters (3) construct methanol addition facilities.

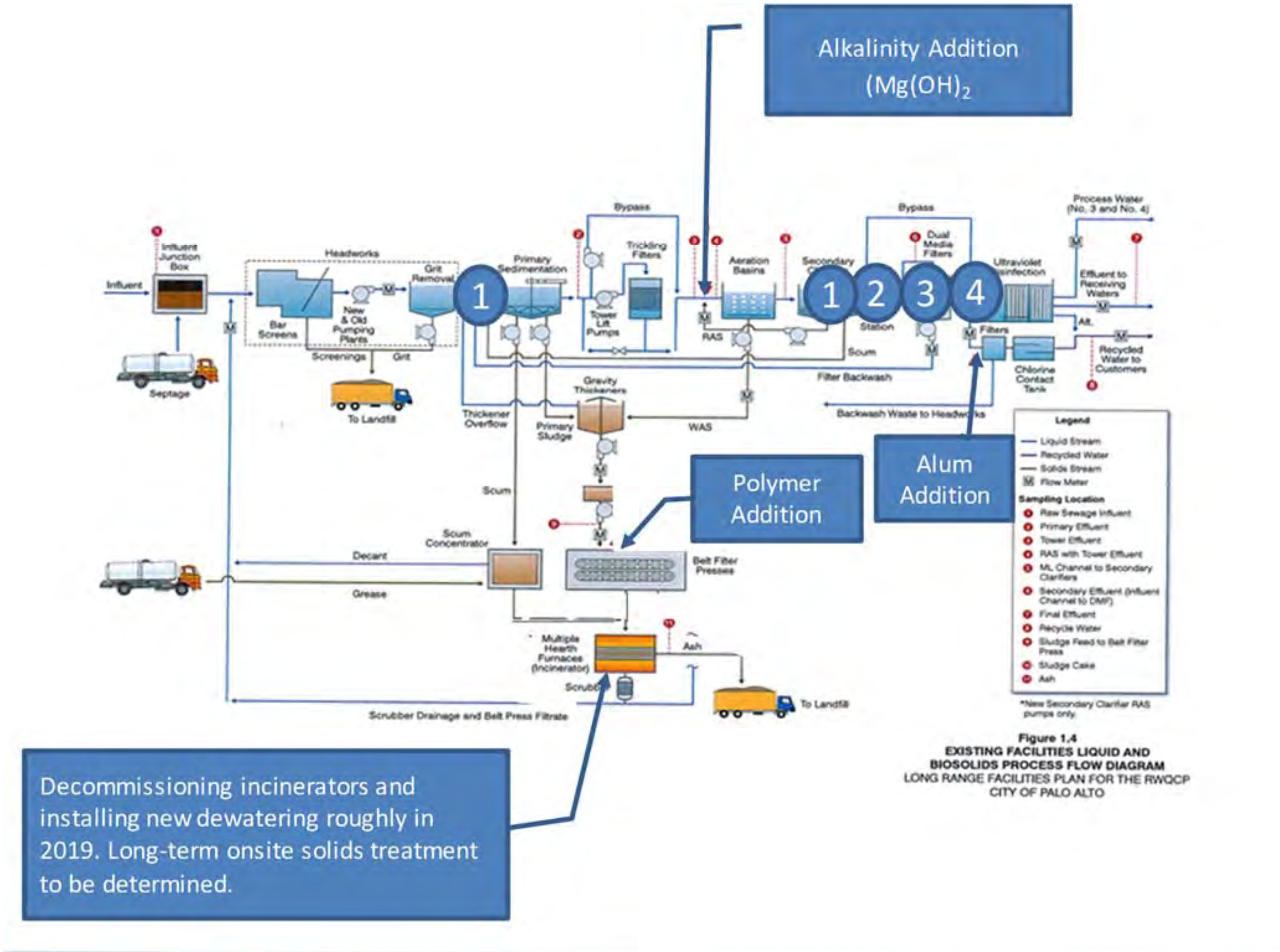

Figure 6-2. Level 3 Upgrade Concept for Palo Alto Regional Water Quality Control Plant

(1) add alum and polymer for P removal at the headworks and upstream of denitrification filters (2) route all secondary effluent to the denitrification filter feed pump station, (3) construct denitrification filters and backwash facilities (4) construct methanol addition facilities.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Alum and Polymer Chemical Feed	Same as Level 2
Secondary	--	--
Tertiary	• Denitrification Filters • Denitrification Filter Pump Station • Denitrification Backwash Facilities • External Carbon Source Chemical Feed	Same as Level 2 plus: • Additional Denitrification Filters • Additional External Carbon Source Chemical Feed • Additional Alum Chemical Feed

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

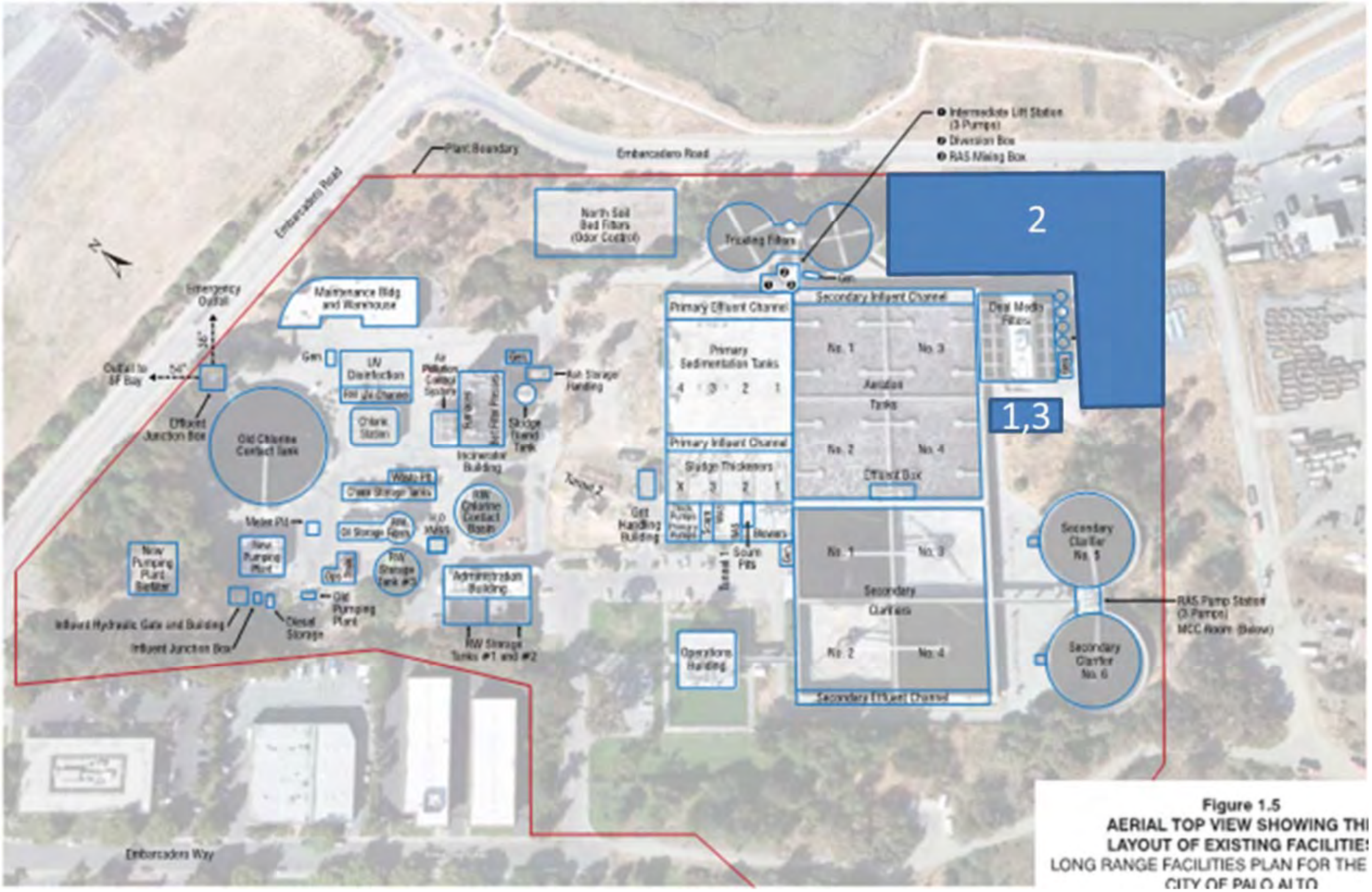

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) additional alum storage and metering facilities, (2) construct new denitrification filters and ancillary facilities, (3) construct methanol storage and metering facilities.

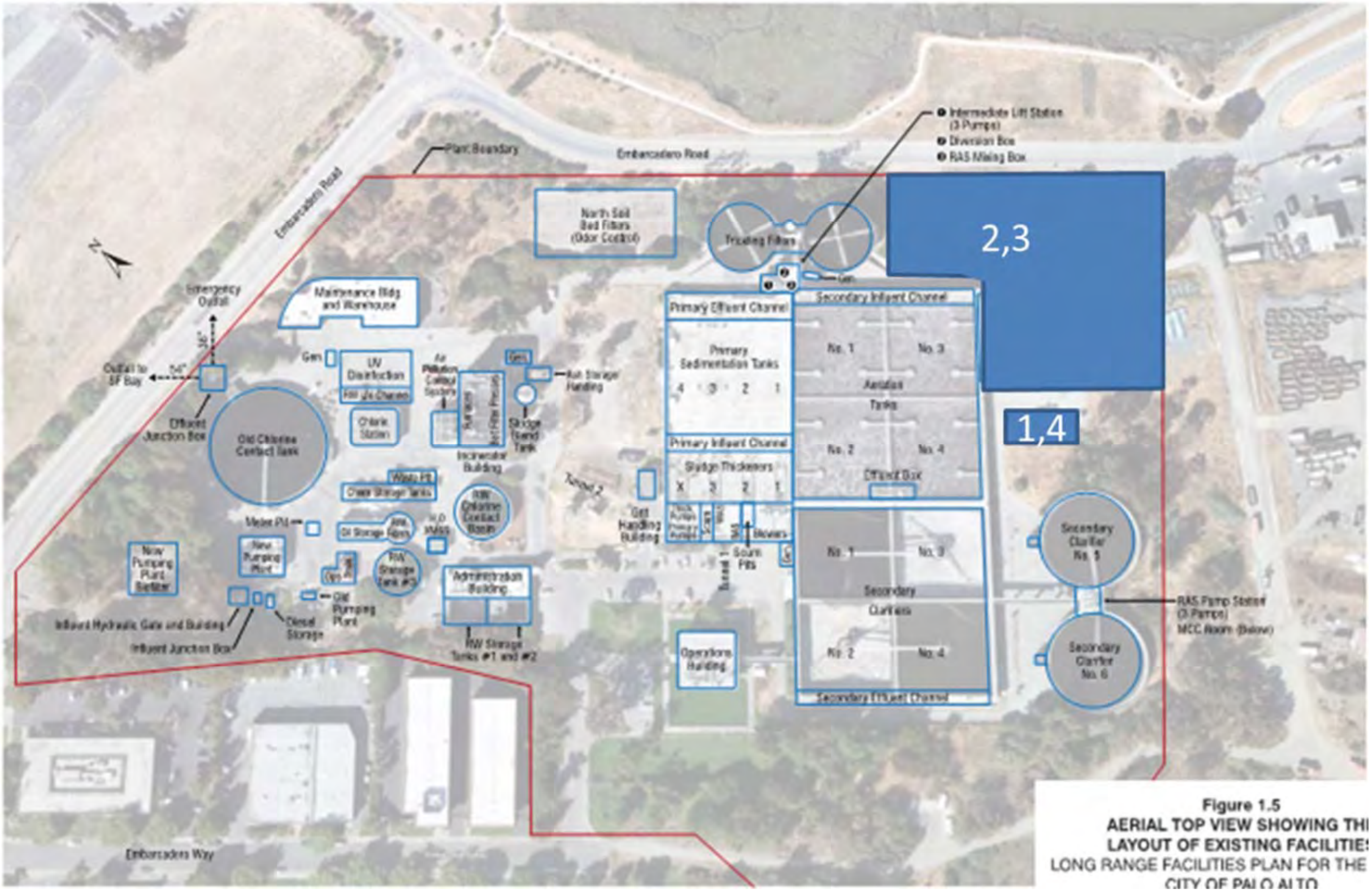

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) additional alum storage and metering facilities, (2) construct new denitrification filters and ancillary facilities, (3) demolish existing dual media filters, and (4) construct methanol storage and metering facilities.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow[10]	mgd	34.0	35.4	34.0	35.4
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	145	146	172	174
Annual O&M	$Mil/yr	4.7	5.1	5.8	7
O&M PV[3]	$ Mil	105	114	131	156
Total PV[3]	$ Mil	250	260	303	330
Unit Capital Cost	$/gpd	4.2	4.1	5.1	4.9
Unit Total PV	$/gpd	7.3	7.3	8.9	9.3
TN Removal					
Capital[2,4]	$ Mil	143	145	171	172
Annual O&M[4]	$ Mil/yr	4.3	4.5	5.2	6.1
O&M PV[3,4]	$ Mil	96	102	116	137
Total PV[3,4]	$ Mil	239	246	287	309
TN Removed (Ave.)[6]	lb N/d	2,550	2,770	3,630	4,810
Annual TN Removed (Ave.)[7]	lb N/yr	930,000	1,009,000	1,325,000	1,755,000
TN Cost[4,8]	$/lb N	8.6	8.1	7.2	5.9
TP Removal					
Capital[2,5]	$ Mil	1.2	1.4	16	30
Annual O&M[5]	$ Mil/yr	0.4	0.5	0.7	1.1
O&M PV[3,5]	$ Mil	10	12	17	24
Total PV[3,5]	$ Mil	11	13	33	53
TP Removed (Ave.)[6]	lb P/d	730	740	810	900
Annual TP Removed (Ave.)[7]	lb P/yr	265,000	270,000	295,000	328,000
TP Cost[5,8]	$/lb P	1.4	1.7	3.7	5.4

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.
10. Design flow shown for year round is the wet season average influent flow.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverages existing secondary process • Robust technology that can absorb variability in flows and loads • Processes can reliably remove TN and TP	• Denitrification filters are additional unit processes to operate • Safety issues associated with storage and use of external carbon source (if methanol) • High operating cost associated with methanol use • Increase in sludge production due to precipitation of phosphorus
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher operating costs associated with methanol use

7 Nutrient Removal by Other Means

The RWQCP has an existing recycled water program that is employed year-round. Recycled water is used for golf course irrigation, landscape irrigation, environmental enhancement, and internal use. This existing program has the effect of reducing nutrients discharged to the Bay. The RWQCP currently recycles approximately 1,200 acre-feet per year (400 million gallons per year), and potential plans could increase recycling to 3,000 acre-feet per year (1,000 million gallons per year) by 2045.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most

stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

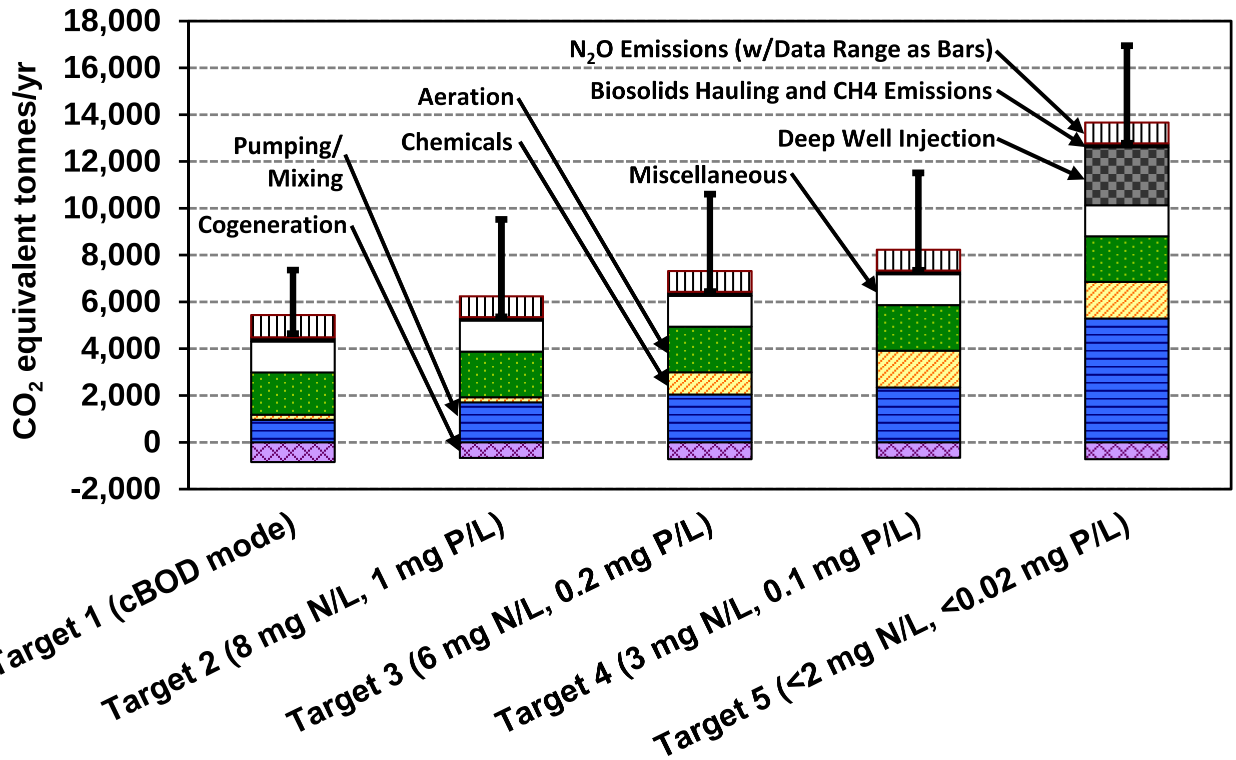

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	-100	-100	1,600	1,700	1,900	1,900	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	200	200	5,200	5,400	7,300	7,600	--
GHG Emissions Increase Total	MT CO_2/yr	100	100	6,800	7,100	9,200	9,500	--
Unit GHG Emissions[2]	lb CO_2/MG	30	30	1,200	1,200	1,600	1,600	--
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	--*	--*	--*	--*	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--**	--**	12	11	9	9	--
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	7	1	13	8	14	11	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. NA – Not applicable because the RWQCP is not a candidate for sidestream treatment.

* The plant currently nitrifies so there is no additional ammonia/TN load reduction and GHG emissions are not increased

** No removal, since no optimizations were identified for ammonia or nitrogen

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, three were identified for future consideration at the Palo Alto RWQCP. These are:

- Zeolite-Anammox –Final effluent would be subsequently treated by a zeolite-anammox process where ammonia sorbs to a zeolite bed and is subsequently removed through a deammonification process.
  - Advantages: Low energy process, minimal operational requirements, minimal instrumentation
  - Disadvantages: Large footprint, no full-scale installations
  - Potential Next Steps: Determine footprint requirements based on previous studies. If appropriate, consider pilot testing the zeolite-anammox process to determine benefits.
- Treatment Wetland –Final effluent would be subsequently treated through a constructed wetland where algae and aquatic plants take up nutrients and nitrogen removal is performed by biofilms.
  - Advantages: Low operations and maintenance, mature technology
  - Disadvantages: Large footprint
  - Potential Next Steps: Determine footprint requirements based on typical wetlands design. Consider pilot testing a small-scale constructed wetland or pilot testing at Renzel Marsh to determine benefits.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit to SVCW is it has the potential to reduce the basin volume for Levels 2 or 3. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN and TP
  - Disadvantages: No installations in North America
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost. See Table 1 below.

The unit costs for power, chemicals, and labor are shown in Table 2 below. A common unit cost basis for all plants in the study was selected this analysis.

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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City of Petaluma

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

City of Petaluma

Petaluma, CA

May 18, 2018
Final Report

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Executive Summary

The City of Petaluma Ellis Creek Water Recycling Facility (Petaluma WRF) discharges to Petaluma River that is connected to San Pablo Bay. It is located at 3890 Cypress Drive, Petaluma, CA 94954 and it serves about 25,300 service connections throughout Petaluma and Penngrove. The plant has average dry weather flow (ADWF) design capacity of 6.7 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season[8]	Current Year Round[8]	Opt. Dry Season[3,8,9]	Opt. Year Round[3,8,9]	Level 2 Dry Season[3,8]	Level 2 Year Round[3,8]	Level 3 Dry Season[3,8]	Level 3 Year Round[3,8]	Side-stream[7,8]
Design Flow	mgd	--	--	--	--	6.7	8.0	6.7	8.0	--
Flow to Bay[2]	mgd	--	3.7	--	3.7	--	4.3	--	4.3	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	--	10	--	10	--*	20	--*	20	20
TN	lb N/d	--	90	--	90	--*	110	--*	110	110
TP	lb P/d	--	60	--	60	--*	40	--*	10	37
Costs[4,5]										
Capital	$ Mil	--	--	--	--	34**	34**	38**	40**	0.4
O&M PV	$ Mil	--	--	--	--	--*	--*	--*	1.4	1.3
Total PV	$ Mil	--	--	--	--	34**	34**	38**	42**	1.7
Unit Costs[6]										
Capital	$/gpd	--	--	--	--	5.1	4.3	5.7	5.0	--
Total PV	$/gpd	--	--	--	--	5.1	4.3	5.7	5.2	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Based on only adding sidestream treatment. No additional liquid stream treatment capacity facilities are included as in the upgrades.
8. Discharge is prohibited May 1 through October 20, except when the facility inflow exceeds the recycled water distribution and storage system capacity.
9. The plant is already optimized and performing nutrient removal so no nutrient optimization concepts were recommended.

* The O&M costs are anticipated to be similar to current.

** The proposed facilities are based on adding treatment capacity as Petaluma is already meeting the Level 3 upgrade levels for ammonia and TN.

The upgrade concentration levels are as follows:

- Level 2: Ammonia of 2 mg N/L, Total Nitrogen of 15 mg N/L, and Total Phosphorus of 1 mg P/L.
- Level 3: Ammonia of 2 mg N/L, Total Nitrogen of 6 mg N/L, and Total Phosphorus of 0.3 mg P/L.

Petaluma is already meeting Level 3 levels for ammonia and total nitrogen. The proposed facilities are based on adding treatment capacity to allow the same level of nutrient removal if the plant flows reach the permitted capacity, and industrial loads increase at the current rate. An operational modification or new facilities would be required to meet the total phosphorus targets. The additional capacity might not be required if industry loading rates decrease. Capital costs, operation and maintenance (O&M) costs and unit costs were developed for each strategy.

The plant was originally designed for nutrient removal. As a result, the plant is already optimized for nutrient removal and no additional optimization strategies are recommended.

A potential sidestream phosphorus load reduction strategy would be metal salt addition to the digested biosolids upstream of dewatering. This strategy would precipitate out the phosphorus with the cake.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Add a third oxidation ditch and secondary clarifier to provide additional treatment capacity.
    b. Add metal salt chemical feed facilities for P precipitation to the secondary clarifiers.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2 to provide additional treatment capacity, plus
    b. Add filtration facilities to reduce total phosphorus loads, and
    c. Add metal salt chemical feed facilities at the filters to reduce total phosphorus loads.

As shown in Table ES-1, the present value costs range from $34 Mil for dry season Level 2 treatment up to $42 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The City of Petaluma Ellis Creek Water Recycling Facility (Petaluma WRF) discharges to Petaluma River that is connected to San Pablo Bay. It is located at 3890 Cypress Drive, Petaluma, CA 94954 and it serves about 25,300 service connections throughout Petaluma and Penngrove. The plant has average dry weather flow (ADWF) design capacity of 6.7 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

Petaluma WRF holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2016-0014. Table 2-1 provides a summary of the permit limitations but is not intended to provide a complete list of constituent limitations in the NPDES permit. Discharge is prohibited May 1 through October 20, except when the facility inflow exceeds the recycled water distribution and storage system capacity.

Table 2-1. NPDES Permit Limitations (Order No. R2-2016-0014; CA0037810)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	6.7	--	--	--
BOD	mg/L	--	30	45	--
TSS	mg/L	--	30	45	--
Ammonia, Total	mg N/L	--	3.0	--	8.0

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for Petaluma WRF. Both liquids processes and solids processes are shown. Facility influent is treated by screening and grit removal, activated sludge (oxidation ditches), and clarification. After clarification, some of the water is pumped to the Discharger's tertiary treatment system (flocculation, filtration, and UV disinfection), and subsequently recycled. Remaining flows are directed through a series of oxidation ponds and constructed wetlands for additional biological treatment. After the treatment wetlands, the water is chlorinated and then flows to either polishing wetlands or a chlorine contact chamber and dechlorination process. Oxidation ditches provide long retention time to achieve nitrogen removal. Solids are thickened, anaerobically digested and dewatered.

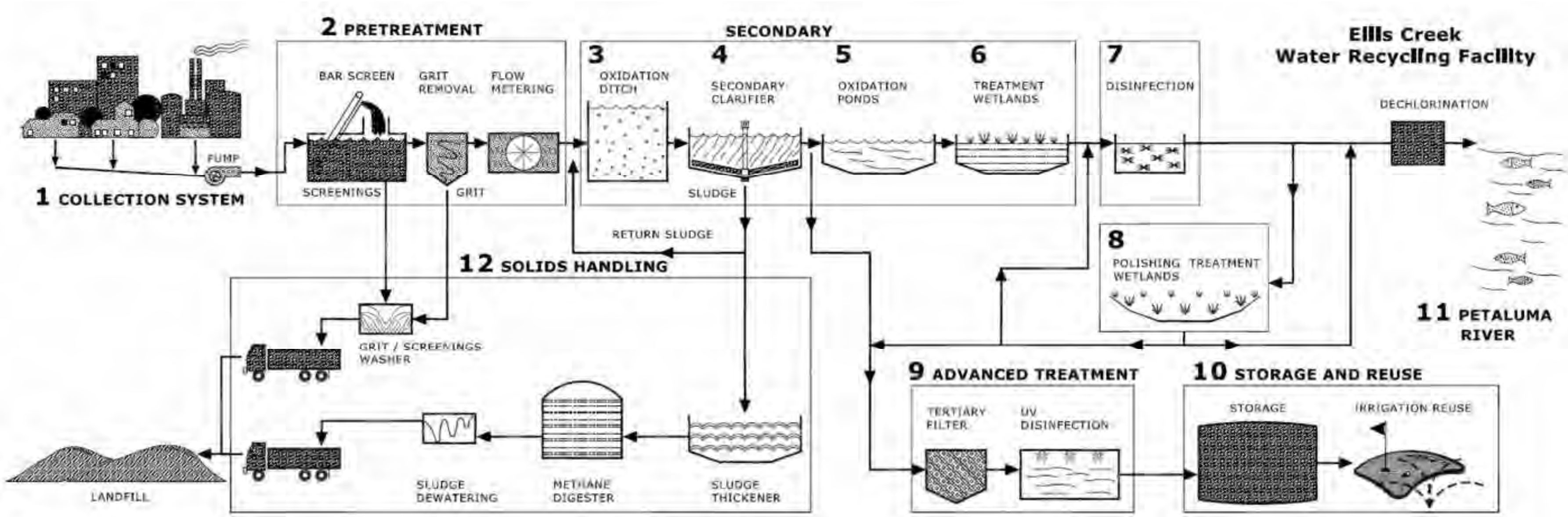

Figure 2-1. Process Flow Diagram for Petaluma WRF

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Petaluma WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	4.7	5.2	5.0	8.0
BOD	lb/d	12,600	14,500	14,100	18,000
TSS	lb/d	10,000	11,800	11,500	16,100
Ammonia	lb N/d	1,300	1,400	1,600	1,900
Total Kjeldahl Nitrogen (TKN)	lb N/d	2,100	2,400	2,600	2,900
Total Phosphorus (TP)	lb P/d	490	380	490	330
Alkalinity	lb $CaCO_3$/d	13,200	13,500	14,200	14,400
BOD	mg/L	324	335	339	271
TSS	mg/L	257	273	277	243
Ammonia	mg N/L	33	32	38	29
TKN	mg N/L	54	55	63	44
TP	mg P/L	12.6	8.8	11.8	5.0
Alkalinity	mg $CaCO_3$/L	339	312	341	217

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

Petaluma is not currently planning any nutrient removal projects, however they are considering a capacity improvement that would also provide nutrient capacity benefits. Due to high influent BOD loads, Petaluma is considering options that may include the addition of primary clarifiers or adding a third oxidation ditch.

2.5 Pilot Testing

The Petaluma WRF has not pilot tested any technologies to reduce nutrient loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The plant is designed for nutrient removal. As a result, the plant is already optimized for nutrient removal and no additional optimization strategies are recommended at current flows and loads.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided, it was determined that Petaluma may be a candidate for sidestream treatment to treat the phosphorus load from the screw press filtrate.

Additional sampling for the sidestream was performed in July, 2015. The sampling results were projected forward to the permitted capacity for use in the sidestream treatment evaluation. The sidestream flows and loads for the permitted capacity are provided in Table 3-1. The permitted capacity flows and loads were used in the facility sizing.

Table 3-1. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Projected to Permitted Flow Capacity
Sidestream Flow[1]	mgd	0.03	0.04
Ammonia	lb N/d	330	480
TKN	lb N/d	870	1,250
TN[2]	lb N/d	870	1,250
OrthoP	lb P/d	180	250
TP	lb P/d	70	110
Alkalinity	lb $CaCO_3$/d	1,100	1,600
Ammonia	mg N/L	1,290	1,290
TKN	mg N/L	3,370	3,370
TN[1]	mg N/L	3,400	3,400
OrthoP	mg P/L	680	680
TP	mg P/L	280	280
Alkalinity	mg/L as CaCO3	4,200	4,200

1. Limited to screw press filtrate.
2. It was assumed that TKN = TN.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Permitted Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	6.7	7.4	7.2	11.4*
BOD	lb/d	18,100	20,800	20,200	25,800
TSS	lb/d	14,400	17,000	16,500	23,200
Ammonia	lb N/d	1,800	2,000	2,300	2,800
TKN	lb N/d	3,000	3,400	3,800	4,200
TP	lb P/d	700	550	700	480
Alkalinity	lb/d as $CaCO_3$	18,900	19,400	20,400	20,700
BOD	mg/L	324	335	339	271
TSS	mg/L	257	273	277	243
Ammonia	mg N/L	33	32	38	29
TKN	mg N/L	54	55	63	44
TP	mg P/L	12.6	8.8	11.8	5
Alkalinity	mg/L as $CaCO_3$	339	312	341	217

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

* The permitted design flow is 12 mgd. The listed value represents the year round maximum month daily average value for sizing unit processes governed by load.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy. The Petaluma WRF was originally designed for nutrient removal. The Petaluma WRF is producing water that meets Level 3 targets for nitrogen and ammonia, and nearly meeting total phosphorus targets. Thus, there are no optimization projects identified.

5 Sidestream Treatment

As previously described, the Petaluma WRF was identified as a potential candidate for sidestream treatment for total phosphorus load reduction.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a metal salts/solids separation facility is recommended for total phosphorus load reduction. While the plant already removes a portion of total phosphorus loads, implementation of chemical precipitation of phosphorus in the sidestream is an opportunity to reliably trim the phosphorus load. Total nitrogen load reduction is not recommended as the plant already reliably removes ammonia and total nitrogen.

The removal of total phosphorus from the sidestream relies upon metal salt dosing either upstream of the screw press or on screw press filtrate. If the former, precipitate will be captured with cake leaving the screw press. If the latter, precipitate would be captured in the liquid stream solids separation processes. This will require a metal salt chemical feed facility to implement. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. Additionally, the use of a metal salt should also reduce the dewatering polymer demand if dosed before the screw press. The solids separation can occur in a stand-alone sidestream tank, simultaneously with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary or secondary clarifiers).

Another option to consider for eliminating the phosphorus recycled stream load is recovery via struvite precipitation from digested biosolids. This process produces a useful byproduct (struvite crystals) that can be sold economically. The finances are typically more attractive for larger plants (>40 mgd). It is recommended that the Petaluma WRF evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant if phosphorus load reduction is required in the future. There are O&M and capital costs associated with struvite recovery that may exceed any economic value of struvite.

Table 5-1 presents the estimated nutrient load reductions based on the sidestream treatment described above. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-1. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d) *	TN (lb N/d) *	TP (lb P/d)
Discharge under Current Operating Mode[1]	lb/d	20	110	74
Discharge with Sidestream Treatment[1]	lb/d	20	110	37
Load Reduction[2]	lb/d	0	0	37
Load Reduction[2]	%	0%	0%	50%
Annual Load Reduction[3]	lb/yr	0	0	7,220

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge over dry and wet seasons. Discharge is prohibited May 1 through October 20, except when the facility inflow exceeds the recycled water distribution and storage system capacity.

* Sidestream treatment for Ammonia/TN discharge load reduction not recommended as previously discussed.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-2. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-2. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

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Table 5-2. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN*	TP
Capital[1]	$ Mil	--	0.4
Annual O&M[2]	$ Mil/yr	--	0.06
Total Present Value[2]	$ Mil	--	1.7
NH4-N Load Reduction[3,5]	lb N/yr	--	--
TN Load Reduction[3,5]	lb N/yr	--	--
TP Load Reduction[4,5]	lb P/yr	--	7,220
NH4-N Cost[3,6]	$/lb N	--	--
TN Cost[3,6]	$/lb N	--	--
TP Cost[4,6]	$/lb P	--	7.8

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

* Sidestream treatment for Ammonia/TN discharge load reduction not recommended as previously discussed.

6 Nutrient Reduction Upgrades

The Petaluma WRF is producing water that meets Level 2 and 3 targets for nitrogen and ammonia, and nearly meeting total phosphorus targets. An operational modification or new facilities would be required to meet the total phosphorus targets. While the plant is reducing nutrient loads, additional capacity would likely be required in the future to maintain similar effluent quality if industry trends continue.

There are several technologies that could be applied at the Petaluma WRF to increase capacity. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. Petaluma should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades used to increase treatment capacity and continue to meet the Level 2 ammonia and total nitrogen discharge targets included the addition of a third oxidation ditch and secondary clarifier. A ditch and secondary clarifier were used as it represents a known technology to the operations staff and the existing ditches have reliably removed ammonia and total nitrogen. Furthermore, an oxidation ditch lends itself to the more stringent Level 3 nutrient discharge targets.

Adding metal salt chemical feed facilities at the secondary clarifiers is recommended for P precipitation. A process flow diagram for Level 2 upgrades is presented in Figure 6-1. An alternative to adding metal salt at the secondary clarifiers is P precipitation of the screw press centrate as described in the Section 5. The analysis is based on the former with metal salt addition to the secondary clarifiers.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2. In addition to those listed for Level 2, Level 3 would add filtration and metal salt chemical feed facilities at the new filters to further reduce total phosphorus. The City is planning an expansion of its tertiary recycled water production capacity, including doubling filtration capacity.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	--	--
Biological	• Add a third oxidation ditch to increase treatment capacity • Add a third secondary clarifier to increase treatment capacity • Add metal salt chemical feed facilities to secondary clarifiers	Same as Level 2
Tertiary	--	• Add additional filters* • Add metal salt chemical feed facilities
* City already in design for additional filter capacity		

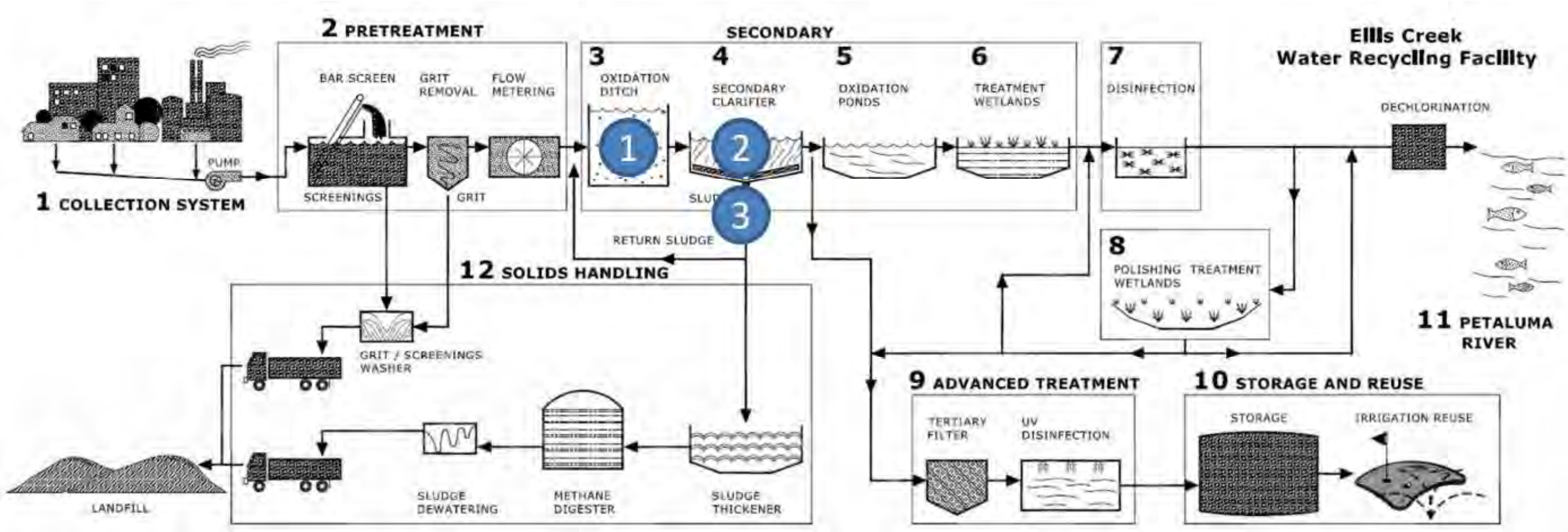

Figure 6-1. Level 2 Upgrade Concepts for Petaluma WRF

(1) Add a third oxidation ditch to increase treatment capacity, (2) add a third secondary clarifier to increase treatment capacity, and (3) add metal salt chemical feed facilities to secondary clarifiers

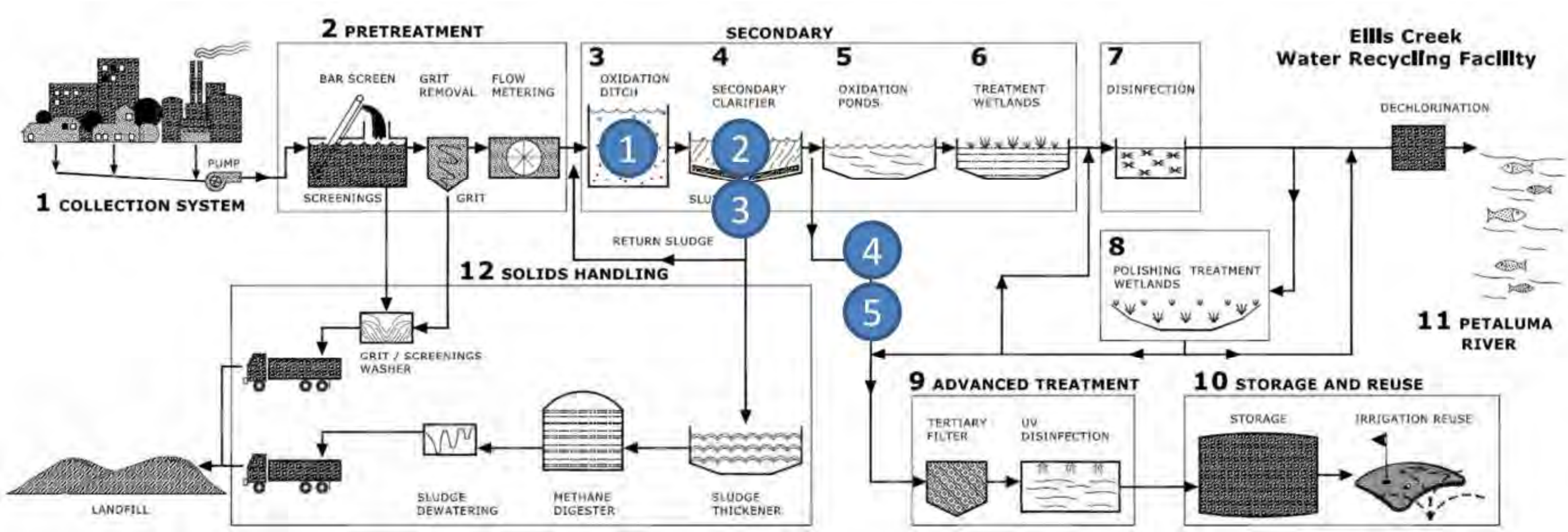

Figure 6-2. Level 3 Upgrade Concepts for Petaluma WRF

(1) Add a third oxidation ditch to increase treatment capacity, (2) add a third secondary clarifier to increase treatment capacity, (3) add metal salt chemical feed facilities to secondary clarifiers, (4) add additional filters, and (5) add metal salt chemical feed facilities to filters

Figure 6-3. Level 2 Upgrade Aerial Layouts for Petaluma WRF

(1) Add a third oxidation ditch to increase treatment capacity, (2) add a third secondary clarifier to increase treatment capacity, and (3) add metal salt chemical feed facilities to secondary clarifiers

Figure 6-4. Level 3 Upgrade Aerial Layouts for Petaluma WRF

(1) Add a third oxidation ditch to increase treatment capacity, (2) add a third secondary clarifier to increase treatment capacity, (3) add metal salt chemical feed facilities to secondary clarifiers, (4) add additional filters, and (5) add metal salt chemical feed facilities to filters

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent targets are summarized in Table 6-2.

Table 6-2. Estimated Capital and O&M Costs for TN and TP Upgrades

Parameter	Unit	Level 2 Dry Season[1,9,**]	Level 2 Year Round[1,9,**]	Level 3 Dry Season[1,9,**]	Level 3 Year Round[1,9,**]
Design Flow	mgd	6.7	8.0	6.7	8.0
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	34	34	38	40
Annual O&M	$Mil/yr	--*	--*	--*	0.06
O&M PV[3]	$ Mil	--*	--*	--*	1.4
Total PV[3]	$ Mil	33	33	39	42
Unit Capital Cost	$/gpd	5.1	4.3	5.7	5.0
Unit Total PV	$/gpd	5.1	4.3	5.7	5.2
TN Removal[9]					
Capital[2,4]	$ Mil	34	34	34	34
Annual O&M[4]	$ Mil/yr	--*	--*	--*	--*
O&M PV[3,4]	$ Mil	--*	--*	--*	--*
Total PV[3,4]	$ Mil	34	34	34	34
TN Removed (Ave.)[6]	lb N/d	--**	--**	--**	--**
Annual TN Removed[7]	lb N/yr	--**	--**	--**	--**
TN Cost[4,8]	$/lb N	--**	--**	--**	--**
TP Removal					
Capital[2,5]	$ Mil	11	11	15	17
Annual O&M[5]	$ Mil/yr	--*	0.01	0.05	0.13
O&M PV[3,5]	$ Mil	--*	0.11	1.2	2.9
Total PV[3,5]	$ Mil	11	11	16	20
TP Removed (Ave.)[6]	lb P/d	--	40	--	60
Annual TP Removed[7]	lb P/yr	--	14,000	--	23,100
TP Cost[5,8]	$/lb P	--	26	--	28

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN load Reduction times 30-years)).

9. Discharge is prohibited May 1 through October 20, except when the facility inflow exceeds the recycled water distribution and storage system capacity.
* The O&M costs are anticipated to be similar to current.
** The facility is already meeting ammonia and total nitrogen values for Level 2 and 3. Additional treatment capacity is included to facilitate maintaining current nutrient load reduction performance into the future.

Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Better able to handle dry to wet weather changes with increased ditch volume • Operators are familiar with the existing technology that would be expanded	• Increased energy consumption to operate a third ditch • Additional ditch to operate and split flow to • Additional chemical handling
Level 3	Same as Level 2	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Additional solids • Additional filters to operate

7 Nutrient Load Reduction by Other Means

The Petaluma WRF has an existing recycled water program that is employed year-round. This existing program has the effect of reducing nutrients discharged to the Bay. The WRF currently recycles approximately 2,115 acre-feet per year (690 million gallons per year). There is funding to expand the recycled water program to approximately 3,000 acre-feet per year (1,300 million gallons per year) with plans to further expand the recycled water program up to approximately 5,400 acre-feet per year (1,760 million gallons per year). The City is planning to expand tertiary recycled water production by 50 percent.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG

emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others. In the case of Petaluma, they are already performing advanced nutrient removal.

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions associated with implementation of a third oxidation ditch are increase in pumping, energy associated with the aeration equipment, plus the additional chemicals for sidestream treatment and meeting the Level 3 facilities.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1,5,7]	Optimization Year Round[1,5,7]	Level 2 Dry Season[1,7]	Level 2 Year Round[1,7]	Level 3 Dry Season[1,7]	Level 3 Year Round[1,7]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	--	--	10	10	40	40	50
GHG Emissions Increase from Chemicals	MT CO_2/yr	--	--	50	60	110	130	10
GHG Emissions Increase Total	MT CO_2/yr	--	--	60	70	150	170	60
Unit GHG Emissions[1]	lb CO_2/MG	--	--	50	60	130	140	70
Unit GHGs for Ammonia Removal[3,6]	lb GHG/lb N	--	--	*	*	*	*	*
Unit GHGs for Total N Removal[3,6]	lb GHG/lb N	--	--	*	*	*	*	*
Unit GHGs for Total P Removal[4]	lb GHG/lb P	--	--	--	--**	--	--**	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. The plant is already optimized and performing nutrient removal so no nutrient optimization concepts were recommended.
6. The facility already meets average ammonia and total nitrogen for Level 2 and 3 so the unit GHG emissions for ammonia and TN are not presented.
7. Discharge is prohibited May 1 through October 20, except when the facility inflow exceeds the recycled water distribution and storage system capacity.

* The facility already meets average ammonia and total nitrogen for Level 2 and 3 so the unit GHG emissions for ammonia and TN are not presented. Adding additional treatment capacity will facilitate maintaining current nutrient load reduction performance into the future.

** Unit GHGs for Total P Removal is projected to be less than zero due to energy savings associated with load reduction.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the Petaluma WRF:

- Nutrient Removal using Granular Sludge – this could be used to phase out the activated sludge. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- High Rate A/B Process – the concept is to capture and divert as much organics and solids prior to the aeration basins. The approach is to seed a reactor upstream of the aeration basins with WAS to flocculate particles with subsequent removal by a solids separation technology upstream of the aeration basins. Diverting solids and organics upstream of the aeration basins will increase the aeration basin capacity and simultaneously increase biogas production. The benefit to Petaluma WRF is it has the potential to not require an additional oxidation ditch capacity in the future for meeting Levels 2 or 3. While there are approximately 12 installations in the Europe, there are no full-scale installations in the US. There are a few projects in the design and construction phase in the US (e.g., Woonsocket, RI).
  - Advantages: Low footprint requirements, energy efficient, and increase downstream capacity in the aeration basins.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Re-evaluate whether there is value in re-testing the Captivator® technology or a comparable technology.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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Pinole-Hercules Water Pollution Control Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Pinole-Hercules Water Pollution Control Plant

Pinole, CA

February 8, 2018
Final Report

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Executive Summary

The Pinole-Hercules Water Pollution Control Plant (PH WPCP) discharges to San Pablo Bay. It is located at 11 Tennent Avenue, Pinole, CA 94564, and it serves about 11,215 service connections throughout the cities of Pinole and Hercules. The plant has an average dry weather flow (ADWF) permitted capacity of 4.06 million gallons per day (mgd) and a peak permitted flow of 10.2 mgd.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3,7]	Opt. Year Round[3,7]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	2.8	3.0	4.1	4.4	4.1	4.4	--
Flow to Bay[2]	mgd	2.6	2.6	2.7	2.7	3.4	3.4	3.4	3.4	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	480	480	--[7]	--[7]	60	60	60	60	590
TN	lb N/d	720	720	--[7]	--[7]	360	340	270	170	720
TP	lb P/d	50	50	--[7]	--[7]	30	30	20	10	50
Costs[4,5]										
Capital	$ Mil	--	--	--[7]	--[7]	21	21	39	42	9.0
O&M PV	$ Mil	--	--	--[7]	--[7]	8	10	12	15	3.4
Total PV	$ Mil	--	--	--[7]	--[7]	30	31	51	57	12.4
Unit Costs[6]										
Capital	$/gpd	--	--	--[7]	--[7]	5.3	4.9	9.6	9.6	--
Total PV	$/gpd	--	--	--[7]	--[7]	7.3	7.1	12.5	13.0	

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. The plant is currently under construction for upgrades/expansion to reduce nutrient loads. As a result, no nutrient optimization concepts were considered.

No optimization is recommended for the PH WPCP because the plant is in the middle of construction for an upgrade/expansion that will reduce nutrient loads to meet or exceed Level 2 limits.

The PH WPCP is a candidate for sidestream treatment if nutrient load reduction is required beyond the nutrient load reduction capacity of the on-going upgrade/expansion project. The recommended sidestream treatment strategies would be deammonification for nitrogen load reduction and chemical precipitation of phosphorus to reduce phosphorus.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L): the on-going upgrade/expansion project will have the ability to meet the Level 2 targets. The unit processes that relate to nutrient load reduction include:
    a. Continue use of recently implemented chemical feed facilities at the primaries and operate as chemically enhanced primary treatment.
    b. Extend the aeration basins and modify to operate in ammonia/total nitrogen load reduction mode (e.g., add mixed liquor return pumping, add blower capacity, etc.).
    c. Add secondary clarifiers.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L):
    a. Same as Level 2, plus:
    b. Add denitrification filters.
    c. Add an external carbon source chemical feed facility.
    d. Add metal salt/polymer chemical feed facilities.

As shown in Table ES-1, and as might be expected, the costs generally increase from sidestream treatment through Level 3 upgrades. Overall, the present value costs range from $31 Mil for Level 2 year round upgrades up to $57 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Pinole-Hercules Water Pollution Control Plant (PH WPCP) discharges to San Pablo Bay. It is located at 11 Tennent Avenue, Pinole, CA 94564, and it serves approximately 11,215 service connections throughout the cities of Pinole and Hercules. The plant has an average dry weather flow (ADWF) permitted capacity of 4.06 million gallons per day (mgd) and a peak permitted flow of 10.2 mgd.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The PH WPCP holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2012-0059; CA0037796. Table 2–1 provides a summary of the permit limitations for the PH WPCP. Table 2–1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2–1. NPDES Permit Limitations (Order No. R2-2012-0059; CA0037796)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak
Flow	mgd	4.06	--	--	--	10.2
BOD	mg/L	--	25	40	--	--
TSS	mg/L	--	30	45	--	--
Total Ammonia, as N	mg/L	--	110	--	180	--

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the PH WPCP. Both liquids processes and solids processes are shown. The wastewater treatment process consists of screening, primary clarification, activated sludge biological treatment, secondary clarification, disinfection with sodium hypochlorite, and dechlorination with sodium bisulfite. Sludge is thickened, anaerobically digested and dewatered.

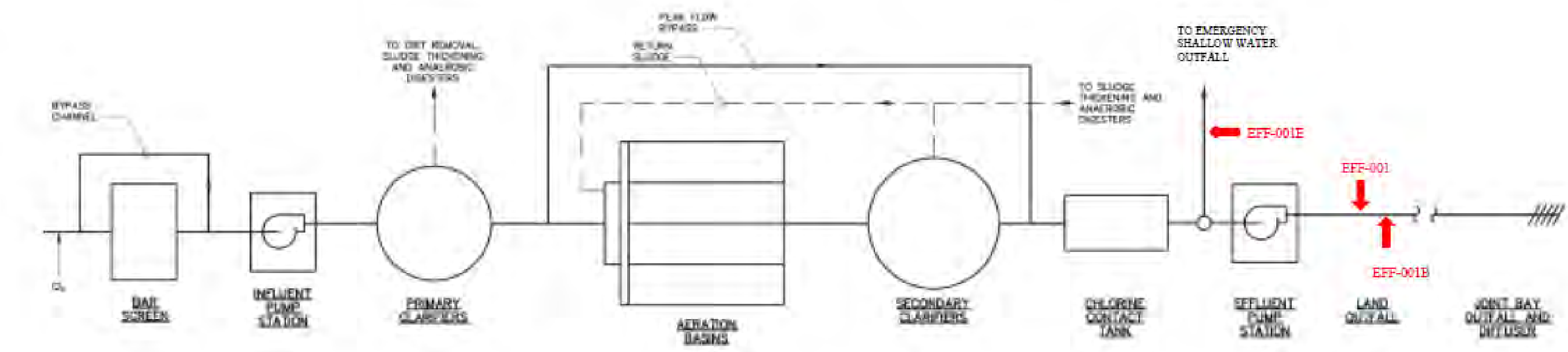

Figure 2-1. Process Flow Diagram for the PH WPCP

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the PH WPCP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.8	2.9	3.0	3.8
BOD	lb/d	6,500	6,500	7,700	7,600
TSS	lb/d	7,100	7,600	8,800	9,700
Ammonia	lb N/d	700	700	700	800
Total Kjeldahl Nitrogen (TKN)	lb N/d	1,000	1,000	1,000	1,200
Total Phosphorus (TP)	lb P/d	120	110	130	110
Alkalinity	lb $CaCO_3$/d	No Data	4,200	No Data	4,400
BOD	mg/L	282	270	304	238
TSS	mg/L	308	315	347	303
Ammonia	mg N/L	30	29	28	25
TKN	mg N/L	43	41	39	38
TP	mg P/L	5.2	4.6	5.1	3.4
Alkalinity	mg $CaCO_3$/L	No Data	174	No Data	138

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

The PH WPCP is currently under construction. The upgrade/expansion project includes the following elements: influent pumping and headworks, replacement of an existing primary clarifier and mechanism, extension of the aeration basins and modification to operate in nitrogen removal mode (to Level 2), blower replacement, new secondary clarifiers, moving disinfection chemicals, new solids handling building and thickeners, and replacement of the effluent pumps.

No additional nutrient removal projects are anticipated in the capital improvement program.

2.5 Pilot Testing

The PH WPCP has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the sidestream treatment and plant upgrades analyses, respectively. In general, the analyses for sidestream treatment and plant upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

As previously described, because the PH WPCP is currently undergoing a major upgrade that will result in effluent limits less than the proposed Level 2 limits, no optimization strategies are proposed.

3.2 Flow and Loading for Sidestream Treatment

The construction upgrade at the PH WPCP does not include sidestream treatment. The PH WPCP could consider sidestream treatment in the long-term if there is an objective to further reduce nutrient loads beyond the capabilities of the on-going upgrade.

Additional sampling for the sidestream was performed in July, 2015. The sampling results were projected forward to the permitted capacity. The sidestream flows and loads for the permitted capacity are provided in Table 3-1. The permitted capacity flows and loads were used in the facility sizing.

Table 3-1. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Permitted Flow Capacity
Sidestream Flow	mgd	0.010	0.015
Ammonia	lb N/d	170	250
TKN	lb N/d	170	250
TN[1]	lb N/d	170	250
TP	lb P/d	10	20
OrthoP	lb P/d	10	10
Alkalinity	lb $CaCO_3$/d	570	840
Ammonia	mg N/L	2,030	2,030
TKN	mg N/L	2,030	2,030
TN[1]	mg N/L	2,030	2,030
TP	mg P/L	120	120
OrthoP	mg P/L	110	110
Alkalinity	mg/L as CaCO3	6,800	6,800

1. It was assumed that TN = TKN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	4.06	4.2	4.5	5.6
BOD	lb/d	9,500	9,600	11,300	11,200
TSS	lb/d	10,400	11,100	12,900	14,200
Ammonia	lb N/d	1,000	1,000	1,000	1,200
TKN	lb N/d	1,500	1,500	1,500	1,800
TP	lb P/d	180	160	190	160
Alkalinity	lb/d as $CaCO_3$	No Data	6,200	No Data	6,500
BOD	mg/L	282	270	304	238
TSS	mg/L	308	315	347	303
Ammonia	mg N/L	30	29	28	25
TKN	mg N/L	43	41	39	38
TP	mg P/L	5.2	4.6	5.1	3.4
Alkalinity	mg/L as CaCO3	No Data	174	No Data	138

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.

- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

There are no optimization concepts developed for the PH WPCP as the plant is in the middle of construction for a major upgrade/expansion project that includes nutrient removal. It is anticipated that the upgrade/expansion project will meet or exceed the Level 2 limits.

5 Sidestream Treatment

As previously described, the PH WPCP was identified as a potential candidate for sidestream treatment if total nitrogen and total phosphorus load reduction is required beyond the nutrient load reduction capacity of the on-going construction upgrade/expansion.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction. The upgraded PH WPCP will remove ammonia in the main plant so sidestream treatment to reduce ammonia discharge loads to the Bay is not recommended.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification) including requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requires 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for the PH WPCP.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks). In the case of the PH WPCP, the ferric chloride chemical feed facilities located at the headworks could be used to precipitate P.

Recovery of the total phosphorus sidestream load via struvite precipitation is another option to eliminate the phosphorus recycle stream loads. This process produces a useful byproduct (struvite crystals) that can be sold economically. However, chemical addition is typically simpler and easier for plants to implement. Thus, a more detailed analysis would be required to determine the optimal solution for the PH WPCP.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed Facility
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)[4]	TN (lb N/d)	TP (lb P/d)
Discharge under Current Operating Mode[1]	lb/d	590	890	61
Discharge with Sidestream Treatment[1]	lb/d	590	720	50
Load Reduction[2]	lb/d	0	170	11
Load Reduction[2]	%	0%	19%	19%
Annual Load Reduction[3]	lb/yr	0	61,300	4,020

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration.
4. The plant already will fully nitrify at the end of construction so sidestream treatment would not further reduce ammonia discharge loads.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in

Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	8.9	0.05
Annual O&M[2]	$ Mil/yr	0.15	0.01
Total Present Value[2]	$ Mil	12.2	0.22
NH4-N Load Reduction[3,5]	lb N/yr	--*	--
TN Load Reduction[3,5]	lb N/yr	61,300	--
TP Load Reduction[4,5]	lb P/yr	--	4,020
NH4-N Cost [3,5,6]	$/lb N	--*	--
TN Cost [3,5,6]	$/lb N	6.6	--
TP Cost [4,5,6]	$/lb P	--	1.9

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (TN load Removed (Ave.) times 365 days times 30-years))

* The plant already will fully nitrify at the end of construction so sidestream treatment would not further reduce ammonia discharge loads.

6 Nutrient Reduction Upgrades

The current upgrade/expansion project is designed to meet the discharge requirements associated with Level 2. There are several technologies that could be applied at the PH WPCP to meet the Level 3 nutrient removal targets.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. PH WPCP should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The Level 2 upgrade/expansion project is currently under construction. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, ferric chloride chemical feed facilities are used upstream of the primary clarifiers, as in the current configuration. Additional aeration basins are being constructed that extend the existing basins. These basins are required to provide permitted capacity for both ammonia/total nitrogen load reduction. All of the basins will require mixed liquor return pumps to return nitrate laden mixed liquor to the anoxic zones for denitrification. New blowers are being added that should have sufficient capacity to satisfy Levels 2 and 3 target limits. In addition, two new secondary clarifiers are being constructed.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those shown for Level 2.

In addition to those listed for Level 2, Level 3 upgrades would require construction of denitrification filters, an external carbon source chemical feed facility, and the ability to feed metal salt/polymer chemicals at the filters. The denitrification filters and external carbon feed are needed to meet the total nitrogen discharge target. The metal salt/polymer chemical feed facilities are provided to precipitate total phosphorus upstream of the filters.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	Ferric chloride chemical feed facilities to operate as CEPT	Same as Level 2
Biological	Activated sludge with the ability to reduce ammonia/total nitrogen loads as part of the plant upgrade/expansion: • Extend the existing aeration basins • Mixed liquor return pumping • New blowers • Additional secondary clarifiers	Same as Level 2
Tertiary	--	• Denitrification filters • External carbon source chemical feed facilities • Metal salt/polymer chemical feed facilities

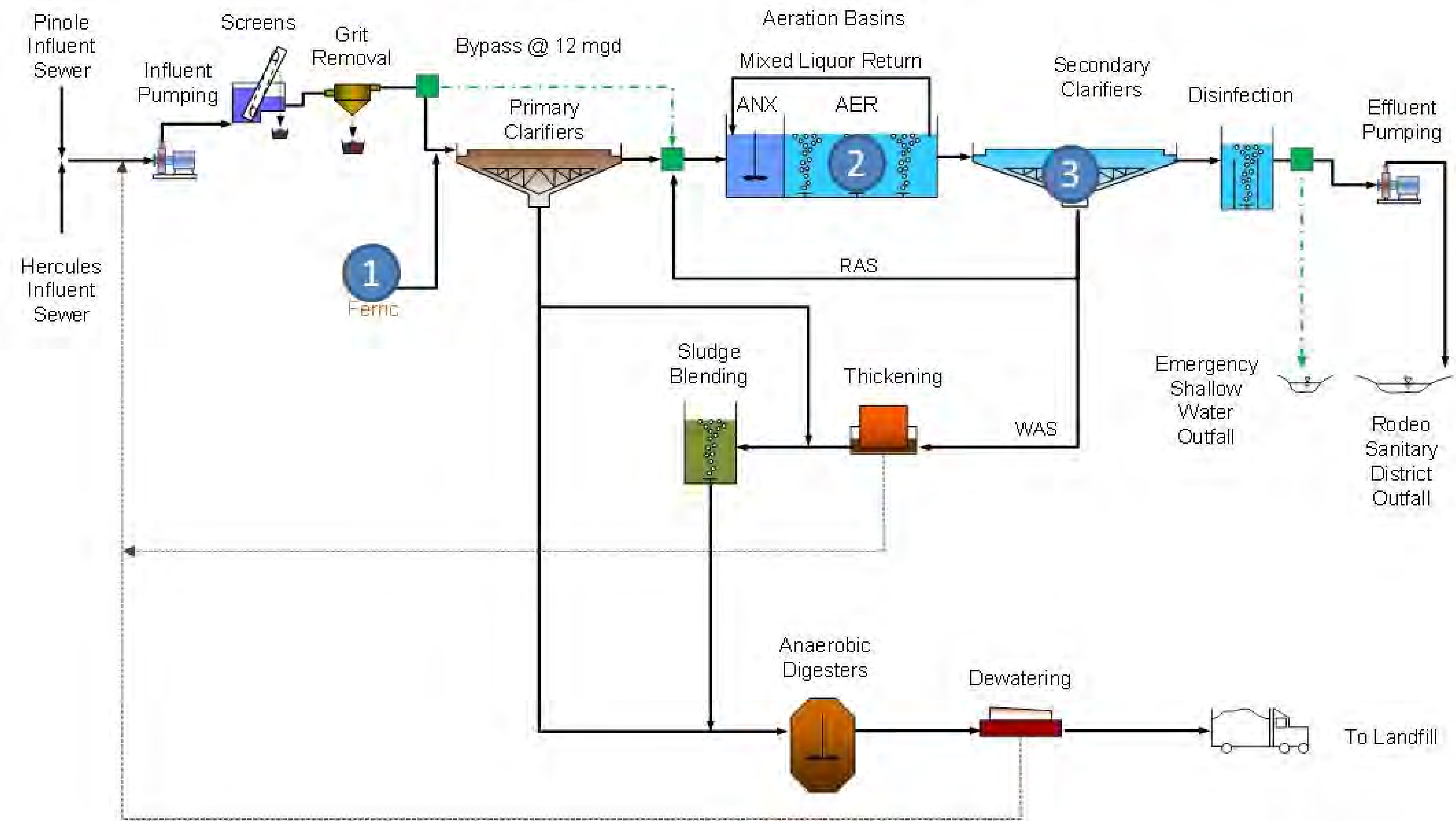

Figure 6-1. Level 2 Upgrade Concepts for PH WPCP

(1) Continue use of recently implemented chemical feed facilities at the primaries and operate in CEPT mode, (2) extend the existing aeration basins and modify to operate in ammonia/total nitrogen load reduction mode, and (3) add new secondary clarifiers.

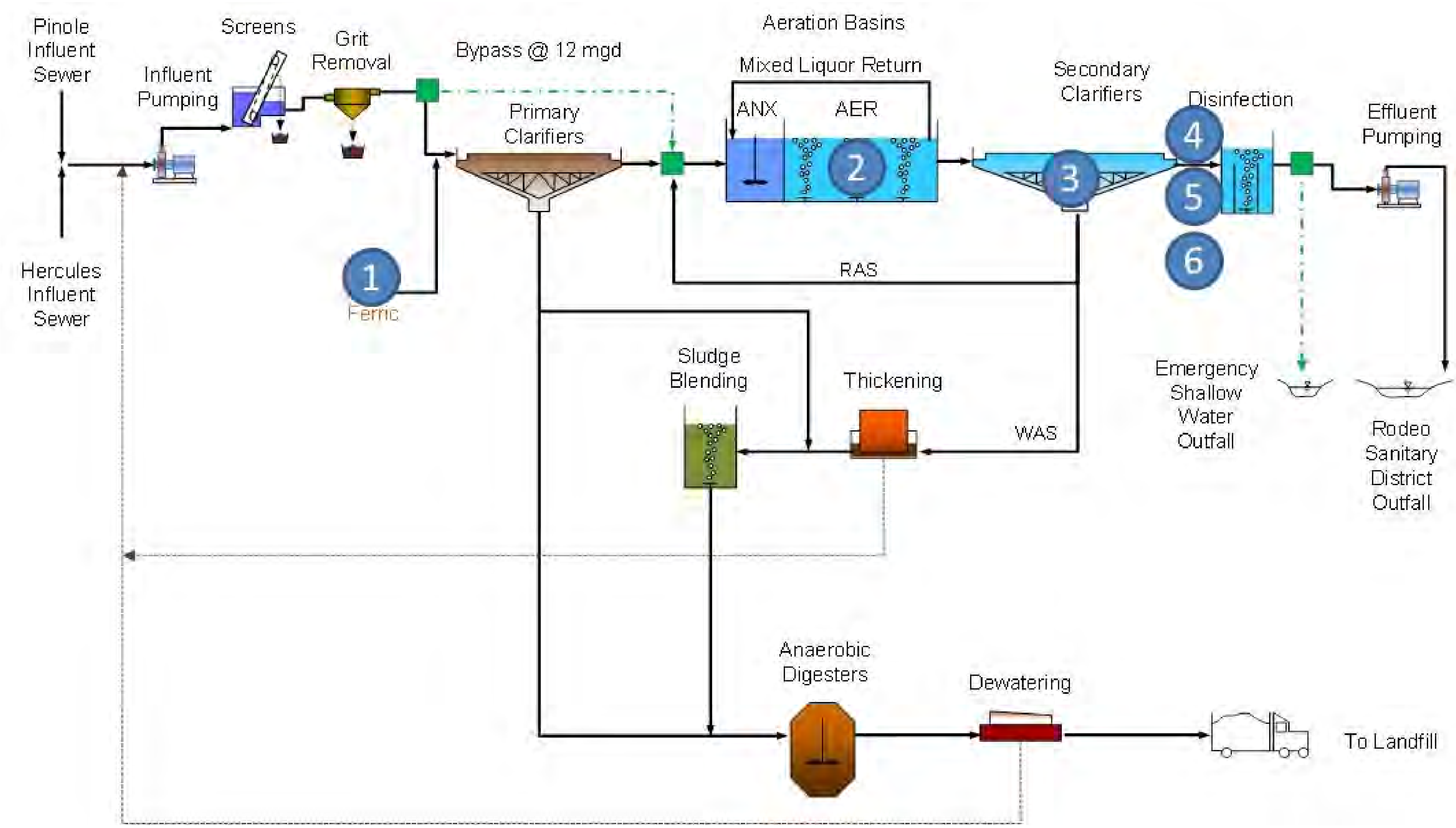

Figure 6-2. Level 3 Upgrade Concepts for PH WPCP

(1) Continue use of recently implemented chemical feed facilities at the primaries and operate in CEPT mode, (2) add additional aeration basins and make the necessary modifications to operate in MLE mode, and (3) add secondary clarifiers, (4) add denitrification filters, (5) add external carbon source chemical feed facilities, and (6) add a metal salt/polymer chemical feed facilities.

Figure 6-3. Level 2 Upgrade Aerial Layouts

(1) Continue use of recently implemented chemical feed facilities at the primaries and operate in CEPT mode, (2) extend the existing aeration basins and modify to operate in ammonia/total nitrogen load reduction mode, and (3) add new secondary clarifiers.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Continue use of recently implemented chemical feed facilities at the primaries and operate in CEPT mode, (2) add additional aeration basins and make the necessary modifications to operate in MLE mode, and (3) add secondary clarifiers, (4) add denitrification filters, (5) add external carbon source chemical feed facilities, and (6) add a metal salt/polymer chemical feed facilities.

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2.

Table 6-2. Estimated Capital and O&M Costs for TN and TP Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	4.1	4.4	4.1	4.4
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	21	21	39	42
Annual O&M	$Mil/yr	0.4	0.4	0.5	0.7
O&M PV[3]	$ Mil	8	10	12	15
Total PV[3]	$ Mil	30	31	51	57
Unit Capital Cost	$/gpd	5.3	4.9	9.6	9.6
Unit Total PV	$/gpd	7.3	7.1	12.5	13.0
TN Removal					
Capital[2,4]	$ Mil	19	19	37	40
Annual O&M[4]	$ Mil/yr	0.2	0.3	0.4	0.5
O&M PV[3,4]	$ Mil	6	7	9	11
Total PV[3,4]	$ Mil	25	26	45	51
TN Removed (Ave.)[6]	lb N/d	530	550	620	720
Annual TN Removed[7]	lb N/yr	192,000	200,000	225,000	263,000
TN Cost[4,8]	$/lb N	4.3	4.4	6.7	6.5
TP Removal					
Capital[2,5]	$ Mil	1.9	1.9	18.3	21.5
Annual O&M[5]	$ Mil/yr	0.1	0.1	0.2	0.2
O&M PV[3,5]	$ Mil	2.5	2.7	3.7	5.3
Total PV[3,5]	$ Mil	4.4	4.6	22.1	26.8
TP Removed (Ave.)[6]	lb P/d	30	30	40	50
Annual TP Removed[7]	lb P/yr	11,300	12,000	14,900	19,300
TP Cost[5,8]	$/lb P	13	13	49	46

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

The costs presented in Table 6-2 for the Level 2 Upgrades are based on the actual construction costs for the current upgrade/expansion project, for those elements required to provide nutrient removal. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Additional capacity for primary clarifiers • Improved settleability in the secondary clarifiers • Reduced solids/BOD discharge loading • Alkalinity recovery associated with the denitrification step	• Additional chemicals from CEPT • Increase in power demand with new blowers • Additional aeration basin to operate • Operate in a new mode that will require the operators to get accustomed to
Level 3	• High quality product water due to additional filtration step	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Additional solids • Safety from external carbon source (if methanol)

7 Nutrient Load Reduction by Other Means

The PH WPCP does not have an existing recycled water program and there are currently no plans to implement a recycled water program.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by

Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

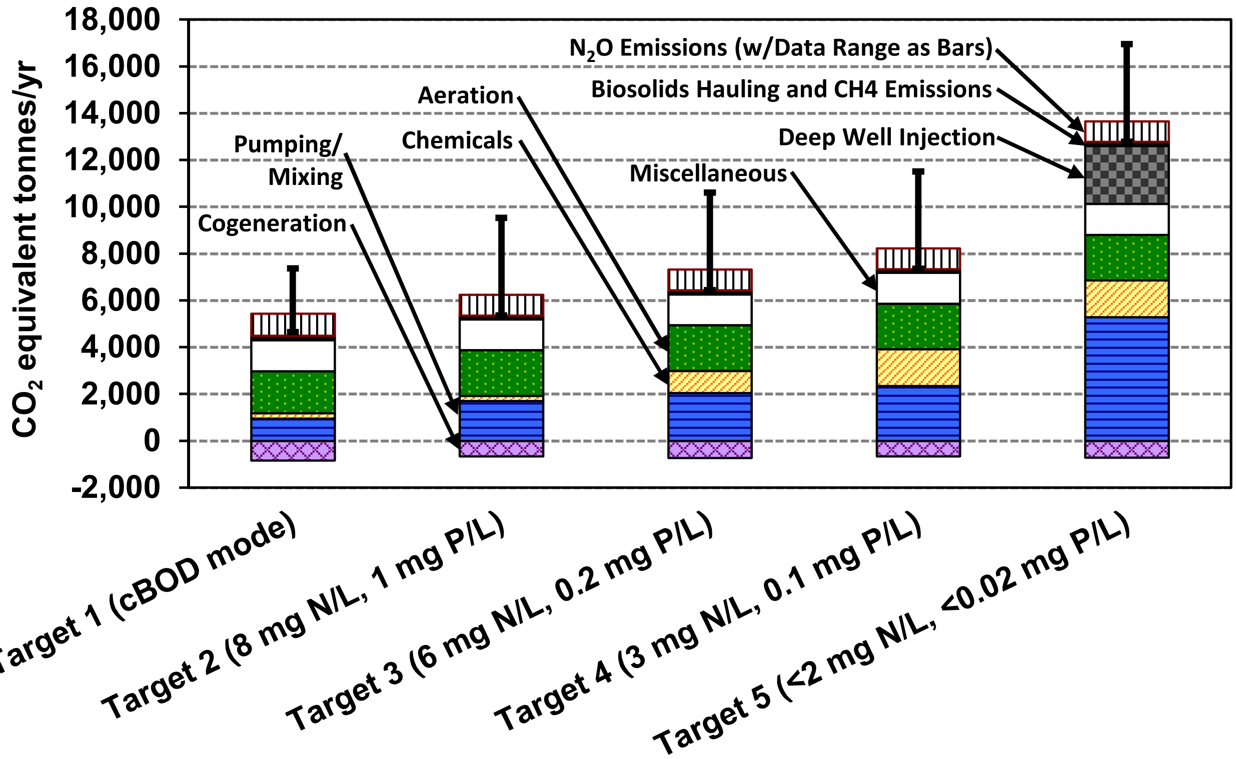

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[3] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on

[3] http://www.epa.gov/cleanenergy/energy-resources/egrid/

additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	--	--	220	230	250	270	26
GHG Emissions Increase from Chemicals	MT CO_2/yr	--	--	20	20	150	160	3
GHG Emissions Increase Total	MT CO_2/yr	--	--	240	250	410	430	29
Unit GHG Emissions[2]	lb CO_2/MG	--	--	340	350	580	600	55
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--	--	2	2	4	4	--
Unit GHGs for Total N Removal[2,3,5]	lb GHG/lb N	--	--	2	2	4	3	1
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--	--	7	6	12	9	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only
4. Based on phosphorus removal only
5. The plant will provide full nitrification and partial denitrification at the end of construction of the on-going upgrade/expansion project.

9 Emerging Technologies

The recommendations presented in the prior sections are based on the current upgrades/expansion construction project. There are many innovative technologies that could also be considered if the PH WPCP needs to consider additional nutrient load reduction.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at PH WPCP:

- Nutrient Removal using Granular Sludge – this could be used as it requires less footprint than the aeration basins that are being extended as part of the upgrades/expansion construction project. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit to PH WPCP is it has the potential to not require basin expansion while achieving additional capacity. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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Richmond Municipal Sewer District

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Bay Area Clean Water Agencies
Nutrient Reduction Study

Richmond Municipal Sewer District

Richmond, CA

April 12, 2018
Final Report

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Executive Summary

The Richmond Municipal Sewer District (RMSD) Water Pollution Control Plant (WPCP) discharges to the Central San Francisco Bay. It shares a common outfall and discharge permit with the West County Wastewater District Treatment Plant. It is located at 601 Canal Boulevard Richmond, CA 94804, and it serves approximately 20,000 service connections throughout the City of Richmond. The plant has an average dry weather flow (ADWF) permitted capacity of 16 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs (e.g., $/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	5.5	6.3	16.0	18.3	16.0	18.3	--
Flow to Bay[2]	mgd	6.2	6.2	6.1	6.1	11.8	11.8	11.8	11.8	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	1,390	1,390	210	200	210	200	210	200	--
TN	lb N/d	1,470	1,470	1,030	980	1,260	1,180	950	590	--
TP	lb P/d	70	70	30	20	100	100	70	30	--
Costs[4,5]										
Capital	$ Mil	--	--	18.4	18.4	65	65	89	102	--
O&M PV	$ Mil	--	--	9.3	10.1	24	26	34	45	--
Total PV	$ Mil	--	--	27.7	28.5	89	91	123	147	--
Unit Costs[6]										
Capital	$/gpd	--	--	3.4	2.9	4.1	3.6	5.5	5.6	--
Total PV	$/gpd	--	--	5.0	4.5	5.5	5.0	7.7	8.0	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Modify the existing ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in Chemically Enhanced Primary Treatment (CEPT) mode. This strategy will reduce total phosphorus loads while increasing the downstream capacity for ammonia and/or total nitrogen load reduction.
2. Replace the mechanical aerators with a fine-bubble aeration system (scheduled for 2018-2019).
3. Increase the solids residence time to partially nitrify. Note, further evaluation would be needed to determine if partial nitrification would be a feasible operating mode with particular emphasis placed on process stability, capacity, and breakpoint chlorination.
4. Modify the initial aeration basin zone to operate as an anoxic selector to reduce total nitrogen loads (scheduled for 2018-2019). This includes addition of mixed liquor return pumps.

The RMSD WPCP is not currently considered a candidate for sidestream treatment. If RMSD loses its ability to send digested biosolids to the West County Wastewater District Treatment Plant, then sidestream treatment should be reconsidered.

The upgrade strategies to achieve Levels 2 and 3 include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Similar to optimization, modify the ferric chloride and add polymer chemical feed facilities to operate the primaries in CEPT mode. This strategy should satisfy the Level 2 total phosphorus targets while increasing the downstream treatment capacity.
    b. Retrofit the existing equalization basins in the activated sludge process to operate as aeration basins.
    c. Add a wet weather flow box upstream of the headworks to attenuate peak flows. The ability to attenuate peak flows at this box is critical once the existing equalization basins are converted.
    d. Modify and expand the existing basins to operate in nitrification/denitrification mode.
    e. Add alkalinity chemical feed facilities.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L):
    a. Same as Level 2, plus:
    b. Add a denitrifying filter complex with a filter feed pumping station to further reduce total nitrogen and total phosphorus loads.
    c. Add an external carbon source at the denitrifying filter complex for total nitrogen load reduction.
    d. Add metal salt/polymer chemical feed facilities upstream at the denitrifying filter complex to further reduce total phosphorus loads.

Capital costs, O&M costs and present value costs were determined for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for any changes in any other process, including solids handling or associated energy requirements.

As shown in Table ES-1, and as might be expected, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season to year round. Overall, the present value costs range from approximately $28 Mil for optimization up to $147 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Richmond Municipal Sewer District (RMSD) Water Pollution Control Plant (WPCP) discharges to the Central San Francisco Bay. It shares a common outfall and discharge permit with the West County Wastewater District (WCWD) Treatment Plant (TP). It is located at 601 Canal Boulevard Richmond, CA 94804, and it serves approximately 20,000 service connections throughout the City of Richmond. The plant has an average dry weather flow (ADWF) permitted capacity of 16 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The RMSD WPCP holds the National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2013-0016; CA0038539. Table 2-1 provides a summary of the permit limitations but is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2013-0016; CA0038539)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Wet Weather Capacity
Flow	mgd	16	--	--	--	20
BOD	mg/L	--	30	45	--	--
TSS	mg/L	--	30	45	--	--
Total Ammonia, as N	mg/L	--	32	--	59	--

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the existing process flow diagram for the RMSD WPCP. Both liquids processes and solids processes are shown. Treatment processes consist of a wet weather flow diversion box plus storage, screening, grit removal (chambers present but not functional), flow equalization, primary sedimentation, activated sludge, chlorination, and dechlorination. No major nutrient removal systems are currently in place.

Waste activated sludge is thickened with dissolved air flotation units and blended with primary solids before anaerobic digestion. The digested biosolids are currently transported approximately 5 miles to the WCWD TP for further processing and disposal.

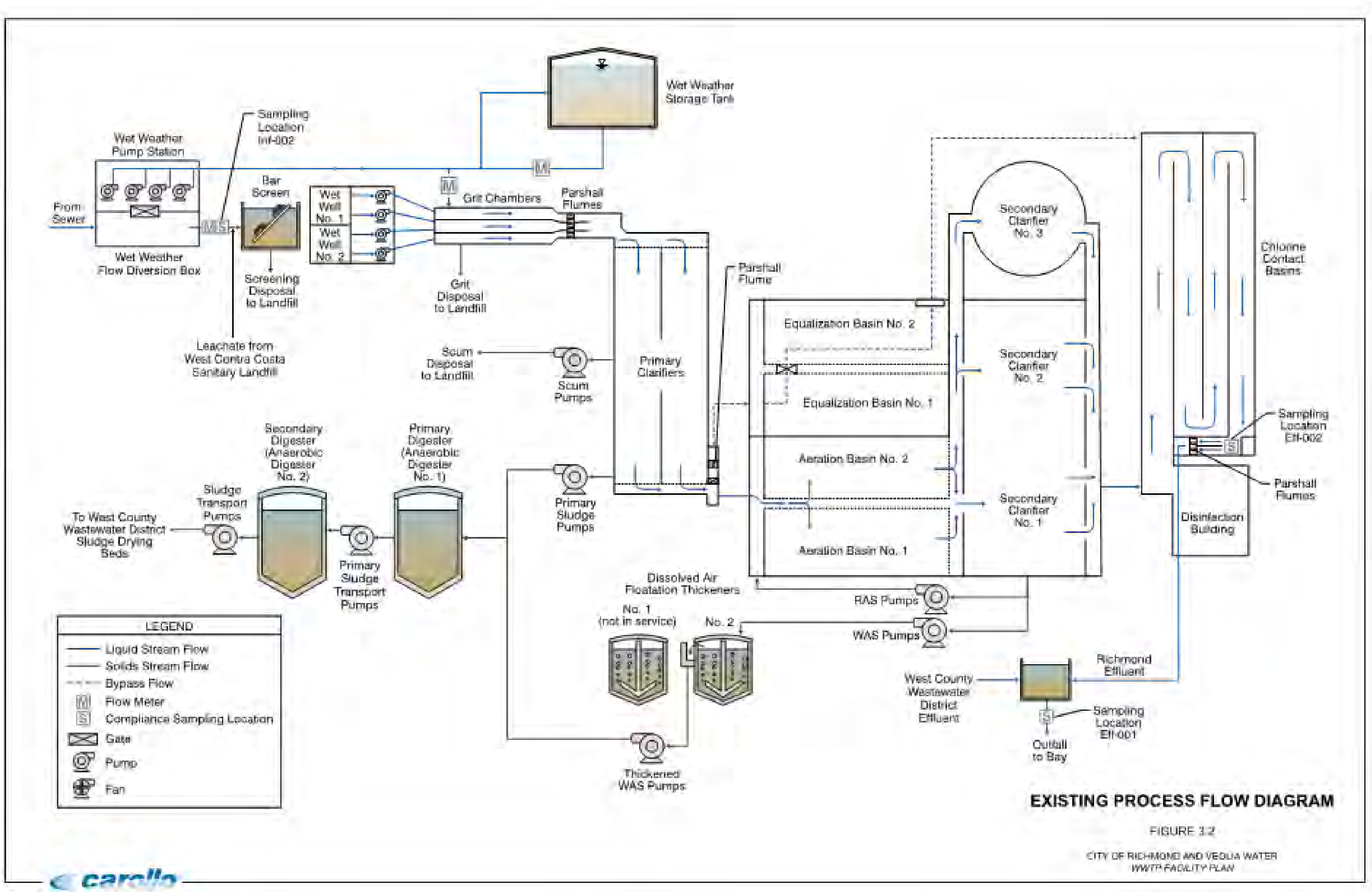

Figure 2-1 Process Flow Diagram for the RMSD WPCP

2.3 Existing Flows and Loads

A data request was submitted to each facility included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the RMSD WPCP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2012-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	5.5	6.0	5.9	10.3
BOD	lb/d	11,500	14,100	14,700	19,200
TSS	lb/d	16,700	20,100	24,000	31,600
Ammonia	lb N/d	2,100	1,800	2,500	2,300
Total Kjeldahl Nitrogen (TKN)	lb N/d	2,600	2,200	2,600	2,500
Total Phosphorus (TP)	lb P/d	210	280	310	320
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	251	284	301	224
TSS	mg/L	364	404	491	368
Ammonia	mg N/L	46	36	51	27
TKN	mg N/L	57	44	53	29
TP	mg P/L	4.6	5.6	6.3	3.7
Alkalinity	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

RMSD recently completed construction of a 5-MG flow equalization basin at the headworks to assist with attenuating peak flows and loads.

RMSD is in the process of converting its mechanical aeration system to a fine-bubble aeration system. The new aeration system is designed to provide more reliable removal of BOD. It is also designed so it can easily be expanded in the future to support full nitrification. These improvements are the initial phase of work that would need to be completed prior to upgrading the aeration basins to provide full nitrification. As part of the update, the initial zones in the aeration basin will be modified to include an anoxic selector. This selector will have the ability to either reduce total phosphorus loads (default) or total nitrogen loads (if the aeration basins are operated to partially nitrify or upgraded and operated to fully nitrify in the future).

2.5 Pilot Testing

RMSD has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for the RMSD WPCP are presented in Table 3-1. The projected flow and load for 2025 was not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30) [1,3]	Year Round MM[1,3]
Flow	mgd	5.5	6.0	5.9	10.3
BOD	lb/d	13,200	16,200	16,900	22,100
TSS	lb/d	19,200	23,100	27,600	36,300
Ammonia	lb N/d	2,400	2,100	2,900	2,700
TKN	lb N/d	3,000	2,500	3,000	2,900
TP	lb P/d	240	320	350	370
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	289	327	346	258
TSS	mg/L	419	465	565	423
Ammonia	mg N/L	53	41	59	31
TKN	mg N/L	66	51	61	33
TP	mg P/L	5.3	6.4	7.2	4.3
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.2 Flow and Loading for Sidestream Treatment

The RMSD WPCP is not currently a candidate for sidestream treatment because the digested biosolids are all conveyed to the WCWD TP. If the RMSD WPCP installs dewatering facilities in the future, sidestream treatment should be considered.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	16.0	17.3	17.1	29.9
BOD	lb/d	33,500	41,000	42,800	55,900
TSS	lb/d	48,600	58,400	69,800	91,800
Ammonia	lb N/d	6,100	5,200	7,300	6,700
TKN	lb N/d	7,600	6,400	7,500	7,200
TP	lb P/d	610	810	900	920
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	251	284	301	224
TSS	mg/L	364	404	491	368
Ammonia	mg N/L	46	36	51	27
TKN	mg N/L	57	44	53	29
TP	mg P/L	4.6	5.6	6.3	3.7
Alkalinity	mg/L as CaCO3	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy.

Several optimization strategies were identified during the RMSD WPCP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The optimization strategies were screened down to four strategies as follows.

- **Optimization Strategy 1:** Modify the existing ferric chloride chemical facilities at the primaries and add polymer chemical feed facilities to operate in CEPT mode. CEPT removes phosphorus and increases the downstream activated sludge basins capacity by enhancing solids and organics capture across the primaries.

- ***Is it feasible?*** Yes. RMSD should evaluate the impact of chemical addition on their ability to meet bioassay toxicity limits.
- ***Potential impact on ability to reduce nutrient discharge loads?*** Phosphorus removal would be enhanced while reducing loading to the downstream unit processes. The ferric chloride will precipitate solids and remove total phosphorus, whereas the polymer will enhance capture of colloidal material to increase downstream capacity for nutrient load reduction.
- ***Result from analysis:*** It will remove phosphorus in the primaries and increase the downstream aeration basin capacity for more reliable ammonia load reduction when the aeration basins are updated to provide full nitrification in the future or if the aeration basins are operated to provide partial nitrification.
- ***Recommendation:*** Carry forward for this analysis; evaluate the impact of chemical addition on their ability to meet bioassay toxicity limits if RMSD moves forward on this strategy.

- **Optimization Strategy 2:** Replace the mechanical aeration system with a fine-bubble aeration system. This replacement is already scheduled with a 2018-2019 completion date. This would provide additional aeration capacity and it should improve sludge settleability. Mechanical aerators have a tendency to break-up floc and result in poor settleability.
  - ***Is it feasible?*** Yes, the RMSD WPCP is already moving forward with this strategy.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** These improvements are the initial phase of work that would need to be completed prior to upgrading the aeration basins to provide full nitrification. Note, further evaluation would be needed to determine if partial nitrification would be a feasible operating mode.
  - ***Result from analysis:*** Enhancing aeration capacity and improving sludge settleability will maximize the secondary treatment capacity available for nutrient removal, when the facilities are upgraded to provide nutrient removal in the future or if the facilities are operated to provide partial nitrification. Note, further evaluation would be needed to determine if partial nitrification would be a feasible operating mode.
  - ***Recommendation:*** Carry forward for this analysis. Note, further evaluation would be needed to determine if partial nitrification would be a feasible operating mode.

- **Optimization Strategy 3:** Increase the solids residence time to reduce ammonia discharge loads. Further evaluation would be needed to determine if this would increase nitrite levels due to partial nitrification. An increase in nitrite would increase chlorine demand due to breakpoint chlorination issues. A solution to breakpoint chlorination is adding supplemental ammonia which would contribute to ammonia/total nitrogen loads.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Would improve the reliability of ammonia removal if breakpoint chlorination is not required.
  - ***Result from analysis:*** Partial nitrification of ammonia loads. Alkalinity would be required. Note, further evaluation would be needed to determine if partial nitrification would be a feasible operating mode with particular emphasis placed on process stability, capacity, and breakpoint chlorination.
  - ***Recommendation:*** Carry forward. Note, further evaluation would be needed to determine if partial nitrification would be a feasible operating mode.

- **Optimization Strategy 4:** Modify the initial aeration basin zone to operate as anoxic selector. This strategy is already scheduled with a 2018-2019 completion date. This strategy is predicated on implementation of strategies 2 and 3. Any nitrate recycled with the return activated sludge (RAS) line would be denitrified once there is contact with primary effluent.

- ***Is it feasible?*** Yes.
- ***Potential impact on ability to reduce nutrient discharge loads?*** The extent of total nitrogen load reduction is directly correlated with the RAS return ratio. For example, a 100% RAS return would reduce approximately half of the nitrified load.
- ***Result from analysis:*** It will remove the majority of nitrate in the RAS line.
- ***Recommendation:*** Carry forward.

Optimizing the primaries to operate in CEPT mode (Strategy 1) would remove total phosphorus loads in the primaries while increasing the downstream activated sludge capacity. RMSD has already initiated implementing two of the listed strategies (2 and 4) that are scheduled to be completed in 2018-2019. Also increasing the SRT (Strategy 3) will provide sufficient interim capacity for partial nitrification and removing a portion of the total nitrogen load. Note, further evaluation would be needed to determine if partial nitrification would be a feasible operating mode.

The recommended strategies are shown with the process flow diagram presented in Figure 4-1. It is noted that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Operate the Primaries in CEPT Mode • Modify the existing ferric chloride chemical feed facilities • Polymer chemical feed facilities	• Operate the chemical feed facilities to optimize solids/organic capture and reduce P loading
Replace the Mechanical Aerators with a Fine-Bubble Aeration System • Remove existing and add a fine-bubble aeration system (diffusers, piping, blowers, electrical, etc.)	• Operate the fine-bubble aeration system
Increase the SRT to Partially Nitrify • None • Alkalinity chemical feed facilities	• Reduce the waste activated sludge flow
Modify the Initial Aeration Basin Zone to Operate as an Anoxic Selector • Add mixers • Add mixed liquor return pumps	• Maintain sufficient mixing in the mixed liquor channel • Maintain mixed liquor pumps

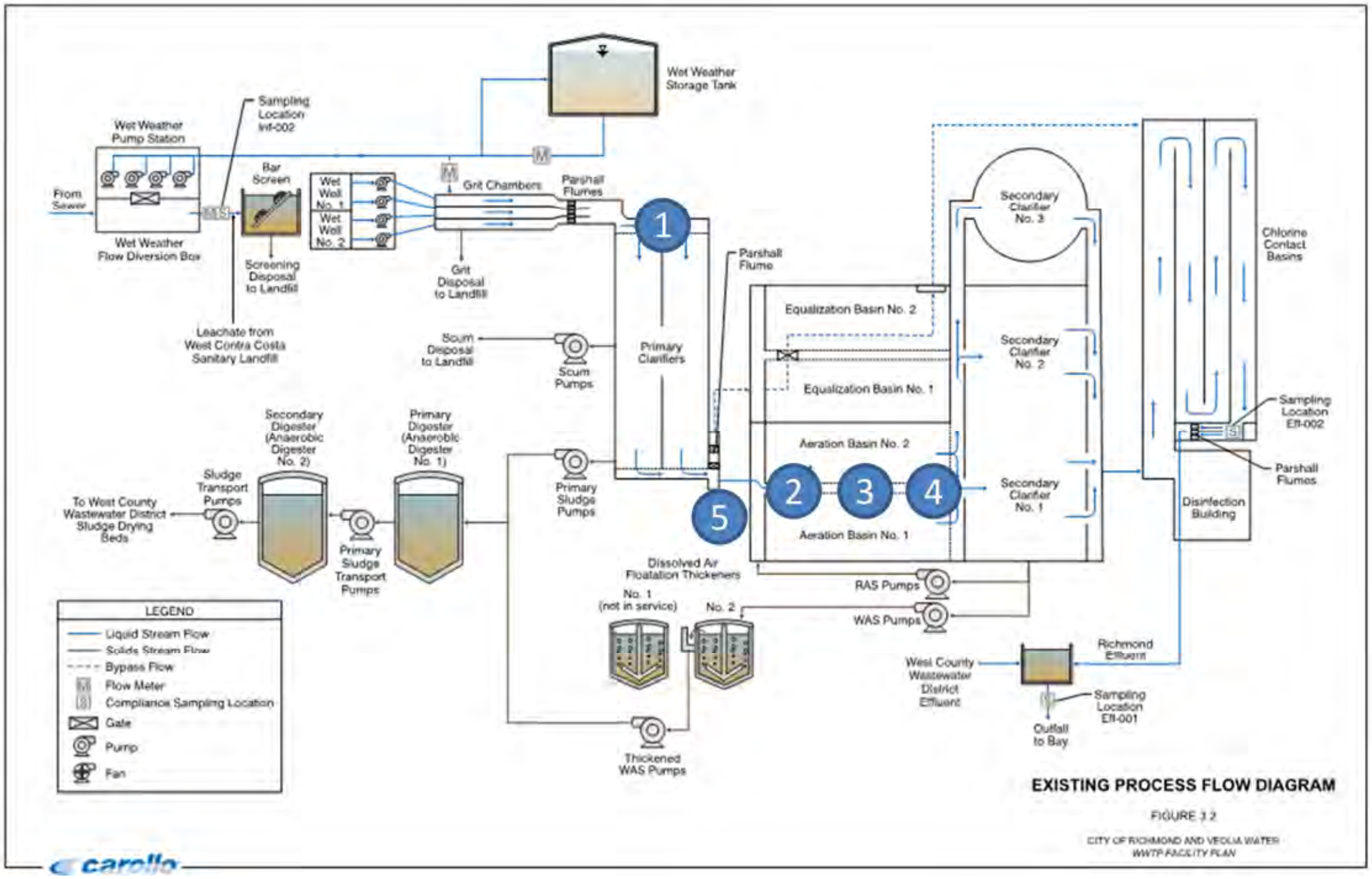

Figure 4-1. Optimization Concept Considered for the RMSD WPCP

(1) Modify the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (2) replace the mechanical aerators with a fine-bubble aeration system (scheduled for 2018-2019), (3) increase the solids residence time to partially nitrify, (4) modify the initial aeration basin to operate as an anoxic selector to reduce total nitrogen loads (scheduled for 2018-2019), and (5) add alkalinity for nitrification.

