Central Contra Costa Sanitary District

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SUBJECT: TOTAL NITRIFICATION STUDY UPDATE - FINAL REPORT

Attached is the final report detailing the Total Nitrification Study Update, District Project 7301. This evaluation is part of the National Pollutant Discharge Elimination System (NPDES) Permit-required Facility Plan and Site Characterization work due to the San Francisco Bay Regional Water Quality Control Board by February 28, 2014 (Order No. R2-2012-0016, VI.C.5.d). The objective of this evaluation was to update design parameters, facility requirements, and costs for nutrient removal based on several possible long-term nutrient discharge limits. Limits evaluated were based on the National Resources Defense Council 2007 petition as well as the NPDES permits for the City of Stockton and the Sacramento Regional County Sanitation District. To meet potential discharge limits, various combinations of the following treatment process options were considered:

- Chemically Enhanced Primary Treatment
- Enhanced Biological Phosphorus Removal (e.g. 4- to 5-Stage Bardenpho Process)
- Nitrification/Denitrification (e.g. 4- to 5-stage Bardenpho Process)
- Conventional Nitrification
- Chemically Enhanced Filtration (e.g. additional phosphorus removal)

Class 4 capital cost estimates ranged from $112 – 239 million, depending on the level of treatment and excluding the cost of contaminated soil remediation; while operation and maintenance cost estimates ranged from $2.98 – 7.98 million/year, also dependent upon the level of treatment. As anticipated, as the level of treatment increased (e.g. lower discharge limits), the capital and operational costs increased.

If you have any questions regarding the information in this report, please contact Samantha Engelage at extension 631.

SE:sdh
Enclosure

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Total Nitrification Study Update – Evaluation of Alternatives and Costs

Central Contra Costa Sanitary District

FINAL REPORT

December 2013

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Executive Summary

In anticipation of future nutrient discharge limitations and as required by the current National Pollutant Discharge Elimination System (NPDES) permit (R2-2012-0016; CA0037648), the Central Contra Costa Sanitary District (District) must evaluate nutrient removal technologies and plan for the potential facilities and costs associated with upgrading its wastewater treatment plant to meet a range of future, potential discharge requirements.

A previous study prepared for the District in 2009, the Total Nitrification Study (2009 Study), evaluated the feasibility of achieving total nitrification (i.e., ammonia removal) at the treatment plant. In that study, eight potential nitrification technologies were screened and four were selected for detailed evaluation, including conventional nitrification, integrated fixed film activated sludge (IFAS), moving bed biofilm reactor (MBBR), and a biological aerated filter (BAF).

Although both IFAS and MBBR technologies provide a reliable nitrification technology, their selection over conventional nitrification is typically driven by space constraints and lower wastewater temperatures than those encountered at the District. In addition, the use of fixed film technologies was relatively unproven, particularly at plants with high flows similar to the District's. Lastly, BAFs had higher capital costs and were also relatively unproven. As a result, conventional nitrification was recommended as the preferred treatment process to achieve the potential nutrient discharge limits.

The purpose of this study was to update the 2009 Study and develop recommended facilities and costs to achieve a range of discharge requirements. Five potential discharge requirements were considered, Tiers I through V, as summarized in Table 1. The discharge requirements for Tiers I, II and III are based on the petition filed by the National Resources Defense Council (NRDC) in November 2007, while Tiers IV and V are based on the recently adopted NPDES permits for the Sacramento Regional County Sanitation District (SRCSD) and the City of Stockton, respectively.

Table 1. Discharge Requirements and Treatment Alternatives

Treatment Goals[a]	Treatment Alternative			
	NDN & EBPR	NDN & CEPT	NDN	Conventional Nitrification
Tier I: TN = 8.0 mg N/L; TP = 1.0 mg P/L	Alternative 1	Alternative 4		
Tier II: TN = 5.0 mg N/L; TP = 0.5 mg P/L	Alternative 2[d]	Alternative 5[d]		
Tier III: TN = 3.0 mg N/L; TP = 0.3 mg P/L	Alternative 3[d]	Alternative 6[d]		
Tier IV: = 2.4 mg N/L; NOx-N = 10.0 mg N/L[b]			Alternative 7	
Tier V: NH3-N = 2.0 mg N/L[c]				Alternative 8

(a) Average monthly effluent limits are shown. TN = Total Nitrogen; TP = Total Phosphorus.
(b) Maximum daily effluent limit for NH3-N is 3.3 mg/L.
(c) Maximum daily effluent limit for NH3-N is 5 mg/L.
(d) This alternative requires chemically enhanced filtration to meet the discharge limits.

As shown in Table 1, eight alternatives based on conventional nitrification, as recommended in the 2009 Study, were developed to meet the discharge requirements. To meet the discharge requirements for each respective Tier, several technologies were considered to augment the conventional nitrification process, including chemically enhanced primary treatment (CEPT), enhanced biological phosphorus removal (EBPR), nitrification/denitrification (NDN), and chemically enhanced filtration (CEF). The matrix presented in Table 1 identifies which Tier each alternative is designed to meet.

A summary of the capital and O&M costs for each alternative is presented in Table 2.

Table 2. Summary of Capital, O&M and Annualized Costs

Alternative	Annual Cost		
	Capital Cost ($ Millions / Year)[a]	O&M Cost ($ Millions / Year)[b]	Total Cost ($ Millions / Year) [c]
Alternative 1, NDN with EBPR Tier I: TN = 8.0 mg N/L; TP = 1.0 mg P/L	$4.54	$2.98	$7.52
Alternative 2, NDN with EBPR Tier I: TN = 5.0 mg N/L; TP = 0.5 mg P/L	$6.36	$4.57	$10.93
Alternative 3, NDN with EBPR Tier II: TN = 3.0 mg N/L; TP = 0.3 mg P/L	$7.60	$6.27	$13.87
Alternative 4, NDN with CEPT Tier II: TN = 8.0 mg N/L; TP = 1.0 mg P/L	$3.55	$4.57	$8.12
Alternative 5, NDN with CEPT Tier III: TN = 5.0 mg N/L; TP = 0.5 mg P/L	$5.58	$6.05	$11.63
Alternative 6, NDN with CEPT Tier III: TN = 3.0 mg N/L; TP = 0.3 mg P/L	$6.72	$7.98	$14.70
Alternative 7, NDN Tier IV: NH3-N = 2.4 mg N/L; NOx-N = 10.0 mg N/L	$3.72	$3.50	$7.22
Alternative 8, Nitrification Tier V: NH3-N = 2.0 mg N/L	$3.66	$3.20	$6.86

(a) Capital costs are estimated to within -30 percent to +50 percent and are presented in current, 2013 dollars. Costs do not include the cost to clean up the contaminated soil adjacent to the plant where the new facilities would likely be located.
(b) Annual O&M costs include power and chemicals for new unit processes only.
(c) Capital costs are amortized over 50 years at 2 percent interest.

As illustrated in Table 2, as the nutrient discharge limits become more restrictive, the capital costs increase. The lowest capital cost alternatives are Alternatives 4, 7, and 8, which have the least stringent discharge limits and associated process requirements. The highest capital costs are associated with the alternatives that were developed to meet the Tier III treatment objectives. In addition, the alternatives with biological nitrogen and phosphorus removal (Alternatives 1, 2 and 3) have higher capital costs than those with biological nitrogen and chemical phosphorus removal (Alternatives 4, 5, and 6) to meet the same respective treatment objective.

The capital costs presented in Table 2 do not include construction of additional secondary clarifiers or the clean up and removal of the contaminated soil adjacent to the District's plant where the new treatment facilities would likely be located. Once the soil contamination cleanup cost is quantified, it should be added to the estimated capital costs for each of the alternatives to present a complete picture of the expected total project cost. Costs were not included for the construction of additional secondary clarifiers because the existing clarifiers are rated to handle the design maximum month overflow conditions, regardless of the discharge limit. However, stress testing of the existing secondary clarifiers is recommended to confirm that additional secondary clarifiers are not needed.

Similar to the capital costs, and as expected, the O&M costs also increase as the discharge limits become more restrictive. However, the alternatives with biological nitrogen and chemical phosphorus removal (Alternatives 4, 5 and 6) have greater O&M costs than their respective counterparts with biological nitrogen removal and biological phosphorus removal (Alternatives 1, 2 and 3). As a result of the higher O&M costs associated with Alternatives 4, 5 and 6, the total annualized costs, including the annualized capital costs, are also higher than their respective counterparts (Alternatives 1, 2 and 3). The alternatives for Tiers IV and V, Alternatives 7 and 8, have the lowest total annualized costs.

Since the District does not yet have direction regarding its future effluent discharge requirements, and because it could be one or two permit cycles before discharge limits are imposed, the District should continue to evaluate advances in nutrient removal technologies, particularly emerging technologies.

1 Purpose

The purpose of this study is to update the Total Nitrification Study that was prepared in 2009 for the Central Contra Costa Sanitary District. The 2009 Study evaluated the feasibility of achieving total nitrification (i.e., ammonia removal) at the District's treatment plant. Eight potential nitrification technologies were screened and four were selected for detailed evaluation, including conventional nitrification, IFAS, MBBR, and a BAF. Although both IFAS and MBBR technologies provide a reliable nitrification technology, their selection over conventional nitrification is typically driven by space constraints and lower wastewater temperatures than those encountered at the District. In addition, the use of fixed film technologies was relatively unproven, particularly at plants with high flows similar to the District's. Lastly, BAFs had higher capital costs and were also relatively unproven. As a result, conventional nitrification was recommended as the preferred treatment process to achieve the potential nutrient discharge limits.

The District's current NPDES permit (R2-2012-0016; CA0037648), issued in February 2012, requires various nutrient removal studies, work plans, and facility plans to be prepared and submitted to the Regional Water Quality Control Board (RWQCB) in 2014. This update was prepared to assist the District with completion of the special studies related to nutrient removal, and includes preparation of the following items:

- Update to the existing treatment plant performance criteria based on recent studies, construction projects and/or future projects (e.g., Primary Sedimentation Basin Upgrades, Nitrifier Growth Rate Study, etc.).
- Identification of five potential future discharge limits for ammonia, total nitrogen, and/or total phosphorous.
- Evaluation of plant upgrade requirements for eight treatment alternatives that can meet the potential future discharge limits.
- Preparation of planning level capital and operations and maintenance (O&M) costs for each alternative.

2 Background

The District currently treats approximately 38 million gallons per day (mgd) of average dry weather flow (ADWF). The plant is permitted to treat 53.8 mgd during average dry weather conditions and up to 250 mgd during peak wet weather flow conditions. A list of the current discharge limits of interest for this study is presented in Table 3.

Table 3. District NPDES Permit of Select Pollutants

Parameter	Units	Average Monthly	Average Weekly	Maximum Daily	Instantaneous Minimum	Instantaneous Maximum
cBOD	mg/L	25	40	-	-	-
TSS	mg/L	30	45	-	-	-
Enterococci	CFU/ 100 ml	35	-	-	-	-
Oil & Grease	mg/L	10	-	20	-	-
pH	s.u.	-	-	-	6.0	9.0
Ammonia-N	mg-N/L	65	-	84		
Ammonia-N	kg/day	5,500	-	-		

A process schematic of the existing treatment plant is shown in Figure 1.