Note: further evaluation would be needed to determine if partial nitrification would be a feasible operating mode.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	1,500	1,500	1,580	1,580	80	80
Discharge with Opt. Strategy[1]	lb N or P/d	210	200	1,030	980	30	20
Load Reduction[2]	lb N or P/d	1,290	1,300	550	600	50	50
Load Reduction[2]	%	86%	86%	35%	38%	67%	69%
Annual Load Reduction[2,3]	lb N or P/yr	470,000	473,000	200,000	219,000	18,900	19,500

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. The estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

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Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	5.5	6.3
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	18.4	18.4
Annual O&M	$ Mil/yr	1.0	1.1
Present Value O&M[3]	$ Mil	9.3	10.1
Present Value Total[3]	$ Mil	27.7	28.5
Unit Capital Cost[8]	$/gpd	3.4	2.9
Unit Total PV Cost[8]	$/gpd	5.0	4.5
TN Removal			
Capital[2,4]	$ Mil	16.6	16.6
Annual O&M[4]	$ Mil/yr	0.6	0.6
O&M PV[3,4]	$ Mil	5.1	5.7
Total PV[3,4]	$ Mil	21.7	22.3
TN Removed (Ave.)[6]	lb N/d	550	600
Annual TN Removed (Ave.)[7]	lb N/yr	200,000	219,000
TN Cost[4,9]	$/lb N	10.9	10.2
TP Removal			
Capital[2,5]	$ Mil	1.4	1.4
Annual O&M[5]	$ Mil/yr	0.2	0.2
O&M PV[3,5]	$ Mil	2.1	2.2
Total PV[3,5]	$ Mil	3.5	3.6
TP Removed (Ave.)[6]	lb P/d	50	50
Annual TP Removed (Ave.)[7]	lb P/yr	18,900	19,500
TP Cost[5,9]	$/lb P	18.0	19.0

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 10 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

* The optimization strategy will not reduce total nitrogen loads. Rather, it will improve ammonia load reduction.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at the RMSD WPCP.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
Operate the Primaries in CEPT Mode • Ability to reduce phosphorus discharge loads • Additional capacity in the primaries • Additional capacity for the downstream unit processes. This capacity will enhance ammonia and total nitrogen load reduction.	• Additional chemical handling • More solids in the liquid stream process to handle
Replace the Mechanical Aerators with a Fine-Bubble Aeration System • Increased oxygen transfer efficiency with the fine-bubble diffuser • Increased oxygen delivery capacity • Improved sludge settleability	• New system to learn to operate and maintain
Increase the SRT to Partially Nitrify • Ability to reduce ammonia and total nitrogen loads • More robust biology to absorb load swings • Improved secondary clarifier settleability due to longer SRT • Increased TSS and BOD load reduction in the Secondary Clarifiers due to longer SRT • Reduced waste activated sludge yield • Improved contaminants of emerging concern removal	• Operating a more complex process • Additional energy demand • Foaming concerns • Alkalinity addition required (at a minimum for the dry season) • Operating to achieve partial nitrification may cause process instability, especially with respect to chlorine disinfection
Modify the Initial Aeration Basin Zone to Operate as an Anoxic Selector • Ability to reduce total nitrogen loads • Improved secondary clarifier settleability • Increased oxygen transfer efficiency due to improved alpha value	• An additional process to operate

5 Sidestream Treatment

As previously described, the RMSD WPCP was not identified as a potential candidate for sidestream treatment.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the RMSD WPCP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. RMSD should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under optimization, Section 4. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, the recently completed 5-MG wet weather storage tank is required to attenuate peak flows. The existing ferric chloride would be modified and polymer chemical feed facilities would be added to operate the primaries in CEPT mode. The existing equalization basins within the activated sludge complex would be converted to aeration basins and additional aeration basins would be required. The ability to attenuate peak flows at the wet weather storage box is critical once the equalization basins are converted. The aeration basins would be modified to operate in nitrification/denitrification mode to facilitate ammonia and total nitrogen load reduction. Additional aeration basins, blower capacity and alkalinity chemical feed facilities would be required for reducing the ammonia load.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would build upon those listed for Level 2.

In addition to those listed for Level 2, Level 3 upgrades would add a denitrifying filter complex to further reduce total nitrogen loads. This filter complex would include a filter feed pumping station, an external carbon source chemical feed facility for total nitrogen load reduction, and metal salt/polymer chemical feed facilities to further reduce total phosphorus loads.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent targets are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Headworks	• Recently constructed wet weather storage tank to attenuate peak flows	Same as Level 2
Primary	• Modify the existing ferric chloride chemical feed facilities • Add new polymer chemical feed facilities	Same as Level 2
Biological	• Retrofit the existing equalization basins to operate as aeration basins • Modify and expand the existing aeration basins to operate in nitrification/ denitrification mode • Add alkalinity chemical feed facilities	Same as Level 2
Tertiary	--	• Filter feed pumping station • Denitrifying filter complex • External carbon source chemical feed facilities • Metal salt chemical feed facilities • Polymer chemical feed facilities

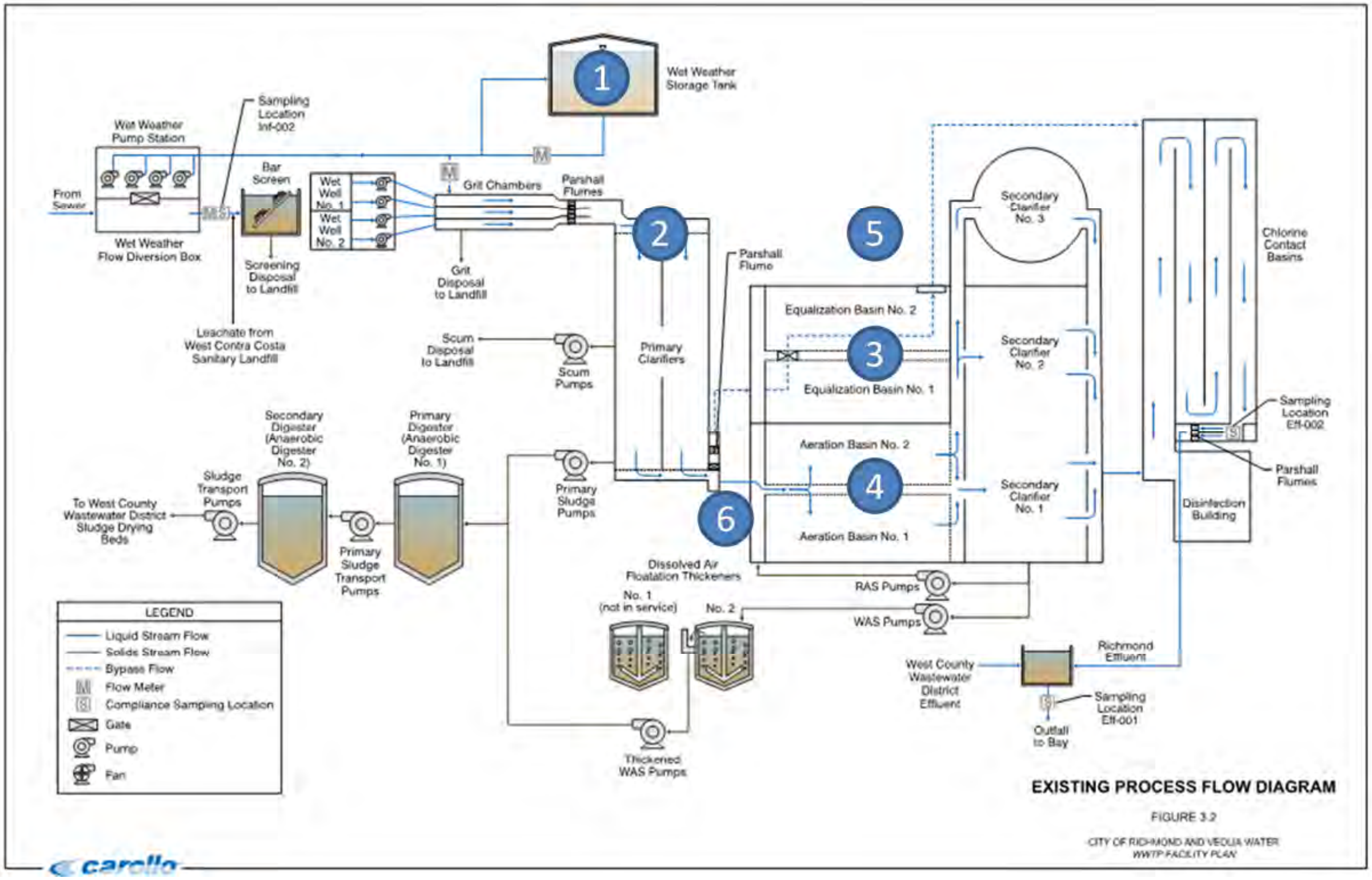

Figure 6-1. Level 2 Upgrade Concepts for the RMSD WPCP

(1) Use the recently constructed wet weather storage tank to attenuate peak flows, (2) Modify the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (3) retrofit the existing equalization basins to operate as an aeration basin, (4) modify the aeration basins to operate in nitrification/denitrification mode, (5) add new aeration basins to operate in nitrification/denitrification mode, and (6) add alkalinity chemical feed facilities

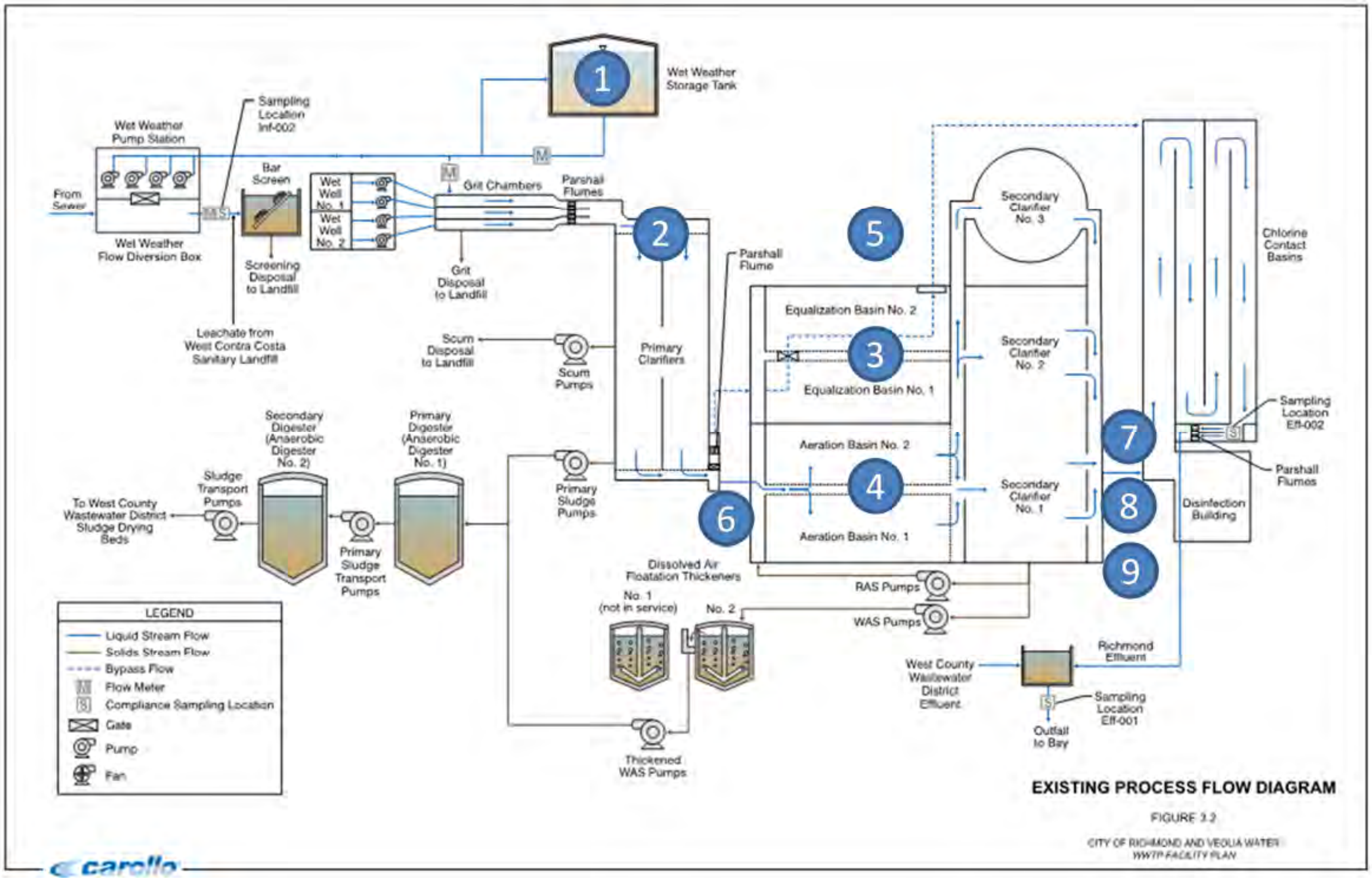

Figure 6-2. Level 3 Upgrade Concepts for the RMSD WPCP

(1) Use the recently constructed wet weather storage tank to attenuate peak flows, (2) Modify the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (3) retrofit the existing equalization basins to operate as an aeration basin, (4) modify the aeration basins to operate in nitrification/denitrification mode, (5) add new aeration basins to operate in nitrification/denitrification mode, (6) add alkalinity chemical feed facilities, (7) add a denitrifying filter complex with a feed pumping station, (9) add an external carbon source chemical feed facility, and (9) add metal salt and polymer chemical feed facilities

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Use the recently constructed wet weather storage tank to attenuate peak flows, (2) Modify the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (3) retrofit the existing equalization basins to operate as an aeration basin, (4) modify the aeration basins to operate in nitrification/denitrification mode, (5) add new aeration basins to operate in nitrification/denitrification mode, and (6) add alkalinity chemical feed facilities

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Use the recently constructed wet weather storage tank to attenuate peak flows, (2) Modify the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (3) retrofit the existing equalization basins to operate as an aeration basin, (4) modify the aeration basins to operate in nitrification/denitrification mode, (5) add new aeration basins to operate in nitrification/denitrification mode, (6) add alkalinity chemical feed facilities, (7) add a denitrifying filter complex with a feed pumping station, (9) add an external carbon source chemical feed facility, and (9) add metal salt and polymer chemical feed facilities

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	16.0	18.3	16.0	18.3
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	65	65	89	102
Annual O&M	$Mil/yr	1.1	1.2	1.5	2
O&M PV[3]	$ Mil	24	26	34	45
Total PV[3]	$ Mil	89	91	123	147
Unit Capital Cost	$/gpd	4.1	3.6	5.5	5.6
Unit Total PV	$/gpd	5.5	5.0	7.7	8.0
TN Removal					
Capital[2,4]	$ Mil	63	63	86	100
Annual O&M[4]	$ Mil/yr	0.5	0.6	0.9	1.4
O&M PV[3,4]	$ Mil	12	14	21	31
Total PV[3,4]	$ Mil	75	77	107	131
TN Removed (Ave.)[6]	lb N/d	1,600	1,700	1,900	2,300
Annual TN Removed (Ave.)[7]	lb N/yr	587,000	616,000	699,000	831,000
TN Cost[4,8]	$/lb N	4.3	4.2	5.1	5.2
TP Removal					
Capital[2,5]	$ Mil	1.5	1.5	23	38
Annual O&M[5]	$ Mil/yr	0.3	0.3	0.5	0.8
O&M PV[3,5]	$ Mil	6.7	7.2	11	18
Total PV[3,5]	$ Mil	8.2	8.7	34	56
TP Removed (Ave.)[6]	lb P/d	40	40	70	110
Annual TP Removed (Ave.)[7]	lb P/yr	12,800	15,200	24,900	40,300
TP Cost[5,8]	$/lb P	21	19	46	46

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Improved phosphorus and nitrogen removal • Increased CECs removal • Improved oxygen transfer efficiency • Improved sludge settleability • Reduced solids yield in the activated sludge processes • Alkalinity recovery associated with denitrification	• Additional chemicals from CEPT and the external carbon source • Additional solids in the primaries • Operate new processes that will require the operators to get accustomed to
Level 3	Same as Level 2, plus: • High quality product water amenable to recycled water • Reduced TSS and BOD discharge loads	Same as Level 2, plus: • Potential safety issue from the external carbon source (if methanol) • More chemicals required than Level 2 • Additional pumping associated with mixed liquor return and filter operation

7 Nutrient Load Reduction by Other Means

RMSD does not currently recycle water. However, RMSD is evaluating the feasibility of recycling approximately 6 acre-feet per year by year 2025. The project is still at the conceptual stage.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by

Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

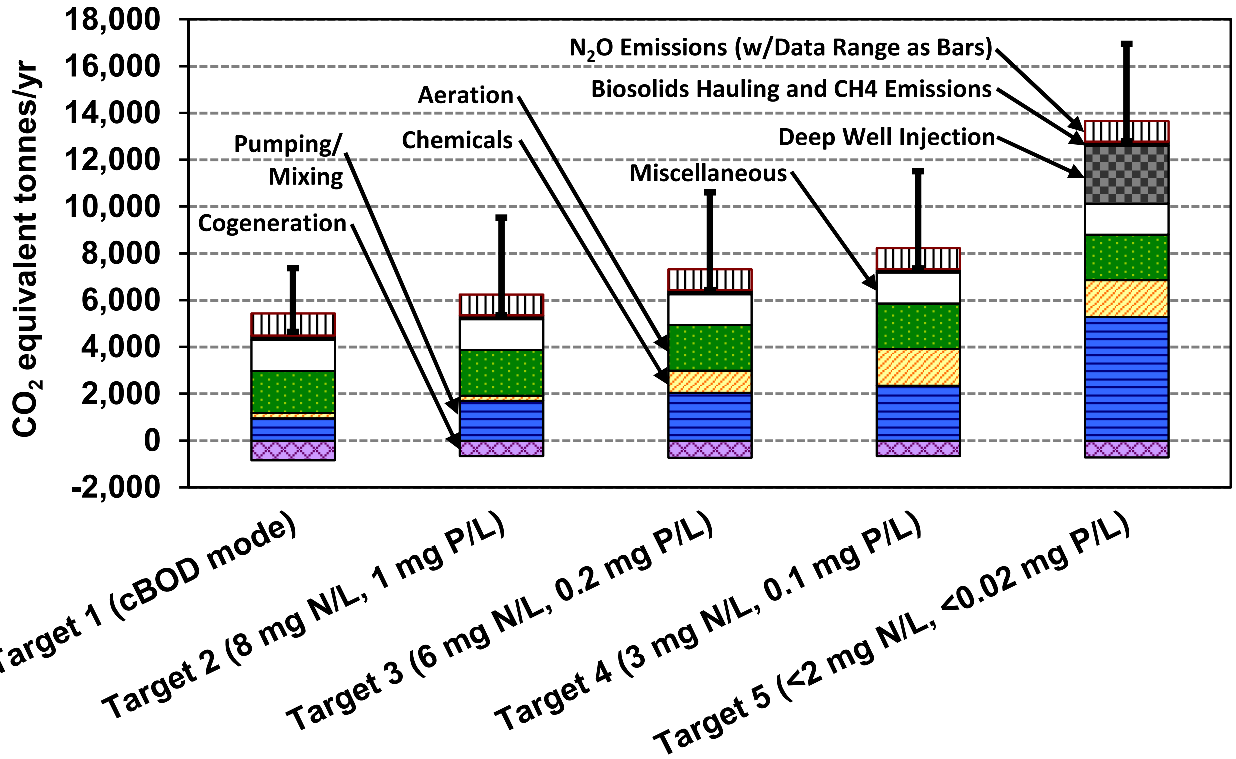

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Chemicals is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional chemicals required to further reduce TN and TP loads.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round*
GHG Emissions Increase from Energy	MT CO_2/yr	200	200	600	600	1,200	1,300	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	9,200	7,000	13,600	11,000	14,400	11,700	--
GHG Emissions Increase Total	MT CO_2/yr	9,400	7,200	14,200	11,600	15,600	13,000	--
Unit GHG Emissions[2]	lb CO_2/MG	9,500	7,300	5,000	4,000	5,400	4,500	--
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	44	34	34	28	34	28	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	2	2	2	2	6	5	--
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	5	6	16	14	69	48	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
* The RMSD WPCP is not currently a candidate for sidestream treatment as previously discussed.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the WPCP:

- Nutrient Removal using Granular Sludge – this could be used to phase out the biotower/activated sludge and/or MBR. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the mechanical aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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Rodeo Sanitary District

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Rodeo Sanitary District

Rodeo, CA

February 20, 2018
Final Report

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Executive Summary

The Rodeo Sanitary District (RSD) Water Pollution Control Facility (WPCF) discharges to San Pablo Bay. It is located at 800 San Pablo Avenue, Rodeo, CA 94572, and it serves a population of approximately 8,900 people in Rodeo and Tormey. The plant has an average dry weather flow (ADWF) permitted capacity of 1.14 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3,7]	Level 3 Year Round[3,7]	Side-stream
Design Flow	mgd	--	--	0.6	0.8	1.1	1.5	1.1	1.5	--
Flow to Bay[2]	mgd	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	10	10	11	11	15	15	15	15	15
TN	lb N/d	83	83	74	70	121	113	88	45	74
TP	lb P/d	17	17	5	5	8	8	6	2	21
Costs[4,5]										
Capital	$ Mil	--	--	0.7	0.7	16	17	25	27	4.2
O&M PV	$ Mil	--	--	0.4	0.6	--*	--*	--*	0.7	1.6
Total PV	$ Mil	--	--	1.1	1.3	16	17	25	28	5.8
Unit Costs[6]										
Capital	$/gpd	--	--	1.2	1.0	14	11	22	18	--
Total PV	$/gpd	--	--	1.8	1.7	14	11	22	19	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. The facilities would likely be placed outside the existing plant facilities. The ability to acquire the neighboring land is essential for implementing such facilities.

* The unit O&M PV is similar or less than the current operating mode.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Maintain the current practice of full nitrification.
2. Add a metal salt and polymer chemical feed facilities for chemically enhanced primary treatment (CEPT). This will increase the capacity on the downstream activated sludge and reduce total phosphorus discharge loads.
3. Operate the standby RAS pump. By operating both existing RAS pumps, return flows to the secondary train will increase and improve total nitrogen removal capacity.

The RSD WPCF is considered a potential candidate for sidestream treatment to reduce nitrogen loads. The recommended sidestream treatment strategy is deammonification for reducing nitrogen loads. The addition of metal salts (e.g., alum or ferric chloride) to the sidestream could also improve phosphorus load reduction.

The upgrade strategies to achieve Levels 2 and 3 include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Add metal salt/polymer chemical feed facilities for CEPT.
    b. Add an additional primary clarifier.
    c. Modify the existing aeration basins with mixed liquor return pumping/piping and operate in step feed mode.
    d. Add an additional aeration basin, blower and RAS pumps.
    e. Add an additional secondary clarifier.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L):
    a. Same as Level 2, plus add denitrification filters with a feed pumping station.
    b. Add an external carbon source chemical feed facilities.
    c. Add metal salt/polymer chemical feed facilities at the denitrifying filters.

As shown in Table ES-1, and as might be expected, the costs generally increase from optimization to Level 2 and Level 3 upgrades, respectively. The costs generally increase for both capital and O&M from the dry season to year round. Overall the present value costs range from $1.1 Mil for dry season optimization up to $28 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Rodeo Sanitary District (RSD) Water Pollution Control Facility (WPCF) discharges to San Pablo Bay. It is located at 800 San Pablo Avenue, Rodeo, CA 94572, and it serves population of approximately 8,900 people in Rodeo and Tormey. The plant has an average dry weather flow (ADWF) permitted capacity of 1.14 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

RSD WPCF holds the National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2012-0027; CA0037826. Table 2-1 provides a summary of the permit limitations for RSD WPCF. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2015-0013; CA0038024)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	1.14	--	--	--
BOD	mg/L	--	25	40	--
TSS	mg/L	--	30	45	--
Total Ammonia, as N	mg/L	--	54	--	140

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the RSD WPCF. The treatment plant consists of comminutors, aerated grit removal, primary clarification, activated sludge biological treatment, secondary clarification, disinfection with sodium hypochlorite, and dechlorination with sodium bisulfite. The aeration basin operates at a high enough SRT to facilitate full nitrification. Solids removed from the wastewater stream are thickened, digested anaerobically, and dewatered for off-site disposal.

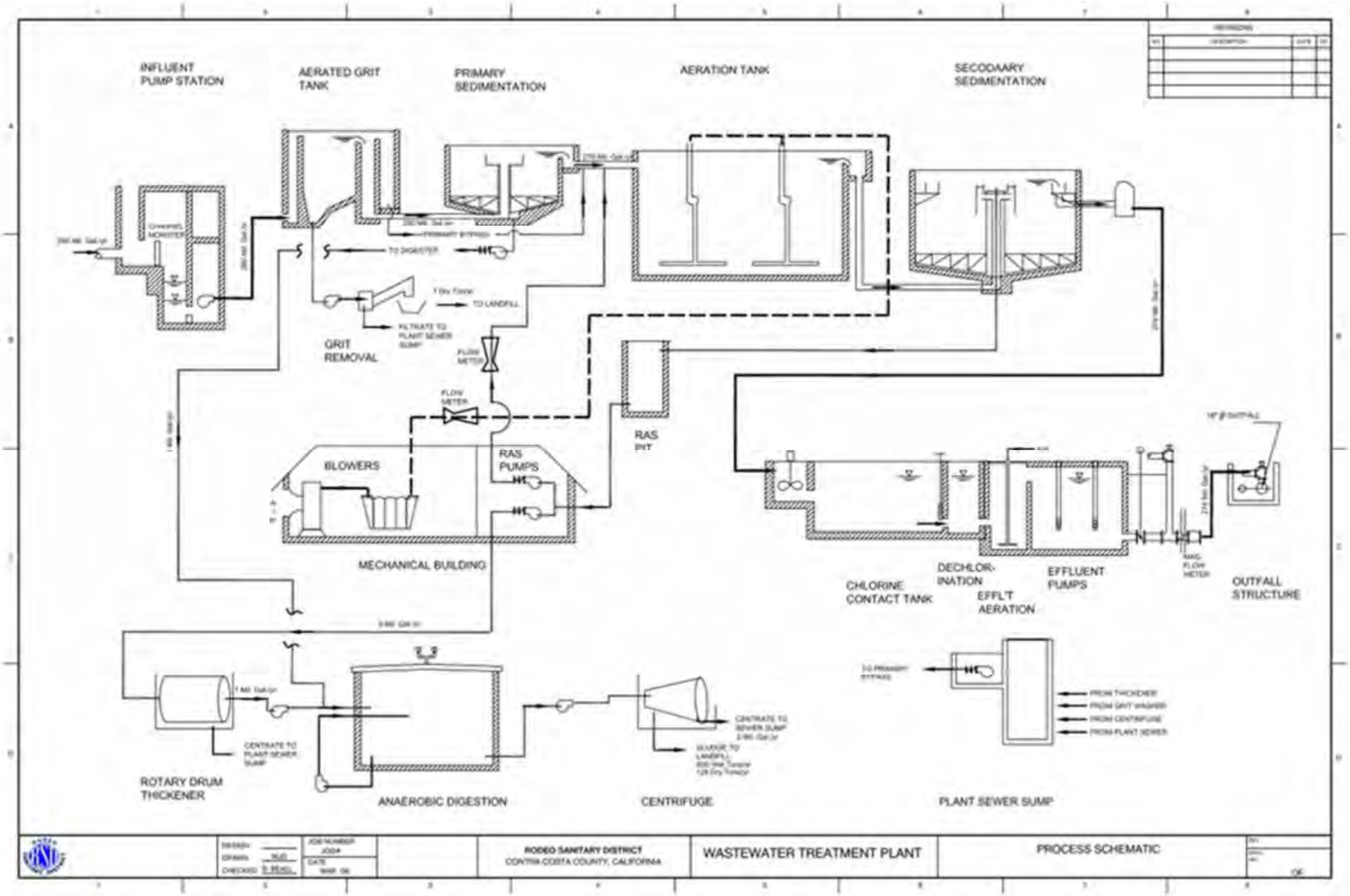

Figure 2-1. Process Flow Diagram for RSD WPCF

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the RSD WPCF is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (12/2011-11/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	0.6	0.7	0.9	1.0
BOD	lb/d	1,000	1,000	1,800	1,200
TSS	lb/d	1,300	1,400	2,500	2,200
Ammonia	lb N/d	100	200	100	200
Total Kjeldahl Nitrogen (TKN)	lb N/d	200	200	200	300
Total Phosphorus (TP)	lb P/d	20	30	20	30
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	200	170	252	140
TSS	mg/L	260	238	350	257
Ammonia	mg N/L	20	34	14	23
TKN	mg N/L	40	34	28	35
TP	mg P/L	4.0	5.1	2.8	3.5
Alkalinity	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

RSD does not currently have any plans to further upgrade the WPCF to achieve further nutrient removal.

2.5 Pilot Testing

RSD has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in

the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for the RSD WPCF are presented in Table 3-1. The projected flow and load for 2025 was not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	0.6	0.7	0.9	1.0
BOD	lb/d	1,100	1,100	2,100	1,400
TSS	lb/d	1,500	1,600	2,900	2,500
Ammonia	lb N/d	100	200	100	200
TKN	lb N/d	200	200	200	300
TP	lb P/d	30	30	20	30
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	230	196	290	161
TSS	mg/L	299	274	403	296
Ammonia	mg N/L	23	39	16	26
TKN	mg N/L	46	39	32	40
TP	mg P/L	4.6	5.9	3.2	4.0
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided, it was determined that RSD WPCF may be a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July, 2015. The sampling results were projected forward to the permitted capacity for use in the sidestream treatment evaluation. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-2. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Permitted Flow Capacity
Sidestream Flow	mgd	0.013	0.025
Ammonia	lb N/d	56	106
TKN	lb N/d	67	128
TN [1]	lb N/d	67	128
OrthoP	lb P/d	10	20
TP	lb P/d	4	8
Alkalinity	lb $CaCO_3$/d	200	370
Ammonia	mg N/L	500	500
TKN	mg N/L	610	610
TN [1]	mg N/L	610	610
OrthoP	mg P/L	90	90
TP	mg P/L	40	40
Alkalinity	mg/L as CaCO3	1,800	1,800

1. It was assumed that TN = TKN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.14	1.3	1.6	2.0
BOD	lb/d	1,900	1,900	3,400	2,300
TSS	lb/d	2,500	2,700	4,800	4,200
Ammonia	lb N/d	200	400	200	400
TKN	lb N/d	400	400	400	600
TP	lb P/d	40	60	40	60
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	200	170	252	140
TSS	mg/L	260	238	350	257
Ammonia	mg N/L	20	34	14	23
TKN	mg N/L	40	34	28	35
TP	mg P/L	4.0	5.1	2.8	3.5
Alkalinity	mg/L as CaCO3	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for July 2015 at 11,155. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for, TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy.

Three optimization strategies were identified during the RSD WPCF site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads.

- **Optimization Strategy 1:** Maintain the current practice of full nitrification in the activated sludge system as a means for maintaining low ammonia discharge loads.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** N/A. Maintain the current practice.
  - ***Result from analysis:*** Full nitrification maintained.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Add ferric chloride/polymer feed facilities at the primary clarifiers to turn them into chemically enhanced primary treatment (CEPT). CEPT will remove phosphorus and increase the TSS and BOD capture at the primaries.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase phosphorus removal and reduce loading to downstream unit processes. This could increase downstream activated sludge treatment capacity.
  - ***Result from analysis:*** It will remove phosphorus at the primaries and increase downstream capacity. However, it will most likely remove more carbon than desired for optimizing total nitrogen load reduction (if required in the future). The extent of this impact would require more detailed analysis.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 3:** Expand RAS return flow by operating the standby pumps as duty.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Remove a portion of the nitrogen load year round.
  - ***Result from analysis:*** There are two existing RAS pumps (1 duty and 1 standby). If both pumps were operational, more RAS would be returned and reduce total nitrogen discharge loads.
  - ***Recommendation:*** Carry forward.

These three strategies could independently reduce total phosphorus and total nitrogen loads, respectively. Strategy 3 is a viable strategy for reducing total nitrogen discharge loads. Both existing RAS pumps would need to operate to provide greater RAS return and better total nitrogen removal. Adding chemicals to the primaries (Strategy 2) would reduce the total phosphorus discharge loads.

The recommended strategies are shown with the process flow diagram presented in Figure 4-1. A description of each strategy and the evaluation results are presented thereafter. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

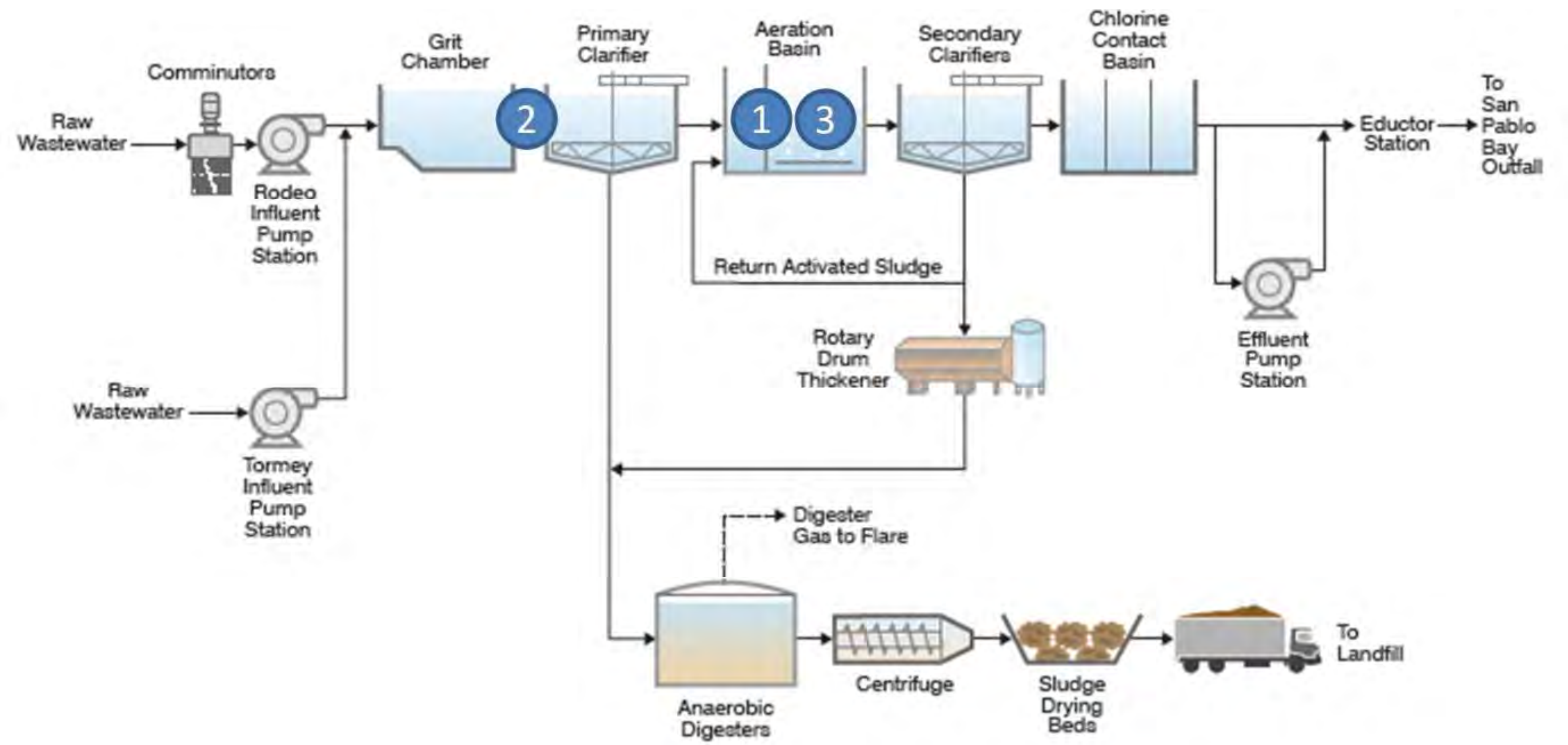

Figure 4-1. Optimization Concepts Considered for RSD WPCF

(1) Maintain full nitrification in the activated sludge system, (2) add metal salt/polymer chemical feed facilities to operate in CEPT mode, and (3) expand RAS return flow by operating the standby unit.

The capital and operational elements of the recommended optimization strategies are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Maintain Full Nitrification in the Activated Sludge: • No capital elements	• Maintain a sufficient SRT for full nitrification
Add Chemical Addition at the Primary Clarifiers • Add ferric chloride/polymer chemical feed facilities	• Operate the chemical feed facilities
Run both RAS pumps • Operate the standby pump as duty	• Operate both RAS pumps

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	11	11	89	89	19	19
Discharge with Opt. Strategy[1]	lb N or P/d	11	11	74	70	5	5
Load Reduction[2]	lb N or P/d	0	0	15	19	13	14
Load Reduction[2]	%	0%	0%	16%	22%	72%	74%
Annual Load Reduction	lb N or P/yr	0	0	5,310	7,080	4,880	5,010

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
4. The plant already fully nitrifies. The optimization concepts will enhance nitrification reliability.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	0.6	0.8
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.7	0.7
Annual O&M	$ Mil/yr	0.04	0.06
Present Value O&M[3]	$ Mil	0.4	0.6
Present Value Total[3]	$ Mil	1.1	1.3
Unit Capital Cost[8]	$/gpd	1.2	1.0
Unit Total PV Cost[8]	$/gpd	1.8	1.7
TN Removal			
Capital[2,4]	$ Mil	--*	--*
Annual O&M[4]	$ Mil/yr	--**	0.01
O&M PV[3,4]	$ Mil	--**	0.1
Total PV[3,4]	$ Mil	--	0.1
TN Removed (Ave.)[6]	lb N/d	15	19
Annual TN Removed (Ave.)[7]	lb N/yr	5,310	7,080
TN Cost[4,9]	$/lb N	--	1.6
TP Removal			
Capital[2,5]	$ Mil	0.7	0.7
Annual O&M[5]	$ Mil/yr	0.05	0.05
O&M PV[3,5]	$ Mil	0.4	0.5
Total PV[3,5]	$ Mil	1.2	1.2
TP Removed (Ave.)[6]	lb P/d	13	14
Annual TP Removed (Ave.)[7]	lb P/yr	4,880	5,010
TP Cost[5,9]	$/lb P	24	24

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

* The optimization concept for total nitrogen load reduction has no capital elements.

** The optimization concept for total nitrogen load reduction has O&M costs similar or less than the current operating mode.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at RSD WPCF.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
Maintain Full Nitrification • Maintain current performance • Low sludge yield • Enhanced contaminants of emerging concern (CEC) removal compared to non-nitrifying activated sludge • Enhanced load reduction for BOD and TSS	• Additional oxygen demand to oxidize ammonia
Add CEPT • Ability to reduce total phosphorus discharge loads • Increased capacity in the activated sludge process	• Additional chemical handling
Use Standby RAS Pump • Ability to reduce nitrogen discharge loads • Recovery of alkalinity lost during nitrification • Improved settleability in the secondary clarifiers	• Modified mode of operation

5 Sidestream Treatment

As previously described, the RSD WPCF was identified as a potential candidate for sidestream treatment. Given the relatively small size of RSD, a detailed evaluation is recommended to determine whether sidestream treatment is feasible given its limited staffing hours.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction. The RSD WPCF already removes ammonia in the main plant so sidestream treatment to reduce ammonia discharge loads to the Bay is not recommended.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification) including requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requires 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for RSD.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks). In the case of the WPCF, ferric chloride addition ahead of the dewatering is recommended where the precipitated P will be captured with the cake.

Recovery of the total phosphorus sidestream load via struvite precipitation is another option to eliminate phosphorus recycle stream loads. This process produces a useful byproduct (struvite crystals) that can be sold economically. Chemical addition is typically simpler and easier for plants to implement.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed Facility
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)[4]	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	15	120	25
Discharge with Sidestream Treatment[2]	lb/d	15	74	21
Load Reduction[3]	lb/d	0	46	4
Load Reduction	%	0%	38%	16%
Annual Load Reduction	lb/yr	0	16,680	1,500

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. The plant already nitrifies so any sidestream treatment will likely not further reduce ammonia discharge loads.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	4.1	0.07
Annual O&M	$ Mil/yr	0.06	0.01
Total Present Value[2]	$ Mil	5.5	0.31
NH4-N Load Reduction[3,5,7]	lb N/yr	0	--
TN Load Reduction[3,5]	lb N/yr	16,680	--
TP Load Reduction[4,5]	lb P/yr	--	1,500
NH4-N Cost [3,5,6,7]	$/lb N	--	--
TN Cost [3,5,6]	$/lb N	11.0	--
TP Cost [4,5,6]	$/lb P	--	10.2

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. The plant already nitrifies so any sidestream treatment will likely not further reduce ammonia discharge loads.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the RSD WPCF to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. RSD should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under the Optimization Section. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, ferric chloride/polymer chemical feed facilities would be added just upstream of the primary clarifiers. This effectively turns the primaries into chemically enhanced primary treatment (CEPT) to increase phosphorus, TSS, and BOD removal. An additional primary clarifier is included due to elevated loading rates on the existing clarifiers at permitted capacity flows.

An additional aeration basin is included to account for additional solids for nutrient removal at permitted capacity. The existing activated sludge basins would be modified to include a mixed liquor return pumping/piping and from a direct feed to a step feed configuration where the primary effluent is distributed along the aeration basin length. The mixed liquor return is necessary to facilitate total nitrogen load reduction. The step feed strategy is a means to reduce solids loading on the secondary clarifiers. Despite the reduced solids loading associated with step feed, an additional secondary clarifier is recommended to account for elevated loadings at permitted capacity. All the new basins are located along the East Bay Parks District property boundary.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

In addition to those listed for Level 2, Level 3 upgrades require slightly larger new aeration basins, addition of denitrification filters, an external carbon source chemical feed facility, and metal salt/polymer chemical feed facilities. Such facilities would likely be placed outside the existing plant facilities. The ability to acquire the neighboring land is essential for implementing such facilities. The denitrification filters and external carbon source are included to further reduce total nitrogen loads. The polishing metal salt/polymer chemical feed facilities are in place to precipitate additional total phosphorus prior to filtration as a means to further reduce total phosphorus.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Ferric chloride/polymer facility to operate as a CEPT • New primary clarifier	Same as Level 2
Biological	• Aeration basins modification with mixed liquor return pumping/piping • Aeration basins modification to operate in step feed mode • New aeration basin • New RAS pumping/piping with the new aeration basin • New Secondary Clarifier	Same as Level 2, plus: • Additional aeration and anoxic volume • Further modifications to the aeration system piping/distribution
Tertiary*	--	• Denitrification filters • External carbon source chemical feed facility • Metal salt/polymer chemical feed facilities

* The facilities would likely be placed outside the existing plant facilities. The ability to acquire the neighboring land is essential for implementing such facilities.

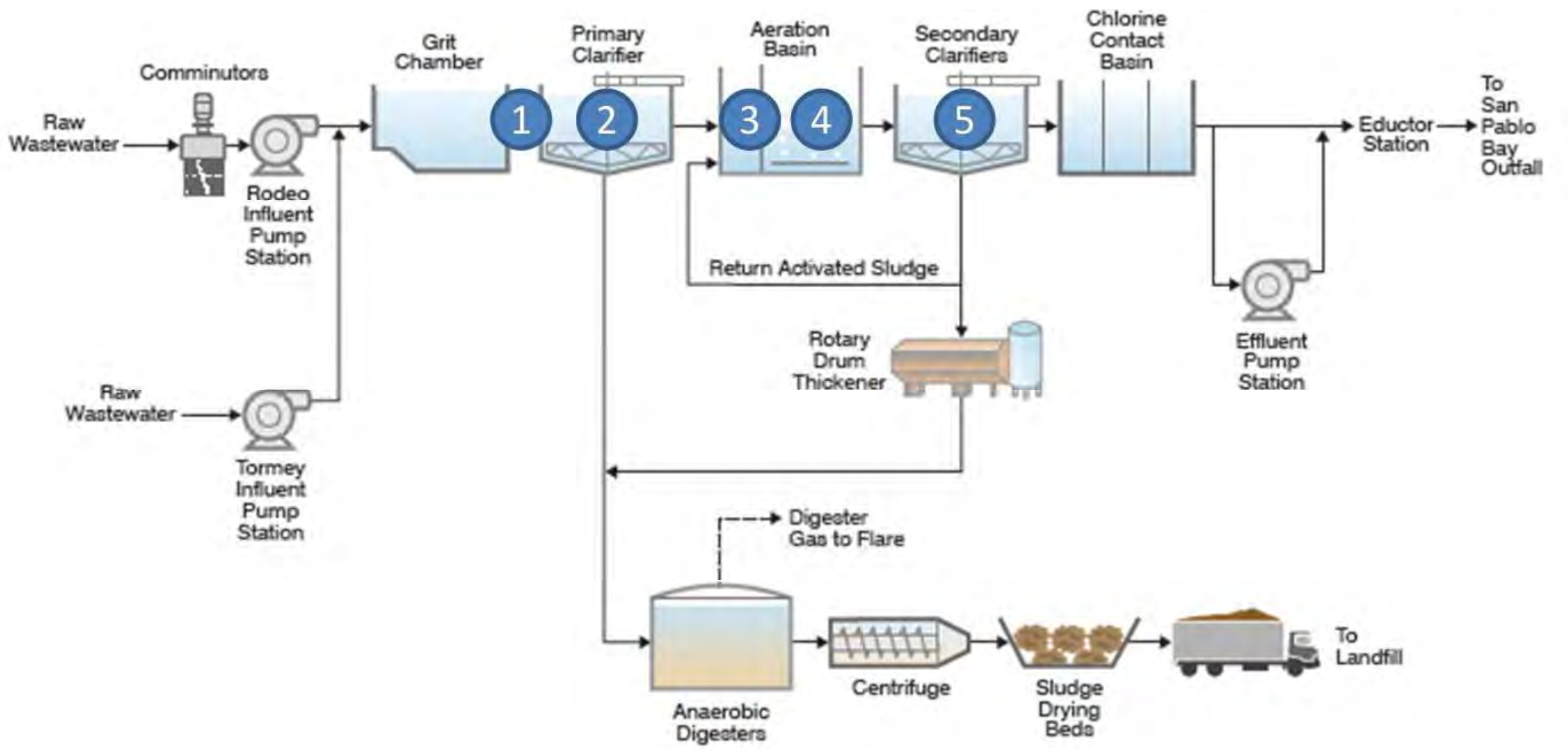

Figure 6-1. Level 2 Upgrade Concepts for Rodeo WPCF

(1) Add metal salt/polymer chemical feed facilities to operate in CEPT mode, (2) add an additional primary clarifier (3) add an additional aeration basin with all the equipment for nitrification/denitrification, (4) modify the existing aeration basins to operate in step feed mode and expand the anoxic zone, and (5) add an additional secondary clarifier

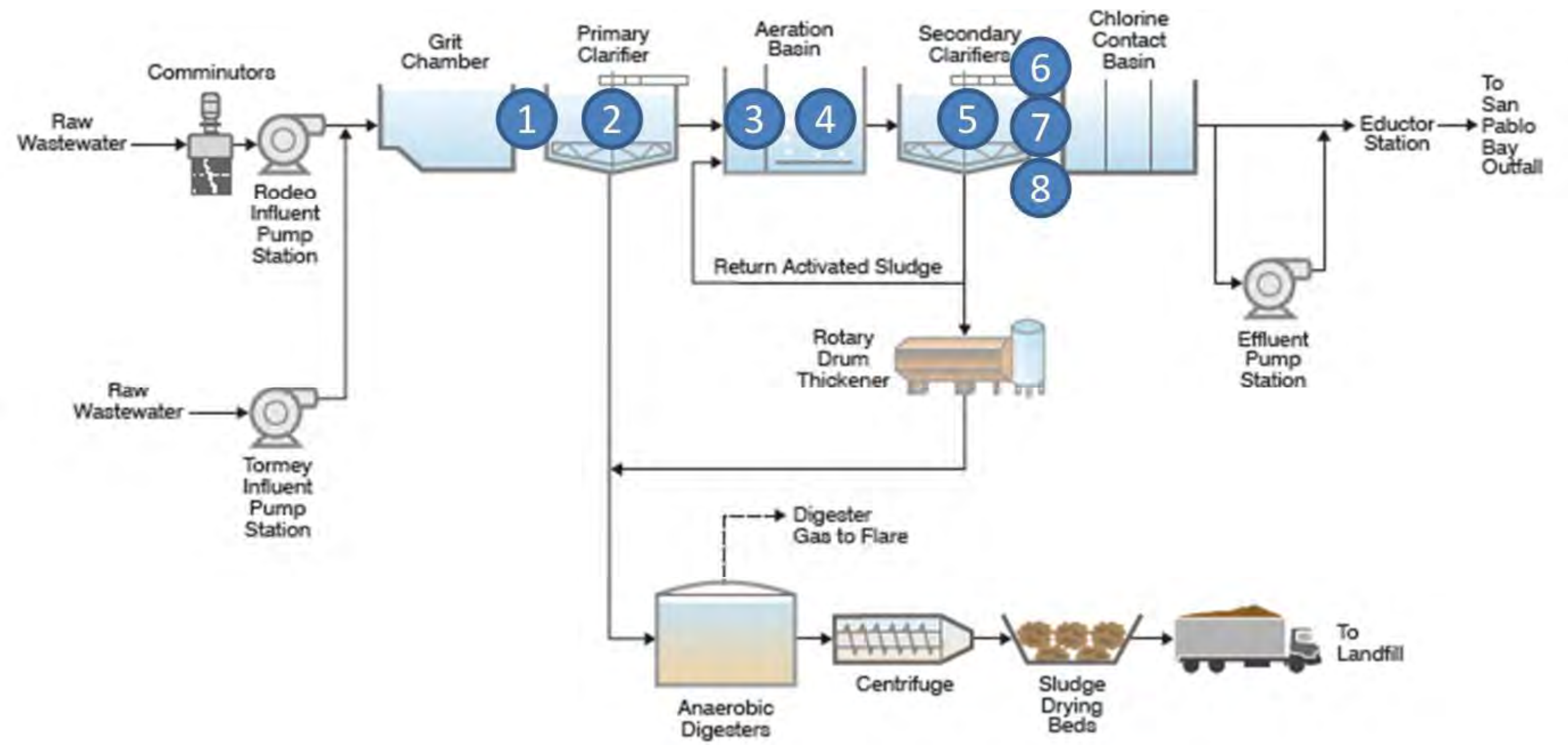

Figure 6-2. Level 3 Upgrade Concepts for Rodeo WPCF

(1) Add metal salt/polymer chemical feed facilities to operate in CEPT mode, (2) add an additional primary clarifier (3) add an additional aeration basin with all the equipment for nitrification/denitrification, (4) modify the existing aeration basins to operate in step feed mode and expand the anoxic zone, (5) add an additional secondary clarifier, (6) add denitrification filters, (7) add an external carbon source chemical feed facilities, and (8) add metal salt/ polymer chemical feed facilities

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt/polymer chemical feed facilities to operate in CEPT mode, (2) add an additional primary clarifier (3) add an additional aeration basin with all the equipment for nitrification/denitrification, (4) modify the existing aeration basins to operate in step feed mode and expand the anoxic zone, and (5) add an additional secondary clarifier

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt/polymer chemical feed facilities to operate in CEPT mode, (2) add an additional primary clarifier (3) add an additional aeration basin with all the equipment for nitrification/denitrification, (4) modify the existing aeration basins to operate in step feed mode and expand the anoxic zone, (5) add an additional secondary clarifier, (6) add denitrification filters, (7) add an external carbon source chemical feed facilities, and (8) add metal salt/ polymer chemical feed facilities

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	1.1	1.5	1.1	1.5
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	16	17	25	27
Annual O&M	$Mil/yr	--*	--*	--*	0.03
O&M PV[3]	$ Mil	--*	--*	--*	0.7
Total PV[3]	$ Mil	16	17	25	28
Unit Capital Cost	$/gpd	14	11	22	18
Unit Total PV	$/gpd	14	11	22	19
TN Removal					
Capital[2,4]	$ Mil	12	12	20	21
Annual O&M[4]	$ Mil/yr	--*	--*	--*	--*
O&M PV[3,4]	$ Mil	--*	--*	--*	--*
Total PV[3,4]	$ Mil	12	12	20	21
TN Removed (Ave.)[6]	lb N/d	7	7	33	75
Annual TN Removed (Ave.)[7]	lb N/yr	2,650	2,700	11,900	27,380
TN Cost[4,8]	$/lb N	147	145	56	26
TP Removal					
Capital[2,5]	$ Mil	2.8	2.8	10.1	11.8
Annual O&M[5]	$ Mil/yr	0.1	0.1	0.1	0.1
O&M PV[3,5]	$ Mil	1.6	1.7	2.3	3.2
Total PV[3,5]	$ Mil	4.3	4.5	12.4	15.0
TP Removed (Ave.)[6]	lb P/d	17	18	20	23
Annual TP Removed (Ave.)[7]	lb P/yr	6,240	6,430	7,140	8,350
TP Cost[5,8]	$/lb P	23	23	58	60

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

* The O&M is similar or less than the current operating mode.

Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Additional capacity for primary clarifiers • Improved settleability in the secondary clarifiers • Alkalinity recovery associated with the denitrification step	• Additional chemicals from CEPT • Additional aeration basin to operate • More energy demand • Operate in a new mode that will require the operators to get accustomed to
Level 3	Same as Level 2 plus the following additional benefits: • Filtered product water is higher quality than existing treated product water	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Safety from external carbon source (if methanol) • Additional aeration basin volume to operate • Additional biosolids handling associated with additional chemicals

7 Nutrient Load Reduction by Other Means

The RSD WPCF does not have a recycled water program and there are no existing plans to implement a recycled water program.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

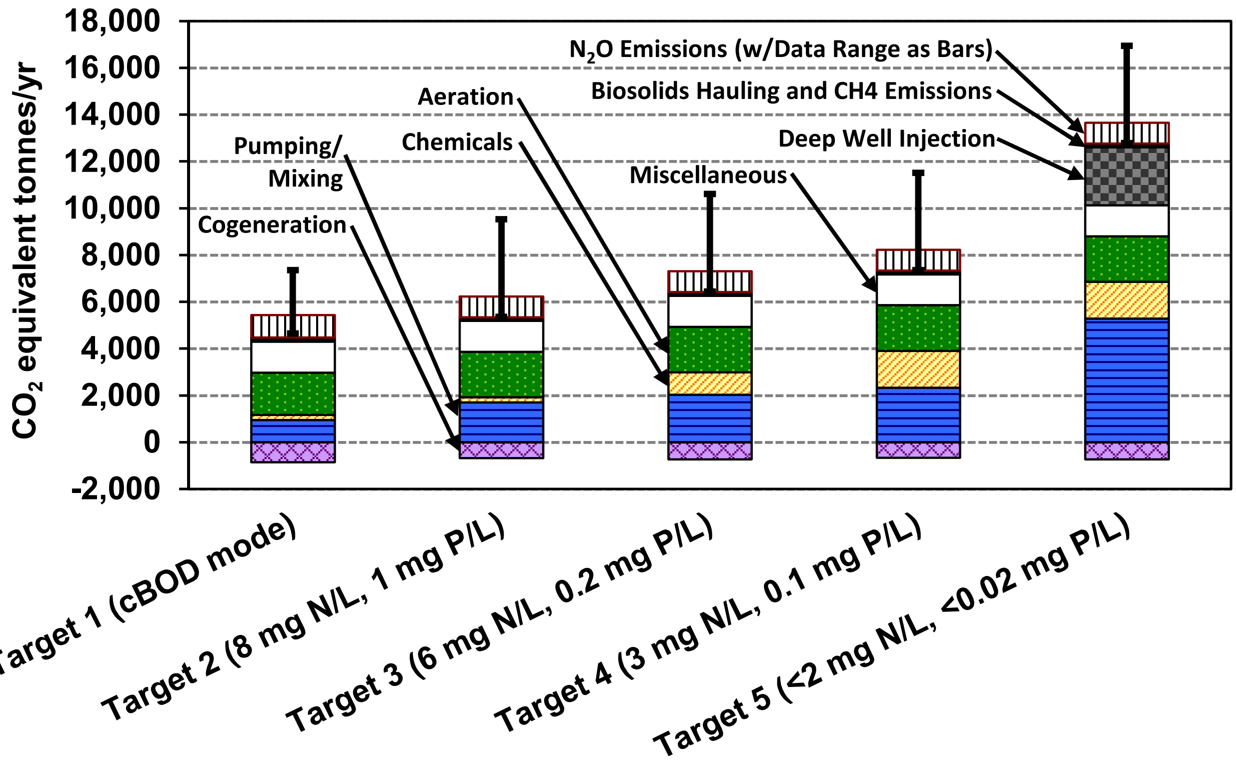

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies,

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	24	27	2	3	19	21	7
GHG Emissions Increase from Chemicals	MT CO_2/yr	3	3	10	12	21	24	1
GHG Emissions Increase Total	MT CO_2/yr	27	30	12	15	39	45	8
Unit GHG Emissions[2]	lb CO_2/MG	230	250	50	70	180	200	76
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--	--	--	--	--	--	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	6	5	--*	--*	2	1	1
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	6	6	7	8	13	13	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. The plant already nitrifies and it is meeting Level 2 and 3 upgrade levels.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at RSD WPCF:

- Nutrient Removal using Granular Sludge – this could be used to phase out the biotower/activated sludge. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit to FSSD is it has the potential to not require basin expansion for Levels 2 or 3. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.23

San Francisco International Airport, Mel Leong Treatment Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

San Francisco International Airport, Mel Leong Treatment Plant

San Francisco, CA

March 23, 2018
Final Report

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Executive Summary

The City and County of San Francisco, San Francisco International Airport, Mel Leong Treatment Plant is located in San Francisco, CA and discharges treated effluent to the Lower San Francisco Bay. The Sanitary Plant has an average dry weather flow (ADWF) permitted capacity of 2.2 million gallons per day (mgd). The facility also includes the Industrial Plant, which is not evaluated in this study.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies for the Sanitary Plant are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3,7]
Design Flow	mgd	--	--	0.6	0.5	1.1	0.9	1.1	0.9	--
Flow to Bay[2]	mgd	1.1	1.1	1.1	1.1	1.7	1.7	1.7	1.7	--
Nutrients to Bay (Average)[2,8]										
Ammonia	lb N/d	450	450	480	480	29	28	29	28	--
TN	lb N/d	460	460	490	490	220	210	150	80	--
TP	lb P/d	31	31	6	6	15	14	10	4	--
Costs[4,5]										
Capital	$ Mil	--	--	0.6	0.6	27	27	36	36	--
O&M PV	$ Mil	--	--	0.3	0.3	17	18	20	23	--
Total PV	$ Mil	--	--	0.8	0.8	44	45	56	58	--
Unit Costs[6]										
Capital	$/gpd	--	--	1.0	1.2	24.7	28.7	32.3	37.6	--
Total PV	$/gpd	--	--	1.5	1.8	40.4	48.1	50.7	61.7	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Not Applicable. The Mel Leong Treatment plant was not considered for sidestream treatment due to due to infrequent dewatering (about 1 to 2 days per week.
8. The effluent loading reported in the Group Annual Report for the airport facility including both the industrial and sanitary plant effluent. This evaluation focuses on the sanitary plant only, and evaluates options to reduce the sanitary plant concentrations to the target limits. Future loads are calculated assuming the industrial plant effluent meets Level 3 effluent concentrations.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Add ferric chloride to the SBRs to increase phosphorus removal. Optimization strategies to reduce ammonia or nitrogen were not feasible, due to insufficient SBR capacity.

The Mel Leong Treatment Plant is not considered a candidate for sidestream treatment due to infrequent dewatering (about 1 to 2 days per week).

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Construct chemical facilities for ferric chloride addition to the SBRs for phosphorus removal,
    b. Modify existing SBRs and blowers to provide sufficient aeration for nitrification and cycles for denitrification
    c. Construct additional SBRs to provide capacity for full nitrification. There is significant uncertainty in this evaluation, due to the high influent nitrogen concentrations and the biocide in the airplane waste, which may slow nitrification rates. Further evaluation by the plant will be required if nitrogen removal is necessary.
    d. Construct alkalinity addition facilities to support nitrification.
    e. Construct external carbon facilities (methanol) for carbon addition for denitrification, since the influent has a low carbon to nitrogen ratio and a high degree of nitrogen removal is needed due to the high influent concentrations.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Construct additional SBR volume for enhanced denitrification, with additional carbon addition.
    c. Construct conventional filters with chemical addition for phosphorus polishing.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $0.8 Mil for dry season optimization up to $58 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The City and County of San Francisco, San Francisco International Airport, Mel Leong Treatment Plant, Sanitary Plant (Sanitary Plant) services an estimated 10,000 airport and airline employees and travelers at the San Francisco International Airport. The Sanitary Plant treats sanitary wastewater from airplanes and airport facilities, including terminal restrooms, hangars, restaurants, and shops. The City and County of San Francisco, San Francisco International Airport, Mel Leong Treatment Plant, Industrial Plant (Industrial Plant) treats industrial wastewater from maintenance shops and vehicle washing, as well as first-flush stormwater runoff from industrial areas. The Discharger may, in emergency situations, use either plant to store or treat flows, spills, or overflows that would normally flow to the other plant to ensure that all wastewater is adequately treated. The Mel Leong Treatment Plant is located at Bldg. 924 Clearwater Drive, San Francisco, California 94128.

This evaluation focuses only on the Sanitary Plant, since the Watershed Permit is focused on municipal discharges.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The Mel Leong Treatment Plant holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2013-0011, NPDES Permit No. CA0038318). Treated wastewater from both the sanitary plant and the industrial plant are discharged to a single pipeline for subsequent dechlorination and discharge to the Lower San Francisco Bay through a common outfall under the joint powers authority of the North Bayside System Unit (NBSU). The NBSU is a joint powers authority comprised of the cities of Burlingame, Millbrae, South San Francisco and San Bruno and the San Francisco International Airport. The NBSU discharge is located at latitude 37°39’55” N and longitude 122°21’41” W.

Table 2-1 provides a summary of the permit limitations that are specific to the Sanitary Plant and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2013-0011; CA0038318)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	2.2 [1]	---	---	---
cBOD[2]	mg/L	---	25	40	---
TSS[2]	mg/L	---	30	45	---
Total Ammonia, as N[3]	mg/L	---	120	---	310

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. Current sanitary plant permitted capacity. Industrial plant permitted capacity is 1.2 mgd, for a total permitted capacity of 3.4 mgd.
2. Monitored at the sanitary plant effluent.
3. Monitored at the combined plant effluent, including flows from the sanitary and industrial plants. The Regional Watershed Permit designates that nutrient monitoring be at the same location as ammonia.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Sanitary Plant. Both liquids and solids processes are shown. The Sanitary Plant consists of screening and grit removal, flow equalization, followed by sequencing batch reactors (SBRs) for secondary treatment. Secondary effluent is disinfected by chlorination. Solids treatment consists of secondary sludge thickening, anaerobic digestion and dewatering using either drying beds or belt filter press.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Sanitary Plant is shown in Table 2-2. Current sanitary plant influent nutrient concentrations are higher than typical municipal plants.

Table 2-2. Current Sanitary Plant Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	0.55	0.51	0.61	0.61
BOD	lb/d	2,400	2,300	2,800	2,800
TSS	lb/d	3,200	2,900	3,700	3,700
Ammonia	lb N/d	560	510	650	650
Total Kjeldahl Nitrogen (TKN)[5]	lb N/d	640	590	750	750
Total Phosphorus (TP)[5]	lb P/d	70	60	80	80
Alkalinity	lb $CaCO_3$/d	2,410	2,230	2,760	2,760
BOD	mg/L	510	530	550	550
TSS	mg/L	690	670	720	720
Ammonia	mg N/L	122	120	129	129
TKN[5]	mg N/L	139	138	148	148
TP[5]	mg P/L	14.7	14.5	15.7	15.7
Alkalinity	mg CaCO3/L	520	520	550	550

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Flow shown is for the sanitary plant. Average effluent flow including industrial plant flow is 1.1 mgd.
5. Annual average TKN and TP based on five samples collected between July 2012 and June 2014. TKN and TP for other conditions were calculated using the ammonia peaking factors.

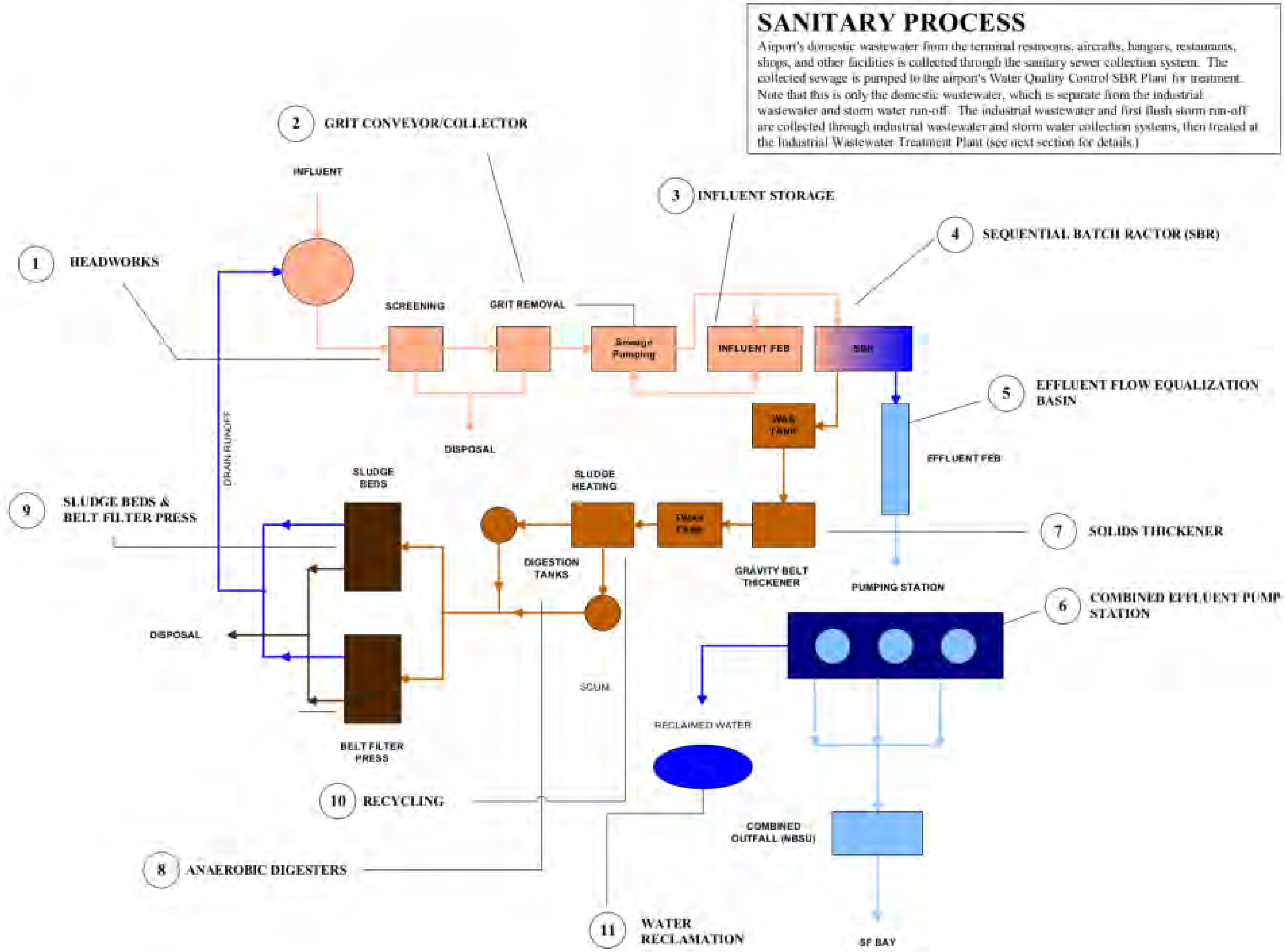

Figure 2-1. Process Flow Diagram for Mel Leong Sanitary Plant

(Source: NPDES Permit Attachment C)

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the Mel Leong Treatment Plant:

- As of 2018, a new Industrial Plant is in construction and will include new DAF tanks, ozone, and biologically active filters.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the Mel Leong Treatment Plant.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

The effluent loading reported in the Group Annual Report for the airport facility including both the industrial and sanitary plant effluent. This evaluation focuses on the sanitary plant only, and evaluates options to reduce the sanitary plant concentrations to the target limits. Load reductions are calculated assuming the industrial plant effluent meets Level 3 effluent concentrations.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Sanitary Plant are presented in Table 3-1. The projected flow and load for the Sanitary Plant in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	0.55	0.51	0.61	0.61
BOD	lb/d	2,700	2,600	3,200	3,200
TSS	lb/d	3,700	3,300	4,200	4,200
Ammonia	lb N/d	650	590	750	750
TKN	lb N/d	740	680	860	860
TP	lb P/d	80	70	90	90
Alkalinity	lb/d as $CaCO_3$	2,770	2,570	3,180	3,180
BOD	mg/L	590	610	630	630
TSS	mg/L	800	770	830	830
Ammonia	mg N/L	140	138	149	149
TKN	mg N/L	160	158	171	171
TP	mg P/L	16.9	16.7	18.0	18.0
Alkalinity	mg/L as $CaCO_3$	600	600	630	630

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

The Mel Leong Treatment Plant is not considered a candidate for sidestream treatment due to infrequent dewatering (about 1 to 2 days per week).

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the buildout flow provided by the plant. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the buildout flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Buildout Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3,4]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.1	1.0	1.2	1.2
BOD	lb/d	4,700	4,500	5,500	5,500
TSS	lb/d	6,400	5,700	7,300	7,300
Ammonia	lb N/d	1,120	1,020	1,300	1,300
TKN	lb N/d	1,280	1,170	1,490	1,490
TP	lb P/d	130	120	160	160
Alkalinity	lb/d as $CaCO_3$	4,790	4,440	5,500	5,500
BOD	mg/L	510	530	550	550
TSS	mg/L	690	670	720	720
Ammonia	mg N/L	122	120	129	129
TKN	mg N/L	139	138	148	148
TP	mg P/L	14.7	14.5	15.7	15.7
Alkalinity	mg/L as $CaCO_3$	520	520	550	550

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Buildout flow provided by the plant. Permitted average dry weather flow is 2.2 mgd. Other flows and loads are based on current flow and loading characteristics.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor’s costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Four optimization strategies were identified during the Sanitary Plant site visit. These were analyzed following the site visit to screen and select the most attractive strategy. The four optimization strategies are described below.

- **Optimization Strategy 1:** Evaluate the extent of biological phosphorus removal in the SBRs, and consider cycle modifications to improve biological phosphorus removal.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** The SBR cycle includes unaerated time, and the preliminary evaluation indicates the available time should be sufficient for biological phosphorus removal. Given the high influent concentrations in the sanitary plant, biological phosphorus removal alone is unlikely to meet Level 2 limits.
  - ***Recommendation:*** Do not carry forward, although plant may want to investigate further if phosphorus removal is required in the future.

- **Optimization Strategy 2:** Add ferric chloride to the SBRs to increase phosphorus removal.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Based on the high influent concentrations, the chemical dose needed to meet Level 2 limits may be higher than the typical municipal plant. The SBRs appear to have the capacity to accommodate the increased mixed liquor suspended solids concentration from ferric chloride addition.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 3:** Evaluate increasing the solids retention time to support nitrification during the aerated portion of the cycle, and denitrification during the unaerated portion. Evaluate whether biocides in the airplane waste are inhibiting nitrification, and whether alkalinity is sufficient for nitrification.
  - ***Is it feasible?*** No.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Reduce ammonia concentrations.
  - ***Result from analysis:*** Preliminary analysis indicates that two operating SBRs do not have sufficient volume or aeration capacity for nitrification. Alkalinity addition would also be necessary. Further study of nitrification inhibition and alkalinity requirements will be necessary if expansion for nitrification is required, since the wastewater is higher strength and contains biocides that could inhibit nitrification.
  - ***Recommendation:*** Do not carry forward at this time.

- **Optimization Strategy 4:** Operate all three SBRs to increase SRT and support nitrification.
  - ***Is it feasible?*** No.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Not feasible.
  - ***Result from analysis:*** Since all the SBR equipment (blowers, mixing pumps, air distribution, decanter) is dedicated to a single SBR, operating all three SBRs is not a reliable mode of operation.
  - ***Recommendation:*** Do not carry forward.

Strategy 2 is the best apparent way to reduce effluent phosphorus loads. Chemical addition (ferric chloride) to the SBRs is included. No feasible alternatives were identified for nitrification or nitrogen removal, because tankage is not available to increase solids retention time.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

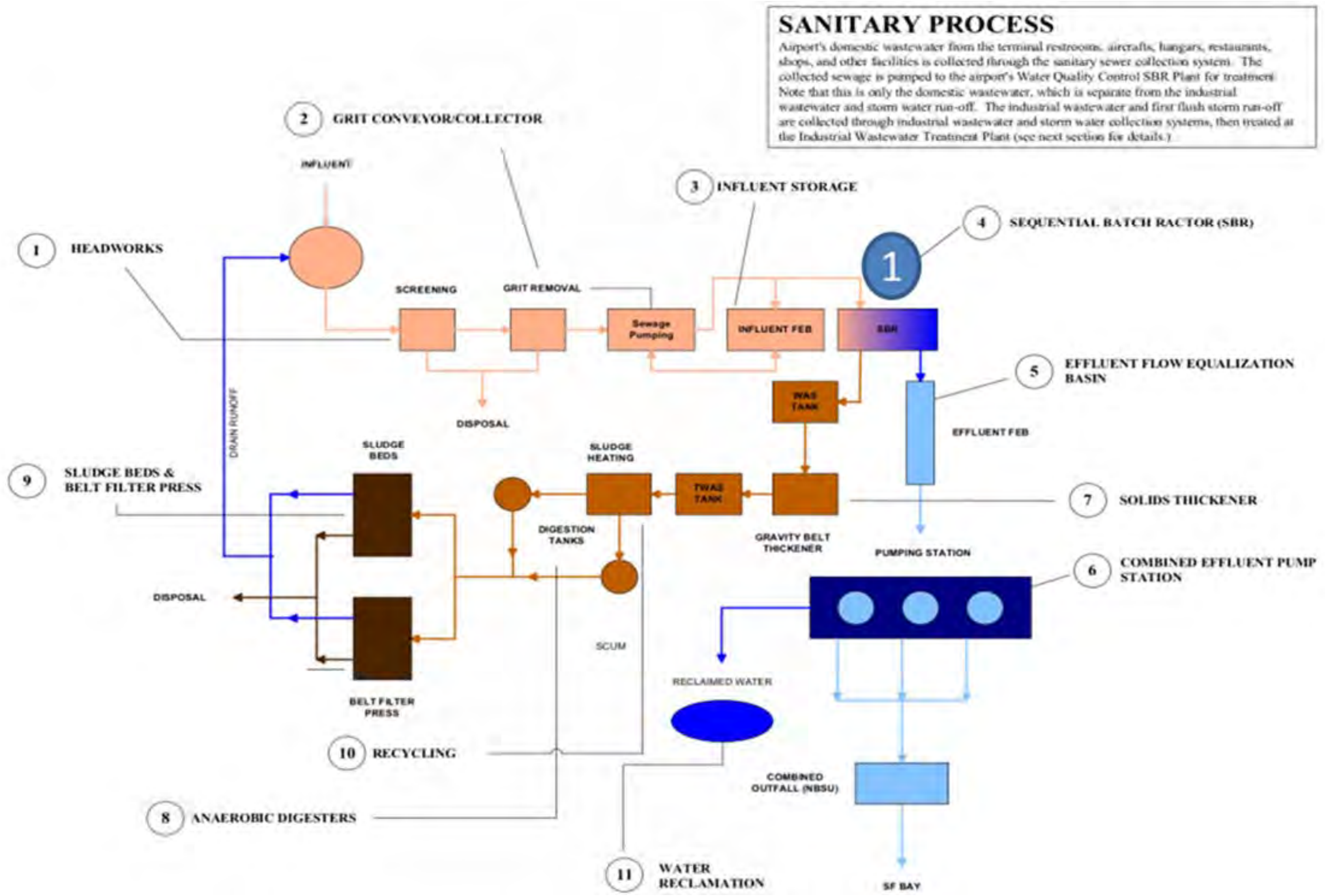

Figure 4-1. Optimization Concepts Considered for the Sanitary Plant

(1) add ferric chloride for P removal.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Ferric chloride storage, chemical metering pump, chemical injection.	Ferric chloride addition to the SBRs.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The Sanitary Plant shows improved phosphorus removal, but no change in ammonia or nitrogen removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1,4]	lb N or P/d	480	480	490	490	33	33
Discharge with Opt. Strategy[1,4]	lb N or P/d	480	480	490	490	6	6
Load Reduction[2,3]	lb N or P/d	0	0	0	0	27	27
Load Reduction[2,3]	%	0%	0%	0%	0%	82%	83%
Annual Load Reduction	lb N or P/yr	0	0	0	0	9,820	9,950

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.
4. Discharge includes loadings from both the sanitary and industrial plant. This evaluation focuses on the sanitary plant only, and evaluates options to reduce the sanitary plant concentrations to the target limits. Load reductions are calculated assuming the industrial plant effluent meets Level 3 effluent concentrations.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	0.6	0.5
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.6	0.6
Annual O&M	$ Mil/yr	0.03	0.03
Present Value O&M[3]	$ Mil	0.3	0.3
Present Value Total[3]	$ Mil	0.8	0.8
Unit Capital Cost[8]	$/gpd	1.0	1.2
Unit Total PV Cost[8]	$/gpd	1.5	1.8
TN Removal			
Capital[2,4]	$ Mil	0.0	0.0
Annual O&M[4]	$ Mil/yr	0.0	0.0
O&M PV[3,4]	$ Mil	0.0	0.0
Total PV[3,4]	$ Mil	0.0	0.0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0.6	0.6
Annual O&M[5]	$ Mil/yr	0.03	0.03
O&M PV[3,5]	$ Mil	0.3	0.3
Total PV[3,5]	$ Mil	0.8	0.8
TP Removed (Ave.)[6]	lb P/d	27	27
Annual TP Removed (Ave.)[7]	lb P/yr	9,820	9,950
TP Cost[5,9]	$/lb P	8.5	8.4

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• Phosphorus reliably removed	• Dependency on chemicals • Chemical costs • Increased sludge production.

5 Sidestream Treatment

Sidestream treatment is not considered a viable option for the Mel Leong Treatment Plant as previously described and thus was not further evaluated.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Sanitary Plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The Sanitary Plant should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Ferric chloride addition to the SBRs is assumed for phosphorus removal, with a higher dose than typically assumed for Level 2 due to the high influent concentrations.

It is assumed for this evaluation that Level 2 nitrogen limits could be met by adding additional SBRs, including aeration blowers and equipment, mixing pumps, and decanters, and retrofitting the existing SBRs to include increased aeration capacity. Based on the low carbon to nitrogen ratio measured in the influent, and the high degree of nitrogen removal needed due to the high influent concentrations, carbon addition (methanol) is included to provide carbon for denitrification. Based on available alkalinity and nitrogen data, alkalinity addition will be needed for nitrification under some conditions. There is significant uncertainty in this evaluation, due to the high influent nitrogen concentrations and the biocide in the airplane waste, which may slow nitrification rates. Further evaluation by the plant will be required if nitrogen removal is necessary.

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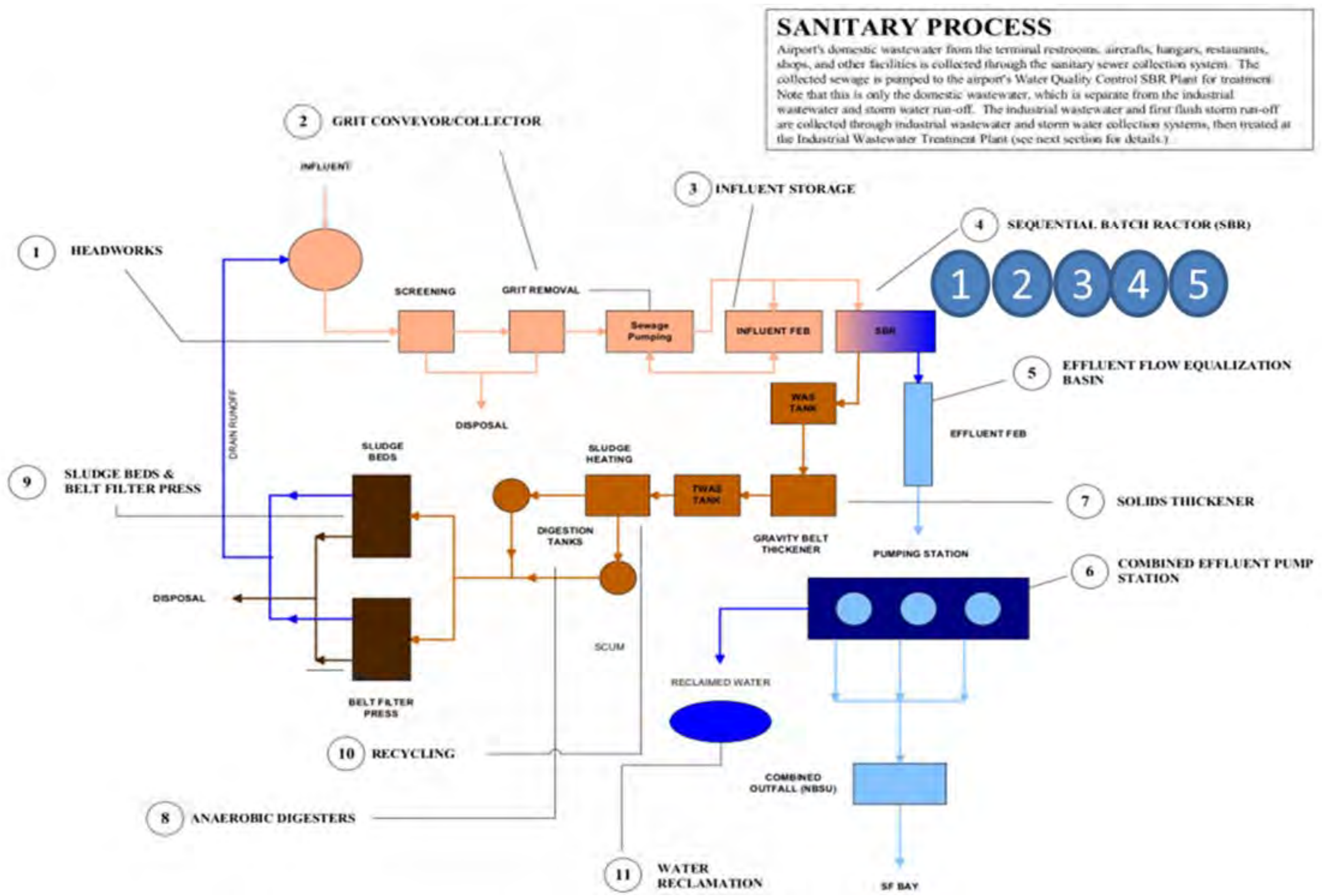

Figure 6-1. Level 2 Upgrade Concept for Sanitary Plant

(1) add ferric chloride for P removal, (2) modify existing SBRs and blowers to provide sufficient aeration for nitrification and cycles for denitrification, (3) construct additional SBRs, (4) construct alkalinity addition facilities to provide alkalinity for nitrification, and (5) construct methanol addition facilities to provide a carbon source for denitrification.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

An additional SBR is included to increase the anoxic time and volume, and additional carbon addition is assumed. Chemical addition and tertiary filtration for phosphorus polishing could be used to meet Level 3 phosphorus limits. Ferric chloride addition before both SBRs and filtration is assumed.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Secondary	• Ferric chloride addition to SBRs for phosphorus removal • Upgrade aeration and cycles in existing SBRs to support full nitrification. • Construct additional SBRs, including blowers, aeration systems, mixing pumps, and decanters. • Alkalinity addition facilities • External carbon source addition facilities	Same as Level 2 plus: • Construct additional SBR volume. • Increase methanol addition to meet lower limits.
Tertiary	---	Same as Level 2 plus: • Conventional Filters • Ferric chloride addition before filtration for phosphorus polishing

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

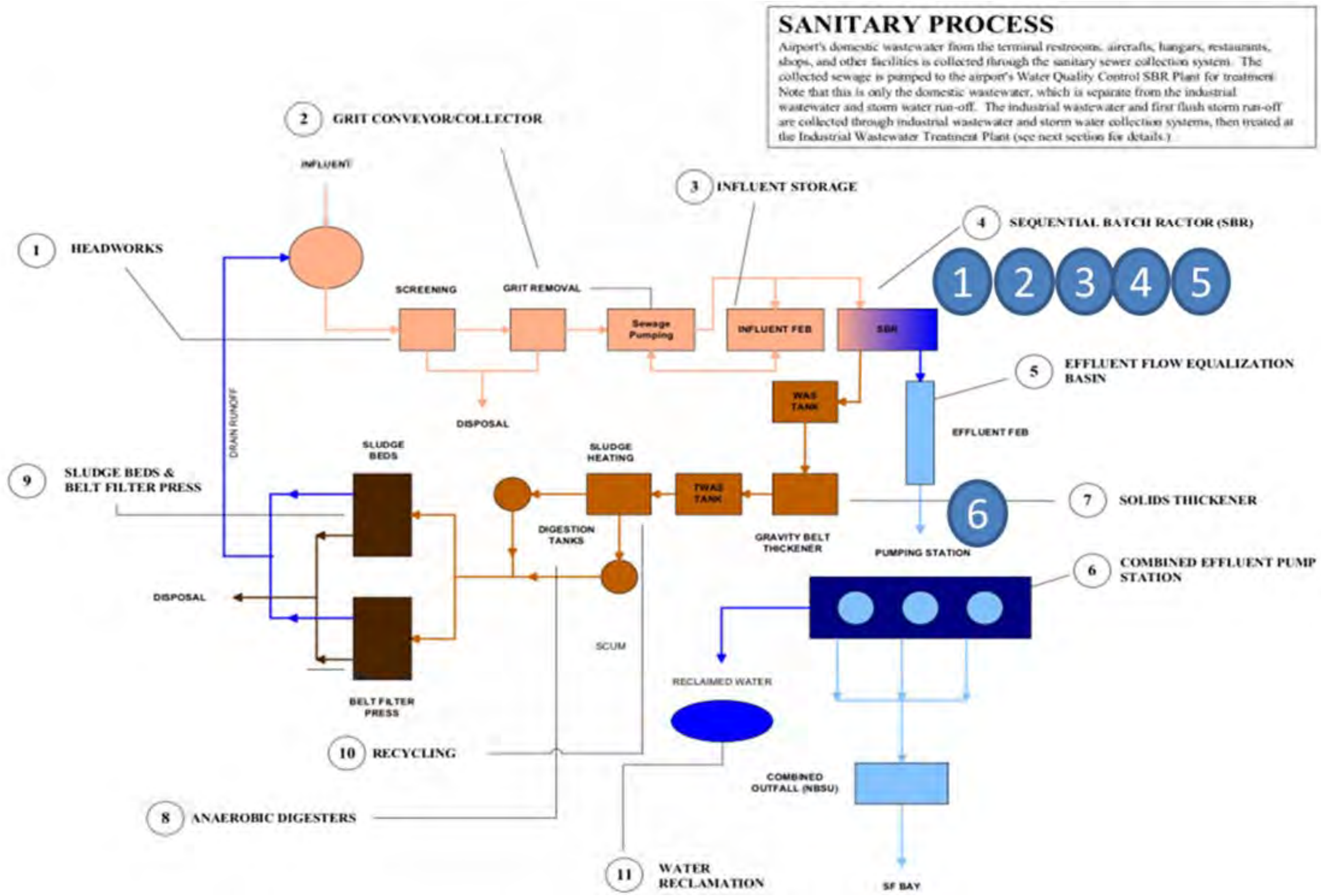

Figure 6-2. Level 3 Upgrade Concept for Sanitary Plant

(1) add ferric chloride for P removal, (2) modify existing SBRs and blowers to provide sufficient aeration for nitrification and cycles for denitrification, (3) construct additional SBRs, (4) construct alkalinity addition facilities to provide alkalinity for nitrification, (5) construct methanol addition facilities to provide a carbon source for denitrification, and (6) granular media filters with chemical addition for phosphorus polishing.

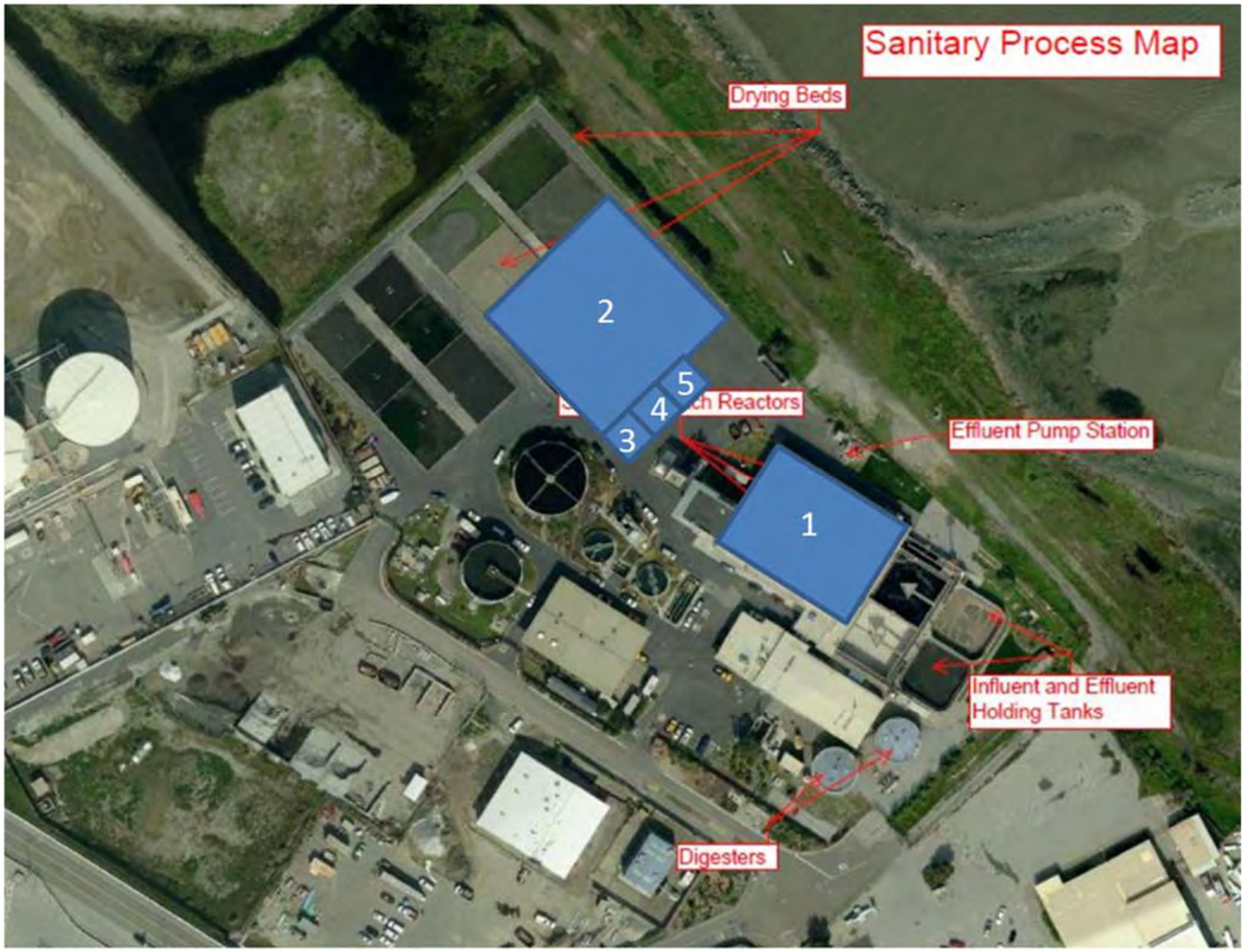

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season Year Round

(1) modify existing SBRs and blowers to provide sufficient aeration for nitrification and cycles for denitrification, (2) construct additional SBRs (3) construct alkalinity addition facilities to provide alkalinity for nitrification, (4) construct methanol addition facilities to provide a carbon source for denitrification, and (5) construct ferric chloride facilities for P removal.

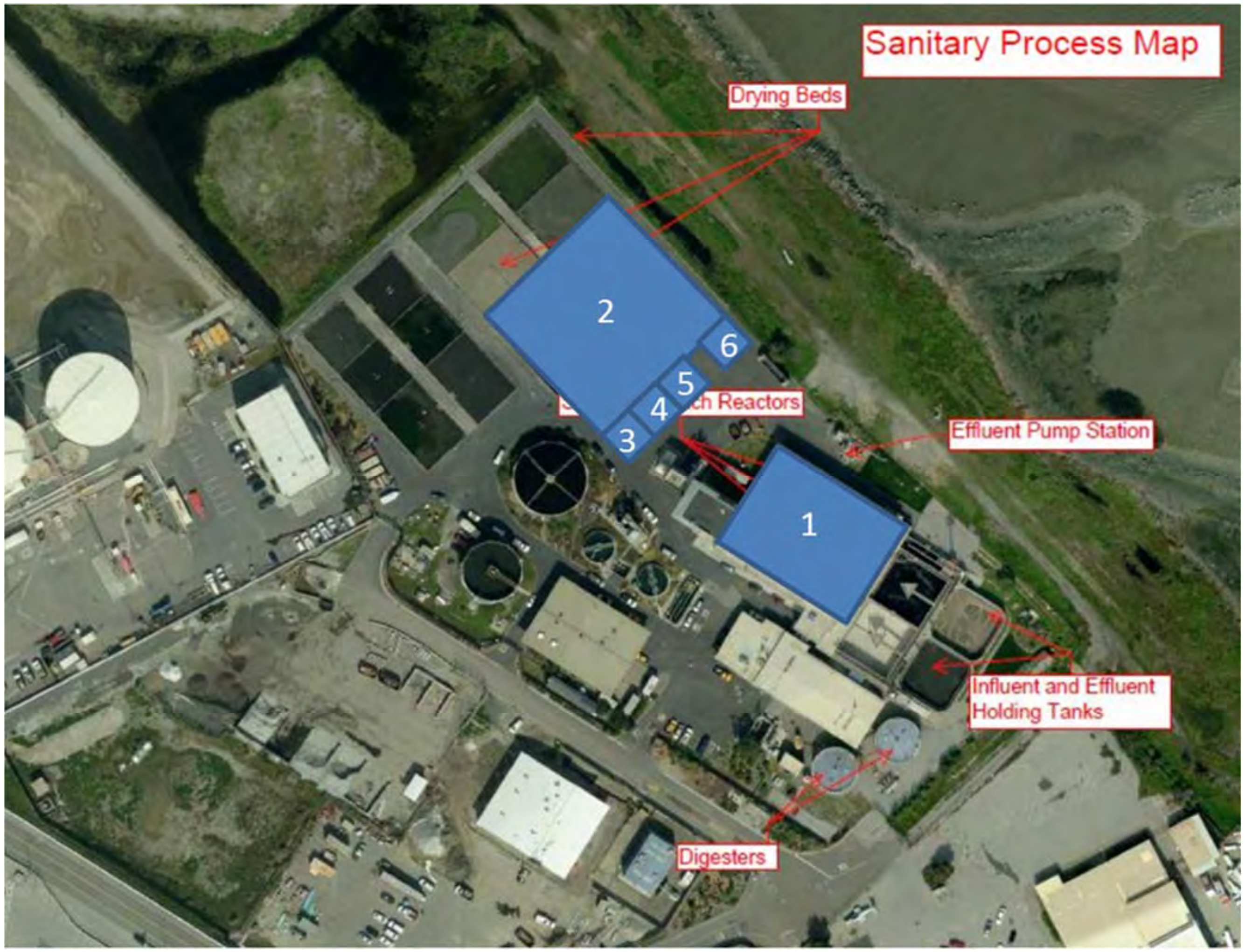

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) modify existing SBRs and blowers to provide sufficient aeration for nitrification and cycles for denitrification, (2) construct additional SBRs (3) construct alkalinity addition facilities to provide alkalinity for nitrification, (4) construct methanol addition facilities to provide a carbon source for denitrification, (5) construct ferric chloride facilities for P removal, and (6) granular media filters with chemical addition for phosphorus polishing source for denitrification.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	1.1	0.9	1.1	0.9
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	27	27	36	36
Annual O&M	$Mil/yr	0.8	0.8	0.9	1.0
O&M PV[3]	$ Mil	17	18	20	23
Total PV[3]	$ Mil	44	45	56	58
Unit Capital Cost	$/gpd	24.7	28.7	32.3	37.6
Unit Total PV	$/gpd	40.4	48.1	50.7	61.7
TN Removal					
Capital[2,4]	$ Mil	27	27	30	30
Annual O&M[4]	$ Mil/yr	0.7	0.8	0.8	0.8
O&M PV[3,4]	$ Mil	16	17	18	19
Total PV[3,4]	$ Mil	43	44	48	48
TN Removed (Ave.)[6]	lb N/d	470	480	530	600
Annual TN Removed (Ave.)[7]	lb N/yr	170,000	175,000	195,000	220,000
TN Cost[4,8]	$/lb N	8.4	8.4	8.2	7.3
TP Removal					
Capital[2,5]	$ Mil	0.6	0.6	6	6
Annual O&M[5]	$ Mil/yr	0.04	0.04	0.1	0.18
O&M PV[3,5]	$ Mil	0.9	0.9	2.3	4.1
Total PV[3,5]	$ Mil	1.5	1.6	8.2	10
TP Removed (Ave.)[6]	lb P/d	31	32	36	41
Annual TP Removed (Ave.)[7]	lb P/yr	11,300	11,600	13,100	15,100
TP Cost[5,8]	$/lb P	4.5	4.5	20.9	22.1

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing MLE process • Robust technology to absorb variability in flows and loads • Ability to reliably remove TN and TP	• Increased operation costs associated with alum addition • Increased sludge production • Increased belt filter press operational time may be necessary if sludge drying bed area is used for additional SBRs.
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use and additional alum use • Higher energy costs for filter feed pumping

7 Nutrient Removal by Other Means

The airport currently recycles less than 1 acre-feet per year (0.2 million gallons per year). By 2025, they plan to recycle 225 acre-feet per year (73 million gallons per year) for terminal restrooms and cooling towers. Most of the nutrients in the recycled water will be returned to the treatment plant, so the nutrient loading discharged to the Bay may be similar.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy

and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

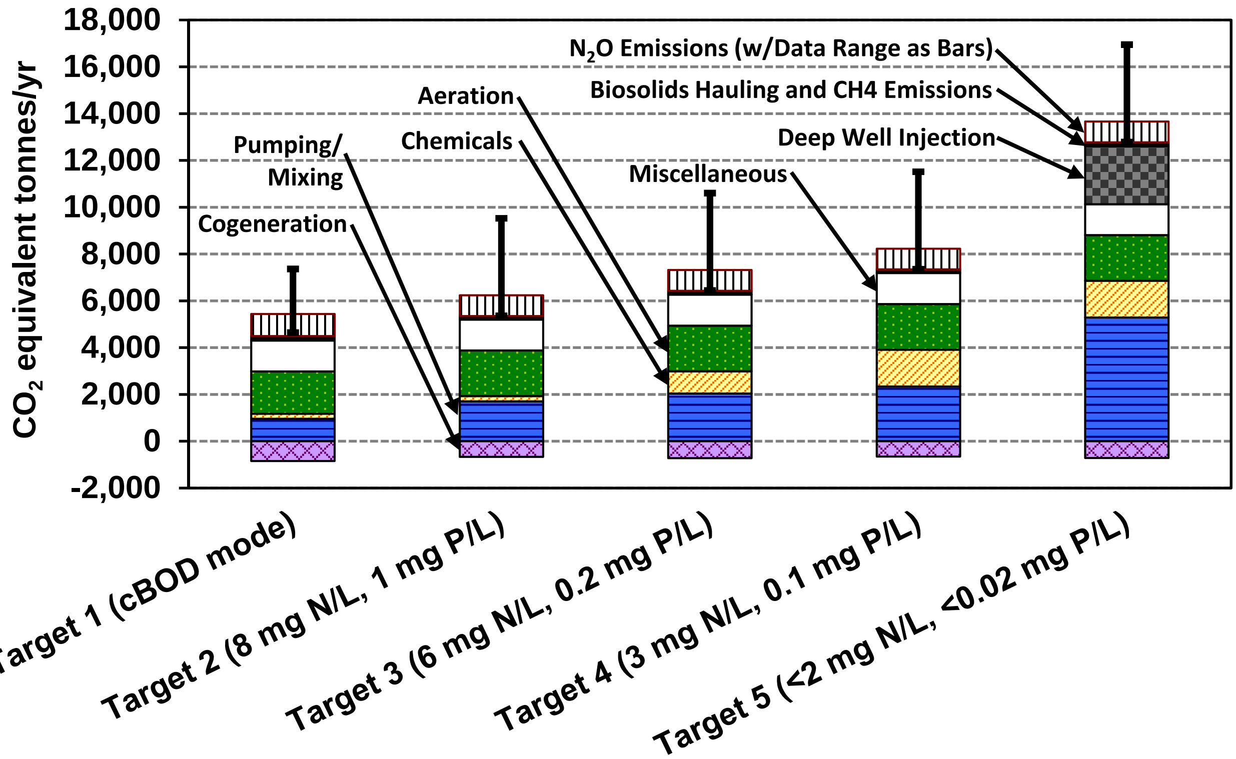

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	2	2	1,300	1,300	1,400	1,400	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	3	3	200	200	200	200	--
GHG Emissions Increase Total	MT CO_2/yr	5	5	1,500	1,500	1,700	1,600	--
								--
Unit GHG Emissions[2]	lb CO_2/MG	60	50	8,800	8,700	9,900	9,700	--
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	12.5	12.4	13.2	13.1	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	19.0	18.2	18.0	15.6	--
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	0.9	0.9	1.7	1.5	10.3	8.4	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. The Mel Leong Treatment Plant was not considered for sidestream treatment due to infrequent dewatering.

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Sanitary Plant. These are:

- Nitrite Shunt – Sanitary Plant aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Nutrient Removal using Granular Sludge – Future nutrient removal could use a granular sludge process. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN and TP
  - Disadvantages: No installations in North America
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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Southeast Water Pollution Control Plant

Bay Area Clean Water Agencies
Nutrient Reduction Study

Southeast Water Pollution Control Plant

San Francisco, CA

March 16, 2018
Final Report

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Executive Summary

San Francisco Public Utilities Commission owns and operates the Southeast Water Pollution Control Plant (SEP) located in San Francisco, CA and discharges treated effluent to lower San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 85.4 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow	mgd	--	--	63.1	78.0	69.4	85.7	69.4	85.7	--
Flow to Bay[2]	mgd	56.9	56.9	59	59	62.6	62.6	62.6	62.6	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	18,600	18,600	20,200	20,200	1,100	1,000	1,100	1,000	17,700
TN	lb N/d	21,300	21,300	23,000	23,000	8,400	7,800	6,000	3,100	21,500
TP	lb P/d	570	570	510	470	560	520	380	160	690
Costs[4,5]										
Capital	$ Mil	--	--	1.9	2.1	1,160	1,160	1,210	1,210	1.9
O&M PV	$ Mil	--	--	15.6	15.6	420	450	480	520	15.6
Total PV	$ Mil	--	--	17.5	17.7	1,580	1,610	1,690	1,730	17.5
Unit Costs[6]										
Capital	$/gpd	--	--	0.03	0.03	16.7	13.5	17.5	14.2	--
Total PV	$/gpd	--	--	0.3	0.2	22.8	18.8	24.4	20.2	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Optimize anaerobic selector operation to improve phosphorus removal. Costs are also included for ferric chloride addition to primary clarifiers, as a backup in case anaerobic selector optimization is not sufficient. Optimization strategies to reduce ammonia or nitrogen were not feasible, due to insufficient aeration tank volume

SEP is considered a candidate for sidestream treatment to reduce nitrogen loads as the plant anaerobically digests biosolids and dewaters to produce a return sidestream laden with nitrogen. The recommended sidestream treatment strategy is deammonification for reducing ammonia/nitrogen loads.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Construct chemical facilities for ferric chloride addition upstream of primary clarifiers,
   b. Convert the secondary process to a membrane bioreactor process due to space constraints. Demolish the existing HPO tanks, and construct new, deep MLE BNR tanks. Construct new blower facilities. Construct new membrane tanks. Construct fine screening to protect membranes. Construct facilities for methanol and alkalinity addition.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Add additional ferric chloride to the BNR tanks for phosphorus polishing.
   c. Construct additional BNR tanks. Configure all BNR tanks as 4-stage BNR, and add additional methanol.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $17.5 Mil for dry season optimization up to $1,730 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The San Francisco Public Utilities Commission (SFPUC) operates the Southeast Water Pollution Control Plant (SEP) serves a population of about 580,000 (2013) in eastern San Francisco and portions of Brisbane and Daly City. SEP treats combined wastewater and stormwater. It is located at 750 Phelps St., San Francisco, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 85.4 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

SEP holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2013-0029, NPDES Permit No. CA0037664). During dry weather, SEP discharges secondary effluent to lower San Francisco Bay through a deep water outfall at a latitude of 37.749444 and a longitude of -122.372778. During wet weather, up to 140 mgd of secondary effluent can be discharged to Islais Creek at latitude 37.747222 and longitude of -122.386944, and up to 110 mgd of combined primary and secondary effluent can be discharged to San Francisco Bay through the deep water outfall. The plant provides primary and secondary treatment to combined wastewater and stormwater. During wet weather, primary treated and disinfected flows may be discharged from the North Point Wet Weather Facility, and equivalent to primary effluent may be discharged through one or more of the 29 combined sewer discharge (CSD) outfalls on the Bayside, as described in the NPDES permit.

Table 2-1 provides a summary of the dry weather permit limitations that are specific to SEP and are specific to nutrients. Days in which the instantaneous influent flows to SEP are greater than 110 mgd and CSDs occur at Islais Creek because of rainfall are designated as “wet weather” days in the permit. The effluent limits in Table 2-1 do not apply on these wet weather days. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. Dry Weather NPDES Permit Limitations (Order No. R2-2013-0029; CA0037664)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	85.4	-	-	-
BOD	mg/L	-	30	45	-
TSS	mg/L	-	30	45	-
Total Ammonia, as N	mg/L	-	190	-	290

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for SEP. Both liquids processes and solids processes are shown. SEP provides primary and secondary treatment to combined wastewater and stormwater. During wet weather, 150 mgd receives primary and secondary treatment, and up to 100 mgd of additional flow receives primary treatment. The treatment train consists of screening and grit removal, primary clarification, followed by secondary treatment with a high purity oxygen activated sludge process including anaerobic selector zones for filament control. All effluent flow is disinfected by chlorination. Solids treatment consists of secondary sludge thickening, anaerobic digestion and centrifuge dewatering.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for SEP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3,4]	Year Round MM[1,3]
Flow[5]	mgd	59.4	66.3	64.3	103.6
BOD	lb/d	147,400	144,900	178,200	184,900
TSS	lb/d	152,600	167,200	182,600	235,600
Ammonia	lb N/d	17,950	19,190	18,950	23,500
Total Kjeldahl Nitrogen (TKN)	lb N/d	24,850	25,650	26,240	29,790
Total Phosphorus (TP)[6]	lb P/d	3,140	3,080	3,790	3,930
Alkalinity	lb $CaCO_3$/d	102,800	101,300	111,700	115,500
BOD	mg/L	300	260	330	210
TSS	mg/L	310	300	340	270
Ammonia	mg N/L	36	35	35	27
TKN	mg N/L	50	46	49	34
TP[6]	mg P/L	6.3	5.6	7.1	4.6
Alkalinity	mg CaCO3/L	210	180	210	130

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Dry season is defined as May 1 to September 30, which is not the same as the definition for dry weather used in the permit. In the permit, wet weather is defined as any day with an instantaneous flow exceeding 110 mgd due to rainfall, and dry weather days are any other days.
5. Influent flow data includes wet weather days, including a maximum peak day flow of 251 mgd.
6. TP based on seven samples collected between July 2012 and June 2014. ADWF, dry season maximum month and year round maximum month were calculated using the BOD peaking factors.

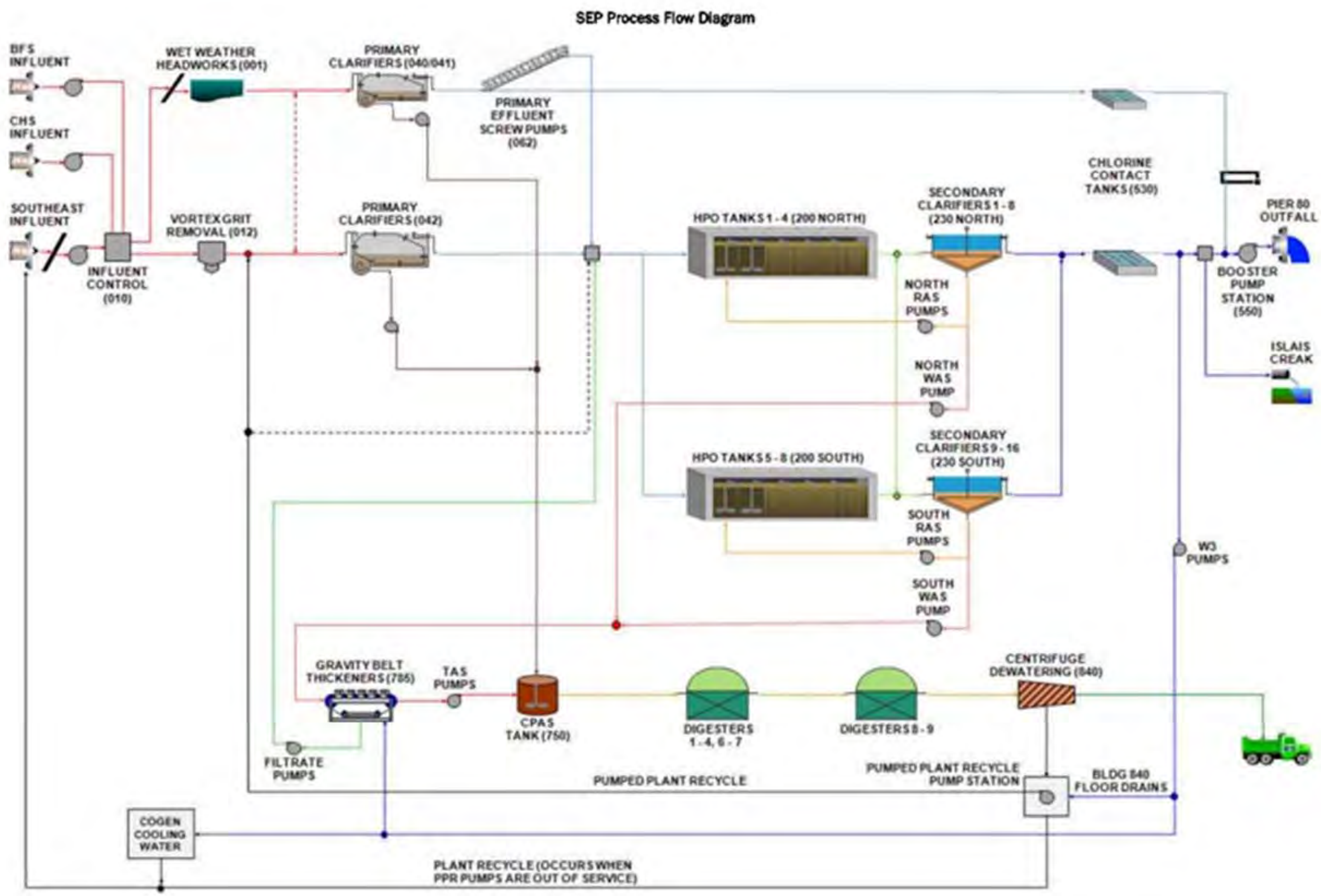

Figure 2-1. Process Flow Diagram for SEP

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at SEP:

- Biosolids Digester Facilities Project (BDFP) startup is scheduled for 2023-2024 to replace all current solids handling facilities with new thickening, pre-dewatering, thermal hydrolysis process, mesophilic anaerobic digestion and final dewatering. Sidestream loading and concentrations may change once new facilities are online, but the project is expected to have a minimal effect on the final effluent concentrations.
- Some chemical phosphorus removal occurs due to ferric chloride addition upstream of centrifuges.
- Some biological phosphorus removal also occurs with the anaerobic selector intended for filament control.
- To ensure anaerobic conditions in the second stage of HPO train and improve selector performance, the plant is modifying oxygen injection point and implementing DO control in the aeration stage.

2.5 Pilot Testing

The following pilot testing projects related to nutrient removal have been performed or are in progress at SEP:

- SEP is currently running deammonification pilot units on dewatering return.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. For most plants, sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity. SEP provided flows and loadings projections through 2045[4], which were used as the basis for optimization and upgrades to achieve Level 2 and Level 3 targets.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for SEP are presented in Table 3-1. The projected flow and load for SEP in 2025 were calculated by interpolation from the projected flows and loadings provided by SEP.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

[4] Sewer System Improvement Program (2014). Wastewater Flow and Load Projections Technical Memorandum. San Francisco Public Utilities Commission, February.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	63.1	70.5	68.4	110.1
BOD[5]	lb/d	171,900	169,000	207,800	215,600
TSS[5]	lb/d	175,600	192,300	210,100	271,100
Ammonia[6]	lb N/d	20,930	22,380	22,090	27,400
TKN[6]	lb N/d	28,980	29,910	30,600	34,740
TP[6]	lb P/d	3,660	3,590	4,420	4,580
Alkalinity[7]	lb/d as $CaCO_3$	110,600	105,900	119,800	119,400
BOD[5]	mg/L	330	290	360	230
TSS[5]	mg/L	330	330	370	300
Ammonia[6]	mg N/L	40	38	39	30
TKN[6]	mg N/L	55	51	54	38
TP[6]	mg P/L	6.9	6.1	7.7	5.0
Alkalinity[7]	mg/L as $CaCO_3$	210	180	210	130

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Interpolated from the ADWF projections provided. Flow projections account for increases in water conservation. Other averaging periods based on current flow peaking factors.
5. Average annual BOD and TSS loadings interpolated from the projections provided by SEP. Other averaging periods based on current loading peaking factors.
6. Ammonia, TKN, and TP loading increase is proportional to BOD loading increase.
7. Alkalinity concentration is assumed to stay the same in the future.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by SFPUC, it was determined that SEP is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the build-out capacity (the influent loadings used for facility upgrades). The sidestream flows and loads for the build-out capacity are provided in Table 3-2. The build-out flows and loads provided by SEP were used in the facility sizing.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. SEP provided build-out average flows and loadings, which were used as the basis for plant upgrades in this report. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the projected average flow or loadings.

Table 3-2. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Design Capacity (AA)
Sidestream Flow	mgd	0.44	0.63
Ammonia	lb N/d	4,600	6,600
TKN	lb N/d	5,600	8,000
TN[1]	lb N/d	5,600	8,000
TP	lb P/d	300	430
Ortho P	lb P/d	230	330
Alkalinity	lb CaCO3/d	13,300	19,200
Ammonia	mg N/L	1,260	1,260
TKN	mg N/L	1,530	1,530
TN[1]	mg N/L	1,530	1,530
TP	mg P/L	80	80
Ortho P	mg P/L	60	60
Alkalinity	mg CaCO3/L	3,700	3,700

1. It was assumed that TN = TKN

Table 3-3. Flow and Load for Upgrades (Projected 2045 Flow and Loading Provided by SEP)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	69.4	77.6	75.2	121.1
BOD[5]	lb/d	212,800	209,100	257,100	266,700
TSS[5]	lb/d	213,900	234,300	255,900	330,200
Ammonia[6]	lb N/d	25,900	27,700	27,340	33,900
TKN[6]	lb N/d	35,860	37,010	37,870	42,990
TP[6]	lb P/d	4,520	4,450	5,470	5,670
Alkalinity[7]	lb/d as $CaCO_3$	121,500	116,400	131,700	131,300
BOD[5]	mg/L	370	320	410	260
TSS[5]	mg/L	370	360	410	330
Ammonia[6]	mg N/L	45	43	44	34
TKN[6]	mg N/L	62	57	60	43
TP[6]	mg P/L	7.8	6.9	8.7	5.6
Alkalinity[7]	mg/L as $CaCO_3$	210	180	210	130

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Projected 2045 average dry weather flow. Flow projections account for increases in water conservation. Other averaging periods based on current flow peaking factors.
5. Average annual BOD and TSS loadings based on projections provided by SEP. Other averaging periods based on current loading peaking factors.
6. Ammonia, TKN, and TP loading increase is proportional to BOD loading increase.
7. Alkalinity concentration is assumed to stay the same in the future.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Three optimization strategies were identified during the SEP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The three optimization strategies are described below.

SEP has identified issues with the analytical method for TP and is now collecting data using mass spectrometry to improve the reliability of the reported phosphorus data. Estimates of effluent phosphorus loading will be based on mass spectrometry (ICP-MS) data from July 2015 through June 2016.

- **Optimization Strategy 1:** Optimize anaerobic selector operation to maintain or improve phosphorus removal.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** The plant is currently modifying oxygen injection point and implementing DO control to improve selector performance. Optimization could include sampling for phosphorus and volatile fatty acids, and using the results to optimize selector operation for biological phosphorus removal.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Add ferric chloride upstream of the primary clarifiers to increase phosphorus removal using chemically enhanced primary treatment (CEPT).
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Chemical storage and metering facilities could be constructed at the plant. Strategy 1 (optimized biological phosphorus removal) may achieve similar performance without chemical addition, but chemical addition facilities are recommended in case optimization is not successful or data issues identify that additional removal is necessary.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 3:** Add ferric chloride to the mixed liquor prior to the secondary clarifiers for phosphorus removal.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Chemical storage and metering facilities could be constructed at the plant. Analysis shows that strategy 1 (optimized biological phosphorus removal) will achieve similar performance without chemical addition, so chemical addition is not recommended.
  - ***Recommendation:*** Do not carry forward at this time.

A combination of strategies 1 and 2 is the best apparent way to reduce effluent phosphorus loads. CEPT costs are included as a backup in case optimization for biological phosphorus removal is not successful. No feasible alternatives were identified for nitrification or nitrogen removal, because tankage is not available to increase solids retention time.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

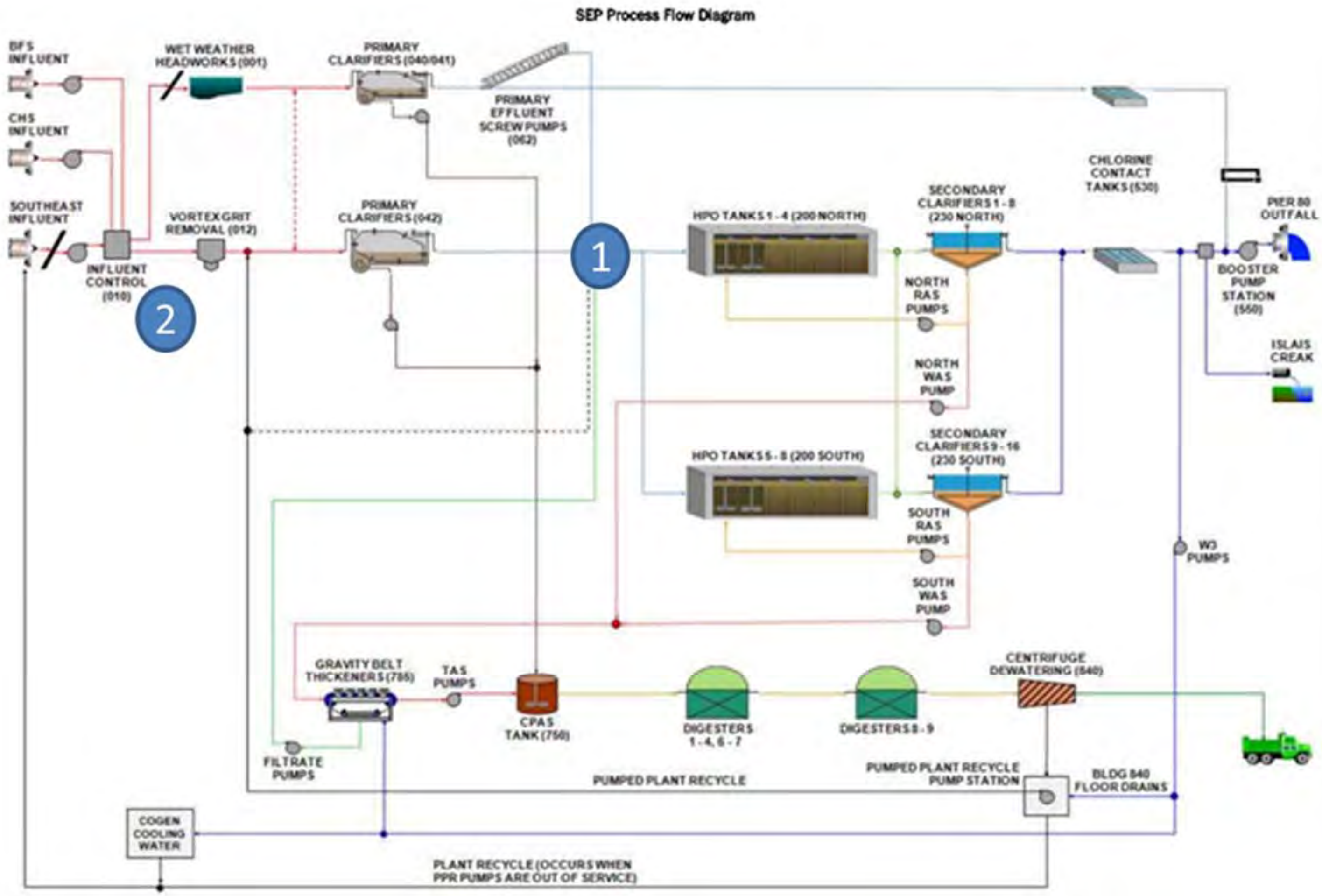

Figure 4-1. Optimization Concepts Considered for SEP

(1) optimize anaerobic selector performance in HPO tanks to promote biological phosphorus removal, and (2) add ferric chloride facilities for P removal, in case biological phosphorus removal is not sufficient.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
None for biological phosphorus removal. Improvements to selector zones are already in progress.	Optimize selector operations for phosphorus removal.
Ferric chloride storage, chemical metering pump, chemical injection (flash mixer)	Ferric chloride operating costs are included, although ferric chloride addition will only be needed if the anaerobic selector optimization does not provide sufficient removal.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. SEP shows improved phosphorus removal, but no change in ammonia or nitrogen removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	20,200	20,200	23,000	23,000	610	610
Discharge with Opt. Strategy[1]	lb N or P/d	20,200	20,200	23,000	23,000	510	470
Load Reduction[2,3]	lb N or P/d	0	0	0	0	110	140
Load Reduction[2,3]	%	0%	0%	0%	0%	18%	23%
Annual Load Reduction	lb N or P/yr	0	0	0	0	39,500	51,100

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce phosphorus; no optimization strategy was identified for nitrogen.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	63.1	78.0
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	1.9	2.1
Annual O&M	$ Mil/yr	1.7	1.7
Present Value O&M[3]	$ Mil	15.6	15.6
Present Value Total[3]	$ Mil	17.5	17.7
Unit Capital Cost[8]	$/gpd	0.03	0.03
Unit Total PV Cost[8]	$/gpd	0.3	0.2
TN Removal			
Capital[2,4]	$ Mil	0.0	0.0
Annual O&M[4]	$ Mil/yr	0.0	0.0
O&M PV[3,4]	$ Mil	0.0	0.0
Total PV[3,4]	$ Mil	0.0	0.0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	1.9	2.1
Annual O&M[5]	$ Mil/yr	1.7	1.7
O&M PV[3,5]	$ Mil	15.6	15.6
Total PV[3,5]	$ Mil	17.5	17.7
TP Removed (Ave.)[6]	lb P/d	108	140
Annual TP Removed (Ave.)[7]	lb P/yr	39,500	51,100
TP Cost[5,9]	$/lb P	44.4	34.7

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• Phosphorus reliably removed • Potential for improved settleability in the secondary clarifiers	• Biological phosphorus removal sludge can be difficult to dewater. • If chemical addition is needed, a dependency on chemicals and increased sludge production.

5 Sidestream Treatment

As previously described, SEP was identified as a potential candidate for sidestream treatment. SEP currently uses anaerobic digesters, followed by dewatering centrifuges. SEP is designing a biosolids digester facilities project (BDFP) that will replace all solids handling facilities with new thickening, pre-dewatering, and thermal hydrolysis process (THP) followed by mesophilic anaerobic digestion and mechanical dewatering. Sidestream treatment for nitrogen removal is not included in the design, but is planned for the future.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for total nitrogen load reduction. SEP already removes phosphorus by adding ferric chloride upstream of the dewatering centrifuges, and additional sidestream phosphorus removal is not recommended.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature (common for RWFs with mechanical dewatering). It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification), such as requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requiring 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for SEP.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements[1]
Feed Pumping (if necessary)	--
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

1. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

Table 5-2. Projected Effluent Annual Average Nitrogen Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)[4]
Current Discharge[1]	lb/d	22,700	26,000	690
Discharge with Sidestream Treatment[2,5]	lb/d	17,700	21,500	690
Load Reduction[3]	lb/d	5,000	4,500	0
Load Reduction	%	22%	17%	0%
Annual Load Reduction[3]	lb/yr	1,837,000	1,630,000	0

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. The plant already removes phosphorus by adding ferric chloride prior to dewatering centrifuges, and no modifications are recommended.
5. The discharge with sidestream treatment does not consider any changes in sidestream loads associated with the addition of a Thermal Hydrolysis Process (THP) upstream of the digesters. Sidestream loading and concentrations may change once new facilities are online, but the project is expected to have a minimal effect on the final effluent concentrations

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP[7]
Capital[1,8]	$ Mil	39	--
Annual O&M[8]	$ Mil/yr	1.4	--
Total Present Value[2,8]	$ Mil	70	--
NH4-N Load Reduction[3,5,8]	lb N/yr	1,837,000	
TN Load Reduction[3,5,8]	lb N/yr	1,630,000	
TP Load Reduction[4,5,8]	lb P/yr	--	
NH4-N Cost [3,5,6,8]	$/lb N	1.3	--
TN Cost [3,5,6,8]	$/lb N	1.4	--
TP Cost [4,5,6,8]	$/lb P	--	--

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. The plant already removes phosphorus by adding ferric chloride prior to dewatering centrifuges, and no modifications are recommended.
8. The costs do not consider any changes in sidestream loads associated with the addition of a Thermal Hydrolysis Process (THP) upstream of the digesters. It is unclear the extent of load increase associated with THP so the current concentrations were assumed and projected forward.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at SEP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. SEP should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

Space is limited on the current site. Previous studies identified locations for facilities to meet a Level 2 nitrogen limit, but space is not available for an activated sludge based alternative with filtration to meet Level 3 nitrogen and phosphorus limits. For this report, a membrane bioreactor process is shown to fit in the identified space.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Ferric chloride addition to the primary clarifiers is assumed for phosphorus removal. Level 2 nitrogen limits could be met by converting the plant to a membrane bioreactor facility. New deep aeration tanks would be constructed in the Modified Ludzack-Ettinger (MLE) configuration, including new aeration blowers. New membrane tanks are also required. Based on the low carbon to nitrogen ratio measured in the primary effluent, carbon addition (methanol) is included to provide carbon for denitrification. Based on available alkalinity and nitrogen data, alkalinity addition will be needed for nitrification. Fine screening is included to protect the membranes.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2. Ferric chloride addition to activated sludge is included for phosphorus polishing. Additional aeration tanks are required, and all aeration tanks would be configured as 4-stage BNR. Additional storage is shown for carbon addition (methanol) to improve denitrification.

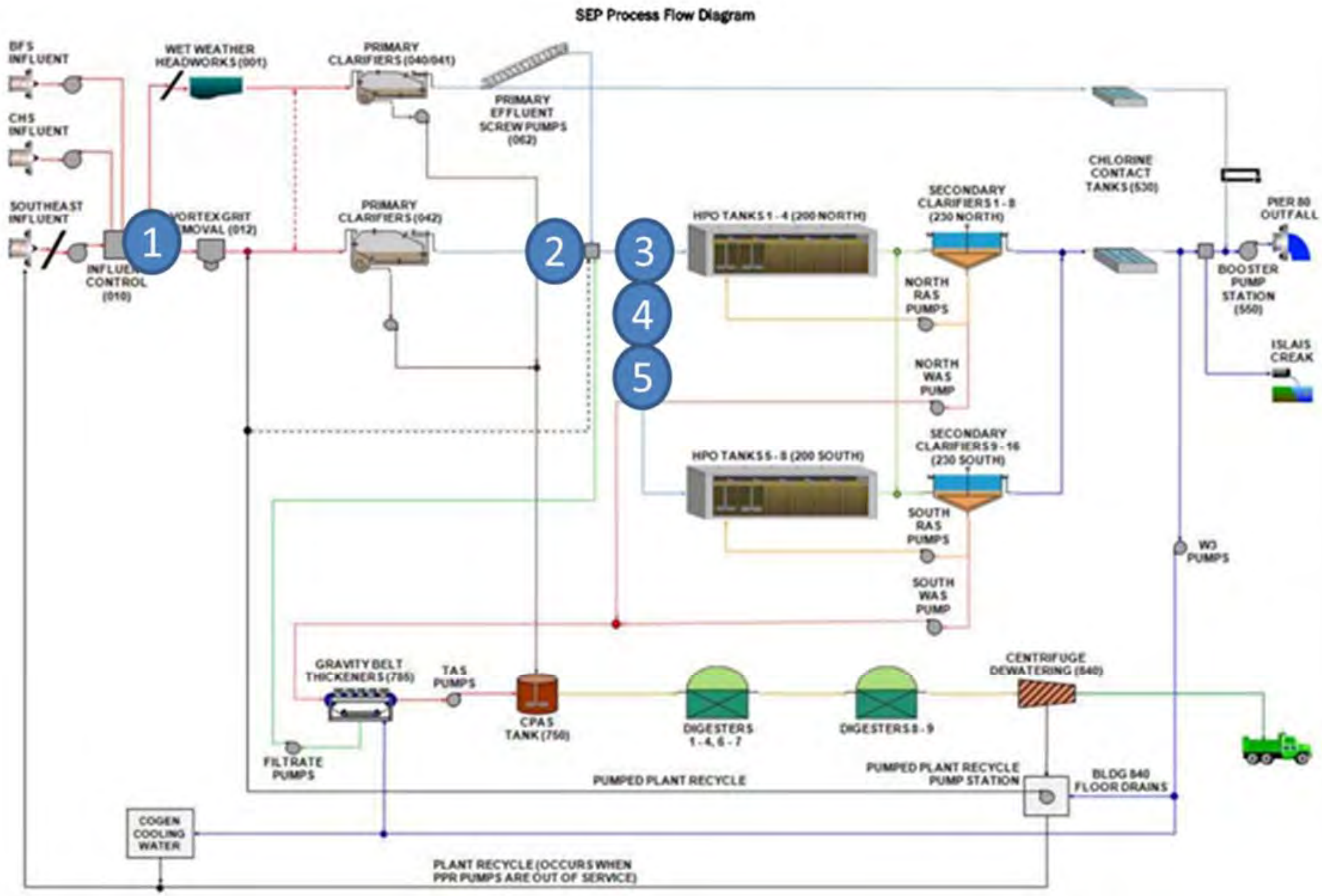

Figure 6-1. Level 2 Upgrade Concept for SEP

(1) add ferric chloride for P removal, and (2) add fine screens to protect MBR, (3) replace secondary process with MLE BNR and MBR, (4) construct alkalinity addition facilities to provide alkalinity for nitrification, and (5) construct methanol addition facilities to provide a carbon source for denitrification.

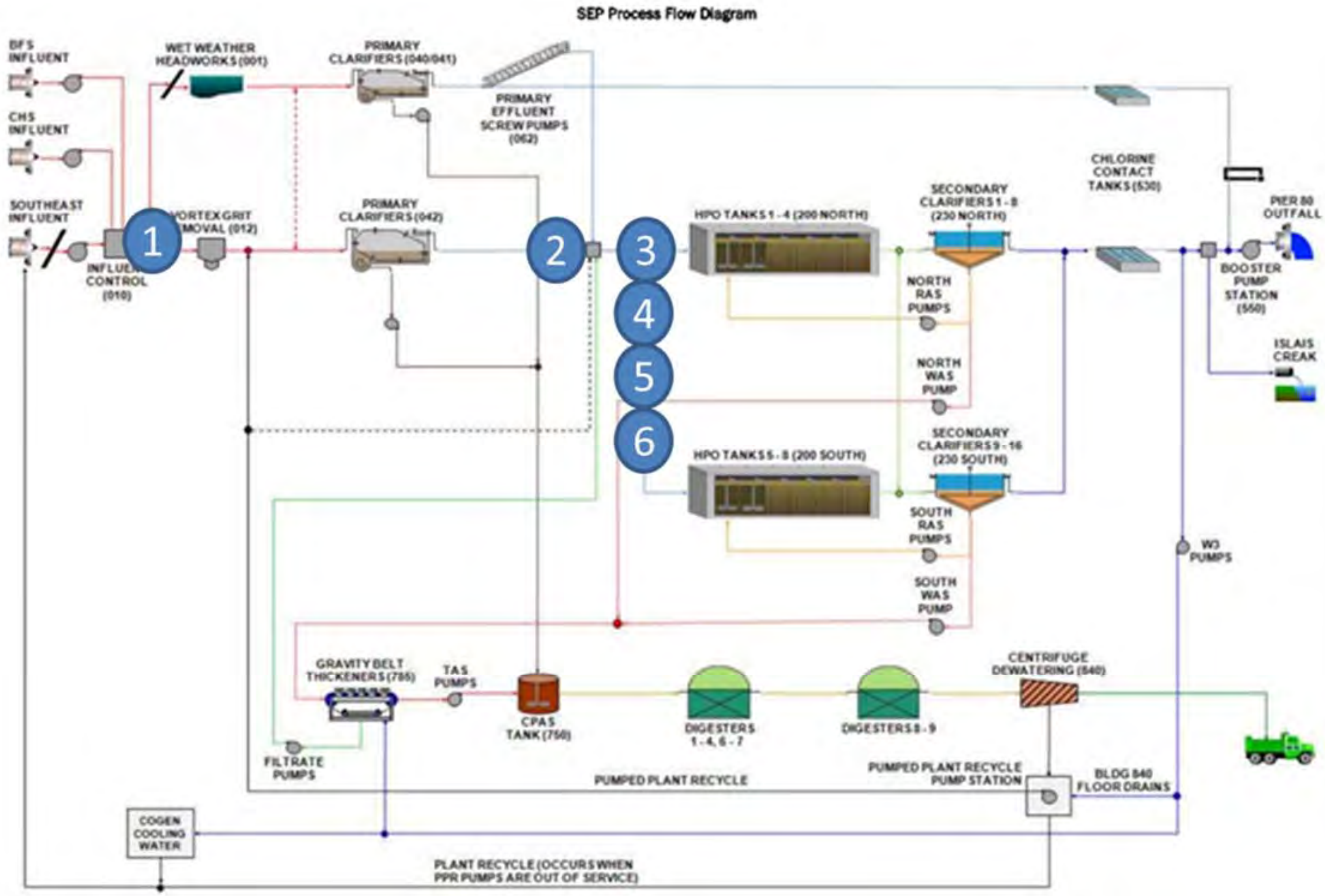

Figure 6-2. Level 3 Upgrade Concept for SEP

(1) add ferric chloride for P removal, and (2) add fine screens to protect MBR, (3) replace secondary process with 4-stage BNR and MBR, (4) construct alkalinity addition facilities to provide alkalinity for nitrification, (5) construct methanol addition facilities to provide a carbon source for denitrification, and (6) add ferric chloride for P removal polishing.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Ferric chloride chemical feed	Same as Level 2
Secondary and Tertiary	• Fine screens to protect membranes • Demolish HPO basins • Construct new deep BNR tanks (MLE), including baffles, mixers, and mixed liquor recycle pumping • New blowers • New membrane tanks for MBR • Alkalinity addition facilities • External carbon source addition facilities • Abandon existing secondary clarifiers	Same as Level 2 plus: • Ferric chloride addition to BNR tanks for phosphorus polishing • Construct additional deep BNR tanks (demolition of some secondary clarifiers needed to make space), and configure all BNR tanks as 4-stage BNR. • Additional external carbon source chemical feed

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Demolish HPO tanks and construct new deep BNR tanks (MLE), (2) Construct new deep BNR tanks (MLE), (3) construct new membrane tanks, (4) construct alkalinity addition facilities to provide alkalinity for nitrification, (5) construct methanol addition facilities to provide a carbon source for denitrification, (6) construct ferric chloride facilities for P removal, and (7) blowers and fine screens.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Demolish HPO tanks and construct new deep BNR tanks (4-stage BNR), (2) construct new deep BNR tanks (4-stage BNR), (3) construct new membrane tanks, (4) construct alkalinity addition facilities to provide alkalinity for nitrification, (5) construct methanol addition facilities to provide a carbon source for denitrification, (6) construct ferric chloride facilities for P removal, and (7) blowers and fine screens.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	69.4	85.7	69.4	85.7
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	1,160	1,160	1,210	1,210
Annual O&M	$Mil/yr	19	20	21	23
O&M PV[3]	$ Mil	420	450	480	520
Total PV[3]	$ Mil	1,580	1,610	1,690	1,730
Unit Capital Cost	$/gpd	16.7	13.5	17.5	14.2
Unit Total PV	$/gpd	22.8	18.8	24.4	20.2
TN Removal					
Capital[2,4]	$ Mil	1,160	1,160	1,210	1,210
Annual O&M[4]	$ Mil/yr	17	18	19	20
O&M PV[3,4]	$ Mil	390	410	420	440
Total PV[3,4]	$ Mil	1,540	1,570	1,630	1,650
TN Removed (Ave.)[6]	lb N/d	17,600	18,100	20,000	22,800
Annual TN Removed (Ave.)[7]	lb N/yr	6,430,080	6,622,900	7,296,920	8,338,180
TN Cost[4,8]	$/lb N	8.0	7.9	7.5	6.6
TP Removal					
Capital[2,5]	$ Mil	1.9	2.1	860	860
Annual O&M[5]	$ Mil/yr	1.6	1.7	5.4	10.7
O&M PV[3,5]	$ Mil	37	39	120	240
Total PV[3,5]	$ Mil	38	41	980	1,100
TP Removed (Ave.)[6]	lb P/d	135	170	314	536
Annual TP Removed (Ave.)[7]	lb P/yr	49,300	62,100	114,500	195,500
TP Cost[5,8]	$/lb P	26	22	285	188

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Robust technology to absorb variability in flows and loads • Ability to reliably remove TN and TP • More organics and solids diverted to fuel the digester	• Increased operation costs associated with ferric chloride, alkalinity, and methanol addition • Increased energy demands for aeration and membranes • Dependency on chemicals • Increased sludge production
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use and additional ferric chloride use

7 Nutrient Removal by Other Means

SEP has a recycled water truck-fill station that recycles approximately 5 acre-feet per year (1.5 million gallons per year). This existing program is expected to cease operation in the upcoming years. SEP has plans to add a recycled water program to recycle approximately 4,000 acre-feet per year (1,300 million gallons per year). The impact of the recycled water program on nutrient discharges will depend on the treatment technology and the recycled water uses.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from

Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

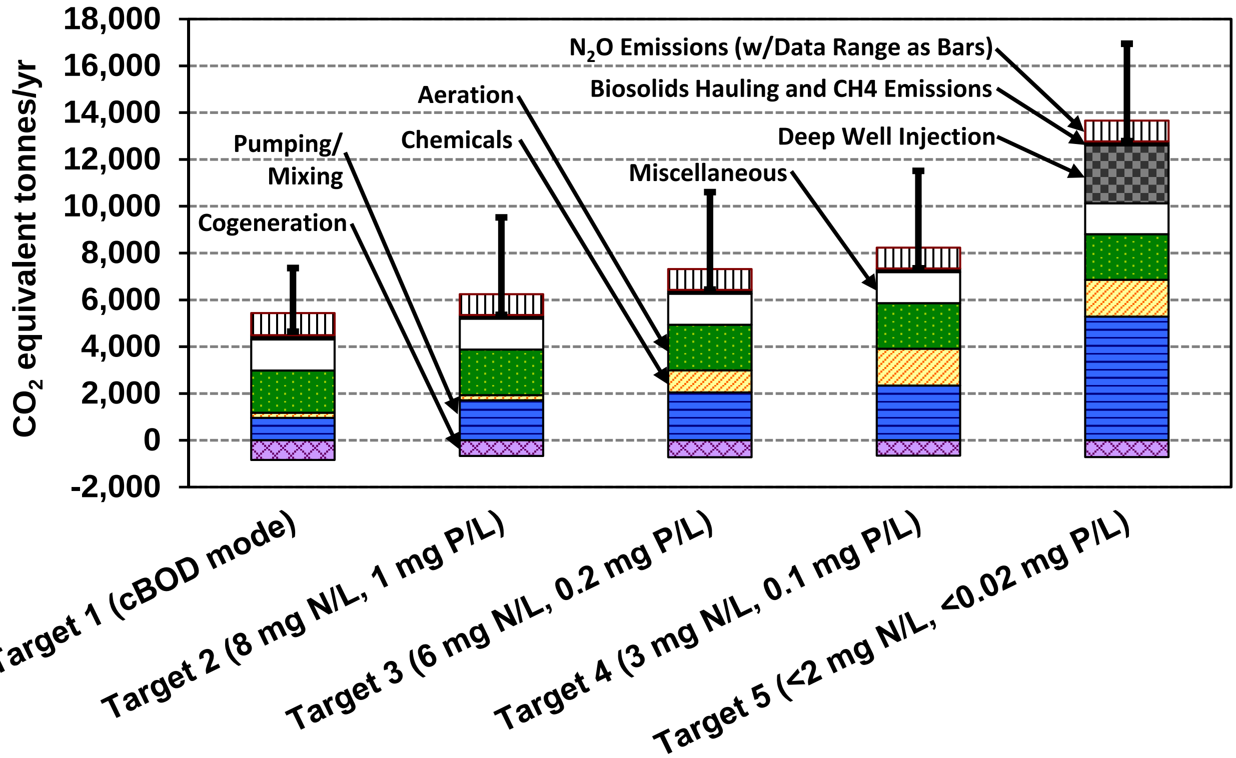

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[5] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[5] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	0	0	19,700	20,200	20,200	20,600	670
GHG Emissions Increase from Chemicals	MT CO_2/yr	200	300	1,800	2,000	4,900	5,500	220
GHG Emissions Increase Total	MT CO_2/yr	200	300	21,500	22,300	25,000	26,100	890
Unit GHG Emissions[2]	lb CO_2/MG	0	0	1,600	1,700	1,900	2,000	9.2
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	5	6	6	6	1.2
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	7	7	7	7	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	13	11	11	10	159	94	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. The GHG emissions do not consider any changes in sidestream loads associated with the addition of a Thermal Hydrolysis Process (THP) upstream of the digesters. It is unclear the extent of load increase associated with THP so the current concentrations were assumed and projected forward.

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at SEP. These are:

- Nitrite Shunt – Future SEP BNR basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Evaluate instrumentation and automation, and consider pilot during design.
- Nutrient Removal using Granular Sludge – Future nutrient removal could use a granular sludge process. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN and TP
  - Disadvantages: No installations in North America
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.25

San Jose-Santa Clara Regional Wastewater Facility

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

San Jose-Santa Clara Regional Wastewater Facility

San Jose, CA

March 22, 2018
Final Report

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Executive Summary

The City of San Jose (City) owns and operates the San Jose-Santa Clara Regional Wastewater Facility (RWF) located in San Jose, CA and discharges treated effluent to the San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 167 million gallons per day (mgd) and a peak permitted wet weather flow of 261 mgd.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow	mgd	--	--	122.2	122.6	166.0	167.0	166.0	167.0	--
Flow to Bay[2]	mgd	86.8	86.8	93.6	93.6	112	112	112	112	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	500	500	560	560	640	640	640	640	670
TN	lb N/d	11,710	11,710	12,030	11,270	14,920	13,970	10,690	5,590	10,100
TP	lb P/d	660	660	800	750	990	930	680	280	880
Costs[4,5]										
Capital	$ Mil	--	--	14	15	110	280	320	510	42
O&M PV	$ Mil	--	--	29	32	120	130	220	350	37
Total PV	$ Mil	--	--	43	47	230	410	540	860	79
Unit Costs[6]										
Capital	$/gpd	--	--	0.1	0.1	0.6	1.7	1.9	3.1	--
Total PV	$/gpd	--	--	0.4	0.4	1.4	2.5	3.3	5.2	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Install internal mixed liquor recycle (IMLR) in existing aeration basins to improve TN removal.

The RWF is considered a candidate for sidestream treatment to reduce nitrogen loads as the plant anaerobically digests biosolids and dewaters to produce a return sidestream laden with nitrogen. The recommended sidestream treatment strategy is deammonification for reducing ammonia/nitrogen loads. However, previous evaluations by the City of sidestream treatment showed that sidestream treatment was not necessary to meet anticipated nutrient reduction requirements, and that centrate should be routed back to the RWF's headworks unit process. In this instance, nutrient reduction could be accomplished through some upgrades to the biological treatment process.

The RWF is not considered a viable candidate for sidestream treatment to reduce phosphorus loads. The plant currently removes phosphorus biologically, so sidestream treatment is not expected to further reduce effluent levels.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Convert existing aeration tanks to modified Ludzack-Ettinger (MLE) process
    b. Construct new MLE tanks
    c. Construct methanol addition facilities
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Convert MLE tanks to 4-stage biological nutrient removal (BNR)
    c. Construct additional 4-stage BNR tanks
    d. Add chemical addition upstream of filters for additional TP removal

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $43 Mil for dry season optimization up to $860 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The San Jose-Santa Clara Regional Wastewater Facility (RWF) serves a population of about 1.4 million. The RWF treats domestic, commercial and industrial wastewaters from the cities of San Jose, Santa Clara, Milpitas, Burbank Sanitation District, Cupertino Sanitation District, West Valley Sanitation District and Santa Clara County Sanitation Districts No. 2 and No.3. The facility is located at 700 Los Esteros Road in San Jose, CA.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The RWF holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2014-0034, NPDES Permit No. CA0037842). The RWF discharges to Artesian Slough, where the effluent mixes with Coyote Creek and subsequently with San Francisco Bay water. The discharge point is located at latitude 37.4398° N and longitude 121.9581° W.

Table 2-1 provides a summary of the seasonal permit limitations that are specific to the RWF, under the NPDES permit and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2014-0034; CA0037842)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak
Flow	mgd	167	---	---	---	261
cBOD	mg/L	---	10	---	20	-
TSS	mg/L	---	10	---	20	-
Total Ammonia, as N	mg/L	---	3.0	---	8.0	-

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the RWF. Both liquids processes and solids processes are shown. The RWF has primary clarifiers followed by a biological nutrient removal activated sludge system for secondary treatment. The RWF currently meets ammonia and level 2 phosphorus removal criteria, effluent total nitrogen does not consistently meet Level 2.

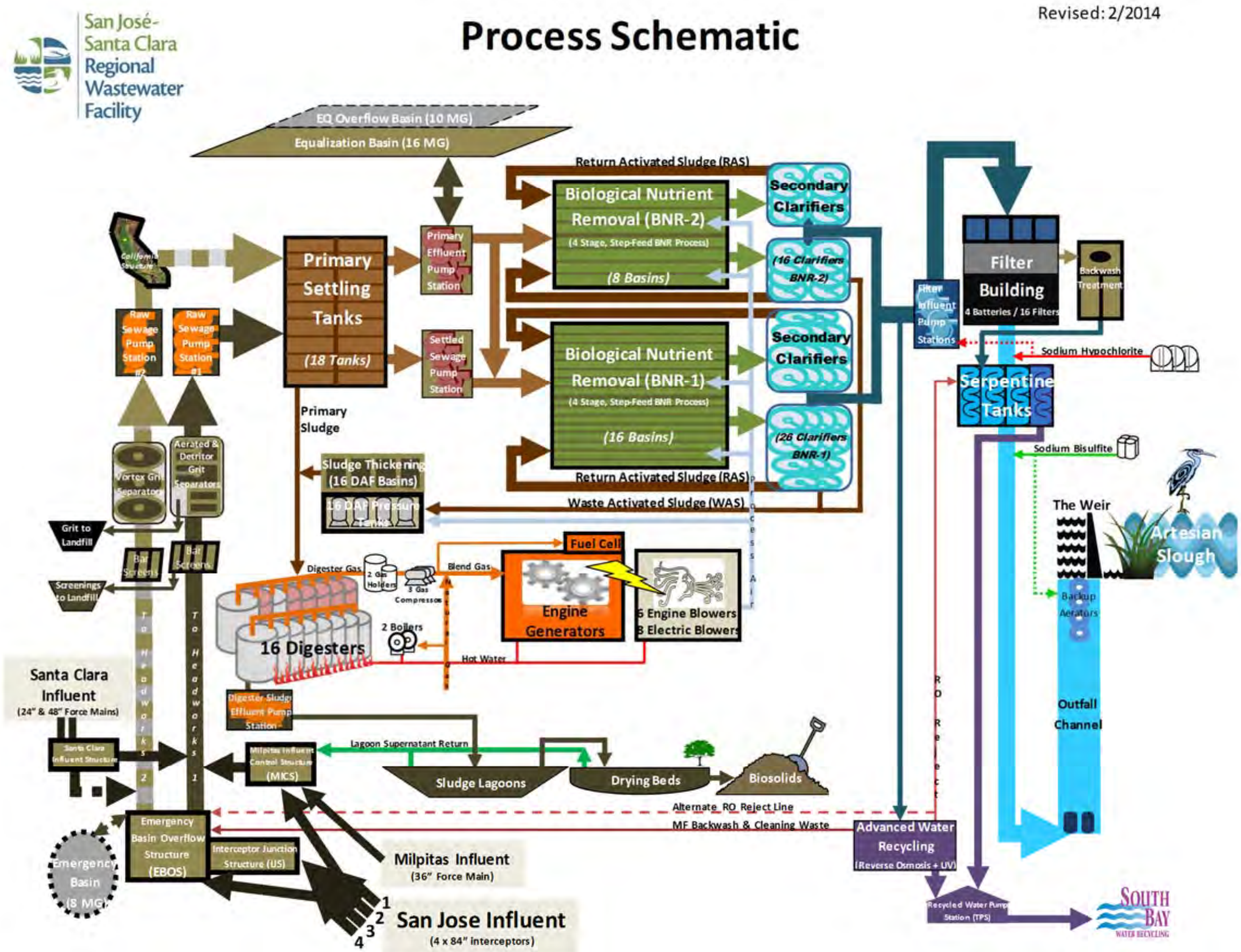

Figure 2-1. Process Flow Diagram for the RWF

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the RWF is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	106	106	109	111
BOD	lb/d	275,800	291,400	311,300	332,500
TSS	lb/d	254,000	249,800	278,300	275,600
Ammonia	lb N/d	27,710	28,770	29,780	31,060
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	42,080	45,910	42,080	49,750
Total Phosphorus (TP)	lb P/d	7,190	7,120	8,440	7,920
Alkalinity	lb $CaCO_3$/d	---	250,000	---	---
BOD	mg/L	310	330	340	360
TSS	mg/L	290	280	310	300
Ammonia	mg N/L	31	33	33	33
TKN	mg N/L	48	52	46	54
TP	mg P/L	8.2	8.1	9.3	8.5
Alkalinity	mg $CaCO_3$/L	---	283	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. No TKN data available for July 2011 – June 2012

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the RWF:

- Permanent facilities for ferric chloride addition and polymer addition upstream of primary clarification.
- An aeration tank and blower upgrade project is being developed to improve process efficiency.
- The tertiary filters are being rehabilitated and rerated to operate at 7.5 gpm/sf, pending approval.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the RWF.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the RWF are presented in Table 3-1. The projected flow and load for the RWF in 2025 was calculated based on 2040 flow and loading projections provided by the City.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	122	122	126	147
BOD	lb/d	347,700	367,500	392,500	423,000
TSS	lb/d	311,600	306,500	341,400	352,500
Ammonia	lb N/d	31,310	32,500	33,630	36,000
TKN	lb N/d	47,530	51,860	47,530	57,650
TP	lb P/d	9,060	8,980	10,640	10,070
Alkalinity	lb/d as $CaCO_3$	---	289,000	---	---
BOD	mg/L	340	360	370	350
TSS	mg/L	310	300	330	290
Ammonia	mg N/L	31	32	32	29
TKN	mg N/L	47	51	45	47
TP	mg P/L	8.9	8.8	10.1	8.2
Alkalinity	mg/L as $CaCO_3$	---	283	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by the City, it was determined that the RWF is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the permitted capacity. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

Table 3-2. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Permitted Flow Capacity, ADWF
Sidestream Flow	mgd	0.9	1.4
Ammonia	lb N/d	5,400	8,600
TKN	lb N/d	9,800	15,500
TN [1]	lb N/d	9,800	15,500
Ortho P	lb P/d	3,540	5,600
TP	lb P/d	690	1,080
Alkalinity	lb $CaCO_3$/d	25,200	39,800
Ammonia	mg N/L	740	740
TKN	mg N/L	1,340	1,340
TN [1]	mg N/L	1,340	1,340
Ortho P	mg P/L	480	480
TP	mg P/L	90	90
Alkalinity	mg $CaCO_3$/L	3,400	3,400

1. It was assumed that TKN = TN

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted flow capacity as ADWF, and loadings match the ultimate projections provided by the City.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	166.0	166.3	171.6	195.0
BOD	lb/d	460,800	487,000	520,200	683,000
TSS	lb/d	428,000	421,000	469,000	534,000
Ammonia	lb N/d	36,600	38,000	39,320	45,000
TKN	lb N/d	55,580	60,640	55,580	72,070
TP	lb P/d	12,010	11,900	14,100	16,260
Alkalinity	lb/d as $CaCO_3$	---	392,500	---	---
BOD	mg/L	330	350	360	420
TSS	mg/L	310	300	330	330
Ammonia	mg N/L	26	27	27	28
TKN	mg N/L	40	44	39	44
TP	mg P/L	8.7	8.6	9.9	10.0
Alkalinity	mg/L as $CaCO_3$	---	283	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs and greenhouse gas (GHG) emissions.

Four optimization strategies were identified during the RWF site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The eleven optimization strategies were screened down to four strategies described below.

- **Optimization Strategy 1:** Consider CEPT to remove phosphorus.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Ferric chloride addition will increase P removal.
  - ***Recommendation:*** There is a ferric chloride and polymer addition project underway, so the cost for this optimization would only include the chemical cost.

- **<u>Optimization Strategy 2:</u>** Add ferric chloride or alum to the mixed liquor to removal phosphorus
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Ferric chloride addition will increase P removal.
  - ***Recommendation:*** Do not carry forward since CEPT will be constructed.

- **<u>Optimization Strategy 3:</u>** Add ferric chloride or alum upstream of the tertiary filters
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Ferric chloride addition will increase P removal.
  - ***Recommendation:*** Do not carry forward since CEPT will be constructed.

- **<u>Optimization Strategy 4:</u>** Add mixed liquor recycle pumps to the existing BNR tanks to improve TN removal
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase TN removal.
  - ***Result from analysis:*** Increased recycle will improve TN removal to meet Level 2 for TN.
  - ***Recommendation:*** Carry forward

Strategy 1 is the best apparent way to reduce effluent phosphorus loads and this is a project that the City will be constructing. Strategy 4 will meet Level 2 TN and is recommended. The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

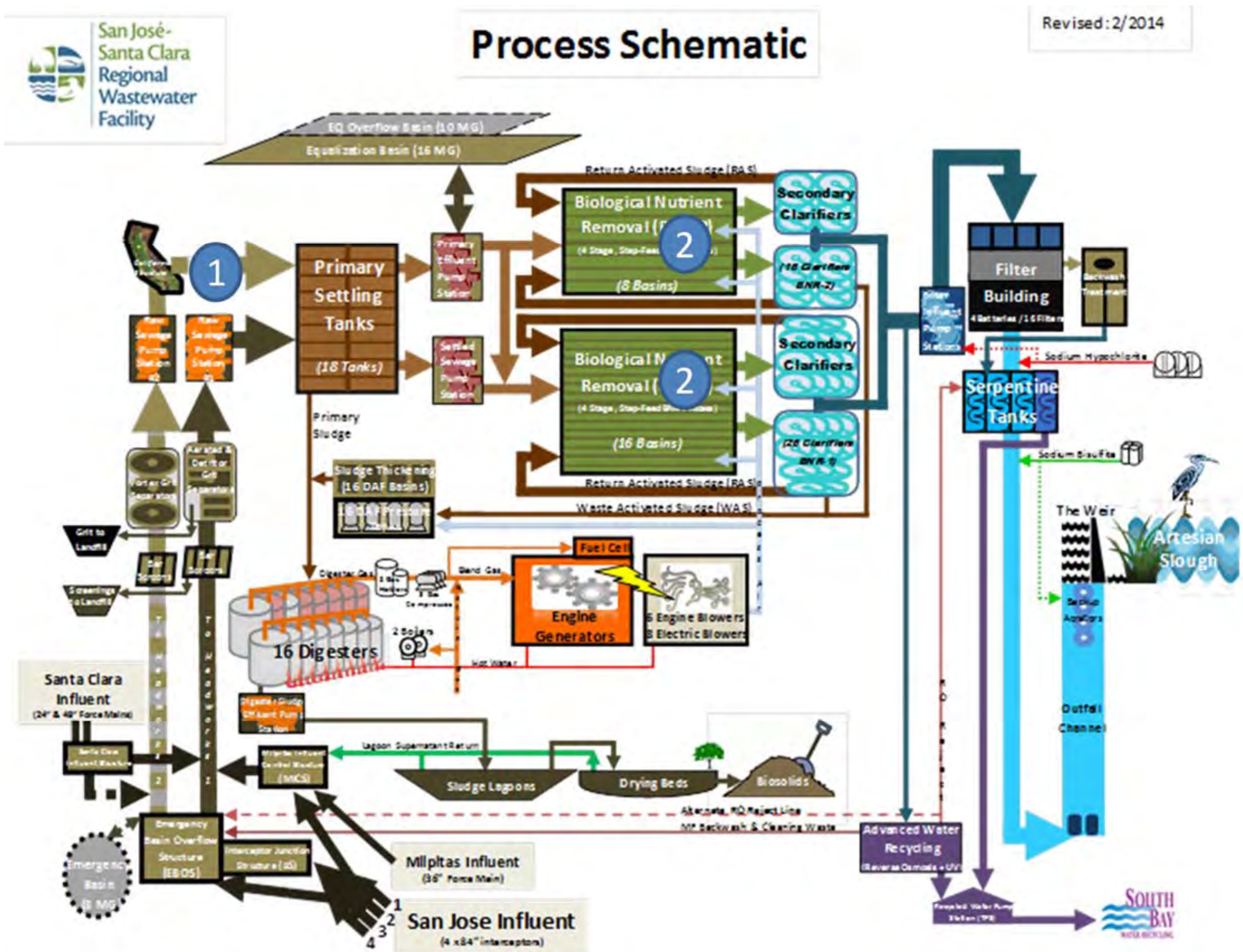

Figure 4-1. Optimization Concepts Considered for the RWF

(1) construct CEPT that will remove phosphorus and (2) add internal mixed liquor recycle pumps to existing BNR tanks.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
CEPT for P Removal • No additional chemical facilities	• Increase dose for P removal
Add mixed liquor recycle • Install new internal mixed liquor pumps in each aeration basin	• Increase energy use due to pumping

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The RWF plant shows minor improvements in TN and TP removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	560	560	13,240	13,240	740	740
Discharge with Opt. Strategy[1]	lb N or P/d	560	560	12,030	11,270	800	750
Load Reduction[2,3,4]	lb N or P/d	0	0	1210	1,970	--*	--*
Load Reduction[2,3,4]	%	0%	0%	9%	15%	--*	--*
Annual Load Reduction	lb N or P/yr	0	0	441,000	719,000	--*	--*

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N since the RWF fully nitrifies.
* TP may increase with the introduction of IMLR, which will stop biological phosphorus removal. Ferric chloride is included, but effluent TP concentrations may increase.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	122.2	122.6
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	13.7	14.7
Annual O&M	$ Mil/yr	3.3	3.5
Present Value O&M[3]	$ Mil	29.4	31.8
Present Value Total[3]	$ Mil	43.1	46.6
Unit Capital Cost[8]	$/gpd	0.1	0.1
Unit Total PV Cost[8]	$/gpd	0.4	0.4
TN Removal			
Capital[2,4]	$ Mil	13.7	14.7
Annual O&M[4]	$ Mil/yr	1.6	1.7
O&M PV[3,4]	$ Mil	14.7	15.7
Total PV[3,4]	$ Mil	28.4	30.4
TN Removed (Ave.)[6]	lb N/d	1,210	1,970
Annual TN Removed (Ave.)[7]	lb N/yr	441,000	719,000
TN Cost[4,9]	$/lb N	6.4	4.2
TP Removal			
Capital[2,5]	$ Mil	0.0	0.0
Annual O&M[5]	$ Mil/yr	1.6	1.8
O&M PV[3,5]	$ Mil	14.7	16.1
Total PV[3,5]	$ Mil	14.7	16.1
TP Removed (Ave.)[6,10]	lb P/d	0	0
Annual TP Removed (Ave.)[7,10]	lb P/yr	0	0
TP Cost[5,9,10]	$/lb P	NA	NA

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since TP may increase with the introduction of IMLR, which will stop biological phosphorus removal. Ferric chloride is included, but effluent TP concentrations may increase.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• More organics and solids diverted to fuel the digester • Phosphorus reliably removed under peak flow scenarios	• Dependency on chemicals • Chemical costs • CEPT (alum) would reduce the organic loading to the BNR, and could cause a carbon limitation and reduce nitrogen removal.

5 Sidestream Treatment

As previously described, the RWF was identified as a potential candidate for sidestream treatment. The RWF currently uses drying beds. In the next 5 to 10 years the RWF is planning to implement mechanical dewatering which was assumed in the analysis. Previous evaluations by the City of sidestream treatment showed that sidestream treatment was not necessary to meet anticipated nutrient reduction requirements, and that centrate should be routed back to the RWF's headworks unit process. In this instance, nutrient reduction could be accomplished through some upgrades to the biological treatment process.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for total nitrogen load reduction. The RWF already removes ammonia in the main plant so sidestream treatment to reduce ammonia discharge loads to the Bay is not recommended. TP load reduction is not recommended as the plant already removes TP by biological phosphorus removal. Thus, sidestream treatment for TP load reduction will most likely not decrease TP discharge loads.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature (common for RWFs with mechanical dewatering). It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification), such as requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requiring 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for the RWF.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements[1]
Feed Pumping (if necessary)	--
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

1. Sidestream treatment for TP discharge load reduction not recommended as previously discussed

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nitrogen Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)[4]
Current Discharge[1]	lb/d	670	15,700	880
Discharge with Sidestream Treatment[2]	lb/d	670	10,100	880
Load Reduction[3]	lb/d	0	5,600	0
Load Reduction	%	0%	36%	0%
Annual Load Reduction	lb/yr	0	2,040,000	0

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. The plant already fully nitrifies and removes phosphorus so sidestream treatment would not further reduce ammonia and total phosphorus discharge loads.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP*
Capital[1]	$ Mil	42	--
Annual O&M	$ Mil/yr	1.6	
Total Present Value[2]	$ Mil	79	
NH4-N Load Reduction[3,5]	lb N/yr	0	
TN Load Reduction[3,5]	lb N/yr	2,040,000	--
TP Load Reduction[4,5]	lb P/yr	--	--
NH4-N Cost [3,5,6]	$/lb N	--	--
TN Cost [3,5,6]	$/lb N	1.3	--
TP Cost [4,5,6]	$/lb P	--	--

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. The plant already fully nitrifies and removes phosphorus so sidestream treatment would not further reduce ammonia and total phosphorus discharge loads.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the RWF plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The RWF should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 upgrades will include converting existing aeration tanks to the MLE process and constructing new MLE aeration tanks. Methanol addition facilities would be included to provide more carbon for denitrification. The CEPT project that the City intends to implement will provide additional phosphorus removal.

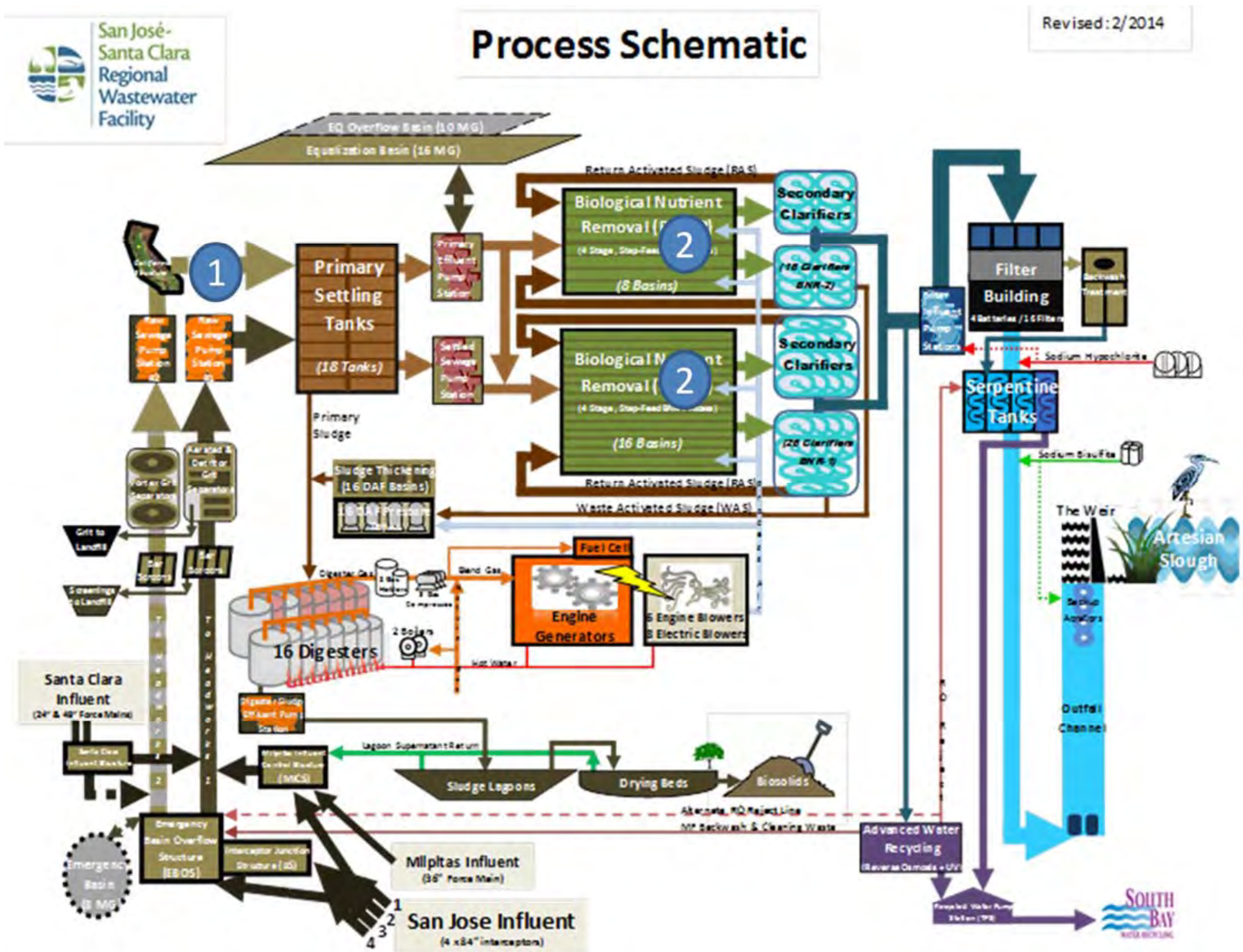

Figure 6-1. Level 2 Upgrade Concept for the RWF

(1) construct CEPT that will remove phosphorus and (2) add new tanks and convert existing tanks MLE.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

The aeration tanks would be converted to a Bardenpho configuration and the methanol addition facilities would be expanded. Ferric chloride addition facilities would be added upstream of tertiary filtration to improve phosphorus removal.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• None	None
Secondary	• Construct new MLE tankage • Convert existing tanks to MLE • Add methanol addition facilities	• Construct new Bardenpho tankage • Convert existing tanks to Bardenpho • Expand methanol addition facilities
Tertiary	• None	• Add ferric chloride facilities upstream of filters

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

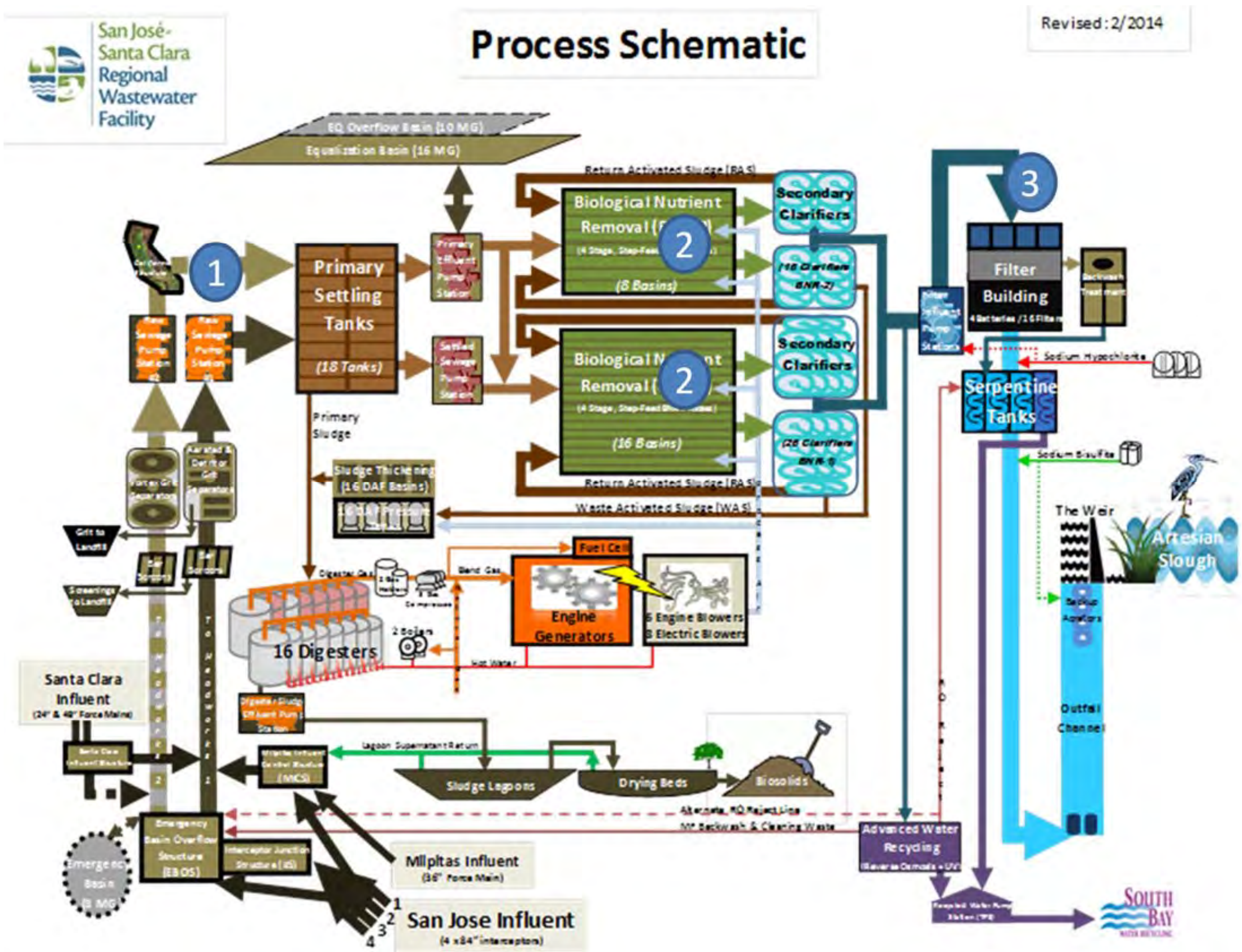

Figure 6-2. Level 3 Upgrade Concept for the RWF

(1) construct CEPT that will remove phosphorus (2) add new tanks and convert existing tanks to 4-stage Bardenpho and (3) add ferric chloride upstream of filters for phosphorus removal.

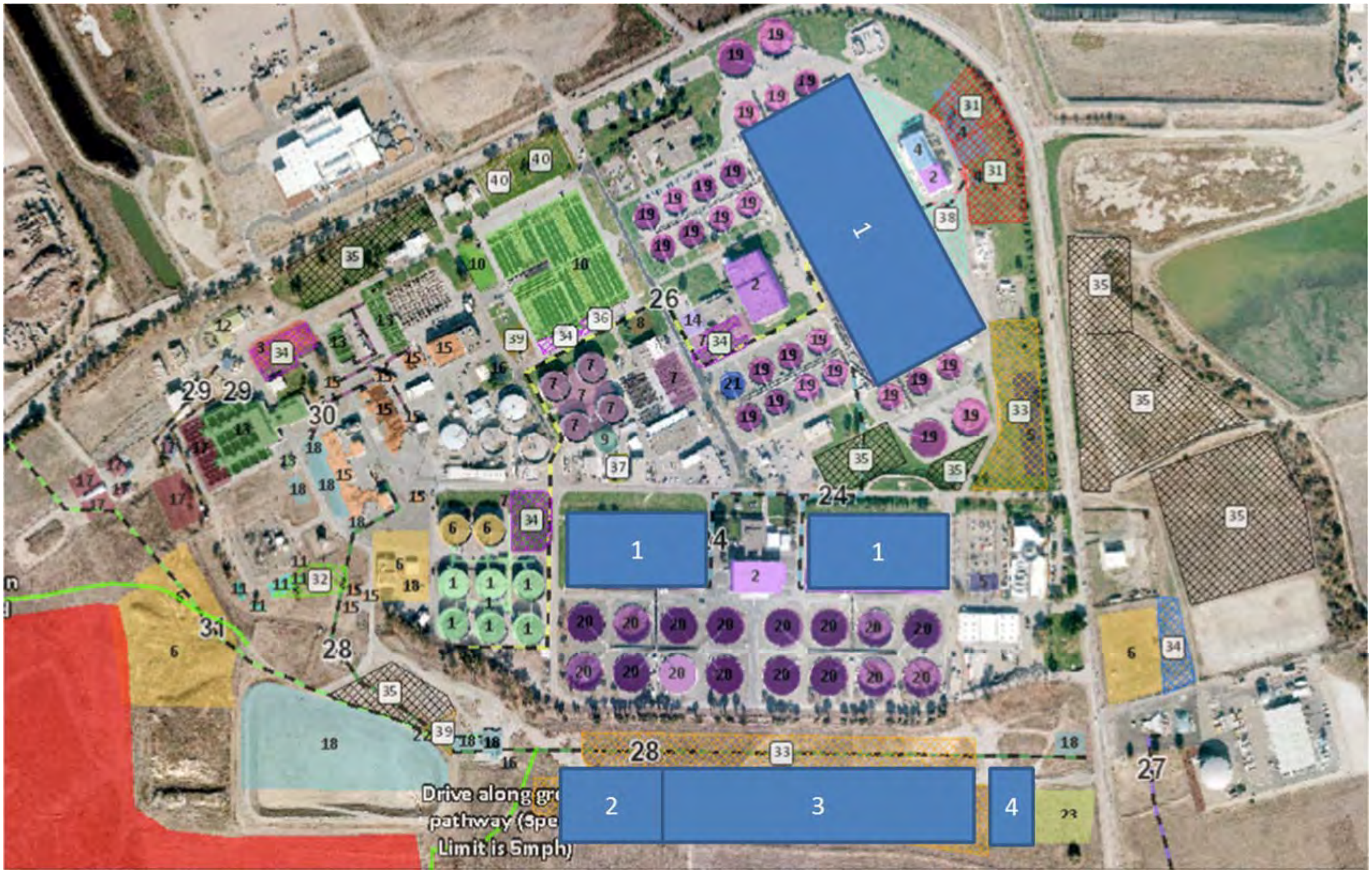

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) convert existing tanks to MLE, (2) add new MLE tanks for dry season, (3) additional MLE tanks for year round, (4) add methanol facilities, (5) add ferric chloride upstream of primary clarifier for phosphorus removal (not shown)

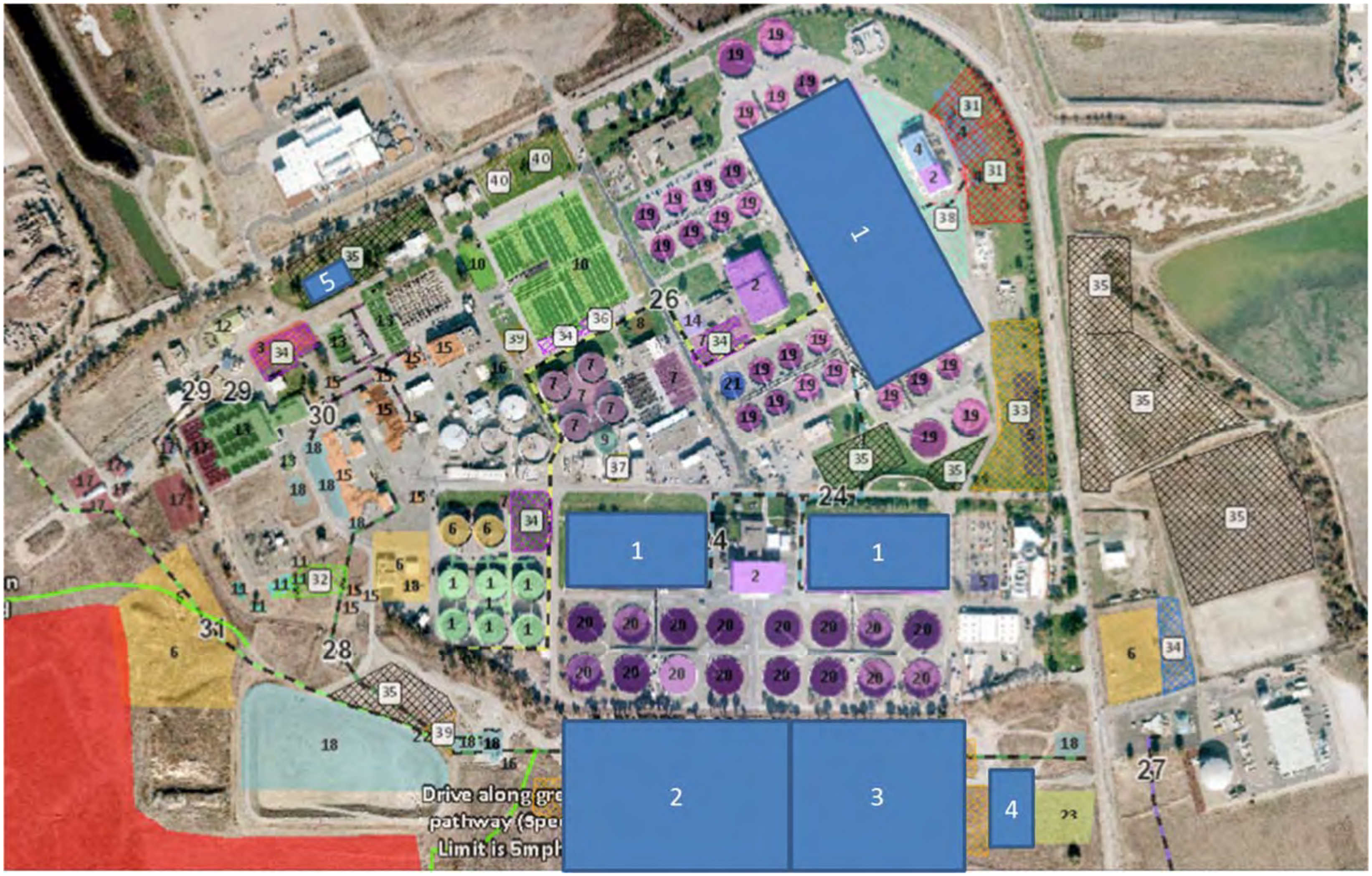

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) convert existing tanks to 4-stage Bardenpho, (2) add new 4-stage Bardenpho tanks for dry season, (3) additional 4-stage Bardenpho tanks for year round, (4) add methanol facilities, (3) add ferric chloride upstream of primary clarifiers and filters for phosphorus removal.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	166	167	166	167
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	110	280	320	510
Annual O&M	$Mil/yr	5.5	5.9	10	15.7
O&M PV[3]	$ Mil	120	130	220	350
Total PV[3]	$ Mil	230	410	540	860
Unit Capital Cost	$/gpd	0.6	1.7	1.9	3.1
Unit Total PV	$/gpd	1.4	2.5	3.3	5.2
TN Removal					
Capital[2,4]	$ Mil	110	280	320	510
Annual O&M[4]	$ Mil/yr	3.5	3.7	6.4	10.1
O&M PV[3,4]	$ Mil	80	80	140	230
Total PV[3,4]	$ Mil	180	360	460	740
TN Removed (Ave.)[6]	lb N/d	800	1,800	5,000	10,100
Annual TN Removed (Ave.)[7]	lb N/yr	290,000	640,000	1,840,000	3,700,000
TN Cost[4,8]	$/lb N	20.9	18.8	8.3	6.6
TP Removal					
Capital[2,5]	$ Mil	0.0	0.0	2.0	2.1
Annual O&M[5]	$ Mil/yr	2.0	2.2	3.6	5.6
O&M PV[3,5]	$ Mil	44	49	81	125
Total PV[3,5]	$ Mil	44	49	83	127
TP Removed (Ave.)[6,10]	lb P/d	0	0	200	600
Annual TP Removed (Ave.)[7,10]	lb P/yr	0	0	74,000	219,000
TP Cost[5,8, 10]	$/lb P	--*	--*	37	19

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.
10. Currently meeting permit target.

* TP may increase with the introduction of IMLR, which will stop biological phosphorus removal. Ferric chloride is included, but effluent TP concentrations may increase.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing secondary process • Robust technology to absorb variability in flows and loads	• Increased energy from mixed liquor return • Safety from external carbon source (if methanol) • High cost associated with methanol use • Increase sludge production
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use • High cost associated with ferric chloride addition

7 Nutrient Removal by Other Means

The RWF has an existing recycled water program that is employed year-round. Recycled water is used for landscape irrigation, golf course irrigation, and commercial and industrial uses. RWF effluent is discharged to Don Edwards National Wildlife Refuge, providing environmental enhancement. The existing program has the effect of reducing nutrients discharged to the Bay. The RWF currently recycles approximately 10,400 acre-feet per year (3,400 million gallons per year) not including discharged effluent, and they are planning to increase recycling to 17,000 acre-feet per year (5,500 million gallons per year) by 2030.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA

Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

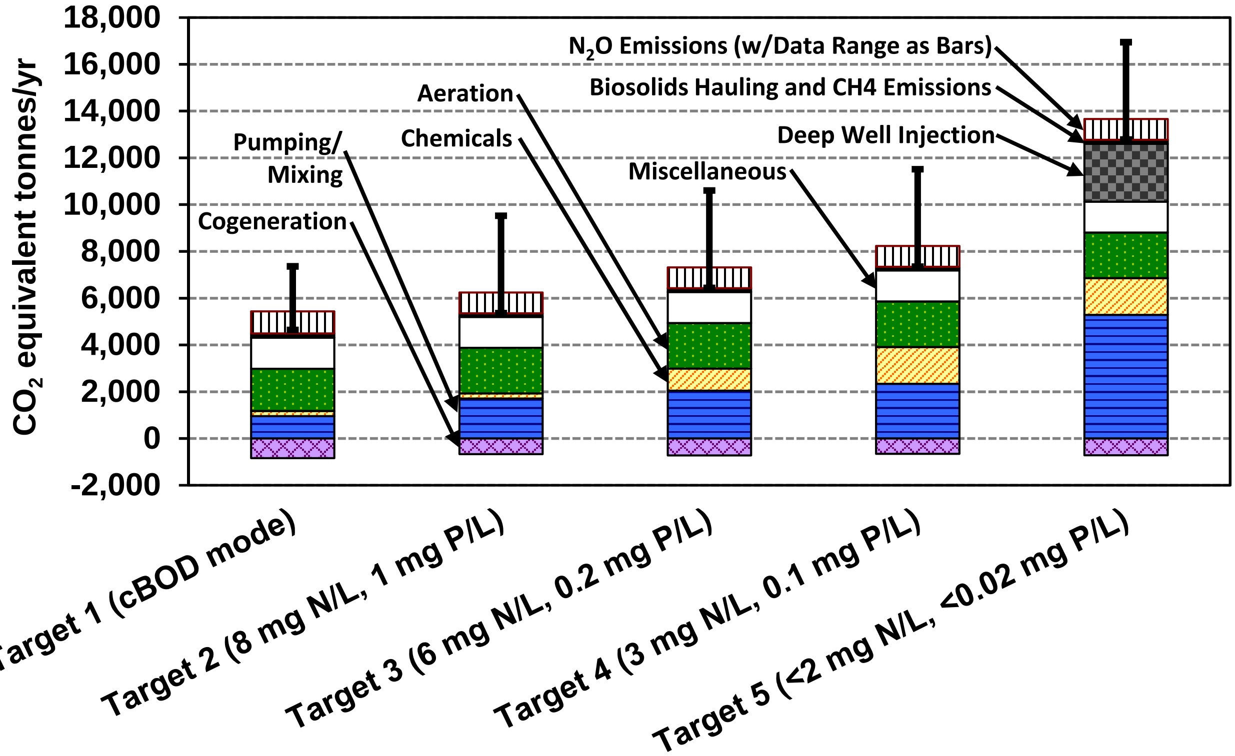

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	4,700	5,200	7,900	8,600	10,200	11,200	840
GHG Emissions Increase from Chemicals	MT CO_2/yr	300	300	400	400	7,700	7,700	50
GHG Emissions Increase Total	MT CO_2/yr	5,000	5,400	8,300	9,000	17,900	18,900	890
Unit GHG Emissions[2]	lb CO_2/MG	200	300	300	300	600	700	62
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	--*	--*	--*	--*	--**
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	24	16	59	30	20	11	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--*	--*	--*	--*	29	10	--**

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

* No removal of ammonia or TP, since the plant fully nitrifies now and meets Level 2 permit limits.

** The plant already fully nitrifies and removes phosphorus so sidestream treatment would not further reduce ammonia and total phosphorus discharge loads.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the RWF. These are:

- Nitrite Shunt – the RWF aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Ballasted Activated Sludge – the RWF secondary process would be converted to a ballasted activated sludge process to reduce process tankage requirements. The BioMag® process supplied by Evoqua utilizes magnetite as a ballast. As a result, the secondary process is operated at an elevated mixed liquor suspended solids concentration because secondary clarifiers can tolerate higher solids loading rates due to improved settleability realized with magnetite use.
  - Advantages: Low footprint requirements, proven technology
  - Disadvantages: Increased operations and maintenance costs
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost. See Table 1 below.

The unit costs for power, chemicals, and labor are shown in Table 2 below. A common unit cost basis for all plants in the study was selected this analysis.

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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City of San Leandro

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

City of San Leandro

San Leandro, CA

May 24, 2018
Final Report

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Executive Summary

The City of San Leandro operates the City of San Leandro Water Pollution Control Plant (SLWPCP) which discharges to South San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 7.6 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	4.8	5.2	7.6	8.1	7.6	8.1	--
Flow to Bay[2]	mgd	5.0	5.0	5.0	5.0	6.5	6.5	6.5	6.5	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	1,240	1,240	200	190	120	110	120	110	1,270
TN	lb N/d	1,240	1,240	1,040	970	690	650	520	320	1,300
TP	lb P/d	114	114	122	114	60	50	40	20	122
Costs[4,5]										
Capital	$ Mil	--	--	10.9	11.9	63	64	87	91	10.0
O&M PV	$ Mil	--	--	3.4	4.3	31	35	39	44	9.8
Total PV	$ Mil	--	--	14.3	16.2	94	99	126	135	19.8
Unit Costs[6]										
Capital	$/gpd	--	--	2.2	2.3	8.3	7.9	11.4	11.2	--
Total PV	$/gpd	--	--	3.0	3.1	12.4	12.2	16.5	16.6	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Implement chemically enhanced primary treatment (CEPT) to the primary clarifiers by adding metal salt and polymer chemical feed facilities.
2. Add alkalinity to the aeration basins (required for nitrification).
3. Operate the aeration basins in series to control solids distribution issues and facilitate nitrification. Additionally, the basins in series will operate in step feed mode to reduce solids loading on the secondary clarifiers and facilitate total nitrogen removal.
4. Add a blower to meet the additional demand associated with nitrification.

The SLWPCP is considered a candidate for sidestream treatment to reduce nitrogen loads as the plant anaerobically digests biosolids and dewaters to produce a return sidestream laden with nitrogen. The recommended sidestream treatment strategy is deammonification for reducing ammonia/nitrogen loads. The plant is also a candidate for sidestream treatment to reduce phosphorus loads by adding a metal salt upstream of the mechanical dewatering.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Implement chemically enhanced primary treatment (CEPT) to the primary clarifiers by adding metal salt and polymer chemical feed facilities.
   b. Add a parallel MBR treatment train.
   c. Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor to remove ammonia/total nitrogen/total phosphorus.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus:
   b. Add filters for denitrification and phosphorus removal.
   c. Add chemical feed facilities for an external carbon source to trim nitrogen at the MBR and denite filters.
   d. Add chemical feed facilities for metal salt addition for phosphorus removal.

As shown in Table ES-1, and as might be expected, the costs generally increase from optimization to sidestream treatment, and again to Level 2 and Level 3 upgrades, respectively. The costs generally increase for both capital and O&M from the dry season to year round. Overall the present value costs range from $14 Mil for dry season optimization up to $135 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The City of San Leandro Water Pollution Control Plant (SLWPCP) discharges to discharges to Lower San Francisco Bay. It is located at 3000 Davis Street San Leandro, CA 94577, and it serves about 15,300 service connections throughout northern two-thirds of the City of San Leandro. The plant has average dry weather flow (ADWF) permitted capacity of 7.6 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

SLWPCP holds the National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2012-0004; CA0037869. SLWPCP shares the permit with other dischargers of the East Bay Dischargers Authority (EBDA). Table 2–1 provides a summary of the permit limitations for the San Leandro WPCP. Table 2–1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2–1. NPDES Permit Limitations (Order No. R2-2012-0004; CA0037869)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	7.6	--	--	--
BOD	mg/L	--	25	40	--
TSS	mg/L	--	30	45	--
Total Ammonia, as N	mg/L	--	93	--	130

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the SLWPCP. Both liquids processes and solids processes are shown. Treatment consists of a headworks, primary sedimentation, trickling filter, activated sludge, secondary clarification, and disinfection by sodium hypochlorite. Treated wastewater from the wastewater treatment facility is transported to EBDA's system for final dechlorination and discharge to the EBDA Common Outfall. The activated sludge process maintains a low SRT for secondary treatment. No major nutrient removal systems are currently in place. Sludge is anaerobically digested, dewatered using a belt filter press and further dried in open drying beds.

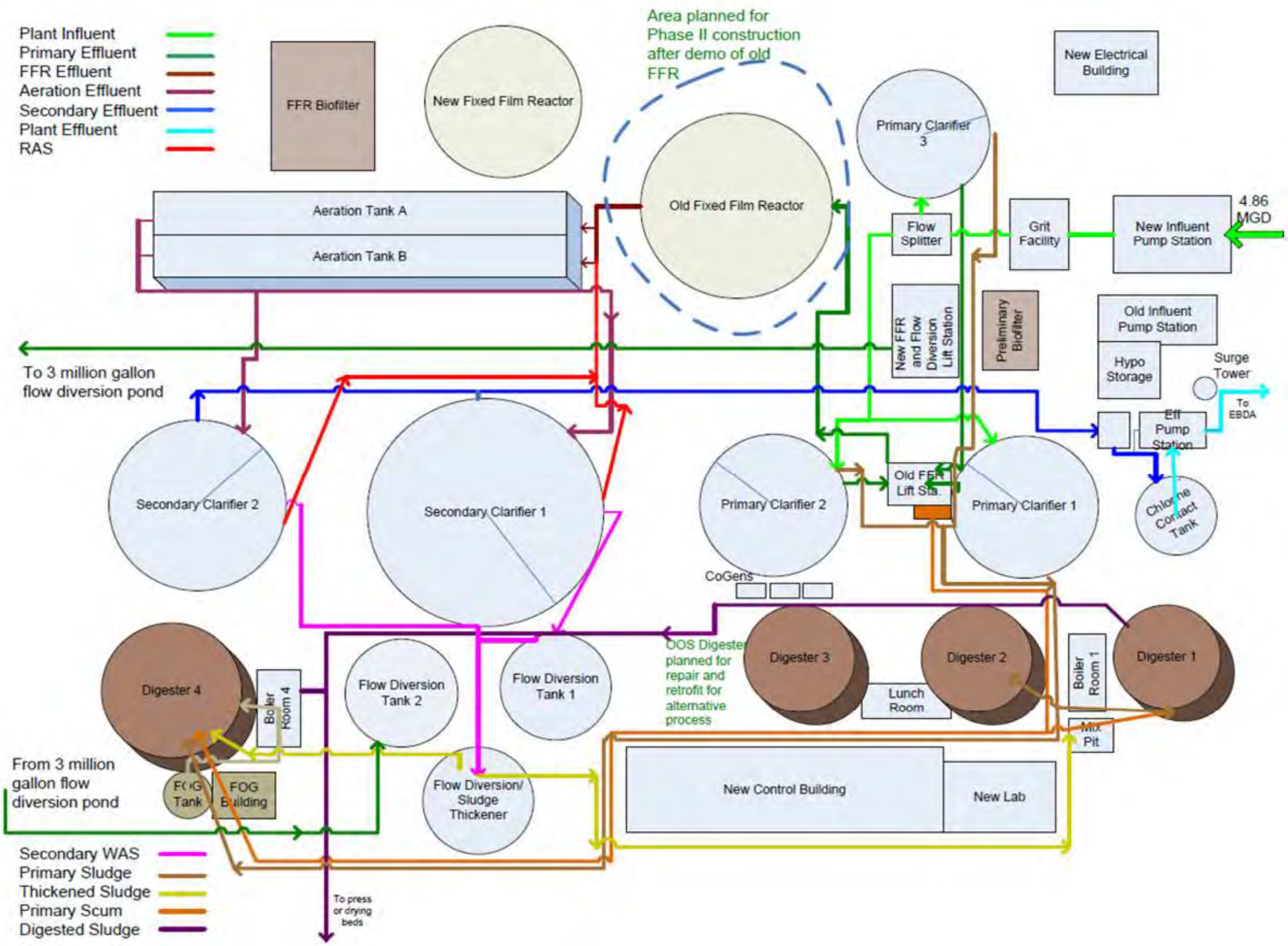

Figure 2-1. Process Flow Diagram for City of San Leandro Water Pollution Control Plant

2.3 Existing Flows and Loads

A data request was submitted to each POTW in December 2014 as a means to understand historical plant performance and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for SLWPCP is shown in Table 2–2.

Table 2–2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	4.8	5.0	5.3	6.4
BOD	lb/d	22,200	21,900	25,000	29,100
TSS	lb/d	19,200	19,200	22,800	24,600
Ammonia	lb N/d	1,100	1,200	1,100	1,300
Total Kjeldahl Nitrogen (TKN)	lb N/d	2,100	2,300	2,100	2,500
Total Phosphorus (TP)	lb P/d	280	310	280	340
Alkalinity[4]	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	549	521	570	549
TSS	mg/L	475	457	520	464
Ammonia	mg N/L	27	29	25	25
TKN	mg N/L	52	55	48	47
TP	mg P/L	6.9	7.4	6.4	6.4
Alkalinity[4]	mg/L $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

2.4 Future Nutrient Removal Projects

The SLWPCP recently completed two projects that have the potential to impact nutrient removal:

1. In 2013, they installed a new high-efficiency turbo blower for the activated sludge aeration basin.
2. The flow equalization storage facility is in place and diurnal flow diversion tanks have started up which should support a more stable and reliable process.