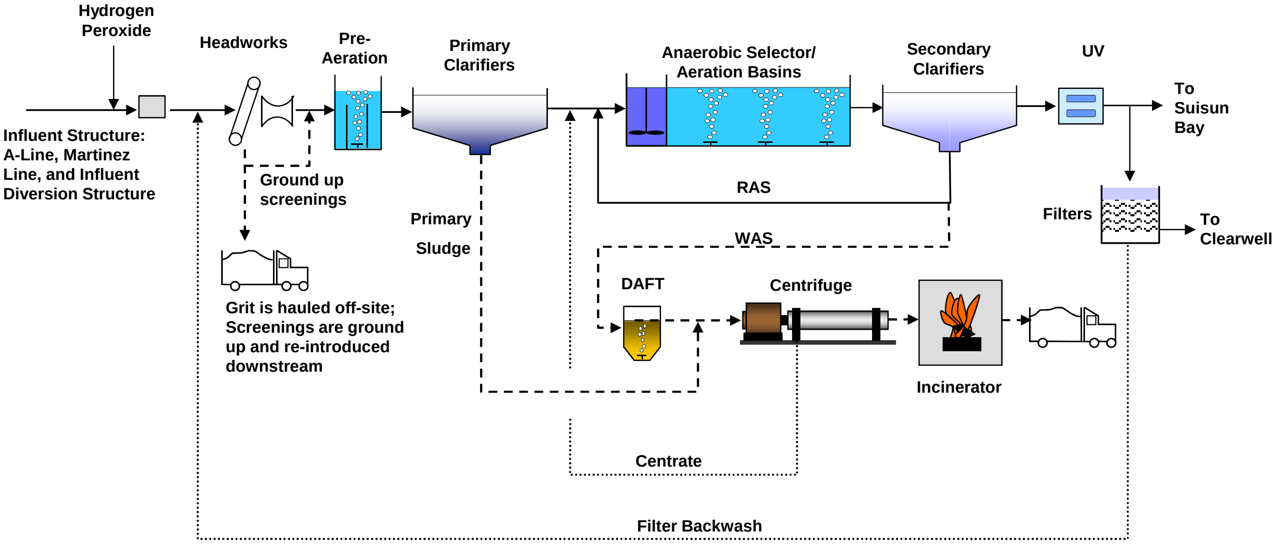

Figure 1. Existing Plant Schematic

As illustrated in Figure 1, the existing treatment plant includes the following liquid and solids treatment facilities:

- Liquid Stream:
  - Headworks (screens, and hydrogen peroxide (H_2O_2) for odor control)
  - Pre-aeration grit tanks
  - Primary clarifiers
  - Flow equalization of primary effluent for wet weather flows (not shown in Figure 1)

  - Activated sludge process (anaerobic selector, aeration zones, and secondary clarifiers) that removes biochemical oxygen demand (BOD) and total suspended solids (TSS)
  - Disinfection (Ultraviolet (UV))
  - Water reclamation (filters that discharge to a clearwell)
  - Discharge to Suisun Bay
- Solids Stream:
  - Thickeners (dissolved air flotation)
  - Dewatering (centrifuge)
  - Incineration (multiple hearth furnace)

As described in the previous section, the District's new NPDES permit requires several nutrient related studies, as summarized below:

- Nutrient Discharge Work Plan, Studies, and Reports. The work plan identifies the nutrient related studies that evaluate the effects of nutrients on Suisun Bay. The work plan delineates a process for disseminating the study findings to the District's stakeholders for review. The work elements include:
  - Continuation of the nutrient studies initiated by the Surface Water Ambient Monitoring Program (SWAMP) by funding an additional sampling site to characterize the San Joaquin River delta input.
  - Increase in collection of representative effluent samples to characterize nutrient forms (e.g., organic and inorganic nitrogen), concentrations, and loads.
  - Conduct collaborative study of the District's contribution to ammonium concentrations in Suisun Bay and related toxicity to copepods in the context of Suisun Bay.
  - Conduct collaborative studies to evaluate the role of ammonia/ammonium on primary productivity and zooplankton abundance, the significance of nutrient ratios, nutrient fate and transport, and the role of sediment biogeochemistry in nutrient fluxes.
- Facility Plan and Site Characterization. The facility plan includes an evaluation of nutrient removal technologies to determine the District's ability to remove nutrients. In addition, the District must evaluate the extent of the soil contamination located adjacent to the plant, in the area which had previously been identified for expansion of the aeration basins to accommodate total nitrification per the 2009 Study.

This report will be used by the District, in combination with other ongoing and completed studies, to satisfy the requirement to prepare a Facility Plan and Site Characterization. As previously described, this study is an update of the 2009 Study. This study evaluates the treatment process requirements needed to meet five potential future discharge limits (two new limits in addition to those included in the 2009 Study). As described later in this report, each of the treatment alternatives considered builds upon the recommendation in the 2009 Study, conventional nitrification.

3 Basis of Planning

The following subsections describe the treatment objectives, flows and loads, and the primary sedimentation basin removal efficiencies associated with planned plant upgrades.

Treatment Objectives

Recent NPDES permits in the Bay Area and the Sacramento-San Joaquin Valley were reviewed to identify potential nutrient limits that could be included in the District's future permits. Table 4 provides a summary of five nutrient limits that were selected to represent a range of potential future limits for the District. The effluent goals presented in Table 2 are based on recommendations by the NRDC as well as recently issued discharge permits. Section 4 provides details of the treatment alternatives that were developed to meet these treatment goals.

Table 4. Potential Nutrient Discharge Limits

Treatment Objective	Units	Average Monthly Effluent Limit (AMEL)	Maximum Daily Effluent Limit (MDEL)	Notes
Tier I				
Total N	mg-N/L	8	--	NRDC Recommendation
Total P	mg-P/L	1		
Tier II			--	
Total N	mg-N/L	5		NRDC Recommendation
Total P	mg-P/L	0.5		
Tier III				
Total N	mg-N/L	3	--	NRDC Recommendation
Total P	mg-P/L	0.3		
Tier IV				SRCSD NPDES Permit (R5-2010-011; CA0077682)
NH_3-N	mg-N/L	2.4	3.3	
NO_3-N	mg-N/L	10	--	
Tier V				City of Stockton NPDES Permit (R5-2008-0155; CA0079138)
NH_3-N	mg-N/L	2	5	

The limits for Tiers I, II, and III are based on a petition filed by the NRDC in November 2007 for Rulemaking with the USEPA to redefine secondary treatment and limit nutrient pollution from wastewater treatment facilities. Ten other regional and national environmental groups, including the Sierra Club and American Rivers, joined the NRDC in the petition. The NRDC argues that nitrogen and phosphorus effluent limitations should be a part of the base technology definition of secondary treatment. The NRDC contended that the USEPA must protect the public by establishing nutrient limits, and specifically that the USEPA unreasonably delayed publishing information on secondary treatment to remove nutrients. The NRDC also notes that nutrient control is properly included within "Secondary Treatment" and cites the following effluent nutrient levels as attainable:

- Effluent Total P at 1.0 mg P/L and Total N at 8.0 mg N/L are consistently attainable using current biological based technologies.

- Effluent Total P at 0.5 mg P/L and Total N at 5 mg N/L are consistently attainable using current biological based technologies that might require complementary chemicals (e.g., external carbon source for denitrification).
- Effluent Total P at 0.3 mg P/L and Total N at 3.0 mg N/L is attainable with existing technology using only improved biological and chemical treatment processes.

In December 2012, the USEPA denied the NRDC petition. The USEPA has agreed to publish information on the degree of effluent reduction attainable through the application of secondary treatment. In the letter to NRDC, the USEPA emphasized that secondary treatment technology is not designed for nutrient removal. In denying the NRDC petition, the USEPA found "a uniform set of nationally applicable, technology-based nutrient limits is not warranted" and that such limits would "require public owned treatment works (POTWs) to incur high costs even where such costs are not necessary to protect water quality."

Although the NRDC petition was denied, Tiers I through III provide a range of nutrient discharge limits that are commonly used for POTWs implementing nutrient removal. Use of these Tiers for this study is considered reasonable for evaluating potential future discharge limits.

In addition to the NRDC Tiers, two Tiers were developed based on recent NPDES permits in the Bay Area and the Sacramento-San Joaquin Valley. Tier IV represents the recent NPDES permit for Sacramento Regional County Sanitation District (SRCSD) issued in 2010 and Tier V represents the City of Stockton’s most recent NPDES permit, issued in 2008. The respective discharges for these two entities are upstream of the District’s discharge in Suisun Bay and represent potential nutrient limits that could be included in the District’s future permits.

Flows and Loads

The buildout flows, loads and peaking factors developed for the 2009 Study were revisited and in some cases updated. The Flows and Loads Technical Memorandum prepared as part of the 2009 Study has been included in Appendix A.

Flow and load peaking factors from the 2009 Study were based on an analysis of data from 2005 through 2008. The influent flows and loads peaking factors, as summarized in Table 5, were estimated as follows:

1. Flows (mgd) and loads (lb/d) were calculated and statistically analyzed according to a log-normal distribution.
2. The appropriate loading values for Annual Average (AA), Maximum Monthly (MM), Maximum Day (MD), and Peak Hour (PH) were taken from a log normal distribution plot at 50, 91.7 (11/12), 99.7 (364/365), and from historical data, respectively.
3. The peaking factors for each averaging period were compared against AA conditions, and a ratio was calculated. For example, the MM:AA load peaking factor for BOD is 1.36.

Table 5. Flows and Loads Peaking Factors

Parameter	Units	ADWF:AA[(a)]	AA:AA	MM:AA[(a)]	MD:AA[(a)]	PH:AA[(a)]
Flow	mgd	0.93[(b)]	1.0	1.37	1.87	2.30
BOD	lb/d	1.0	1.0	1.36	1.86	-
TSS	lb/d	1.0	1.0	1.43	2.05	-
NH4-N	lb N/d	1.0	1.0	1.28	1.65	-
TKN-N	lb N/d	1.0	1.0	1.36	1.85	-
TP-P	lb P/d	1.0	1.0	1.33	1.77	-

(a) Used in the 2009 Total Nitrification Study

(b) Based on the Sacramento Regional ADWF:AA Flow Peaking Factor

For this study update, the ADWF was based on the plant's rated flow of 53.8 mgd. Flows for the other averaging periods were calculated based on peaking factors developed in the 2009 Study. The average annual concentrations presented in the 2009 Study were used to calculate the average annual load. Loads for the other averaging periods were calculated based on peaking factors. The flows and loads used for this study are summarized in Table 6.

Table 6. 2013 Nitrification Update Flows and Loads

Parameter	Units	ADWF	AA	MM	MD	PH
Flow	mgd	53.8	57	78	107	146
BOD	lb/d	85,000	85,000	116,000	158,000	-
TSS	lb/d	98,000	98,000	140,000	201,000	-
NH4-N	lb N/d	11,000	11,000	14,000	18,000	-
TKN	lb N/d	17,000	17,000	23,000	31,000	-
TP-P	lb P/d	3,000	3,000	4,000	5,000	-
BOD	mg/L	189	179	178	178	-
TSS	mg/L	218	206	215	226	-
NH4-N	mg N/L	25	23	22	20	-
TKN	mg N/L	38	36	35	35	-
TP-P	mg P/L	7.0	6.0	6.0	6.0	-

Primary Sedimentation Basins

In 2012, the District installed fiberglass baffles in Primary Sedimentation Basin 4 (PSB 4) to evaluate and quantify the improvement that the baffles could have on solids and organics removal. Based on the data collected and analyzed by District staff, the baffles improve primary sedimentation basin performance. As a result, the District plans to install fiberglass baffles in the remaining primary sedimentation basins. Therefore, the alternatives presented in this study assume solids and organic removal rates for baffled primary sedimentation basins.