2.5 Pilot Testing

The SLWPCP has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loading for optimizing the plant operation for nutrient removal is presented in Table 3–1 based on a nominal 15 percent increase in flow and loading by 2025. Any recommended modifications may impact the plant's future treatment capacity. Thus, any changes for optimization are considered an interim solution.

Table 3–1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	4.8	5.0	5.3	6.4
BOD	lb/d	25,500	24,500	28,800	29,400
TSS	lb/d	22,100	22,100	26,200	28,300
Ammonia	lb N/d	1,300	1,400	1,300	1,500
TKN	lb N/d	2,400	2,600	2,400	2,900
TP	lb P/d	320	360	320	390
Alkalinity[4]	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	631	583	656	555
TSS	mg/L	547	526	597	534
Ammonia	mg N/L	32	33	30	28
TKN	mg N/L	59	62	55	55
TP	mg P/L	7.9	8.6	7.3	7.4
Alkalinity[4]	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by SLWPCP, it was determined that the SLWPCP may be a candidate for sidestream treatment.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Additional sampling for the sidestream was performed in July, 2015. The sampling results were projected forward to the permitted capacity for use in the sidestream treatment evaluation. The sidestream flows and loads for the permitted capacity are provided in Table 3–2. The permitted capacity flows and loads were used in the facility sizing.

Table 3–2. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Projected to Permitted Flow Capacity
Sidestream Flow	mgd	0.03	0.05
Ammonia	lb N/d	280	450
TKN	lb N/d	570	890
TN[1]	lb N/d	570	890
TP	lb P/d	90	140
OrthoP	lb P/d	20	30
Alkalinity	lb $CaCO_3$/d	1,400	2,200
Ammonia	mg N/L	1,150	1,150
TKN	mg N/L	2,300	2,300
TN[1]	mg N/L	2,300	2,300
TP	mg P/L	370	370
OrthoP	mg P/L	80	80
Alkalinity	mg/L as CaCO3	5,800	5,800

1. It was assumed that TKN = TN.

3.3 Flow and Loading for Facility Upgrades

The flow and loading for facility upgrades to meet Level 2 and Level 3 nutrient targets are based on the plant permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the plant permitted capacity. The flows and loading for facility upgrades are given in Table 3–3.

Table 3–3. Flow and Load for Facility Upgrades (Projected to Permitted Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	7.6	7.9	8.2	10.0
BOD	lb/d	34,800	34,300	39,200	45,600
TSS	lb/d	30,100	30,100	35,800	38,600
Ammonia	lb N/d	1,700	1,900	1,700	2,100
TKN	lb N/d	3,300	3,600	3,300	3,900
TP	lb P/d	440	490	440	530
Alkalinity[4]	lb/d as $CaCO_3$	-	-	-	-
BOD	mg/L	549	521	570	549
TSS	mg/L	475	457	520	464
Ammonia	mg N/L	27	29	25	25
TKN	mg N/L	52	55	48	47
TP	mg P/L	6.9	7.4	6.4	6.4
Alkalinity[4]	mg/L as $CaCO_3$	-	-	-	-

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.

- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy.

Five optimization strategies were identified during the SLWPCP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The five optimization strategies were screened down to four strategies as follows.

- <u>**Optimization Strategy 1:**</u> Modify the primary clarifiers to operate as chemically enhanced primary treatment (CEPT) by adding ferric chloride and polymer.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Remove phosphorus in the primaries and reduce overall loadings to downstream biological processes.
  - ***Result from analysis:*** It will remove phosphorus at the primaries and increase downstream capacity. The phosphorus load reduction is limited to the wet season as the facility is already removing phosphorus during the dry. It has the potential to remove more carbon than desired for future total nitrogen removal (if required in the future).
  - ***Recommendation:*** Carry forward.

- <u>**Optimization Strategy 2:**</u> Baseload flows to the fixed film reactors (FFRs) for nitrification
  - ***Is it feasible?*** Yes

- ***Potential impact on ability to reduce nutrient discharge loads?*** Remove more nutrients in the process by keeping flows to the FFRs consistent.
- ***Result from analysis:*** The nutrient removal benefits were marginal as the FFRs are heavily loaded.
- ***Recommendation:*** Do not carry forward.

- **Optimization Strategy 3:** Operate the aeration basins in series to control solids distribution issues between the two basins and to facilitate ammonia and total nitrogen removal. The first train would be retrofitted to operate as an anoxic zone.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy could successfully reduce the year round ammonia/total nitrogen discharge load.
  - ***Result from analysis:*** This strategy will address solids distribution between the two trains and assist with ammonia/total nitrogen load reduction. An extra blower is required to meet the additional demand associated with nitrification. The extent of total nitrogen load reduction will depend on the return activated sludge pumping rate. There are concerns with the secondary clarifiers to handle additional solids loading.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 4:** Operate the aeration basins in step feed mode to reduce solids loading on the secondary clarifiers and enhance total nitrogen load reduction. This strategy is predicated on implementation of Optimization Strategy 3.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy could successfully reduce the year round total nitrogen discharge load.
  - ***Result from analysis:*** This strategy would reduce solids loading on the secondary clarifiers to a level that would not require additional secondaries. Additionally, this strategy builds upon the total nitrogen load reduction in Strategy 3. The extent of total nitrogen load reduction beyond Strategy 3 will depend upon the step feed distribution and would require additional analysis.
  - ***Recommendation:*** Carry forward.

Strategies 1, 3, and 4 could reduce ammonia, total nitrogen, and total phosphorus loads. The recommended strategies are shown with the process flow diagram presented in Figure 4-1. A description of each strategy and the evaluation results are presented thereafter. It is noted, however, that recommended modifications for optimization may impact the plant’s treatment capacity. Thus, any changes for optimization should be considered an interim solution.

The capital and operational elements of the recommended optimization strategies are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Implement chemically enhanced primary treatment (CEPT) • Add metal salt chemical feed facilities • Add polymer chemical feed facilities	• Operate the chemical feed facilities
Operate the aeration basins in series • Replace the existing aeration basin overflow pipes layout. The pipes would most likely require replacement due to corrosion • Modify a portion of the first train to operate as an anoxic zone • Add a blower to meet the additional demand associated with nitrification	• Operate in a new mode that the operations staff will need to get accustomed to • Maintain the additional blower
Operate the aeration basins in step feed mode • Add additional piping to facilitate feeding the aeration basins along the length	• Operate in a new mode that the operations staff will need to get accustomed to

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	1,340	1,340	1,340	1,340	122	122
Discharge with Opt. Strategy[1]	lb N or P/d	200	190	1,040	970	122	114
Load Reduction[2]	lb N or P/d	1,140	1,150	300	370	0	8
Load Reduction[2]	%	85%	86%	23%	28%	0%	7%
Annual Load Reduction	lb N or P/yr	416,000	420,000	110,000	134,000	0	2,900

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.

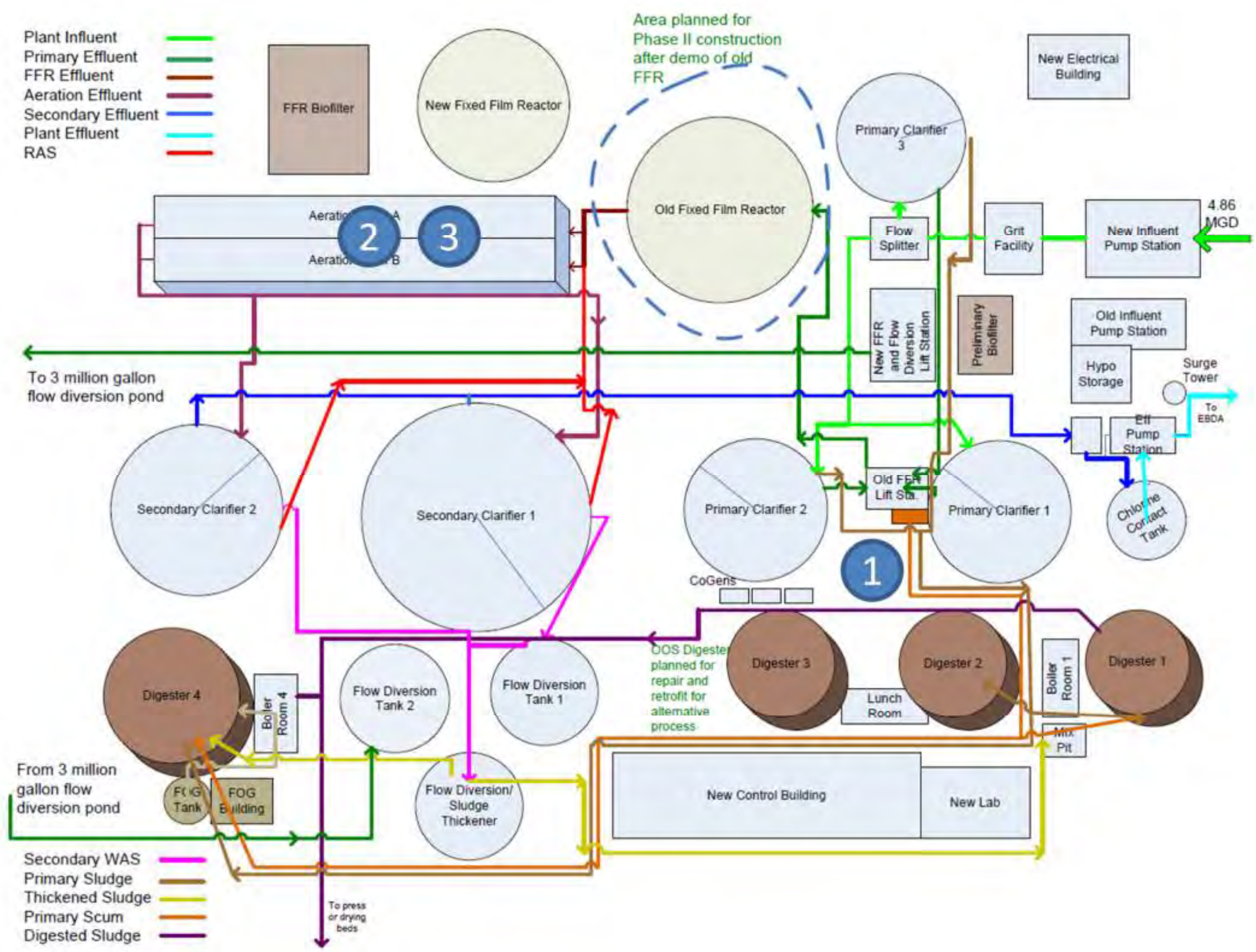

Figure 4-1. Optimization Concepts Considered for SLWPCP

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) operate the aeration basins in series and add an anoxic zone and blower, and (3) provide piping/pumping to operate in step feed mode (requires implementation of concept (2))

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	4.8	5.2
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	10.9	11.9
Annual O&M	$ Mil/yr	0.3	0.4
Present Value O&M[3]	$ Mil	3.4	4.3
Present Value Total[3]	$ Mil	14.3	16.2
Unit Capital Cost[8]	$/gpd	2.2	2.3
Unit Total PV Cost[8]	$/gpd	2.9	3.1
TN Removal			
Capital[2,4]	$ Mil	10.0	10.9
Annual O&M[4]	$ Mil/yr	0.2	0.3
O&M PV[3,4]	$ Mil	2.4	3.3
Total PV[3,4]	$ Mil	12.4	14.2
TN Removed (Ave.)[6]	lb N/d	300	370
Annual TN Removed (Ave.)[7]	lb N/yr	110,000	134,000
TN Cost[4,9]	$/lb N	11	11
TP Removal			
Capital[2,5]	$ Mil	2.0	2.0
Annual O&M[5]	$ Mil/yr	0.2	0.2
O&M PV[3,5]	$ Mil	1.6	1.8
Total PV[3,5]	$ Mil	3.6	3.8
TP Removed (Ave.)[6]	lb P/d	--**	8
Annual TP Removed (Ave.)[7]	lb P/yr	--**	2,900
TP Cost[5,9]	$/lb P	--**	130

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

** The optimization strategy will not reduce total phosphorus loads during the dry. Rather, it will improve the load reduction reliability.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at SLWPCP.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
Add CEPT • Ability to reduce total phosphorus discharge loads • Increased capacity in the FFRs and activated sludge process • Increased solids/organics diverted to the digesters, which translates to increased biogas production	• Additional chemicals to handle • Carbon management issues for meeting low level total nitrogen discharge limits (if required in the future)
Operate Aeration Basins in Series • Ability to reduce ammonia/total nitrogen loads	• Changed mode of operation • Most likely requires alkalinity • Additional loading on the secondary clarifiers • Additional energy demand associated with extra blower
Operate Aeration Basins in Step Feed Mode • Ability to further reduce total nitrogen loads (predicated on implementation of operating aeration basins in series) • Alkalinity recovery • Reduce solids loading on the secondaries compared to operating in non-step feed mode	• Changed mode of operation that requires operator input on step feed distribution • Occasionally bleed ammonia if step feed is not appropriately distributed between the in series trains

5 Sidestream Treatment

As previously described, the SLWPCP was identified as a potential candidate for sidestream treatment. The plant currently uses belt filter presses followed by drying beds.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia and total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/denitrification) including requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requires 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for the SLWPCP.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks). In the case of the SLWPCP, ferric chloride addition ahead of the dewatering is recommended where the precipitated phosphorus will be captured with the cake.

Recovery of the total phosphorus sidestream load via struvite precipitation is another option to eliminate the phosphorus recycle stream loads. This process produces a useful byproduct (struvite crystals) that can be sold economically. Chemical addition is typically simpler and easier for plants to implement. Plants are encouraged to evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant as an alternative to chemical phosphorus recycle load control.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed Facility
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	1,600	1,600	146
Discharge with Sidestream Treatment[2]	lb/d	1,270	1,300	122
Load Reduction[3]	lb/d	330	300	24
Load Reduction	%	21%	18%	17%
Annual Load Reduction	lb/yr	119,700	106,400	8,800

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	9.9	0.10
Annual O&M	$ Mil/yr	0.42	0.02
Total Present Value[2]	$ Mil	19.3	0.48
NH4-N Load Reduction[3,5]	lb N/yr	119,700	--
TN Load Reduction[3,5]	lb N/yr	106,400	--
TP Load Reduction[4,5]	lb P/yr	--	8,800
NH4-N Cost [3,5,6]	$/lb N	5.4	--
TN Cost [3,5,6]	$/lb N	6.0	--
TP Cost [4,5,6]	$/lb P	--	1.8

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the SLWPCP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. SLWPCP should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under the Optimization Section. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, metal salt and polymer chemical feed facilities would be added at the primaries to operate in CEPT for reducing the downstream facility needs (similar to Optimization Concept). A parallel MBR would be constructed in the area where the current old fixed film reactor is located. The existing aeration basins would be modified to operate as a biological nutrient removal (BNR) reactor. In order to do this, the reactors would be operated in series (similar to the optimization concept) plus there would be anaerobic/anoxic zones fully outfitted with the appropriate mixed liquor return pumping between the zones. Other process improvement technologies to consider include IFAS (integrated fixed film activated sludge) and moving bed bioreactor (MBBR).

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

In addition to those listed for Level 2, Level 3 upgrades requires an external carbon source chemical feed facility, alum/polymer chemical feed facilities at newly constructed filters, a rapid mix/flocculation tank upstream of the filters, and new filters for nitrogen and phosphorus removal. The external carbon source is provided to meet the carbon requirements for meeting the TN discharge target. The chemical feed facilities and the rapid mix/flocculation step prior to the filters is in place to remove solids loading associated with chemical precipitation upstream of the filters. The additional chemical feed facilities would operate on a daily basis to meet the TP discharge target.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-1 and Figure 6-2, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	Implement chemically enhanced primary treatment (CEPT): • Add metal salt chemical feed facilities • Add polymer chemical feed facilities	Same as Level 2
Biological	• Parallel MBR • Retrofit the aeration basins to operate as a BNR reactor to achieve ammonia/total nitrogen/total phosphorus load reduction	Same as Level 2, plus: • External Carbon Source Chemical Feed Facility for MBR
Tertiary	--	• Denitrification and phosphorus removal filters to reduce load from the parallel MBR facilities • Add an external carbon source chemical feed facilities • Add a metal salt chemical feed facilities

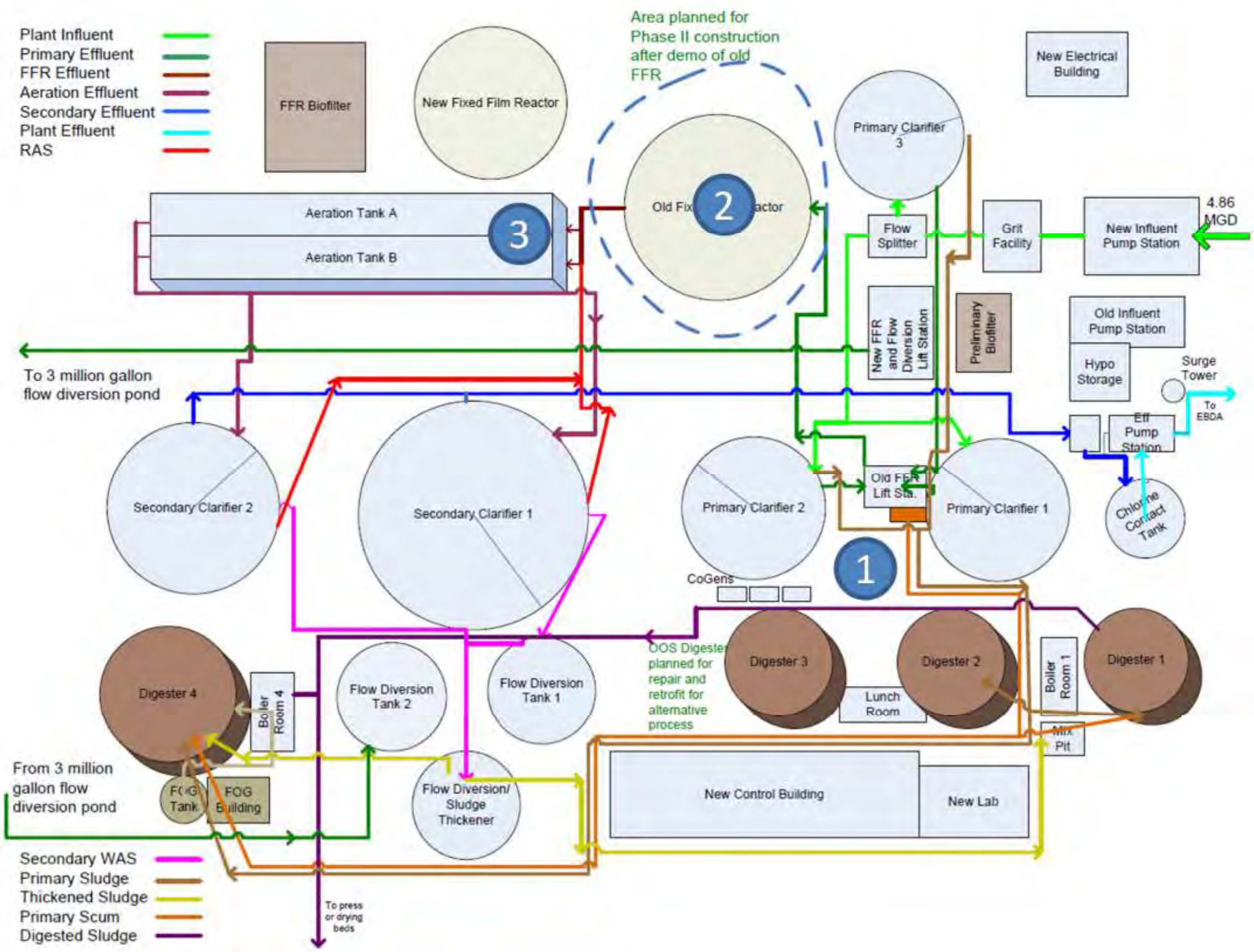

Figure 6-1. Level 2 Upgrade Concepts for SLWPCP

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) add a parallel treatment MBR, (3) Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor

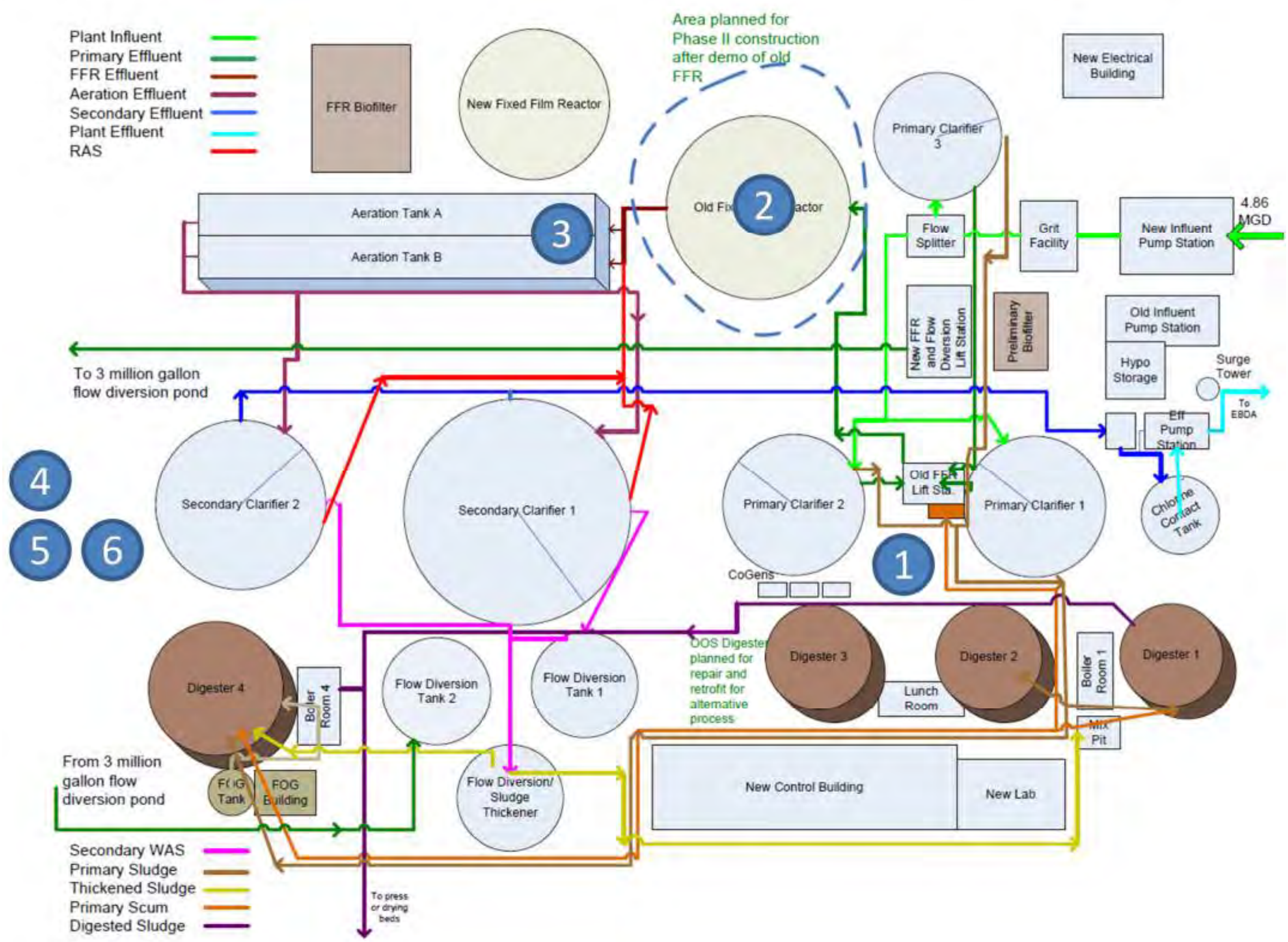

Figure 6-2. Level 3 Upgrade Concepts for SLWPCP

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) add a parallel treatment MBR, (3) Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor (4), add filters for denitrification and P removal (5) metal salt facilities for P removal (6) add external carbon source chemical feed facilities for MBR and denite filters

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) add a parallel treatment MBR, (3) Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) add a parallel treatment MBR, (3) Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor, (4) add filters for denitrification and P removal (5) ferric facilities for P removal (6) add external carbon source chemical feed facilities for MBR and denite filters

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	7.6	8.1	7.6	8.1
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	63	64	87	91
Annual O&M	$Mil/yr	1.4	1.6	1.7	2.0
O&M PV[3]	$ Mil	31	35	39	44
Total PV[3]	$ Mil	94	99	126	135
Unit Capital Cost	$/gpd	8.3	7.9	11.4	11.2
Unit Total PV	$/gpd	12.4	12.2	16.5	16.6
TN Removal					
Capital[2,4]	$ Mil	62	63	86	90
Annual O&M[4]	$ Mil/yr	1.3	1.5	1.6	1.9
O&M PV[3,4]	$ Mil	30	34	37	42
Total PV[3,4]	$ Mil	92	97	123	131
TN Removed (Ave.)[6]	lb N/d	910	950	1,080	1,270
Annual TN Removed (Ave.)[7]	lb N/yr	331,000	347,000	395,000	465,000
TN Cost[4,8]	$/lb N	9.2	9.3	10.4	9.4
TP Removal					
Capital[2,5]	$ Mil	43	43	65	69
Annual O&M[5]	$ Mil/yr	1.3	1.4	1.4	1.5
O&M PV[3,5]	$ Mil	29	31	32	34
Total PV[3,5]	$ Mil	71	74	98	103
TP Removed (Ave.)[6]	lb P/d	88	92	107	130
Annual TP Removed (Ave.)[7]	lb P/yr	32,000	33,000	39,000	47,000
TP Cost[5,8]	$/lb P	74	73	83	73

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Additional primary clarifiers capacity • Enhanced phosphorus and nitrogen load reduction • MBR produces higher quality product water than current facilities	• Increased energy demand from MBR • Additional process to operate • Operate in a new mode that will require the operators to get accustomed to
Level 3	Same as Level 2 plus the following additional benefits: • Further alkalinity recovery due to more denitrification than the other Levels • Further improved product water due to filtration step	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Additional solids • Safety from external carbon source (if methanol) • Additional aeration basin volume to operate • Operating an additional biological process (i.e., sidestream treatment)

7 Nutrient Load Reduction by Other Means

The SLWPCP has an existing recycled water program that is employed year-round. This existing program has the effect of reducing nutrients discharged to the Bay. The plant recycles approximately 570 acre-feet per year (185 million gallons per year). There are plans to further expand the recycled water program up to approximately 710 acre-feet per year (230 million gallons per year).

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology

selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

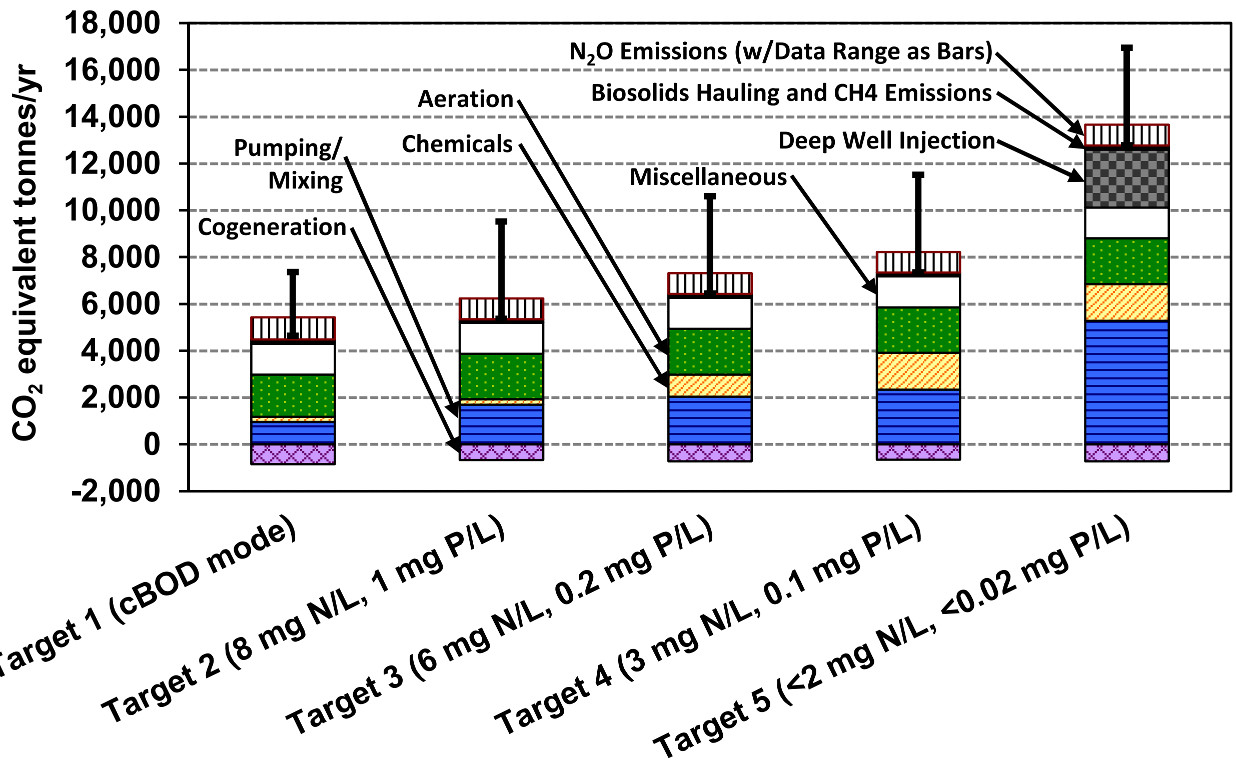

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical

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[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	570	610	1,650	1,760	1,680	1,800	44
GHG Emissions Increase from Chemicals	MT CO_2/yr	50	50	20	30	340	360	1
GHG Emissions Increase Total	MT CO_2/yr	620	660	1,680	1,790	2,020	2,150	45
Unit GHG Emissions[2]	lb CO_2/MG	700	800	1,300	1,400	1,500	1,600	54
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	3	3	7	7	6	7	0.9
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	12	10	11	11	11	10	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--*	50	70	70	60	60	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

* The plant is not removing additional phosphorus load during for the dry season optimization.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the SLWPCP:

- Granular Activated Sludge – this could be used to phase out the biotower/activated sludge. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit to the SLWPCP is it has the potential to not require basin expansion for Levels 2 or 3. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.27

San Mateo Wastewater Treatment Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

San Mateo Wastewater Treatment Plant

San Mateo, CA

May 14, 2018
Final Report

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Executive Summary

The San Mateo Wastewater Treatment Plant (San Mateo WWTP) discharges treated effluent to Lower San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 15.7 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3,7]	Opt. Year Round[3,7]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3,8]
Design Flow	mgd	--	--	--	--	15.7	16.2	15.7	16.2	--
Flow to Bay[2]	mgd	10.4	10.4	--	--	13.2	13.2	13.2	13.2	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	2,850	2,850	--	--	230	220	230	220	60
TN	lb N/d	3,480	3,480	--	--	1,410	1,320	1,050	660	440
TP	lb P/d	270	270	--	--	120	110	80	30	110
Costs[4,5]										
Capital	$ Mil	--	--	--	--	330	330	330	330	12
O&M PV	$ Mil	--	--	--	--	140	150	190	330	6
Total PV	$ Mil	--	--	--	--	470	480	510	660	18
Unit Costs[6]										
Capital	$/gpd	--	--	--	--	20.8	20.2	21.0	20.4	--
Total PV	$/gpd	--	--	--	--	29.6	29.4	32.8	41.0	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Not Applicable. No optimizations were recommended since plant is upgrading to nutrient removal.
8. These values are based on anticipated sidestream and discharge loads following upgrades

No plant optimizations are proposed for the San Mateo WWTP since the WWTP is in the process of upgrading for nutrient removal.

The San Mateo WWTP could consider sidestream treatment if there is an objective to further reduce total nitrogen loads beyond the capabilities of the WWTP upgrades currently under design. A deammonification sidestream treatment technology should be considered if further total nitrogen load reduction is desired.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow are based on the planned upgrades that are currently in progress and include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. The secondary treatment process is designed around a membrane bioreactor (MBR) technology using a BNR configuration and membrane tanks for solids separation. The BNR for the planned upgrade is a 4-stage Bardenpho consisting of anoxic, aeration, deoxygenation and post anoxic zones. The proposed WWTP upgrade project has been designed to achieve 9 mg TN-N/L.
    b. The process has three clarifiers that can operate as primary clarifiers under Normal Operating Mode. During wet weather mode, one clarifier operates in CEPT mode to send flow to the MBR and the two clarifiers are coupled with a biological contact basin to operate as secondary clarifiers (known as the BioCET process) to treat excess flows.
    c. To achieve Level 2 phosphorus requirements, an anaerobic selector could be added in the future to convert the process to a 5-stage Bardenpho. The anaerobic selector is not part of the upgrade that is happening now, but the costs are included as part of Level 2 for this evaluation.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Carbon source is added to reduce effluent nitrogen concentrations.
    c. Ferric chloride is added to the BNR tanks for phosphorus reduction.

Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy and are summarized in Table ES-1. Overall the present value costs range from $470 Mil for dry season Level 2 up to $660 Mil for Level 3 year round upgrades including chemicals for Level 3 and higher O&M costs associated with higher flows.

In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The San Mateo Wastewater Treatment Plant (San Mateo WWTP) services a population of about 155,000, which includes the industrial, commercial, and domestic wastewater from the Cities of San Mateo, Foster City, Hillsborough and portions of Belmont and unincorporated San Mateo County. The San Mateo WWTP is located at 2050 Detroit Drive in San Mateo, CA.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The San Mateo WWTP holds the NPDES permit (Order No. R2-2013-0006, NPDES Permit No. CA0037541). The treated wastewater is discharged to the Lower San Francisco Bay. The San Mateo WWTP discharge is located at latitude 37° 34’ 50” N and longitude 122° 14’ 45” W.

Table 2-1 provides a summary of the permit limitations that are specific to the San Mateo WWTP and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2013-0006; CA0037541)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Effluent Limitations – October through April					
Flow	mgd	15.7	-	-	-
cBOD	mg/L	-	25	40	-
TSS	mg/L	-	30	45	-
Total Ammonia, as N	mg/L	-	66	-	120
Effluent Limitations – May through September					
Flow[1]	mgd	40	-	-	-
cBOD	mg/L	-	15	25	-
TSS	mg/L	-	20	30	-
Total Ammonia, as N	mg/L	-	66	-	120

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. Permitted capacity for peak wet weather flow with secondary treatment is 40 mgd. When the flow exceeds 40 mgd for an extended period, diversion of primary -treated effluent around the secondary treatment units may occur to prevent a washout of microbial populations. Primary effluent is blended with secondary-treated wastewater in the chlorine contact tank.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the existing San Mateo WWTP. Both liquids and solids processes are shown. The existing San Mateo WWTP consists of primary clarification followed by conventional activated sludge for secondary treatment (i.e. carbonaceous treatment only). Effluent is disinfected by chlorination, then dechlorinated prior to discharge to the San Francisco Bay. Solids treatment consists of primary and secondary sludge thickening, anaerobic digestion and centrifuge dewatering.

When influent flow exceeds 40 mgd for an extended period, diversion of primary treated effluent around the secondary treatment units may occur to prevent a washout of the biological process. During this diversion, primary effluent is blended with secondary-treated wastewater in the chlorine contact tank.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the San Mateo WWTP is shown in Table 2-2.

Table 2-2. Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	11.0	11.5	11.9	15.8
cBOD	lb/d	26,400	26,400	28,300	29,700
TSS	lb/d	31,000	30,500	37,400	36,500
Ammonia[4]	lb N/d	3,200	3,200	3,440	3,610
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	4,280	4,280	4,600	4,830
Total Phosphorus (TP)[4]	lb P/d	410	410	440	460
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
cBOD	mg/L	290	270	290	230
TSS	mg/L	340	320	380	280
Ammonia[4]	mg N/L	35	33	35	27
TKN[4]	mg N/L	47	45	46	37
TP[4]	mg P/L	4.4	4.2	4.4	3.5
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Annual average ammonia, TKN and TP based on four samples collected between July 2012 and June 2014. Ammonia, TKN and TP for other conditions were calculated using the BOD peaking factors.

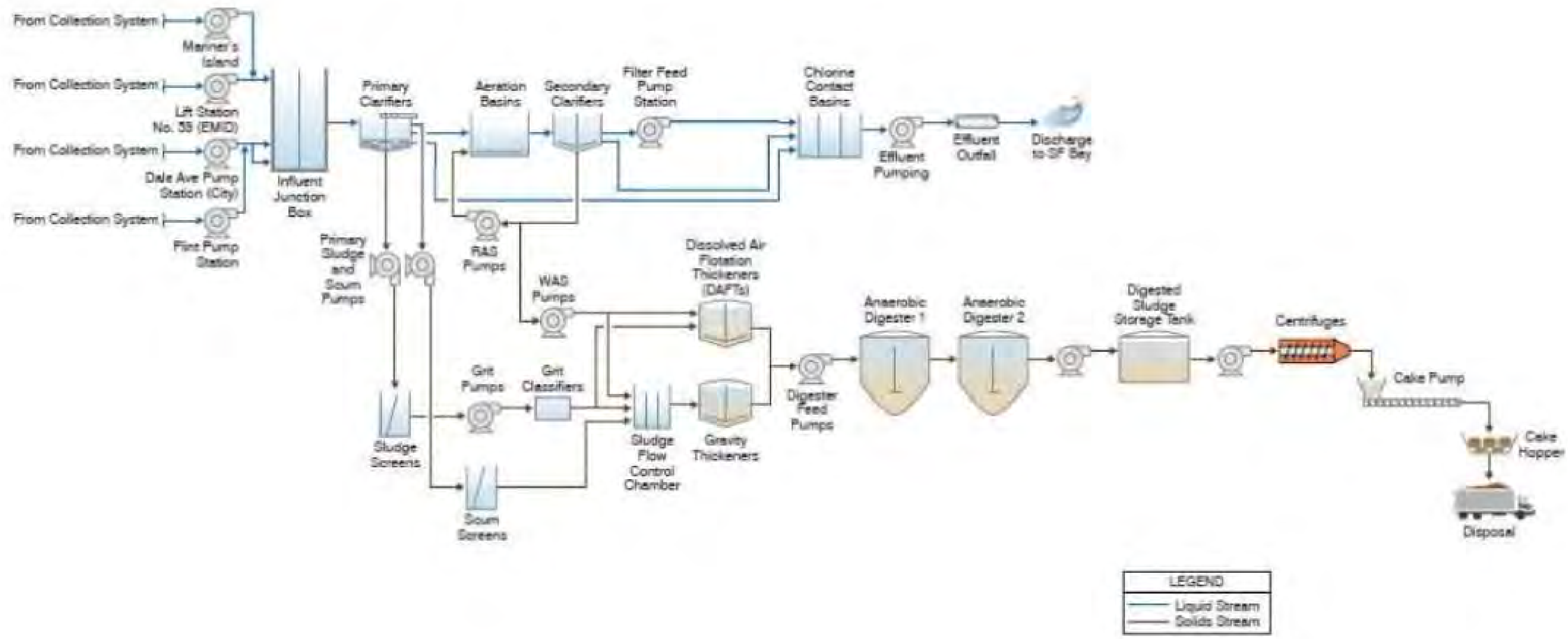

Figure 2-1. Process Flow Diagram for San Mateo WWTP

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the San Mateo WWTP:

- The Final Draft Integrated Wastewater Master Plan was prepared in 2014, identifying treatment plant upgrades to increase secondary treatment capacity to 60 mgd and eliminate blending during wet weather events.
- Following completion of the Master Plan the City of San Mateo established the Clean Water Program (CWP). The CWP is a comprehensive 10-year plan to upgrade the aging wastewater collection system and San Mateo WWTP. The goals of the CWP are to:
  - enhance the reliability of the wastewater collection and treatment system
  - increase capacity to manage heavy flows to eliminate SSOs,
  - comply with regulatory requirements,
  - produce better-quality treated water that meets current and future permit requirements and that can be used as recycled water in the future, and
  - align with the City's sustainability goals.
- The upgrade and expansion of the San Mateo WWTP is the largest project under the CWP. The new facilities will be designed to handle influent flows of 21 mgd (maximum month) and 78 mgd (peak wet weather flows with both in-system and onsite storage). These new facilities are being designed to provide advanced treatment to 21 million mgd and allow the plant to better handle wet weather events up to 78 mgd. Upon completion of the upgrades the WWTP will produce a high quality effluent for dry weather flows that is low in nitrogen (designed to achieve 9 TN-N/L limit)- and meets un-restricted Title 22 requirements. Planned upgrades are described in Section 6.2.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the San Mateo WWTP; however, testing was conducted to validate the wet weather secondary treatment (BioCET) process.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

No optimizations are proposed for the San Mateo WWTP since the WWTP is in the process of being upgraded to nutrient removal.

3.2 Flow and Loading for Sidestream Treatment

The upgrades, currently under design, for the San Mateo WWTP do not include sidestream treatment. The San Mateo WWTP could consider sidestream treatment if there is an objective to further reduce total nitrogen loads beyond the capabilities of the on-going upgrades.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the upgrade capacity. The sidestream flows and loads for the upgrade capacity are provided in Table 3-1. The upgrade capacity flows and loads were used in the facility sizing.

Table 3-1. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Design Capacity (AA)
Sidestream Flow	mgd	0.07	0.11
Ammonia	lb N/d	500	710
TKN	lb N/d	700	1,000
TN [1]	lb N/d	700	1,000
TP	lb P/d	60	80
Ortho P	lb P/d	30	40
Alkalinity	lb $CaCO_3$/d	2,100	3,000
Ammonia	mg N/L	800	800
TKN	mg N/L	1,140	1,140
TN[1]	mg N/L	1,140	1,140
TP	mg P/L	90	90
Ortho P	mg P/L	50	50
Alkalinity	mg $CaCO_3$/L	3,400	3,400

1. It was assumed that TN = TKN

3.3 Flow and Loading for Facility Upgrades

The flow and loads used for the plant upgrades analysis are presented in Table 3-2. These values are based on the design flows and loadings used for upgrade project currently under design.

Table 3-2. Flow and Load for Facility Upgrades (Based on Upgrade Project Loadings)

Parameter	Unit	Average Annual[2]	Year Round MM[1,2]
Flow	mgd	16.0	21.0
cBOD	lb/d	32,100	37,000
TSS	lb/d	35,600	51,700
Ammonia	lb N/d	3,700	4,600
TKN	lb N/d	5,500	6,800
TP	lb P/d	700	900
Alkalinity	lb/d as $CaCO_3$	---	---
cBOD	mg/L	240	210
TSS	mg/L	270	300
Ammonia	mg N/L	28	26
TKN	mg N/L	41	39
TP	mg P/L	5.2	5.1
Alkalinity	mg/L as $CaCO_3$	---	---

1. MM = Maximum Month.
2. Flows and loadings are based on the upgrade project design.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.

- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

No optimization concepts were developed for the San Mateo WWTP as the plant is in the middle of design for a major upgrade/expansion project that includes nutrient removal.

5 Sidestream Treatment

The San Mateo WWTP could consider sidestream treatment if there is an objective to further reduce total nitrogen loads beyond the capabilities of the WWTP upgrades currently under design.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology should be considered if further total nitrogen load reduction is desired. TP load reduction is not recommended.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow nitrification of 50 percent of the sidestream ammonia, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification) including requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requires 50 percent less alkalinity than conventional nitrification. Sidestream deammonification would reduce the amount of external carbon used in the BNR reactors. Based on these benefits, deammonification should be considered for the San Mateo WWTP if total nitrogen load reduction is required beyond that being achieved with the upgrade project.

In the event sidestream treatment is implemented a list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements[1]
Feed Pumping (if necessary)	--
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

1. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and upgrade capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)[4]	TN (lb N/d)	TP (lb P/d)[4]
Anticipated Discharge under the Upgrade Mode[1,5]	lb/d	60	680	110
Discharge with Sidestream Treatment[2,5]	lb/d	60	440	110
Load Reduction[3,5]	lb/d	0	240	0
Load Reduction	%	0%	35%	0%
Annual Load Reduction[3]	lb/yr	0	87,600	0

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. The on-going plant upgrades will result in full nitrification and total phosphorus removal so sidestream treatment would not further reduce ammonia and/or TP discharge loads.
5. These values are based on anticipated sidestream and discharge loads following on-going plant upgrades.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN[7]	TP[7]
Capital[1]	$ Mil	12	--
Annual O&M	$ Mil/yr	0.3	--
Total Present Value[2]	$ Mil	18	--
NH4-N Load Reduction[3,5,8]	lb N/yr	--	--
TN Load Reduction[3,5,8]	lb N/yr	87,600	--
TP Load Reduction[4,5,8]	lb P/yr	--	--
NH4-N Cost [3,5,6]	$/lb N	--	--
TN Cost [3,5,6]	$/lb N	6.9	--
TP Cost [4,5,6]	$/lb P	--	--

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. The plant upgrades will fully nitrify at the end of construction so sidestream treatment would not further reduce ammonia discharge loads.
8. These values are based on anticipated sidestream and discharge loads following upgrades.

6 Nutrient Reduction Upgrades

The technologies selected for this evaluation are based on the facility upgrade project currently in progress.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 nitrogen discharge requirements are shown with the process flow diagram presented in Figure 6-1.

The planned upgrades to the San Mateo WWTP project upon completion will be able to operate in two different operating modes:

- Normal operating mode (refer to Figure 6-1 for a schematic drawing).
- Wet weather operating mode (refer to Figure 6-1 for a schematic drawing).

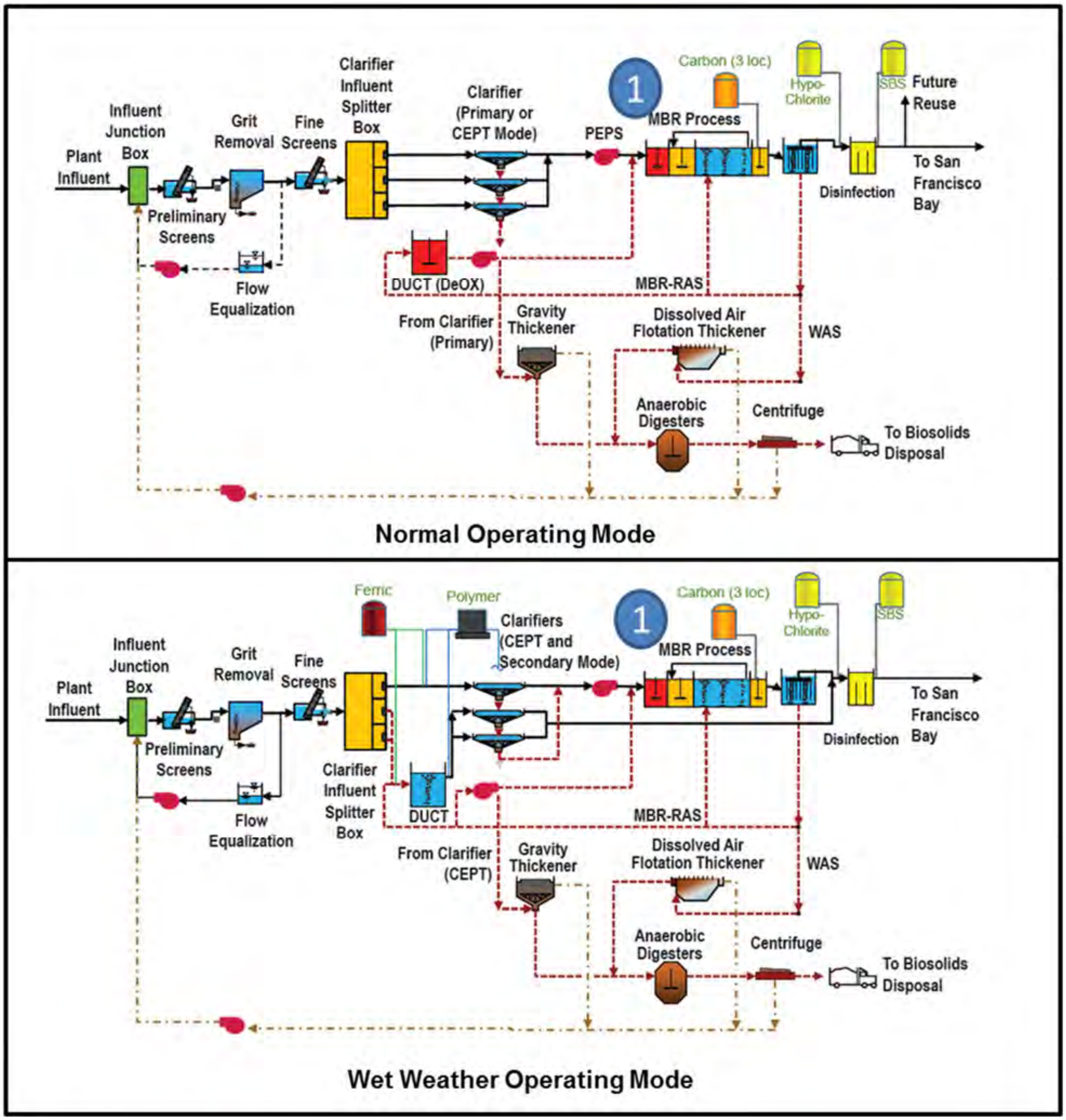

Figure 6-1. Level 2 Upgrade Concept for San Mateo WWTP

Figure shows the planned upgrades for Level 2 nitrogen limits, including normal operating mode and wet weather operating mode. For Level 2 phosphorus limits, add (1) anaerobic selector zone for phosphorus removal.

The normal operating mode is the default mode in which the plant operates most (nearly all) of the time, including moderate rain events. During normal operating mode the flow is directed as follows:

- All screened and degritted influent is routed to the clarifiers operating in conventional primary treatment mode.
- Primary effluent is pumped to the membrane bioreactor (MBR) for secondary treatment.
- MBR effluent is disinfected.
- Disinfected effluent is then conveyed via gravity or is pumped to the San Francisco Bay

The wet weather operating mode is used to manage storm event flows through the plant to provide secondary treatment to the maximum extent possible. Normal conditions are referred herein to those occurring year round that are not being influenced by excessive flows resulting from a storm event. During storm conditions, the process is temporarily reconfigured to operate in a wet weather mode to meet secondary treatment requirements. The wet weather mode is called BioCET and is comprised of a DUCT operating as a BioCET biological contact tank and two dual use clarifiers. During a wet weather operating mode, the flow is directed is as follows:

- Screened and degritted influent above 60 MGD is directed to flow equalization,
- Screened and degritted influent above the MBR capacity is split between one clarifier operating in Chemically Enhanced Primary Treatment (CEPT) mode and the DUCT (operating in BioCET biological mode) that is coupled with two remaining clarifiers, converted to operate as secondary clarifiers. Chemical addition to improve the clarifiers solids/liquid separation capacity is provided when operating in this mode.
- Flow from the two clarifiers operating as secondary clarifiers is conveyed by gravity to the existing chlorine contact basin.
- CEPT effluent flows to the MBR for secondary and tertiary treatment. A portion of MBR-return activated sludge (RAS) is pumped to the DUCT (operating in BioCET biological mode) to provide secondary treatment to flows not directed to the MBR process.
- Underflow from the clarifiers (operating as secondary clarifiers) is returned to the MBR process.
- MBR effluent is combined with the secondary effluent prior to entering the chlorine contact basin for disinfection.
- Disinfected effluent is then conveyed via gravity or is pumped to the San Francisco Bay

To meet Level 2 phosphorus limits, an anaerobic selector could be added in the future to convert the process to a 5-stage Bardenpho. The anaerobic selector is not part of the upgrade that is happening now, but the costs are included as part of Level 2 for this evaluation.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

The upgrades are the same for Level 2 with the addition of a carbon source to further reduce effluent nitrogen concentrations, and ferric chloride addition to the BNR tanks for additional phosphorus reduction.

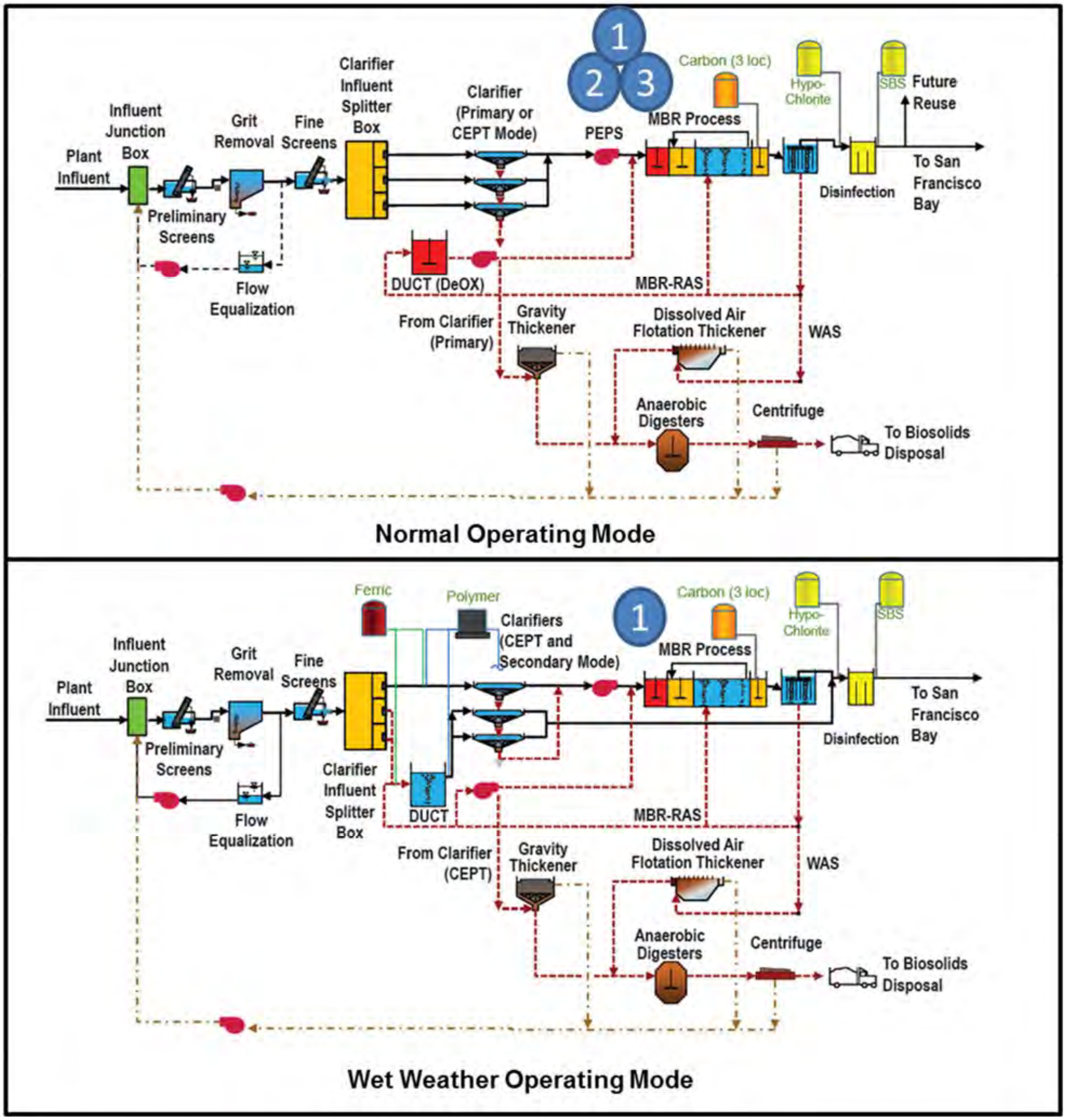

Figure 6-2. Level 3 Upgrade Concept for San Mateo WWTP

Figure shows the planned upgrades for Level 2 nitrogen limits, including normal operating mode and wet weather operating mode. For Level 3, add (1) anaerobic selector zone for phosphorus removal, (2) carbon addition for additional denitrification, and (3) ferric chloride addition for phosphorus polishing.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. A layout of these key facilities is shown in Figure 6-3.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Preliminary	• Preliminary screens (6 mm) • Grit removal • Fine Screens (2mm)	Same as Level 2
Primary	• Ferric chloride and polymer addition for CEPT and BioCET mode • New clarifiers (used as primary clarifiers during normal operation)	Same as Level 2
Secondary and tertiary	• New BNR tanks configured with anoxic, aeration, deoxygenation and post anoxic zones as part of the planned upgrade • New dual-use contact tank for BioCET mode, used for RAS deoxygenation during normal operation • New membrane tanks for MBR • New aeration system • Future addition of anaerobic selectors for phosphorus removal	Same as Level 2 plus: • Ferric chloride addition to BNR tanks for additional phosphorus reduction • Facilities for external carbon source addition.

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs include the planned upgrades, as well as future improvements for phosphorus removal. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

Figure 6-3. Level 2 and 3 Upgrade Aerial Layouts

Planned upgrade project includes: (1) headworks with fine screening, (2) dual-use clarifiers, (3) dual use contact tank (DUCT), (4) new secondary treatment process in the BNR configuration, (5) MBR membrane tanks and equipment, (6) administration building, (7) below grade utility corridors, (8) flow equalization basins, (9) chemical storage, (10) disinfection improvements, (11) odor control), (12) site work, (13) landscaping, and (14) new warehouse. Note that only items associated with nutrient removal are included in the BACWA capital costs.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow[10]	mgd	15.7	16.2	15.7	16.2
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	330	330	330	330
Annual O&M	$Mil/yr	6.2	6.7	8.3	14.9
O&M PV[3]	$ Mil	140	150	190	330
Total PV[3]	$ Mil	470	480	510	660
Unit Capital Cost	$/gpd	20.8	20.2	21.0	20.4
Unit Total PV	$/gpd	29.6	29.4	32.8	41.0
TN Removal					
Capital[2,4]	$ Mil	310	320	320	320
Annual O&M[4]	$ Mil/yr	6.1	6.6	8.2	14.8
O&M PV[3,4]	$ Mil	140	150	180	330
Total PV[3,4]	$ Mil	450	460	500	650
TN Removed (Ave.)[6]	lb N/d	2,360	2,450	2,720	3,110
Annual TN Removed (Ave.)[7]	lb N/yr	863,000	894,000	993,000	1,135,000
TN Cost[4,8]	$/lb N	17.4	17.2	16.8	19.1
TP Removal					
Capital[2,5]	$ Mil	11	11	210	210
Annual O&M[5]	$ Mil/yr	0.1	0.1	2.0	4.7
O&M PV[3,5]	$ Mil	3	3	45	105
Total PV[3,5]	$ Mil	14	14	255	314
TP Removed (Ave.)[6]	lb P/d	180	190	220	260
Annual TP Removed (Ave.)[7]	lb P/yr	66,000	68,600	80,200	96,700
TP Cost[5,8]	$/lb P	7	7	106	108

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only. Level 3 costs include membrane costs, which are also needed for nitrogen removal, since filtration is required for Level 3.
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.
10. Design flow shown for year round is the wet season average influent flow.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Ability to reliably remove TN and TP • Wet weather mode to handle high peak flows • Effluent will be suitable for reuse	• Increased operation costs associated with polymer and ferric addition for wet weather treatment • Increased energy demand for aeration and membranes • Dependency on chemicals
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with carbon and ferric addition

7 Nutrient Removal by Other Means

The San Mateo WWTP does not currently produce recycled water. Upgrades (in design phase) will produce Title 22 unrestricted water, with plan to ultimately reuse all dry weather flow. The City is interested in finding a reuse partner for the high quality MBR effluent, and timing of reuse has not been determined.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

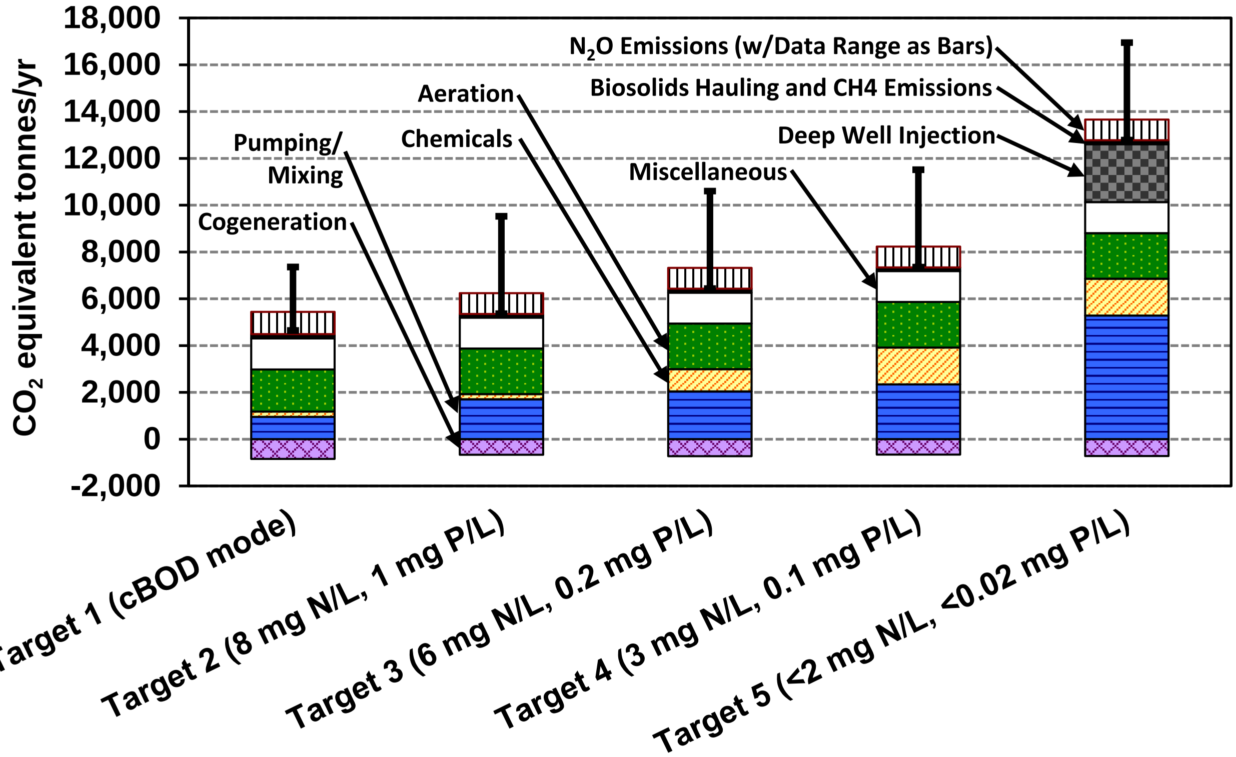

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	--*	--*	7,500	7,800	7,500	7,800	72
GHG Emissions Increase from Chemicals	MT CO_2/yr	--*	--*	0	0	4,400	9,500	2
GHG Emissions Increase Total	MT CO_2/yr	--*	--*	7,500	7,800	11,900	17,400	75
Unit GHG Emissions[1]	lb CO_2/MG	--*	--*	2,800	3,000	4,500	6,500	41
Unit GHGs for Ammonia Removal[1,2,5]	lb GHG/lb N	--*	--*	16	16	16	16	--**
Unit GHGs for Total N Removal[1,2]	lb GHG/lb N	--*	--*	19	19	26	33	1.8
Unit GHGs for Total P Removal[1,3,5]	lb GHG/lb P	--*	--*	3	3	138	114	--**

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only. Level 3 costs include membrane costs, since filtration is required for Level 3.

* No optimizations were identified since plant is upgrading to nutrient removal.

** The plant upgrades will fully nitrify and remove TP at the end of construction so sidestream treatment would not further reduce ammonia and/or TP discharge loads

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the San Mateo WWTP. These are:

- Nitrite Shunt – San Mateo WWTP aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Simultaneous nitrification/denitrification (SND) – San Mateo WWTP aeration basins would be operated at low dissolved oxygen (DO) levels to promote SND. Under this operating scenario, nitrification and denitrification occurs in the same tankage and dedicated anoxic zones are not necessary. As a result, there is a significant reduction in aeration requirements. This requires the installations of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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Sausalito-Marin City Sanitary District

Bay Area Clean Water Agencies
Nutrient Reduction Study

Sausalito-Marin City Sanitary District

Sausalito, CA

June 15, 2018
Final Report

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Executive Summary

The Sausalito-Marin City Sanitary District (SMCSD) Wastewater Treatment Plant (WWTP) discharges to the Central San Francisco Bay. It is located at 1 East Road, Sausalito, CA 94965, and it serves approximately 6,500 service connections throughout the City of Sausalito, unincorporated Marin City, Tamalpais Community Service District, and the Golden Gate National Recreation Area (National Park Service). The plant has an average dry weather flow (ADWF) permitted capacity of 1.8 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	1.4	1.6	1.8	2.1	1.8	2.1	--
Flow to Bay[2]	mgd	1.3	1.3	1.3	1.3	1.5	1.5	1.5	1.5	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	110	110	90	80	30	30	30	30	100
TN	lb N/d	310	310	330	330	210	190	150	80	340
TP	lb P/d	44	44	26	25	14	13	10	4	50
Costs[4,5]										
Capital	$ Mil	--	--	0.8	0.8	45	46	47	48	0.7
O&M PV	$ Mil	--	--	0.6	0.7	26	28	29	32	0.3
Total PV	$ Mil	--	--	1.4	1.5	71	74	76	80	1.0
Unit Costs[6]										
Capital	$/gpd	--	--	0.6	0.5	25	22	26	23	--
Total PV	$/gpd	--	--	1.0	1.0	39	35	42	39	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Expand the ferric chloride chemical feed facilities at the influent and increase the dosing to operate in chemically enhanced primary treatment (CEPT) mode for reducing total phosphorus discharge loads.
2. Add polymer chemical feed facilities in the primaries to operate in CEPT mode to enhance solids capture to increase downstream capacity for ammonia load reduction.
3. Increase the fixed film reactor internal recirculation rate to enhance ammonia load reduction.

The SMCSD WWTP is considered a potential candidate for sidestream treatment. Deammonification is the recommended sidestream treatment technology to reduce ammonia and total nitrogen loads.

The upgrade strategies to achieve Levels 2 and 3 include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Similar to the optimization strategy, expand the ferric chloride facilities and add polymer chemical feed facilities to operate the primaries in CEPT mode to meet the total phosphorus discharge targets.
    b. Replace the fixed film reactors, secondary clarifiers, and filters with a membrane bioreactor (MBR) process.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus:
    b. Expand the MBR aeration basins.
    c. Add chemical feed facilities for an external carbon source to trim total nitrogen.
    d. Add metal salt/polymer chemical feed facilities upstream of the membrane tanks to trim total phosphorus.

As shown in Table ES-1, and as might be expected, the costs generally increase from optimization to sidestream treatment, and again to Level 2 and Level 3 upgrades, respectively. The costs generally increase for both capital and O&M from the dry season to year round. Overall the present value costs range from $1.4 Mil for dry season optimization up to $80 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Sausalito-Marin City Sanitary District (SMCSD) Wastewater Treatment Plant (WWTP) discharges to the Central San Francisco Bay. It is located at 1 East Road, Sausalito, CA 94965, and it serves approximately 6,500 service connections throughout the City of Sausalito, unincorporated Marin City, Tamalpais Community Service District, and the Golden Gate National Recreation Area (National Park Service). The plant has an average dry weather flow (ADWF) permitted capacity of 1.8 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The SMCSD WWTP holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2012-0083; CA0038067. Table 2-1 provides a summary of the permit limitations but is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2015-0013; CA0038024)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	1.8	--	--	--
BOD	mg/L	--	25	40	--
TSS	mg/L	--	30	45	--
Total Ammonia, as N	mg/L	--	180	--	380

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the existing process flow diagram for the SMCSD WWTP. Both liquids processes and solids processes are shown. Treatment consists of primary clarification, biological treatment through fixed-film reactors, secondary clarification, filtration (up to 1 mgd of flow), disinfection with chlorine and de-chlorination. The fixed-film reactors remove a portion of the ammonia load. Solids treatment consists of co-thickening in the primaries, anaerobic digestion and mechanical dewatering using a screw press.

2.3 Existing Flows and Loads

A data request was submitted to each facility included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the SMCSD WWTP is shown in Table 2-2.

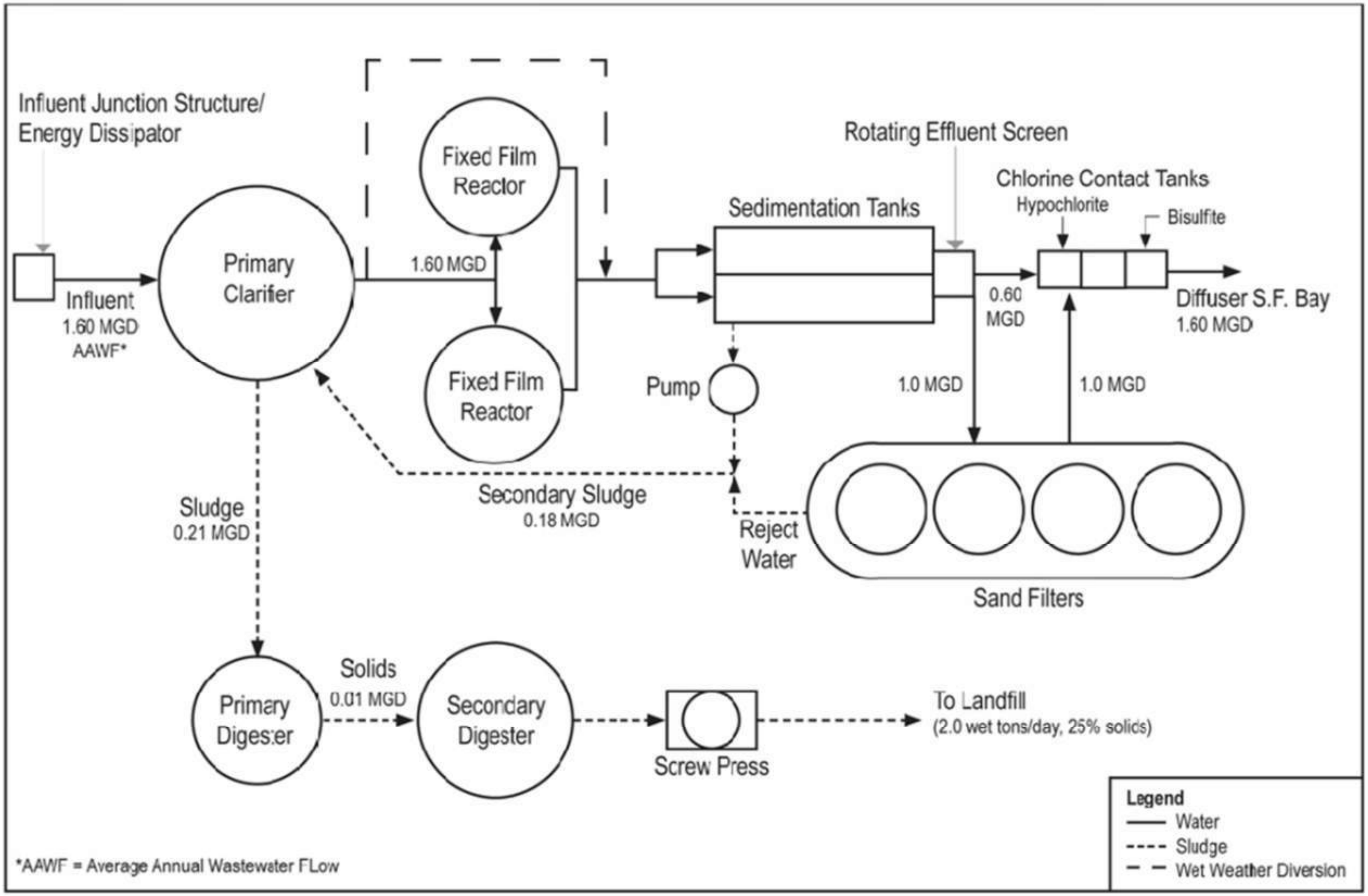

Figure 2-1 Process Flow Diagram for the SMCSD WWTP

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.4	1.5	1.4	2.3
BOD	lb/d	2,700	2,600	3,200	3,900
TSS	lb/d	5,000	4,400	5,700	6,700
Ammonia	lb N/d	300	300	300	300
Total Kjeldahl Nitrogen (TKN)	lb N/d	500	500	500	600
Total Phosphorus (TP)	lb P/d	50	60	70	70
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	234	206	266	201
TSS	mg/L	434	349	474	345
Ammonia	mg N/L	26	24	25	15
TKN	mg N/L	43	40	42	31
TP	mg P/L	4.3	4.8	5.8	3.6
Alkalinity	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

The SMCSD is already removing a portion of the influent ammonia load. The WWTP has several on-going projects (scheduled to be completed in 2019) with five components that will impact nutrient removal:

1. Providing 0.6 MG of flow equalization for storing primary effluent. This will stabilize flows to the secondary treatment train, providing more consistent performance and capacity.
2. A new primary clarifier is being added.
3. The fixed film reactors will have their media replaced.
4. The fixed film reactor feed pumping capacity will increase from 6 to 9 mgd firm.
5. The plant is adding filtration capacity by replacing the continuous sand backwash filters with cloth media filters.

The SMCSD is proposing to study a pilot/small-scale recycled water filling station with an estimated capacity of 10,000 to 15,000 gallons per day.

2.5 Pilot Testing

The SMCSD has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for the SMCSD WWTP are presented in Table 3-1. The projected flow and load for 2025 was not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30) [1,3]	Year Round MM[1,3]
Flow	mgd	1.4	1.5	1.4	2.3
BOD	lb/d	3,100	3,000	3,700	4,500
TSS	lb/d	5,800	5,100	6,600	7,700
Ammonia	lb N/d	340	340	340	340
TKN	lb N/d	600	600	600	700
TP	lb P/d	60	70	80	80
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	269	237	306	231
TSS	mg/L	499	401	545	397
Ammonia	mg N/L	30	28	29	17
TKN	mg N/L	49	46	48	36
TP	mg P/L	4.9	5.5	6.7	4.1
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by the SMCSD, it was determined that the WWTP is a candidate for sidestream treatment. Additional sampling for the sidestream was performed in July, 2015. The sampling results were projected forward to the permitted capacity. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows were used in the facility sizing.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-2. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Permitted Flow Capacity
Sidestream Flow	mgd	0.005	0.007
Ammonia	lb N/d	17	23
TKN	lb N/d	20	30
TN[1]	lb N/d	20	30
TP	lb P/d	2	2
OrthoP	lb P/d	1	2
Alkalinity	lb $CaCO_3$/d	50	70
Ammonia	mg N/L	410	410
TKN	mg N/L	490	490
TN[1]	mg N/L	490	490
TP	mg P/L	40	40
OrthoP	mg P/L	35	35
Alkalinity	mg/L as CaCO3	1,300	1,300

1. It was assumed that TN = TKN

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	1.8	2.0	1.9	3.0
BOD	lb/d	3,500	3,400	4,200	5,100
TSS	lb/d	6,500	5,700	7,400	8,700
Ammonia	lb N/d	400	400	400	400
TKN	lb N/d	600	700	700	800
TP	lb P/d	60	80	90	90
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	234	206	266	201
TSS	mg/L	434	349	474	345
Ammonia	mg N/L	26	24	25	15
TKN	mg N/L	43	40	42	31
TP	mg P/L	4.3	4.8	5.8	3.6
Alkalinity	mg/L as CaCO3	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy.

Several optimization strategies were identified during the SMCSD WWTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The optimization strategies were screened down to two strategies as follows.

- **Optimization Strategy 1:** Expand the existing ferric chloride chemical feed facilities and add polymer chemical feed facilities at the primary clarifiers to operate in chemically enhanced primary treatment (CEPT) mode. The existing ferric chloride chemical feed facilities do not have sufficient capacity for CEPT. At most plants, CEPT has been shown to remove phosphorus and increases the TSS and BOD capture at the primaries.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Phosphorus removal would be enhanced while likely reducing loading to the downstream unit processes. The ferric chloride should precipitate solids and remove total phosphorus, whereas the polymer should enhance capture of colloidal material to increase downstream capacity for nutrient load reduction.
  - ***Result from analysis:*** It should remove phosphorus at the primaries and increase downstream capacity. However, it also should remove more carbon than desired which may negatively impact the ability to denitrify downstream (if required in the future). The extent of this impact would require more detailed analysis.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Enhance nitrification by increasing the internal recirculation rate at the fixed film reactors. Use an ammonia probe in the sedimentation tanks to evaluate the optimal internal recirculation rates for increased nitrification. Further evaluation would be needed to determine if this would increase nitrite levels due to partial nitrification. An increase in nitrite would increase chlorine demand.
  - ***Is it feasible?*** Yes, it is possible with the fixed film reactor pumping station expansion.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Could improve ammonia removal performance.
  - ***Result from analysis:*** Improvement is marginal at best. Increasing the internal recirculation rate is recommended. An ammonia probe could be used as a tool to inform operators on performance.
  - ***Recommendation:*** Carry forward. Increasing the internal recirculation rate is recommended. An ammonia probe is not necessary but would be useful for informing operators.

Optimizing the primaries to operate in CEPT mode (Strategy 1) should remove total phosphorus loads in the primaries while increasing the downstream capacity for potential ammonia and total nitrogen load reduction. Increasing the FFRs internal recirculation (Strategy 2) should enhance ammonia load reduction. Any ammonia nitrified to nitrate in secondary sludge might be denitrified during co-thickening in the primaries (credit not taken as it is unclear on the extent of denitrification that would occur). The recommended strategies are shown with the process flow diagram presented in Figure 4-1. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Ferric Chloride Dosing Optimization at the Primaries • Expand the existing chemical feed facilities	• Operate the ferric chemical feed facilities to optimize P removal
Add Polymer Chemical Feed Facilities to the Primaries • Add the chemical feed facilities	• Operate the polymer chemical feed facilities to maximize solids/organics capture in the primaries
Increase the FFR Internal Recirculation Rate • None	• Increase the pumping rate

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	110	110	330	330	48	48
Discharge with Opt. Strategy[1]	lb N or P/d	90	80	330	330	26	25
Load Reduction[2]	lb N or P/d	30	30	0	0	21	23
Load Reduction[2]	%	25%	30%	0%	0%	45%	48%
Annual Load Reduction	lb N or P/yr	10,600	12,600	0	0	7,800	8,400

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

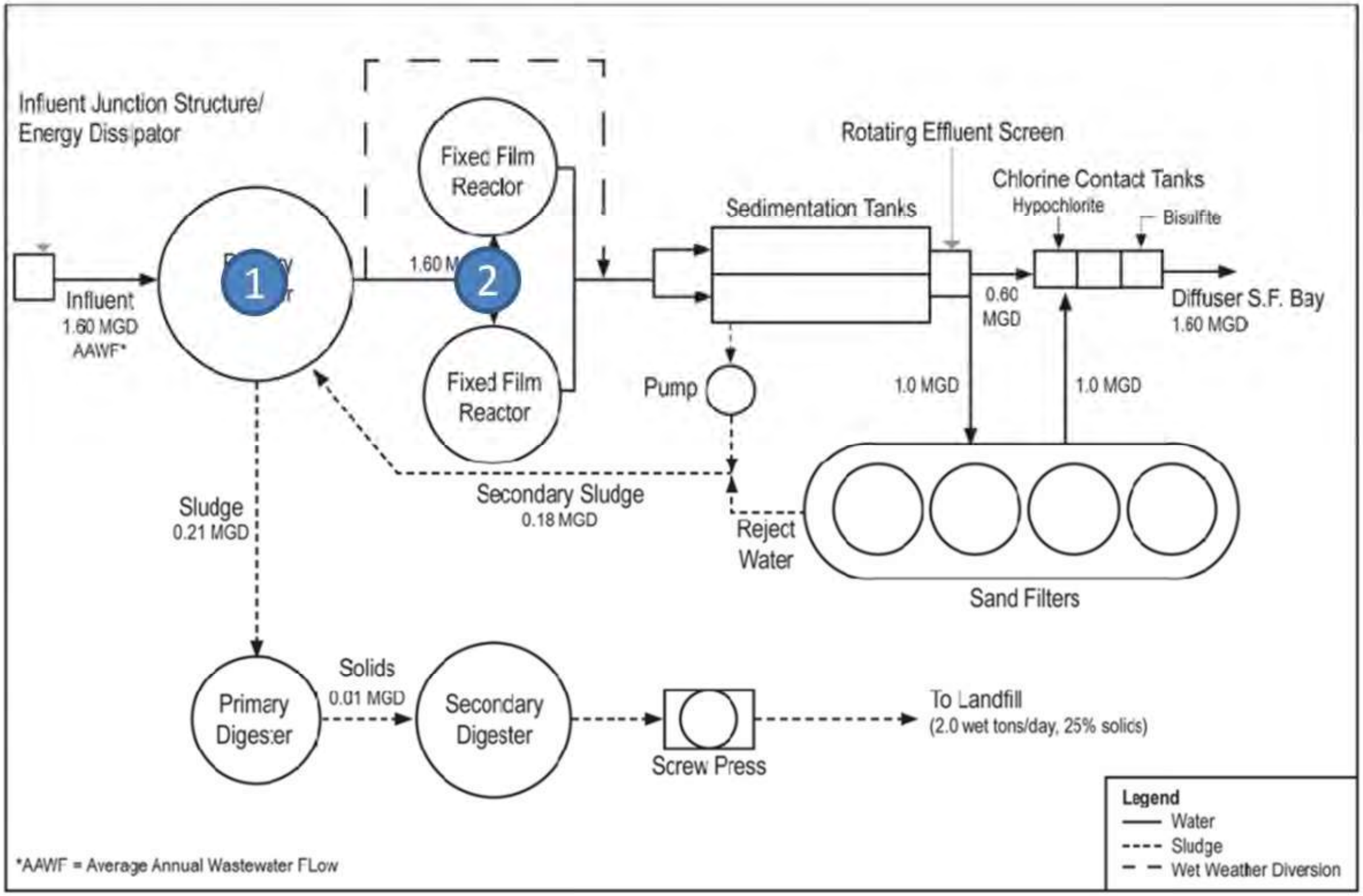

Figure 4-1. Optimization Concept Considered for the SMCSD WWTP

(1) Expand the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode and (2) increase the fixed film reactor internal recirculation rate

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	1.4	1.6
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.8	0.8
Annual O&M	$ Mil/yr	0.07	0.08
Present Value O&M[3]	$ Mil	0.6	0.7
Present Value Total[3]	$ Mil	1.4	1.5
Unit Capital Cost[8]	$/gpd	0.6	0.5
Unit Total PV Cost[8]	$/gpd	1.0	1.0
TN Removal			
Capital[2,4]	$ Mil	0.4	0.4
Annual O&M[4]	$ Mil/yr	0.04	0.05
O&M PV[3,4]	$ Mil	0.3	0.4
Total PV[3,4]	$ Mil	0.7	0.8
TN Removed (Ave.)[6]	lb N/d	0*	0*
Annual TN Removed (Ave.)[7]	lb N/yr	0*	0*
TN Cost[4,9]	$/lb N	--*	--*
TP Removal			
Capital[2,5]	$ Mil	0.8	0.8
Annual O&M[5]	$ Mil/yr	0.05	0.06
O&M PV[3,5]	$ Mil	0.5	0.5
Total PV[3,5]	$ Mil	1.3	1.4
TP Removed (Ave.)[6]	lb P/d	21	23
Annual TP Removed (Ave.)[7]	lb P/yr	7,800	8,400
TP Cost[5,9]	$/lb P	16	16

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

* No credit was taken on total nitrogen load reduction for optimization as it is unclear if any load reduction would actually occur.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at the SMCSD WWTP.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
Expand ferric chloride chemical feed facilities • Ability to reduce phosphorus discharge loads • Additional potential capacity for the primaries • Additional capacity for the downstream unit processes. This capacity will enhance ammonia and potentially total nitrogen load reduction.	• Additional chemical handling • More solids in the liquid stream process to handle
Add polymer chemical feed facilities • Additional potential capacity for the primaries • Additional capacity for the downstream unit processes. This capacity will enhance ammonia and potentially total nitrogen load reduction.	• Additional chemical handling • More solids in the liquid stream process to handle
Increase the FFR Internal Recirculation Rate • Ability to reduce ammonia and potentially total nitrogen loads	• Additional pumping • Forfeit a portion of the FFR capacity

5 Sidestream Treatment

As previously described, the SMCSD WWTP was identified as a potential candidate for sidestream treatment.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia and total nitrogen load reduction. TP load reduction is not recommended as the sidestream contribution to plant discharge is negligible.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification) including requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requires 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for the WWTP.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements*
Feed Pumping (if necessary)	--
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

* Sidestream treatment for TP discharge load reduction not recommended for the SMCSD WWTP.

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)[4]
Current Discharge[1]	lb/d	120	360	51
Discharge with Sidestream Treatment[2]	lb/d	100	340	51
Load Reduction[3]	lb/d	20	20	0[4]
Load Reduction	%	15%	5%	0%
Annual Load Reduction	lb/yr	6,680	5,950	0[4]

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	0.7	--[7]
Annual O&M	$ Mil/yr	0.01	--[7]
Total Present Value[2]	$ Mil	1.0	--[7]
NH4-N Load Reduction[3,5]	lb N/yr	6,680	--
TN Load Reduction[3,5]	lb N/yr	5,950	--
TP Load Reduction[4,5]	lb P/yr	--	--[7]
NH4-N Cost [3,5,6]	$/lb N	5.0	--
TN Cost [3,5,6]	$/lb N	5.6	--
TP Cost [4,5,6]	$/lb P	--	--[7]

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the SMCSD WWTP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. SMCSD should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under the Optimization Section. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, the ferric chloride chemical feed facilities would be expanded and polymer chemical feed facilities added (CEPT) to increase phosphorus, TSS, and BOD removal. For N removal, and to accommodate site limitations, the existing FFRs, secondary clarifiers, and filters would be replaced with MBRs. Phasing would be needed over two summer seasons to allow replacement of each FFR while the other remains in service to treat dry season flows. This approach strands the new FFR and filter assets recently installed.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would build upon those listed for Level 2.

In addition to those listed for Level 2, Level 3 upgrades require additional MBR (aeration/anoxic) volume, an external carbon source chemical feed facility, and alum/polymer chemical feed facilities at the MBR. The basin expansion is to allow an additional anoxic and oxic zone to trim the TN load down to the target. The external carbon source is provided to meet the carbon requirements for meeting the TN discharge target. The chemical feed facilities step prior to the MBR is in place to remove solids loading associated with chemical precipitation upstream of the MBR. The additional chemical feed facilities would operate on a daily basis to meet the TP discharge target.

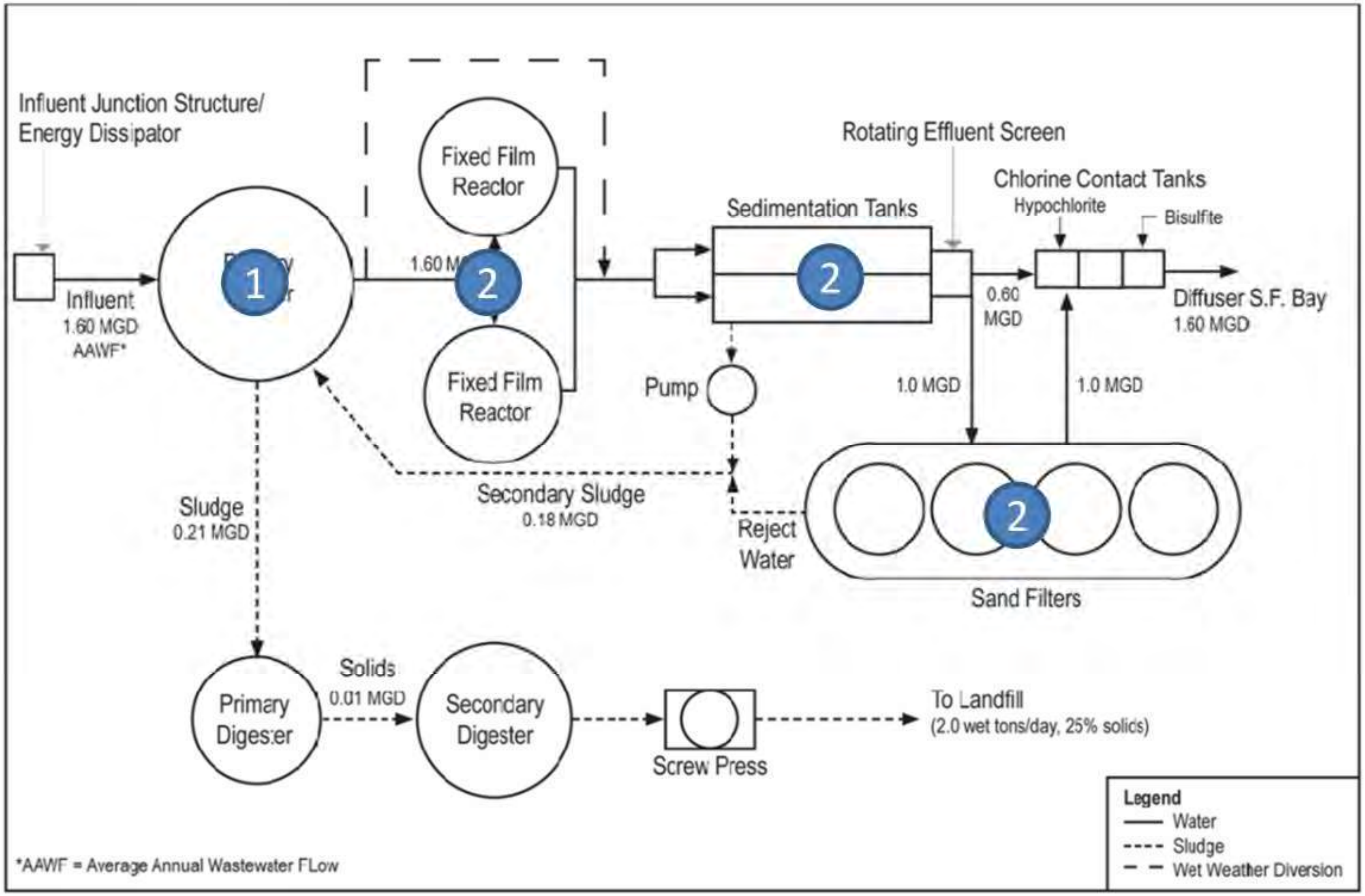

Figure 6-1. Level 2 Upgrade Concepts for the SMCSD WWTP

(1) Expand the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (2) Replace fixed film reactors, sedimentation tanks, and filters with an MBR

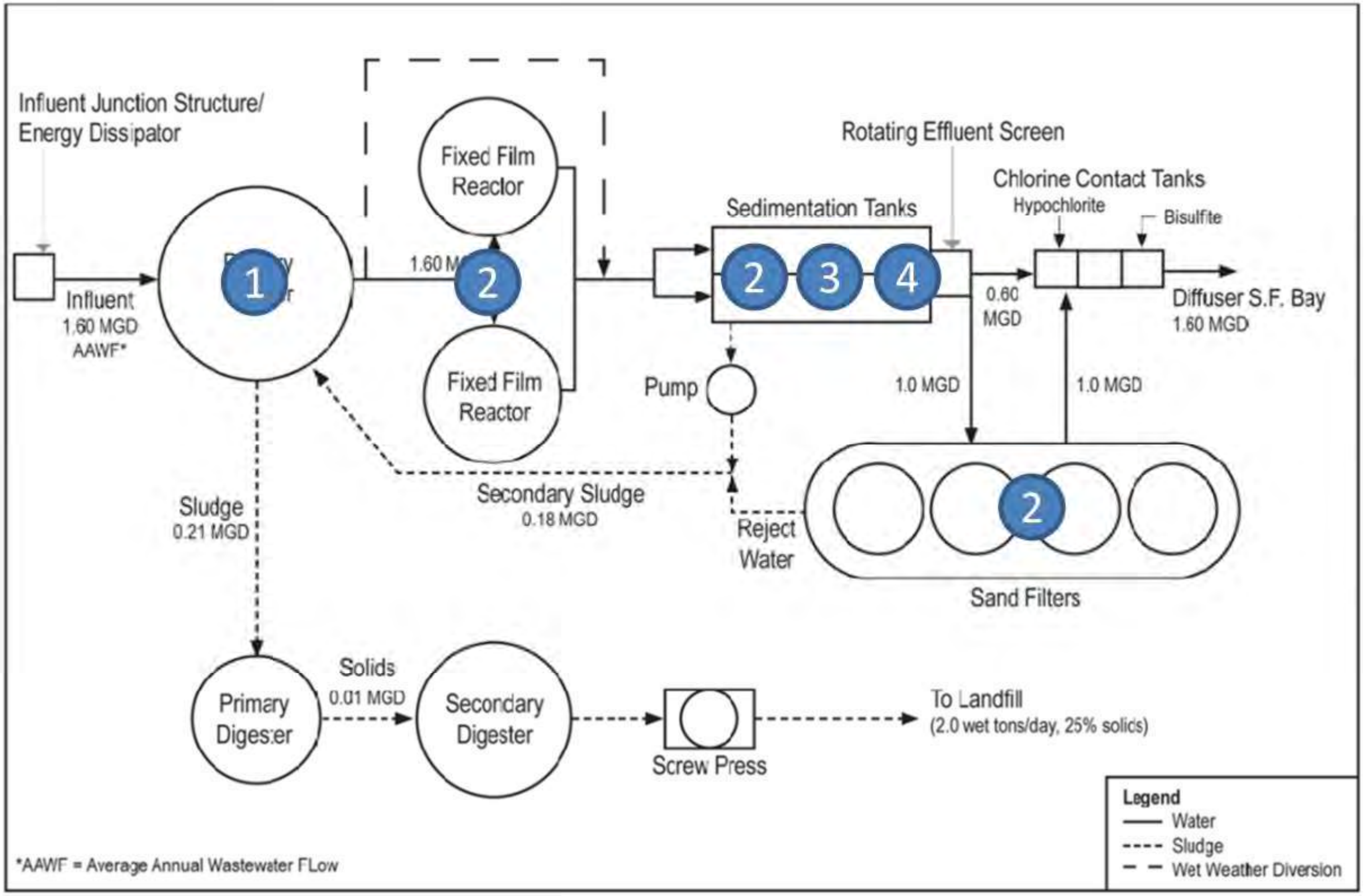

Figure 6-2. Level 3 Upgrade Concepts for the SMCSD WWTP

(1) Expand the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (2) Replace fixed film reactors, sedimentation tanks, and filters with an MBR, (3) add an external carbon source chemical feed facilities, (4) add a metal salt/polymer chemical feed facilities

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent targets are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Expand the ferric chloride chemical feed facilities • Add polymer chemical feed facilities	Same as Level 2
Biological	• Replace the FFRs, secondaries, and filters with an MBR facility: o New aeration basins o New Membrane tanks o RAS/WAS pumping stations o New aeration system o Other MBR ancillary facilities	Same as Level 2, plus: • Expansion of MBR • External Carbon Source Chemical Feed Facility • Metal salt/polymer chemical feed facilities

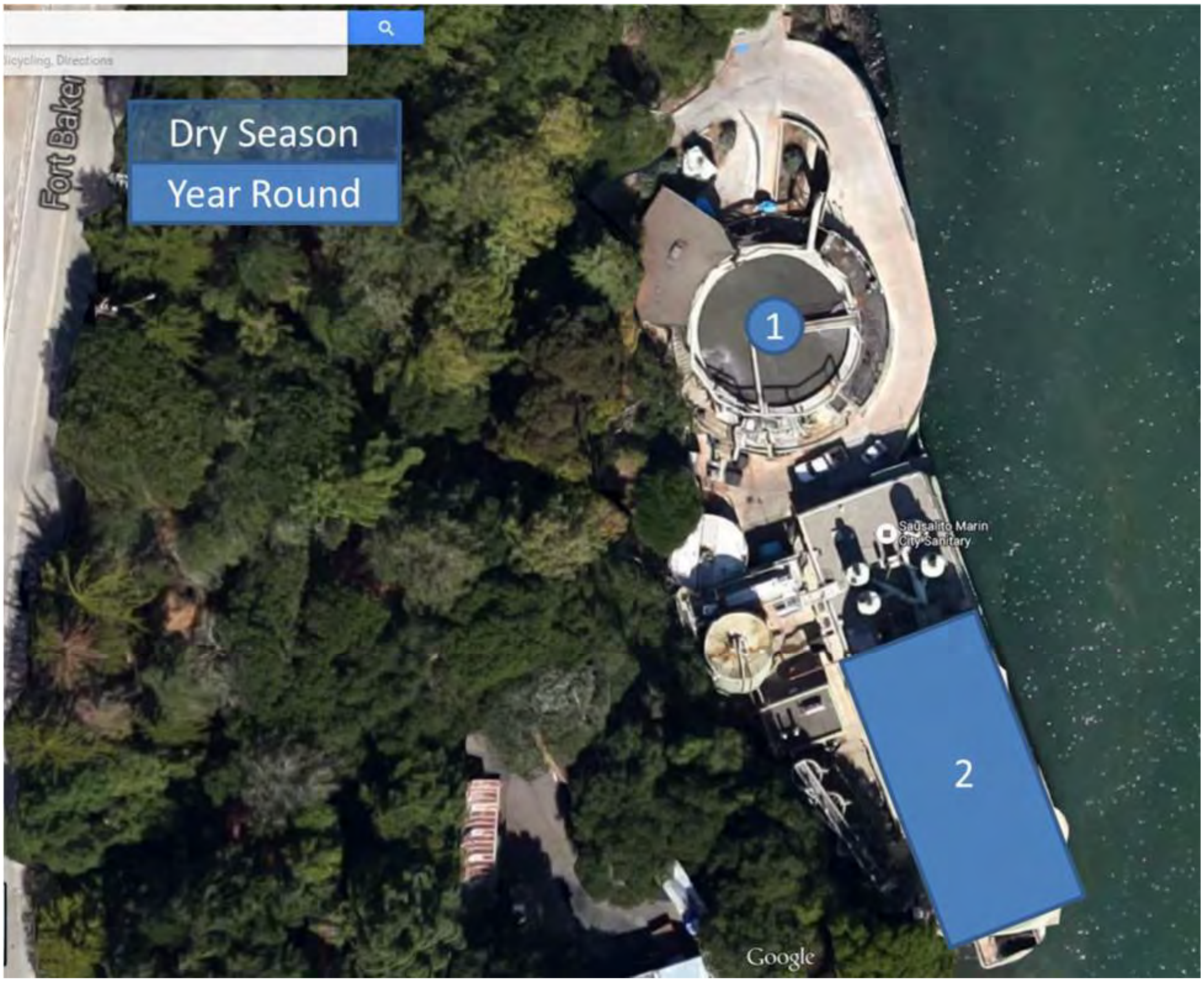

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Expand the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (2) Replace fixed film reactors, sedimentation tanks, and filters with an MBR

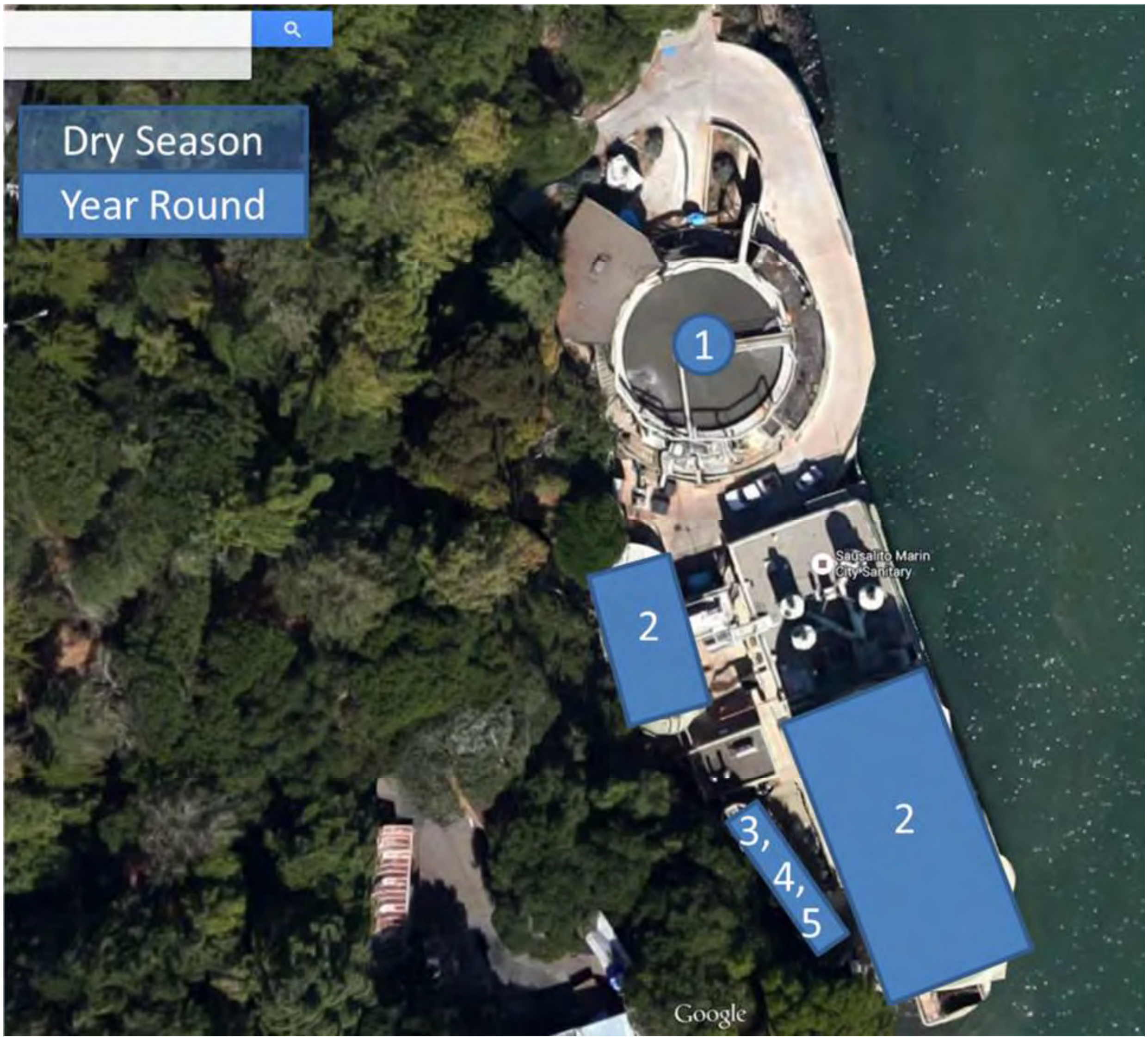

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Expand the ferric chloride and add new polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (2) Replace fixed film reactors, sedimentation tanks, and filters with an MBR, (3) add an external carbon source chemical feed facilities, (4) add a metal salt/polymer chemical feed facilities

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	1.8	2.1	1.8	2.1
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	45	46	47	48
Annual O&M	$Mil/yr	1.1	1.2	1.3	1.4
O&M PV[3]	$ Mil	26	28	29	32
Total PV[3]	$ Mil	71	74	76	80
Unit Capital Cost	$/gpd	25	22	26	23
Unit Total PV	$/gpd	39	35	42	39
TN Removal					
Capital[2,4]	$ Mil	44	46	46	47
Annual O&M[4]	$ Mil/yr	1.1	1.2	1.3	1.4
O&M PV[3,4]	$ Mil	25	27	28	31
Total PV[3,4]	$ Mil	69	73	74	78
TN Removed (Ave.)[6]	lb N/d	150	160	200	280
Annual TN Removed (Ave.)[7]	lb N/yr	55,000	60,000	75,000	102,000
TN Cost[4,8]	$/lb N	42	41	33	26
TP Removal					
Capital[2,5]	$ Mil	22	23	23	23
Annual O&M[5]	$ Mil/yr	0.7	0.7	0.7	0.7
O&M PV[3,5]	$ Mil	15	16	16	17
Total PV[3,5]	$ Mil	37	39	39	40
TP Removed (Ave.)[6]	lb P/d	40	40	40	50
Annual TP Removed (Ave.)[7]	lb P/yr	13,700	14,000	15,200	17,300
TP Cost[5,8]	$/lb P	89	91	85	77

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Better phosphorus and nitrogen removal • Increased chemicals of emerging concern (CECs) removal • High quality product water amenable to recycled water • MBR has a compact footprint compared to existing secondary treatment	• Additional chemicals from CEPT • Increase energy demand from the MBR • Safety from external carbon source • Operate in a new process that will require the operators to get accustomed to
Level 3	Same as Level 2	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2

7 Nutrient Load Reduction by Other Means

The SMCSD WWTP does not currently employ a recycled water program. There are plans to implement a recycled water program by 2025 to recycle approximately 0.05 acre-feet per year (16,000 gallons per year). A recycled water program will have the effect of reducing nutrients discharged to the Bay.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

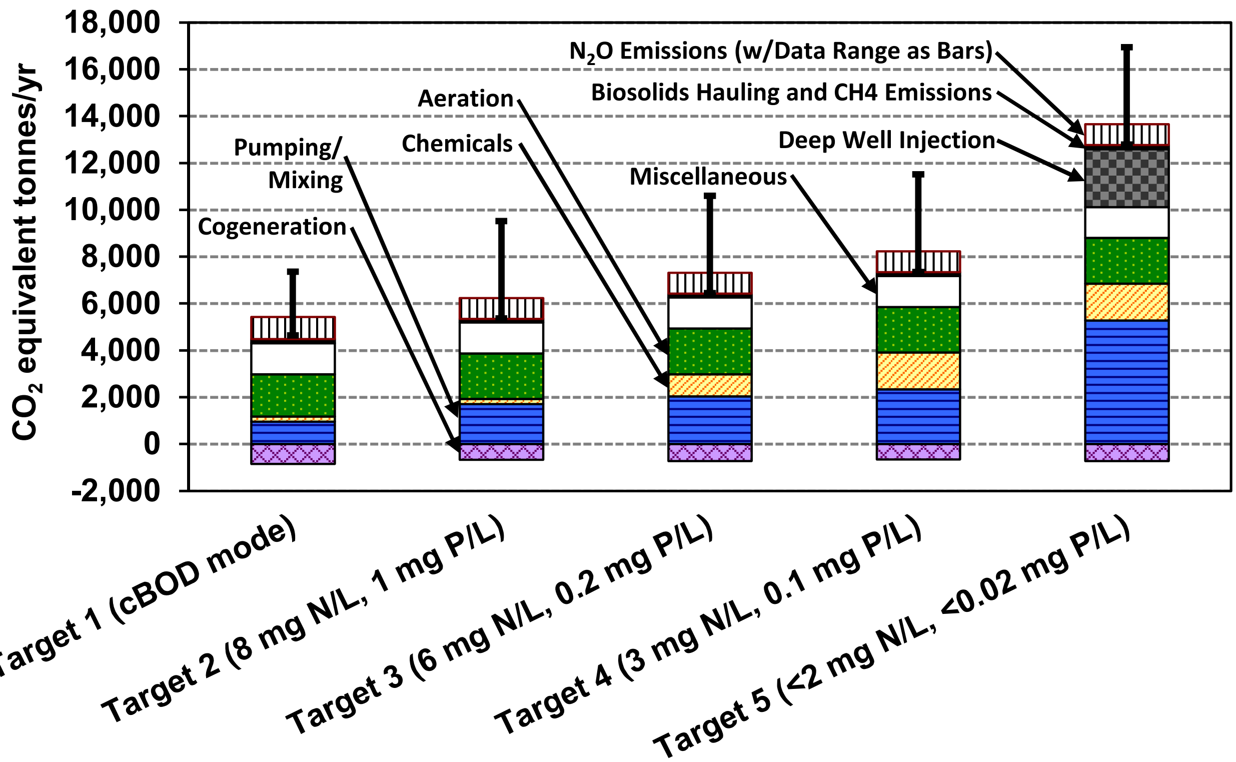

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	49	49	610	620	650	660	2
GHG Emissions Increase from Chemicals	MT CO_2/yr	6	7	10	10	90	100	1
GHG Emissions Increase Total	MT CO_2/yr	55	55	620	630	740	760	3
Unit GHG Emissions[2]	lb CO_2/MG	220	220	1,900	1,900	2,300	2,300	14
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	10	8	40	40	40	40	1
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	25	23	21	16	1
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	4	4	57	57	52	47	--**

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

* No credit was taken on total nitrogen load reduction for optimization as it is unclear if any load reduction would actually occur.

** Sidestream treatment for TP discharge load reduction not recommended as previously discussed.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the SMCSD WWTP:

- Granular Activated Sludge – this could be used to phase out the FFRs and sedimentation tanks. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Emerging Membrane Bioreactor (MBR) – the report considered established MBR technologies. There are emerging MBR technologies (e.g., FibrePlate™) that provide an even more compact footprint than established MBR technologies. The footprint savings relates to less required membrane area. Such a membrane savings results in a reduced unit energy demand for air scour compared to established MBR technologies. The benefit to the WWTP is it has the potential to further save footprint with a reduced energy demand with respect to established MBR technologies. While there are limited installations in North America of such MBR technologies, several plants are evaluating such technologies for upcoming designs.
  - Advantages: Low footprint requirements, more energy efficient than established MBR technologies, high quality product water amenable to reuse, ability to remove ammonia, TN, and TP.
  - Disadvantages: Limited installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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Sewerage Agency of Southern Marin

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Bay Area Clean Water Agencies
Nutrient Reduction Study

Sewerage Agency of Southern Marin

Mill Valley, CA

April 25, 2018
Final Report

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Executive Summary

The Sewerage Agency of Southern Marin (SASM) Wastewater Treatment Plant (WWTP) discharges to the Central San Francisco Bay. It is located at 450 Sycamore Avenue, Mill Valley, CA 94941, and it serves approximately 14,800 service connections throughout the Southern Marin Service Areas. The plant provides secondary treatment of domestic wastewater for its six member agencies: the City of Mill Valley, Almonte Sanitary District, Alto Sanitary District, Homestead Valley Sanitary District, Richardson Bay Sanitary District, and the Kay Park Area of the Tamalpais Community Services District. The plant has an average dry weather flow (ADWF) permitted capacity of 3.6 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions*

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3,**]	Level 2 Year Round[3,**]	Level 3 Dry Season[3,**]	Level 3 Year Round[3,**]	Side-stream
Design Flow	mgd	--	--	2.2	2.9	3.6	4.8	3.6	4.8	--
Flow to Bay[2]	mgd	2.4	2.4	2.4	2.4	3.2	3.2	3.2	3.2	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	100	100	70	60	60	50	60	50	--
TN	lb N/d	490	490	530	530	440	410	330	160	--
TP	lb P/d	100	100	50	50	30	30	20	10	--
Costs[4,5]										
Capital	$ Mil	--	--	0.6	0.7	27	32	37	48	--
O&M PV	$ Mil	--	--	--***	0.1	6	7	8	12	--
Total PV	$ Mil	--	--	0.6	0.8	33	38	45	60	--
Unit Costs[6]										
Capital	$/gpd	--	--	0.3	0.2	8	7	10	10	--
Total PV	$/gpd	--	--	0.3	0.3	9	8	13	12	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

* The plant is in the early stages of 2-year capital improvement projects which will improve plant performance. The strategies from this effort should be re-evaluated and baseline conditions updated to reflect the results from the on-going capital improvement projects.

** The presented upgrades equipment siting locations is on private property that would need to be acquired for implementation (cost not included). There is a chance the land would not be available to acquire, in which case the recommendations would no longer be feasible.

***The O&M costs are anticipated to be similar to current.

SASM is in the early stages of a 2-year WWTP capital improvement projects, the first major improvement projects at the plant in 36 years. The planned improvements are expected to improve effectiveness the treatment processes. Upon completion of the current project, the nutrient removal recommendations listed below should be re-evaluated and baseline conditions updated to reflect the results of the project.

Based on the current plant conditions, the recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Add metal salt and polymer chemical feed facilities to operate the primaries in chemically enhanced primary treatment (CEPT) mode. This strategy will reduce total phosphorus loads while increasing the downstream capacity for ammonia and/or total nitrogen load reduction.
2. Enhance nitrification in the trickling filters by increasing the internal recirculation.

Based on the current plant conditions, the SASM WWTP is not considered a candidate for sidestream treatment.

Based on the current plant conditions, the upgrade strategies to achieve Levels 2 and 3 include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Similar to the optimization, add metal salt and polymer chemical feed facilities to operate the primaries in CEPT mode for meeting the total phosphorus discharge targets.
   b. Add a new trickling filter and feed pumping station for reducing the ammonia load at permitted capacity.
   c. Add a denitrifying filter with a feed pumping station for reducing total nitrogen loads.
   d. Add an external carbon source at the denitrifying filters to facilitate denitrification.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Add metal salt/polymer chemical feed facilities upstream of the denitrifying filters to further reduce total phosphorus.

The upgrades equipment siting locations presented in the report is on private property that would need to be acquired for implementation. The cost for such land acquisition is not included in this effort. There is a chance the land would not be available to acquire, in which case the recommendations would no longer be feasible and need to be re-visited.

As shown in Table ES-1, and as might be expected, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season to year round. Overall the present value costs range from $0.6 Mil for dry season optimization up to $60 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Sewerage Agency of Southern Marin (SASM) Wastewater Treatment Plant (WWTP) discharges to Central San Francisco Bay. It is located at 450 Sycamore Avenue, Mill Valley, CA 94941, and it serves approximately 14,800 service connections throughout the Southern Marin Service Areas. It provides secondary treatment of domestic wastewater for its six member agencies: the City of Mill Valley, Almonte Sanitary District, Alto Sanitary District, Homestead Valley Sanitary District, Richardson Bay Sanitary District, and the Kay Park Area of the Tamalpais Community Services District. The plant has an average dry weather flow (ADWF) permitted capacity of 3.6 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The SASM WWTP holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2012-0094; CA0037711. Table 2-1 provides a summary of the permit limitations but is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2012-0094; CA0037711)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak Design Flow
Flow	mgd	3.6	--	--	--	24.7
BOD	mg/L	--	30	45	--	--
TSS	mg/L	--	30	45	--	--
Total Ammonia, as N	mg/L	--	12.3	--	32	--

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the existing process flow diagram for the SASM WWTP. Both liquids processes and solids processes are shown. Treatment processes consist of screening, grit removal, flow equalization, primary sedimentation, secondary treatment (trickling filters), secondary clarification, disinfection (chlorination), and dechlorination. Trickling filters provide partial ammonia removal. No major nutrient removal systems are currently in place.

Solids removed from the wastewater stream are treated by gravity thickening, primary and secondary digestion, and dewatering by belt filter press.

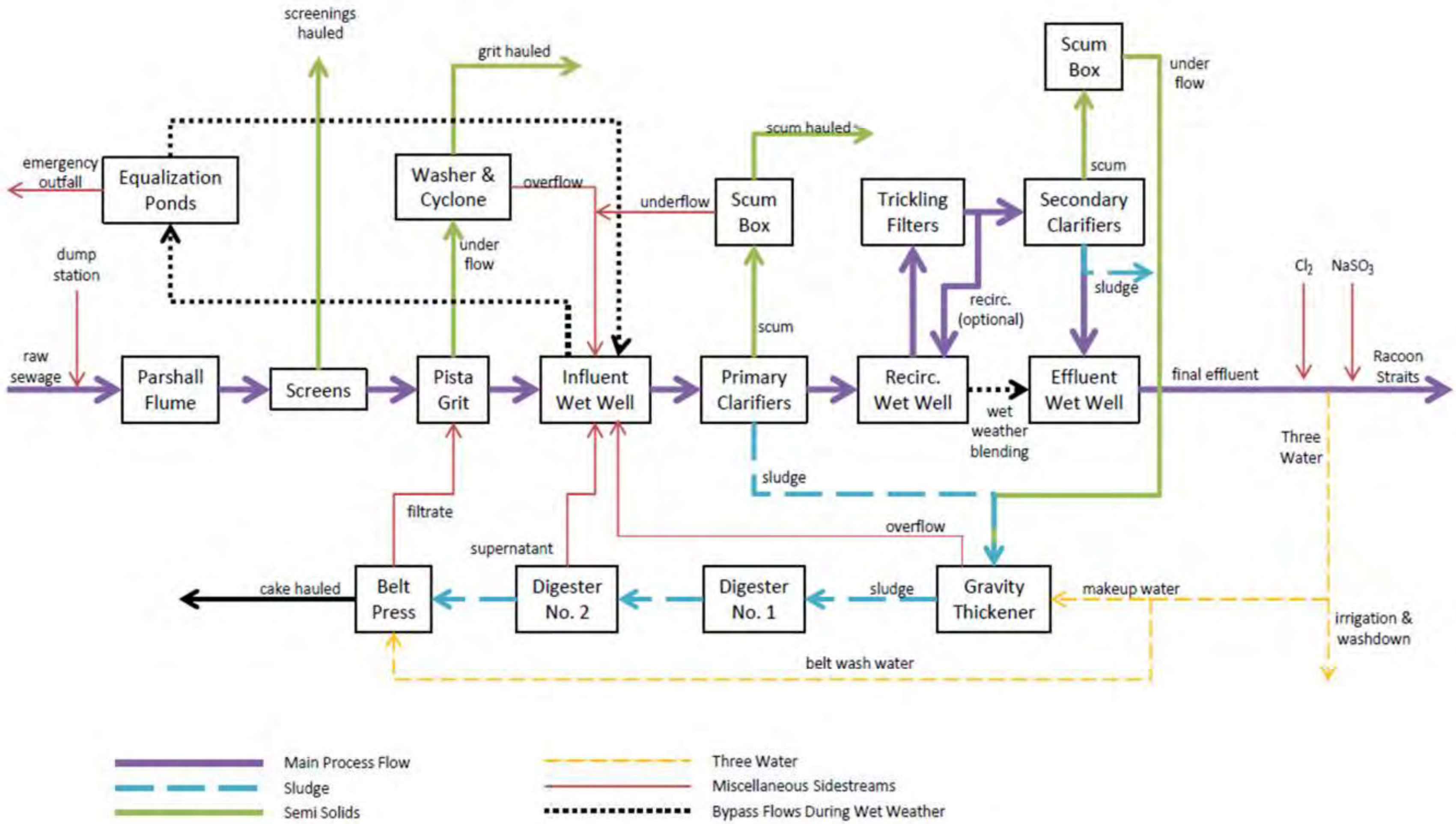

Figure 2-1 Process Flow Diagram for the SASM WWTP

2.3 Existing Flows and Loads

A data request was submitted to each facility included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the SASM WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.2	2.6	2.5	4.8
BOD	lb/d	4,500	5,100	5,900	6,700
TSS	lb/d	5,800	6,200	7,500	8,200
Ammonia	lb N/d	500	500	500	600
Total Kjeldahl Nitrogen (TKN)	lb N/d	800	900	800	1,000
Total Phosphorus (TP)	lb P/d	220	140	220	130
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	250	237	288	168
TSS	mg/L	322	288	366	206
Ammonia	mg N/L	28	23	24	15
TKN	mg N/L	44	42	39	25
TP	mg P/L	12.2	6.5	10.7	3.3
Alkalinity	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

The SASM WWTP is already nitrifying their influent ammonia load. Additionally, the SASM WWTP is planning to continue seasonal recycled water as a means to divert nutrient loads away from the Central Bay.

The planned 2018 to 2019 CIP elements that impact nutrient removal include the following:

- Bid alternate for primary clarifier rehabilitation (e.g., weir re-leveling).
- Bid alternate for full replacement of all trickling filter elements (except the foundation).
- Secondary clarifier improvements (e.g., recoat the mechanisms).
- Recirculation and effluent pumping station improvements. A portion of the elements are bid alternates.

These projects represent the first major improvement projects at the plant in 36 years. The planned improvements are expected to improve effectiveness the treatment processes. Upon completion of the current projects, the nutrient removal recommendations for the WWTP should be re-evaluated and baseline conditions updated to reflect the results of the project.

2.5 Pilot Testing

The SASM WWTP has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loads that formed the basis of the optimization analysis for the SASM WWTP are presented in Table 3-1. The projected flow and load for 2025 was not available; as a result, a 15 percent increase for loads was used for future projections with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.2	2.6	2.5	4.8
BOD	lb/d	5,200	5,900	6,800	7,700
TSS	lb/d	6,700	7,100	8,600	9,400
Ammonia	lb N/d	600	600	600	700
TKN	lb N/d	900	1,000	900	1,100
TP	lb P/d	250	160	250	150
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	288	273	331	193
TSS	mg/L	370	331	421	237
Ammonia	mg N/L	32	26	28	17
TKN	mg N/L	51	48	45	29
TP	mg P/L	14.0	7.5	12.3	3.8
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by the SASM WWTP, it was determined that the WWTP is not a candidate for sidestream treatment. The WWTP does not operate dewatering frequently enough (limited to approximately 1.5 days per week) to justify sidestream treatment.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	3.6	4.3	4.1	8.0
BOD	lb/d	7,500	8,500	9,800	11,200
TSS	lb/d	9,700	10,400	12,500	13,700
Ammonia	lb N/d	800	800	800	1,000
TKN	lb N/d	1,300	1,500	1,300	1,700
TP	lb P/d	370	230	370	220
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	250	237	288	168
TSS	mg/L	322	288	366	206
Ammonia	mg N/L	28	23	24	15
TKN	mg N/L	44	42	39	25
TP	mg P/L	12.2	6.5	10.7	3.3
Alkalinity	mg/L as CaCO3	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for, TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy. As previously stated, the existing plant treatment mode is in the early stages of 2-year capital improvement projects which should improve the plant treatment performance. Once completed, the listed optimization strategies should be re-evaluated and baseline conditions updated to reflect the results from the on-going capital improvement projects.

Several optimization strategies were identified during the SASM WWTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The optimization strategies were screened down to three strategies as follows.

- **Optimization Strategy 1:** Add metal salt and polymer chemical feed facilities to operate in chemically enhanced primary treatment (CEPT) mode. Ferric chloride is recommended as it will also assist with odor controls. They currently add ferric chloride at the end of the forcemain just before it enters the headworks. The current dosing is below the required dosing for CEPT so dedicated facilities at the WWTP were assumed. CEPT removes phosphorus and increases the TSS and BOD capture at the primaries.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Phosphorus removal would be enhanced while reducing loading to the downstream unit processes. The ferric chloride will precipitate solids and remove total phosphorus, whereas the polymer will enhance capture of colloidal material to increase downstream capacity for nutrient load reduction.
  - ***Result from analysis:*** It will remove phosphorus in the primaries and increase the downstream trickling filter capacity for more reliable ammonia load reduction.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Enhance nitrification in the trickling filters. The nitrification process can be enhanced by increasing the internal recirculation rate. Use an ammonia probe in the sedimentation tanks to evaluate the optimal internal recirculation rates for increased nitrification. Further evaluation would be needed to determine if this would increase nitrite levels due to partial nitrification. An increase in nitrite would increase chlorine demand.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Could improve the reliability of ammonia removal.
  - ***Result from analysis:*** Improvement is recognized during peak loading events.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 3:** Operate the trickling filters in series as a means to dedicate a trickling filter to operate as a nitrifying trickling filter. This mode should enhance the reliability of ammonia load reduction during peak loadings.
  - ***Is it feasible?*** Yes, but it will require replacing a frozen valve plus piping modifications that might negatively impact the hydraulic capacity.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Will improve the reliability for nitrification during peak loading events.
  - ***Result from analysis:*** Improvement is only recognized during peak loading events as the existing operating mode fully nitrifies during day to day conditions.
  - ***Recommendation:*** Do not carry forward as the load reduction potential is outweighed by the valve replacement and piping modifications.

Optimizing the primaries to operate in CEPT mode (Strategy 1) would remove total phosphorus loads in the primaries while increasing the downstream trickling filters capacity. Optimizing the trickling filter internal recirculation rate (Strategy 2) would enhance ammonia load reduction. The recommended strategies are shown with the process flow diagram presented in Figure 4-1. A description of the strategies and the evaluation results are presented thereafter. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Add Metal Salt and Polymer Chemical Feed Facilities to Operate in CEPT Mode • Metal salt chemical feed facilities • Polymer chemical feed facilities	• Operate the chemical feed facilities to optimize solids/organic capture and reduce P loading
Enhance Nitrification in the Trickling Filters by Optimizing the Internal Recirculation Rate • None; an ammonia probe could be added in the secondary clarifiers but it is not essential.	• Operate the trickling filters

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season[4]	NH4-N Year Round[4]	TN Dry Season[5]	TN Year Round[5]	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	110	110	530	530	100	100
Discharge with Opt. Strategy[1]	lb N or P/d	70	60	530	530	50	50
Load Reduction[2]	lb N or P/d	40	50	--*	--*	50	60
Load Reduction[2]	%	37%	42%	0%	0%	52%	54%
Annual Load Reduction	lb N or P/yr	14,600	16,500	0	0	19,800	20,500

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. The plant currently partially nitrifies.
5. The ammonia loads reduced as part of the optimization strategy does not reduce total nitrogen loads.

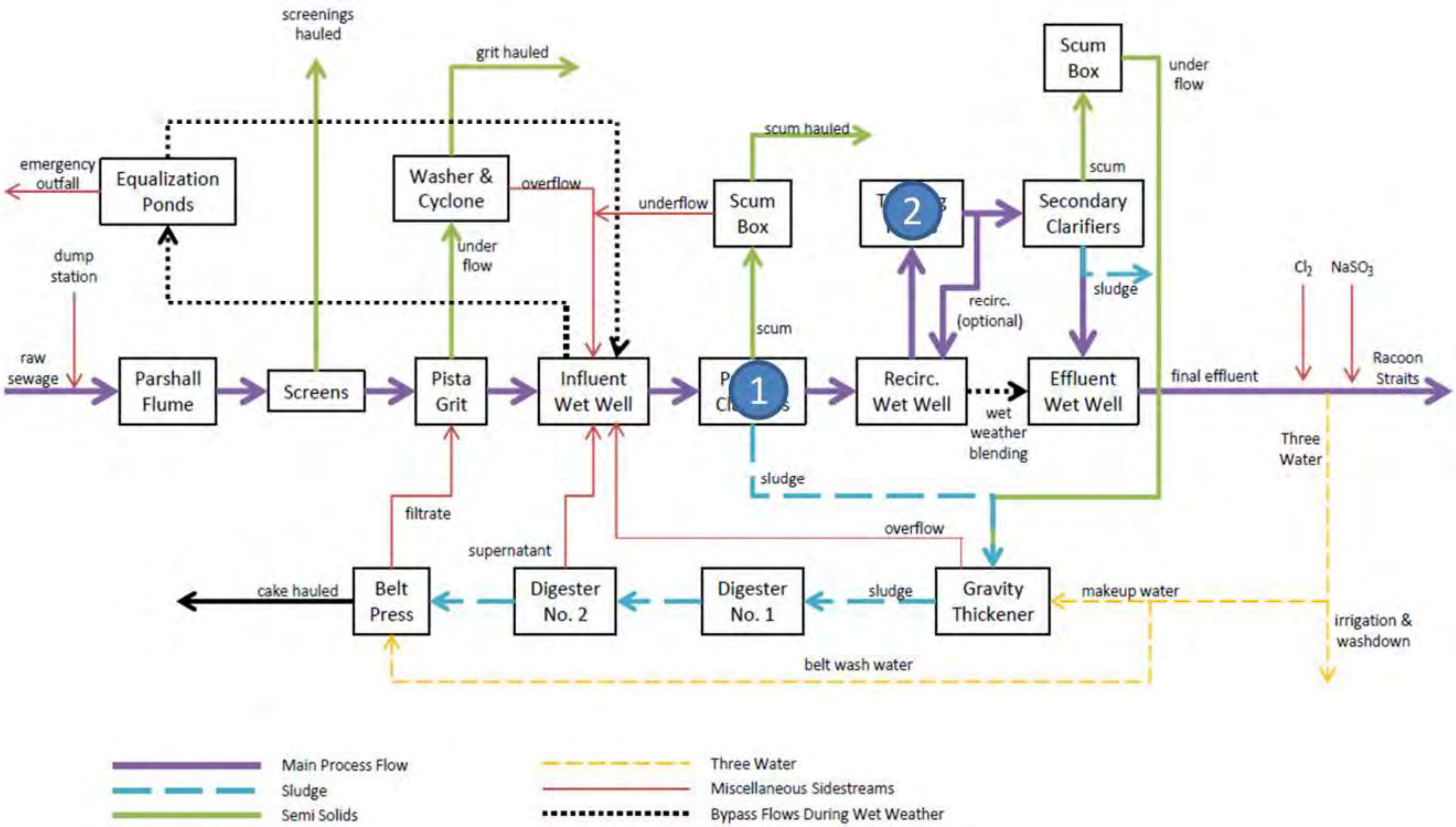

Figure 4-1. Optimization Concept Considered for the SASM WWTP

(1) Add metal salt and polymer chemical feed facilities to operate the primary clarifiers in CEPT mode and (2) enhance nitrification in the trickling filters by increasing the internal recirculation rate

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	2.2	2.9
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.6	0.7
Annual O&M	$ Mil/yr	--*	0.01
Present Value O&M[3]	$ Mil	--*	0.1
Present Value Total[3]	$ Mil	0.6	0.8
Unit Capital Cost[8]	$/gpd	0.3	0.2
Unit Total PV Cost[8]	$/gpd	0.3	0.3
TN Removal			
Capital[2,4]	$ Mil	0.6	0.7
Annual O&M[4]	$ Mil/yr	--*	0.01
O&M PV[3,4]	$ Mil	--*	0.1
Total PV[3,4]	$ Mil	0.6	0.8
TN Removed (Ave.)[6]	lb N/d	--**	--**
Annual TN Removed (Ave.)[7]	lb N/yr	--**	--**
TN Cost[4,9]	$/lb N	--**	--**
TP Removal			
Capital[2,5]	$ Mil	0.6	0.7
Annual O&M[5]	$ Mil/yr	--*	0.01
O&M PV[3,5]	$ Mil	--*	0.1
Total PV[3,5]	$ Mil	0.6	0.8
TP Removed (Ave.)[6]	lb P/d	54	56
Annual TP Removed (Ave.)[7]	lb P/yr	19,800	20,500
TP Cost[5,9]	$/lb P	3.2	3.9

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

* The O&M costs are anticipated to be similar to current.

** The optimization strategy will not reduce total nitrogen loads. Rather, it will improve the reliability and overall ammonia load reduction.

These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at the SASM WWTP.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
Add Metal Salt and Polymer Chemical Feed Facilities to Operate in CEPT Mode • Ability to reduce phosphorus discharge loads • Additional capacity in the primaries • Additional capacity for the downstream unit processes. This capacity will enhance ammonia and total nitrogen load reduction.	• Additional chemical handling • More solids in the liquid stream process to handle
Enhance Nitrification in the Trickling Filters by Optimizing the Internal Recirculation Rate • Increased reliability for ammonia load reduction • More robust biology to absorb load swings	• Additional pumping

5 Sidestream Treatment

As previously described, the SASM WWTP was not identified as a potential candidate for sidestream treatment.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the SASM WWTP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. SASM should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

As previously stated, the existing plant treatment mode is in the early stages of 2-year capital improvement projects which should improve the plant treatment performance. Once completed, the listed upgrade strategies should be re-evaluated and baseline conditions updated to reflect the results from the on-going capital improvement projects.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under the Optimization Section. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, the metal salt and polymer chemical feed facilities would be added to operate the primaries in CEPT mode. An additional trickling filter and feed pumping station would be added to provide sufficient capacity to nitrify permitted capacity loads. The nitrified trickling filter effluent would be followed by a denitrifying filter for total nitrogen load reduction. An external carbon source would be required at the denitrifying filters to facilitate denitrification.

The presented upgrades equipment siting locations is on private property that would need to be acquired for implementation. The cost for such land acquisition is not included in this effort. There is a chance the land would not be available to acquire, in which case the recommendations would no longer be feasible and need to be re-visited.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would build upon those listed for Level 2.

In addition to those listed for Level 2, Level 3 upgrades requires a metal salt and polymer chemical feed facilities at the denitrifying filters to further reduce the total phosphorus loads. The external carbon source dosing would be increased to further reduce the total nitrogen loads.

Similar to the Level 2 upgrades, the presented upgrades equipment siting locations is on private property that would need to be acquired for implementation. The cost for such land acquisition is not included in this effort. There is a chance the land would not be available to acquire, in which case the recommendations would no longer be feasible and need to be re-visited.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent targets are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Metal salt chemical feed facilities • Polymer chemical feed facilities	Same as Level 2
Biological	• Nitrifying trickling filter pumping station • Nitrifying trickling filter	Same as Level 2
Tertiary	• Denitrifying filter • Filter feed pumping station • External carbon source chemical feed facilities	Same as Level 2, plus: • Metal salt chemical feed facilities • Polymer chemical feed facilities

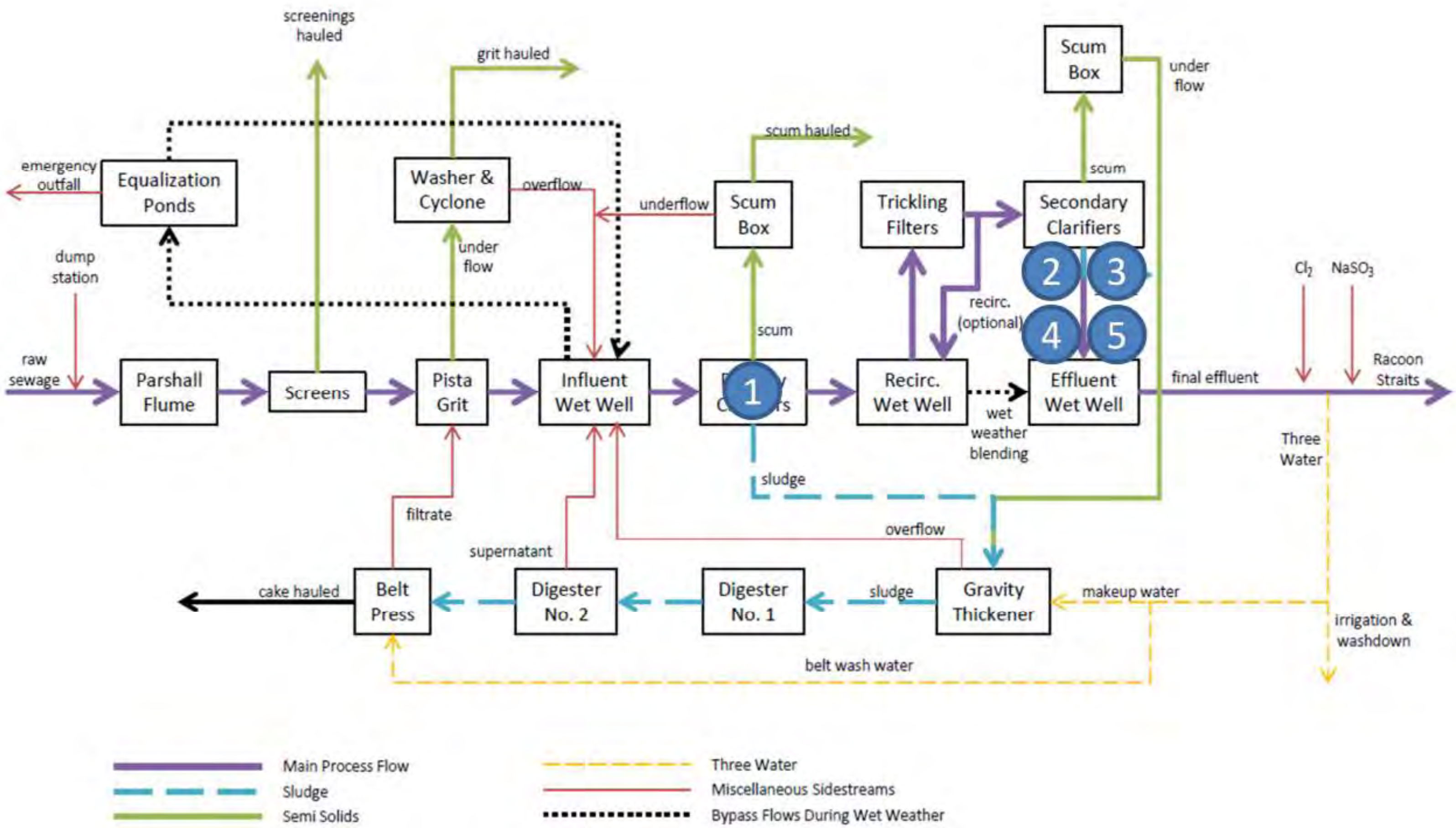

Figure 6-1. Level 2 Upgrade Concepts for the SASM WWTP

(1) Add metal salt and polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (2) add a nitrifying trickling filter feed pumping station, (3) add a nitrifying trickling filter for future ammonia loadings capacity, (4) add denitrifying filters with a feed pumping station, and (5) add an external carbon source chemical feed facilities

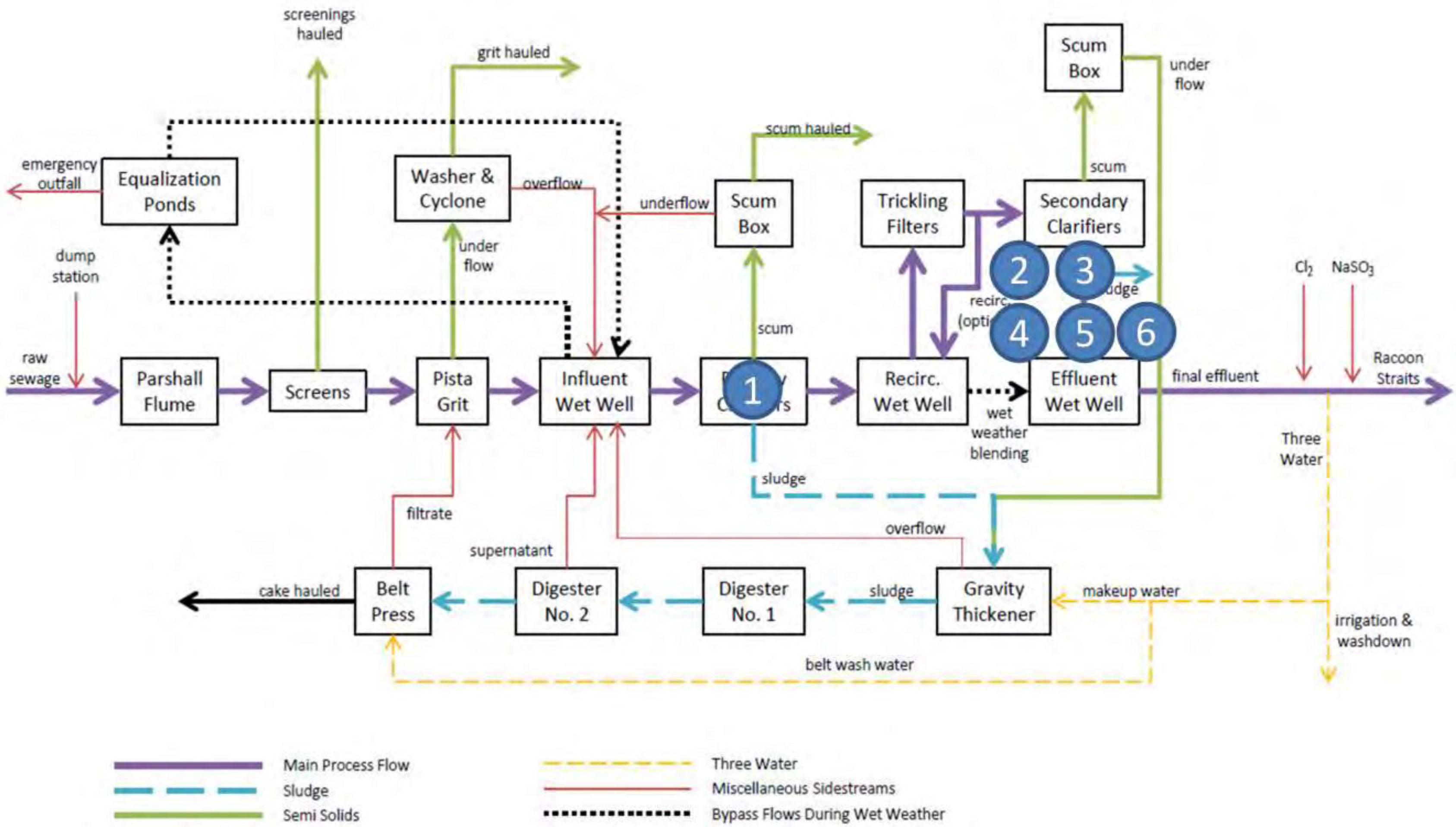

Figure 6-2. Level 3 Upgrade Concepts for the SASM WWTP

(1) Add metal salt and polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (2) add a nitrifying trickling filter feed pumping station, (3) add a nitrifying trickling filter for future ammonia loadings capacity, (4) add denitrifying filters with a feed pumping station, (5) add an external carbon source chemical feed facilities, and (6) add metal salt and polymer chemical feed facilities

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt and polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (2) add a nitrifying trickling filter feed pumping station, (3) add a nitrifying trickling filter for future ammonia loadings capacity, (4) add denitrifying filters with a feed pumping station, and (5) add an external carbon source chemical feed facilities

Note: The presented upgrades equipment siting locations is on private property that would need to be acquired for implementation. There is a chance the land would not be available to acquire if upgrades were required, in which case the recommendations would no longer be feasible.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt and polymer chemical feed facilities to operate the primary clarifiers in CEPT mode, (2) add a nitrifying trickling filter feed pumping station, (3) add a nitrifying trickling filter for future ammonia loadings capacity, (4) add denitrifying filters with a feed pumping station, (5) add an external carbon source chemical feed facilities, and (6) add metal salt and polymer chemical feed facilities

Note: The presented upgrades equipment siting locations is on private property that would need to be acquired for implementation. There is a chance the land would not be available to acquire if upgrades were required, in which case the recommendations would no longer be feasible.

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades*

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	3.6	4.8	3.6	4.8
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	27	32	37	48
Annual O&M	$Mil/yr	0.2	0.3	0.4	0.5
O&M PV[3]	$ Mil	6	7	8	12
Total PV[3]	$ Mil	33	38	45	60
Unit Capital Cost	$/gpd	8	7	10	10
Unit Total PV	$/gpd	9	8	13	12
TN Removal					
Capital[2,4]	$ Mil	27	32	36	48
Annual O&M[4]	$ Mil/yr	0.3	0.3	0.4	0.5
O&M PV[3,4]	$ Mil	6	7	8	11
Total PV[3,4]	$ Mil	33	39	45	59
TN Removed (Ave.)[6]	lb N/d	220	250	330	490
Annual TN Removed (Ave.)[7]	lb N/yr	80,000	91,000	121,000	180,000
TN Cost[4,8]	$/lb N	14	14	12	11
TP Removal					
Capital[2,5]	$ Mil	2.1	2.3	3.1	3.8
Annual O&M[5]	$ Mil/yr	0.1	0.2	0.2	0.3
O&M PV[3,5]	$ Mil	3.3	3.6	4.4	5.7
Total PV[3,5]	$ Mil	5.4	5.9	7.5	9.5
TP Removed (Ave.)[6]	lb P/d	100	100	110	120
Annual TP Removed (Ave.)[7]	lb P/yr	36,000	37,000	39,000	44,000
TP Cost[5,8]	$/lb P	5	5	6	7

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

* The presented upgrades equipment siting locations is on private property that would need to be acquired for implementation (cost not included). There is a chance the land would not be available to acquire, in which case the recommendations would no longer be feasible.

Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Better phosphorus and nitrogen removal • Increased chemicals of emerging concern (CECs) removal • High quality product water amenable to recycled water	• Additional chemicals from CEPT and the external carbon source • Additional solids • Increase energy demand from additional pumping at the nitrifying trickling filter an denitrifying filters • Potential safety issue from the external carbon source (if methanol) • Operate new processes that will require the operators to get accustomed to
Level 3	Same as Level 2	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2

7 Nutrient Load Reduction by Other Means

The SASM WWTP has an existing recycled water program that is employed for most months of the year. This existing program has the effect of reducing nutrients discharged to the Bay. The WWTP currently recycles approximately 33 acre-feet per year (11 million gallons per year). There are no existing plans to further expand the recycled water program.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology

selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

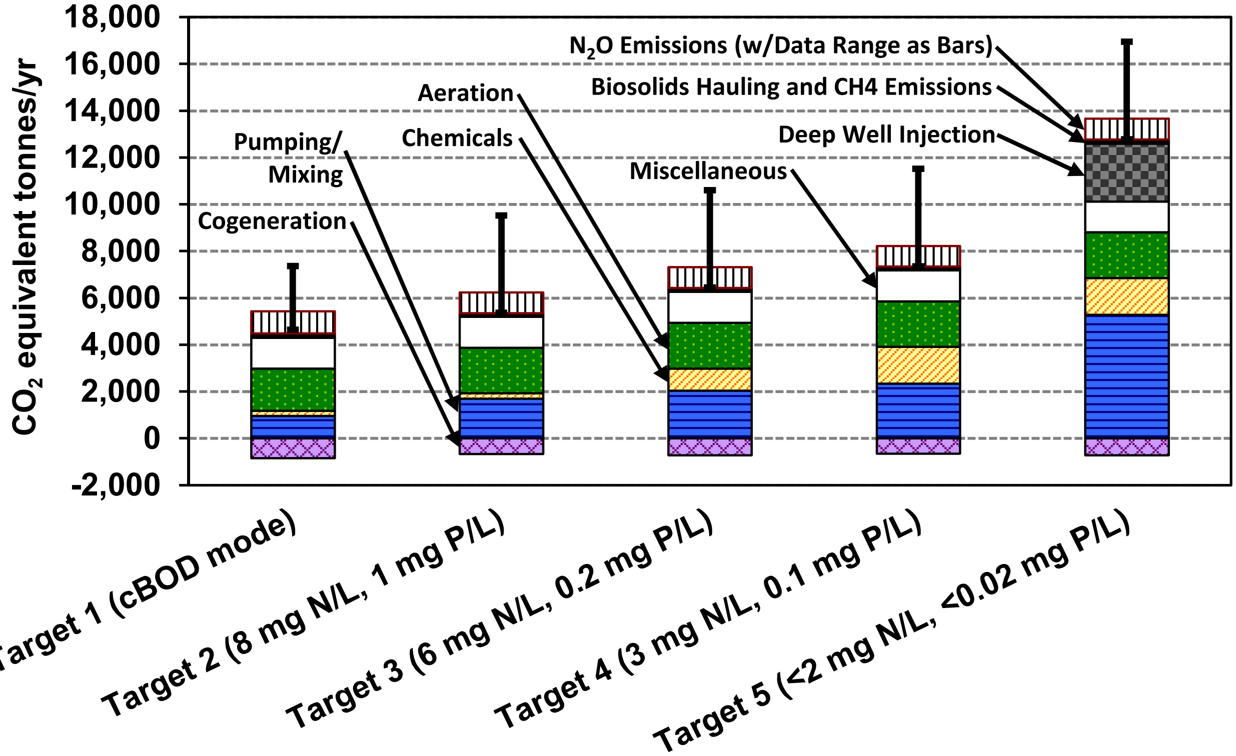

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to trim both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	--*	--*	10	30	100	140	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	10	10	160	220	310	390	--
GHG Emissions Increase Total	MT CO_2/yr	--*	--*	180	240	410	530	--
Unit GHG Emissions[2]	lb CO_2/MG	--*	--*	300	340	690	740	--
Unit GHGs for Ammonia Removal[2,3]	lb GHG/lb N	--*	--*	--*	--*	--*	--*	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	4	5	4	5	--
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	1	1	3	3	6	8	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

* The value is less than the current unit GHGs so it is excluded.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the SASM WWTP:

- Emerging Membrane Bioreactor (MBR) – a base-loaded parallel treatment MBR might be of interest for the SASM WWTP. The existing facilities could be used to treat the diurnal and peak flows and loads. The benefit of a parallel MBR is it can produce a high quality product water for recycling water while leveraging the existing assets to reduce MBR facilities. While MBRs by themselves are not emerging, there are emerging MBR technologies (e.g., FibrePlate™) that provide an even more compact footprint than established MBR technologies. The footprint savings relates to less required membrane area. Such a membrane savings results in a reduced unit energy demand for air scour compared to established MBR technologies. The benefit to the WWTP is it has the potential to further save footprint with a reduced energy demand with respect to established MBR technologies. While there are limited installations in North America of such MBR technologies, several plants are evaluating such technologies for upcoming designs.
  - Advantages: Low footprint requirements, more energy efficient than established MBR technologies, high quality product water amenable to reuse, ability to remove ammonia, TN, and TP.
  - Disadvantages: Limited installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.
- Nutrient Removal using Granular Sludge – similar to the emerging MBR, this could be used to as baseloaded parallel treatment complemented with the existing facilities to treat diurnal and peak flows and loads. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor’s Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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Silicon Valley Clean Water Wastewater Treatment Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Silicon Valley Clean Water Wastewater Treatment Plant

Redwood City, CA

March 16, 2018
Final Report

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Executive Summary

Silicon Valley Clean Water owns and operates the Silicon Valley Clean Water (SVCW) Wastewater Treatment Plant (WWTP) located in Redwood City, CA and discharges treated effluent to lower San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 29 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow	mgd	--	--	12.5	14.4	29.0	33.3	29.0	33.3	--
Flow to Bay[2]	mgd	12.6	12.6	12.6	12.6	21.5	21.5	21.5	21.5	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	4,360	4,360	4,690	4,690	380	360	380	360	5,800
TN	lb N/d	4,760	4,760	5,110	5,110	2,870	2,690	2,060	1,080	6,600
TP	lb P/d	390	390	100	100	190	180	130	50	540
Costs[4,5]										
Capital	$ Mil	--	--	1.0	1.4	120	150	190	230	20.0
O&M PV	$ Mil	--	--	1.4	1.4	97	100	110	120	16.2
Total PV	$ Mil	--	--	2.4	2.8	220	250	300	350	36.2
Unit Costs[6]										
Capital	$/gpd	--	--	0.1	0.1	4.3	4.4	6.6	6.8	--
Total PV	$/gpd	--	--	0.2	0.2	7.6	7.5	10.4	10.5	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Implement chemical addition before the filters to increase phosphorus removal. For full-scale implementation, modifications to half of the filters would be needed, as well as chemical facility upgrades. As a backup, the plant could add ferric chloride to primary clarifiers for phosphorus removal.

SVCW is considered a potential candidate for sidestream treatment to reduce nitrogen loads. The recommended sidestream treatment strategy is deammonification for reducing ammonia/nitrogen loads. The addition of metal salts (e.g., alum or ferric chloride) to the sidestream could also improve phosphorus removal.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

2. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Implement ferric chloride addition upstream of primary clarifiers for phosphorus removal,
   b. Convert the plant to an activated sludge biological nutrient removal (BNR) facility in the Modified Ludzack-Ettinger (MLE) configuration, with construction of additional aeration tanks, blowers, and secondary clarifiers. Abandon the fixed film reactors. Construct facilities for alkalinity addition. Based on the low carbon to nitrogen ratio measured in the primary effluent, capital costs for carbon addition (methanol) are included.
3. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Construct additional filter cells, and implement chemical addition before the filters for phosphorus polishing.
   c. Construct additional BNR tanks. Configure all BNR tanks as 4-stage BNR, and add additional methanol.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $2.4 Mil for dry season optimization up to $350 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Silicon Valley Clean Water Wastewater Treatment Plant (SVCW) serves a population of about 199,000, which includes the West Bay Sanitary District, City of Belmont, City of San Carlos, and City of Redwood City. It is located at 1400 Radio Rd., Redwood City, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 29 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

SVCW holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2012-0062, NPDES Permit No. CA0038369). SVCW discharges to the Lower San Francisco Bay at a latitude of 37^0 33’ 40” N and longitude of 122^0 13’ 02” W. Table 2-1 provides a summary of the dry weather permit limitations that are specific to SVCW and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2012-0062; CA0038369)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Effluent Limitations – October through April					
Flow[1]	mgd	29	-	-	-
cBOD[2]	mg/L	-	16	24	-
TSS[2]	mg/L	-	16	24	-
Total Ammonia, as N	mg/L	-	173	-	250
Effluent Limitations – May through September					
Flow[1]	mgd	29	-	-	-
cBOD[2]	mg/L	-	8	12	-
TSS[2]	mg/L	-	8	12	-
Total Ammonia, as N	mg/L	-	173	-	250

This table identifies relevant permit limitations only and does not include a complete list of permit limitations
1. The facility is designed for a peak wet weather flow of 71 mgd.
2. cBOD and TSS include a minimum percent removal of 85% through the WWTP.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for SVCW. Both liquids processes and solids processes are shown. SVCW provides advanced secondary treatment, with primary clarifiers, a trickling filter and activated sludge system for secondary treatment, dual-media filters, and chlorine disinfection. No major nutrient removal systems are currently in place. Solids treatment consists of primary and secondary sludge thickening, anaerobic digestion, rotary press dewatering and sludge drying beds.

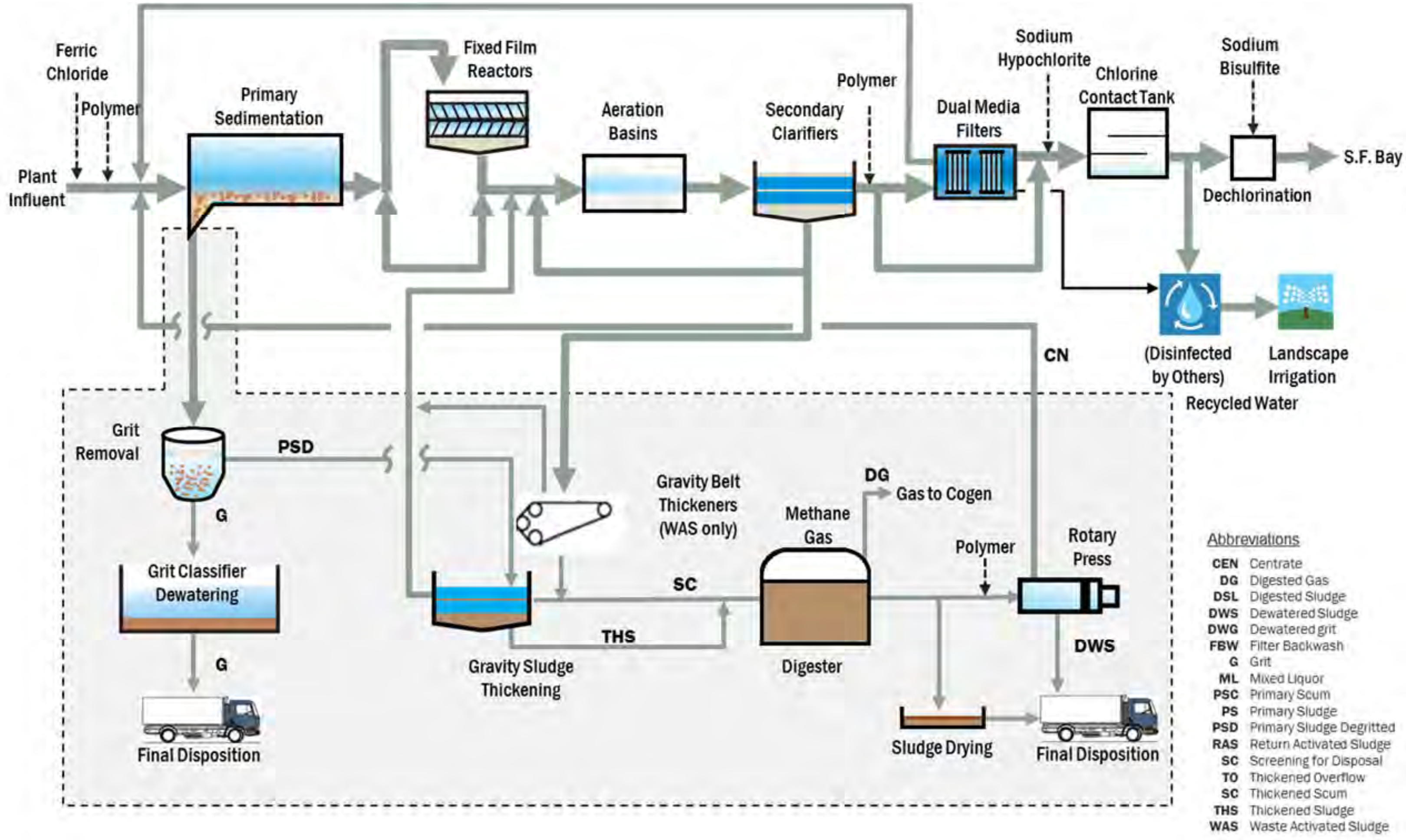

Figure 2-1. Process Flow Diagram for SVCW

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for SVCW is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	12.5	13.5	13.6	17.3
BOD	lb/d	27,500	28,400	30,000	31,400
TSS	lb/d	30,000	31,500	33,000	35,900
Ammonia[4]	lb N/d	4,210	4,350	4,590	4,800
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	6,570	6,800	7,180	7,510
Total Phosphorus (TP)[4]	lb P/d	1,100	1,130	1,200	1,250
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	260	250	260	220
TSS	mg/L	290	280	290	250
Ammonia[4]	mg N/L	40	39	40	33
TKN[4]	mg N/L	63	60	63	52
TP[4]	mg P/L	10.5	10.1	10.6	8.7
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Ammonia based on three samples collected between July 2012 and June 2014. TKN and TP based on four samples collected between July 2012 and June 2014. ADWF, dry season maximum month, and year round maximum month were calculated using the BOD peaking factors.

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at SVCW:

- SVCW plans to characterize nutrient loadings at all three influent pump stations during the summer of 2017. SVCW is installing flowmeters and sampling ports on all sidestreams to characterize sidestream nutrient loadings.
- Increased seasonal recycled water generation to meet Redwood City's plans to expand recycled water distribution will reduce nutrient loading to the SF Bay.
- SVCW is looking at possibly implementing a proprietary biosolids to energy system including a biodryer and pyrolysis process that could take half of the digested sludge. Under this process,

additional ammonia load captured from the drying process would be returned to the plant. The projected ammonia load is low since the flow from the biodryer system is low.

- Invent mixers/aerators were tested in one aeration basin, and installation is planned for the other three aeration basins. The mixers/aerators are expected to improve oxygen transfer and reduce energy use for current operations.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at SVCW.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for SVCW are presented in Table 3-1. The projected flow and load for the SVCW in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by SVCW, it was determined that SVCW is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the permitted capacity. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	12.5	13.5	13.6	17.3
BOD	lb/d	31,600	32,700	34,500	36,100
TSS	lb/d	34,500	36,200	37,900	41,300
Ammonia	lb N/d	4,840	5,000	5,280	5,520
TKN	lb N/d	7,560	7,820	8,250	8,630
TP	lb P/d	1,260	1,300	1,380	1,440
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	300	290	300	250
TSS	mg/L	330	320	330	290
Ammonia	mg N/L	46	44	47	38
TKN	mg N/L	72	70	73	60
TP	mg P/L	12.1	11.6	12.1	10.0
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

Table 3-2. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Design Capacity (AA)
Sidestream Flow	mgd	0.17	0.40
Ammonia	lb N/d	970	2,240
TKN	lb N/d	1,150	2,650
TN[1]	lb N/d	1,150	2,650
TP	lb P/d	100	220
Ortho P	lb P/d	70	150
Alkalinity	lb CaCO3/d	2,830	6,550
Ammonia	mg N/L	670	670
TKN	mg N/L	800	800
TN[1]	mg N/L	800	800
TP	mg P/L	70	70
Ortho P	mg P/L	50	50
Alkalinity	mg CaCO3/L	2,000	2,000

1. It was assumed that TN = TKN.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period

values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	29.0	31.2	31.4	40.0
BOD	lb/d	63,500	65,600	69,300	72,500
TSS	lb/d	69,300	72,800	76,200	83,000
Ammonia	lb N/d	9,720	10,050	10,610	11,100
TKN	lb N/d	15,190	15,710	16,580	17,350
TP	lb P/d	2,530	2,620	2,770	2,900
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	260	250	260	220
TSS	mg/L	290	280	290	250
Ammonia	mg N/L	40	39	40	33
TKN	mg N/L	63	60	63	52
TP	mg P/L	10.5	10.1	10.6	8.7
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Eleven optimization strategies were identified during the SVCW site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The eleven optimization strategies were screened down to six strategies as described below.

- **Optimization Strategy 1:** Resume ferric chloride addition upstream of the primary clarifiers to increase phosphorus removal using chemically enhanced primary treatment (CEPT).
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Plant has the chemical facilities for CEPT. Plant staff halted CEPT due to struggles maintaining a target F/M in the aeration basins.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Implement chemical addition before the filters to increase phosphorus removal.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** The plant has 12 filter cells which could be used for phosphorus polishing with chemical addition. Filter loading rates at peak flows are high, so chemical addition may need to be suspended during peak flow events. Half the filters (Side B) have facilities for chemical feed (aluminum chlorohydrate), but the other half (Side A) would require modification.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 3:** Use CEPT to unlock capacity and allow nitrification.
  - ***Is it feasible?*** No, since CEPT is not expected to significantly improve BOD removal.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase nitrification.
  - ***Result from analysis:*** According to plant staff they currently struggle to maintain a target F/M in the aeration basins, and further reduction of BOD through CEPT is not recommended. Based on reported primary clarifier performance, CEPT is not expected to significantly improve BOD removal, so unlocking capacity through CEPT is not recommended.
  - ***Recommendation:*** Do not carry forward.

- **Optimization Strategy 4:** Utilize the offline aeration tanks for nitrification during the dry season. The tanks are needed during the wet season for inventory management. Modification of aeration setpoints (cycled aerobic/anoxic) could give some nitrogen removal if nitrification is implemented. Ammonia based aeration control could be included.
  - ***Is it feasible?*** Not without major modifications.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Nitrify and increase N removal during dry season.
  - ***Result from analysis:*** Analysis confirmed that wet season nitrification is not feasible, since the tanks are needed during the wet season for inventory management. Surface overflow rates at peak flows in existing clarifiers exceeded typical design criteria, but for this evaluation it is assumed that the existing secondary clarifiers are sufficient for current operation. Dry season nitrification would require major modifications. Initial evaluations indicate that the existing aeration system (Invent mixer aerators) will not be sufficient for the high nitrification oxygen demand. Due to low alkalinity concentrations, chemical storage and metering facilities would be needed for alkalinity during the dry season to support nitrification. If the FFRs are abandoned, the existing tank volume is not sufficient for nitrification in the dry season, due to increased BOD loads. With the FFRs in place, carbon addition would be needed for denitrification. This strategy was not carried forward due to scope of the improvements (considered to be capital improvements).
  - ***Recommendation:*** Do not carry forward.

- **<u>Optimization Strategy 5:</u>** Use one trickling filter to nitrify recycle flows and some primary effluent.
  - ***Is it feasible?*** Not without major modifications.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase nitrification.
  - ***Result from analysis:*** The plant has unused trickling filter capacity, which could be used for nitrification. Major piping and pumping changes would be necessary to facilitate separate feed to one trickling filter for nitrification. These modifications would be difficult and expensive, due to the existing configuration. This strategy was not carried forward due to scope of the improvements (considered to be capital improvements).
  - ***Recommendation:*** Do not carry forward.

- **<u>Optimization Strategy 6:</u>** Recycle nitrified secondary effluent to the primary influent for denitrification.
  - ***Is it feasible?*** No, since plant does not nitrify.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase N removal.
  - ***Result from analysis:*** If other modifications are made to allow nitrification, the plant could recycle nitrate-rich secondary effluent to the primary influent for denitrification. Major piping changes would be needed, which would be very difficult in the compact plant site. This strategy was not carried forward due to the scope of the improvements (considered to be capital improvements), and since nitrification would be needed.
  - ***Recommendation:*** Do not carry forward.

Strategy 2 (chemical addition before filtration) is the best apparent way to reduce effluent phosphorus loads, with strategy 1 as a backup if needed.

No feasible alternatives were identified for nitrification or nitrogen removal, because the required improvements are major capital improvements (new aeration system, alkalinity system and carbon feed).

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

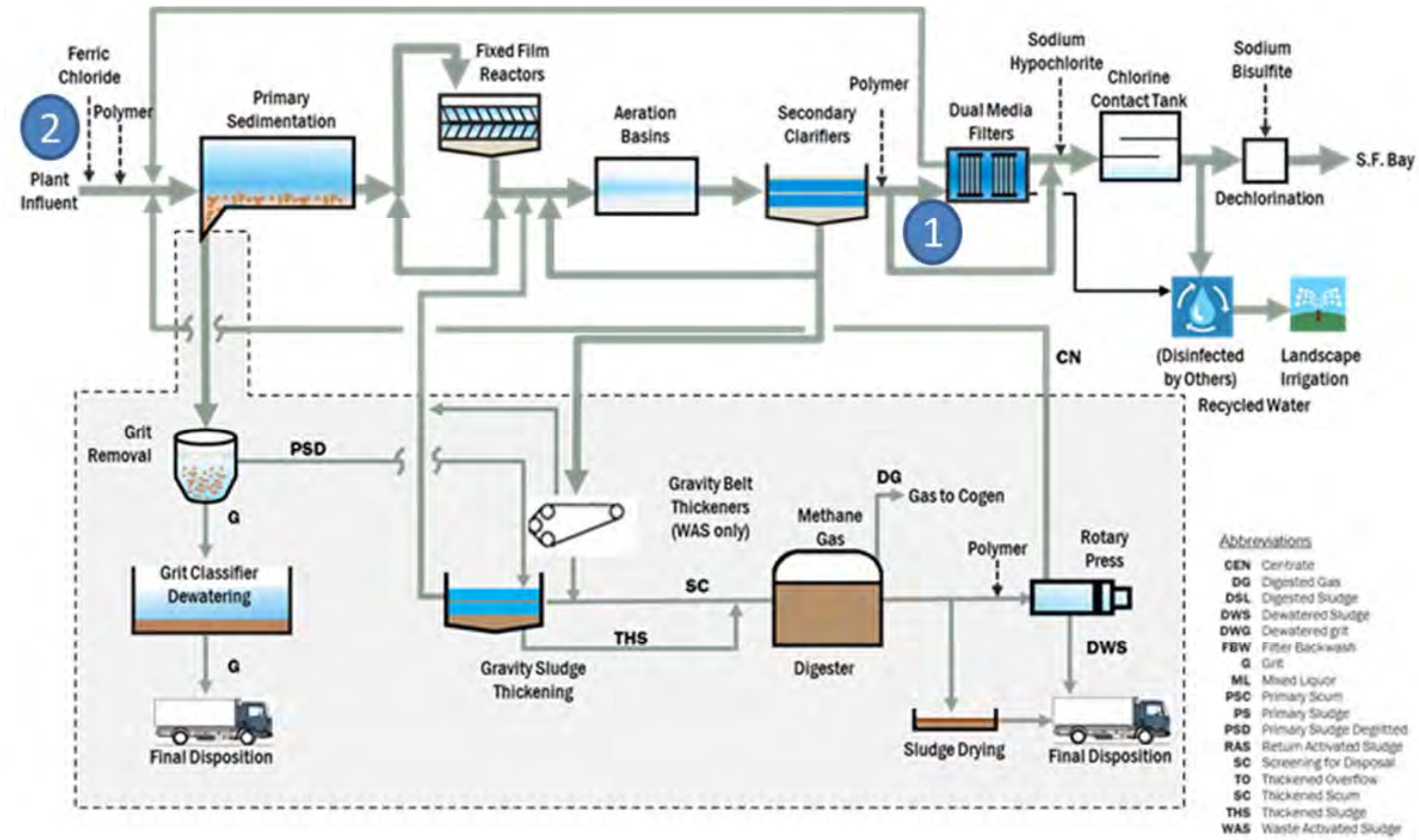

Figure 4-1. Optimization Concepts Considered for SVCW

(1) test chemical addition to filters for P removal, and modify filters for full-scale use if test is successful, or (2) use ferric chloride before primary sedimentation for P removal if chemical addition to filters is not successful.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Alum chloride storage, chemical metering pump, chemical injection (flash mixer) for addition to filters	Chemical addition costs.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. SVCW shows improved phosphorus removal, but no change in nitrogen removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	4,690	4,690	5,110	5,110	420	420
Discharge with Opt. Strategy[1]	lb N or P/d	4,690	4,690	5,110	5,110	110	100
Load Reduction[2,3]	lb N or P/d	0	0	0	0	310	320
Load Reduction[2,3]	%	0%	0%	0%	0%	75%	76%
Annual Load Reduction	lb N or P/yr	0	0	0	0	113,000	116,000

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	12.5	14.4
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	1.0	1.4
Annual O&M	$ Mil/yr	0.2	0.2
Present Value O&M[3]	$ Mil	1.0	1.4
Present Value Total[3]	$ Mil	2.4	2.8
Unit Capital Cost[8]	$/gpd	0.1	0.1
Unit Total PV Cost[8]	$/gpd	0.2	0.2
TN Removal			
Capital[2,4]	$ Mil	0.0	0.0
Annual O&M[4]	$ Mil/yr	0.0	0.0
O&M PV[3,4]	$ Mil	0.0	0.0
Total PV[3,4]	$ Mil	0.0	0.0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	1.0	1.4
Annual O&M[5]	$ Mil/yr	0.2	0.2
O&M PV[3,5]	$ Mil	1.4	1.4
Total PV[3,5]	$ Mil	2.4	2.8
TP Removed (Ave.)[6]	lb P/d	310	320
Annual TP Removed (Ave.)[7]	lb P/yr	113,000	116,000
TP Cost[5,9]	$/lb P	2.1	2.5

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• Phosphorus reliably removed	• Dependency on chemicals • Chemical costs • Increased sludge production

5 Sidestream Treatment

As previously described, SVCW was identified as a potential candidate for sidestream treatment. The WWTP currently uses a combination of rotary presses and drying beds. The sidestream treatment facilities were based on the assumption that all digested biosolids go through the rotary presses.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia/total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature (common for WWTPs with mechanical dewatering). It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification), such as requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requiring 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for SVCW.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. SVCW already has ferric chloride and anionic polymer chemical feed facilities that were previously used for CEPT. These facilities could be potentially used for this application. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks).

Another option to consider for eliminating the phosphorus recycled stream load is recovery via struvite precipitation. This process produces a useful byproduct (struvite crystals) that can be sold economically. The finances are typically more attractive for larger plants (>40 mgd). It is recommended that SVCW evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant if phosphorus load reduction is required in the future.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements[1]
Feed Pumping (if necessary)	Metal Salt Chemical Feed[1]
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

1. SVCW already has ferric chloride chemical feed facilities that could be potentially leveraged for this application.

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	7,200	7,900	640
Discharge with Sidestream Treatment[2]	lb/d	5,800	6,600	540
Load Reduction[3]	lb/d	1,400	1,300	100
Load Reduction	%	20%	16%	16%
Annual Load Reduction[3]	lb/yr	527,100	468,500	37,700

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP[7]
Capital[1]	$ Mil	19.6	0.4
Annual O&M	$ Mil/yr	0.6	0.08
Total Present Value[2]	$ Mil	34.0	2.2
NH4-N Load Reduction[3,5]	lb N/yr	527,100	--
TN Load Reduction[3,5]	lb N/yr	468,500	--
TP Load Reduction[4,5]	lb P/yr	--	37,700
NH4-N Cost [3,5,6]	$/lb N	2.2	--
TN Cost [3,5,6]	$/lb N	2.4	--
TP Cost [4,5,6]	$/lb P	--	2.0

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. SVCW has ferric chloride chemical feed facilities that could be potentially leveraged for this application. These projected costs are based on the addition of new ferric chloride chemical feed facilities.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at SVCW to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. SVCW should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Ferric chloride addition to the primary clarifiers is assumed for phosphorus removal. Level 2 nitrogen limits could be met by converting the plant to an activated sludge BNR facility in the Modified Ludzack-Ettinger (MLE) configuration. The fixed film reactors would be abandoned, and additional aeration tanks and secondary clarifiers constructed. New blowers would be required. Based on the low carbon to nitrogen ratio measured in the primary effluent, capital costs for carbon addition (methanol) are included to provide carbon if needed for denitrification, but no methanol is included in the operating costs. Based on available alkalinity and nitrogen data, alkalinity addition will be needed for nitrification.

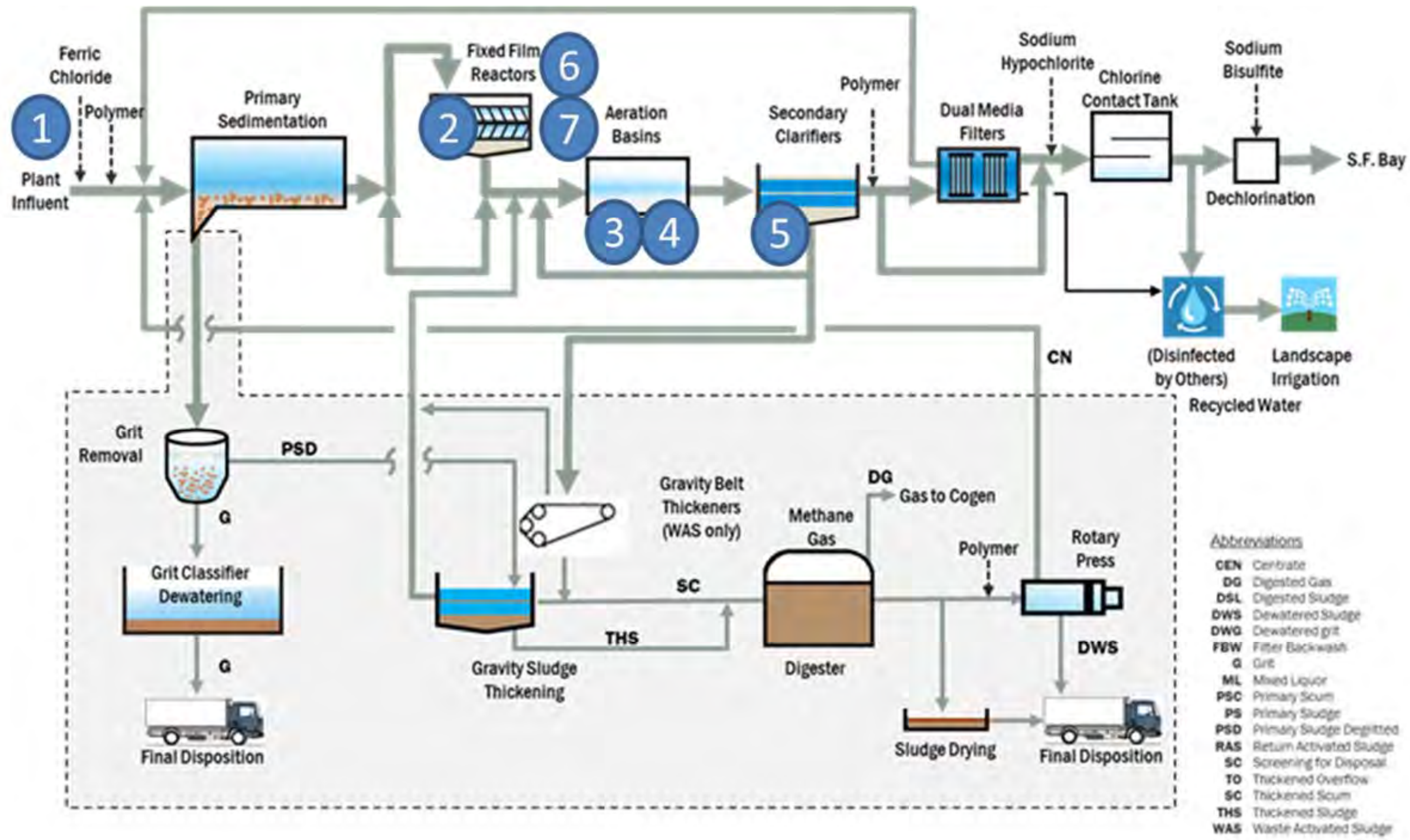

Figure 6-1. Level 2 Upgrade Concept for SVCW

(1) ferric chloride for P removal using existing facilities, (2) abandon the fixed film reactors, (3) convert aeration basins to MLE BNR, (4) construct additional MLE BNR basins, (5) construct additional secondary clarifiers, (6) construct alkalinity addition facilities to provide alkalinity for nitrification, and (7) construct methanol addition facilities to provide a carbon source for denitrification.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2. Additional aeration tanks are required, and all aeration tanks would be configured as 4-stage BNR. Chemical addition (alum) before filtration is used for phosphorus polishing. Additional filter cells are required. Additional storage is included for carbon addition (methanol) to improve denitrification.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Ferric chloride chemical feed using existing facilities	Same as Level 2
Secondary and Tertiary	• Abandon FFRs • Reconfigure existing aeration tanks as BNR tanks (MLE), including baffles, mixers, and mixed liquor recycle pumping • Construct new deep BNR tanks (MLE), including baffles, mixers, and mixed liquor recycle pumping • New blowers • Additional secondary clarifiers • Alkalinity addition facilities • External carbon source addition facilities	Same as Level 2 plus: • Construct additional deep BNR tanks, and configure all BNR tanks as 4-stage BNR. • Additional external carbon source chemical feed • Chemical (alum) storage for phosphorus polishing in filters • Additional filter cells for phosphorus polishing

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

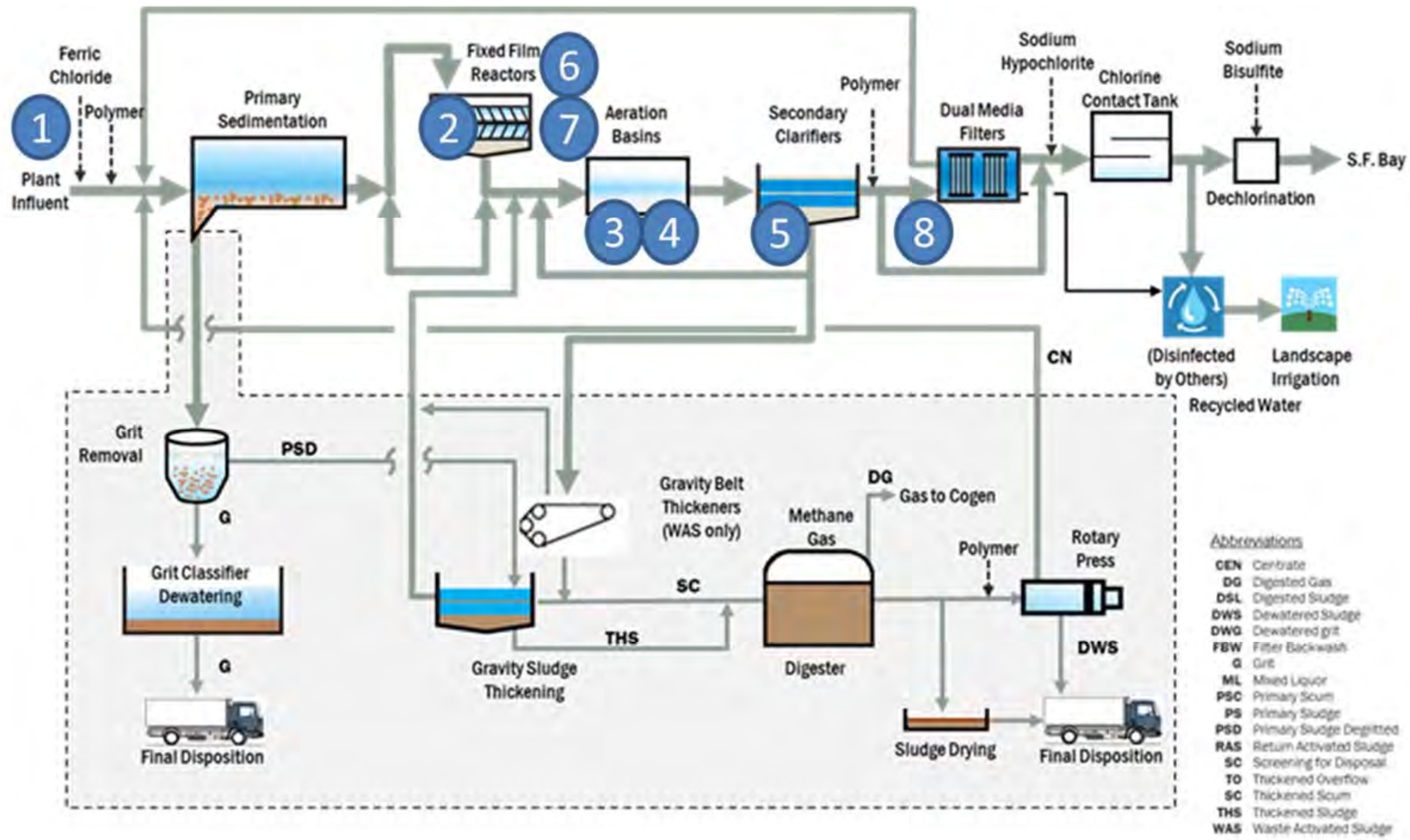

Figure 6-2. Level 3 Upgrade Concept for SVCW

(1) ferric chloride for P removal using existing facilities, (2) abandon the fixed film reactors, (3) convert aeration basins to 4-stage BNR, (4) construct additional 4-stage BNR basins, (5) construct additional secondary clarifiers, (6) construct alkalinity addition facilities to provide alkalinity for nitrification, (7) construct methanol addition facilities to provide a carbon source for denitrification, (8) chemical addition (alum) before filtration for phosphorus polishing.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Convert existing aeration tanks to MLE, (2) new MLE basins, (3) new secondary clarifiers, (4) methanol and caustic.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Convert existing aeration tanks to 4-stage BNR, (2) new 4-stage BNR basins, (3) new secondary clarifiers, (4) methanol, caustic, and alum, (5) new filters (in addition to current filters) for phosphorus polishing of dry season flow, and (6) additional filters if year round phosphorus polishing is required.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	29.0	33.3	29.0	33.3
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	120	150	190	230
Annual O&M	$Mil/yr	4.3	4.6	5.0	5.5
O&M PV[3]	$ Mil	97	100	110	120
Total PV[3]	$ Mil	220	250	300	350
Unit Capital Cost	$/gpd	4.3	4.4	6.6	6.8
Unit Total PV	$/gpd	7.6	7.5	10.4	10.5
TN Removal					
Capital[2,4]	$ Mil	120	150	170	200
Annual O&M[4]	$ Mil/yr	3.8	4.0	4.2	4.5
O&M PV[3,4]	$ Mil	85	90	95	100
Total PV[3,4]	$ Mil	210	240	270	300
TN Removed (Ave.)[6]	lb N/d	5,000	5,180	5,810	6,800
Annual TN Removed (Ave.)[7]	lb N/yr	1,830,000	1,890,000	2,120,000	2,480,000
TN Cost[4,8]	$/lb N	3.8	4.2	4.2	4.0
TP Removal					
Capital[2,5]	$ Mil	0	0	20	28
Annual O&M[5]	$ Mil/yr	0.6	0.6	0.8	1.0
O&M PV[3,5]	$ Mil	13	13	17	23
Total PV[3,5]	$ Mil	13	13	37	51
TP Removed (Ave.)[6]	lb P/d	450	460	510	590
Annual TP Removed (Ave.)[7]	lb P/yr	163,000	168,000	186,000	214,000
TP Cost[5,8]	$/lb P	2.6	2.7	6.6	8.0

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Robust technology to absorb variability in flows and loads • Ability to reliably remove TN and TP • More organics and solids diverted to fuel the digester	• Increased operation costs associated with ferric chloride, alkalinity, and methanol addition • Increased energy demands for aeration and membranes • Dependency on chemicals • Increased sludge production
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use and additional alum use

7 Nutrient Removal by Other Means

SVCW has an existing recycled water program that is employed year-round. Recycled water is used for golf course irrigation, landscape irrigation, industrial use, and a truck-fill station. This existing program has the effect of reducing nutrients discharged to the Bay. SVCW currently recycles approximately 700 acre-feet per year (200 million gallons per year) and they are planning to increase recycling to 1,600 acre-feet per year (500 million gallons per year) by 2040.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from

Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

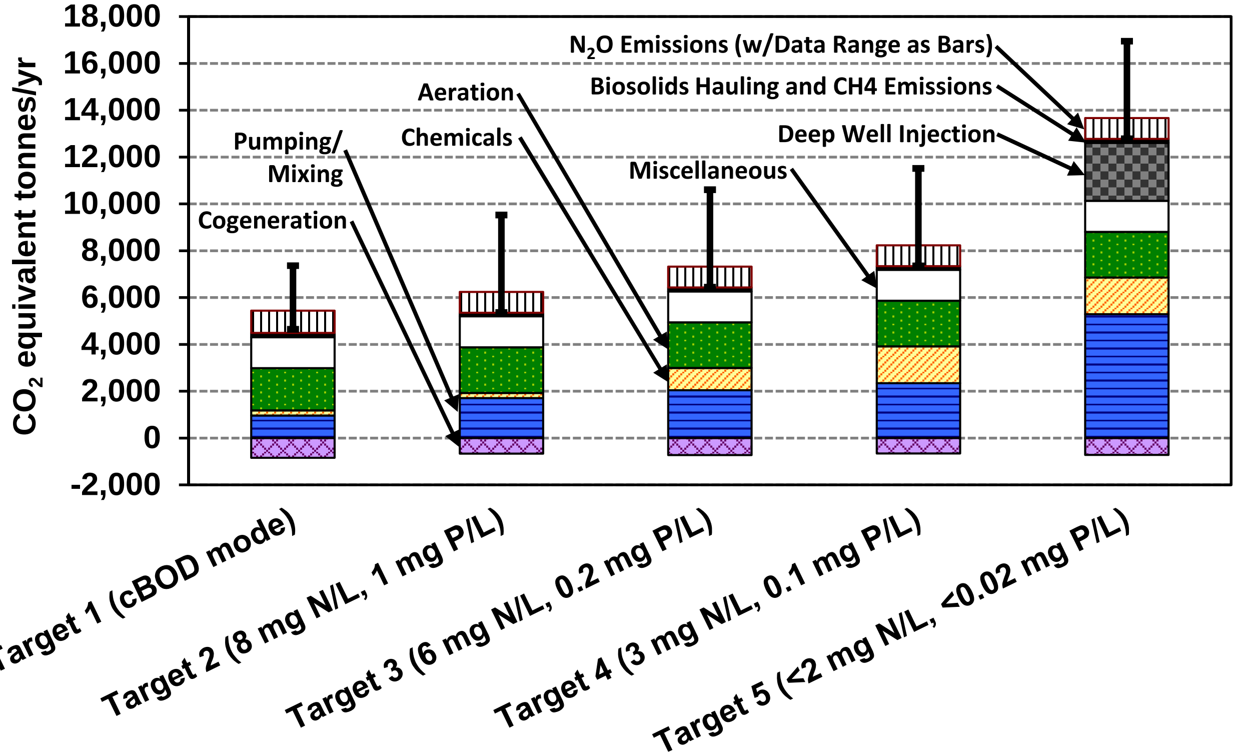

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	4	5	5,400	5,900	5,500	6,000	190
GHG Emissions Increase from Chemicals	MT CO_2/yr	150	160	26,800	25,200	16,500	13,900	70
GHG Emissions Increase Total	MT CO_2/yr	160	170	32,300	31,100	21,900	19,900	260
Unit GHG Emissions[2]	lb CO_2/MG	70	70	6,200	5,900	4,200	3,800	120
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	28	27	18	16	1.2
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	35	33	21	17	0.9
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	3	3	1	2	7	7	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. SVCW has ferric chloride chemical feed facilities that could be potentially leveraged for this application. These projected GHG emissions are based on the addition of new ferric chloride chemical feed facilities.

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at SVCW. These are:

- Nitrite Shunt – Future SVCW BNR basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Evaluate instrumentation and automation, and consider pilot during design.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit to SVCW is it has the potential to reduce the basin volume for Levels 2 or 3. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN and TP
  - Disadvantages: No installations in North America
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.31

Sonoma Valley County Sanitation District

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Sonoma Valley County Sanitation District

Sonoma, CA

May 18, 2018
Final Report

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Executive Summary

The Sonoma Valley County Sanitation District (SVCSD) Wastewater Treatment Plant (WWTP) discharges to tributaries of San Pablo Bay. It is located at 22675 8th Street East, Sonoma, CA 95476, and it serves approximately 17,200 service connections throughout the City of Sonoma and the unincorporated areas of Agua Caliente, Boyes Hot Springs, Eldridge, Fetters Hot Springs, Glen Ellen, Schellville, Temelec, and Vineburg. The plant has an average dry weather flow (ADWF) permitted capacity of 3 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season[7]	Current Year Round[7]	Opt. Dry Season[3,7,8]	Opt. Year Round[3,7,8]	Level 2 Dry Season[3,7]	Level 2 Year Round[3,7]	Level 3 Dry Season[3,7]	Level 3 Year Round[3,7]	Side-stream
Design Flow	mgd	--	--	--[8]	--[8]	3.0	4.3	3.0	4.3	--
Flow to Bay[2]	mgd	--	1.1	--[8]	--[8]	--	1.2	--	1.2	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	--	3	--[8]	--[8]	--	3	--	3	--
TN	lb N/d	--	50	--[8]	--[8]	--	60	--	60	--
TP	lb P/d	--	20	--[8]	--[8]	--	10	--	3	--
Costs[4,5]										
Capital	$ Mil	--	--	--[8]	--[8]	--	1.5	--	3.7	--
O&M PV	$ Mil	--	--	--[8]	--[8]	--	--*	--	5.3	--
Total PV	$ Mil	--	--	--[8]	--[8]	--	1.5	--	8.9	--
Unit Costs[6]										
Capital	$/gpd	--	--	--[8]	--[8]	--	0.4	--	0.9	--
Total PV	$/gpd	--	--	--[8]	--[8]	--	0.4	--	2.1	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. The plant does not discharge during the dry season and a portion of the wet season days.
8. The plant is already optimized and performing nutrient removal so no nutrient optimization concepts were recommended.

* The O&M costs are anticipated to be similar to current.

No optimization is recommended because the SVCSD WWTP is already meeting the ammonia and total nitrogen levels for Level 3 upgrade.

The SVCSD WWTP is not considered a candidate for sidestream treatment to reduce nitrogen or phosphorus loads because the sidestream loads are negligible since the plant does not have digesters.

The upgrade strategies to achieve Levels 2 and 3 for the full plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Optimize aeration on/off to enhance total nitrogen load reduction.
   b. Implement biological phosphorus removal treatment by adding a stand-alone anaerobic zone upstream of the aeration basins.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus:
   b. Add an external carbon source chemical feed facility to more reliably remove total nitrogen.
   c. Add metal salt chemical feed facilities upstream of the filters.

As shown in Table ES-1, there are no dry season costs as the WWTP does not discharge during this period. The costs increase from Levels 2 to 3 upgrades with total present value costs of $1.5 Mil and $8.9 Mil, respectively. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Sonoma Valley County Sanitation District (SVCSD) Wastewater Treatment Plant (WWTP) discharges to tributaries of San Pablo Bay. It is located at 22675 8th Street East, Sonoma, CA 95476, and it serves approximately 17,200 service connections throughout the City of Sonoma and the unincorporated areas of Agua Caliente, Boyes Hot Springs, Eldridge, Fetters Hot Springs, Glen Ellen, Schellville, Temelec, and Vineburg. The plant has an average dry weather flow (ADWF) permitted capacity of 3 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The SVCSD WWTP holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2014-0020; CA0037800. Table 2–1 provides a summary of the permit limitations for the SVCSD WWTP. Table 2–1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2–1. NPDES Permit Limitations (Order No. R2-2014-0020; CA0037800)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak
Flow	mgd	3	--	--	--	16
BOD	mg/L	--	30	45	--	--
TSS	mg/L	--	30	45	--	--
Total Ammonia, as N	mg/L	--	1.8	--	--	--

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the SVCSD WWTP. Both liquids processes and solids processes are shown. Influent is treated by the following processes in succession: screening, grit removal, primary treatment and flow equalization using aerated equalization basins, secondary treatment in aeration basins, secondary clarification, tertiary treatment using cloth media filtration, chlorination and dechlorination. Secondary treatment provides ammonia and total nitrogen load removal.

Solids are thickened, dewatered and disposed of in a landfill.