As described later in Section 4, chemically enhanced primary treatment (CEPT) is included in three of the proposed treatment alternatives because it offers the advantage of reducing organic and nutrient loads to the secondary system. Table 7 presents the solids and organic removal rates with CEPT and baffled primary sedimentation basins under ADWF and MM conditions.

Table 7. Primary Sedimentation Basin Performance

Scenario	Primary Performance, TSS Removal (%)		Primary Performance, BOD Removal (%)	
	Average Annual	Maximum Month and Maximum Day	Average Annual	Maximum Month and Maximum Day
With Baffles, No CEPT(a)	65%	50%	31%	25%
With Baffles, With CEPT(b)	73%	55%	35%	28%

(a) Average annual values are from CCCSD Report – Engelage, S., Field verification of primary sedimentation basin baffles, 2013, Central Contra Costa Sanitary District: Central Contra Costa Sanitary District. MM and MD values are estimated based on professional judgment.
(b) Estimated based on literature review and professional judgment.

Screenings

In addition to changes with the primary clarifiers, the District also plans to change the current screenings operation. As shown in Figure 1, the District currently grinds up the screenings and re-introduces them downstream where they settle out either with the primary sludge or further downstream in the secondary clarifiers, and ultimately go to incineration. The screenings are inert and do not contribute to the sludge treatment capability, but they consume valuable treatment capacity of the secondary clarifiers. An evaluation was performed on screenings alternatives that considered several different strategies to remove the screenings and not re-introduce them into the plant. The analysis presented in this study is based on the planned changes for the screenings as listed in the RMC and MWH Report (referred to as Alternative 1.5).[1]

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[1] RMC Water and Environment, in association with MWH, and Central Contra Costa Sanitary District (2011). Primary Sedimentation Expansion Project Preliminary Design Report for Central Contra Costa Sanitary District, Martinez, CA.

4 Treatment Alternatives

To meet the treatment Tiers listed in Table 4, the following technologies were considered in various combinations:

- Chemically enhanced primary treatment (CEPT)
- Enhanced biological phosphorus removal (EBPR) by modifying existing secondary treatment system (e.g., 4- to 5-stage Bardenpho Process)
- Nitrification/Denitrification (NDN) by modifying existing secondary treatment system (e.g., 4- to 5-stage Bardenpho Process)
- Conventional nitrification
- Chemically enhanced filtration (CEF)

The nitrification and nitrogen removal was carried out biologically for all Tiers, whereas phosphorus removal was evaluated through either a chemical approach or a combination of chemical and biological removal.

A description of the processes and the corresponding flowsheets for biological nitrogen removal with biological P removal, biological nitrogen removal with chemical P removal, nitrogen removal, and conventional nitrification is provided in the subsections below.

Biological Nitrogen Removal with Biological P Removal

Biological Nitrogen removal with biological P removal was evaluated for Tiers I, II, and III (Alternatives 1, 2, and 3). A flowsheet that represents all three Tiers is presented in Figure 2. A checklist of additional processes required at the District's plant to meet Tiers I, II, and III (Alternatives 1, 2, and 3) using biological nitrogen removal and biological P removal is provided in Table 8.

Table 8. Process Elements for NDN and EBPR

Tier	Alternative	CEPT	Anaerobic Zone Expansion	Anoxic Zone Addition	Aerobic Zone Expansion	2nd Anoxic Zone	2nd Aerobic Zone	External Carbon Source	Filters
I (8 mg N/L; 1 mg P/L)	1		✓	✓	✓				
II (5 mg N/L; 0.5 mg P/L)	2		✓	✓	✓	✓	✓	✓	✓
III (3 mg N/L; 0.3 mg P/L)	3		✓	✓	✓	✓	✓	✓	✓

CEPT was not used for the alternatives considered in this section. The existing primary sedimentation basins with baffles were used with the performance criteria presented in Table 7.

The additional equipment requirements and operations for each Tier (Alternatives 1, 2, and 3) are described in the following subsections.

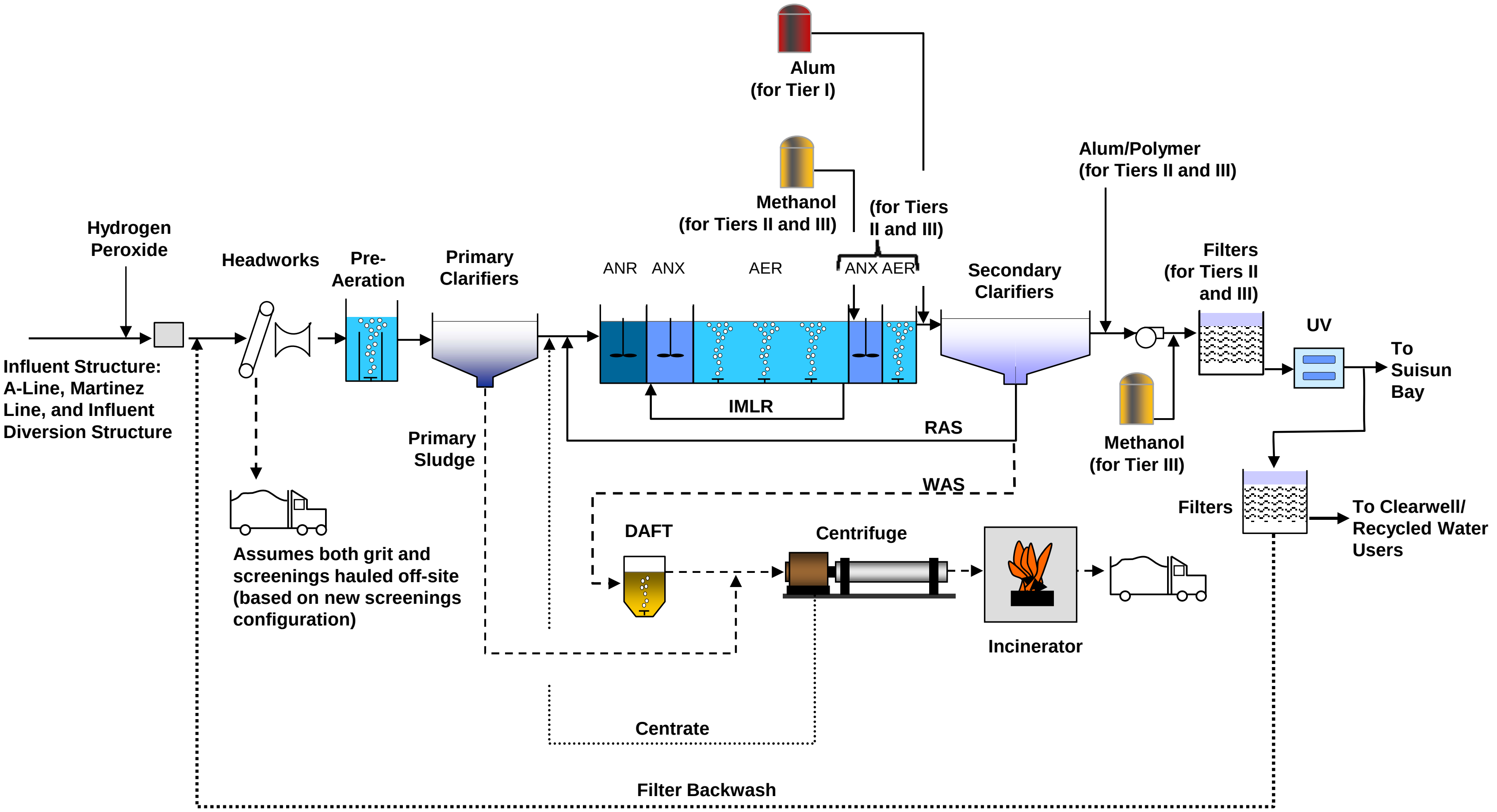

Figure 2. Flowsheet for NDN and EBPR (Tiers I, II, and III)

Tier I – Alternative 1

Alternative 1 includes biological nitrogen removal and biological P removal to meet the Tier 1 treatment objectives. Alternative 1 would include modifications to the activated sludge process for nitrogen removal that includes: i) addition of an anoxic zone, ii) addition of an internal mixed liquor return (IMLR) pump, iii) addition of alum chemical feed provisions for emergency situations, and iv) expansion of the aerobic zones. Conversion of the existing facility from an anaerobic/oxic (A/O) facility to an A2/O, whereby the additional 'A' is an abbreviation for addition of an anoxic zone located between the anaerobic and aerobic zones. The anoxic zone facilitates the removal of nitrogen through denitrification (i.e., $NO_3^- \rightarrow N_{2(g)}$). Creating conditions favorable for denitrification requires IMLR pumps that return nitrified water leaving the aeration basins to the front of the anoxic zones. The nitrified water will contain nitrate, which promotes anoxic conditions as long as oxygen is depressed (e.g., <0.2 mg/L). The effluent total nitrogen level governs the extent of internal recycling. IMLR pumping rates will lie somewhere between 2 to 3 times the flow entering the activated sludge basins. Chemical feed provisions are recommended between the aeration basins and the secondary clarifiers to serve as a backup for meeting total phosphorus limits. Additionally, a larger aerobic volume is required for the longer aerobic SRT (about 8 days).

Modifications required to meet the Tier I (Alternative 1) phosphorus objective include expansion of the anaerobic zone. Existing operational data reveals that effluent phosphorus values average about 1.3 mg P/L. Dropping this value to 1 mg P/L or less requires a larger anaerobic selector. At the average annual design flow, the hydraulic residence time (HRT) within the anaerobic selector is just under 30 minutes, with roughly 15 minutes for maximum day flow. Achieving the Tier I (Alternative 1) objectives requires an HRT of approximately one hour for average annual flow conditions.

Key changes to the existing plant for Tier I (Alternative 1) include:

- Add an anoxic selector in between the anaerobic and aerobic zones and operate the activated sludge as an A2O process.
- Add an internal mixed liquor return (IMLR) pumping and piping to internally recycle flow leaving the aeration basin and return to the front of the anoxic zone.
- Expand the aerobic zones to provide sufficient oxygen to perform organics removal and nitrification.
- Add chemical feed provisions for alum in between the basins and the secondary clarifiers. This process is recommended for emergency situations to ensure that the phosphorus limit is met.
- Expand the existing anaerobic selector to provide sufficient detention time to reliably meet a discharge limit of 1 mg P/L.

Tier II – Alternative 2

Alternative 2 includes biological nitrogen removal and biological phosphorus removal to meet the Tier II treatment objectives. Alternative 2 requires considerably more modifications than Alternative 1. Modifications in the activated sludge include converting the plant to a 5-stage Bardenpho process or a modified University of Cape Town (modified-UCT) configuration. Either option requires one anaerobic zone, two separate anoxic zones, and two separate aerobic zones. Figure 2 shows a Bardenpho process with two separate IMLR lines.

Modifications to the activated sludge for meeting the Tier II (Alternative 2) nitrogen limits are: i) anoxic and oxic zones, ii) IMLR pumps, and iii) methanol chemical feed facilities to the second anoxic zone. Similar to Tier I (Alternative 1), the anoxic and aerobic zones provide conditions favorable for nitrogen removal but require more volume and IMLR pumping in Alternative 2 to meet the lower discharge nitrogen limits. Additionally, an external carbon source (e.g., methanol) is required in the second anoxic zone to serve as a carbon and energy source for denitrification.

Examples of external carbon feed sources are as follows (Gu et al., 2010):

- Pure chemicals (e.g., methanol, ethanol, acetate, sugar, and butanol)
- Commercially available (e.g., Unicarb, Micro C™, etc)
- Raw industrial/agricultural byproducts (e.g., corn syrup, molasses, brewery waste, etc.)
- Sludge fermentation products
- Electron donors (e.g., hydrogen gas, methane, etc.)

The selection of a carbon source is governed by a combination of cost, safety, dose control, and tertiary denitrification process type (Gu et al., 2010). A pure chemical is recommended for the District because they are the most proven and reliable. Unfortunately, the most common chemical form, methanol, poses a safety risk due to its flammability. Despite the safety issues associated with methanol, it was used in this evaluation as it is a proven and reliable commodity on the scale required by the District. A picture of a methanol feed facility is shown in Figure 3.

The activated sludge process will not be able to meet the phosphorus limit for Tier II (Alternative 2). As a result, additional modifications are required to meet the phosphorus limits, including: i) expansion of the anaerobic zone and ii) addition of a filter complex with chemical feed facilities. As with Tier I (Alternative 1), the anaerobic zone must be expanded to account for phosphorus limits. To reliably meet the phosphorus limits, filtration with a metal salt and polymer is recommended downstream of the activated sludge process. The metal salt/polymer precipitates phosphorus out of solution and forms flocs for subsequent removal in the filters.

Figure 3. Methanol Feed Facility at the York River WWTP (Hampton Roads Sanitation District)

Alum is preferred over ferric at the filters to reduce any interference on ultraviolet transmittance (UVT). Figure 4 illustrates the impact of dissolved iron concentration on UVT for UV disinfection. A reduced UVT could de-rate the existing UV facilities capacity. Expanding the UV facilities for the same rated capacity is not considered an option so alum was used for this evaluation.

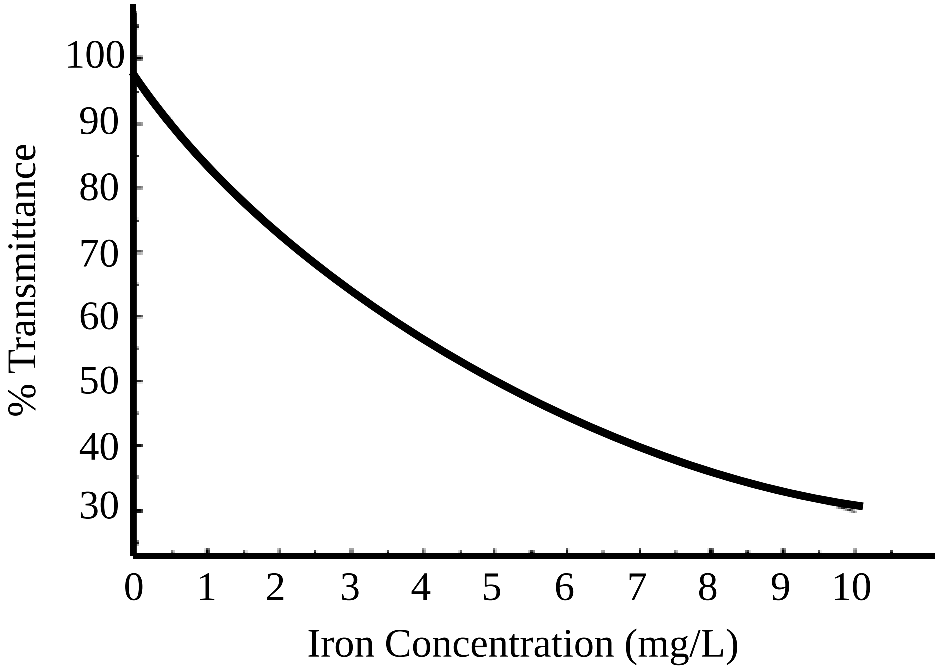

Figure 4. Effect of Iron on UV Transmittance for UV Disinfection

Key changes to the existing plant for Tier II (Alternative 2) include:

- Convert the current AO process to a 5-stage Bardenpho or modified-UCT which includes one anaerobic zone, two separate anoxic zones, and two separate aerobic zones.
- Add IMLR pumping and piping to internally recycle flow leaving the aeration basin and return to the front of the anoxic zone.
- Expand the aerobic zones to provide sufficient oxygen to perform organics removal and nitrification.
- Add methanol feed facilities to the second anoxic zone for denitrification.
- Expand the existing anaerobic selector to provide sufficient detention time to remove phosphorus.
- Add a granular media filter complex with chemical feed facilities for CEF.

Tier III – Alternative 3

Alternative 3 includes nitrogen removal and biological phosphorus removal to meet the Tier III treatment objectives. Tier III (Alternative 3) builds upon the Tier II (Alternative 2) plant modifications. Similar to Tier II (Alternative 2), the activated sludge process would be converted to a 5-stage Bardenpho or modified-UCT. All five zones would be larger than that required to meet the Tier II objectives (Alternative 3). The IMLR pumping would also increase, as would the methanol dosing in the second anoxic zone.

The activated sludge process will not be able to meet either nitrogen or phosphorous limits for Tier III (Alternative 3). To overcome this limitation, the filter complex would require expansion to denitrifying filters. Denitrifying filters have a lower loading rate than conventional filters to allow sufficient contact time for polishing denitrification. This requires a filter complex approximately twice as large as that included in Tier II (Alternative 2). Additionally, the chemical feed facilities at the filter complex would require methanol, alum, and polymer. Methanol would be fed upstream of the filters to provide a carbon and energy source for the biomass that performs denitrification. Similar to Tier II (Alternative 2), alum and polymer are dosed upstream of the filters for soluble phosphorus precipitation. The precipitated phosphorus is removed by downstream filters. The alum and polymer dosing is greater than Tier II (Alternative 2) to meet the more stringent limits associated with Tier III (Alternative 3).

Key changes to the existing plant for Tier III (Alternative 3) include:

- Convert the current AO process to a 5-stage Bardenpho or modified-UCT which includes one anaerobic zone, two separate anoxic zones, and two separate aerobic zones.
- Add IMLR pumping and piping to internally recycle flow leaving the aeration basin and return to the front of the anoxic zone.
- Expand the aerobic zones to provide sufficient oxygen to perform organics and nitrification.

- Add methanol feed facilities to the second anoxic zones for denitrification.
- Expand the existing anaerobic selector to provide sufficient detention time to remove phosphorus.
- Add a granular media filter complex with denitrifying filters and chemical feed facilities for CEF.

Biological Nitrogen Removal with Chemical Phosphorus Removal

Biological nitrogen removal with chemical P removal was evaluated for Tiers I, II, and III (Alternatives 4, 5, and 6). A flowsheet that represents all three Tiers is presented in Figure 5. A checklist of additional processes required at the District's plant to meet Tiers I, II, and III (Alternatives 4, 5, and 6) using biological nitrogen removal and chemical P removal is provided in Table 9.

Table 9. Process Elements for NDN and CEPT

Tier	Alternative	CEPT	Anaerobic Zone Expansion	Anoxic Zone Addition	Aerobic Zone Expansion	2nd Anoxic Zone	2nd Aerobic Zone	External Carbon Source	Filters
I (8 mg N/L; 1 mg P/L)	4	✓		✓	✓				
II (5 mg N/L; 0.5 mg P/L)	5	✓		✓	✓	✓	✓	✓	✓
III (3 mg N/L; 0.3 mg P/L)	6	✓		✓	✓	✓	✓	✓	✓

Nitrogen removal for all three Tiers occurs in a similar fashion to the nutrient removal with biological P removal as discussed in the prior section. In contrast, phosphorus removal would be accomplished with chemical removal strategies for these alternatives. CEPT is included for all Tiers considered in this section (Alternatives 4, 5, and 6). The use of CEPT increases solids and organics capture in the primaries. The existing primary treatment equipment with baffles and ferric/polymer feed was used with the performance levels stated in Table 7. In addition to CEPT, meeting the more stringent phosphorus limits for Tiers II and III (Alternatives 5 and 6) requires CEF.

Although CEPT can assist in liquid stream footprint reduction it can negatively impact solids treatment, in particular the multiple hearth furnace (MHF). Chemical precipitation impacts the sludge moisture content, sludge caloric value, and ratio of volatile to total solids. In addition to the impact on the solids composition, the use of metal salts decreases the ash fusion temperature in the MHF, which leads to the creation of sintered masses, known as clinkers, that can block drop holes and lock the rabble arm.[2]

The additional equipment requirements and operations for each Tier (Alternatives 4, 5, and 6) are described in the following subsections.

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[2] Niessen, W.R. (2002) Combustion and Incineration Processes: Applications in Environmental Engineering. CRC Press, Marcel Dekker, Monticello, NY.