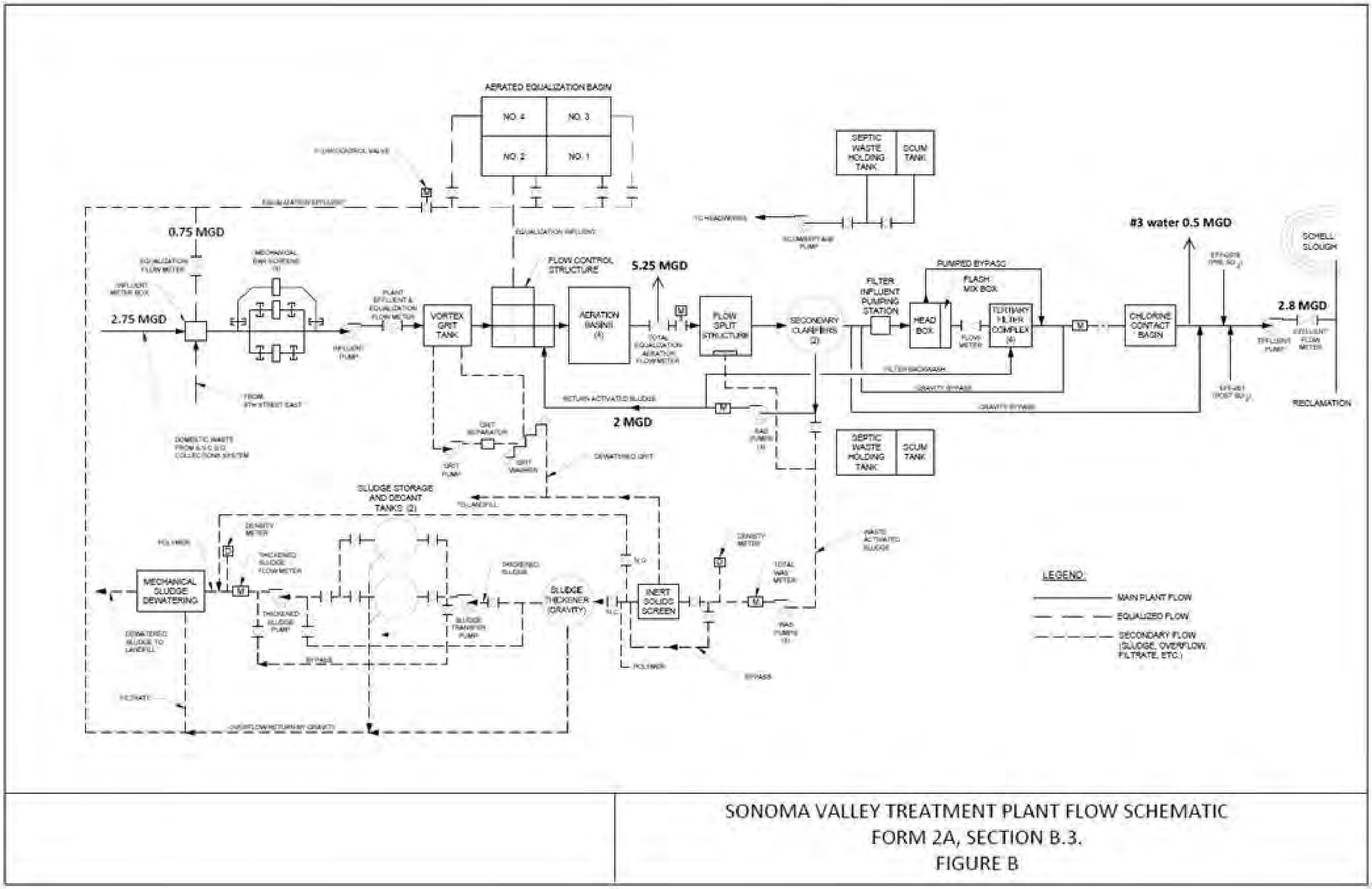

Figure 2-1. Process Flow Diagram for SVCSD WWTP

2.3 Existing Flows and Loads

A data request was submitted to each POTW in December 2014 as a means to understand historical plant performance and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the SVCSD WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	2.4	3.0	2.8	6.5
BOD	lb/d	5,300	6,200	6,900	8,700
TSS	lb/d	5,600	6,700	7,100	10,700
Ammonia[4]	lb N/d	No Data	No Data	No Data	No Data
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	No Data	No Data	No Data	No Data
Total Phosphorus (TP)[4]	lb P/d	No Data	No Data	No Data	No Data
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	263	246	294	161
TSS	mg/L	278	266	302	198
Ammonia[4]	mg N/L	No Data	No Data	No Data	No Data
TKN[4]	mg N/L	No Data	No Data	No Data	No Data
TP[4]	mg P/L	No Data	No Data	No Data	No Data
Alkalinity	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. No nutrient data provided in the initial data request.

2.4 Future Nutrient Removal Projects

The SVCSD does not have any projects planned to provide further nutrient removal.

2.5 Pilot Testing

The SVCSD WWTP has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

As previously described, no optimization strategies were identified as the WWTP is currently producing water that meets Level 3 upgrade levels for ammonia and total nitrogen. A portion of the total phosphorus load is also currently removed.

3.2 Flow and Loading for Sidestream Treatment

Based on the solids processing train for the SVCSD WWTP (no digestion), it was determined that the SVCSD WWTP is a not candidate for sidestream treatment.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-1. These values are based on the plant's permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-1. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30) [1,3]	Year Round MM[1,3]
Flow	mgd	3.0	3.7	3.5	8.0
BOD	lb/d	6,600	7,700	8,600	10,800
TSS	lb/d	7,000	8,300	8,800	13,300
Ammonia[4]	lb N/d	No Data	No Data	No Data	No Data
TKN[4]	lb N/d	No Data	No Data	No Data	No Data
TP[4]	lb P/d	No Data	No Data	No Data	No Data
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	263	246	294	161
TSS	mg/L	278	266	302	198
Ammonia[4]	mg N/L	No Data	No Data	No Data	No Data
TKN[4]	mg N/L	No Data	No Data	No Data	No Data
TP[4]	mg P/L	No Data	No Data	No Data	No Data
Alkalinity	mg/L as CaCO3	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. No nutrient data provided in the initial data request. Given that the plant is already nearly meeting Level 3 values, the influent nutrient loading information is not required to develop planning level facility needs.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-2 shows the discount rate and period used for the different scenarios.

Table 3-2. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

The SVCSD WWTP was originally designed for nutrient removal. The WWTP is producing water that meets Level 3 upgrade levels for ammonia and total nitrogen. Thus, no optimization projects were identified.

5 Sidestream Treatment

As previously described, the SVCSD WWTP was not identified as a potential candidate for sidestream treatment.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the SVCSD WWTP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The SVCSD should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under the Optimization Section. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, the aeration on/off strategy would be optimized for enhanced total nitrogen load removal. An additional stand-alone anaerobic basin would be required to implement biological phosphorus removal that operates in front of the existing basins.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2. In addition to those listed for Level 2, Level 3 upgrades require an external carbon source and metal salt chemical feed facilities. The external carbon source is required at the activated sludge system to meet the carbon requirements for meeting the TN discharge target. The additional metal salt chemical feed facilities are required at the filtration facility to meet the TP discharge target.

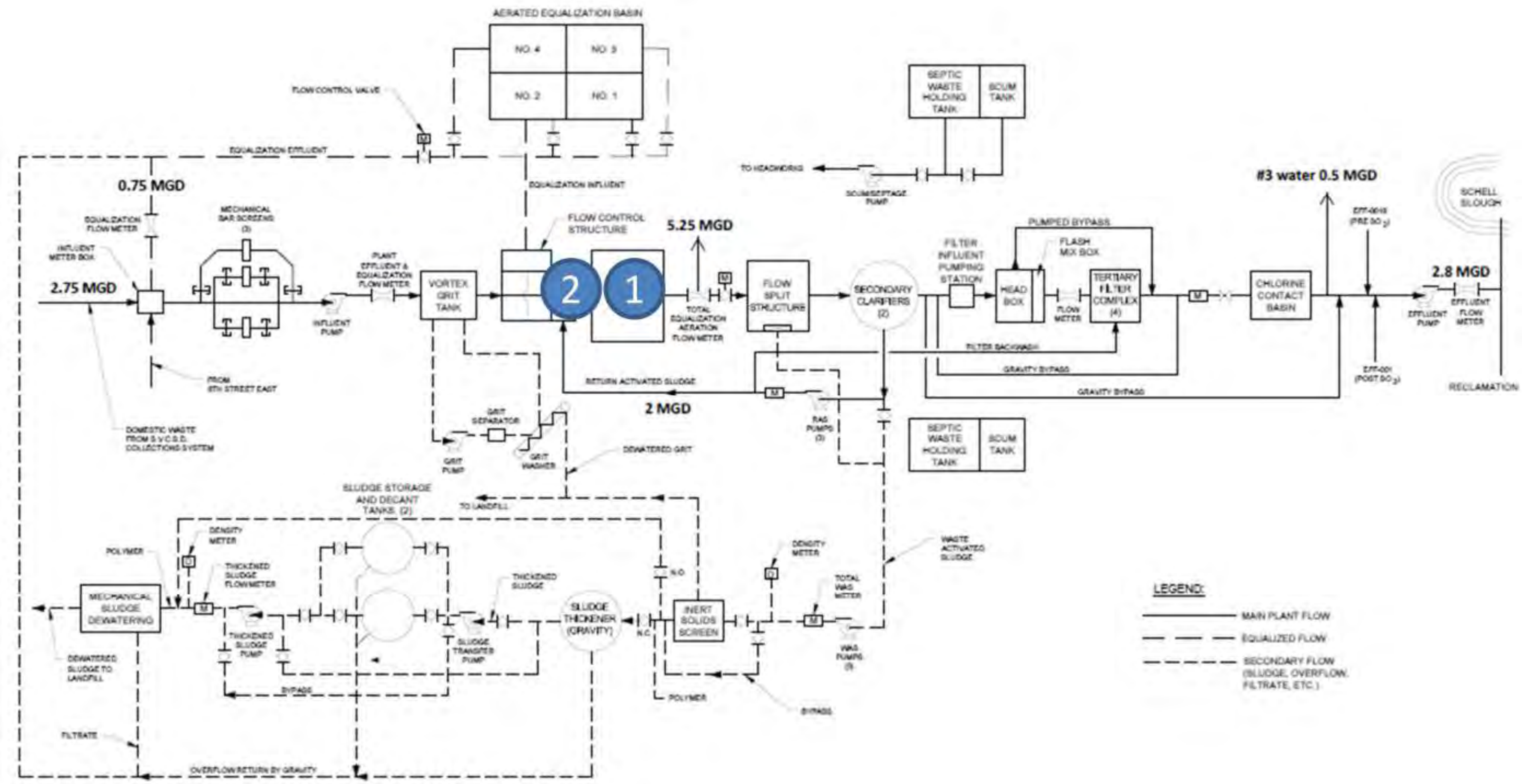

Figure 6-1. Level 2 Upgrade Concepts for SVCSD WWTP

(1) Optimize aeration on/off timing to enhance total nitrogen load removal and (2) add a stand-alone anaerobic basin in front of the aeration basins for biological phosphorus removal

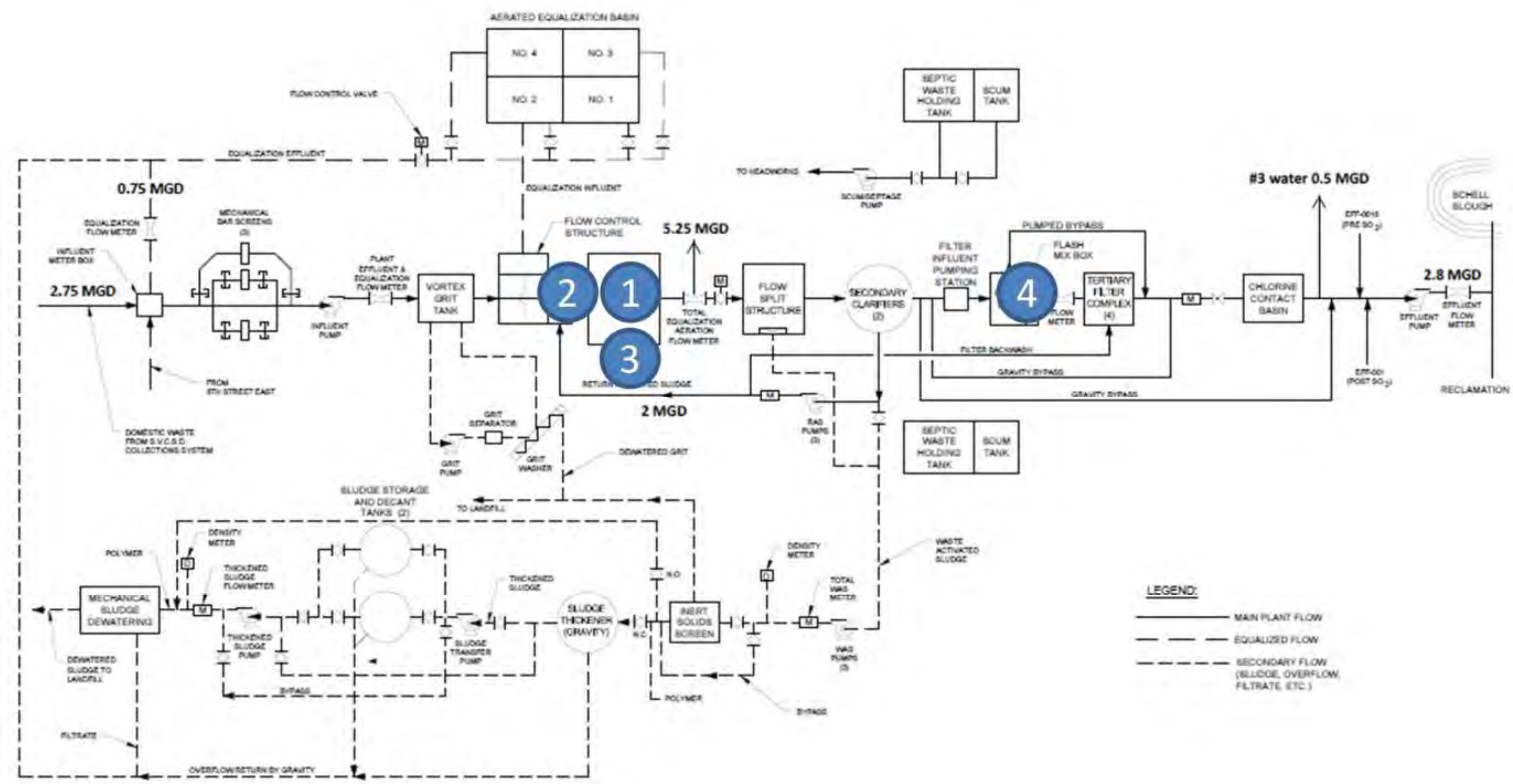

Figure 6-2. Level 3 Upgrade Concepts for SVCSD WWTP

(1) Optimize aeration on/off timing to enhance total nitrogen load removal, (2) add a stand-alone anaerobic basin in front of the aeration basins for biological phosphorus removal, (3) add an external carbon source chemical feed facilities, and (4) a metal salt chemical feed facilities

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Biological	• Implement an Optimized Aeration On/Off Strategy • Add a Stand-Alone Anaerobic Basin(s)	Same as Level 2, plus: • External Carbon Source Chemical Feed Facility
Tertiary	• None	Same as Level 2, plus: • Add Ferric Chemical Feed Facilities

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

Figure 6-3. Level 2 Upgrade Aerial Layouts

(1) Optimize aeration on/off timing to enhance total nitrogen load removal and (2) add a stand-alone anaerobic basin in front of the aeration basins for biological phosphorus removal

Figure 6-4. Level 3 Upgrade Aerial Layouts

(1) Optimize aeration on/off timing to enhance total nitrogen load removal, (2) add a stand-alone anaerobic basin in front of the aeration basins for biological phosphorus removal, (3) add an external carbon source chemical feed facilities, and (4) a metal salt chemical feed facilities

Table 6-2. Estimated Capital and O&M Costs for TN and TP Upgrades

Parameter	Unit	Level 2 Dry Season[1,9]	Level 2 Year Round[1,9]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	3.0	4.3	3.0	4.3
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	--	1.5	--	3.7
Annual O&M	$Mil/yr	--	--*	--	0.2
O&M PV[3]	$ Mil	--	--*	--	5.3
Total PV[3]	$ Mil	--	1.5	--	8.9
Unit Capital Cost	$/gpd	--	0.4	--	0.9
Unit Total PV	$/gpd	--	0.4	--	2.1
TN Removal					
Capital[2,4]	$ Mil	--	--**	--	1.4**
Annual O&M[4]	$ Mil/yr	--	--*,**	--	0.2**
O&M PV[3,4]	$ Mil	--	--*,**	--	3.8**
Total PV[3,4]	$ Mil	--	--**	--	5.1**
TN Removed (Ave.)[6]	lb N/d	--	--**	--	--**
Annual TN Removed[7]	lb N/yr	--	--**	--	--**
TN Cost[4,8]	$/lb N	--	--**	--	--**
TP Removal					
Capital[2,5]	$ Mil	--	1.5	--	2.3
Annual O&M[5]	$ Mil/yr	--	0.6	--	0.6
O&M PV[3,5]	$ Mil	--	12.4	--	13.9
Total PV[3,5]	$ Mil	--	13.9	--	16.2
TP Removed (Ave.)[6]	lb P/d	--	15	--	21
Annual TP Removed[7]	lb P/yr	--	5,300	--	7,800
TP Cost[5,8]	$/lb P	--	90	--	70

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. The plant does not discharge during the dry season and a portion of the wet season days.

* The O&M costs are anticipated to be similar to current.

** The plant is already meeting Level 2 and 3 upgrade levels. Any additional facilities are provided to enhance performance reliability.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Improved settleability in the secondary clarifiers • Additional filtration capacity due to improved secondary clarifier effluent (the extent is unclear and would require verification testing) • Reduced solids/BOD discharge loading	• Additional anaerobic basin to operate • Operate in a new mode with air on/off that will require the operators to get accustomed to
Level 3	Same as Level 2	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Additional solids • Safety from external carbon source (if methanol)

7 Nutrient Load Reduction by Other Means

The SVCSD WWTP has an existing recycled water program that is employed year-round with no Bay discharge during the dry season. This existing program has the effect of reducing nutrients discharged to the Bay, especially for the dry season when there is no Bay discharge. SVCSD currently recycles approximately 2,300 acre-feet per year (760 million gallons per year) and they are planning to increase the approximately 50 percent by year 2020.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy

and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

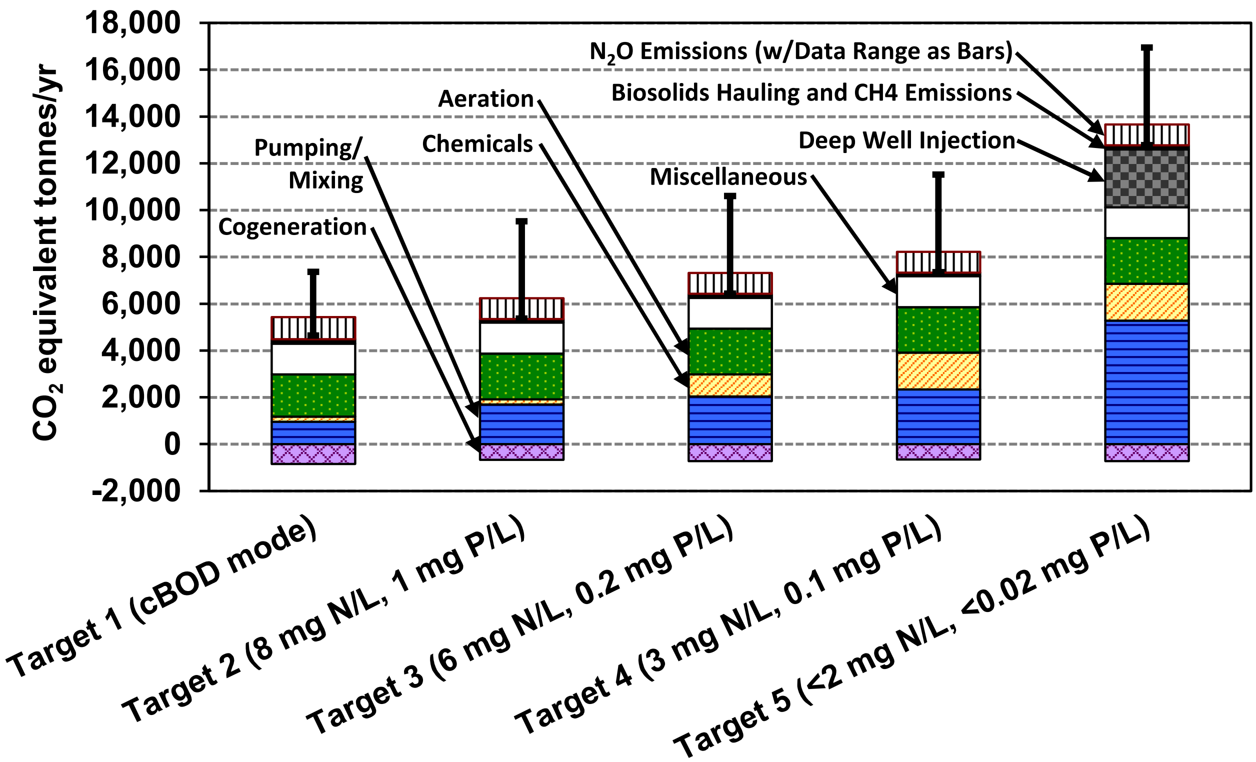

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

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[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1,5,7]	Optimization Year Round[1,5,7]	Level 2 Dry Season[1,7]	Level 2 Year Round[1,7]	Level 3 Dry Season[1,7]	Level 3 Year Round[1,7]	Sidestream Year Round[8]
GHG Emissions Increase from Energy	MT CO_2/yr	--	--	--	--*	--	--*	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	--	--	--	--*	--	400	--
GHG Emissions Increase Total	MT CO_2/yr	--	--	--	--*	--	400	--
Unit GHG Emissions[2]	lb CO_2/MG	--	--	--	--*	--	640	--
Unit GHGs for Ammonia Removal[2,3,6]	lb GHG/lb N	--	--	--	--	--	--	--
Unit GHGs for Total N Removal[2,3,6]	lb GHG/lb N	--	--	--	--	--	--	--
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--	--	--	220	--	150	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only
4. Based on phosphorus removal only
5. The plant is already optimized and performing nutrient removal so no nutrient optimization concepts were recommended.
6. The plant already meets Level 2 and 3 upgrade levels so any upgrades will not increase the unit GHG demand for ammonia and total nitrogen.
7. The plant does not discharge during the dry season and a portion of the wet season days.
8. The plant was not deemed a potential candidate for sidestream treatment.

* The values are equal or less than the current operating mode.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the SVCSD WWTP:

- Nutrient Removal using Granular Sludge – this could be used to phase out the biotower/activated sludge. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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South San Francisco and San Bruno Water Quality Control Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

South San Francisco and San Bruno Water Quality Control Plant

South San Francisco, CA

June 15, 2018
Final Report

BACWA BAY AREA CLEAN WATER AGENCIES

HDR

Brown AND Caldwell

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Executive Summary

The City of South San Francisco and San Bruno Water Quality Control Plant (South SF-SB WQCP) located in South San Francisco, CA discharges treated effluent to San Pablo Lower San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 13 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow	mgd	--	--	9.5	12.3	13.0	14.1	13.0	14.1	--
Flow to Bay[2]	mgd	8.8	8.8	9.9	9.9	11.2	11.2	11.2	11.2	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	1,850	1,850	1,910	1,910	200	190	200	190	1,750
TN	lb N/d	2,530	2,530	2,600	2,600	1,490	1,400	1,060	560	2,680
TP	lb P/d	350	350	100	90	100	90	70	30	390
Costs[4,5]										
Capital	$ Mil	--	--	0	0	47	48	106	112	13.6
O&M PV	$ Mil	--	--	0.5	0.5	60	64	75	92	17.1
Total PV	$ Mil	--	--	0.5	0.5	108	112	181	204	30.7
Unit Costs[6]										
Capital	$/gpd	--	--	0	0	3.6	3.4	8.1	7.9	--
Total PV	$/gpd	--	--	0.05	0.04	8.3	7.9	13.9	14.4	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Use the anaerobic selectors for biological phosphorus removal once the current upgrade is complete. Ferric chloride addition upstream of the primary clarifiers to increase phosphorus removal can be used as a backup in case additional phosphorus removal is needed. No feasible alternatives were identified for nitrification or nitrogen removal, because tankage is not available to increase solids retention time.

The South SF-SB WQCP is considered a candidate for sidestream treatment to reduce nitrogen and phosphorus loads as the plant anaerobically digests biosolids and dewaters to produce a return sidestream laden with both nitrogen and phosphorus. The recommended sidestream treatment strategy is a conventional nitrification technology for reducing ammonia/total nitrogen loads and chemical precipitation of phosphorus for reducing phosphorus loads.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Add ferric chloride upstream of primary clarifiers for phosphorus removal existing chemical addition facilities,
    b. Convert the existing aeration basins to BNR tanks in the MLE configuration, and construct additional aeration basins. Construct new blowers, carbon addition facilities, and alkalinity addition facilities.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Construct additional aeration tanks, and configure all aeration tanks as 4-stage BNR. Carbon addition would be used to meet Level 3 nitrogen limits.
    c. Construct conventional filters with ferric chloride dosing for phosphorus polishing.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $0.5 Mil for dry season optimization up to $204 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The City of South San Francisco and San Bruno Water Quality Control Plant (South SF-SB WQCP) services a population of about 110,500, which includes the industrial, commercial, and domestic wastewater from the cities of South San Francisco and San Bruno, the Town of Colma and portions of the City of Daly City. It is located at 195 Belle Air Road, South San Francisco, CA.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The South SF-SB WQCP holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2014-0012, NPDES Permit No. CA0038130). The treated wastewater is discharged to the Lower San Francisco Bay through a common outfall under the joint powers authority of the North Bayside System Unit (NBSU). The NBSU is a joint powers authority comprised of the cities of Burlingame, Millbrae, South San Francisco and San Bruno and the San Francisco International Airport. The South SF-SB WQCP discharge is located at latitude 37.66° N and longitude -122°.36 W.

Table 2-1 provides a summary of the permit limitations that are specific to the South SF-SB WQCP and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2014-0012; CA0038130)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak
Flow	mgd	13[1]	---	---	---	-
BOD	mg/L	---	30	45	---	-
TSS	mg/L	---	30	45	---	-
Total Ammonia, as N	mg/L	---	110	---	190	-

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

1. Current permitted capacity. Permitted capacity for peak wet weather flow with secondary treatment is 30 mgd. When influent flow exceeds 30 mgd, excess primary effluent receives separate disinfection and then combines with secondary treatment prior to dechlorination and disposal. When the Plant's effluent (NBSU pipeline) flow rate exceeds 64 mgd, fully treated effluent is pumped to a 7 million-gallon effluent storage pond.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the South SF-SB WQCP. Only liquids processes are shown. The South SF-SB WQCP consists of screening and grit removal, primary clarification, followed by conventional activated sludge for secondary treatment. Flow is split between two sets of aeration basin trains. One set includes selector zones. Most of the effluent nitrogen is ammonia, indicating that the plant does not consistently nitrify. Secondary effluent is disinfected by chlorination. Solids treatment consists of secondary sludge thickening, anaerobic digestion and belt filter press dewatering.

When influent flow exceeds 30 mgd, excess primary effluent receives separate disinfection and then combines with secondary treatment prior to dechlorination and disposal. When the Plant's effluent (NBSU pipeline) flow rate exceeds 64 mgd, fully treated effluent is pumped to a 7 million-gallon effluent storage pond.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the South SF-SB WQCP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	8.4	8.8	8.6	11.4
BOD	lb/d	26,000	27,300	28,200	30,700
TSS	lb/d	25,100	25,300	27,600	28,700
Ammonia	lb N/d	2,380	2,340	2,510	2,700
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	3,950	3,880	4,150	4,470
Total Phosphorus (TP)[4]	lb P/d	610	600	650	700
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	370	370	390	320
TSS	mg/L	360	350	380	300
Ammonia	mg N/L	34	32	35	28
TKN[4]	mg N/L	56	53	58	47
TP[4]	mg P/L	8.8	8.3	9.0	7.3
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Annual average TKN and TP based on eleven samples collected between July 2012 and June 2014. TKN and TP for other conditions were calculated using the ammonia peaking factors.

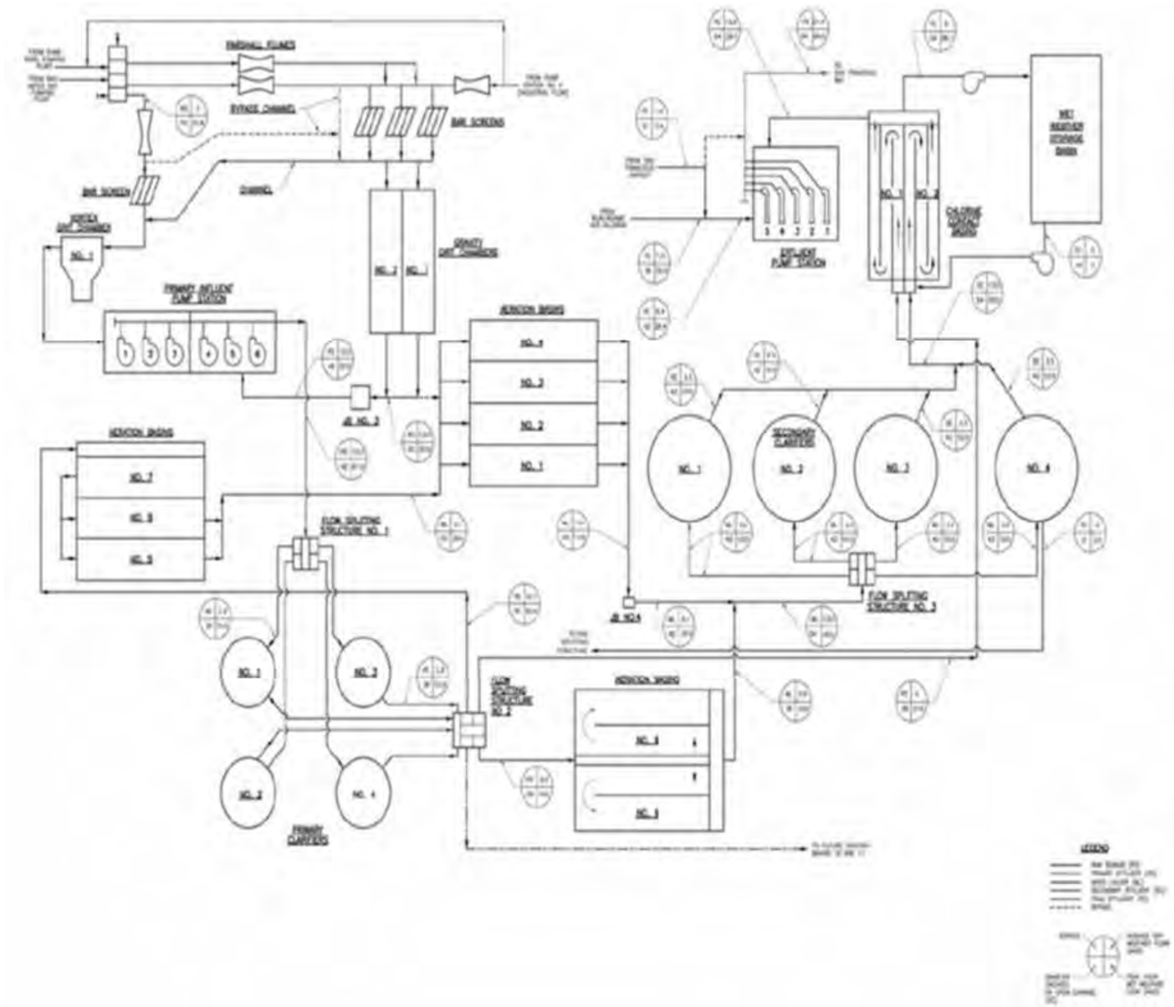

Figure 2-1. Process Flow Diagram for South SF-SB WQCP

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the South SF-SB WQCP:

- The facility is currently in the design phase of an upgrade project. The project will include a fourth secondary clarifier to increase wet weather capacity.
- The operational basins will also be upgraded. Unaerated selector zones will be added to the set of basins that currently do not have them (Basins 5-7). With the new anaerobic selectors, biological phosphorus removal is expected.
- Mixers will be upgraded in existing selector zones (Basins 8-9).
- Aeration basins 1 through 4 will be repaired (concrete and structural repairs) for use as primary influent equalization following grit removal. In the future, these tanks could be converted back to aeration basins.
- A recycled water study is ongoing.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the South SF-SB WQCP.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the South SF-SB WQCP are presented in Table 3-1. South SF-SB WQCP provided projections through 2040[4]. The projected flow and load for the South SF-SB WQCP in 2025 was interpolated from projections provided.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

[4] Carollo (2011). South San Francisco/San Bruno Water Quality Control Plant Facility Plan Update.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	9.5	12.3	9.7	14.3
BOD[5]	lb/d	27,600	30,200	29,900	37,400
TSS[5]	lb/d	21,200	21,400	23,300	35,800
Ammonia[6]	lb N/d	2,530	2,430	2,660	3,290
TKN[6]	lb N/d	4,180	4,030	4,400	5,440
TP[6]	lb P/d	650	630	680	850
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	350	300	370	310
TSS	mg/L	270	210	290	300
Ammonia	mg N/L	32	24	33	28
TKN	mg N/L	53	39	54	46
TP	mg P/L	8.3	7.0	8.7	7.4
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Interpolated from the projections provided. Dry season maximum month based on current flow peaking factors.
5. ADWF and year round maximum month interpolated from the projections provided. Other averaging periods based on current loading peaking factors.
6. Ammonia, TKN, and TP loading increase is proportional to BOD loading increase.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by the South SF-SB WQCP, it was determined that the South SF-SB WQCP is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the permitted capacity. The sidestream flows and loads for the permitted capacity are provided in Table 3-2. The permitted capacity flows and loads were used in the facility sizing.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Design Capacity (AA)
Sidestream Flow	mgd	0.06	0.09
Ammonia	lb N/d	530	820
TKN	lb N/d	1,130	1,750
TN[1]	lb N/d	1,130	1,750
TP	lb P/d	210	330
Ortho P	lb P/d	50	80
Alkalinity	lb $CaCO_3$/d	2,760	4,280
Ammonia	mg N/L	1,100	1,100
TKN	mg N/L	2,330	2,330
TN[1]	mg N/L	2,330	2,330
TP	mg P/L	440	440
Ortho P	mg P/L	100	100
Alkalinity	mg $CaCO_3$/L	5,700	5,700

1. It was assumed that TN = TKN

Table 3-3. Flow and Load for Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	13.0	13.5	13.4	17.7
BOD	lb/d	40,300	42,200	43,600	47,500
TSS	lb/d	38,900	39,100	42,800	44,400
Ammonia	lb N/d	3,690	3,620	3,880	4,180
TKN	lb N/d	6,110	6,000	6,430	6,920
TP	lb P/d	950	930	1,000	1,080
Alkalinity	lb/d as $CaCO_3$	---	---	---	---
BOD	mg/L	370	370	390	320
TSS	mg/L	360	350	380	300
Ammonia	mg N/L	34	32	35	28
TKN	mg N/L	56	53	58	47
TP	mg P/L	8.8	8.3	9.0	7.3
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. ADWF based on permitted average dry weather flow. Other flows and loads are based on current flow and loading characteristics.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Six optimization strategies were identified during the South SF-SB WQCP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The six optimization strategies were screened down to three strategies described below.

- **Optimization Strategy 1:** Use the anaerobic selectors for biological phosphorus removal (once upgrade is completed).
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** The plant is currently in the design phase of an upgrade project, which includes the addition of anaerobic selector zones with mixers in all operating basins. Once complete, biological phosphorus removal is expected.
  - ***Recommendation:*** Carry forward.
- **Optimization Strategy 2:** Increase the ferric chloride dose to the primary clarifiers to increase phosphorus removal using chemically enhanced primary treatment (CEPT). Plant currently adds 15 mg/L of ferric chloride, as well as polymer.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Strategy 1 (biological phosphorus removal) may achieve similar performance without chemical addition, but chemical addition is included in case additional removal is necessary.
  - ***Recommendation:*** Carry forward as a backup to strategy 1.
- **Optimization Strategy 3:** Increase solids retention time (SRT) to fully nitrify and reduce ammonia concentrations. Optimize CEPT to unlock capacity so existing tanks can nitrify. Add mixed liquor recycle for nitrogen removal in unaerated zones.
  - ***Is it feasible?*** No, the existing tank volume is not sufficient for nitrification.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Reduce ammonia concentrations.
  - ***Result from analysis:*** Analysis indicates that the volume of the existing tanks is not sufficient for nitrification, even with CEPT.
  - ***Recommendation:*** Do not carry forward.

A combination of strategies 1 and 2 is the best apparent way to reduce effluent phosphorus loads. CEPT is included as a backup in case additional phosphorus removal is needed. No feasible alternatives were identified for nitrification or nitrogen removal, because tankage is not available to increase solids retention time.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

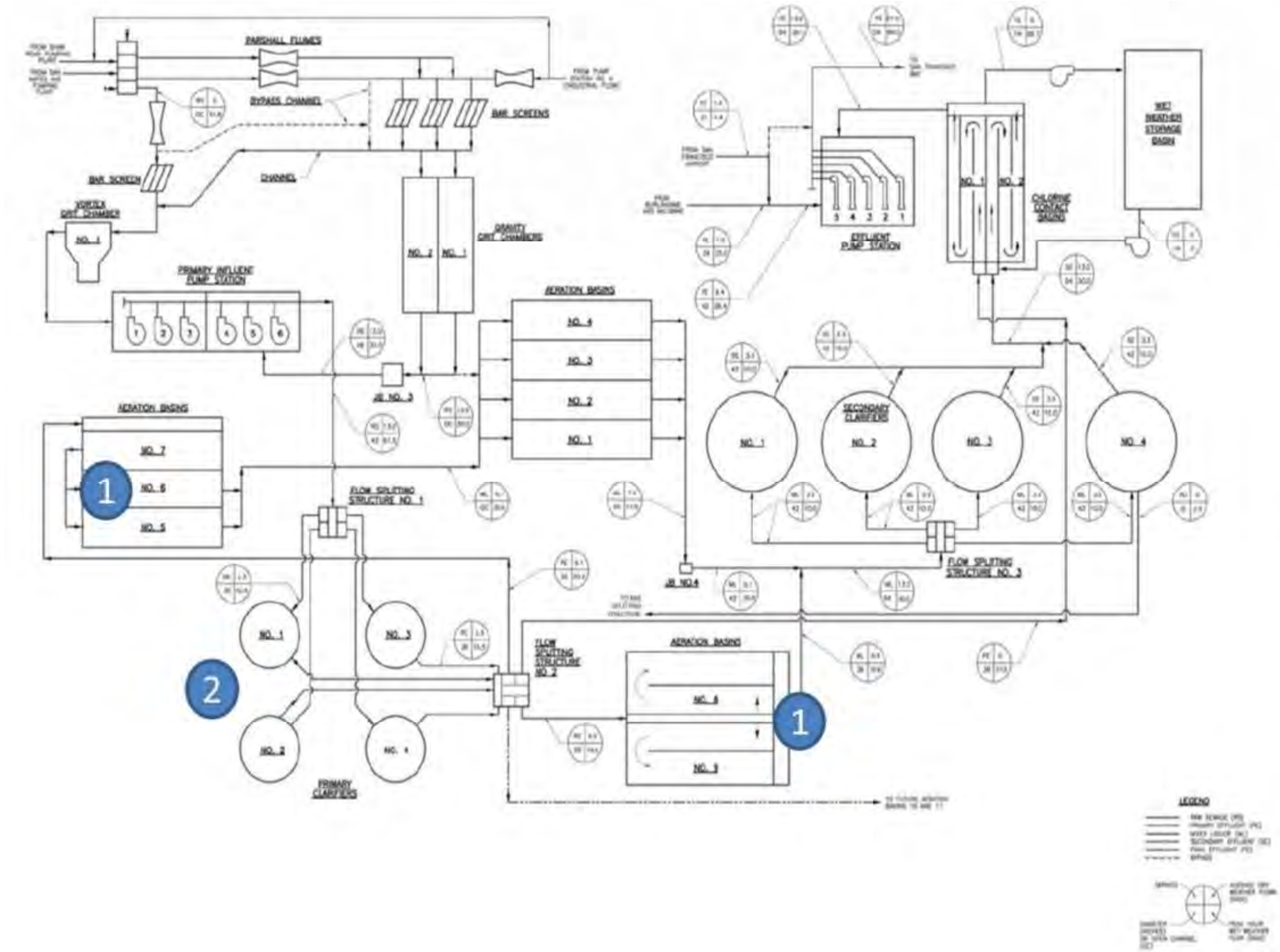

Figure 4-1. Optimization Concepts Considered for the South SF-SB WQCP

(1) use anaerobic selectors for biological phosphorus removal, and (2) addition of ferric chloride for P removal using existing chemical addition facilities, in case biological phosphorus removal is not sufficient.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
None for biological phosphorus removal. Improvements to selector zones are already in progress.	Operate anaerobic selector zones.
None for ferric chloride addition, since CEPT facilities are existing	Ferric chloride cost is not included, since the anaerobic selectors are anticipated to provide sufficient removal.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The South SF-SB WQCP plant shows improved phosphorus removal, but no change in nitrogen removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	1,910	1,910	2,600	2,600	360	360
Discharge with Opt. Strategy[1]	lb N or P/d	1,910	1,910	2,600	2,600	100	90
Load Reduction[2,3]	lb N or P/d	0	0	0	0	270	270
Load Reduction[2,3]	%	0%	0%	0%	0%	74%	75%
Annual Load Reduction	lb N or P/yr	0	0	0	0	97,000	99,000

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Capital costs for the current upgrade are not included in these costs. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce phosphorus; no optimization strategy was identified for nitrogen.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	9.5	12.3
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.0	0.0
Annual O&M	$ Mil/yr	0.1	0.1
Present Value O&M[3]	$ Mil	0.5	0.5
Present Value Total[3]	$ Mil	0.5	0.5
Unit Capital Cost[8]	$/gpd	0	0
Unit Total PV Cost[8]	$/gpd	0.05	0.04
TN Removal			
Capital[2,4]	$ Mil	0.0	0.0
Annual O&M[4]	$ Mil/yr	0.0	0.0
O&M PV[3,4]	$ Mil	0.0	0.0
Total PV[3,4]	$ Mil	0.0	0.0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0.0	0.0
Annual O&M[5]	$ Mil/yr	0.1	0.1
O&M PV[3,5]	$ Mil	0.5	0.5
Total PV[3,5]	$ Mil	0.5	0.5
TP Removed (Ave.)[6]	lb P/d	270	270
Annual TP Removed (Ave.)[7]	lb P/yr	97,000	99,000
TP Cost[5,9]	$/lb P	0.5	0.5

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• Phosphorus reliably removed • Potential for improved settleability in the secondary clarifiers	• Biological phosphorus removal sludge can be difficult to dewater, and can cause struvite precipitation in solids processing.

5 Sidestream Treatment

As previously described, the South SF-SB WQCP was identified as a potential candidate for sidestream treatment. The South SF-SB WQCP currently uses anaerobic digesters, followed by dewatering belt filter presses.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a conventional nitrifying sidestream treatment technology is recommended for ammonia/TN load reduction and metal salts/solids separation facilities for total phosphorus load reduction.

Conventional nitrification is recommended at the South SF-SB WQCP over the innovative deammonification technologies due to concerns over low sidestream treatment design temperatures. South SF-SB WQCP typically dewaters about 5 days per week. A flow equalization feed tank would be required to balance flows for periods when dewatering is off-line. During such periods, the water in the flow equalization tanks would cool down to ambient temperatures. Additionally, this temperature concern is exacerbated with the presence of ambient washwater required to operate their belt filter presses. Given the potentially wide range of operating temperatures (about 15 to 30 degrees C), the robust conventional nitrification technology is recommended to reliably treat such a wide range of temperatures.

Conventional nitrifying sidestream treatment is an established technology where ammonia is oxidized to nitrate. The nitrate formed in the sidestream is expected to be removed in the main stream process via biological denitrification at either the headworks and/or primary clarifiers. Nitrate removal in the main stream process is easier than sidestream denitrification where organic carbon is not readily available.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. South SF-SB WQCP might be able to leverage the existing ferric chloride and polymer chemical feed facilities that feed upstream of the primary clarifiers. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks).

Another option to consider for eliminating the phosphorus recycled stream load is recovery via struvite precipitation. This process produces a useful byproduct (struvite crystals) that can be sold economically. The finances are typically more attractive for larger plants (>40 mgd). It is recommended that the South SF-SB WQCP evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant if phosphorus load reduction is required in the future.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nitrogen Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb N or P/d	2,360	3,220	450
Discharge with Sidestream Treatment[2]	lb N or P/d	1,750	2,680	390
Load Reduction[3]	lb N or P/d	610	540	60
Load Reduction	%	26%	17%	14%
Annual Load Reduction[3]	lb N or P/yr	222,800	198,000	22,300

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	13.3	0.3
Annual O&M	$ Mil/yr	0.7	0.04
Total Present Value[2]	$ Mil	29.5	1.2
NH4-N Load Reduction[3,5]	lb N/yr	222,800	--
TN Load Reduction[3,5]	lb N/yr	198,000	--
TP Load Reduction[4,5]	lb P/yr	--	22,300
NH4-N Cost [3,5,6]	$/lb N	4.4	--
TN Cost [3,5,6]	$/lb N	5.0	--
TP Cost [4,5,6]	$/lb P	--	1.8

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the South SF-SB WQCP plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The South SF-SB WQCP should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Ferric chloride addition to the primary clarifiers is assumed for phosphorus removal. Level 2 nitrogen limits could be met by converting the existing aeration basins to BNR tanks in the Modified Ludzack-Ettinger (MLE) configuration, and constructing additional aeration basins. New blowers would also be required. Based on the low carbon to nitrogen ratio measured in the primary effluent, capital costs for carbon addition facilities (methanol) are included to provide carbon if needed for denitrification, but no methanol is included in the operating costs. Based on available alkalinity and nitrogen data, alkalinity addition will be needed for nitrification.

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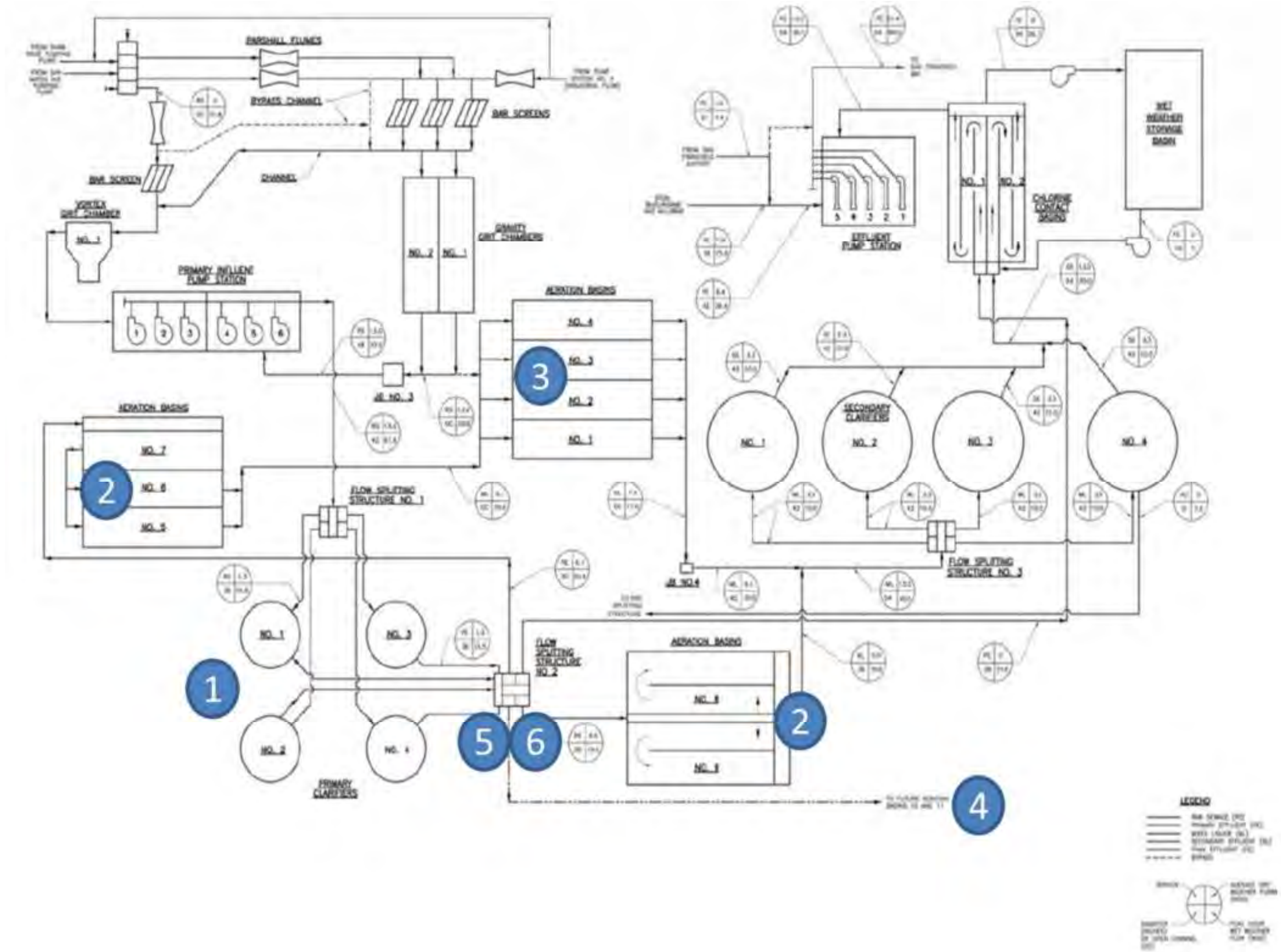

Figure 6-1. Level 2 Upgrade Concept for South SF-SB WQCP

(1) ferric chloride for P removal using existing chemical addition facilities, (2) configure aeration basins 5-9 as MLE with IMLR, (3) rebuild aeration basins 1-4 as MLE, including structural repair, flow distribution, baffles, mixers, diffusers, and mixed liquor recycle pumping, (4) construct new MLE tanks, (5) construct alkalinity addition facilities to provide alkalinity for nitrification, and (6) construct methanol addition facilities to provide a carbon source for denitrification.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Additional aeration tanks are required, and all aeration tanks would be configured as 4-stage BNR. Carbon addition would be used to meet Level 3 nitrogen limits. Chemical addition and tertiary filtration for phosphorus polishing could be used to meet Level 3 phosphorus limits. Ferric chloride addition before both primary clarification and filtration is assumed.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

6.4 Project Costs for Level 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Existing ferric chloride feed facilities	Same as Level 2
Secondary	• Rebuild aeration basins 1-4 as MLE, including structural repair, flow distribution, baffles, mixers, diffusers, and mixed liquor recycle pumping • Convert aeration basins 5-9 to MLE with IMLR • Construct new deep (22 ft) BNR tanks (MLE), including baffles, mixers, and mixed liquor recycle pumping in an area that may have contaminated soil. • New blowers • Alkalinity addition facilities • External carbon source addition facilities	Same as Level 2 plus: • Ferric chloride addition before filtration for phosphorus polishing • Construct additional deep BNR tanks, and configure all BNR tanks as 4-stage BNR.
Tertiary	---	Same as Level 2 plus: • Conventional Filters • Ferric chloride addition before filtration for phosphorus polishing

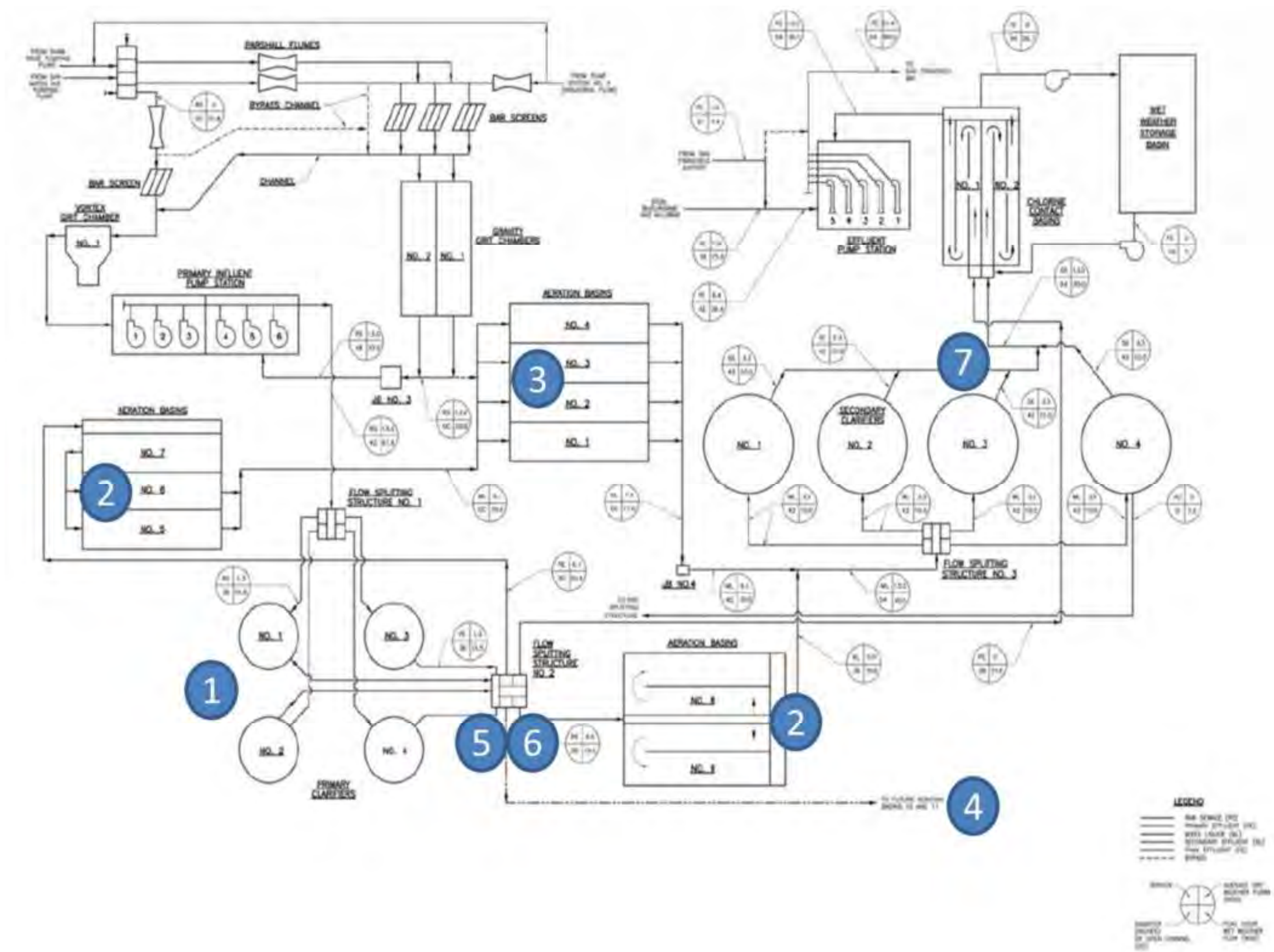

Figure 6-2. Level 3 Upgrade Concept for South SF-SB WQCP

(1) ferric chloride for P removal using existing chemical addition facilities, (2) configure aeration basins 5-9 as 4-stage BNR with additional baffles, mixers, and IMLR, (3) rebuild aeration basins 1-4 as 4-stage BNR, including structural repair, flow distribution, baffles, mixers, diffusers, and mixed liquor recycle pumping, (4) construct new 4-stage BNR tanks, (5) construct alkalinity addition facilities to provide alkalinity for nitrification, (6) construct methanol addition facilities to provide a carbon source for denitrification, and (7) granular media filters.

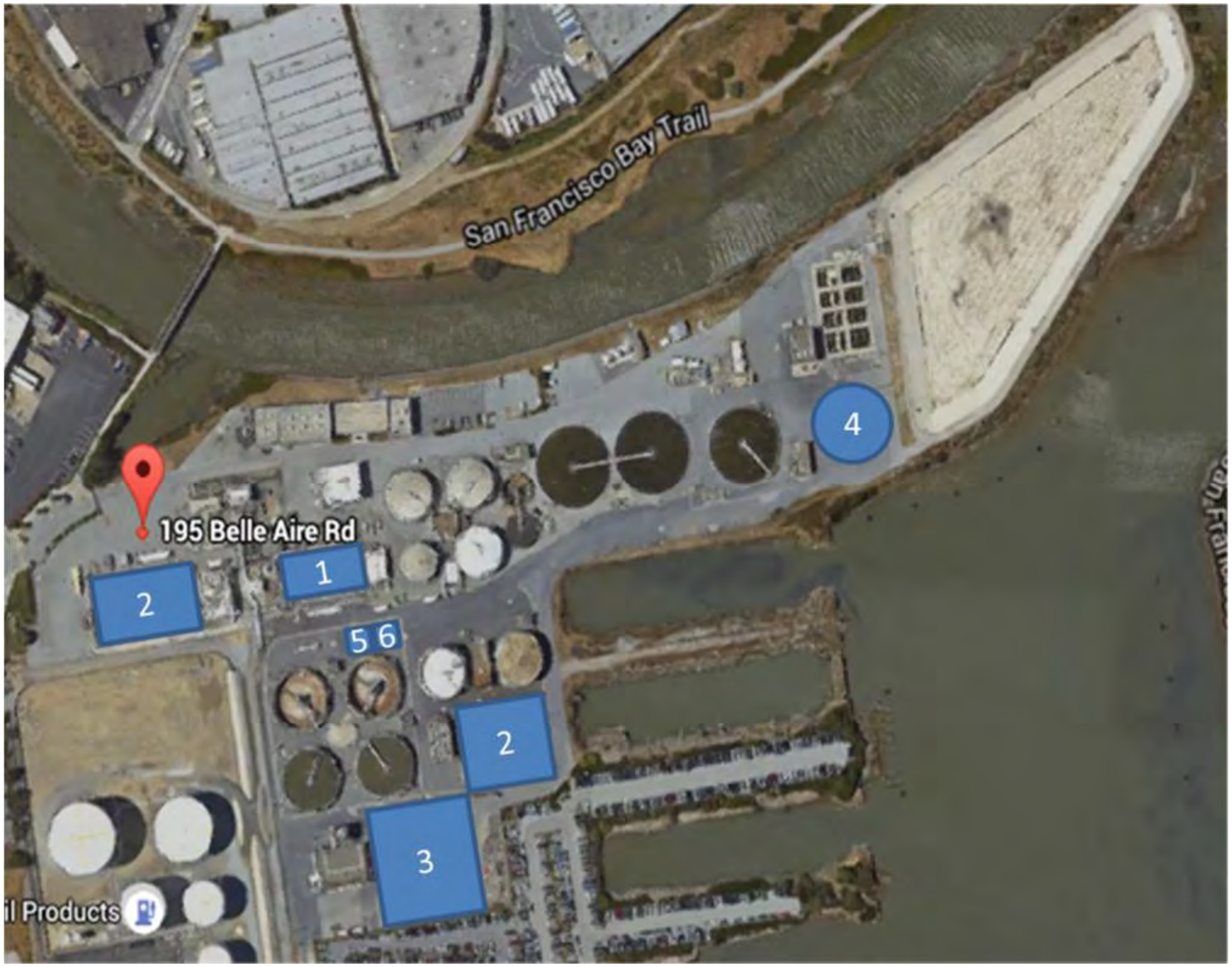

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) rebuild aeration basins 1-4 as MLE, including structural repair, flow distribution, baffles, mixers, diffusers, and mixed liquor recycle pumping, (2) convert aeration basins 5-9 to MLE with IMLR, (3) construct new MLE tanks, (4) fourth clarifier (currently in design), (5) construct alkalinity addition facilities to provide alkalinity for nitrification, and (6) construct methanol addition facilities to provide a carbon source for denitrification.

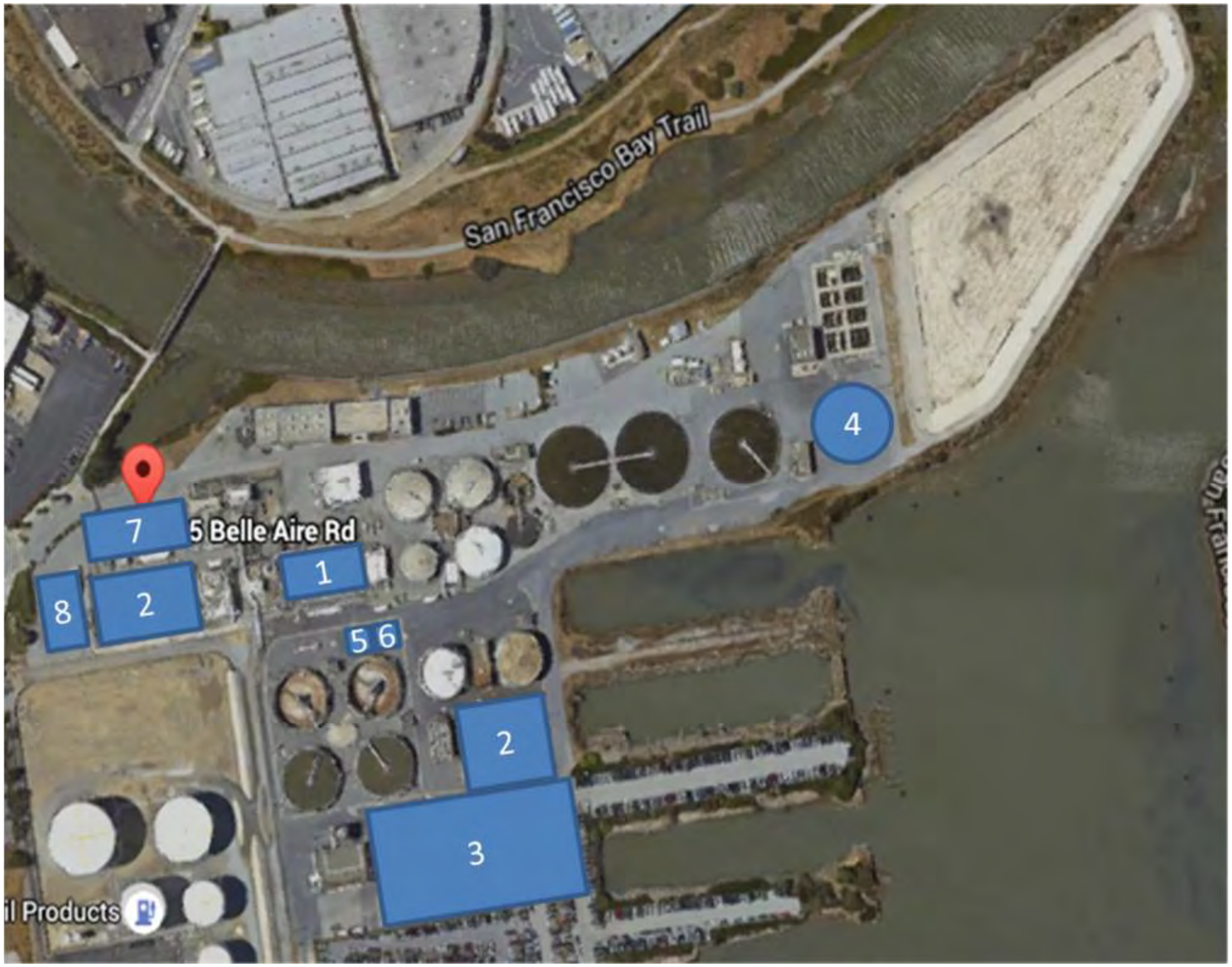

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) rebuild aeration basins 1-4 as 4-stage BNR, including structural repair, flow distribution, baffles, mixers, diffusers, and mixed liquor recycle pumping, (2) convert aeration basins 5-9 to 4-stage BNR with additional baffles, mixers, and IMLR, (3) construct new 4-stage BNR tanks, (4) fourth clarifier (currently in design), (5) construct alkalinity addition facilities to provide alkalinity for nitrification, (6) construct methanol addition facilities to provide a carbon source for denitrification, (7) filters for dry season flows, (8) additional filters for full filtration of wet season flows.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	13.0	14.1	13.0	14.1
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	47	48	106	112
Annual O&M	$Mil/yr	2.7	2.9	3.4	4.1
O&M PV[3]	$ Mil	60	64	75	92
Total PV[3]	$ Mil	108	112	181	204
Unit Capital Cost	$/gpd	3.6	3.4	8.1	7.9
Unit Total PV	$/gpd	8.3	7.9	13.9	14.4
TN Removal					
Capital[2,4]	$ Mil	47	48	82	82
Annual O&M[4]	$ Mil/yr	2.6	2.7	2.9	3.2
O&M PV[3,4]	$ Mil	58	61	65	71
Total PV[3,4]	$ Mil	105	109	147	153
TN Removed (Ave.)[6]	lb N/d	1,730	1,820	2,150	2,660
Annual TN Removed (Ave.)[7]	lb N/yr	630,000	664,000	786,000	970,000
TN Cost[4,8]	$/lb N	5.6	5.5	6.2	5.3
TP Removal					
Capital[2,5]	$ Mil	0	0	24	30
Annual O&M[5]	$ Mil/yr	0.1	0.1	0.5	0.9
O&M PV[3,5]	$ Mil	2.8	3.2	10	21
Total PV[3,5]	$ Mil	2.8	3.2	34	50
TP Removed (Ave.)[6]	lb P/d	350	350	380	420
Annual TP Removed (Ave.)[7]	lb P/yr	127,000	129,000	139,000	153,000
TP Cost[5,8]	$/lb P	0.7	0.8	8.1	10.9

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage the existing aeration tanks, selector zones, and secondary clarifiers • Robust technology to absorb variability in flows and loads • Ability to reliably remove TN and TP • More organics and solids diverted to fuel the digester	• Increased operation costs associated with ferric addition • Increased energy demand for aeration • Dependency on chemicals • Increased sludge production
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use and additional alum use • Higher energy costs for filter feed pumping

7 Nutrient Removal by Other Means

The South SF-SB WQCP does not currently produce recycled water. Planning studies have identified 950 acre-feet per year (310 million gallons per year) of industrial and irrigation demands.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

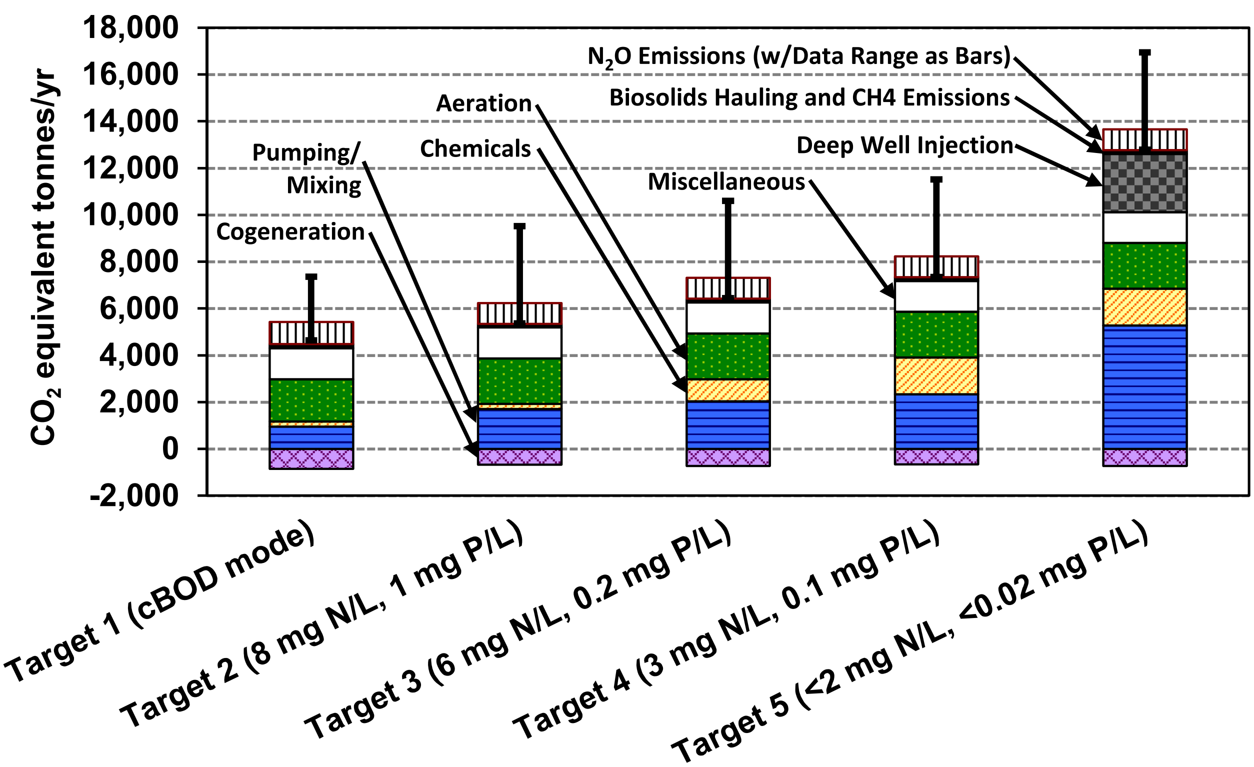

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[5] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[5] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	24	24	2,500	2,600	3,300	3,400	82
GHG Emissions Increase from Chemicals	MT CO_2/yr	3	6	1,000	1,000	1,400	1,400	3
GHG Emissions Increase Total	MT CO_2/yr	27	30	3,500	3,600	4,700	4,800	85
Unit GHG Emissions[2]	lb CO_2/MG	15	16	1,600	1,600	2,100	2,100	51
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	9.8	9.9	9.9	10	0.9
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	12.2	11.9	11.4	9.4	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	0.6	0.7	0.4	0.4	10	9.7	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the South SF-SB WQCP. These are:

- Nitrite Shunt – South SF-SB WQCP aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Simultaneous nitrification/denitrification (SND) – South SF-SB WQCP aeration basins would be operated at low dissolved oxygen (DO) levels to promote SND. Under this operating scenario, nitrification and denitrification occurs in the same tankage and dedicated anoxic zones are not necessary. As a result, there is a significant reduction in aeration requirements. This requires the installations of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.33

City of Sunnyvale

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

City of Sunnyvale

Sunnyvale, CA

May 18, 2018
Final Report

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Executive Summary

The Sunnyvale Water Pollution Control Plant (WPCP) discharges to a tributary of South San Francisco Bay. It is located at 1444 Borregas Ave, Sunnyvale, CA 94088 and it serves approximately 28,300 service connections throughout the City of Sunnyvale, Rancho Rinconada, and Moffett Field. The plant currently has an average dry weather flow (ADWF) permitted capacity of 29.5 million gallons per day (mgd) but is in the process of de-rating the plant to 19.5 mgd ADWF.

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/lb N or P) were developed for each strategy, as appropriate. Unit costs include only the respective facilities and costs needed to address ammonia, total nitrogen (TN) or total phosphorus (TP) load reductions, respectively.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3,7]	Opt. Year Round[3,7]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	--[7]	--[7]	19.5	19.5	19.5	19.5	--
Flow to Bay[2]	mgd	10.6	10.6	--[7]	--[7]	13.6	13.6	13.6	13.6	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	410	410	--[7]	--[7]	230	230	230	230	440
TN	lb N/d	1,970	1,970	--[7]	--[7]	1,830	1,700	1,350	680	1,520
TP	lb P/d	470	470	--[7]	--[7]	120	110	90	30	350
Costs[4,5]										
Capital	$ Mil	--	--	--[7]	--[7]	242	244	383	388	16.4
O&M PV	$ Mil	--	--	--[7]	--[7]	44	48	66	92	11.6
Total PV	$ Mil	--	--	--[7]	--[7]	286	292	448	480	28.0
Unit Costs[6]										
Capital	$/gpd	--	--	--[7]	--[7]	12	13	20	20	--
Total PV	$/gpd	--	--	--[7]	--[7]	15	15	23	25	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. The plant is currently optimized and performing ammonia and total nitrogen removal so no nutrient optimization concepts were recommended.

No optimization is recommended because the Sunnyvale WPCP is already nitrifying and denitrifying a portion of the load. In addition, in 2017 the City began the design and construction of a major upgrade to accommodate future nutrient removal.

The Sunnyvale WPCP is considered a candidate for sidestream treatment to reduce ammonia, total nitrogen, and total phosphorus discharge loads. The recommended sidestream treatment technology is a deammonification technology for ammonia/total nitrogen load reduction and a metal salts chemical precipitation technology for total phosphorus load reduction.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Build new headworks and primary sedimentation tanks (decommission the existing facilities).
    b. Add a metal salt coagulant (e.g., ferric chloride) to the primary sedimentation tanks to remove total phosphorus.
    c. Perform split treatment where approximately one-third of the primary effluent is pumped to the existing ponds, fixed growth reactors (FGRs) and dissolved air flotation tanks (AFTs) for ammonia and nitrogen load reduction.
    d. Construct a new activated sludge facility that will treat the remaining flow (approximately two-thirds) for ammonia and nitrogen load reduction. This system will include all the facilities associated with an activated sludge system for performing nitrification/denitrification (e.g., aeration basins, secondary clarifiers, RAS/WAS pumping, aeration system and diffusers, mixed liquor return pumping, etc.).
    e. Add a sidestream treatment reactor that will reduce ammonia/total nitrogen loads and provide biological seed for the new activated sludge facility. Credit was not taken for any activated sludge basin volume savings associated with seeding as this is an emerging concept.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L):
    a. Same as Level 2 for headworks, primary sedimentation tanks, metal salt coagulant addition to the primary sedimentation tanks, sidestream treatment, plus:
    b. Decommission the ponds, FGRs, and AFTs.
    c. Construct an approximately 8-MG flow equalization pond to attenuate the instantaneous peak flows.
    d. Expand the activated sludge system facilities for treating all the primary effluent flows and loads.
    e. Expand the existing filter complex and modify to operate as a denitrifying filter complex. The filter expansion would be sited at the existing chlorine contact tanks.
    f. Add an external carbon source at the filter complex for total nitrogen load reduction.
    g. Add metal salt/polymer chemical feed facilities at the filter complex for total phosphorus load reduction.
    h. Construct a new UV disinfection facility to replace the existing chlorine contact tanks.

Capital costs, O&M costs and present value costs were determined for sidestream treatment and the Level 2 and 3 upgrades. These costs do not account for changes in solids handling requirements or energy requirements in other unit processes.

As shown in Table ES-1, and as might be expected, the costs generally increase from sidestream treatment to the Level 2 and Level 3 upgrades. Overall, the present value costs range from $28 Mil for sidestream treatment up to $480 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Sunnyvale Water Pollution Control Plant (WPCP) discharges to the tributary of South San Francisco Bay. It is located at 1444 Borregas Ave, Sunnyvale, CA 94088 and it serves approximately 28,300 service connections throughout the City of Sunnyvale, Rancho Rinconada, and Moffett Field. The plant has an average dry weather flow (ADWF) permitted capacity of 29.5 million gallons per day (mgd). The plant will be de-rated to 19.5 mgd ADWF permitted capacity as part of an upcoming upgrade project.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The Sunnyvale WPCP holds National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2014-0035; CA0037621. Table 2-1 provides a summary of the permit limitations for the Sunnyvale WPCP. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Conditions (R2-2014-0035)

Parameter	Unit	Average Dry Weather[2]	Average Monthly	Average Weekly	Maximum Daily	Peak[3]
Flow[2]	mgd	29.5				40
BOD	mg/L		10	-	20	-
TSS	mg/L		20	-	30	-
Total Ammonia, as N (October-May)	mg/L		18	-	26	-
Total Ammonia, as N (June-September)	mg/L		2		5	

1. This table identifies relevant permit limitations only and does not include a complete list of permit limitations.
2. The average dry weather flow is in the process of being de-rated to 19.5 mgd ADWF permitted capacity as part of the upcoming upgrade project.
3. Represents the peak design flow (not permitted peak flow).

2.2 Process Flow Diagram

Figure 2-1 shows the current process flow diagram for the Sunnyvale WPCP. Wastewater treatment processes at the plant include grinding and grit removal, primary sedimentation, secondary and advanced treatment through the use of oxidation ponds, fixed-growth reactors (FGRs), dissolved air flotation tanks (DAFTs), dual media filtration, disinfection (chlorine gas), and dechlorination (sodium bisulfite). The ponds, FGRs, and DAFTs provide nitrification and partial denitrification. Sludge is anaerobically digested, dewatered on gravity drainage tiles and solar dried.

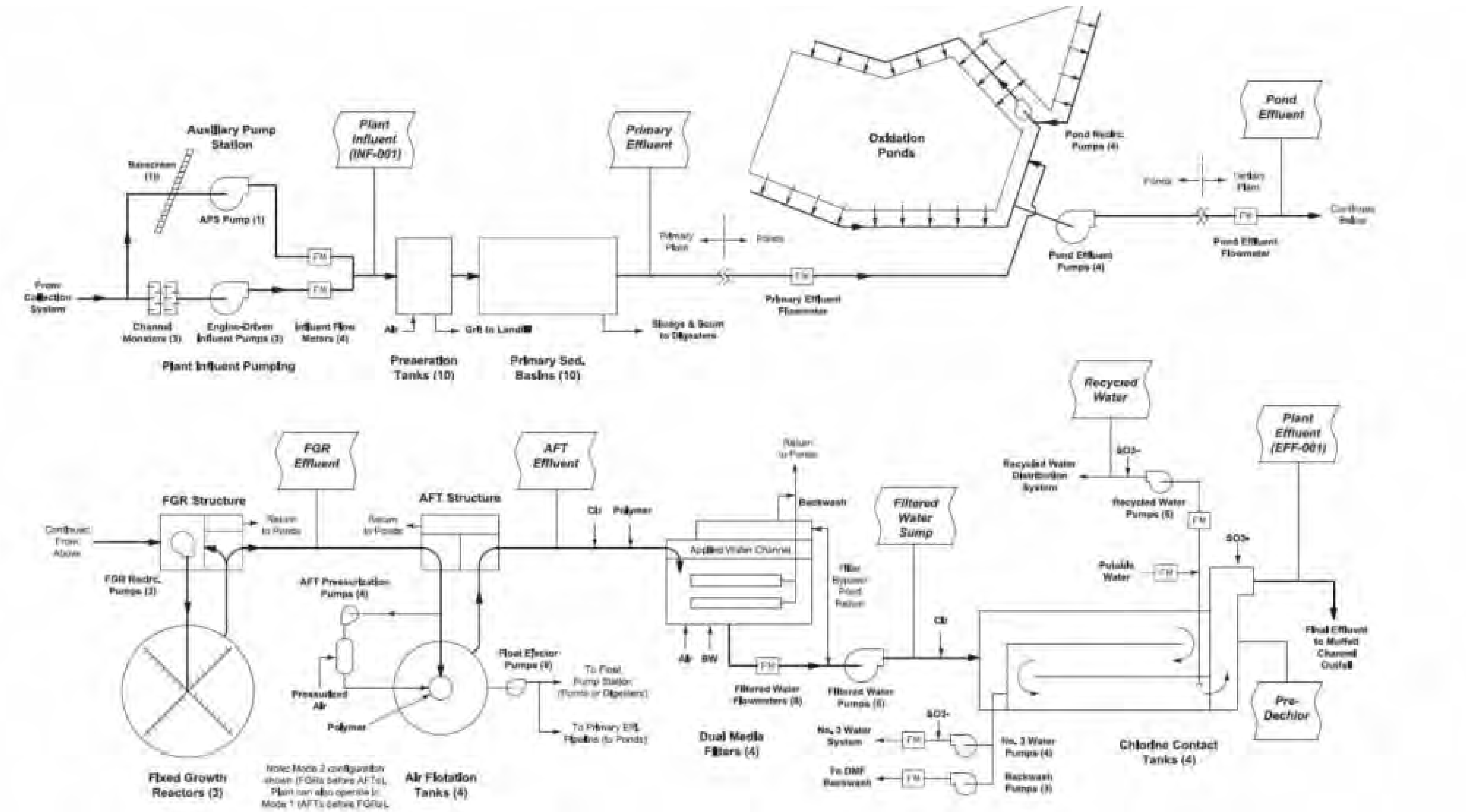

Figure 2-1. Process Flow Diagram for Sunnyvale WPCP (Source: R2-2014-0035)

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Sunnyvale WPCP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	13.2	13.2	13.6	14.3
BOD	lb/d	24,700	25,800	27,100	29,900
TSS	lb/d	28,700	30,600	34,500	37,800
Ammonia	lb N/d	3,200	3,200	3,800	3,800
Total Kjeldahl Nitrogen (TKN)	lb N/d	4,800	4,900	4,800	5,000
Total Phosphorus (TP)	lb P/d	650	640	650	640
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	225	234	240	252
TSS	mg/L	261	278	305	318
Ammonia	mg N/L	29	29	34	32
TKN	mg N/L	44	44	42	42
TP	mg P/L	5.9	5.8	5.7	5.4
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month
2. Nutrient data began in July of 2012.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

2.4 Future Nutrient Removal Projects

Sunnyvale is in the preliminary stages for a major upgrade of its secondary treatment process that is scheduled to begin in 2017 and which will accommodate future nutrient removal. The project entails adding the ability to operate in CEPT mode during wet weather events, and replacing the ponds, FGRs, and DAFTs with an activated sludge system designed for ammonia/total nitrogen removal. The first phase will perform parallel treatment where a portion of the flow will go through the FGRs and DAFTs, and the remaining flow through the activated sludge process. The second phase will treat all of the flow through the activated sludge process and decommission the ponds, FGRs, and DAFTs. The planning level efforts suggest that the design will achieve full nitrification and total nitrogen levels down to 15 mg N/L by yr 2024 (phase one), followed by 10 mg N/L by year 2033 (phase two).

2.5 Pilot Testing

Sunnyvale has not conducted any nutrient removal related pilot testing.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

As previously stated, no optimization is recommended because the Sunnyvale WPCP is already nitrifying and denitrifying a portion of the load. In addition, in 2017 the City began the design and construction of a major upgrade to accommodate future nutrient removal.

3.2 Flow and Loading for Sidestream Treatment

As part of the on-going upgrade and expansion project, it was determined that the WPCP is a candidate for sidestream treatment. Given the lack of data that would reflect future plant operations associated with the on-going upgrade and expansion project, an engineer's best judgment was applied for developing the sidestream design flows and loads as listed in Table 3-1. The design maximum month flows and loads were used in the facility sizing.

Table 3-1. Flow and Load for Sidestream Treatment (Based on Plant Permitted Capacity)

Criteria	Unit	Design Average Annual	Design Maximum Month
Sidestream Flow	mgd	0.14	0.18
Ammonia	lb N/d	1,080	1,320
TKN	lb N/d	1,140	1,390
TN [1]	lb N/d	1,140	1,390
TP	lb P/d	250	310
OrthoP	lb P/d	240	290
Alkalinity	lb $CaCO_3$/d	4,990	6,100
Ammonia	mg N/L	900	900
TKN	mg N/L	950	950
TN [1]	mg N/L	950	950
TP	mg P/L	210	210
OrthoP	mg P/L	200	200
Alkalinity	mg $CaCO_3$/L	4,200	4,200

1. It was assumed that TN = TKN.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the design flows and loadings for the planned upgrade.

Table 3-2. Flow and Load for Facility Upgrades (Based on Upgrade Project Loadings)

Parameter	Unit	Average Annual[2]	Year Round MM[1,2]
Flow	mgd	20.4	26.2
cBOD	lb/d	35,000	41,000
TSS	lb/d	41,000	51,000
Ammonia	lb N/d	3,800	4,600
TKN	lb N/d	5,400	6,600
TP	lb P/d	810	990
Alkalinity	lb/d as $CaCO_3$	---	---
cBOD	mg/L	206	188
TSS	mg/L	241	233
Ammonia	mg N/L	22	21
TKN	mg N/L	32	30
TP	mg P/L	4.8	4.5
Alkalinity	mg/L as $CaCO_3$	---	---

1. MM = Maximum Month.
2. Flows and loadings are based on the upgrade project design.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for, TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

Optimization concepts were not developed for the Sunnyvale WPCP since the existing plant configuration is already optimized for ammonia and total nitrogen load reduction. Additionally, the Sunnyvale WPCP is planning to initiate a design in 2017 that the first phase will be completed by year 2024.

The Sunnyvale WPCP is currently nitrifying and denitrifying a portion of the influent nitrogen load. Nitrification occurs within the fixed growth reactors (FGRs) and a portion of the nitrified FGR effluent is returned to the ponds for denitrification. In recent years, the FGR feed distribution arms rotational speed were reduced by reconfiguring the distribution arm nozzles and ammonia probes were added to the FGRs to optimize nitrification and address seasonality issues. Additionally, as ammonia removal rates show a decline in performance, the plant staff implements snail treatment (approximately twice per year) which results in immediate nitrification improvements.

5 Sidestream Treatment

As previously described, the Sunnyvale WPCP was identified as a potential candidate for sidestream treatment. The WWTP currently uses mechanical dewatering. The biosolids composition and in turn sidestream wastewater characteristics will be different than current with the upgrades and expansion project. Given that, an engineer's best judgment was made in projecting flows and loads as described in Section 3.2.

A deammonification sidestream treatment technology is recommended for total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature (common for WWTPs with mechanical dewatering). It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification), such as requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, requires 50 percent less alkalinity than conventional nitrification, and the wasted granulated solids could potentially serve as a seed for the main plant. Based on these benefits, deammonification is recommended for the WPCP.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks).

Another option to consider for eliminating the phosphorus recycled stream load is recovery via struvite precipitation. This process produces a useful byproduct (struvite crystals) that can be sold economically. The finances are typically more attractive for larger plants (>40 mgd). It is recommended that the Sunnyvale WPCP evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant if phosphorus load reduction is required in the future.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)[4]	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	440	2,140	510
Discharge with Sidestream Treatment[2]	lb/d	440	1,520	350
Load Reduction[3]	lb/d	0	630	160
Load Reduction	%	0%	29%	32%
Annual Load Reduction[3]	lb/yr	0	228,400	60,230

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
4. The plant already fully nitrifies so any sidestream treatment or upgrades will only improve ammonia load reduction reliability.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	15.8	0.6
Annual O&M	$ Mil/yr	0.39	0.13
Total Present Value[2]	$ Mil	24.4	3.6
NH4-N Load Reduction[3,5,7]	lb N/yr	0	--
TN Load Reduction[3,5]	lb N/yr	228,400	--
TP Load Reduction[4,5]	lb P/yr	--	60,230
NH4-N Cost [3,5,6]	$/lb N	--	--
TN Cost [3,5,6]	$/lb N	3.6	--
TP Cost [4,5,6]	$/lb P	--	2.0

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. The plant already fully nitrifies so any sidestream treatment or upgrades will only improve ammonia load reduction reliability.

6 Nutrient Reduction Upgrades

As previously stated, the City of Sunnyvale is in the conceptual design stages for a major upgrade project that began in 2017 for removing nutrients at the plant. The design will be able to meet a total nitrogen discharge target of 15 mg N/L by year 2024.

The development of upgrade strategies was based on the Sunnyvale WPCP Master Plan recommendations for an activated sludge system coupled with updates from the City regarding the on-going design. The design will occur in two separate phases. Phase one of the on-going upgrades includes the new headworks/primaries, split treatment where a portion of the flow will go through the existing ponds, fixed growth reactors (FGRs), and dissolved air flotation units (AFTs), the remaining flow through a new activated sludge process, a sidestream treatment reactor, and others. The second phase will treat all of the flow through the activated sludge process, construct a flow equalization basin to attenuate peak flows, decommission the ponds, FGRs, and DAFTs, and others.

The facilities for Level 3 are intended to expand upon the Level 2 facilities to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements.

6.1 Plant Upgrades to Meet Level 2

The plant upgrades to meet Level 2 include the Master Plan recommendations of a new headworks/ primaries, the previously described phase one split treatment approach for meeting the ammonia and total nitrogen limits, and a metal salt coagulant (e.g., ferric chloride) dosing at the primaries to meet the total phosphorus limit.

The process flow diagram for Level 2 upgrades is presented in Figure 6-1. The upgrades include the cost associated with constructing new headworks and primaries plus the decommissioning costs. The primaries would be dosed a metal salt coagulant on a daily basis. The existing ponds, FGRs, and AFTs will treat approximately one-third of the primary effluent. The remaining primary effluent (approximately two-thirds) will be treated with a new activated sludge system that operates as a Modified Ludzack-Ettinger (MLE) configuration with all the corresponding facilities (e.g., aeration basins, aeration system, mixed liquor return pumping/piping, secondary clarifiers, return and waste activated sludge, etc.).

The mechanical dewatering return stream would be treated with a deammonification reactor (same as listed in Section 5). The wasted solids from the deammonification reactor can be concentrated and serve as a biological seed to the MLE reactor. The seed has the potential to intensify the MLE process and subsequently reduce basin volume requirements. Basin volume savings credit was not taken for intensifying the MLE reactor as this is an emerging concept. However, it is recommended that the City monitor this strategy to potentially reduce the reactor volumes required in phase two.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2. The ponds, FGRs, and AFTs would be decommissioned, a flow equalization basin would be constructed to attenuate peak flows, and the MLE activated sludge basin volume and the number of secondary clarifiers would be increased to treat all the primary effluent flows and loads. Following the MLE activate sludge facilities, the existing filters would be expanded and modified to operate a denitrifying filters. The filters would require an external carbon source chemical feed facilities to meet the total nitrogen limits. The filters would also require metal salt and polymer chemical feed facilities upstream of the filters to precipitate phosphorus prior to filtration for meeting the total phosphorus limits. The filter expansion would likely occur on the existing chlorine contact tanks area. As a result, a new UV disinfection technology is recommended to replace the chlorine contact tanks.

Similar to Level 2 upgrades, a sidestream reactor will be used to treat the mechanical dewatering return stream. As previously stated, the wasted solids from the deammonification reactor can be concentrated and serve as a biological seed to the MLE and in turn reduce the MLE basin volume requirements. Basin volume savings credit was not taken for intensifying the MLE reactor as this is an emerging concept. However, it is recommended that the City monitor this strategy to potentially reduce the reactor volumes required in phase two.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Headworks	• New headworks and decommission the existing headworks	Same as Level 2
Primary	• New primaries and decommission the existing primaries • Metal salt coagulant chemical feed facilities	Same as Level 2
Flow Equalization	--	• Flow equalization in a portion of the existing ponds to attenuate primary effluent peak flows
Biological	• Continue to use the existing ponds, FGRs, and AFTs to treat a portion of the flows and loads. • Construct a new air activated sludge process (MLE configuration) to treat the remaining portion of flows and loads, which includes: o New anoxic zones o New aeration basins o Mixed liquor return pumping o Fine-bubble aeration system • Construct new secondary clarifiers with RAS and WAS pumping	Same as Level 2, plus: • Decommission the existing ponds, FGRs, and AFTs. • Expand the air activated sludge process (MLE configuration) to treat all the flow. • Expand the secondary clarifiers and RAS and WAS pumping
Tertiary	--	• Expand and modify the existing filter complex to operate as a denitrifying filter complex • Add an external carbon source chemical feed facilities • Metal salt chemical feed facilities • Polymer chemical feed facilities • New UV disinfection facility because the denitrifying filter complex would use the existing chlorine contact tanks area
Biosolids	• Sidestream treatment deammonification reactor	Same as Level 2

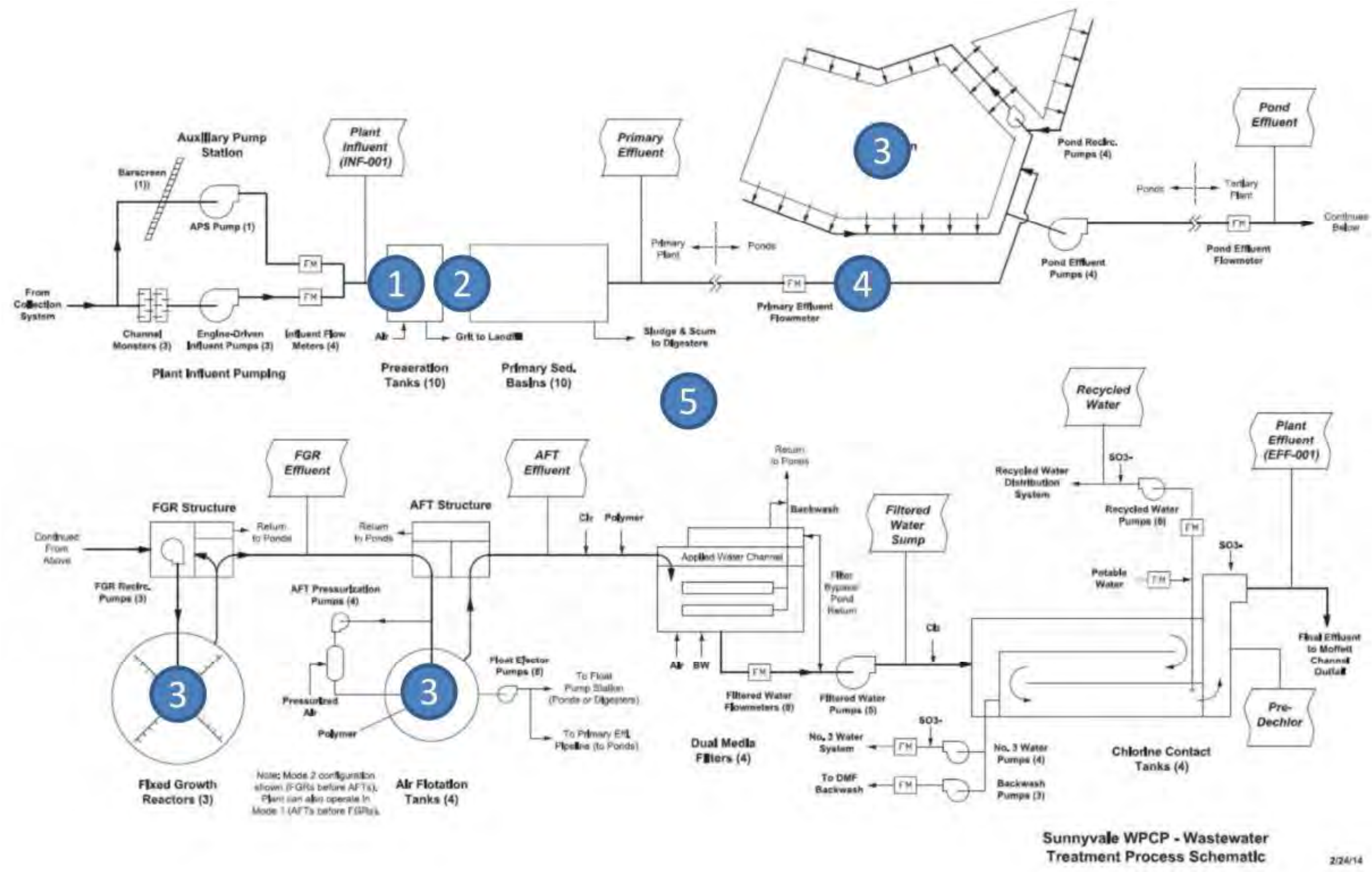

Figure 6-1. Level 2 Upgrade Concepts for Sunnyvale WPCP

(1) Decommission and construct a new headworks and primaries, (2) metal salt coagulant chemical feed facilities, (3) split treatment where a portion of flow is sent to the existing ponds/FGRs/AFTs, (4) the remaining flow is sent to the new activated sludge system (MLE configuration) with new secondary clarifiers, and (5) sidestream treatment using a deammonification technology (credit was not taken for seeding and intensifying the activated sludge system)

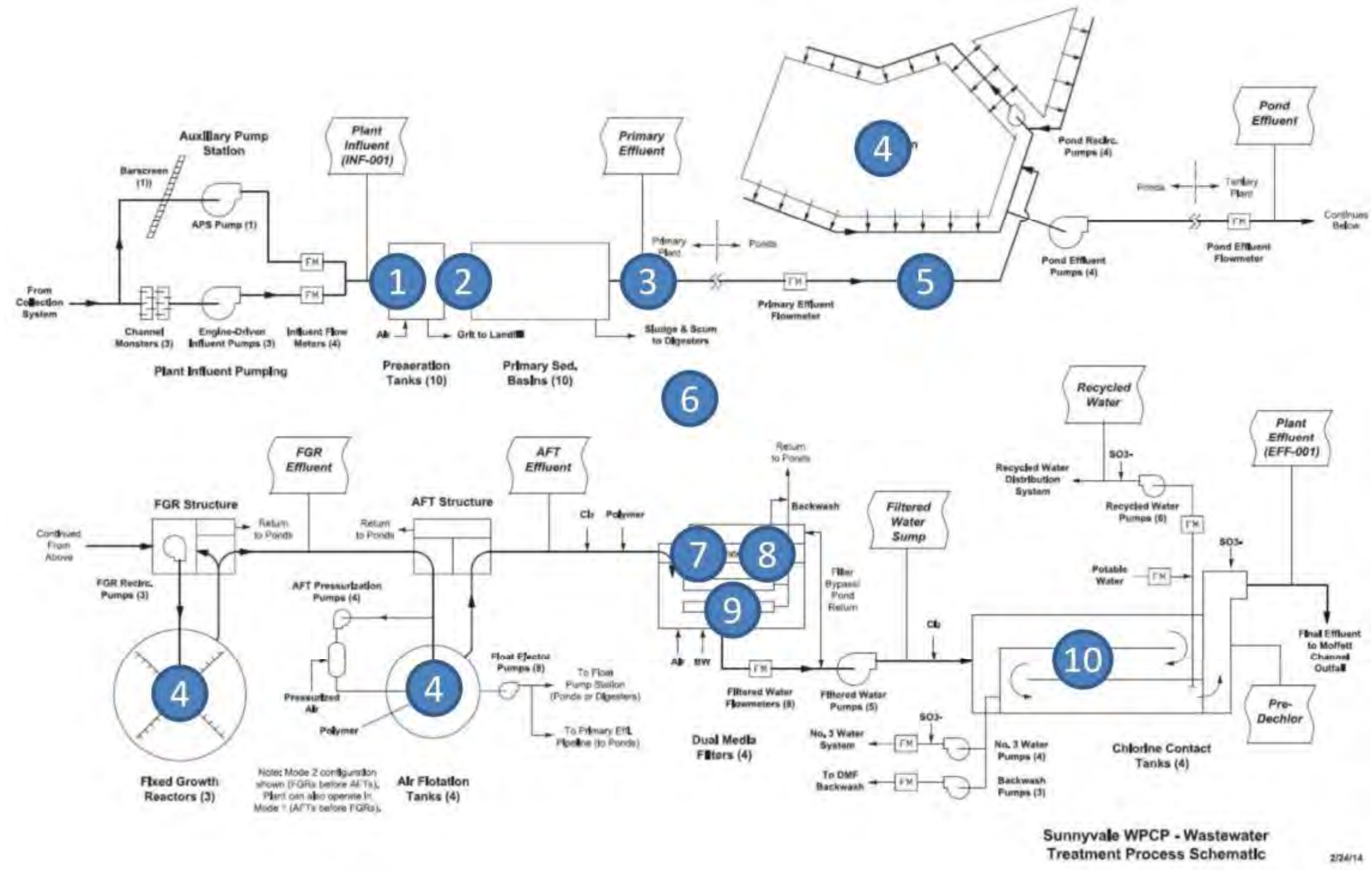

Figure 6-2. Level 3 Upgrade Concepts for Sunnyvale WPCP

(1) Decommission and construct a new headworks and primaries, (2) metal salt coagulant chemical feed facilities, (3) flow equalization basins, (4) decommission the ponds/FGRs/AFTs, (5) expand the activated sludge system (MLE configuration) and secondary clarifiers from Level 2 to treat all the flow, (6) sidestream treatment using a deammonification technology (credit was not taken for seeding and intensifying the activated sludge system), (7) expand the existing filter complex and modify to operate as a denitrifying filter complex, (8) add an external carbon source chemical feed facilities, (9) add metal salt and polymer chemical feed facilities, and (10) replace the chlorine contact tanks with UV disinfection as a means to provide necessary footprint for the denitrifying filters.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Decommission and construct a new headworks and primaries, (2) metal salt coagulant chemical feed facilities, (3) split treatment where a portion of flow is sent to the existing ponds/FGRs/AFTs, (4) the remaining flow is sent to the new activated sludge system (MLE configuration) with new secondary clarifiers, and (5) sidestream treatment using a deammonification technology (credit was not taken for seeding and intensifying the activated sludge system)

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Decommission and construct a new headworks and primaries, (2) metal salt coagulant chemical feed facilities, (3) flow equalization basins, (4) decommission the ponds/FGRs/AFTs, (5) expand the activated sludge system (MLE configuration) and secondary clarifiers from Level 2 to treat all the flow, (6) sidestream treatment using a deammonification technology (credit was not taken for seeding and intensifying the activated sludge system), (7) expand the existing filter complex and modify to operate as a denitrifying filter complex, (8) add an external carbon source chemical feed facilities, (9) add metal salt and polymer chemical feed facilities, and (10) replace the chlorine contact tanks with UV disinfection as a means to provide necessary footprint for the denitrifying filters.