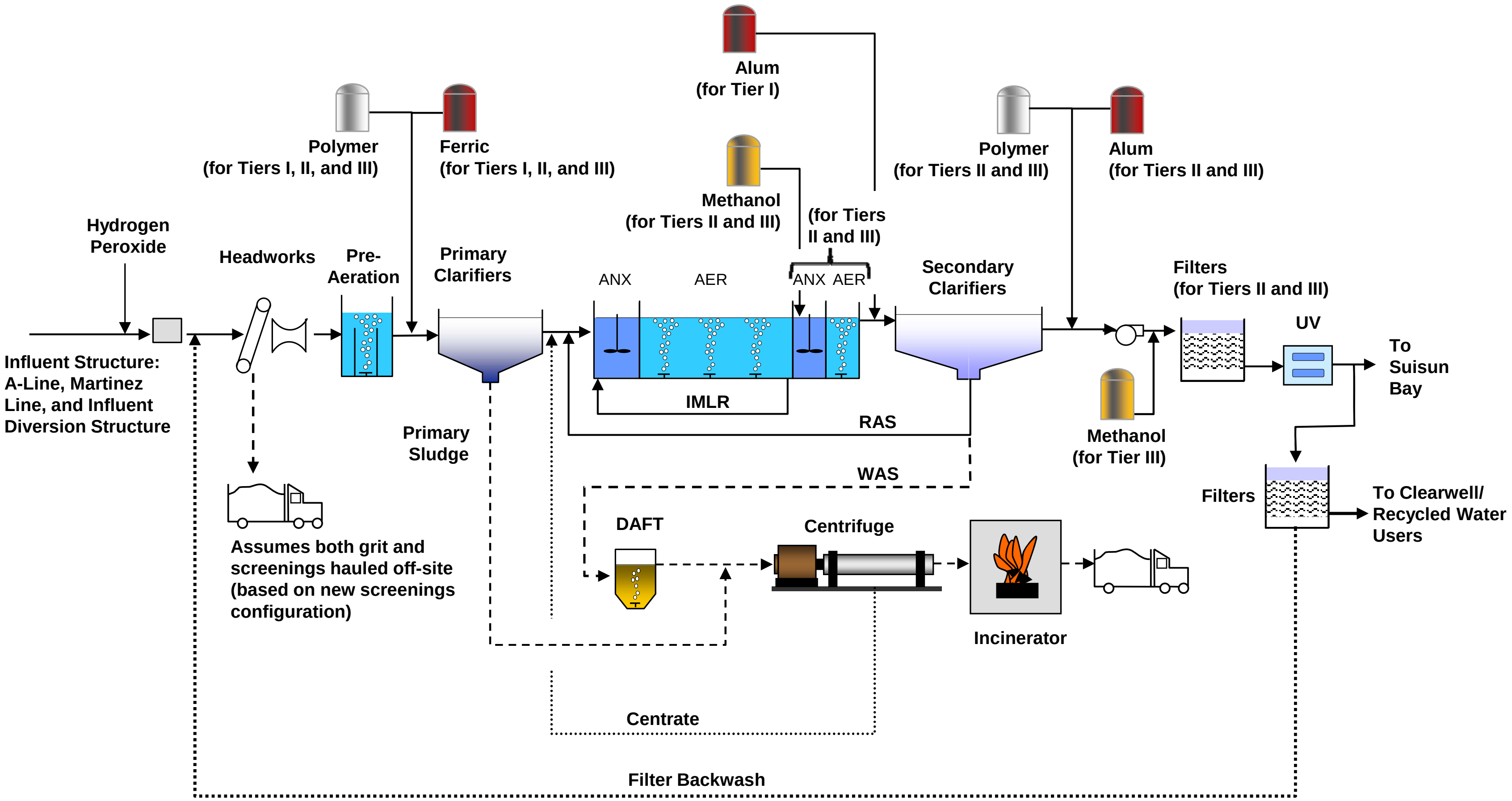

Figure 5. Flowsheet for NDN and CEPT (Tiers I, II, and III)

Tier I – Alternative 4

Alternative 4 includes nitrogen removal and chemical P removal to meet the Tier 1 treatment objectives. Tier I (Alternative 4) includes modifications to the activated sludge process for nitrogen removal that are similar to that described for Tier II (Alternatives 2) and Tier III (Alternative 3). The key modifications are: i) conversion of the anaerobic zone to an anoxic zone for denitrification, ii) addition of an IMLR pump, iii) addition of alum chemical feed provisions for emergency situations, and iv) expansion of the aerobic zones. Conversion of the anaerobic zone to anoxic conditions will occur naturally as the IMLR pumps return nitrified water leaving the aeration basins to the front of the anoxic zones. The nitrified water will contain nitrate, which promotes anoxic conditions as long as oxygen is depressed (e.g., <0.2 mg/L). The effluent total nitrogen level governs the extent of IMLR required for each alternative. For Alternative 4, the internal recycling will lie somewhere between 2 to 3 times the flow entering the activated sludge basins. Chemical feed provisions are recommended between the aeration basins and the secondary clarifiers to serve as backup for meeting total phosphorus limits. The aerobic zones need to be expanded to account for a longer detention time to transfer sufficient oxygen for both organics and nitrification.

Meeting the Tier I (Alternative 4) phosphorus objective requires chemical feed facilities at the primaries for CEPT. Metal salt (ferric assumed) and polymer feed facilities would be added to the primaries to operate in CEPT mode. This mode of operation would enhance solids, organics, and precipitated phosphorus capture in the primaries. The use of CEPT will facilitate meeting the Tier I (Alternative 4) phosphorus objective at 1 mg P/L. Additionally, operating a plant in CEPT mode will result in less solids production in the activated sludge process due to more organics capture in the primaries.

Key changes to the existing plant for Tier I (Alternative 4) include:

- Add metal salt/polymer chemical feed facilities at the primaries for CEPT.
- Use of CEPT will reduce the solids production in the activated sludge process.
- Convert the anaerobic zone to an anoxic zone for denitrification.
- Add IMLR pumping and piping to recycle flow leaving the aeration basin and return to the anoxic zone.
- Expand the aerobic zones to account for a longer aerobic SRT and additional aeration requirements associated with nitrification.

Tier II – Alternative 5

Alternative 5 includes nitrogen removal and chemical P removal to meet the Tier II treatment objectives. For Alternative 5, the activated sludge process must be converted to either a 4-stage Bardenpho or a UCT configuration. Either option will require two separate anoxic zones and two separate aerobic zones.

Modifications to the activated sludge for meeting the Tier II (Alternative 5) nitrogen limits are: i) conversion of anaerobic zone to an anoxic zone, ii) IMLR pumps and piping, iii) methanol chemical feed facilities, and iv) expansion of the aerobic zones. Similar to Alternative 4, the anaerobic zone will be converted to an anoxic zone for denitrification. The second anoxic zone and expanded aerobic zones are required for the nitrogen discharge limit. The IMLR pumping is increased to meet the lower discharge nitrogen limits. Additionally, an external carbon source (e.g., methanol) is required in the second anoxic zone to serve as a carbon and energy source for denitrification.

To meet the Tier II (Alternative 5) phosphorus limit, CEPT is required plus a filter complex with chemical feed facilities for CEF. The use of CEPT will reduce solids production in the downstream activated sludge process. Ferric/polymer was used in the CEPT with alum/polymer for CEF. Alum is preferred over ferric at the filter complex as previously stated to reduce any interference on the downstream UV disinfection.

Key changes to the existing plant for Tier II (Alternative 5) include:

- Add metal salt/polymer chemical feed facilities at the primaries for CEPT.
- Use of CEPT will reduce the solids production in the activated sludge process.
- Convert the anaerobic zone to an anoxic zone for denitrification.
- Add IMLR pumping and piping to recycle flow leaving the aeration basin and return to the anoxic zone.
- Expand the aerobic zones to account for a longer aerobic SRT and additional aeration requirements associated with nitrification.
- Add a filter complex with chemical feed facilities for CEF.

Tier III – Alternative 6

Alternative 6 includes nitrogen removal and chemical P removal to meet the Tier III treatment objectives. The activated sludge process will not be able to meet either Tier III (Alternatives 3 and 6) nutrient limit. The modifications to the activated sludge process required to meet the nitrogen limit are similar to those in Tier II (Alternative 5), except on a larger scale for volumes, pumping, and dosing. Despite a larger activated sludge process, it cannot meet the nitrogen limit. To overcome this limitation, the filter complex would be larger and a methanol feed facility is included to create denitrifying filters.

Denitrifying filters are designed with a lower loading rate than conventional filters to allow sufficient contact time for polishing denitrification. The denitrifying filters would be fed methanol upstream of the filters to provide a carbon and energy source for the biomass.

Meeting the Tier III (Alternative 6) phosphorus limit would be similar to Tier II (Alternative 5) by CEPT and CEF. The key difference is the chemical dosing for both CEPT and CEF is greater than Tier II (Alternative 5).

Key changes to the existing plant for Tier III (Alternative 6) include:

- Add metal salt/polymer chemical feed facilities at the primaries for CEPT.
- Use of CEPT will reduce the solids production in the activated sludge process.
- Convert the anaerobic zone to an anoxic zone for denitrification.
- Add IMLR pumping and piping to recycle flow leaving the aeration basin and return to the anoxic zone.
- Expand the aerobic zones to account for a longer aerobic SRT and additional aeration requirements associated with nitrification.
- Add a filter complex for denitrifying filters with chemical feed facilities for CEF.

Nitrification/Denitrification (Nitrogen Removal)

Nitrogen removal by NDN was evaluated for Tier IV (Alternative 7). A flowsheet that represents Tier IV (Alternative 7) is presented in Figure 6. A checklist of additional processes required at the District's plant to meet the Tier IV (Alternative 7) requirements is provided in Table 10.

Table 10. Process Elements for NDN

Tier	Alternative	CEPT	Anaerobic Zone Expansion	Anoxic Zone Addition	Aerobic Zone Expansion	2nd Anoxic Zone	2nd Aerobic Zone	External Carbon Source	Filters
IV (2.2 mg NH4-N/L for MM and 3.3 mg NH4-N/L for MD; 10 mg NO3-N/L for MM)	7			✓	✓				

A description for the additional equipment requirements and operations is provided in the following subsection.

Tier IV – Alternative 7

To meet the Tier IV nitrogen objective, Alternative 7 includes modifications to the activated sludge process similar to Tier I (Alternatives 1 and 4). The key modifications are: i) conversion of the anaerobic zone to an anoxic zone for denitrification, ii) addition of an internal mixed liquor return (IMLR) pump, and iii) expansion of the aerobic zones. Conversion of the anaerobic zone to anoxic conditions will occur naturally as the IMLR pumps return nitrified water leaving the aeration basins to the front of the anoxic zones. The nitrified water will contain nitrate, which promotes anoxic conditions as long as oxygen is depressed (e.g., <0.2 mg/L). The effluent total nitrogen level governs the extent of internal recycling. For Tier IV (Alternative 7), the internal recycling will lie somewhere between 2 to 3 times the flow entering the activated sludge basins. The aerobic zones need to be expanded to account for a longer detention time to transfer sufficient oxygen for both organics removal and nitrification. Additionally, a larger aerobic volume is required for the longer aerobic SRT (about 8 days).

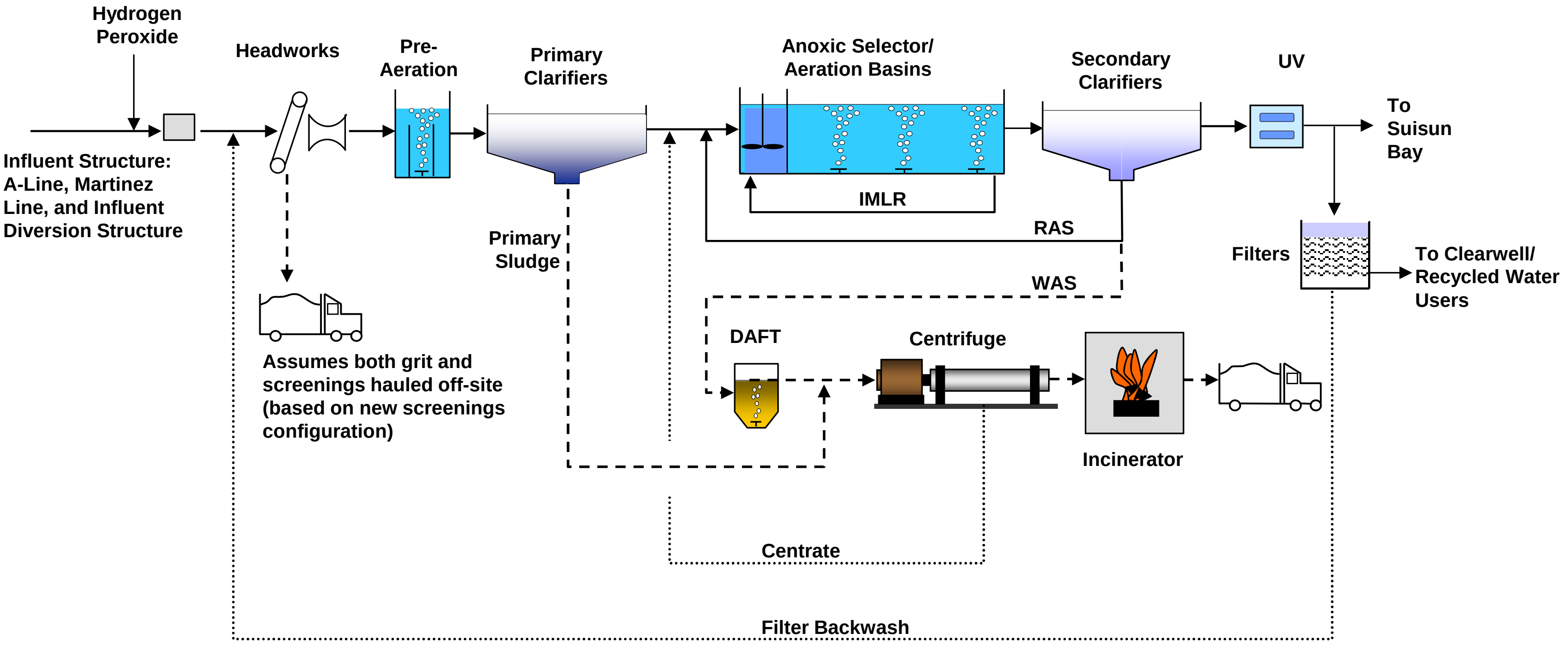

Figure 6. Flowsheet for NDN (Tier IV)

The ability to remove phosphorus will be compromised by converting the anaerobic zone to an anoxic zone for denitrification. As soon as nitrate is present without oxygen (i.e., anoxic conditions), the biological phosphorus removal mechanism will break down. Converting the anaerobic zone to an anoxic zone for denitrification should not significantly impact the solids removal performance of the secondary clarifiers.

The key changes to the existing plant for Tier IV (Alternative 7) include:

- Convert the anaerobic zone to an anoxic zone for denitrification.
- Add IMLR pumping and piping to recycle flow leaving the aeration basin and return to the anoxic zone.
- Expand the aerobic zones to account for a longer aerobic SRT and additional aeration requirements associated with nitrification.

Conventional Nitrification (Ammonia Removal)

Ammonia removal by biological nitrification was evaluated for Tier V under Alternative 8. A flowsheet that represents Alternative 8 (Alternative 8) is presented in Figure 7. A checklist of additional processes required at the District's plant to meet the Tier V requirements is provided in Table 11.

Table 11. Process Elements for Conventional Nitrification

Tier	Alternative	CEPT	Anaerobic Zone Expansion	Anoxic Zone Addition	Aerobic Zone Expansion	2nd Anoxic Zone	2nd Aerobic Zone	External Carbon Source	Filters
V (2.0 mg NH4-N/L for MM and 5.0 mg NH4-N/L for MD)	8				✓				

A description for the additional equipment requirements and operations is provided in the subsection below.

Tier V – Alternative 8

To meet the Tier V (Alternative 8) ammonia objective requires modifications to the activated sludge process. Of all the alternatives, this alternative has the simplest modifications with only expansion of the aerobic zone. The selector would remain to improve sludge settleability. No IMLR pumps or methanol feed facilities are required as there is no total nitrogen limit. The aerobic zones need to be expanded to account for a longer detention time to transfer sufficient oxygen for both organics removal and nitrification. Additionally, a larger aerobic volume is required for the longer aerobic SRT (about 8 days).

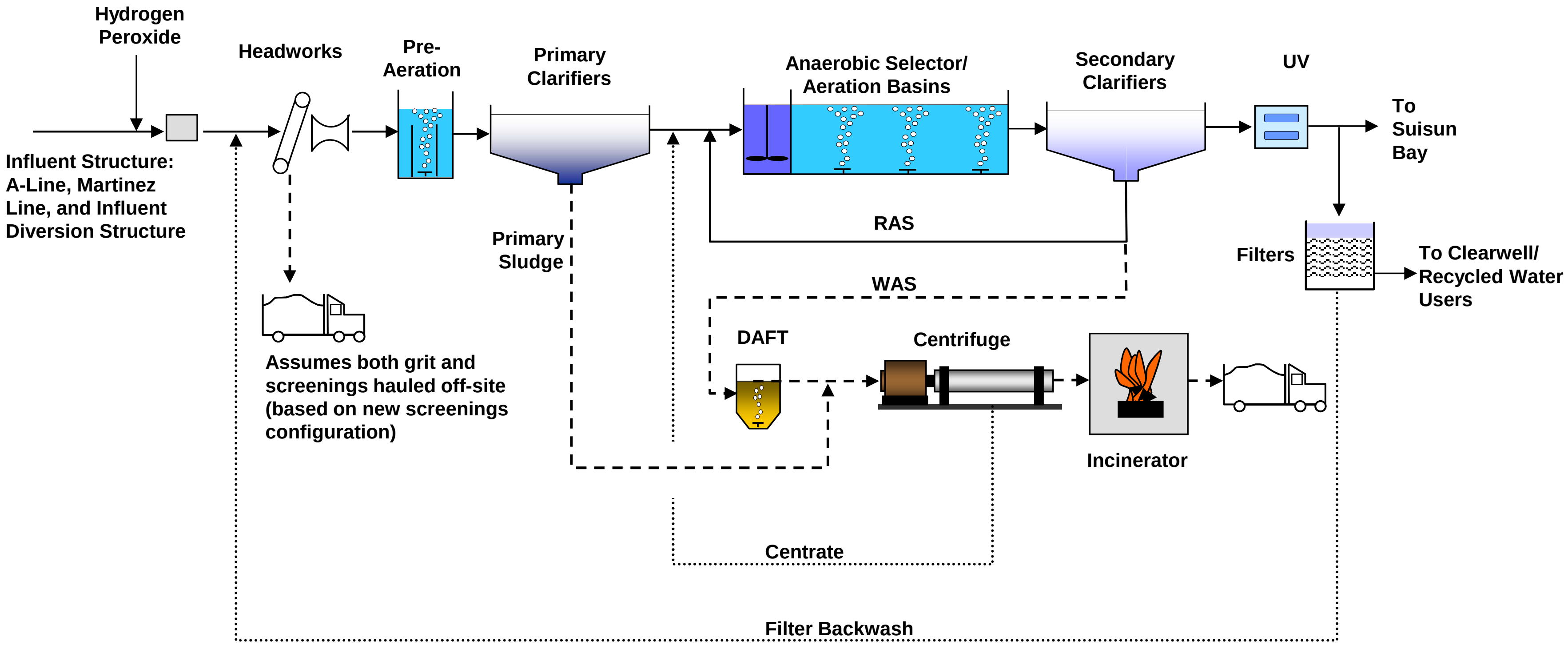

Figure 7. Flowsheet for Conventional Nitrification (Tier V)

One consideration for this alternative is the potential for floating solids in the secondary clarifiers. Nitrate levels in the secondaries will average about 20 mg NO3-N/L. Typically, nitrate levels in the secondaries greater than about 13 mg NO3-N/L can result in denitrification in the secondaries. Denitrification creates nitrogen gas bubbles which can cause biomass to rise to the surface and in turn leave with the liquid effluent. This concern should be addressed if the District advances this alternative to the design phase.

The key change to the existing plant for Tier V (Alternative 8) is:

- Expand the aerobic zones to account for a longer aerobic SRT and additional aeration requirements associated with nitrification.

Summary of Alternatives

A summary of the treatment alternatives is listed in Table 12. To meet such limits, a detailed listing of the new process elements by Tier is provided in Table 13.

Table 12. Ammonia and Nutrient Removal Treatment Alternatives Matrix

Treatment Goals[a]	Treatment Alternative			
	NDN & EBPR	NDN & CEPT	NDN	Conventional Nitrification
Tier I: TN = 8.0 mg N/L; TP = 1.0 mg P/L	Alternative 1	Alternative 4		
Tier II: TN = 5.0 mg N/L; TP = 0.5 mg P/L	Alternative 2	Alternative 5		
Tier III: TN = 3.0 mg N/L; TP = 0.3 mg P/L	Alternative 3	Alternative 6		
Tier IV: = 2.4 mg N/L; NOx-N = 10.0 mg N/L[b]			Alternative 7	
Tier V: NH3-N = 2.0 mg N/L[c]				Alternative 8

(a) Average monthly effluent limits are shown. Refer to Table 4 for details on MDEL treatment objectives for each tier.
(b) Maximum daily effluent limit for NH3-N is 3.3 mg/L.
(c) Maximum daily effluent limit for NH3-N is 5 mg/L.

Table 13. Proposed Unit Process Elements for Each Treatment Alternative

Process Elements	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
CEPT								
Chemical Feed (Metal Salt and Polymer)				✓	✓	✓		
BNR Basin								
Flow Box Split Box	✓	✓	✓	✓	✓	✓	✓	✓
Basin Concrete	✓	✓	✓	✓	✓	✓	✓	✓
Diffusers	✓	✓	✓	✓	✓	✓	✓	✓
Blowers	✓	✓	✓	✓	✓	✓	✓	✓
Mixers	✓	✓	✓	✓	✓	✓	✓	
Internal Mixed Liquor Return Pumping	✓	✓	✓	✓	✓	✓	✓	
Chemical Feed (External Carbon Source)		✓	✓		✓	✓		
Filtration (Required for Tier II and III)								
Filter Pumping Station		✓	✓		✓	✓		
Filter Media		✓	✓		✓	✓		
Chemical Feed (Metal Salt and Polymer)		✓	✓		✓	✓		
Chemical Feed (External Carbon Source)			✓			✓		
Filter Backwash Storage		✓	✓		✓	✓		
Filter Backwash Pumping Station		✓	✓		✓	✓		

5 Mass Balance Modeling

As described in Section 4, eight alternatives were developed to meet the defined treatment objectives. The following section summarizes the modeling assumptions, and the modeling results and associated design criteria for each alternative.

Modeling Assumptions

The District's calibrated Biowin® model was utilized to develop facility sizing for each alternative. The BioWin® modeling was performed by subconsultant, Hazen and Sawyer. The model was updated to reflect recent studies, including the Nitrifier Growth Rate Study completed in October 2013. Table 14 summarizes the model assumptions and sizing criteria for each of the alternatives. Additional details regarding assumptions used in the model are summarized in Appendix B.

The alternatives were modeled under steady state conditions. Process equipment sizing for Tiers I through III was based on maximum month conditions, while equipment sizing for Tiers IV and V should be based on maximum day conditions to meet effluent limits. However, because the biological processes can not meet steady state over only one day, the maximum day condition was not modeled. Instead, Tiers IV and V were modeled under steady state maximum month conditions with an additional safety factor applied for sizing process equipment. The additional safety factor is represented by a longer SRT. The Tier IV (Alternative 7) SRT is 18 percent greater than Tier I (Alternative 1).

Modeling Results

The facility needs for each alternative are presented in Table 15. To put the results in context in comparison to past studies, it is important to note that there are several differences between this Study Update and the 2009 Study:

- This study is based on the rated plant capacity (53.8 mgd ADWF), whereas the 2009 Study was based on data from December 2004 through December 2008. As a result, the flows and loads are higher for this study.
- The model assumes that screenings will be ground, compacted, and hauled off-site.[1]
- New information is available for the primary clarifier solids and organics capture based on research data gathered in 2013 coupled with industry standards (where necessary). The 2009 Study relied on estimates for improved performance with the introduction of baffles. Additionally, the 2009 Study used a fixed solid and organics capture removal percentage for all averaging periods. As a result, primary performance did not deteriorate during the wet weather events as the data supports. This has impacts on the sizing of downstream equipment.