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Permitted Capacity Flow	mgd	19.5	19.5	19.5	19.5
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	242	244	383	388
Annual O&M	$Mil/yr	2.0	2.1	2.9	4.1
O&M PV[3]	$ Mil	44	48	66	92
Total PV[3]	$ Mil	286	292	448	480
Unit Capital Cost	$/gpd	12	13	20	20
Unit Total PV	$/gpd	15	15	23	25
TN Removal					
Capital[2,4]	$ Mil	242	244	377	381
Annual O&M[4]	$ Mil/yr	1.6	1.7	2.6	3.8
O&M PV[3,4]	$ Mil	37	39	58	85
Total PV[3,4]	$ Mil	279	283	436	467
TN Removed (Ave.)[6]	lb N/d	320	440	790	1,460
Annual TN Removed (Ave.)[7]	lb N/yr	115,000	160,000	288,000	533,000
TN Cost[4,8]	$/lb N	81	59	50	29
TP Removal					
Capital[2,5]	$ Mil	195	195	273	274
Annual O&M[5]	$ Mil/yr	1.1	1.2	1.8	2.7
O&M PV[3,5]	$ Mil	24	27	41	61
Total PV[3,5]	$ Mil	220	222	313	335
TP Removed (Ave.)[6]	lb P/d	390	400	430	480
Annual TP Removed (Ave.)[7]	lb P/yr	143,000	146,000	156,000	175,000
TP Cost[5,8]	$/lb P	51	51	67	64

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Additional capacity for primary clarifiers (if chemical dose increased) • Enhanced solids capture in the primaries (if chemical dose increased) • Additional biogas production (if chemical dose increased at primaries) • Additional filtration capacity due to improved secondary clarifier effluent (the extent is unclear and would require verification testing) • Reduced solids/BOD discharge loading • Alkalinity recovery associated with the denitrification step	• Additional chemicals from metal salt coagulant at the primaries • Increase in overall energy use • Operate in a new mode that will require the operators to get accustomed to • Most likely reduced CEC removal compared to treating all the flow with the ponds, FGRs, and AFTs
Level 3	Same as Level 2 plus the following additional benefits: • Further alkalinity recovery due to more denitrification than the other Levels	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Additional solids • Safety from external carbon source (if methanol) • Additional aeration basin volume to operate

7 Nutrient Load Reduction by Other Means

The Sunnyvale WPCP has an existing recycled water program that is employed for most months of the year. This existing program has the effect of reducing nutrients discharged to the Bay. The WPCP currently recycles approximately 725 acre-feet per year (240 million gallons per year). There is funding to further expand the recycled water program to approximately 1,275 acre-feet per year (415 million gallons per year) by the year 2020 and plans to expand the program by 5% every 5 years thereafter.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG

emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

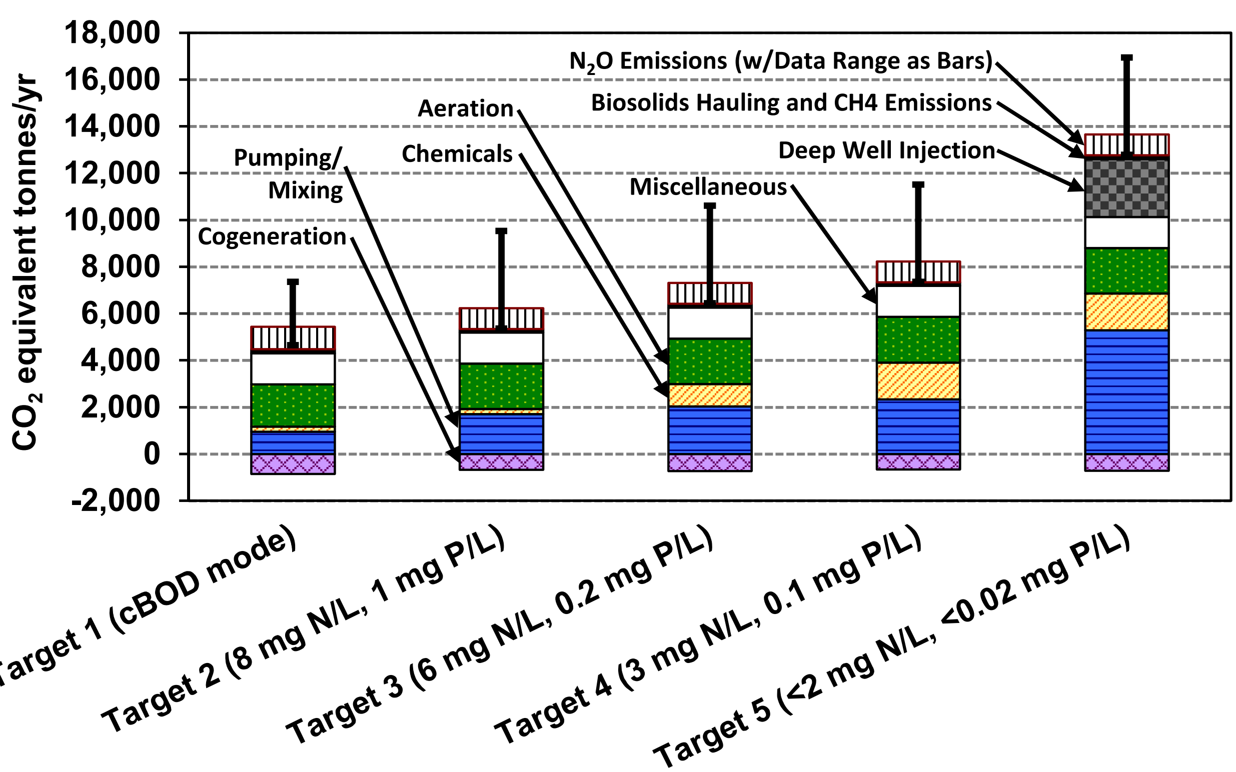

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with sidestream treatment and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from use of ponds and other facilities to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1,6]	Optimization Year Round[1,6]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	--	--	1,100	1,100	3,500	3,700	90
GHG Emissions Increase from Chemicals	MT CO_2/yr	--	--	100	100	400	400	10
GHG Emissions Increase Total	MT CO_2/yr	--	--	1,200	1,200	3,900	4,100	100
Unit GHG Emissions[2]	lb CO_2/MG	--	--	400	400	1,200	1,300	60
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--	--	--	--	--	--	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--	--	30	20	40	20	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--	--	10	10	40	40	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. The plant already fully nitrifies so any sidestream treatment or upgrades will only improve ammonia load reduction reliability.
6. Optimization was not considered as the plant is under design for a major upgrade and expansion that should be able to meet the Level 2 limits (except for TP).

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at Sunnyvale WPCP:

- Granular Activated Sludge – this could be used instead of the activated sludge technology recommended in the Master Plan. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Consider this technology as part of the upcoming design.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could be included as part of the upcoming design/upgrade project. The membrane is used to deliver air (inside-out) to the activated sludge system and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit to Sunnyvale is it has the potential to reduce overall project footprint. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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Treasure Island Wastewater Treatment Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Treasure Island Wastewater Treatment Plant

San Francisco, CA

March 16, 2018
Final Report

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Executive Summary

The United States Navy owns the Treasure Island Wastewater Treatment Plant (WWTP) located in San Francisco, CA and discharges treated effluent to Central San Francisco Bay. Treasure Island is in the midst of comprehensive redevelopment. The Treasure Island Development Authority operates and maintains the plant and its associated collection system under the Base Caretaker Cooperative Agreement between the Discharger and the City and County of San Francisco. Pursuant to the Cooperative Agreement, the San Francisco Public Utilities Commission operates and maintains the treatment plant, while the Discharger retains ownership of the system until a transfer of ownership to the Treasure Island Development Authority. The plant has an average dry weather flow (ADWF) permitted capacity of 2 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3,7]
Design Flow	mgd	--	--	0.3	0.3	1.3	1.3	1.3	1.3	
Flow to Bay[2]	mgd	0.3	0.3	0.3	0.3	0.8	0.8	0.8	0.8	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	6.9	6.9	7.4	7.4	14	13	14	13	--
TN	lb N/d	33	33	36	36	83	83	75	40	--
TP	lb P/d	5.8	5.8	2.7	2.5	7	7	5	2	--
Costs[4,5]										
Capital	$ Mil	--	--	0.5	0.5	42	42	44	44	--
O&M PV	$ Mil	--	--	0.1	0.1	21	22	23	24	--
Total PV	$ Mil	--	--	0.6	0.6	62	64	67	68	--
Unit Costs[6]										--
Capital	$/gpd	--	--	1.6	1.6	32.1	32.9	34.0	34.8	--
Total PV	$/gpd			1.8	1.9	48.0	50.1	51.6	53.8	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Not Applicable. Treasure Island was not considered for sidestream treatment due to infrequent dewatering.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Implement alum addition at the primary clarifiers to remove total phosphorus. This is expected to meet Level 2 phosphorus loads. Based on the effluent data, the plant currently meets the Level 2 nitrogen criteria with lightly loaded trickling filters that nitrify, and a high recycle due to large pump size that allows denitrification in the trickling filter biofilms. No further optimizations were identified for nitrogen.

Treasure Island is not considered a candidate for sidestream treatment due to infrequent dewatering (about 3 days per week).

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Construct new biological nutrient removal (BNR) tanks in the Modified Ludzack-Ettinger (MLE) configuration, including blowers and alkalinity addition for nitrification,
   b. Construct new membrane bioreactors, including fine screening to protect membranes, and
   c. Construct chemical facilities for alum addition to the BNR tanks
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Construct additional BNR tank volume in the 4-stage configuration, and
   c. Construct external carbon (methanol) facilities for carbon addition to the second anoxic zone for denitrification.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $0.6 Mil for dry season optimization up to $68 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Treasure Island Wastewater Treatment Plant (WWTP) currently serves a population of about 2,900, which includes Treasure Island and Yerba Buena Island. It is located at 1220 Avenue M, San Francisco, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 2.0 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The Treasure Island WWTP holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2015-0004, NPDES No. CA0110116). The treated wastewater is discharged to the Central San Francisco Bay at latitude of 37.832778 and longitude of -122.369444.

Table 2-1 provides a summary of the permit limitations that are specific to the Treasure Island WWTP and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2015-0004; CA0110116)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	2.0[1]	-	-	-
cBOD	mg/L	-	30	45	-
TSS	mg/L	-	30	45	-
Total Ammonia, as N	mg/L	-	130	-	330

This table identifies relevant permit limitations only and does not include a complete list of permit limitations
1. The facility is designed to provide secondary treatment for a flow of 4.4 MGD during wet weather.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Treasure Island WWTP. Both liquids processes and solids processes are shown. The Treasure Island WWTP consists of screening and grit removal, primary clarification, trickling filters, secondary sedimentation, and chlorine disinfection. Solids treatment consists of secondary sludge thickening, anaerobic digestion and centrifuge dewatering.

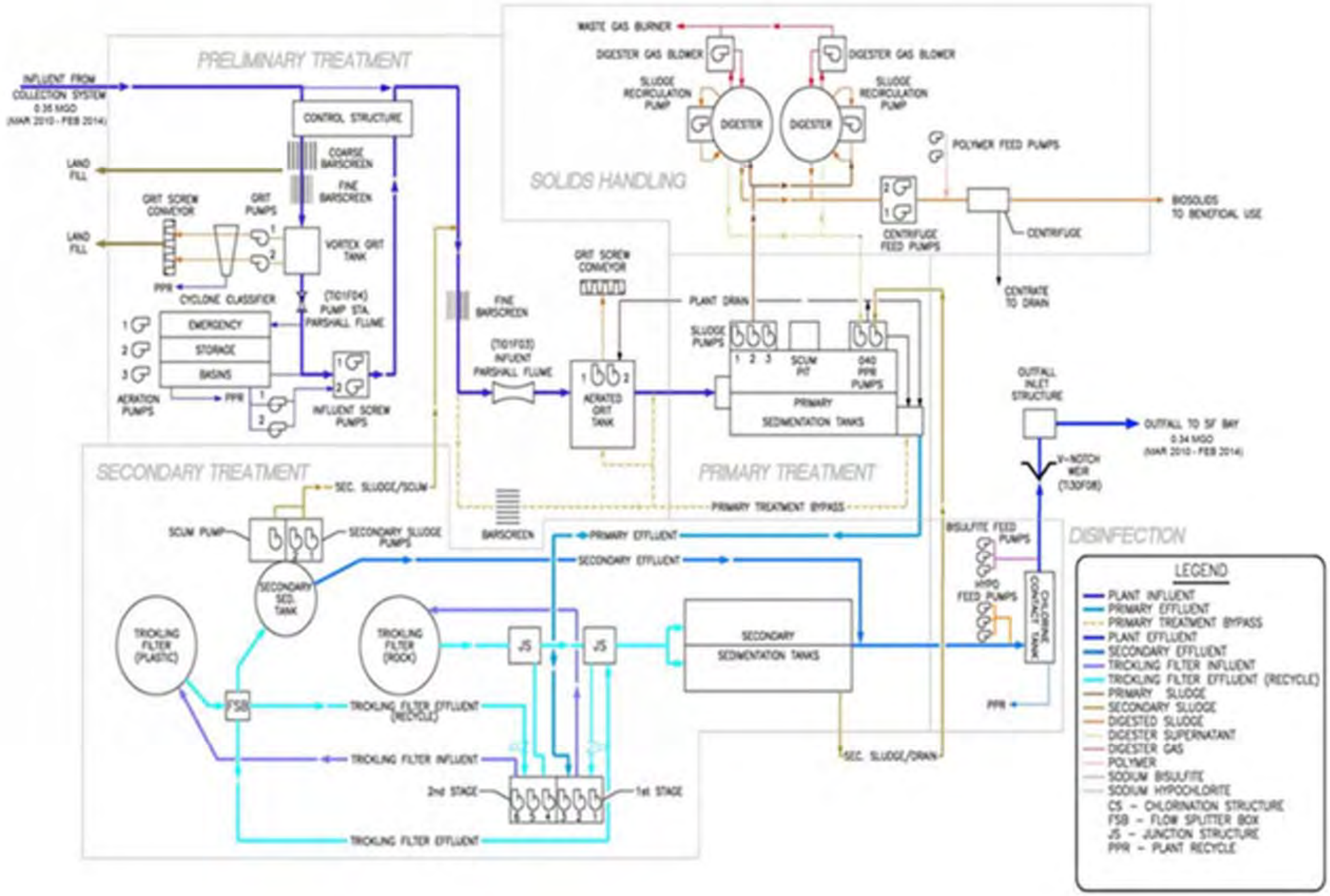

Figure 2-1. Process Flow Diagram for Treasure Island WWTP

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Treasure Island WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	0.3	0.3	0.4	0.4
BOD	lb/d	420	440	520	580
TSS	lb/d	470	430	550	570
Ammonia[4]	lb N/d	70	69	80	90
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	80	86	100	110
Total Phosphorus (TP)[4]	lb P/d	10	10	10	10
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	160	160	170	160
TSS	mg/L	170	160	180	160
Ammonia[4]	mg N/L	24	26	27	25
TKN[4]	mg N/L	30	32	33	31
TP[4]	mg P/L	3.6	3.8	4.0	3.7
Alkalinity	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Ammonia, TKN and TP were based on three samples each collected between February 2014 and June 2014. ADWF, dry season maximum month and year round maximum month were calculated using the BOD peaking factors.

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the Treasure Island WWTP:

- As part of redevelopment, a new wastewater treatment plant is planned. Additionally, much of the existing utility infrastructure, including the sanitary sewers and storm drains, will be replaced or rehabilitated. Current conceptual plans are for a new treatment plant to be constructed in 2020.

2.5 Pilot Testing

There have not been any pilot testing projects related to nutrient removal performed at the Treasure Island WWTP.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Treasure Island WWTP are presented in Table 3-1. The projected flow and load for the Treasure Island WWTP in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	0.3	0.3	0.4	0.4
BOD	lb/d	490	510	600	660
TSS	lb/d	540	490	630	660
Ammonia	lb N/d	77	80	94	105
TKN	lb N/d	96	99	117	130
TP	lb P/d	11	12	14	16
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	180	190	200	180
TSS	mg/L	200	180	210	180
Ammonia	mg N/L	28	29	31	29
TKN	mg N/L	35	37	39	35
TP	mg P/L	4.2	4.4	4.6	4.2
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

Treasure Island is not considered a candidate for sidestream treatment due to infrequent dewatering (about 3 days per week).

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. According to the 2011 Environmental Impact Report[4], the new wastewater treatment plant would have the capacity to treat both the estimated dry weather wastewater flow of 1.3 mgd and the estimated peak wet weather wastewater flow of about 2.9 mgd, serving a population of 18,640 people. The flow for facility upgrades to meet Level 2 and level 3 nutrient criteria will be based on these flows. Since the current BOD and TSS concentrations are unusually low, assume standard per capita loading rates (0.22 lb BOD/capita-d, 0.25 lb TSS/capita-d, 0.032 lb TKN/capita-d, and 0.0076 lb TP/capita-d). The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the plant permitted capacity.

Table 3-2. Flow and Load for Upgrades (Based on Environmental Impact Report Flow and Population)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	1.3	1.3	1.4	1.7
BOD[5]	lb/d	4,000	4,100	4,900	5,400
TSS[5]	lb/d	5,100	4,700	6,000	6,300
Ammonia[5]	lb N/d	460	480	570	630
TKN[5]	lb N/d	580	600	710	780
TP[5]	lb P/d	140	140	170	190
Alkalinity	lb/d as $CaCO_3$	---	---	---	---
BOD[5]	mg/L	370	380	400	370
TSS[5]	mg/L	470	430	500	430
Ammonia[5]	mg N/L	43	45	47	43
TKN[5]	mg N/L	53	56	59	54
TP[5]	mg P/L	12.6	13.2	13.9	12.8
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. ADWF based on 2011 Environmental Impact Report. Other flows are based on current peaking factors.
5. Average annual based on the population from the 2011 Environmental Impact Report and standard per capita loading rates (0.22 lb BOD/capita-d, 0.25 lb TSS/capita-d, 0.032 lb TKN/capita-d, and 0.0076 lb TP/capita-d). Other loadings are based on current peaking factors

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site

[4] Treasure Island / Yerba Buena Island Redevelopment Project Final EIR, April 21, 2011.

plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Two optimization strategies were identified during the Treasure Island WWTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The two strategies are described below.

- **Optimization Strategy 1:** Add alum upstream of the primary clarifiers to increase phosphorus removal using chemically enhanced primary treatment (CEPT).
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Alum storage and metering facilities could be constructed at the plant. The improvements would include: (a) construction of a chemical storage facility with chemical metering pumps, and (b) construction of chemical feed piping from the storage facility to the plant influent. Ferric chloride could also be used.
  - ***Recommendation:*** Carry forward.
- **Optimization Strategy 2:** Use recycle to promote denitrification in trickling filters.
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Reduce nitrogen concentrations.
  - ***Result from analysis:*** Based on the effluent data provided, the plant currently meets the Level 2 nitrogen criteria (the lightly loaded trickling filters nitrify, and high recycle due to large pump size allows denitrification in the trickling filter biofilms).
  - ***Recommendation:*** Continue current operation.

Strategy 1 is the best apparent way to reduce effluent phosphorus loads. Strategy 2 represents the current operation, and is recommended to maintain current nitrogen removal.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

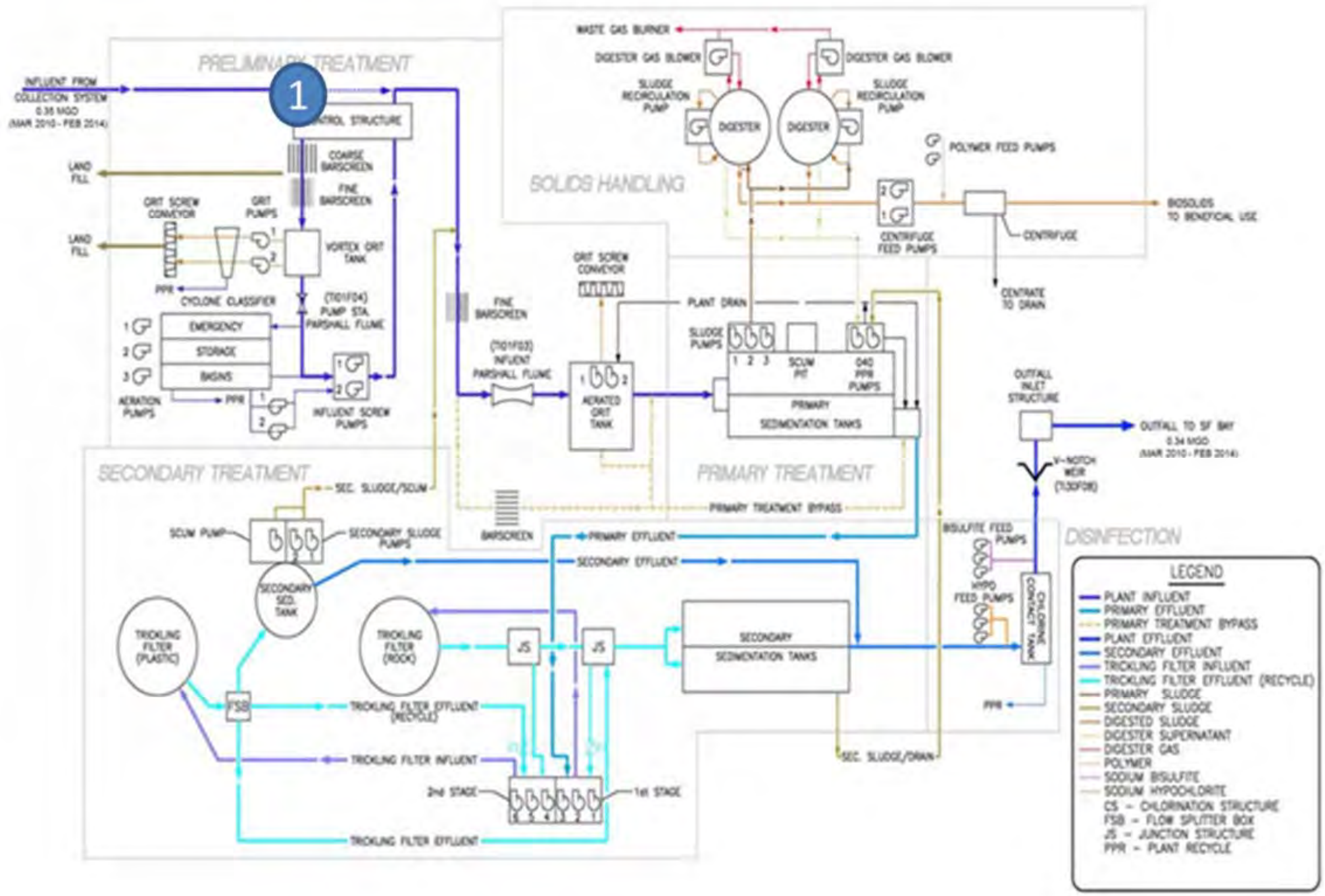

Figure 4-1. Optimization Concepts Considered for the Treasure Island WWTP

(1) alum addition upstream of the primary clarifiers for P removal, including chemical storage and metering.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Alum storage, chemical metering pump, chemical injection (flash mixer)	Dose alum upstream of the primary clarifiers.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The Treasure Island WWTP plant shows improved phosphorus removal, but no change in nitrogen removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	7.4	7.4	36	36	6.2	6.2
Discharge with Opt. Strategy[1]	lb N or P/d	7.4	7.4	36	36	2.7	2.5
Load Reduction[2,3]	lb N or P/d	0	0	0	0	3.5	3.7
Load Reduction[2,3]	%	0%	0%	0%	0%	57%	59%
Annual Load Reduction	lb N or P/yr	0	0	0	0	1,290	1,350

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce phosphorus; no optimization strategy was identified for nitrogen.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	0.3	0.3
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.5	0.5
Annual O&M	$ Mil/yr	0.01	0.01
Present Value O&M[3]	$ Mil	0.1	0.1
Present Value Total[3]	$ Mil	0.6	0.6
Unit Capital Cost[8]	$/gpd	1.6	1.6
Unit Total PV Cost[8]	$/gpd	1.8	1.9
TN Removal			
Capital[2,4]	$ Mil	0.0	0.0
Annual O&M[4]	$ Mil/yr	0.0	0.0
O&M PV[3,4]	$ Mil	0.0	0.0
Total PV[3,4]	$ Mil	0.0	0.0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0.5	0.5
Annual O&M[5]	$ Mil/yr	0.01	0.01
O&M PV[3,5]	$ Mil	0.1	0.1
Total PV[3,5]	$ Mil	0.6	0.6
TP Removed (Ave.)[6]	lb P/d	3.5	3.7
Annual TP Removed (Ave.)[7]	lb P/yr	1,290	1,350
TP Cost[5,9]	$/lb P	47	45

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• More organics and solids diverted to fuel the digester • Phosphorus reliably removed under peak flow scenarios	• Dependency on chemicals • Chemical costs

5 Sidestream Treatment

Sidestream treatment is not considered a viable option for Treasure Island as previously described and thus was not further evaluated.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Treasure Island WWTP plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The Treasure Island WWTP should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

As part of redevelopment, a new wastewater treatment plant is planned. Additionally, much of the existing utility infrastructure, including the sanitary sewers and storm drains, will be replaced or rehabilitated. Timing of redevelopment is uncertain.

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 nitrogen limits could be met by constructing a membrane bioreactor facility, using a Modified Ludzack-Ettinger (MLE) configuration in the BNR tanks. Alum addition to the BNR tanks could be used for phosphorus removal. Facilities for alkalinity addition are included in the capital costs. Fine screening is included to protect the membranes, but other facilities (solids handling, disinfection, administration building, etc.) are not included. For this evaluation, primary clarifiers were not included.

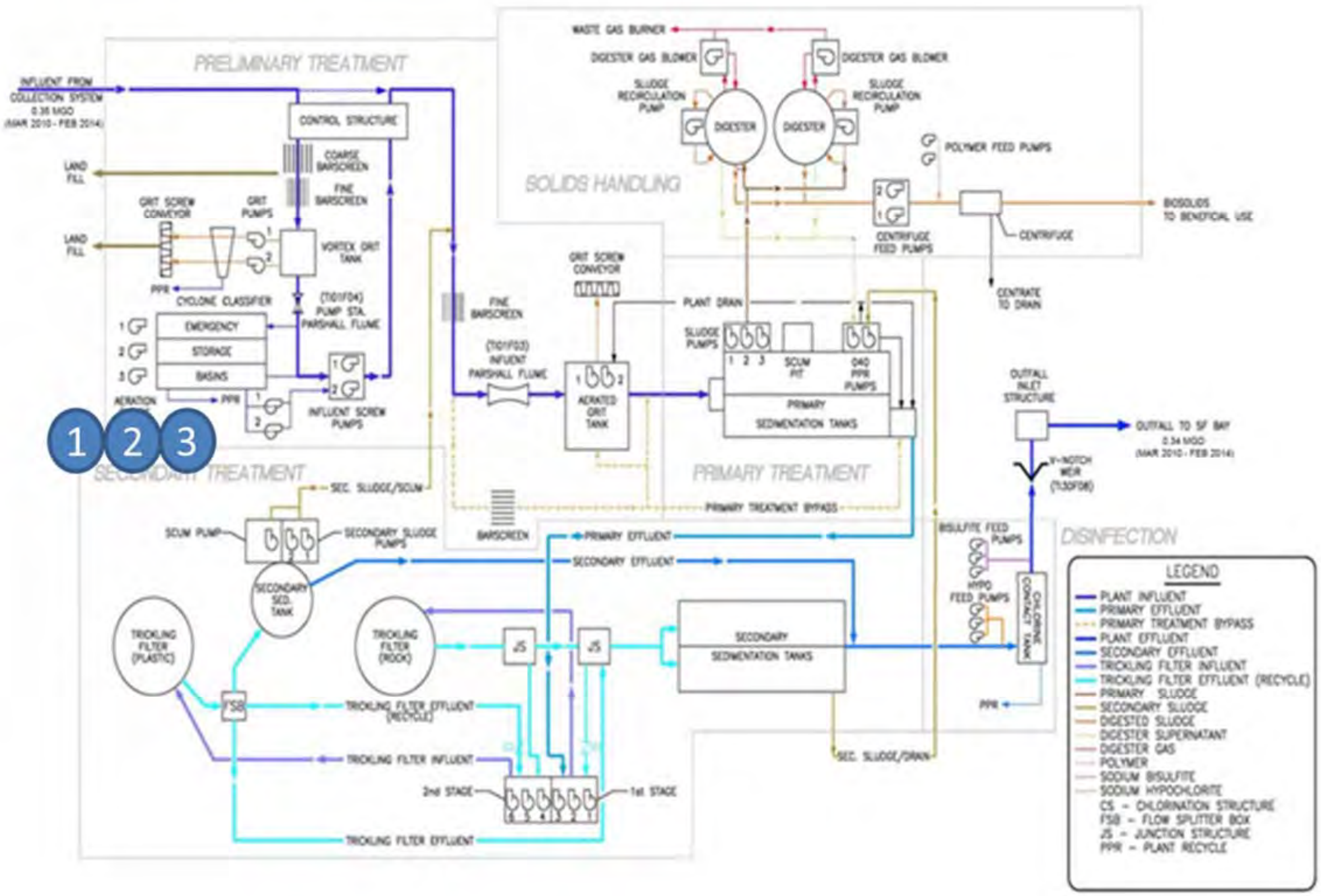

Figure 6-1. Level 2 Upgrade Concept for Treasure Island WWTP

(1) Replace existing plant with new MBR plant with MLE BNR. Assumed no primary clarifiers for this evaluation. Include fine screening to protect membranes. (2) Alum addition to aeration basins for phosphorus removal. (3) Alkalinity addition facilities are included.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Level 3 upgrades could be met by constructing a membrane bioreactor facility, using 4-stage BNR configuration in the BNR tanks. Alum addition to the BNR tanks could be used for phosphorus removal. Carbon addition (methanol) is needed to meet Level 3 nitrogen limits. Facilities for alkalinity addition are also included in the capital costs. For this evaluation, primary clarifiers were not included. Fine screening is included to protect the membranes, but other facilities (solids handling, disinfection, administration building, etc.) are not included.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Secondary and Tertiary	• New BNR tanks in the MLE configuration • New blowers • New membrane bioreactor • Alum addition facilities • Alkalinity addition facilities • Fine screening to protect membranes	Same as Level 2 except: • Additional BNR tank volume, with configuration changed to 4-stage • External carbon source addition facilities

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

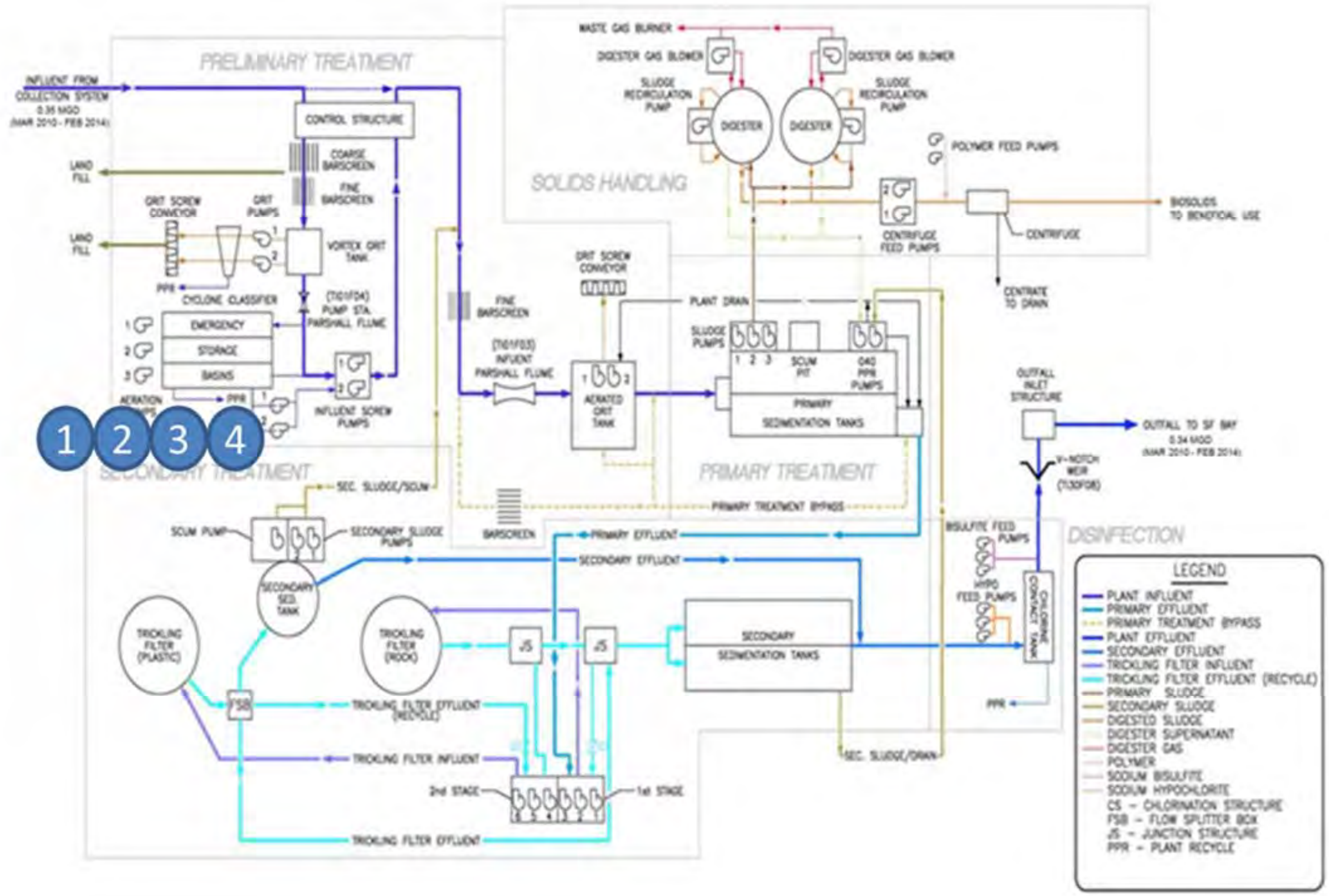

Figure 6-2. Level 3 Upgrade Concept for Treasure Island WWTP

(1) Replace existing plant with new MBR plant with 4-stage BNR. Assumed no primary clarifiers for this evaluation. Include fine screening to protect membranes. (2) Alum addition to aeration basins for P removal. (3) Alkalinity addition facilities are included. (4) Methanol addition to second stage anoxic for N removal.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Headworks with fine screening, (2) BNR tanks (MLE), (3) MBR membrane tanks, (4) Blower building, (5) alum storage, and (6) alkalinity addition storage. Layout shown does not include influent pumping, disinfection, solids handling, administration building, etc.

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Headworks with fine screening, (2) BNR tanks (4-stage), (3) MBR membrane tanks, (4) Blower building, (5) alum storage, (6) alkalinity addition storage, and (7) methanol storage. Layout shown does not include influent pumping, disinfection, solids handling, administration building, etc.).

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	1.3	1.3	1.3	1.3
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	42	42	44	44
Annual O&M	$Mil/yr	0.9	1.0	1	1.1
O&M PV[3]	$ Mil	21	22	23	24
Total PV[3]	$ Mil	62	64	67	69
Unit Capital Cost	$/gpd	32.1	32.9	34.0	34.8
Unit Total PV	$/gpd	48.0	50.1	51.6	53.8
TN Removal					
Capital[2,4]	$ Mil	41	41	44	44
Annual O&M[4]	$ Mil/yr	0.9	1.0	1.0	1.0
O&M PV[3,4]	$ Mil	20	22	22	24
Total PV[3,4]	$ Mil	62	63	66	67
TN Removed (Ave.)[6]	lb N/d	120	120	120	160
Annual TN Removed (Ave.)[7]	lb N/yr	42,700	42,700	45,600	58,300
TN Cost[4,8]	$/lb N	48	49	48	38
TP Removal					
Capital[2,5]	$ Mil	0.5	0.5	18	18
Annual O&M[5]	$ Mil/yr	0.01	0.01	0.15	0.33
O&M PV[3,5]	$ Mil	0.3	0.3	3.3	7.5
Total PV[3,5]	$ Mil	0.8	0.8	21	26
TP Removed (Ave.)[6]	lb P/d	28	28	30	33
Annual TP Removed (Ave.)[7]	lb P/yr	10,000	10,200	10,900	11,900
TP Cost[5,8]	$/lb P	2.7	2.7	65	71

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Robust technology to absorb variability in flows and loads • Ability to reliably remove TN and TP	• Increased operation costs associated with alum addition • Increased energy demands for aeration and membranes
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use and additional alum use

7 Nutrient Removal by Other Means

The Treasure Island WWTP does not currently produce recycled water. Based on the 2016 Treasure Island Recycled Water Master Plan, by 2030 the plant will recycle 300 acre-feet per year (100 million gallons per year) for outdoor use (irrigation). Another 162 acre-feet per year (50 million gallons per year) will be used for indoor use, which will be returned to the treatment plant.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

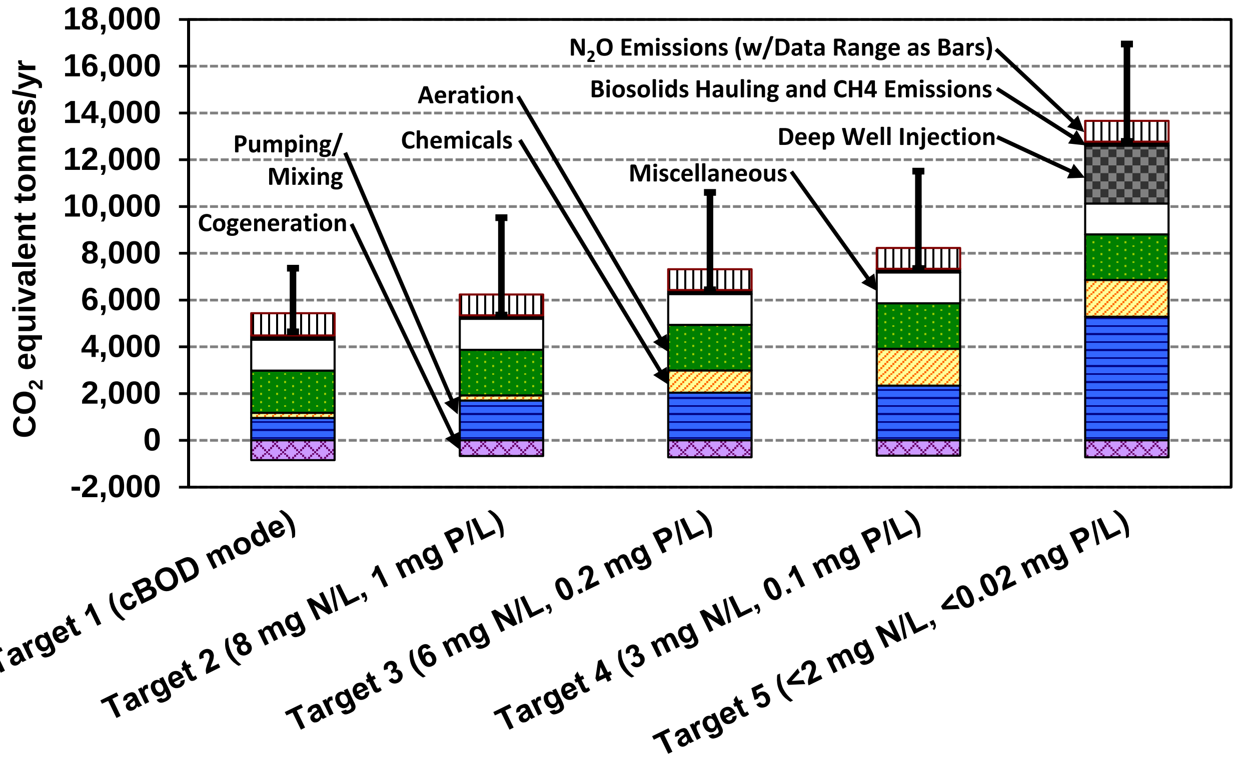

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[5] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

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[5] http://www.epa.gov/cleanenergy/energy-resources/egrid/

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	1	1	1,100	1,200	1,200	1,300	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	4	4	16	16	200	200	--
GHG Emissions Increase Total	MT CO_2/yr	5	5	1,100	1,200	1,300	1,400	--
								--
Unit GHG Emissions[2]	lb CO_2/MG	87	87	5,400	5,800	6,100	6,600	--
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	260	270	260	270	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	60	60	60	50	--
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	8	8	4	4	34	31	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. Treasure Island was not considered for sidestream treatment due to infrequent dewatering

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Treasure Island WWTP. These are:

- Nitrite Shunt – Treasure Island WWTP BNR basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Simultaneous nitrification/denitrification (SND) –Treasure Island BNR basins would be operated at low dissolved oxygen (DO) levels to promote SND. Under this operating scenario, nitrification and denitrification occurs in the same tankage and dedicated anoxic zones are not necessary. As a result, there is a significant reduction in aeration requirements. This requires the installations of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowances used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor’s Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.35

Union Sanitary District Wastewater Treatment Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Union Sanitary District Wastewater Treatment Plant

Union City, CA

April 2, 2018
Final Report

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Executive Summary

Union Sanitary District owns and operates a Wastewater Treatment Plant located in Union City, CA and discharges treated effluent to Lower San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 33 million gallons per day (mgd).

A summary of the flows and loads for the current conditions (based on 2011 through 2014 data), optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow[7]	mgd	--	--	22.1	22.3	41.5	41.9	41.5	41.9	--
Flow to Bay[2]	mgd	24.4	24.4	24.4	24.4	33.6	33.6	33.6	33.6	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	7,540	7,540	8,110	8,110	590	550	590	550	8,400
TN	lb N/d	8,740	8,740	9,400	9,400	4,400	4,140	3,100	1,650	10,400
TP	lb P/d	530	530	200	190	290	280	200	80	640
Costs[4,5]										
Capital	$ Mil	--	--	1.3	1.7	500	500	510	510	28.1
O&M PV	$ Mil	--	--	5.0	5.0	150	170	190	220	22.0
Total PV	$ Mil	--	--	6.3	6.6	650	670	700	730	50.1
Unit Costs[6]										
Capital	$/gpd	--	--	0.1	0.1	12.0	12.0	12.3	12.2	--
Total PV	$/gpd	--	--	0.3	0.3	15.8	16.0	16.8	17.4	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current effluent flows and loads to the Bay are the 3-year average (July 2011 through June 2014), based on the data provided by USD. The 2015 BACWA Nutrient Reduction Study Group Annual Report data was not used, since values were only provided for the combined EBDA discharge. The reported flows and loads for optimization, upgrades, and sidestream represent average projected effluent loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream), accounting for growth during the period of analysis.
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. Design flow is based on influent flow projections for the end of the period of analysis. For year round, design flow shown is the average wet season flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Add ferric chloride upstream of the primary clarifiers to remove phosphorus. Ferric chloride addition is expected to meet Level 2 phosphorus concentrations. Optimization strategies to reduce ammonia or nitrogen were not feasible, due to insufficient aeration tank volume.

USD is considered a candidate for sidestream treatment to reduce nitrogen and phosphorus loads as the plant anaerobically digests biosolids and dewaters to produce a return sidestream laden with both nitrogen and phosphorus. The recommended sidestream treatment strategy is a deammonification technology for reducing ammonia/nitrogen loads and chemical precipitation of phosphorus for reducing phosphorus loads.

The current site does not have sufficient space for an activated sludge nutrient removal process, so a membrane bioreactor (MBR) process is shown for this report. USD could consider purchase of additional land to provide space for other nutrient removal processes. The upgrade strategy to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Construct chemical facilities for ferric chloride addition upstream of primary clarifiers,
    b. Convert the secondary process to a membrane bioreactor process. Convert existing aeration basins and three of the existing secondary clarifiers to Modified Ludzack-Ettinger (MLE) aeration tanks, including covers and odor control. Construct new membrane tanks. Construct fine screening to protect membranes. Construct facilities for methanol and alkalinity addition.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus
    b. Add additional ferric chloride to the aeration basins for phosphorus polishing.
    c. Convert three additional existing secondary clarifiers (six total) to 4-stage biological nutrient removal (BNR), and configure all tanks as 4-stage BNR. Add additional methanol for denitrification.

As shown in Table ES-1, the costs generally increase from optimization to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $5.9 Mil for dry season optimization up to $730 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The Union Sanitary District (USD) Wastewater Treatment Plant (WWTP) serves a population of about 347,000, which includes the industrial, commercial, and domestic wastewater for the Newark, Union City and the Fremont area. It is located at 5072 Benson Rd., Union City, CA. The plant has an average dry weather flow (ADWF) permitted capacity of 33 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

USD normally discharges treated effluent through a common outfall under the Joint Exercise of Power Agency (JEPA) of the East Bay Dischargers Authority (EBDA). EBDA member agencies include the City of Hayward, City of San Leandro, Oro Loma Sanitary District, Castro Valley Sanitary District, and Union Sanitary District. The Livermore-Amador Valley Water Management Agency (LAVWMA) leases capacity from EBDA. The EBDA discharge is located at latitude 37°41’40” and longitude 122°17’42”. EBDA holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2012-0004, NPDES No. CA0037869). The plant also sends some flow to Hayward Marsh (Order No. R2-2011-0058, NPDES No. CA0038636).

USD also has a wet weather outfall which discharges to Old Alameda Creek. USD holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2015-0045, NPDES No. CA0038733). The Old Alameda Creek intermittent wet weather discharge is located at latitude 37.59397 and longitude -122.09192. Discharge is prohibited, except during peak wet weather flows after USD fully utilizes the maximum hydraulic capacity available in the EBDA pipeline or during the exercise of the discharge flap gate.

Table 2-1 provides a summary of the permit limitations that are specific to the USD, under the EBDA NPDES permit, and are specific to nutrients. Table 2-1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2012-0004; CA0037869)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak
Flow[1]	mgd	33.0[2]	-	-	-	-
cBOD	mg/L	-	25	40[3]	-	-
TSS	mg/L	-	30	45[3]	-	-
Total Ammonia, as N[4]	mg/L	-	93	-	130	-

This table identifies relevant permit limitations only and does not include a complete list of permit limitations. Limitations shown are for the normal discharge through the EBDA outfall.

1. Flow shown is for the EBDA outfall. Discharge to the Old Alameda Creek intermittent wet weather discharge (Order No. R2-2015-0045, CA 0038733) is only permitted during peak wet weather flows after USD fully utilizes the maximum hydraulic capacity in the EBDA pipeline or during exercise of the discharge flap gate. The plant also sends some flow to Hayward Marsh (Order No. R2-2011-0058, NPDES No. CA0038636).
2. The average dry weather flow limit for USD may be increased to 38 mgd upon completion of its planned new treatment plant facilities. USD submitted an antidegradation study for plant improvements that affirms that an increase in the effluent discharge flow rate conforms to federal and State Antidegradation Policy requirements.
3. The Old Alameda Creek intermittent wet weather discharge includes same average weekly limits for cBOD and TSS as shown above.
4. The Hayward Marsh effluent limits include an average monthly ammonia of 34 mg/L and a maximum daily ammonia of 120 mg/L.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the USD WWTP. Both liquids processes and solids processes are shown. The USD WWTP consists of screening, primary clarification, activated sludge process including aeration basins and secondary clarifiers. Secondary effluent is disinfected by chlorine disinfection. Solids treatment consists of primary sludge degritting, separate primary and secondary sludge thickening, anaerobic digestion and centrifuge dewatering.

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the USD WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	22.1	22.2	22.9	23.7
cBOD	lb/d	47,700	49,900	53,300	56,700
TSS	lb/d	61,300	63,100	66,800	68,800
Ammonia	lb N/d	6,230	6,650	6,920	7,630
Total Kjeldahl Nitrogen (TKN)[5]	lb N/d	7,920	8,450	8,790	9,700
Total Phosphorus (TP)[5]	lb P/d	890	950	990	1,090
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
cBOD	mg/L	260	270	280	290
TSS	mg/L	330	340	350	350
Ammonia	mg N/L	34	36	36	39
TKN[5]	mg N/L	43	46	46	49
TP[5]	mg P/L	4.8	5.2	5.2	5.5
Alkalinity[6]	mg CaCO3/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Flow shown is the reported influent flow. Reported effluent flows were 24.6 mgd (ADWF) and 24.4 mgd (Average Annual)
5. TKN and TP based on five samples collected between July 2012 and June 2014. ADWF, dry season maximum month and year round maximum month were calculated using the ammonia peaking factors.
6. Primary effluent alkalinity averaged 307 mg/L.

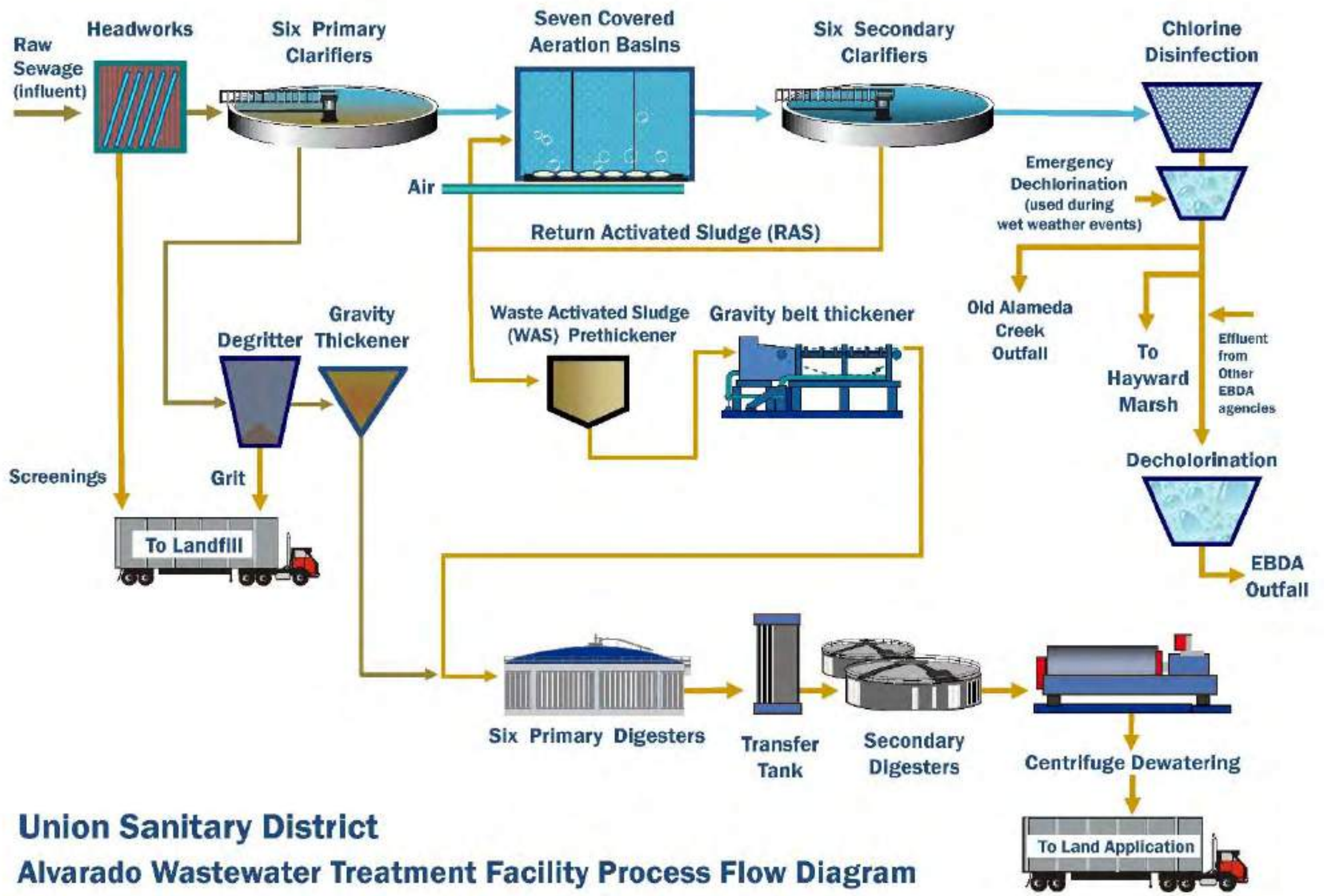

Figure 2-1. Process Flow Diagram for USD WWTP

2.4 Future Nutrient Removal Projects

The following nutrient related projects have been completed or are in progress at the USD WWTP:

- USD is implementing a local limit on industrial ammonia discharges to reduce plant influent nitrogen.

2.5 Pilot Testing

USD has performed two separate pilot-scale tests related to ammonia and nitrogen removal. USD pilot-tested ANITA™ Mox Anammox process for sidestream (centrate) treatment. The process performed well, with 79 to 84 percent ammonia removal with no alkalinity addition. USD also conducted the Hayward Marsh ammonia removal pilot study using zeolite anammox.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on buildout capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the USD WWTP are presented in Table 3-1. The projected flow and load for the USD WWTP in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by USD, it was determined that USD is a candidate for sidestream treatment.

Additional sampling for the sidestream was performed in July 2015. The sampling results were projected forward to the build-out capacity. The sidestream flows and loads for the build-out capacity are provided in Table 3-2. The build-out capacity flows and loads were used in the facility sizing.

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	22.1	22.2	22.9	23.7
cBOD	lb/d	54,900	57,400	61,300	65,200
TSS	lb/d	70,500	72,600	76,900	79,200
Ammonia	lb N/d	7,170	7,650	7,960	8,780
TKN	lb N/d	9,110	9,720	10,110	11,150
TP	lb P/d	1,030	1,100	1,140	1,260
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
cBOD	mg/L	300	310	320	330
TSS	mg/L	380	390	400	400
Ammonia	mg N/L	39	41	42	44
TKN	mg N/L	49	52	53	56
TP	mg P/L	5.6	5.9	6.0	6.4
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Flow shown is the projected influent flow. Projected effluent flows are 24.6 mgd (ADWF) and 24.4 mgd (Average Annual).

Table 3-2. Flows and Loads for Sidestream Treatment

Criteria	Unit	Current	Design Capacity (AA)
Sidestream Flow	mgd	0.14	0.27
Ammonia	lb N/d	1,880	3,530
TKN	lb N/d	1,900	3,500
TN[1]	lb N/d	1,900	3,500
TP	lb P/d	150	280
Ortho P	lb P/d	100	180
Alkalinity	lb CaCO3/d	6,200	11,700
Ammonia	mg N/L	1,560	1,560
TKN	mg N/L	1,600	1,600
TN[1]	mg N/L	1,600	1,600
TP	mg P/L	120	120
Ortho P	mg P/L	80	80
Alkalinity	mg CaCO3/L	5,200	5,200

1. It was assumed that TN = TKN

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-3. For most plants, these values are based on the plant's permitted flow capacity as ADWF. However, the USD WWTP provided an estimated build-out ADWF of 41.5 mgd, which was used as the basis for plant upgrades in this report. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the buildout flow capacity.

Table 3-3. Flow and Load for Facility Upgrades (Projected to Build-Out Flow Capacity)

Parameter	Unit	Build-Out Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow[4]	mgd	41.5	41.7	43.0	44.5
cBOD	lb/d	89,500	93,600	100,000	106,400
TSS	lb/d	115,100	118,500	125,500	129,200
Ammonia	lb N/d	11,700	12,490	12,990	14,330
TKN	lb N/d	14,860	15,870	16,500	18,200
TP	lb P/d	1,680	1,790	1,860	2,050
Alkalinity	lb/d as $CaCO_3$	---	---	---	---
cBOD	mg/L	260	270	280	290
TSS	mg/L	330	340	350	350
Ammonia	mg N/L	34	36	36	39
TKN	mg N/L	43	46	46	49
TP	mg P/L	4.8	5.2	5.2	5.5
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Flows shown are influent flows. Projected effluent flows are assumed to equal to influent flows. Peak hour flow for upgrades is 73.3 mgd.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical

Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy as well as the estimated costs.

Eight optimization strategies were identified during the USD WWTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The eight optimization strategies were screened down to four strategies described below.

- **Optimization Strategy 1:** Add ferric chloride upstream of the primary clarifiers to increase phosphorus removal using chemically enhanced primary treatment (CEPT).
  - ***Is it feasible?*** Yes.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Ferric chloride storage and metering facilities could be constructed at the plant. The improvements would include: (a) construction of a chemical storage facility with chemical metering pumps, and (b) construction of chemical feed piping from

the storage facility to the plant influent. Due to digestion limitations, the planned digester will be needed before this strategy can be implemented. The USD WWTP currently adds ferrous chloride at the influent pump station. Ferrous chloride could be used in future instead of ferric chloride. Chemical could be added at the pump stations, but primary performance would not be enhanced.

   - ***Recommendation:*** Evaluate further.

- <u>**Optimization Strategy 2:**</u> Add mixers to the selector zones in the plug flow west aeration tanks, and operate an anaerobic selector for biological phosphorus removal.
   - ***Is it feasible?*** No. A previous study indicated that the volume in the west aeration tanks is not sufficient. Reconfiguring the east tanks with selector zones is a major capital expense.
   - ***Potential impact on ability to reduce nutrient discharge loads?*** Reduce phosphorus concentrations.
   - ***Result from analysis:*** Analysis indicates that the volume of the west aeration tanks, which could easily be converted to include anaerobic selectors, is not sufficient for biological phosphorus removal. Reconfiguring the east aeration tanks would be a major capital project.
   - ***Recommendation:*** Do not evaluate further.

- <u>**Optimization Strategy 3:**</u> Increase the solids retention time in the existing aeration tanks to allow for nitrification. Add CEPT to unlock capacity so existing tanks can nitrify.
   - ***Is it feasible?*** No. The aeration tank volume with all aeration tanks is not sufficient for nitrification.
   - ***Potential impact on ability to reduce nutrient discharge loads?*** Improve nitrification and nitrogen removal performance.
   - ***Result from analysis:*** Analysis indicates that the existing tank volume is not sufficient for nitrification.
   - ***Recommendation:*** Do not evaluate further at this time.

- <u>**Optimization Strategy 4:**</u> Modify the plant for split treatment, with nitrification in some aeration tanks.
   - ***Is it feasible?*** No. Major capital expense would be needed to separate the mixed liquor and RAS, or to convert the unused east aeration tanks into sequencing batch reactors.
   - ***Potential impact on ability to reduce nutrient discharge loads?*** Improve nitrogen removal.
   - ***Result from analysis:*** Reconfiguring the flow distribution or converting some tanks to sequencing batch reactors would be a major capital project.
   - ***Recommendation:*** Do not evaluate further.

Strategy 1 is the best apparent way to reduce effluent phosphorus loads; no feasible strategies were determined to reduce ammonia or increase nitrogen removal.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

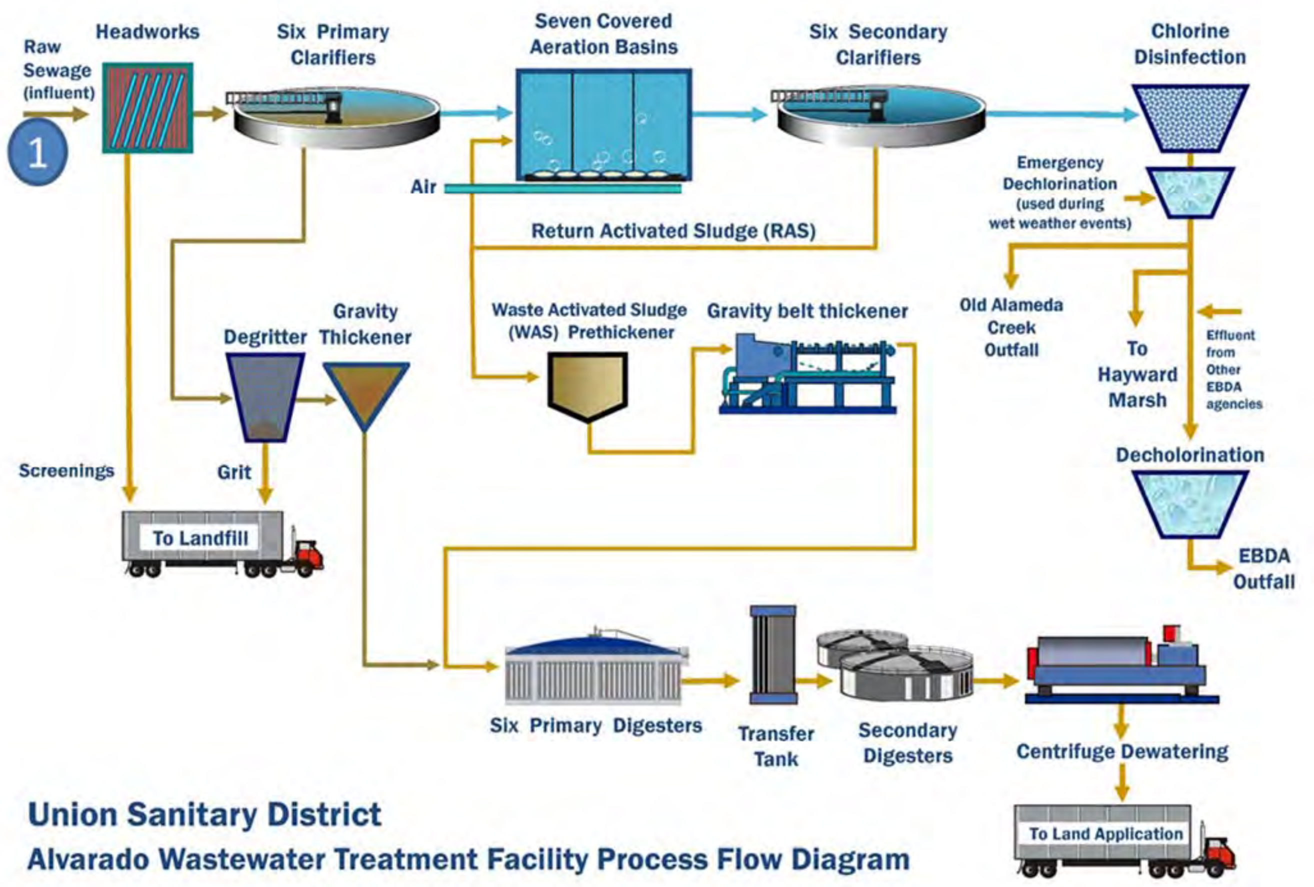

Figure 4-1. Optimization Concepts Considered for the USD WWTP

(1) ferric chloride addition upstream of the primary clarifiers for P removal, including chemical storage and metering.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Ferric chloride storage, chemical metering pump, chemical injection (flash mixer)	Dose ferric chloride upstream of the primary clarifiers.

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The USD WWTP plant shows improved phosphorus removal, but no change in ammonia or removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	8,110	8,110	9,400	9,400	570	570
Discharge with Opt. Strategy[1]	lb N or P/d	8,110	8,110	9,400	9,400	200	190
Load Reduction[2,3]	lb N or P/d	0	0	0	0	370	380
Load Reduction[2,3]	%	0%	0%	0%	0%	65%	67%
Annual Load Reduction	lb N or P/yr	0	0	0	0	136,000	140,000

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes, although the planned digester will be needed before this strategy can be implemented. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce phosphorus; no optimization strategy was identified for nitrogen.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	22.1	22.3
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	1.3	1.7
Annual O&M	$ Mil/yr	0.6	0.6
Present Value O&M[3]	$ Mil	5.0	5.0
Present Value Total[3]	$ Mil	6.3	6.6
Unit Capital Cost[8]	$/gpd	0.1	0.1
Unit Total PV Cost[8]	$/gpd	0.3	0.3
TN Removal			
Capital[2,4]	$ Mil	0	0
Annual O&M[4]	$ Mil/yr	0	0
O&M PV[3,4]	$ Mil	0	0
Total PV[3,4]	$ Mil	0	0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	1.3	1.7
Annual O&M[5]	$ Mil/yr	0.6	0.6
O&M PV[3,5]	$ Mil	5.0	5.0
Total PV[3,5]	$ Mil	6.3	6.6
TP Removed (Ave.)[6]	lb P/d	370	380
Annual TP Removed (Ave.)[7]	lb P/yr	136,000	140,000
TP Cost[5,9]	$/lb P	4.6	4.7

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• More organics and solids diverted to fuel the digester • Phosphorus reliably removed under peak flow scenarios	• Dependency on chemicals • Chemical costs • Increased sludge production, which is anticipated to exceed current digester capacity until the planned digester is completed.

5 Sidestream Treatment

As previously described, USD was identified as a potential candidate for sidestream treatment. The WWTP currently uses anaerobic digesters, followed by dewatering centrifuges. USD pilot tested a deammonification pilot a few years back for ammonia/nitrogen load reduction that achieved 79 to 84 percent ammonia removal with no required alkalinity addition.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature (common for plants with mechanical dewatering). It also offers several benefits over conventional nitrogen removal (i.e., nitrification/ denitrification), such as requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requiring 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for USD.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. USD already adds ferrous chloride to the Irvington Pumping Station and peroxide at the headworks for odor control. Adding ferric chloride effort might result in reducing peroxide at the headworks if the ferric chloride residual is high enough to reduce odors at the headworks. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks).

Another option to consider for eliminating the phosphorus recycled stream load is recovery via struvite precipitation. This process produces a useful byproduct (struvite crystals) that can be sold economically. The finances are typically more attractive for larger plants (>40 mgd). It is recommended that USD evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant if phosphorus load reduction is required in the future.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and buildout capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nitrogen Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	10,800	12,600	770
Discharge with Sidestream Treatment[2]	lb/d	8,400	10,400	640
Load Reduction[3]	lb/d	2,400	2,200	130
Load Reduction	%	22%	17%	17%
Annual Load Reduction[3]	lb/yr	888,000	789,000	47,600

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP*
Capital[1]	$ Mil	27.6	0.5
Annual O&M	$ Mil/yr	0.9	0.1
Total Present Value[2]	$ Mil	47.4	2.7
NH4-N Load Reduction[3,5]	lb N/yr	888,000	--
TN Load Reduction[3,5]	lb N/yr	789,000	--
TP Load Reduction[4,5]	lb P/yr	--	47,600
NH4-N Cost [3,5,6]	$/lb N	1.8	--
TN Cost [3,5,6]	$/lb N	2.0	--
TP Cost [4,5,6]	$/lb P	--	1.9

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the USD WWTP plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The USD WWTP should evaluate other available technologies that may be applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The current site does not have sufficient space for an activated sludge nutrient removal process, so a membrane bioreactor (MBR) process is shown for this report. USD could consider purchase of additional land to provide space for other nutrient removal processes.

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Ferric chloride addition to the primary clarifiers is assumed for phosphorus removal. Level 2 nitrogen limits could be met by converting the plant to a membrane bioreactor facility. The existing aeration tanks and three of the six secondary clarifiers would be converted to a Modified Ludzack-Ettinger (MLE) configuration. Additional blower capacity would also be required. To keep the plant in service during construction, new membrane tanks are shown in the location reserved for future secondary clarifiers. Based on the low carbon to nitrogen ratio measured in the primary effluent, carbon addition (methanol) is included to provide carbon for denitrification. Facilities for alkalinity addition are included in the capital costs. Fine screening is included to protect the membranes. Further evaluation is needed to confirm the feasibility, costs, and construction sequencing associated with converting existing tanks, compared to the costs of constructing new tanks.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2. Ferric chloride addition to activated sludge is included for phosphorus polishing. Three additional secondary clarifiers would be converted to aeration tanks, and all aeration tanks would be configured as 4-stage BNR. Additional storage is shown for carbon addition (methanol) to improve denitrification.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Ferric chloride chemical feed	Same as Level 2
Secondary and Tertiary	• Fine screens to protect membranes • Convert west aeration tanks to MLE, including one additional baffle per tank, new mixers, mixed liquor recycle pumping, and new diffusers • Convert east aeration tanks and three secondary clarifiers to MLE, including flow distribution, baffles, mixers, diffusers, mixed liquor recycle pumping, covers, and odor control. • Additional blower capacity • New membrane tanks for MBR • Alkalinity addition facilities • External carbon source addition facilities	Same as Level 2 plus: • Ferric chloride addition to aeration tanks for phosphorus polishing • Convert three additional secondary clarifiers to aeration tanks (4-stage BNR) including flow distribution, baffles, mixers, diffusers, mixed liquor recycle pumping, covers, and odor control. • Configure all aeration tanks as 4-stage BNR. • Additional external carbon source chemical feed

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

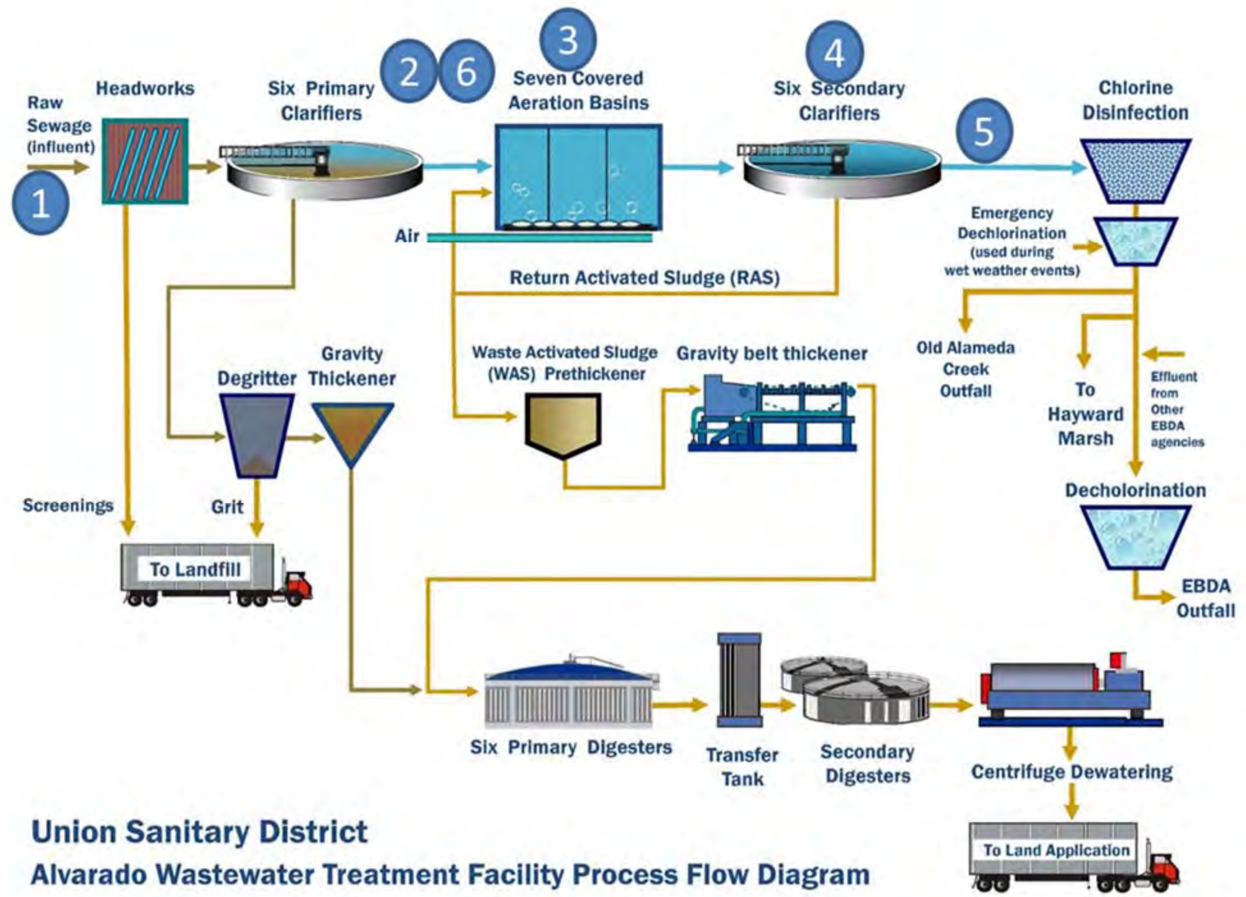

Figure 6-1. Level 2 Upgrade Concept for USD WWTP

(1) ferric chloride addition upstream of the primary clarifiers for P removal, including chemical storage and metering, (2) add fine screens to protect membranes, (3) convert existing aeration tanks to MLE configuration, (4) convert three secondary clarifiers to MLE aeration tanks, (5) construct new MBR membrane tanks, and (6) methanol and alkalinity addition to aeration basins, including chemical storage and metering.

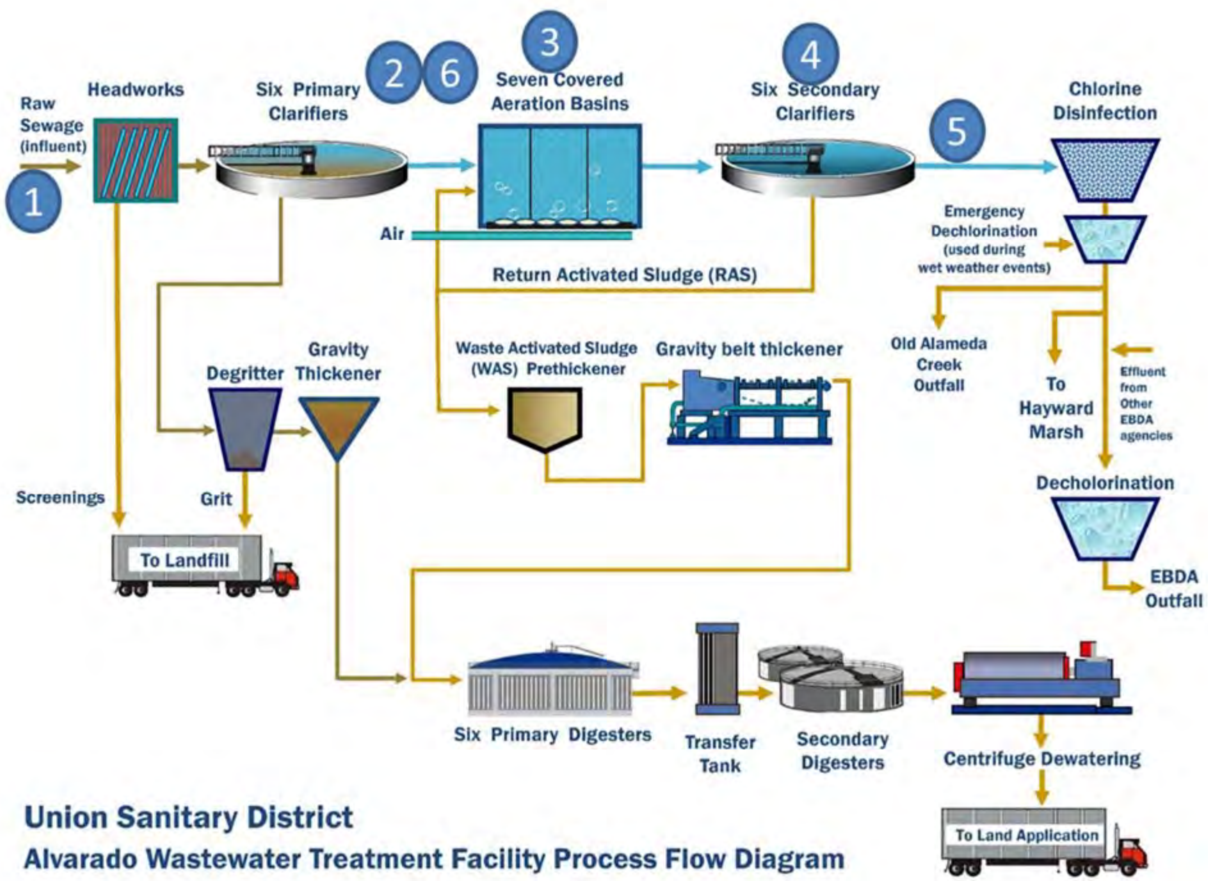

Figure 6-2. Level 3 Upgrade Concept for USD WWTP

(1) ferric chloride addition upstream of the primary clarifiers for P removal, including chemical storage and metering, (2) add fine screens to protect membranes, (3) convert existing aeration tanks to 4-stage BNR configuration, (4) convert six secondary clarifiers to 4-stage BNR aeration tanks, (5) construct new MBR membrane tanks, and (6) methanol and alkalinity addition to aeration basins, including chemical storage and metering.

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) construct new membrane tanks in the area reserved for future secondary clarifiers, (2) modify west aeration tanks to MLE with mixers, additional baffles, and mixed liquor recycle pumping, (3) convert east aeration tanks and secondary clarifiers 4 to 6 to MLE (all new tank internals, including flow distribution, baffles, mixers, diffusers, mixed liquor recycle pumping, and covers for odor control), (4) chemical addition facilities (ferric chloride, alkalinity, and methanol), and (5) add fine screens to protect membranes (location to be determined).

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) construct new membrane tanks in the area reserved for future secondary clarifiers, (2) modify west aeration tanks to 4-stage BNR with mixers, additional baffles, and mixed liquor recycle pumping, (3) convert east aeration tanks and secondary clarifiers 1 to 6 to 4-stage BNR (all new tank internals, including flow distribution, baffles, mixers, diffusers, mixed liquor recycle pumping, and covers for odor control), (4) chemical addition facilities (ferric chloride, alkalinity, and methanol), and (5) add fine screens to protect membranes (location to be determined).).

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	41.5	41.9	41.5	41.9
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	500	500	510	510
Annual O&M	$Mil/yr	6.9	7.5	8.4	9.7
O&M PV[3]	$ Mil	150	170	190	220
Total PV[3]	$ Mil	650	670	700	730
Unit Capital Cost	$/gpd	12.0	12.0	12.3	12.2
Unit Total PV	$/gpd	15.8	16.0	16.8	17.4
TN Removal					
Capital[2,4]	$ Mil	500	500	510	510
Annual O&M[4]	$ Mil/yr	6.1	6.7	7.2	8.0
O&M PV[3,4]	$ Mil	140	150	160	180
Total PV[3,4]	$ Mil	630	650	670	690
TN Removed (Ave.)[6]	lb N/d	8,200	8,400	9,500	10,900
Annual TN Removed (Ave.)[7]	lb N/yr	2,982,000	3,080,000	3,457,000	3,985,000
TN Cost[4,8]	$/lb N	7.1	7.0	6.5	5.8
TP Removal					
Capital[2,5]	$ Mil	1.8	1.9	430	430
Annual O&M[5]	$ Mil/yr	0.8	0.8	2.8	5.5
O&M PV[3,5]	$ Mil	18	19	60	120
Total PV[3,5]	$ Mil	20	21	490	550
TP Removed (Ave.)[6]	lb P/d	470	490	570	690
Annual TP Removed (Ave.)[7]	lb P/yr	173,000	180,000	209,000	250,000
TP Cost[5,8]	$/lb P	3.8	3.9	78	73

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Robust technology to absorb variability in flows and loads • Ability to reliably remove TN and TP • More organics and solids diverted to fuel the digester	• Increased operation costs associated with ferric chloride and methanol addition • Increased energy demands for aeration and membranes • Dependency on chemicals • Increased sludge production
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use and additional ferric chloride use

7 Nutrient Removal by Other Means

The USD WWTP sends approximately 3,100 acre-feet per year (1,000 million gallons per year) to the Hayward Marsh for environmental enhancement. Future use of the Hayward Marsh is to be determined. USD has no current plans to implement a recycled water program.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

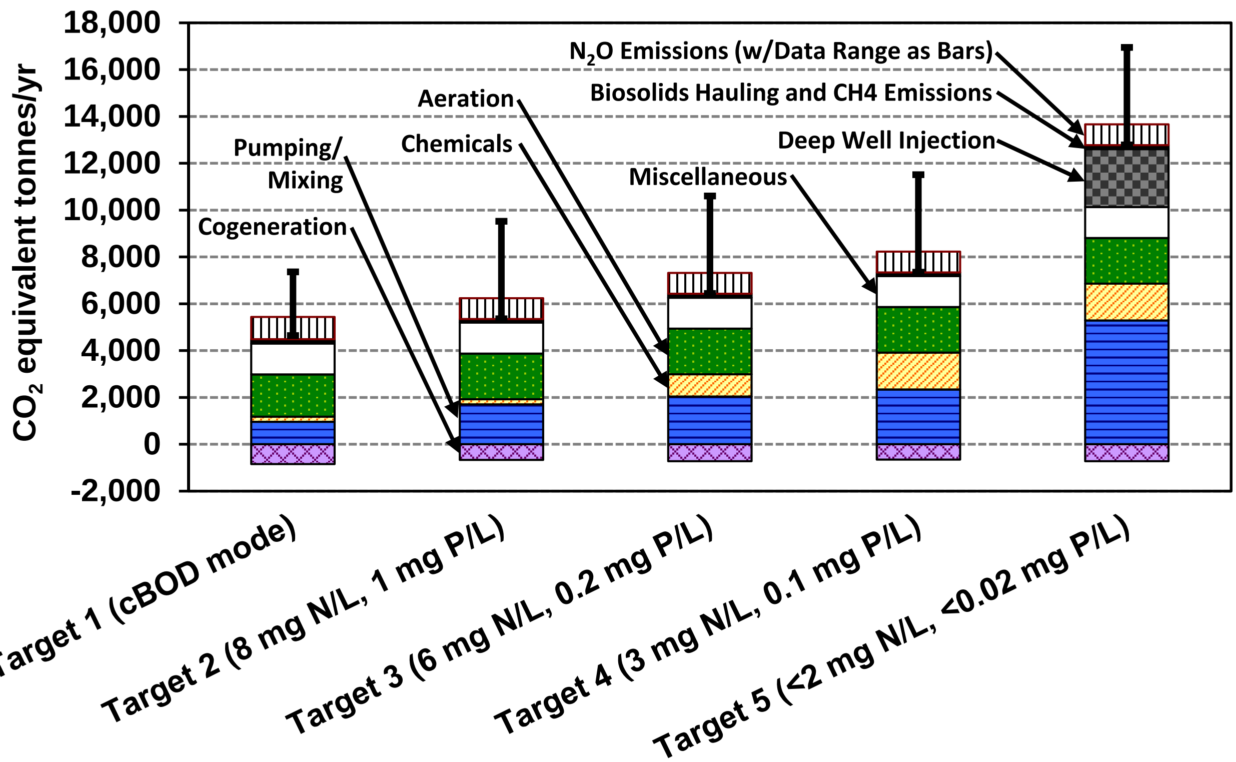

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	10	10	9,800	10,100	10,100	10,400	330
GHG Emissions Increase from Chemicals	MT CO_2/yr	80	80	1,100	1,100	2,900	2,900	50
GHG Emissions Increase Total	MT CO_2/yr	90	90	10,900	11,200	13,000	13,300	380
Unit GHG Emissions[2]	lb CO_2/MG	23	23	1,600	1,600	1,900	1,900	93
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	6	6	6	6	1.0
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	8	8	8	7.	0.9
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	1	1	2	2	43	36	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. SVCW has ferric chloride chemical feed facilities that could be potentially leveraged for this application. These projected GHG emissions are based on the addition of new ferric chloride chemical feed facilities.

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the USD WWTP. These are:

- Nitrite Shunt – USD WWTP aeration basins would be operated to promote nitrite shunt where ammonia is oxidized to nitrite and subsequently denitrified. As a result, there is significant reduction in aeration requirements for nitrification and carbon requirements for denitrification. This requires installation of sensors and process automation.
  - Advantages: Low energy process, minimal operational requirements
  - Disadvantages: Increase complexity due to instrumentation
  - Potential Next Steps: Determine costs associated with instrumentation and automation changes.
- Nutrient Removal using Granular Sludge – Future nutrient removal could use a granular sludge process. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN and TP
  - Disadvantages: No installations in North America
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

Table 1. Allowances used in developing the Opinion of Probable Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

D.36

Vallejo Flood and Wastewater District Wastewater Treatment Plant

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

Vallejo Flood and Wastewater District Wastewater Treatment Plant

Vallejo, CA

March 21, 2018
Final Report

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Executive Summary

The Vallejo Flood and Wastewater District (Vallejo) owns and operates Wastewater Treatment Plant (Vallejo WWTP) located in Vallejo, CA and discharges treated effluent year-round to Carquinez Strait, and to Mare Island Strait when wet weather flows exceed 30 MGD. The plant has an average dry weather flow (ADWF) permitted capacity of 15.5 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs ($/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-Stream[3]
Design Flow	mgd	--	--	9.2	10.4	15.5	17.5	15.5	17.5	--
Flow to Bay[2]	mgd	9.9	9.9	9.9	9.9	13.3	13.3	13.3	13.3	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	1,330	1,330	1,430	1,430	240	220	240	220	--
TN	lb N/d	2,140	2,140	2,300	2,300	1,780	1,670	1,290	670	--
TP	lb P/d	280	280	80	80	120	110	80	30	--
Costs[4,5]										
Capital	$ Mil	--	--	0.9	1.2	120	120	140	150	--
O&M PV	$ Mil	--	--	2.2	2.2	67	71	79	94	--
Total PV	$ Mil	--	--	3.1	3.3	190	190	220	240	--
Unit Costs[6]										
Capital	$/gpd	--	--	0.1	0.1	7.9	7.0	9.1	8.4	--
Total PV	$/gpd	--	--	0.3	0.3	12.2	11.0	14.2	13.7	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are based on the 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Implement chemically enhanced primary treatment (CEPT) to support partial nitrification in the trickling filter and phosphorus removal in the primary clarifier.

The Vallejo WWTP is not considered a candidate for sidestream treatment to reduce nitrogen or phosphorus loads as the plant implements lime stabilization for biosolids processing.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
   a. Construct nitrifying trickling filters and pump station
   b. Construct denitrification filters and pump station
   c. Methanol addition facilities
   d. Add chemical feed facilities at the primaries and operate as CEPT
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
   a. Same as Level 2, plus
   b. Expand the denitrification filters
   c. Add chemical feed facilities upstream of filters for additional TP removal.

As shown in Table ES-1, the costs generally increase from optimization n to Level 2 and Level 3 upgrades. The costs generally increase for both capital and O&M from the dry season (operated year round) to year round. Overall the present value costs range from $3.1 Mil for dry season optimization up to $240 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases

1 Introduction

The Vallejo Flood and Wastewater District Wastewater Treatment Plant (Vallejo WTP) serves a population of approximately 117,000 (2012) within the City of Vallejo, the former Mare Island Naval Facility and an adjacent unincorporated area. The plant is located at 450 Ryder St., Vallejo, CA.

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

The Vallejo WTP holds the National Pollutant Discharge Elimination System (NPDES) permit (Order No. R2-2017-0035, NPDES Permit No. CA0037699). The plant discharges year-round to the Mare Island Strait and to Carquinez Strait when wet weather flows exceed 30 MGD. The Carquinez Strait discharge is located at latitude 38° 03' 53" N and longitude 122° 13' 42" W. The Mare Island Strait discharge is located at latitude 38° 05' 23" N and longitude 122° 15' 12" W.

Table 2-1 provides a summary of the seasonal permit limitations that are specific to the Vallejo WTP, under the NPDES permit and are specific to nutrients. The table is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2017-0035, CA0037699)

Criteria	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Peak
Flow	mgd	15.5	---	---	---	60
CBOD	mg/L	---	25	40	---	---
TSS	mg/L	---	30	45	---	---
Ammonia	mg N/L	---	44	---	86	---

This table identifies relevant permit limitations only and does not include a complete list of permit limitations

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the Vallejo WWTP. The plant has primary clarifiers, followed by a trickling filter/solids contact system for secondary treatment. The trickling filters have been observed to perform some nitrification. Solids are lime stabilized and hauled off site.

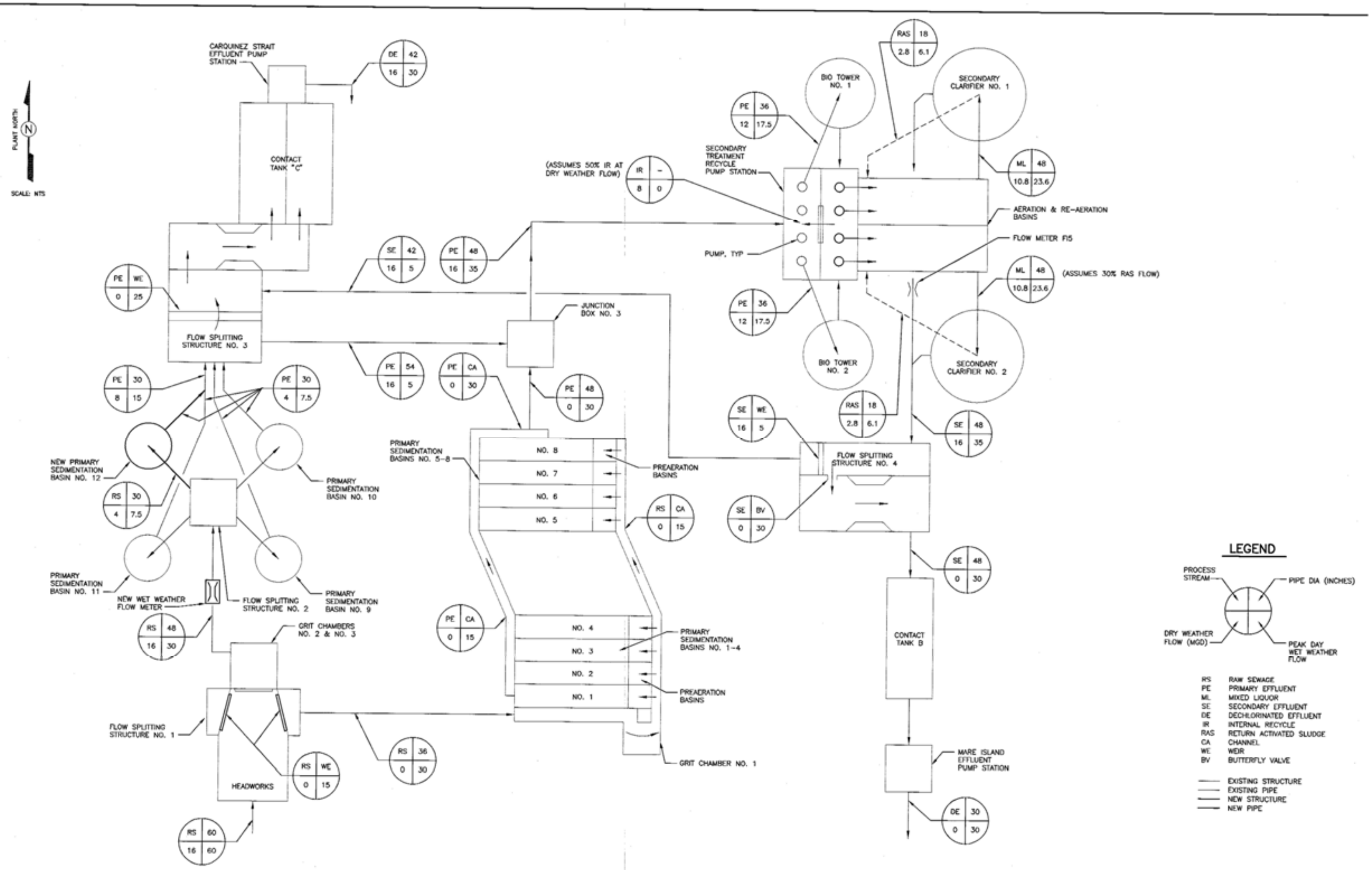

Figure 2-1. Process Flow Diagram for Vallejo Flood and Wastewater District Wastewater Treatment Plant

2.3 Existing Flows and Loads

A data request was submitted to each POTW included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the Vallejo WWTP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	9.2	9.8	9.8	14.6
BOD	lb/d	19,500	19,400	20,700	20,900
TSS	lb/d	19,500	19,600	20,800	22,100
Ammonia	lb N/d	2,280	2,280	2,380	2,460
Total Kjeldahl Nitrogen (TKN)[4]	lb N/d	3,440	3,250	3,610	3,930
Total Phosphorus (TP)[4]	lb P/d	390	410	420	540
Alkalinity	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	250	240	250	170
TSS	mg/L	260	240	260	190
Ammonia	mg N/L	30	28	29	21
TKN[4]	mg N/L	46	41	45	36
TP[4]	mg P/L	5.2	5.2	5.3	5.0
Alkalinity	mg $CaCO_3$/L	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. TP and TKN available for July 2012 – June 2014 only

2.4 Future Nutrient Removal Projects

No nutrient related projects have been completed or are in progress at Vallejo WWTP.

2.5 Pilot Testing

Vallejo WWTP is developing a recycled water utilities plan.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in

the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025. Where that information is unavailable, a 15 percent increase in loadings was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades to achieve Level 2 and Level 3 effluent targets were developed based on permitted capacity.

3.1 Flow and Loading for Optimization

The flow and loads that formed the basis of the optimization analysis for the Vallejo WWTP are presented in Table 3-1. The projected flow and load for the Vallejo WWTP in 2025 was not available; as a result, a 15 percent increase for loads was used with no increase in flow.

Table 3-1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	10.6	11.3	11.3	16.8
BOD	lb/d	22,425	22,310	23,805	24,035
TSS	lb/d	22,425	22,540	23,920	25,415
Ammonia	lb N/d	2,622	2,622	2,737	2,829
TKN	lb N/d	3,956	3,738	4,152	4,520
TP	lb P/d	449	472	483	621
Alkalinity	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	254	237	253	172
TSS	mg/L	254	240	254	181
Ammonia	mg N/L	30	28	29	20
TKN	mg N/L	45	40	44	32
TP	mg P/L	5.08	5.02	5.14	4.43
Alkalinity	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.2 Flow and Loading for Sidestream Treatment

Vallejo is not considered a candidate for sidestream treatment due to their lack of anaerobic digestion upstream of the mechanical dewatering. Furthermore, the plant adds lime upstream of dewatering which results in pH conditions not amenable to biologically mediated sidestream treatment (>12 s.u.).

[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. These values are based on the plant's permitted flow capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the permitted flow capacity.

Table 3-2. Flow and Load for Facility Upgrades (Projected to Permitted Flow Capacity)

Parameter	Unit	Permitted Flow Capacity, ADWF[1,2,3]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	15.5	16.5	16.5	24.6
BOD	lb/d	32,909	32,740	34,902	35,257
TSS	lb/d	32,909	33,077	35,149	37,310
Ammonia	lb N/d	3,848	3,848	4,013	4,157
TKN	lb N/d	5,805	5,485	6,092	6,640
TP	lb P/d	658	692	711	907
Alkalinity	lb/d as $CaCO_3$			---	---
BOD	mg/L	254	237	253	172
TSS	mg/L	254	240	255	182
Ammonia	mg N/L	30	28	29	20
TKN	mg N/L	45	40	44	32
TP	mg P/L	5.1	5.0	5.2	4.4
Alkalinity	mg/L as $CaCO_3$	---	---	---	---

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and operations and maintenance (O&M) costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load for the recommended strategy. Two optimization strategies were identified during the Vallejo WWTP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The two optimization strategies are described below.

- **Optimization Strategy 1:** Add ferric chloride upstream of the primary clarifiers to precipitate phosphorus
  - ***Is it feasible?*** Yes, but this would require new facilities.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Increase P removal.
  - ***Result from analysis:*** Ferric chloride addition will increase P removal.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Perform chemically enhanced primary treatment (CEPT) to improve primary clarifier performance so that trickling filters can nitrify
  - ***Is it feasible?*** Yes, but this would require new facilities.
  - ***Potential impact on ability to reduce nutrient discharge loads?*** Minimal impact since trickling filters already partially nitrify and CEPT would only serve to remove the additional BOD associated with the projected 15% increase in BOD loading.
  - ***Result from analysis:*** Implementation of this technology would have minimal benefit.
  - ***Recommendation:*** Carry forward in conjunction with Strategy 1 to maintain current nitrification.