Table 14. Summary of Model Assumptions and Sizing Criteria

Parameter	Units	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
CEPT									
Ferric Dose	mg Fe/L	--	--	--	7	9	11	--	--
Polymer Dose	mg/L	--	--	--	0.5	0.5	0.5	--	--
Flow to Size Chem Feed Facilities	--	Max Month	Max Month	Max Month	Max Month	Max Month	Max Month	Max Day	Max Day
BNR									
Temperature to Size BNR	C	18	18	18	18	18	18	18	18
Flow to Size Flow Split	--	Peak Hour	Peak Hour	Peak Hour	Peak Hour	Peak Hour	Peak Hour	Peak Hour	Peak Hour
Flow to Size BNR	--	Max Month	Max Month	Max Month	Max Month	Max Month	Max Month	Max Day	Max Day
Aerobic SRT for Maximum Month	days	7.2	7.4	9.0	6.8	7.6	8.7	9.1	8.5
MLSS Upper Limit at Maximum Month	mg/L	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
Secondary Clarifier Loading Limit									
Hydraulically for Maximum Month	gpd/sf	750	750	750	750	750	750	750	750
Hydraulically for Maximum Day	gpd/sf	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Solids for Maximum Month	lb/sf/d	36	36	36	36	36	36	36	36
Solids for Maximum Day	lb/sf/d	40	40	40	40	40	40	40	40
Wet Weather Act Sludge Feeding	--	Step Feed	Step Feed	Step Feed	Step Feed	Step Feed	Step Feed	Step Feed	Step Feed
IMLR Pumping	%	200	300	300	200	300	300	200	--
Flow to Size IMLR Pumps	--	Max Month	Max Month	Max Month	Max Month	Max Month	Max Month	Max Month	--
Flow to Size Methanol Feed Facilities	--	--	Max Month	Max Month	--	Max Month	Max Month	--	--
Flow to Size Alum Provisions	--	Max Month	--	--	Max Month	--	--	--	--
Filtration (Required for Tier II and III)									
Flow to Size Filters	--	--	Peak Hour	Peak Hour	--	Peak Hour	Peak Hour	--	--
Loading Rate	gpm/sf	--	7.5	3.75	--	7.5	3.75	--	--
Filter Backwash Rate	%	--	5	5	--	5	5	--	--
Alum Dose	mg/L		20	25		20	25	--	--
Polymer Dose	--	--	0.5	1.0	--	0.5	1.0	--	--
Flow to Size Chem Feed Facilities	--	--	Max Month	Max Month	--	Max Month	Max Month	--	--
Flow to Size Filter Pumping Station	--	--	Peak Hour	Peak Hour	--	Peak Hour	Peak Hour	--	--

Table 15. Summary of Facility Needs from Modeling Results

Parameter	Units	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
CEPT									
Ferric Demand	gal/d	0	0	0	3,600	4,800	5,800	0	0
Ferric Storage	gal	0	0	0	16,000	21,000	25,000	0	0
Polymer Demand	gal/day	0	0	0	60	60	60	0	0
Polymer Storage	gal	0	0	0	900	900	900	0	0
BNR									
Volume	MG	33	38	42	24	31	34	26	25
Blower Power	hp	3,000	3,200	3,400	3,300	3,300	3,500	3,600	3,500
Aeration Demand	scfm	55,000	57,000	60,000	60,000	60,000	63,000	65,000	64,000
Anaerobic Mixing	hp	110	110	110	0	0	0	0	100
Anoxic Mixing	hp	340	430	430	210	350	350	150	0
IMLR Pumps	mgd	160	240	240	160	240	240	160	0
IMLR Pumps	hp	400	600	600	400	600	600	400	0
RAS Pumps	mgd	79	79	79	79	79	79	79	79
RAS Pumps	hp	600	600	600	600	600	600	600	600
Methanol Vol. (for BNR)	gal/d	0	800	800	0	400	400	0	0
Methanol Storage Vol. (for BNR)	gal	0	10,900	10,900	0	4,900	4,900	0	0
Alum Feed Demand	gal/d	3,700	0	0	3,700	0	0	0	0
Alum Feed Storage	gal	1,200	0	0	1,200	0	0	0	0
Filtration (Required for Tier II and III)									
Filter Feed Pumps – Flow	mgd	0	122	122	0	122	122	0	0
Filter Feed Pumps – Power	hp	0	460	460	0	460	460	0	0
Filters - Number (Duty + Standby)	No.	0	30	50	0	30	50	0	0
Filter Backwash Flow (instantaneous)	mgd	0	10	10	0	10	10	0	0
Filters Backwash - Storage Volume	MG	0	0	1	0	0	1	0	0
Filter Backwash Pumps- Power	hp	0	10	10	0	10	10	0	0

Parameter	Units	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
Filtration Alum - Demand	gal/day	0	400	400	0	700	800	0	0
Filtration Alum - Storage	gal	0	6,000	6,000	0	9,000	12,000	0	0
Filter Polymer - Demand	gal/day	0	20	30	0	20	30	0	0
Filter Polymer - Storage	gal	0	220	450	0	220	450	0	0
Filtration - Methanol Vol.	gal/d	0	0	1,500	0	0	1,500	0	0
Filtration - Methanol Vol.	gal	0	0	21,000	0	0	21,000	0	0

- This study is based on a calibrated BioWin® model, whereas the 2009 Study was based on a simpler model and with limited site specific data. The calibrated BioWin® model uses site specific nitrifier growth rates developed in 2013.[3] The use of the BioWin® model should improve accuracy with respect to equipment sizing.

The subsections below will describe results for each of the unit processes (i.e., CEPT, BNR, and Filtration).

CEPT

Alternatives 2, 4 and 6 include CEPT. The daily demand and storage of the chemicals for CEPT (i.e., ferric as iron and polymer) are summarized in Table 15. CEPT has two primary purposes for the District where it will reduce solids loading on the activated sludge process and will also enable phosphorus removal. The dosing demand increases with the more stringent limits, progressively increasing from Tier I to II and III (Alternatives 4, 5, and 6), respectively. This is attributed to the additional chemical demands required to remove more phosphorus while maintaining the primary clarifier performance criteria (refer to Table 7). The addition of filters and methanol addition for Tiers II (Alternatives 2 and 5) and III (Alternatives 3 and 6) results in more solids being recycled within the plant, and in turn more chemical demand at the primaries.

The ferric chloride and polymer storage facilities are based on providing a minimum of 14-days of storage.

BNR

The existing activated sludge process has a total basin volume of approximately 10 MG. The required basin volumes developed for the alternatives in this study range from 24 to 42 MG. These values are larger than the 2009 Study due to the differences previously described.

The basins for Alternatives 4, 5 and 6 (NDN and CEPT) are smaller compared to their counterparts for NDN and EBPR. The footprint savings for NDN and CEPT is attributed to more solids and organics captured in the primary clarifiers. This benefit is recognized in the anaerobic and anoxic mixer horsepower. The smaller basins require less power for the mixers. However, despite the savings in space and mixers for NDN and CEPT, there are chemical facilities required in the primaries which are not needed for the other alternatives.

The blower power requirements for all treatment objectives range from 3,000 to 3,600 hp. Alternatives 7 and 8 have the highest blower facility requirements due to the maximum day ammonia discharge limit requirements. The blowers must be sized to account for that maximum ammonia load that occurs once per year. The NDN and CEPT alternatives have a higher blower demand than their NDN and EBPR counterparts to account for getting more air into a smaller footprint.

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[3] HDR (2013) Nitrifier Growth Rate Testing: Bench-Scale Test Results. Prepared for Central Contra Costa Sanitary District, Martinez, CA.

The aeration demand associated with the blower power requirement has the same multiplier to translate between the two parameters. The aeration transfer efficiency will improve for all Tiers with respect to the existing plant due to an improved alpha factor. The alpha factor represents the ability to transfer air across process water. Facilities with longer aerobic SRT have improved alpha. In the case of the District, previous off-gas testing to quantify the alpha factor in the existing basins produced a value of just under 0.30. Increasing the aerobic SRT to about 8.0 days should increase the alpha from 0.30 to about 0.50. Despite an improved alpha factor, the blower demand is greater than the existing plant due to increased aeration demands associated with organics and ammonia removal.

The IMLR pumps vary based on nutrient discharge limits. Tiers I (Alternatives 1 and 4) and IV (Alternative 7) are set at 200 percent of basin influent, whereas Tiers II and III (Alternatives 2, 3, 5, and 6) are set at 300 percent of basin influent. Tier V (Alternative 8) does not have any IMLR pumps because it does not include denitrification.

The RAS pumps are fixed for all alternatives. There is no variability is this parameter because it is based on hydraulics. The criterion is to provide sufficient capacity to convey 100 percent of the activated sludge feed flow during maximum month conditions.

Methanol addition is only required for Tiers II (Alternatives 2 and 5) and III (Alternatives 3 and 6). The methanol provides the carbon and energy required to meet the lower nitrogen limits. The NDN and CEPT Tiers (Alternatives 5 and 6) have less methanol demand for two reasons: i) more solids/organics capture in the primaries and ii) no methanol demand for biological phosphorus removal. For Tier III (Alternatives 3 and 6), methanol is required at the denitrifying filters for polishing nitrate.

Filtration

Alternatives 2, 3, 5 and 6 require filters. The peak flow was used to size the feed and backwash pumps.

Tier II (Alternatives 2 and 5) relies on filters for capturing solids that contain precipitated phosphorus to meet the phosphorus limits. Tier III (Alternatives 3 and 6) require a larger surface area to account for both biological nitrogen removal (denitrification) and solids removal of precipitated phosphorus.

In addition, the denitrifying filters in Tier III (Alternatives 3 and 6) requires the addition of methanol to provide the carbon and energy requirements of denitrification. The methanol demand at the denitrifying filters is the same for both Tier III alternatives (Alternatives 3 and 6) because the nitrate filter feed loads are comparable.

As previously stated in Section 4, alum is preferred over ferric chloride at the filters to reduce the possibility of dissolved iron negatively impacting UV disinfection due to a reduction in transmissivity. The alum, polymer and methanol storage facilities are based on providing a minimum of 14-days of storage.

6 Estimated Costs

The following subsections provide a summary of capital costs and operation and maintenance costs (O&M) for chemicals and power. The cost estimates are opinions of probable cost and are based on professional judgment. The estimates are considered planning level values. A detailed analysis (at the predesign stage) would be needed to refine these costs.

Basis of Cost Estimates

The cost opinions presented herein include a range of costs associated with the level of detail used in this analysis. Cost opinions based on conceptual engineering can be expected to follow the Association for the Advancement of Cost Engineering (AACE International) Recommended Practice No. 17R-97 Cost Estimate Classification System estimate Class 4. A Class 4 estimate is based on a 5 to 10 percent project definition and has an expected accuracy range of -30 to +50 percent. These estimates are considered an “order-of-magnitude estimate.”