Strategies 1 and 2 are the best apparent way to reduce effluent phosphorus loads and maintain existing level of nitrification; no feasible strategies were determined to increase nitrogen removal.

The recommended strategy is shown with the process flowsheet presented in Figure 4-1. A description of the recommended strategy and the evaluation results are presented below. It is noted, however, that recommended modifications for optimization may impact the plant's treatment capacity. Thus, any changes for optimization should be considered an interim solution.

The capital and operational elements of the recommended optimization strategy are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements (Increase ferric chloride addition at headworks to increase phosphorus removal)

Capital Elements	Operating Elements
Ferric chloride storage tanks Polymer system Chemical metering pumps	Chemical costs

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy described in Table 4-1. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025. The Vallejo WWTP plant shows improved phosphorus removal but no change in ammonia or nitrogen removal.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	1,430	1,430	2,300	2,300	300	300
Discharge with Opt. Strategy[1]	lb N or P/d	1,430	1,430	2,300	2,300	80	80
Load Reduction[2,3]	lb N or P/d	0	0	0	0	220	220
Load Reduction[2,3]	lb N or P/d	0	0	0	0	72%	74%
Annual Load Reduction	lb N or P/d	0%	0%	0%	0%	79,100	81,100

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. Calculated nutrient reduction is zero for NH4-N and TN since no optimizations were identified.

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce phosphorus; no optimization strategy was identified for nitrogen.

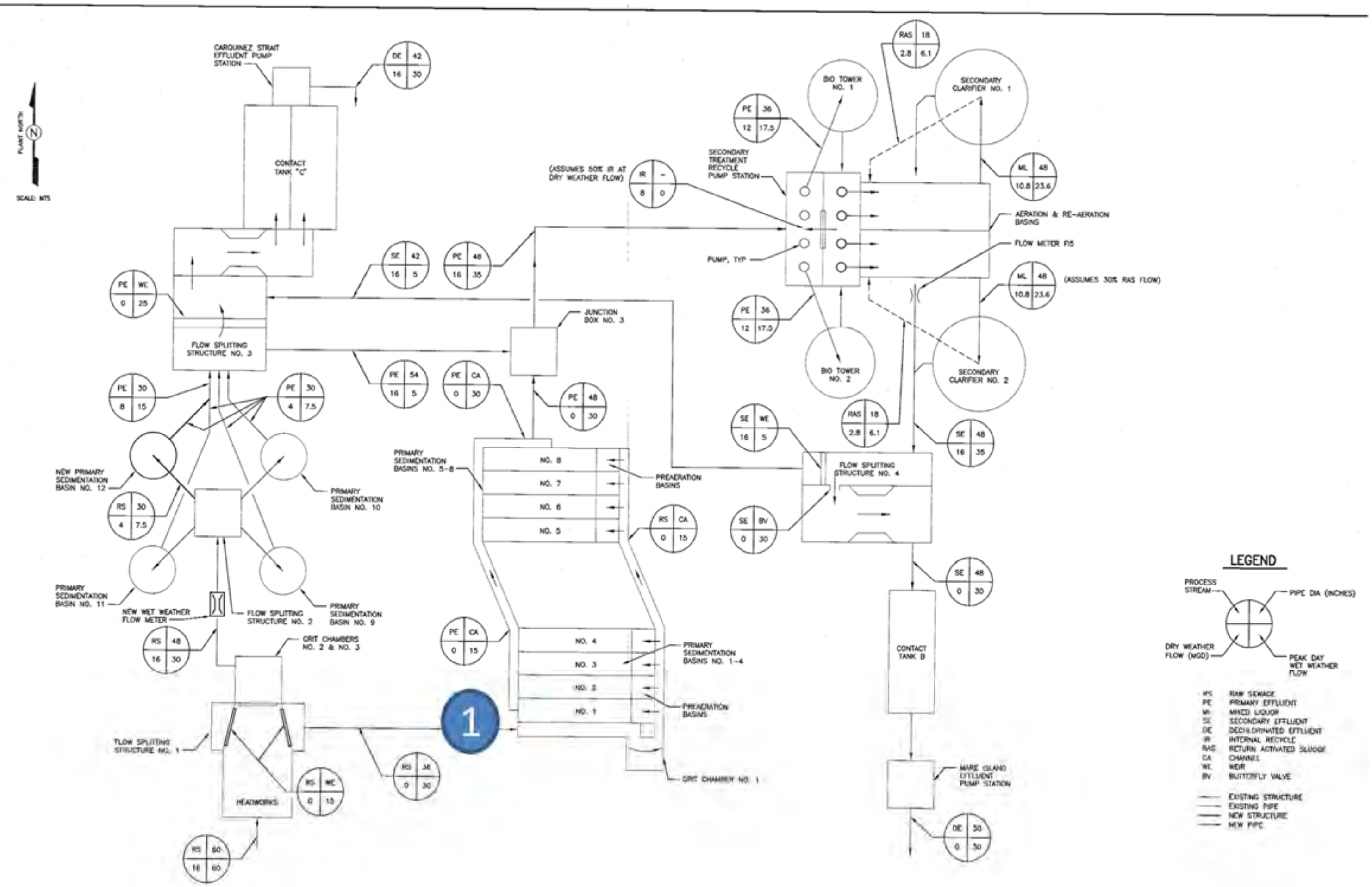

Figure 4-1. Optimization Concepts Considered for the Vallejo WWTP

(1) Construct CEPT for P removal and to continue partial ammonia removal.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	9.2	10.4
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	0.9	1.2
Annual O&M	$ Mil/yr	0.2	0.2
Present Value O&M[3]	$ Mil	2.2	2.2
Present Value Total[3]	$ Mil	3.1	3.3
Unit Capital Cost[8]	$/gpd	0.1	0.1
Unit Total PV Cost[8]	$/gpd	0.3	0.3
TN Removal			
Capital[2,4]	$ Mil	0.0	0.0
Annual O&M[4]	$ Mil/yr	0.0	0.0
O&M PV[3,4]	$ Mil	0.0	0.0
Total PV[3,4]	$ Mil	0.0	0.0
TN Removed (Ave.)[6,10]	lb N/d	0	0
Annual TN Removed (Ave.)[7,10]	lb N/yr	0	0
TN Cost[4,9,10]	$/lb N	NA	NA
TP Removal			
Capital[2,5]	$ Mil	0.9	1.2
Annual O&M[5]	$ Mil/yr	0.2	0.2
O&M PV[3,5]	$ Mil	2.2	2.2
Total PV[3,5]	$ Mil	3.1	3.3
TP Removed (Ave.)[6]	lb P/d	220	220
Annual TP Removed (Ave.)[7]	lb P/yr	79,100	81,100
TP Cost[5,9]	$/lb P	3.9	4.1

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).
10. Calculated nutrient reduction is zero, since no optimizations were identified for nitrogen

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategy.

Table 4-4. Ancillary Benefits and Impacts for Optimization Strategy

Ancillary Benefits	Adverse Impacts
• Phosphorus reliably removed under peak flow scenarios	• Dependency on chemicals • Chemical costs • CEPT would reduce the organic loading to the trickling filters and the trickling filters would continue to nitrify.

5 Sidestream Treatment

Sidestream treatment is not considered a viable option for Vallejo as previously described and thus was not further evaluated.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the Vallejo WWTP plant to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. The Vallejo WWTP should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements are shown with the process flow diagram presented in Figure 6-1. Level 2 upgrades could be met by constructing nitrifying trickling filters (NTF) and denitrification filters downstream of the existing secondary process for nitrogen removal and implementing ferric chloride addition to the primary clarifiers for phosphorus removal. These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure (i.e. TF/SC processes).

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

Level 3 upgrades would require additional chemical addition immediately upstream of denitrification filters since chemical addition upstream of filtration would be required to meet phosphorus levels. Additional methanol use would be necessary at the denitrification filters to achieve Level 3 nitrogen levels. Additional denitrification filters would be necessary. These processes were selected because they could be located within the plant boundaries and maximize existing infrastructure (i.e. TF/SC processes).

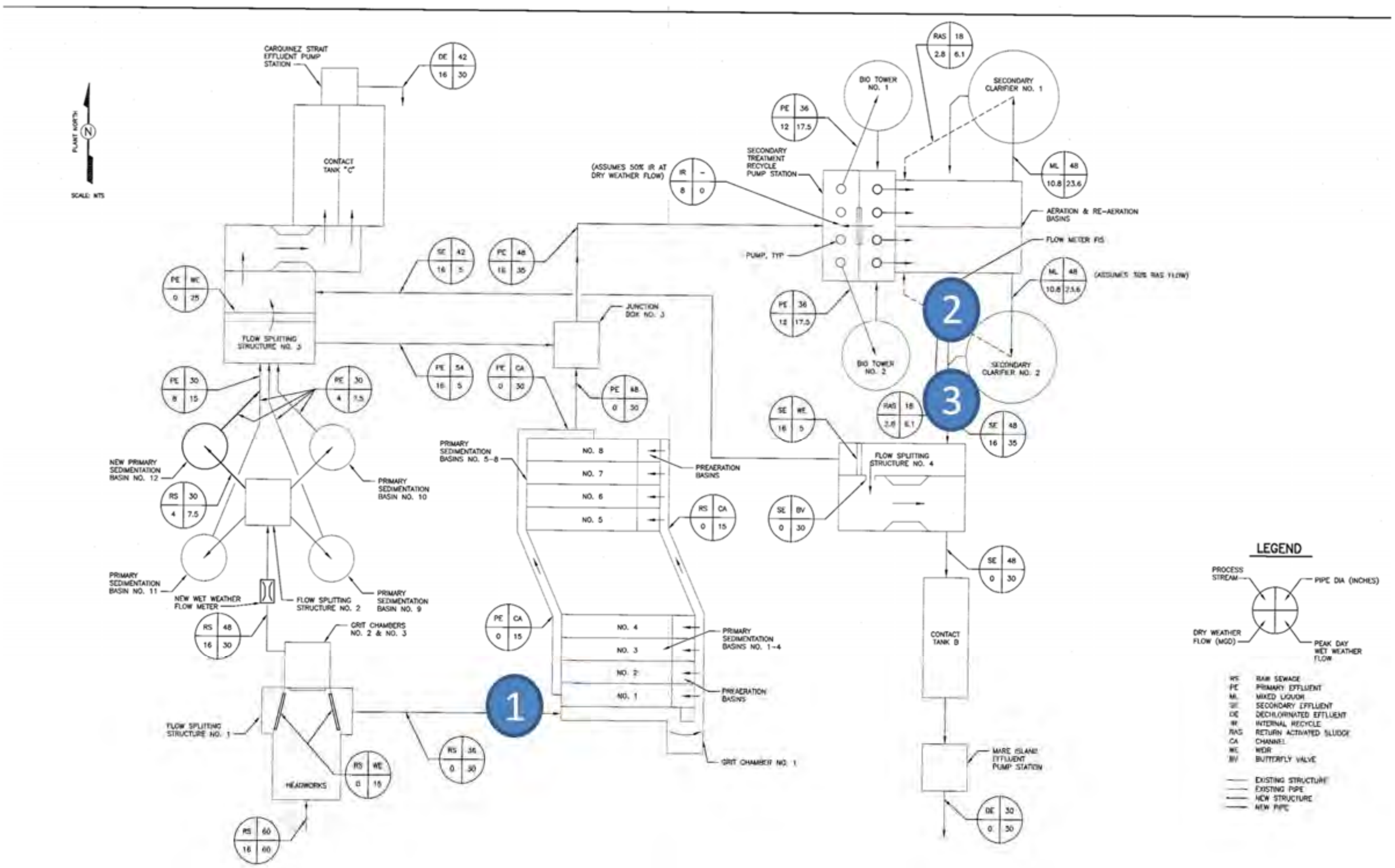

Figure 6-1. Level 2 Upgrade Concept for Vallejo WWTP

(1) construct CEPT for P removal, (2) construct new nitrifying trickling filters and (3) construct new denitrification filters and conventional filters.

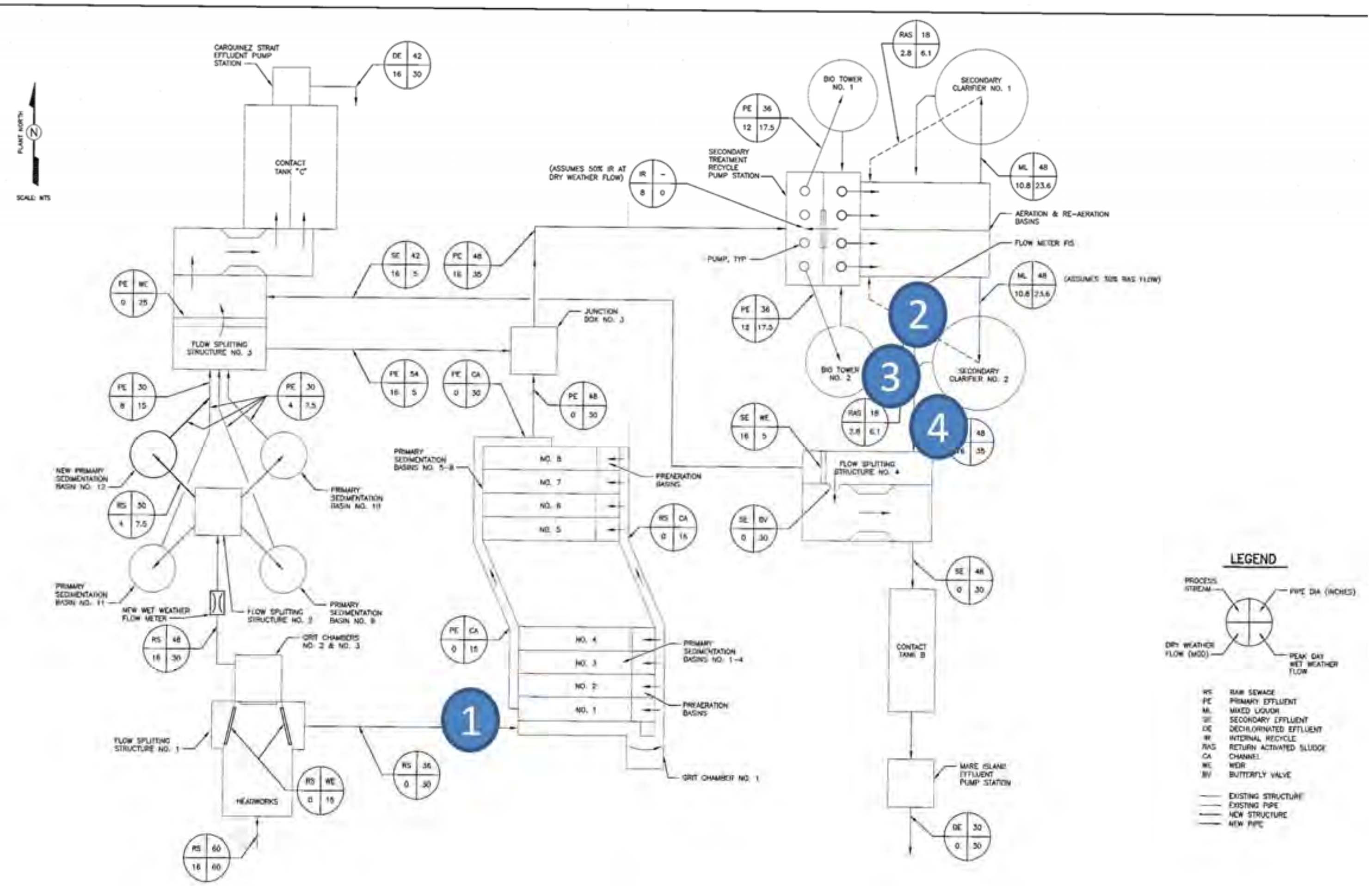

Figure 6-2. Level 3 Upgrade Concept for Vallejo WWTP

(1) construct CEPT for P removal, (2) construct new nitrifying trickling filters, (3) construct chemical addition for P removal and (4) construct new denitrification filters.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. These costs do not account for any changes in solids handling requirements or energy requirements in other unit processes. Operating costs represent the average cost for the 30-year period. Nutrient reduction is also calculated as the average of the 30-year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (i.e., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address TN or TP reductions.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Ferric Chloride and Polymer Chemical Feed • Alkalinity addition	Same as Level 2
Secondary	--	--
Tertiary	• Nitrifying Trickling Filters • Nitrifying Trickling Filter Pump Station • Denitrification Filters • Denitrification Filter Pump Station • Caustic Soda Addition Facilities • External Carbon Source Chemical Feed	Same as Level 2 plus: • Additional Denitrification Filters • Additional External Carbon Source Chemical Feed • Ferric Chloride Chemical Feed

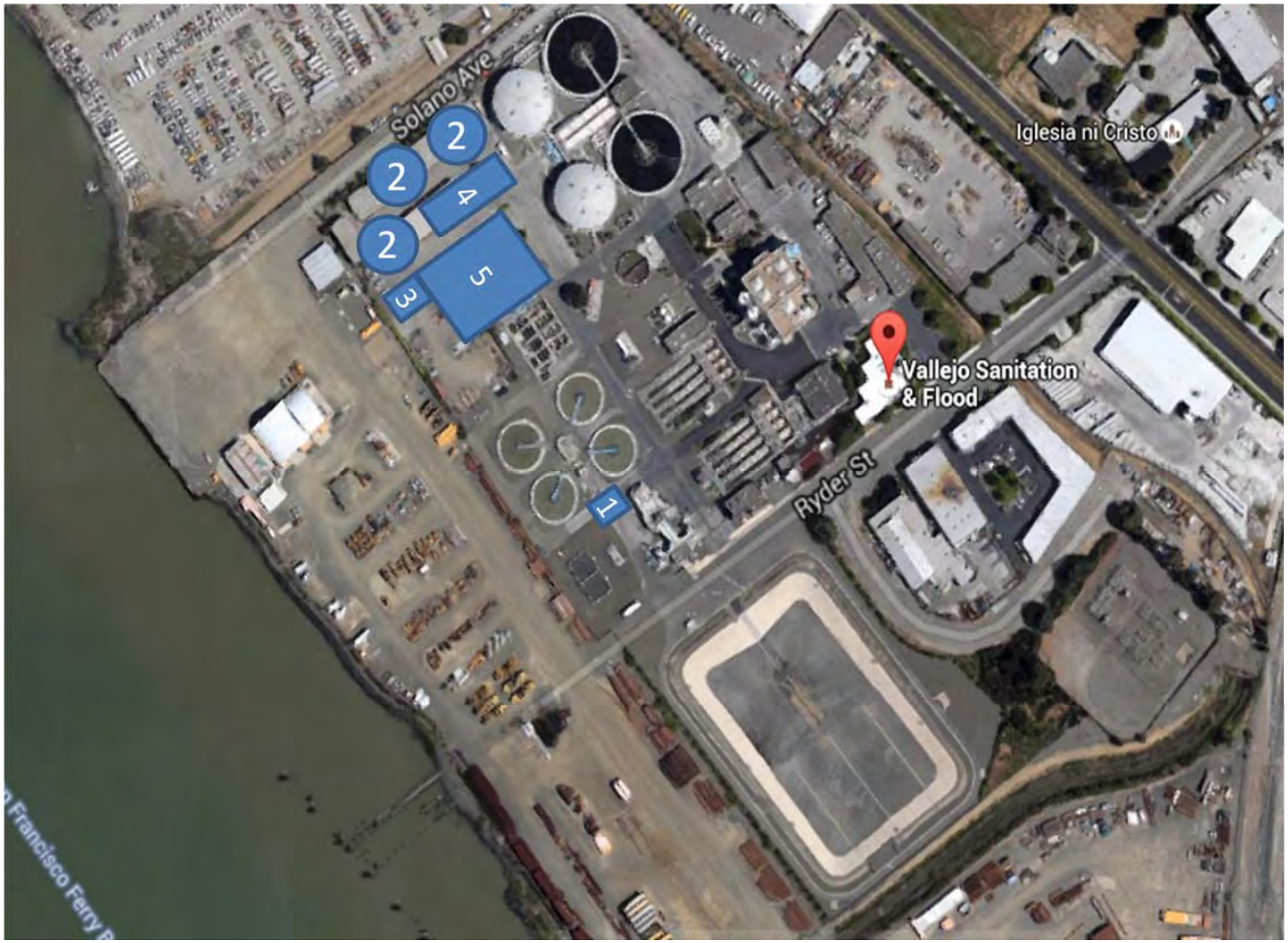

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) chemical addition facilities, (2) new nitrifying trickling filters, (3) chemical addition facilities, (4) nitrifying trickling filter and denitrification filter pumping stations and (5) denitrification and conventional filters and ancillary equipment.

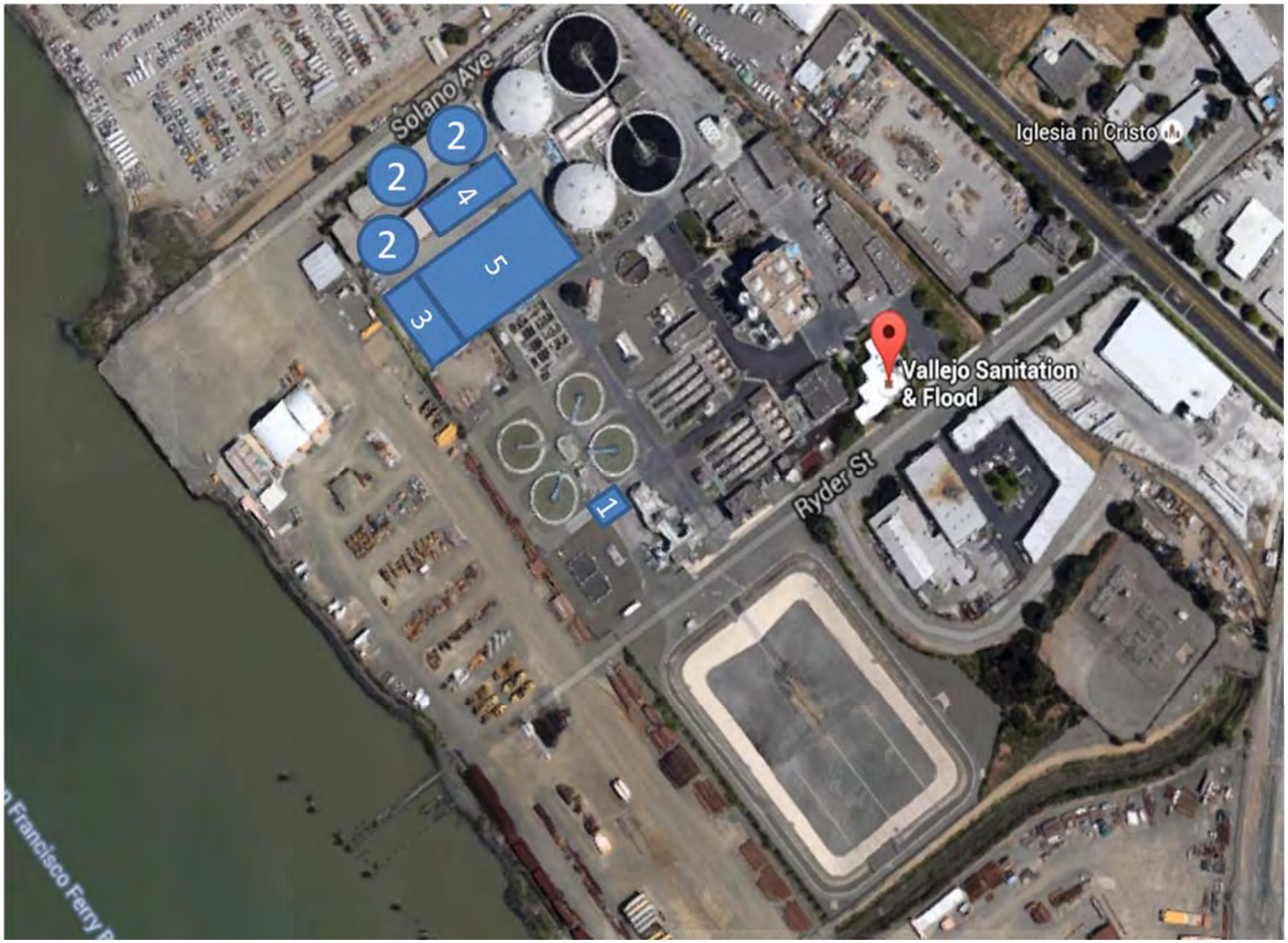

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) chemical addition facilities, (2) new nitrifying trickling filters, (3) chemical addition facilities, (4) nitrifying trickling filter and denitrification filter pumping stations, and (5) denitrification filters and ancillary equipment.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1,9]	Level 3 Year Round[1,9]
Design Flow	mgd	15.5	17.5	15.5	17.5
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	120	120	140	150
Annual O&M	$Mil/yr	3.0	3.2	3.5	4.2
O&M PV[3]	$ Mil	67	71	79	94
Total PV[3]	$ Mil	190	190	220	240
Unit Capital Cost	$/gpd	7.9	7.0	9.1	8.4
Unit Total PV	$/gpd	12.2	11.0	14.2	13.7
TN Removal					
Capital[2,4]	$ Mil	120	120	140	140
Annual O&M[4]	$ Mil/yr	2.7	2.8	3.1	3.5
O&M PV[3,4]	$ Mil	59	63	69	79
Total PV[3,4]	$ Mil	180	180	210	220
TN Removed (Ave.)[6]	lb N/d	1,100	1,200	1,600	2,200
Annual TN Removed (Ave.)[7]	lb N/yr	397,000	440,000	576,000	804,000
TN Cost[4,8]	$/lb N	15.1	13.9	12.1	9.3
TP Removal					
Capital[2,5]	$ Mil	1.1	1.2	84	88
Annual O&M[5]	$ Mil/yr	0.3	0.3	0.7	1.3
O&M PV[3,5]	$ Mil	7	8	16	28
Total PV[3,5]	$ Mil	8	9	100	117
TP Removed (Ave.)[6]	lb P/d	260	260	290	340
Annual TP Removed (Ave.)[7]	lb P/yr	93,000	96,000	107,000	124,000
TP Cost[5,8]	$/lb P	3.0	3.1	31.2	31.2

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. Level 3 costs include costs associated with Level 2.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Ancillary Benefits	Adverse Impacts
Level 2	• Leverage existing secondary process • Robust technology to absorb variability in flows and loads • Ability to reliably remove TN and TP	• Increased energy from NTF pumping and tertiary filter pumping • Additional unit processes to operate • Safety from external carbon source (if methanol) • High cost associated with methanol use • Increase sludge production
Level 3	Same as Level 2.	Same as Level 2 plus the following additional adverse impacts: • Higher costs associated with methanol use

7 Nutrient Removal by Other Means

Vallejo does not currently produce recycled water. Vallejo is in the beginning stage of a feasibility study to determine what treatment processes would be needed to create recycled water, identify potential customers, and determine how to partner with the City of Vallejo to potentially distribute recycled water in the future.

8 Greenhouse Gas Emissions

The impact of new unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from

Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

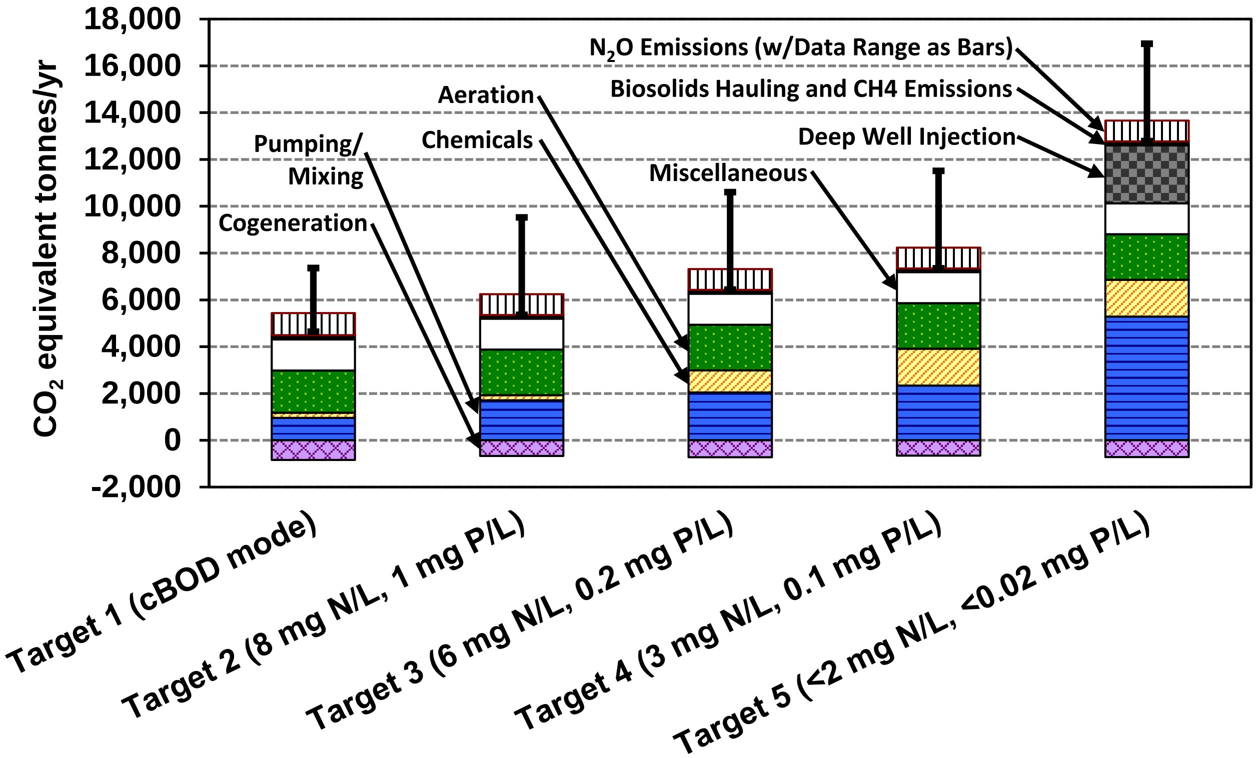

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values4 for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round[5]
GHG Emissions Increase from Energy	MT CO_2/yr	5	5	1,500	1,500	1,800	1,900	--
GHG Emissions Increase from Chemicals	MT CO_2/yr	31	33	21,200	22,400	21,900	23,200	--
GHG Emissions Increase Total	MT CO_2/yr	36	38	22,700	23,900	23,700	25,100	--
								--
Unit GHG Emissions[2]	lb CO_2/MG	22	23	8,200	8,600	8,600	9,100	--
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--*	--*	80	90	80	90	--
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	--*	--*	130	120	90	70	--
Unit GHGs for Total P Removal[2,4,5]	lb GHG/lb P	1	1	1	1	20	18	--

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. Not applicable because Vallejo is not a candidate for sidestream treatment.

* No removal, since no optimizations were identified for ammonia or nitrogen.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

In reviewing the innovative technologies, two were identified for future consideration at the Vallejo WWTP. These are:

- Zeolite-Anammox – Vallejo WWTP final effluent would be subsequently treated by a zeolite-anammox process where ammonia sorbs to a zeolite bed and is subsequently removed through a deammonification process.
  - Advantages: Low energy process, minimal operational requirements, minimal instrumentation
  - Disadvantages: Large footprint, no full-scale installations
  - Potential Next Steps: Determine footprint requirements based on previous studies and identify potential location. If appropriate, consider pilot testing the zeolite-anammox process to determine benefits.
- Treatment Wetland – Vallejo WWTP final effluent would be subsequently treated through a constructed wetland where algae and aquatic plants take up nutrients and nitrogen removal is performed by biofilms.
  - Advantages: Low operations and maintenance, mature technology
  - Disadvantages: Large footprint
  - Potential Next Steps: Determine footprint requirements based on typical wetlands design and identify potential location. Consider pilot testing a small-scale constructed wetland to determine benefits.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost. See Table 1 below.

The unit costs for power, chemicals, and labor are shown in Table 2 below. A common unit cost basis for all plants in the study was selected this analysis.

Table 1. Allowances used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Bulk Chlorine	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

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West County Wastewater District

8

Bay Area Clean Water Agencies
Nutrient Reduction Study

West County Wastewater District

Richmond, CA

May 21, 2018
Final Report

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Executive Summary

The West County Wastewater District (WCWD) Treatment Plant (TP) discharges to the Central San Francisco Bay. It shares a common outfall and discharge permit with the Richmond Municipal Sewer District (RMSD) Water Pollution Control Plant (WPCP). The WCWD TP is located at 2377 Garden Tract Road, Richmond, CA 94801, and it serves approximately 32,300 service connections throughout parts of the City of Richmond, City of San Pablo, and adjacent unincorporated areas. The plant has an average dry weather flow (ADWF) permitted capacity of 12.5 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs (e.g., $/gpd) were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3,7]	Opt. Year Round[3,7]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	7.7	9.4	10.4	12.7	10.4	12.7	--
Flow to Bay[2]	mgd	1.9	1.9	1.9	1.9	2.2	2.2	2.2	2.2	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	11	10	--[7]	--[7]	13	13	13	13	13
TN	lb N/d	450	450	--[7]	--[7]	300	270	250	110	340
TP	lb P/d	46	46	--[7]	--[7]	20	18	16	5	32
Costs[4,5,8]										
Capital	$ Mil	--	--	--[7]	--[7]	53	55	70	79	19
O&M PV	$ Mil	--	--	--[7]	--[7]	31	36	42	51	26
Total PV	$ Mil	--	--	--[7]	--[7]	84	91	111	130	45
Unit Costs[6]										
Capital	$/gpd	--	--	--[7]	--[7]	5.1	4.4	6.7	6.3	--
Total PV	$/gpd	--	--	--[7]	--[7]	8.1	7.2	10.7	10.3	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 10 years (optimization) and 30 years (sidestream and upgrades).
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
7. The plant completed major upgrades/expansion project in late 2017 that improved nitrification reliability, total nitrogen load reduction, and others. As a result, no optimization strategies were considered.
8. These cost includes the major upgrades/expansion project completed in late 2017 ($48.3 Mil).

The WCWD TP completed several plant expansion and upgrade projects in late 2017. The expansion and upgrades increased nutrient load reduction by enhancing the nitrification reliability and facilitated denitrification by a Modified Ludzack-Ettinger (MLE) process configuration. Given these recently completed projects, no new optimization strategies were considered for the WCWD TP.

The WCWD TP is considered a potential candidate for sidestream treatment to reduce total nitrogen and total phosphorus discharge loads. A nitrifying sequencing batch reactor is recommended for total nitrogen load reduction and a metal salts chemical precipitation technology is recommended for total phosphorus load reduction.

The upgrade strategies to achieve Levels 2 and 3 include:

1. Level 2 (15 mg TN-N/L and 1 mg Total P/L):
   a. Use the recently completed plant expansion and upgrade projects (e.g., the additional aeration basin) to meet the ammonia and nearly meet the total nitrogen load reduction requirements.
   b. Add metal salt coagulant chemical feed facilities at the primaries to meet the Level 2 total phosphorus concentrations.
   c. Increase the return activated sludge (RAS) pumping capacity to gain secondary clarifier capacity and enhance denitrification (if required to reliably meet Level 2 concentrations).
   d. Add an external carbon source chemical feed facilities in case it is required to reliably meet Level 2 total nitrogen concentrations.
2. Level 3 (6 mg TN-N/L and 0.3 mg Total P/L)
   a. Same as Level 2, plus:
   b. Add a denitrifying filter complex with a filter feed pumping station.
   c. Add an external carbon source at the filter complex for total nitrogen load reduction.
   d. Add metal salt/polymer chemical feed facilities at the filter complex for total phosphorus load reduction.

Capital costs, O&M costs and present value costs were determined for optimization, sidestream treatment, Level 2 upgrades and Level 3 upgrades. These costs do not account for changes in solids handling requirements or energy requirements in other unit processes.

As shown in Table ES-1, and as might be expected, the costs generally increase from sidestream treatment to Level 2 and Level 3 upgrades, respectively. The costs generally increase for both capital and O&M from the dry season to year round. Overall, the present value costs range from approximately $45 Mil for sidestream treatment up to approximately $130 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions increased from sidestream treatment to the Level 2 and 3 upgrades.

1 Introduction

The West County Wastewater District (WCWD) Treatment Plant (TP) discharges to the Central San Francisco Bay. It shares a common outfall and discharge permit with the Richmond Municipal Sewer District (RMSD) Water Pollution Control Plant (WPCP). The WCWD TP is located at 2377 Garden Tract Road, Richmond, CA 94801, and it serves approximately 32,300 service connections throughout parts of the City of Richmond, City of San Pablo, and adjacent unincorporated areas. The plant has an average dry weather flow (ADWF) permitted capacity of 12.5 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

WCWD holds the National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2013-0016; CA0038539. Table 2-1 provides a summary of the permit limitations but is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2-1. NPDES Permit Limitations (Order No. R2-2013-0016; CA0038539)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily	Wet Weather Capacity
Flow	mgd	12.5	--	--	--	21
BOD	mg/L	--	30	45	--	--
TSS	mg/L	--	30	45	--	--
Total Ammonia, as N	mg/L	--	32	-	59	--

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the existing process flow diagram for the WCWD TP. Both liquids processes and solids processes are shown. Treatment processes consist of screening, grit removal, flow equalization, primary sedimentation, Modified Ludzack-Ettinger (MLE) biological nutrient removal (BNR), secondary sedimentation, chlorination, and dechlorination. The MLE BNR facilities fully nitrify.

Approximately 80 percent of the treated water is recycled at East Bay Municipal Utility District water reclamation plants. The water is filtered separately at each water reclamation plant.

Waste activated sludge is thickened with dissolved air flotation units and blended with primary solids before anaerobic digestion. The digested biosolids are combined with those from RMSD WPCP and further treated in a sludge drying lagoon.

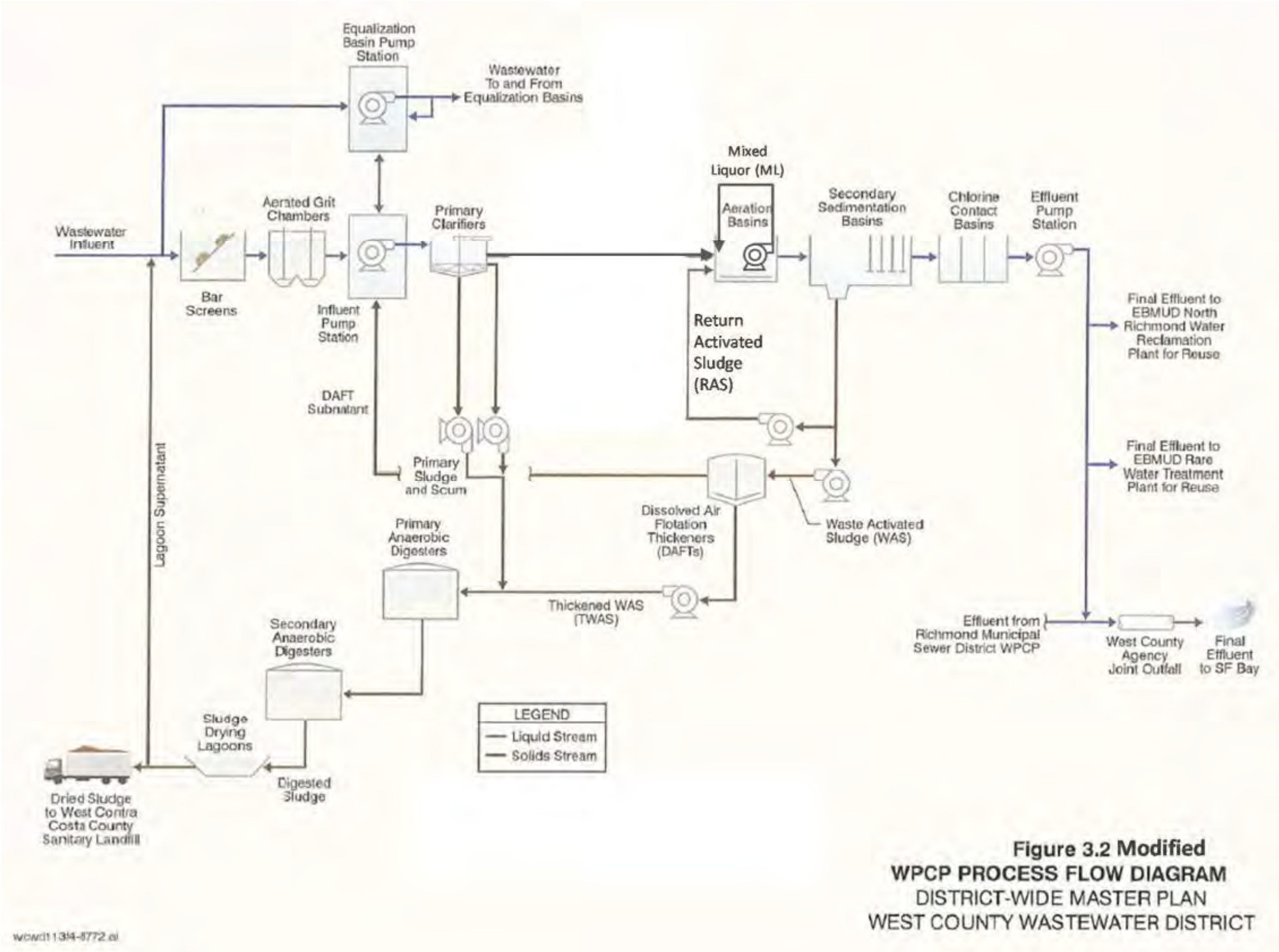

Figure 2-1 Process Flow Diagram for the WCWD TP

2.3 Existing Flows and Loads

A data request was submitted to each facility included in the Watershed Permit in December 2014 as a means to understand historical flows and loads, plant performance, and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for the WCWD TP is shown in Table 2-2.

Table 2-2. Current Influent Flows and Loads (7/2012-6/2014)

Criteria	Unit	ADWF[1,2]	Average Annual	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	7.7	8.7	9.0	13.7
BOD	lb/d	18,500	18,700	20,100	21,300
TSS	lb/d	24,500	22,100	27,900	24,000
Ammonia	lb N/d	2,200	2,700	2,300	4,000
Total Kjeldahl Nitrogen (TKN)	lb N/d	3,600	4,200	3,600	5,700
Total Phosphorus (TP)	lb P/d	470	490	470	590
Alkalinity[4]	lb $CaCO_3$/d	No Data	14,900	No Data	17,400
BOD	mg/L	288	257	269	186
TSS	mg/L	381	304	373	210
Ammonia	mg N/L	34	37	31	35
TKN	mg N/L	56	58	48	50
TP	mg P/L	7.3	6.7	6.3	5.2
Alkalinity[4]	mg $CaCO_3$/L	No Data	205	No Data	152

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Data not provided.

2.4 Recently Completed Nutrient Removal Projects

WCWD recently completed several major upgrade and expansion projects. A list of the key projects recently constructed and in operation since the end of 2017 are as follows:

- Total Nitrogen Removal Improvements construction completed in late 2017 (Master Plan ID, PPP07). The key project elements include:
  - Roughing filter demolished and taken out of service.
  - Removed splitter box that routes RAS after roughing filter.
  - Added a new aeration basin in available space west of existing aeration basin.
  - Converted existing aeration basin to Modified Ludzack-Ettinger (MLE) mode. This required a new mixed liquor return pumping station to promote return of nitrate laden mixed liquor to the

front-end non-aerated selector zones for biological denitrification (i.e., total nitrogen load reduction).

- Evaluated use of anaerobic zone for future biological phosphorus removal.
- Replaced ceramic disk diffuser in each aeration basin with membrane diffusers (3,850 new membrane diffusers per basin).

- Ammonia Removal Improvements (Master Plan ID PPP04) and Alkalinity Feed System (Master Plan ID PPP06) project completed in late 2017. The project augmented the aeration basins with additional alkalinity to eliminate ammonia bleed through (prone to occur from October through January).
- Secondary Sedimentation Optimization Project (Master Plan ID PPP05): to eliminate periods of high effluent solids; improve the overall filterability of the effluent including dealing with polymeric substances issue likely due to trickling filters and exacerbated by drought. These issues seem to have been resolved with the Master Plan ID PPP04 and PPP06 project improvements listed above by adding more alkalinity.

2.5 Pilot Testing

WCWD has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

Optimization concepts were not developed for the WCWD TP as the plant recently completed several major upgrades and expansion projects as listed in Section 2.4. The recently completed projects will maintain the ability to reliably meet the upgrade ammonia concentration (2 mg N/L) and will likely meet the Level 2 upgrade total nitrogen concentration (15 mg N/L).

3.2 Flow and Loading for Sidestream Treatment

It was determined from provided data that the WCWD TP may be a sidestream treatment candidate.

Additional sampling for the sidestream was performed in July, 2015. The sidestream flows and loads for the permitted capacity are provided in Table 3–1. The sampling results were projected forward to the permitted capacity and used for facility sizing.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Table 3–1. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Projected to Permitted Flow Capacity
Flow	mgd	0.23	0.37
Ammonia	lb N/d	720	1,130
TKN	lb N/d	1,020	1,610
Total N[1]	lb N/d	1,020	1,610
Total P	lb P/d	290	450
OrthoP	lb P/d	250	400
Alkalinity	lb $CaCO_3$/d	1,660	2,610
Ammonia	mg N/L	370	370
TKN	mg N/L	530	530
Total N[1]	mg N/L	530	530
Total P	mg P/L	150	150
OrthoP	mg P/L	130	130
Alkalinity	mg/L as CaCO3	900	900

1. It was assumed that TKN = Total N.

3.3 Flow and Loading for Facility Upgrades

The flow and loads that formed the basis of the plant upgrades analysis are presented in Table 3-2. A combination of flow projections from the 2012 Master Plan was used in conjunction with the more recent concentration data provided by WCSD in 2015 for the facility upgrades analysis.

Table 3-2. Flow and Load for Facility Upgrades

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	10.4	12.7	12.1	18.5
BOD	lb/d	25,000	27,200	27,100	28,700
TSS	lb/d	33,000	32,200	37,600	32,400
Ammonia	lb N/d	2,900	3,900	3,100	5,400
TKN	lb N/d	4,900	6,100	4,800	7,700
Total P	lb P/d	630	710	640	800
Alkalinity	lb/d as $CaCO_3$	No Data	21,730	No Data	23,460
BOD	mg/L	288	257	269	186
TSS	mg/L	381	304	373	210
Ammonia	mg N/L	34	37	31	35
TKN	mg N/L	56	58	48	50
Total P	mg P/L	7.3	6.7	6.3	5.2
Alkalinity	mg/L as CaCO3	No Data	205	No Data	152

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for, Total N and Total P reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
  - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
  - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-3 shows the discount rate and period used for the different scenarios.

Table 3-3. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

Optimization concepts were not developed for the WCWD TP as the plant recently completed several major upgrades and expansion projects as listed in Section 2.4 (total project cost in 2017 was $48.3 Mil). Data from the recently completed projects suggest that it will maintain the ability to reliably meet the upgrade ammonia concentration (2 mg N/L) and nearly meet the Level 2 upgrade total nitrogen concentration (15 mg N/L). It is anticipated that the performance will improve over time.

5 Sidestream Treatment

As previously described, the WCWD TP was identified as a potential candidate for sidestream treatment. The WCWD TP currently uses anaerobic digesters, followed by sludge drying lagoons. Additionally, the sludge drying lagoons receives digester biosolids from the City of Richmond WPCP. This evaluation is based on the continuation of receiving biosolids from the City of Richmond. If this additional load goes away, WCWD should update the sidestream treatment evaluation accordingly.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a conventional nitrifying sidestream treatment technology is recommended for TN load reduction and metal salts/solids separation facilities for total phosphorus load reduction. The WCWD TP already removes ammonia in the main plant so sidestream treatment to reduce ammonia discharge loads to the Bay is not recommended.

Conventional nitrification is recommended at the WCWD TP over the innovative deammonification technologies due to concerns over low sidestream treatment design temperatures. The sludge drying lagoons cool down to ambient temperatures, which is a concern during the colder months.

Conventional nitrifying sidestream treatment is an established technology where ammonia is oxidized to nitrate. The nitrate formed in the sidestream is expected to be removed in the main stream process via biological denitrification at either the headworks and/or primary clarifiers. Nitrate removal in the main stream process is easier than sidestream denitrification where organic carbon is not readily available.

The removal of total phosphorus from the lagoon supernatant would rely upon metal salt and subsequent solids separation in the primaries. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Nutrient Load Reduction

Ammonia/Total N Load Reduction Elements	Total P Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge*

Parameter	Units	NH4-N (lb N/d)[4]	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	13	530	54
Discharge with Sidestream Treatment[2]	lb/d	13	340	32
Load Reduction[3]	lb/d	0	180	22
Load Reduction	%	0%	34%	40%
Annual Load Reduction	lb/yr	0	66,200	7,900

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers the portion of loads diverted to recycle water (approximately 80 percent for the WCWD TP).
4. The plant already fully nitrifies so sidestream treatment would not further reduce ammonia discharge loads.

* Based on receiving digested biosolids from the City of Richmond WPCP. If this additional load goes away, WCWD should update the evaluation accordingly.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment*

Parameter	Units	Ammonia/TN[7]	TP
Capital[1]	$ Mil	18.0	0.9
Annual O&M	$ Mil/yr	1.0	0.2
Total Present Value[2]	$ Mil	39.6	5.8
NH4-N Load Reduction[3,5]	lb N/yr	--	--
TN Load Reduction[3,5]	lb N/yr	66,200	--
TP Load Reduction[4,5]	lb P/yr	--	7,900
NH4-N Cost [3,5,6]	$/lb N	--	--
TN Cost [3,5,6]	$/lb N	19.9	--
TP Cost [4,5,6]	$/lb P	--	24.5

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers the portion of loads diverted to recycled water (approximately 80 percent for the WCWD TP).
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
7. The plant already fully nitrifies so sidestream treatment would not further reduce ammonia discharge loads.

* Based on receiving digested biosolids from the City of Richmond WPCP. If this additional load goes away, WCWD should update the evaluation accordingly.

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the WCWD TP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to expand upon expansion/upgrade projects completed in late 2017 (see Section 2.4) and consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The analysis is based on maintaining the receiving of digested biosolids from the City of Richmond WPCP. If this additional load goes away, the listed facility needs would be reduced.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. WCWD should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements use the recently constructed for the expansion/upgrade projects (see Section 2.4). The total project cost for these recently constructed for the expansion/upgrade projects ($48.3 Mil in 2017) is included in the cost estimate as they are essential to meeting the Level 2 concentrations. The initial data from the recently constructed expansion/upgrade projects suggest that the facility will maintain the ability to reliably meet Level 2 ammonia limits and nearly meet total nitrogen concentrations. This analysis is based on this initial dataset and that additional facilities would be required to reliably meet the Level 2 concentrations. It is possible that the new facilities performance will improve in the future and that the additional listed facilities would not be required.

The process flow diagram for Level 2 upgrades is presented in Figure 6-1. A metal salt coagulant chemical feed facilities would be added to the primaries for phosphorus removal. Additional return activated sludge (RAS) pumping capacity and an external carbon source chemical feed facilities are included to reliably meet the Level 2 total nitrogen concentrations. Additional RAS pumping capacity would be added to increase secondary clarifier capacity and to enhance denitrification (if required to reliably meet Level 2 concentrations). The external carbon source chemical feed facilities are included as the plant data suggests that the carbon to nitrogen ratio is on the lower end for denitrification and might be required to supplement the biological process.

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would build upon those listed for Level 2 with tertiary add-on facilities. A denitrifying filter complex with a feed pumping station would be added that includes several chemical feed facilities. Specifically, an external carbon source chemical feed facility to meet total nitrogen targets and metal salt/polymer chemical feed facilities to meet the total phosphorus targets.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent targets are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-3 and Figure 6-4, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	• Add ferric chloride chemical feed facilities	Same as Level 2
Biological	• The recently completed expansion/upgrade projects (e.g., new aeration basin) are essential to meet the Level 2 concentrations • Additional RAS pumping capacity to increase secondary clarifier capacity and enhance denitrification • Add an external carbon source chemical feed facilities	Same as Level 2
Tertiary	--	• Add a denitrifying filter complex and feed pumping station • Add an external carbon source chemical feed facilities • Metal salt chemical feed facilities • Polymer chemical feed facilities

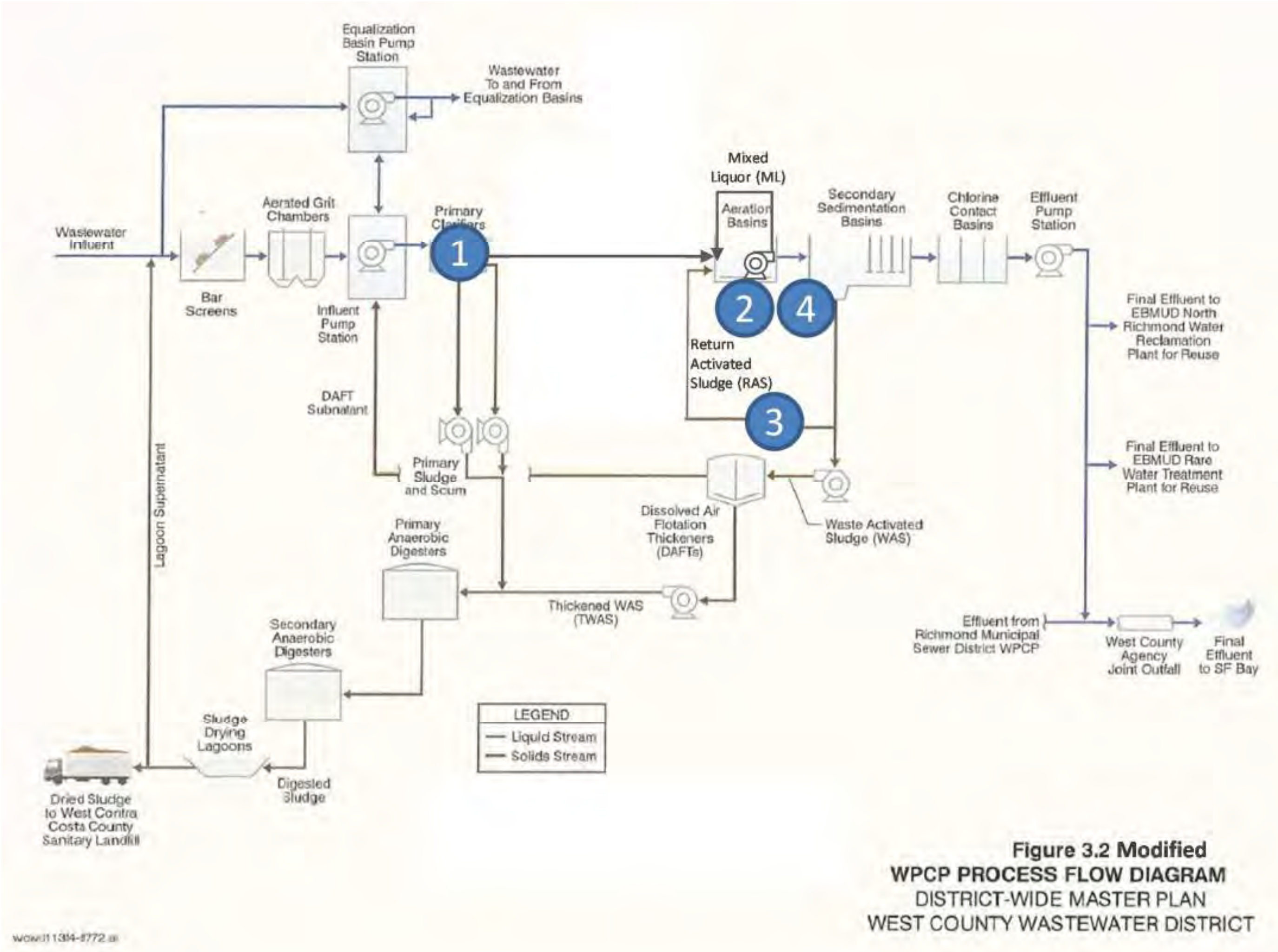

Figure 6-1. Level 2 Upgrade Concepts for the WCWD TP

(1) Add metal salt coagulant chemical feed facilities to the primary clarifiers, (2) the recently completed expansion/upgrade projects (see Section 2.4), (3) increase the RAS pumping capacity, and (4) add an external carbon source chemical feed facilities to the activated sludge facilities

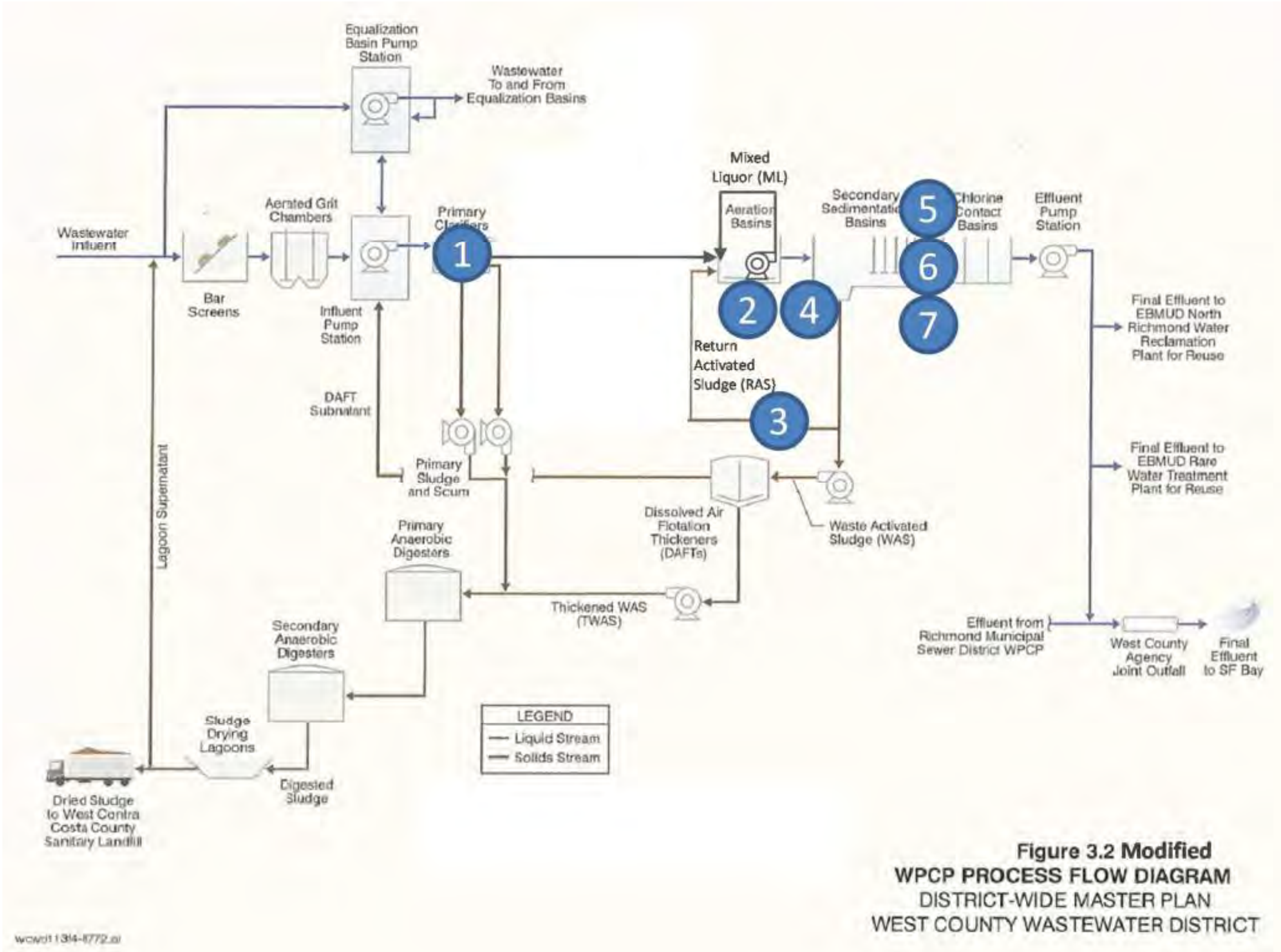

Figure 6-2. Level 3 Upgrade Concepts for the WCWD TP

(1) Add metal salt coagulant chemical feed facilities to the primary clarifiers, (2) the recently completed expansion/upgrade projects (see Section 2.4), (3) increase the RAS pumping capacity, (4) add an external carbon source chemical feed facilities to the activated sludge facilities, (5) add a denitrifying filter complex and feed pumping station, (6) add external carbon source chemical feed facilities, and (7) add metal salt and polymer chemical feed facilities

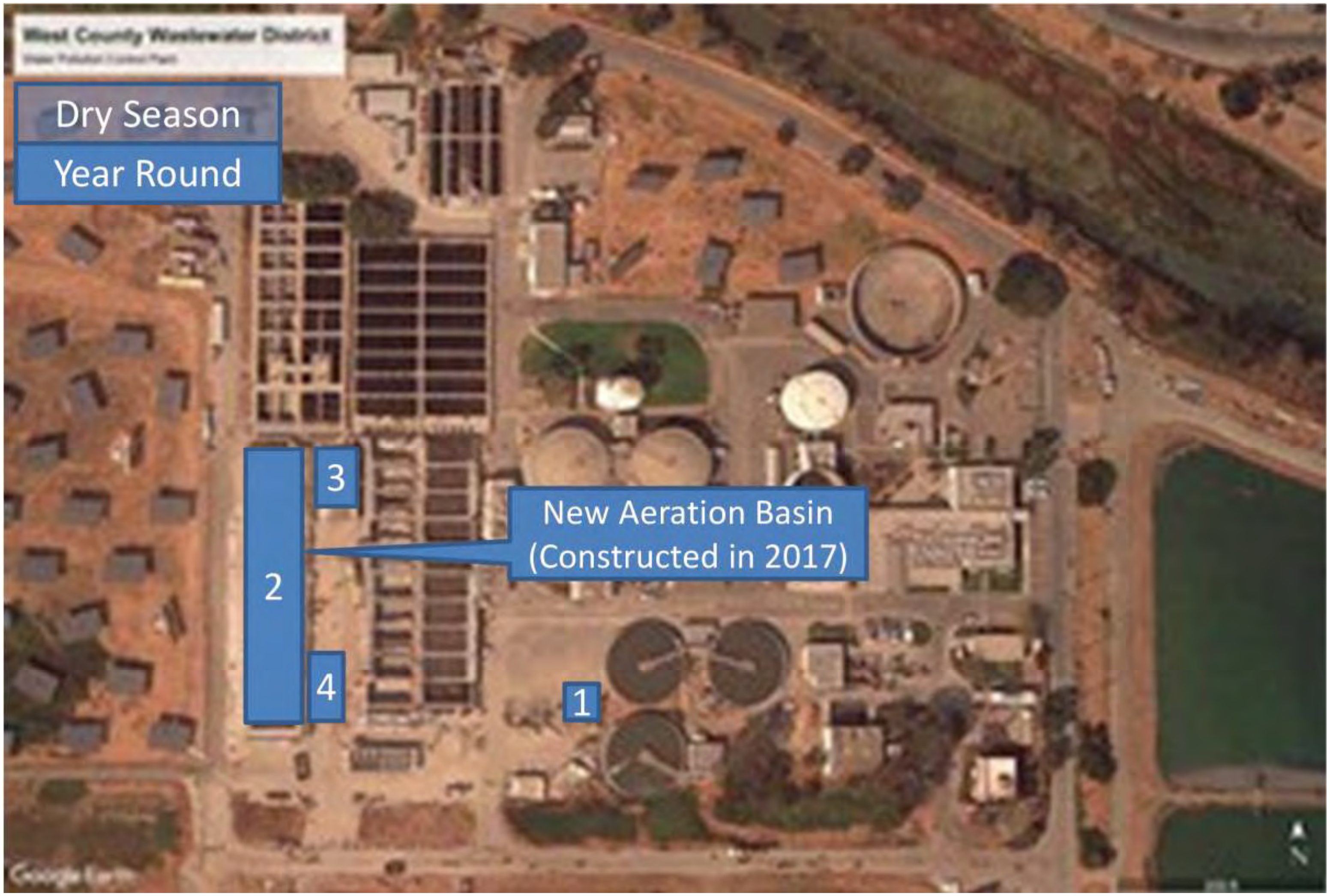

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt coagulant chemical feed facilities to the primary clarifiers, (2) the recently completed expansion/upgrade projects (see Section 2.4), (3) increase the RAS pumping capacity, and (4) add an external carbon source chemical feed facilities to the activated sludge facilities

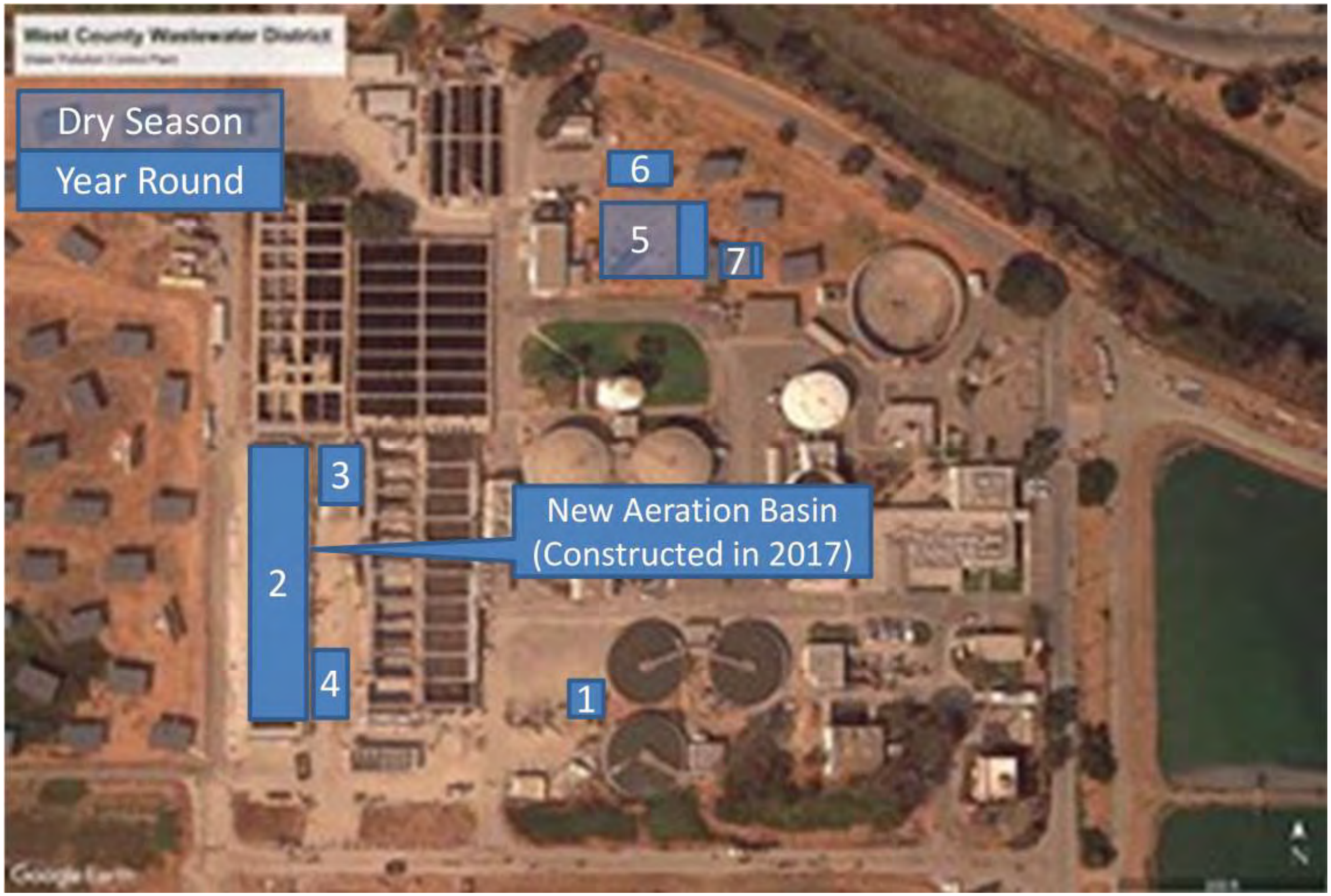

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt coagulant chemical feed facilities to the primary clarifiers, (2) the recently completed expansion/upgrade projects (see Section 2.4), (3) increase the RAS pumping capacity, (4) add an external carbon source chemical feed facilities to the activated sludge facilities, (5) add a denitrifying filter complex and feed pumping station, (6) add external carbon source chemical feed facilities, and (7) add metal salt and polymer chemical feed facilities

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	10.4	12.7	10.4	12.7
Cost for Ammonia, TN, and TP Removal					
Capital[2,9]	$ Mil	53	55	70	79
Annual O&M[9]	$Mil/yr	1.4	1.6	1.9	2.3
O&M PV[3,9]	$ Mil	31	36	42	51
Total PV[3,9]	$ Mil	84	91	111	130
Unit Capital Cost[9]	$/gpd	5.1	4.4	6.7	6.3
Unit Total PV[9]	$/gpd	8.1	7.2	10.7	10.3
TN Removal					
Capital[2,4,9]	$ Mil	50	52	66	75
Annual O&M[4,9]	$ Mil/yr	--	--	0.1	0.3
O&M PV[3,4,9]	$ Mil	--	--	2	8
Total PV[3,4,9]	$ Mil	50	52	68	83
TN Removed (Ave.)[6]	lb N/d	230	250	280	420
Annual TN Removed (Ave.)[7]	lb N/yr	82,200	91,600	100,900	151,800
TN Cost[4,8]	$/lb N	20	19	23	18
TP Removal					
Capital[2,5]	$ Mil	3	3	12	16
Annual O&M[5]	$ Mil/yr	1.5	1.6	1.8	2.1
O&M PV[3,5]	$ Mil	33	37	41	48
Total PV[3,5]	$ Mil	36	40	53	63
TP Removed (Ave.)[6]	lb P/d	30	40	40	50
Annual TP Removed (Ave.)[7]	lb P/yr	12,200	12,900	13,600	17,600
TP Cost[5,8]	$/lb P	100	100	130	120

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers the portion of loads diverted to recycled water.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).
9. The costs includes the recently completed expansion and upgrade projects (see Section 2.4).

Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Improved phosphorus and nitrogen removal • Increased chemicals of emerging concern (CECs) removal • Improved oxygen transfer efficiency • Improved sludge settleability • Reduced solids yield in the activated sludge processes • Alkalinity recovery associated with denitrification • Further reduced TSS and BOD discharge loads	• Additional chemicals from metal salt coagulant and the external carbon source • Additional solids in the primaries • Operate new processes that will require the operators to get accustomed to • Additional pumping associated with RAS • Potential safety issue from the external carbon source (if methanol)
Level 3	Same as Level 2, plus: • High quality product water amenable to recycled water • Further reduced TSS and BOD discharge loads	Same as Level 2, plus: • Potential safety issue from the external carbon source (if methanol) • More chemicals required than Level 2 • Additional pumping associated with filter operation

7 Nutrient Load Reduction by Other Means

The WCWD TP has an extensive recycled water program that reduces approximately 80 percent of their discharge flows and loads year round. Prior to the recent conversion from trickling filter/activated sludge to MLE BNR, the WCWD TP recycled approximately 7,700 acre-feet per year (2,300 million gallons per year). With the MLE BNR facilities in operation, their recycled water program is capable of producing 10,300 acre-feet per year in year 2019.

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

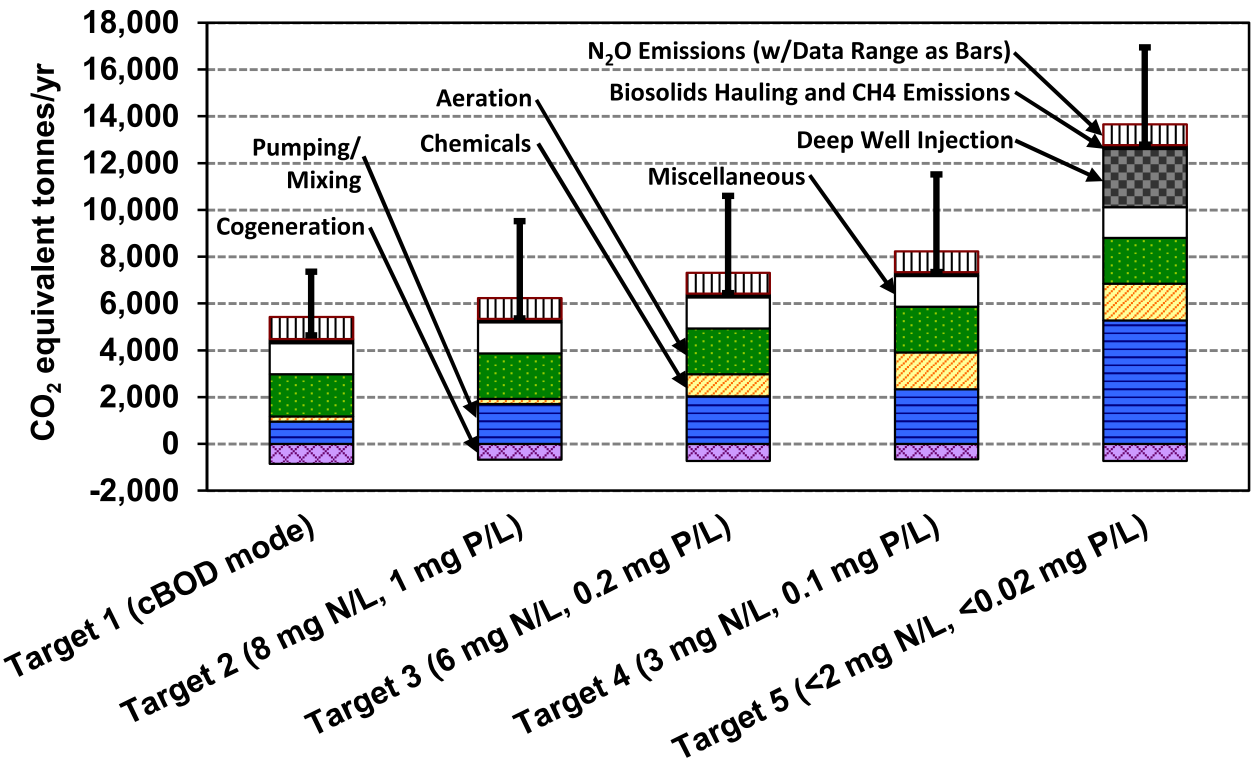

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase from sidestream treatment to Level 2 and 3 upgrades. Chemicals are the predominant contributor to GHG emissions, regardless of treatment level. Specifically, alkalinity and an external carbon source are the key contributors in Level 2 and 3 upgrades.

[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1,6]	Optimization Year Round[1,6]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy[2]	MT CO_2/yr	--	--	0	0	400	500	30
GHG Emissions Increase from Chemicals[2,*]	MT CO_2/yr	--	--	11,600	14,200	9,100	11,200	60
GHG Emissions Increase Total[2]	MT CO_2/yr	--	--	11,600	14,200	9,500	11,700	90
Unit GHG Emissions[2]	lb CO_2/MG	--	--	5,900	7,300	4,900	6,000	1,660
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	--	--	--	--	--	--	--
Unit GHGs for Total N Removal[2,3,5]	lb GHG/lb N	--	--	--**	--**	10	10	2.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--	--	2,100	2,400	1,500	1,400	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.
5. The plant fully nitrifies and recently completed and expansion/upgrade projects for total nitrogen load reduction that should nearly meet Level 2 upgrade concentrations.
6. No optimization concepts were considered as the plant recently completed several expansion/upgrade projects that should meet the Level 2 upgrade ammonia and total nitrogen concentrations.

* The chemicals contribution is attributed to alkalinity demand. The values decrease for Level 3 as more alkalinity is recovered during biological denitrification.

** The values are equal or less than the current operating mode.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the WCWD TP:

- Nutrient Removal using Granular Sludge – this could be used to phase out the biotower/activated sludge and/or MBR. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, Total N, and Total P.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the mechanical aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
  - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, Total N, and Total P.
  - Disadvantages: No installations in North America.
  - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

E

Agency Acceptance Letters

Contents of Appendix E

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CITY OF AMERICAN CANYON
PUBLIC WORKS DEPARTMENT

May 3, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street
Suite 1400
Oakland, CA 94612

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of the City of American Canyon, I have reviewed the individual plant report prepared for the Water Reclamation Facility (WRF) that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting Team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The WRF report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2015, which is when the data included in the report was compiled.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for the WRF, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the timeframe and context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Steven L. Hartwig, P.E., T.E.
Public Works Director/City Engineer

THE CITY OF BENICIA CALIFORNIA

CITY HALL • 250 EAST L STREET • BENICIA, CA 94510 • (707) 746-4200 • FAX (707) 747-8120

Public Works Department

April 17, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

SUBJECT: ACCEPTANCE OF PLANT-SPECIFIC FINDINGS FOR THE NUTRIENT REDUCTION REPORT

Dear Mr. Wolfe:

On behalf of the City of Benicia I have reviewed the individual plant report prepared for the City of Benicia Wastewater Treatment Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The City of Benicia Wastewater Treatment Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for City of Benicia Wastewater Treatment Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Jeff Gregory
Wastewater Treatment Plant Superintendent

JG:/dg
F:\Pubworks\WWTP\RWQCB Correspondence\Nutrient Reduction Report Agency Acceptance.docx

cc: William Tarbox, Public Works Director
Christian Di Renzo, Assistant Public Works Director

VEOLIA

June 6, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board
Bay Area Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of City of Burlingame, I have reviewed the individual plant report prepared for the Burlingame WWTP that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Burlingame WWTP report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for Burlingame WWTP, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Antrena Trimble, Project Manager

Veolia North America
Burlingame Wastewater Treatment Facility
1103 Airport Boulevard
Burlingame, CA 94010
Tel. 650-342-3727 Fax. 650-342-3712
www.veolianorthamerica.com

CENTRAL SAN
CENTRAL CONTRA COSTA SANITARY DISTRICT 5019 IMHOFF PLACE, MARTINEZ, CA 94553-4392

June 20, 2018

PHONE: (925) 228-9500
FAX: (925) 228-4624
www.centralsan.org

ROGER S. BAILEY
General Manager

KENTON L. ALM
Counsel for the District
(510) 808-2000

KATIE YOUNG
Secretary of the District

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

RE: ACCEPTANCE OF PLANT-SPECIFIC FINDINGS FOR THE NUTRIENT REDUCTION REPORT

Dear Mr. Wolfe,

On behalf of Central Contra Costa Sanitary District (Central San), I have reviewed the individual plant report prepared for Central San that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Central San report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversight of our staff who worked with the Consultant in preparing the report for Central San, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Roger S. Bailey
General Manager

CENTRAL MARIN SANITATION AGENCY

Jason R. Dow P.E.
General Manager

1301 Andersen Drive, San Rafael, CA 94901-5339 **Phone (415) 459-1455** **Fax (415) 459-3971** **www.cmsa.us**

May 7, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Subject: **Acceptance of Central Marin Sanitation Agency Specific Findings for the Nutrient Reduction Report**

Dear Mr. Wolfe,

On behalf of Central Marin Sanitation Agency (CMSA), I have reviewed the individual plant report prepared for CMSA that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The CMSA plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The CMSA report was prepared after the Consultants visited the wastewater treament site, interacted with Agency staff, prepared a draft report for our staff's review, and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for CMSA, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Jason R. Dow, P.E.
General Manager

Delta Diablo

May 31, 2018

TRANSMITTED VIA EMAIL

Mr. Bruce Wolfe, Executive Officer
San Francisco Bay Regional Water Quality Control Board

SUBJECT: ACCEPTANCE OF PLANT-SPECIFIC FINDINGS FOR THE NUTRIENT REDUCTION REPORT

Dear Mr. Wolfe:

On behalf of Delta Diablo, I have reviewed the individual plant report prepared for Delta Diablo that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Delta Diablo report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review, and responded to staff's comments. A representative group of BACWA members (i.e., Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for Delta Diablo, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Vince De Lange
General Manager

AWR/VPD:dcj

Dublin San Ramon Services District
Water, wastewater, recycled water

Regional Wastewater Treatment Facility
7399 Johnson Drive
Pleasanton, CA 94588-3862

main (925) 846-4565
fax (925) 462-0658
www.dsrsd.com

April 16, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Dublin San Ramon Services District, I have reviewed the individual plant report prepared for the Dublin San Ramon Services District Regional Wastewater Treatment Facility that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The DSRSD Regional Wastewater Treatment Facility report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for the DSRSD Regional Wastewater Treatment Facility, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Jeff Carson,
Operations Manager

EAST BAY
MUNICIPAL UTILITY DISTRICT

EILEEN M. WHITE
DIRECTOR OF WASTEWATER
(510) 287-1149
eileen.white@ebmud.com

January 4, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Optimization and Upgrade Study

Dear Mr. Wolfe:

On behalf of East Bay Municipal Utility District (EBMUD), I have reviewed the individual plant report prepared for EBMUD's Main Wastewater Treatment Plant (MWWTP) that is included as an appendix to the *Optimization/Upgrade Study Report*. The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The MWWTP report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the *Optimization/Upgrade Study Report*. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversight of our staff who worked with the Consultant in preparing the report for EBMUD's MWWTP, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you.

Eileen M. White

Eileen M. White, P.E.

EMW:llo

375 ELEVENTH STREET . OAKLAND . CA 94607-4240
P.O. BOX 24055 . OAKLAND . CA 94623-1055

FAIRFIELD-SUISUN SEWER DISTRICT
1010 Chadbourne Road • Fairfield, California 94534 • (707) 429-8930 • www.fssd.com
Gregory G. Baatrup, General Manager

May 21, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

RE: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr.Wolfe,

On behalf of the Fairfield-Suisun Sewer District, I have reviewed the individual plant report prepared for the Fairfield-Suisun Sewer District Wastewater Treatment Plant (WWTP) that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Nutrient Reduction Report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report.

In accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Gregory Baatrup
General Manager

HAYWARD

June 15, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Optimization and Upgrade Study

Dear Mr. Wolfe,

On behalf of the City of Hayward, I have reviewed the individual plant report prepared for the City's Water Pollution Control Facility (WPCF) that is included as an appendix to Nutrient Optimization/Upgrade Report. Our plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Hayward WPCF report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Optimization/Upgrade Report. Our individual plant report represents my best understanding of our facility as of 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for WPCF, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Alex Ameri
Director of Utilities & Environmental Services

Las Gallinas
VALLEY SANITARY DISTRICT

May 15, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Las Gallinas Valley Sanitary District, I have reviewed the individual plant report prepared for the Las Gallinas Valley Sanitary District Wastewater Treatment Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Las Gallinas Valley Sanitary District Wastewater Treatment Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for Las Gallinas Valley Sanitary District Wastewater Treatment Plant I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report.

Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Chris DeGabriele
Interim General Manager

LIVERMORE
CALIFORNIA

April 9, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe:

On behalf of the City of Livermore, I have reviewed the individual plant report prepared for the Livermore Water Reclamation Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Livermore Water Reclamation Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversight of our staff who worked with the Consultant in preparing the report for the Livermore Water Reclamation Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Helen Ling
Water Resources Division Manager

cc: Darren Greenwood, Public Works Director
Jimmie Truesdell, Water Resources Operations Manager

March 7, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of *The city of Millbrae*, I have reviewed the individual plant report prepared for the City of Millbrae that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The City of Millbrae report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for the City of Millbrae, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Dan Mount Interim Superintendent

MT. VIEW SANITARY DISTRICT
3800 ARTHUR ROAD
P.O. BOX 2757
MARTINEZ, CA 94553
TEL 925.228.5635
FAX 925.228.7585
WWW.MVSD.ORG

April 30, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Mt. View Sanitary District, I have reviewed the individual plant report prepared for the Mt. View Sanitary District plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Mt. View Sanitary District report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for Mt. View Sanitary District, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Neal B. Allen
District Manager

NapaSan

May 24, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Napa Sanitation District (NapaSan), I have reviewed the individual plant report prepared for the NapaSan Wastewater Treatment Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The NapaSan Wastewater Treatment Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for NapaSan Wastewater Treatment Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete.

Thank you,

James Keller, Jr.
Director of Operations

NapaSan
1515 Soscol Ferry Road
Napa, CA 94558

Office (707) 258-6000
Fax (707) 258-6048

www.napasan.com

NOVATO SANITARY DISTRICT

500 DAVIDSON STREET * NOVATO * CALIFORNIA 94945 * PHONE (415) 892-1694 * FAX (415) 898-2279
www.novatosan.com

April 26, 2018

Mr. Bruce Wolfe, Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Novato Sanitary District (NSD), I have reviewed the individual plant report prepared for the NSD Wastewater Treatment Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The NSD Wastewater Treatment Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for NSD Wastewater Treatment Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Sandeep Karkal, P.E.
General Manager-Chief Engineer

ORO LOMA SANITARY DISTRICT

February 12, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Subject: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Oro Loma Sanitary District, I have reviewed the individual plant report prepared for Oro Loma that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR consulting team under a contract with Bay Area Clean Water Agencies (BACWA). This report represents the Oro Loma facility in 2017 and outlines a methodology and costs to obtain selected levels of nutrient treatment.

I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. The Nutrient Reduction Report is, to the best of my knowledge, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Jason Warner
General Manager

2655 Grant Avenue, San Lorenzo, California 94580-1838 ▪ info@oroloma.org ▪ P: (510) 276-4700 ▪ F: (510) 276-1528 ▪ www.oroloma.org

Public Works Department
Environmental Services Division
Regional Water Quality Control Plant
2501 Embarcadero Way
Palo Alto, CA 94303

April 3, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of the City of Palo Alto Regional Water Quality Control Plant (RWQCP), I have reviewed the individual plant report prepared for the RWQCP that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The RWQCP report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for the RWQCP, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

James S. Allen

James S. Allen
Plant Manager
Regional Water Quality Control Plant

CITY OF PETALUMA

POST OFFICE BOX 61
PETALUMA, CA 94953-0061

January 11, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Optimization and Upgrade Study

Mr. Wolfe,

On behalf of The City of Petaluma, I have reviewed the individual plant report prepared for the Ellis Creek Water Recycling Facility that is included as an appendix to the Nutrient Optimization and Upgrade Study. The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Ellis Creek Water Recycling Facility report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for Nutrient Optimization and Upgrade Study. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversight of our staff who worked with the Consultant in preparing the report for the Ellis Creek Water Recycling Facility, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Respectfully,

Dan St. John, FASCE,
Director of Public Works

C: Leah Godsey Walker, Environmental Services Manager
Robert C. Wilson, Environmental Services Supervisor

S:\Environmental Services\ECWRF-NPDES\petaluma_acceptance_letter.docx

May 8, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Optimization and Upgrade Study

Dear Mr. Wolfe,

On behalf of City of Pinole, I have reviewed the individual plant report prepared for the Pinole- Hercules Water Pollution Control Plant that is included as an appendix to BACWA Nutrient Reduction Study. The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Pinole-Hercules Water Pollution Control Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for BACWA Nutrient Reduction Study. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversight of our staff who worked with the Consultant in preparing the report for Pinole-Hercules Water Pollution Control Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Ron Tobey, Plant Manager

May 4, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Veolia Water and the City of Richmond, I have reviewed the individual plant report prepared for the Richmond Water Pollution Control Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Richmond Water Pollution Control Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for Richmond Water Pollution Control Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Aaron Winer

Area Manager – Richmond Project Manager

Veolia North America

RODEO SANITARY DISTRICT
800 SAN PABLO AVE. · RODEO, CA 94572-1232
(510) 799-2970 · FAX (510) 799-5403

April 30, 2018

Mr. Bruce Wolfe, Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Rodeo Sanitary District, I have reviewed the individual plant report prepared for the Rodeo Sanitary District Water Pollution Control Facility (RSD WPCF) that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The RSD WPCF report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility as of 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for RSD WPCF, I acknowledge the recommended approach and cost estimates for reducing nutrients at our facility. While I agree that the costs appear reasonable with respect to the context of the overall report, I cannot agree that these costs will be reasonable for any particular facility, such as small facilities like RSD WPCF.

In accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Steven S. Beall, P.E.
District Manger
Rodeo Sanitary District

April 12, 2018

Mr. Bruce H. Wolfe
Executive Officer
Regional Water Quality Control Board
San Francisco Bay Region
1515 Clay Street, Suite 1400
Oakland, CA 94612

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of San Francisco International Airport, I have reviewed the individual plant report prepared for San Francisco International Airport's Mel Leong Treatment Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Mel Leong Treatment Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for Mel Leong Treatment Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable in the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Leroy P. Sisneros
Director of Facilities

Post Office Box 8097 San Francisco, California 94128 Tel 650.821.5000 Fax 650.821.5005 www.flysfo.com

San Francisco
Water Power Sewer
Services of the San Francisco Public Utilities Commission

525 Golden Gate Avenue,
San Francisco,
T 41!
F 41!
TTY 41!

May 4, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of the San Francisco Public Utilities Commission's Wastewater Enterprise (WWE), I have reviewed the individual plant reports prepared for the Southeast Water Pollution Control Plant (SEP) and the Treasure Island Wastewater Treatment Plant (TI) that are included as appendices to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). These reports were prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The SEP and TI reports were prepared after the Consultants visited the plants, interacted with plant staff, prepared draft reports for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facilities in 2017.

In the context of the regional Nutrient Reduction Report, the assumptions, approach and cost estimates for reducing nutrients at each facility are reasonable. In accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete.

Thank you,

Brian Henderson
Interim Assistant General Manager, Wastewater Enterprise

San José-Santa Clara
Regional Wastewater Facility

April 23, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of the San Jose-Santa Clara Regional Wastewater Facility (RWF), I have reviewed the individual plant report prepared for the RWF that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The RWF report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

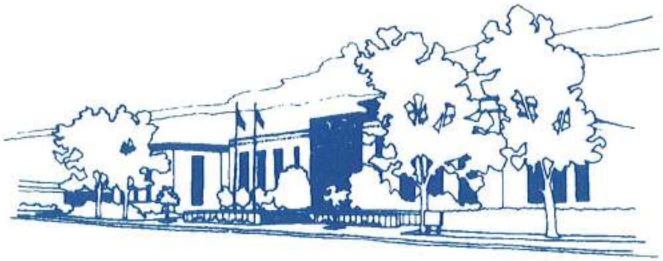
With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for San Jose-Santa Clara Regional Wastewater Facility, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Amit Mutsuddy
Deputy Director, San Jose-Santa Clara Regional Wastewater Facility

700 Los Esteros Rd. San José, CA 95134 tel (408) 635-6600 fax (408) 945-5442 www.sanjoseca.gov/esd

City of San Leandro
Civic Center, 835 E. 14th Street
San Leandro, California 94577
www.sanleandro.org



March 1, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe:

On behalf of City of San Leandro, I have reviewed the individual plant report prepared for the City of San Leandro Water Pollution Control Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The City of San Leandro Water Pollution Control Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for City of San Leandro Water Pollution Control Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Judy Walker

Judy Walker, Acting Plant Manager
City of San Leandro
Wastewater Treatment Plant
jwalker@sanleandro.org

cc: D. Pollart, J. Jenson, M. Connor

DEPARTMENT OF PUBLIC WORKS
Brad B. Underwood, P.E., L.S., Director

330 W 20th Avenue
San Mateo, CA 94403-1338
Telephone: (650) 522 -7300
Fax: (650) 522-7301
www.cityofsanmateo.org

May 15, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of the City of San Mateo, I have reviewed the individual plant report prepared for the San Mateo Wastewater Treatment Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The San Mateo Wastewater Treatment Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for the San Mateo Wastewater Treatment Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Brad B. Underwood
Public Works Director

CC:

Daniela.Brandao@jacobs.com
gdejesus@cityofsanmateo.org
czammit@cityofsanmateo.org
Jay.Witherspoon@jacobs.com
Chron

SAUSALITO-MARIN CITY SANITARY DISTRICT

1 EAST ROAD • SAUSALITO, CALIFORNIA 94965
OFFICE 415.332.0244 • PLANT 415.332.0240 • FAX 415.332.0453

May 4, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of the Sausalito – Marin City Sanitary District (SMCSD), I have reviewed the individual plant report prepared for the District's treatment plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). SMCSD's report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for the District, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Jeffrey M. Kingston
General Manager
SMCSD

S A S M
SEWERAGE AGENCY OF
SOUTHERN MARIN

A Joint Powers Agency
- Almonte S.D.
- Alto S.D.
- City of Mill Valley
- Homestead Valley S.D.
- Richardson Bay S.D.
- Tamaulipas C.S.D.

April 25, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of the Sewerage Agency of Southern Marin (SASM), I have reviewed the individual plant report prepared for SASM that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The SASM report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for SASM, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

M. Grushayev

Mark Grushayev, WWT Manager

26 Corte Madera Avenue - Mill Valley, California 94941 Tel: (415) 388-2402 Fax: (415) 381-8128

Silicon Valley Clean Water
Joint Powers Authority ~ A Public Entity

SVCW

1400 Radio Road
Redwood City, California 94065
650.591.7121 | Fax: 650.591.7122
www.svcw.org

City of San Carlos | City of Redwood City | City of Belmont | West Bay Sanitary District

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Silicon Valley Clean Water (SVCW), I have reviewed the individual plant report prepared for the Silicon Valley Clean Water Wastewater Treatment Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The SVCW report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for SVCW, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Monte Hamamoto
Chief Operating Officer
Silicon Valley Clean Water

SONOMA COUNTY WATER AGENCY

CF/70-712-43 Wastewater Monitoring
Reports - Sonoma Valley CSD (ID 2977)

May 22, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street Suite 1400
Oakland, CA 94612

RE: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe:

On behalf of Sonoma Valley County Sanitation District, I have reviewed the individual plant report prepared for the Sonoma Valley Treatment Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Sonoma Valley Treatment Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for Sonoma Valley Treatment Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted.

Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Grant Davis
General Manager
Grant.Davis@scwa.ca.gov

mg t:\pinks\05-21-2018\agency acceptance letter_20180118.docx

OFFICE OF THE SUPERINTENDENT OF
WATER QUALITY CONTROL
(650) 877-8555
FAX (650) 829-3855

April 4, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of the South San Francisco-San Bruno Water Quality Control Plant (WQCP) we have reviewed the individual plant report prepared for the WQCP that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The South San Francisco-San Bruno Water Quality Control Plant report was prepared after the Consultants visited the plant site, interacted with key plant staff, prepared a draft report for our review and responded to our comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents our best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for the WQCP, we agree that the recommended approach and cost estimates for reducing future nutrient loads from our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Brian Schumacker, Plant Superintendent

South San Francisco-San Bruno Water Quality Control Plant

Sunnyvale

Water Pollution Control Plant
1444 Borregas Avenue
Sunnyvale, CA 94088-3707
TDD/TYY 408-730-7501
sunnyvale.ca.gov

May 15, 2018

Mr. Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of Sunnyvale Water Pollution Control Plant, I have reviewed the individual plant report prepared for the Sunnyvale Water Pollution Control Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Sunnyvale Water Pollution Control Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report Sunnyvale Water Pollution Control Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted.

Sunnyvale

Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Ms. Bhavani Yerrapotu, P.E., B.C.E.E.

WPCP Division Manager

City of Sunnyvale

UNION
SANITARY
DISTRICT

June 18, 2018

Bruce Wolfe
Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay St., Suite 1400
Oakland, CA 94612

Re: Acceptance of Plant-Specific Findings for the Nutrient Optimization and Upgrade Study

Dear Mr. Wolfe,

On behalf of Union Sanitary District, I have reviewed the individual plant report prepared for the Alvarado Wastewater Treatment Plant that is included as an appendix to Nutrient Optimization/Upgrade Report. Our plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Alvarado Wastewater Treatment Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. It is my understanding that a representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Optimization/Upgrade Report. Our individual plant report represents their best understanding of our facility as of 2017.

The level of involvement and oversite of our staff was minimal and cursory. Our staff worked cooperatively with the Consultant in preparing the report for Alvarado Wastewater Treatment Plant. I have no objections to the recommended approach and planning level cost estimates for reducing nutrients at our facility. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified

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www.unionsanitary.com

personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Paul R. Eldredge, P.E.
General Manager/District Engineer
Union Sanitary District

(707) 644-8949 (Admin)
(707) 644-8976 (Billing)
VallejoWastewater.org
450 Ryder Street
Vallejo, CA 94590

Vallejo FLOOD & WASTEWATER DISTRICT

May 1, 2018

California Regional Water Quality Control Board
San Francisco Bay Region
1515 Clay Street, Suite 1400
Oakland, CA 94612

Attention: Mr. Bruce Wolfe, Executive Officer

Dear Mr. Wolfe,

On behalf of Vallejo Flood and Wastewater District, I have reviewed the individual plant report prepared for the Vallejo Flood and Wastewater District Wastewater Treatment Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Vallejo Flood and Wastewater District Wastewater Treatment Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for theVallejo Flood and Wastewater District Wastewater Treatment Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

VALLEJO FLOOD AND WASTEWATER DISTRICT

Melissa Morton

MELISSA A. MORTON
District Manager

Cc: Environmental Services

WCWD
WEST COUNTY WASTEWATER DISTRICT

Community Partner for Our Bay, Our Environment

May 22, 2018

Mr. Bruce Wolfe
1515 Clay St.
Ste 1400
Oakland, CA. 94612

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of West County Wastewater District, I have reviewed the individual plant report prepared for the Water Pollution Control Plant that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The Water Pollution Control Plant report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for the Water Pollution Control Plant, I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted.

Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

Ken Cook

Interim Water Quality Manager