The cost associated with each new unit process is based on a unit variable, such as the required footprint, volume, demand (e.g., lb O2/hr), diameter, etc. For example, the aeration system sizing/cost is governed by the maximum month airflow demand. Additionally, the cost associated with constructing an aeration basin is based on the volume.

The capital costs include the following allowances and contingencies:

- Sales Tax on Equipment – 8%
- Contractor Overhead and Profit – 10%
- Construction Contingency – 25%
- Engineering/Administration/Permitting/Construction Management – 25%

O&M cost estimates for power and chemicals were prepared for each new unit process. The O&M costs for chemicals and power were calculated from preliminary process calculations. For example, a chemical dose was assumed based on industry accepted dosing rates and the corresponding annual chemical cost for that particular chemical. The unit costs for chemicals are based on values provided by the District.

Table 16. Unit Cost Values

Parameter[a]	Units	Value
Power		
Unit Energy Rate	$/kWh	0.13
Chemicals		
Ferric	$/lb	0.31
Polymer	$/lb	1.07
Methanol	$/gal	2.75
Alkalinity	$/lb (dry)	0.88
Alum	$/lb active chemical	0.15

(a) Unit cost of power is an average rate provided by the District. Unit costs for chemicals were provided by the District; they were derived from the Bay Area Chemical Consortium price list (except methanol which is based on HDR experience).

The economic impacts of each alternative will be compared based on the total annualized cost. The annualized capital cost will be based on a 50 year period at 2 percent interest.

Capital Costs

The estimated capital costs for each alternative are provided in Table 17. The costs range from about $110 million to $240 million. The capital costs are based on the facility needs values discussed in Section 5. Tiers IV (Alternative 7) and V (Alternative 8) are generally less expensive due to the less stringent or no limit for nitrate and phosphorus. The Tier III alternative with NDN and EBPR is the most expensive alternative because it has the largest BNR basin, requires methanol in the BNR and filters, and requires the largest filter complex.

A discussion of relative costs for each unit process is provided in the following subsections.

CEPT

Ferric and polymer chemical feed facilities are only required for Alternatives 4, 5 and 6, which include NDN and CEPT. The ferric cost increases with the more stringent nutrient discharge limit, increasing from Tier I to Tier III. The polymer dosing was fixed for all three Tiers, so the associated costs are consistent for Alternatives 4, 5 and 6.

BNR

The BNR volume is the dominant contributor to the overall capital costs. The BNR cost is directly related to basin volume, which increases with the more stringent nutrient discharge limits. The components of the BNR also increase in cost with the more stringent nutrient discharge limits. These components include the following:

- Blowers
- Anaerobic mixing (if required for phosphorus removal)
- Anoxic mixing (if required for nitrogen removal)
- IMLR pumping and piping
- Methanol chemical feed facility for Tiers II and III

Construction of additional secondary clarifiers was not included in the capital cost estimates. The secondary clarifier solids loading and hydraulic loading rates exceed the assumed criteria (36 lb/d/sf for maximum month conditions with a 3,500 mg/L MLSS for maximum month conditions; 750 gpd/sf for maximum month conditions). Rather than assume additional secondary clarifiers are required, testing is recommended to confirm the upper limit on the solids loading rate. Stress testing of the secondary clarifiers is recommended to confirm whether additional secondary clarifiers are required with a longer SRT. If it is determined that additional secondary clarifiers are required, the cost estimates should be updated accordingly.

Table 17. Estimated Capital Costs

Parameter	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
CEPT								
Ferric Feed	$0	$0	$0	$410,000	$480,000	$510,000	$0	$0
Polymer Feed	$0	$0	$0	$230,000	$230,000	$230,000	$0	$0
Subtotal	$0	$0	$0	$650,000	$720,000	$750,000	$0	$0
BNR								
Flow Split	$280,000	$280,000	$280,000	$280,000	$280,000	$280,000	$280,000	$280,000
Biological Process	$64,620,000	$73,440,000	$81,360,000	$49,150,000	$60,930,000	$67,410,000	$52,200,000	$51,300,000
Air Supply System	$2,560,000	$2,630,000	$2,720,000	$2,720,000	$2,720,000	$2,790,000	$2,850,000	$2,820,000
Methanol Feed	$0	$500,000	$500,000	$0	$500,000	$500,000	$0	$0
Subtotal	$67,460,000	$76,850,000	$84,860,000	$52,150,000	$64,430,000	$70,980,000	$55,330,000	$54,400,000
Filtration								
Filter Feed Pumping	$0	$6,220,000	$6,220,000	$0	$6,220,000	$6,220,000	$0	$0
Granular Media Filter	$0	$9,740,000	$19,300,000	$0	$9,740,000	$19,300,000	$0	$0
Alum Feed	$0	$270,000	$280,000	$0	$320,000	$340,000	$0	$0
Polymer Feed	$0	$300,000	$370,000	$0	$300,000	$370,000	$0	$0
Methanol Feed	$0	$0	$500,000	$0	$0	$500,000	$0	$0
Backwash Pumping	$0	$480,000	$480,000	$0	$480,000	$480,000	$0	$0
Wash Water Surge Basin	$0	$670,000	$880,000	$0	$690,000	$880,000	$0	$0
Subtotal	$0	$17,680,000	$28,030,000	$0	$17,730,000	$28,090,000	$0	$0
Raw Construction Cost	$67,470,000	$94,530,000	$112,890,000	$52,790,000	$82,870,000	$99,820,000	$55,340,000	$54,410,000
Site Work (15%)	$10,120,000	$14,180,000	$16,930,000	$7,920,000	$12,430,000	$14,970,000	$8,300,000	$8,160,000
Construction Subtotal	$77,590,000	$108,710,000	$129,820,000	$60,710,000	$95,300,000	$114,790,000	$63,640,000	$62,570,000
Sales Tax (8%)	$5,400,000	$7,560,000	$9,030,000	$4,220,000	$6,630,000	$7,990,000	$4,430,000	$4,350,000
Overhead and Profit (10%)	$8,300,000	$11,630,000	$13,890,000	$6,490,000	$10,190,000	$12,280,000	$6,810,000	$6,690,000
Construction Bid Price	$91,290,000	$127,900,000	$152,740,000	$71,420,000	$112,120,000	$135,060,000	$74,880,000	$73,610,000
Contingency (25%)	$22,820,000	$31,980,000	$38,190,000	$17,860,000	$28,030,000	$33,770,000	$18,720,000	$18,400,000
Construction Cost	$114,110,000	$159,880,000	$190,930,000	$89,280,000	$140,150,000	$168,830,000	$93,600,000	$92,010,000
ELAC(a) (25%)	$28,530,000	$39,970,000	$47,730,000	$22,320,000	$35,040,000	$42,210,000	$23,400,000	$23,000,000
Total Project Cost(b)	$142,640,000	$199,850,000	$238,660,000	$111,600,000	$175,190,000	$211,040,000	$117,000,000	$115,010,000
Annualized Capital Cost(c)	$4,539,000	$6,360,000	$7,595,000	$3,551,000	$5,575,000	$6,716,000	$3,723,000	$3,660,000

(a) Includes Engineering, Legal, Administration, and Construction Management.

(b) Costs are a Class 4 estimate, -30 percent to +50%, and are presented in current, 2013 dollars. The cost for removal of contaminated soil at the site where the new aeration basins would be located (refer to Section7) is not included.

(c) Capital costs are amortized over 50 years at 2 percent interest.

Filtration

To achieve the treatment objectives for Tiers II (Alternatives 2 and 5) and III (Alternatives 3 and 6), filtration is required. Thus, a filter feed pumping station has been included and sized based on the peak flow. The pumping cost is the same for the alternatives in both Tiers. In addition, alum and polymer are required for the filters. The alum dosing is greater for the Tier III alternatives to account for the more stringent phosphorus limit, whereas the polymer dose is fixed.

The Tier II alternatives include a conventional granular media filter for capturing solids which is reflected in the costs. In contrast, the Tier III alternatives (Alternatives 3 and 6) include a denitrifying filter complex which requires a footprint approximately twice as large as the Tier II conventional granular media filters. Additionally, the Tier III alternatives require a methanol chemical feed facility to provide the carbon and energy source for denitrification.

The remaining filtration costs are the backwash storage and pumps. These costs are comparable for the alternatives associated with both Tiers II and III. The backwash cycles can be staggered and dampen out the backwash flows across the complex.

Annual Power and Chemical Costs

The annual power and chemical costs for the new unit processes for each alternative are presented in Table 18 and Table 19, respectively. As shown, the range in annual power costs is relatively narrow, at $3.0 million to $3.7 million, compared to the range in chemicals costs, which range from zero to about $4.3 million per year. The subsections below describe the power and chemical requirements for each of the unit processes.

Power

The power requirements for each of the new unit processes is described below.

CEPT. The annual power demands for CEPT are negligible because the only facilities requiring power are the chemical feed delivery pumps and the SCADA system. Additionally, the pumps operate at low flows because the tanks all have concentrated stock solutions.

BNR. The annual power demand for the BNR process ranges from approximately 23,000 MWh/yr to nearly 27,000 MWh/yr. The BNR would be the primary energy consumer for each of the alternatives. It is well known that aeration typically constitutes approximately 40 to 60 percent of a plant’s annual power demand.

For each of the alternatives, providing more than the required air or internally recycling more water via IMLR pumps will not result in significant additional nutrient removal. Once the ammonia is nitrified, the limiting factor in removing total nitrogen and/or phosphorus, for Tiers I through IV, is the presence of a carbon source. The addition of an external carbon source (i.e., methanol) does not require significant power. As a result, the difference in power demand between the Tiers is negligible for the BNR.

Table 18. Annual Energy Costs

Parameter	Units	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
CEPT									
Ferric Feed Energy	kWh/yr	0	0	0	1,600	1,600	1,600	0	0
Polymer Feed Energy	kWh/yr	0	0	0	1,600	1,600	1,600	0	0
Subtotal	kWh/yr	0	0	0	3,200	3,200	3,200	0	0
BNR									
Blowers	kWh/yr	19,200,000	20,500,000	20,500,000	21,500,000	21,400,000	21,400,000	23,200,000	22,800,000
IMLR Pumps	kWh/yr	1,900,000	2,900,000	2,900,000	1,900,000	2,900,000	2,900,000	1,900,000	0
RAS Pumps	kWh/yr	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000
Methanol Feed Energy	kWh/yr	0	1,600	1,600	0	1,600	1,600	0	0
Subtotal	kWh/yr	22,900,000	25,200,000	26,200,000	25,200,000	26,100,000	26,800,000	26,900,000	24,600,000
Filtration (Required for Tier II and III)									
Feed Pumps	kWh/yr	0	1,440,000	1,440,000	0	1,440,000	1,440,000	0	0
Backwash Pumps	kWh/yr	0	20,000	40,000	0	20,000	40,000	0	0
Alum Feed Energy	kWh/yr	0	1,600	1,600	0	1,600	1,600	0	0
Polymer Feed Energy	kWh/yr	0	1,600	1,600	0	1,600	1,600	0	0
Methanol Feed Energy	kWh/yr	0	0	3,800	0	0	3,800	0	0
Subtotal	kWh/yr	0	1,500,000	1,500,000	0	1,500,000	1,500,000	0	0
Total – Annual Energy Demand(a)	kWh/yr	22,900,000	26,700,000	27,700,000	25,200,000	27,600,000	28,300,000	26,900,000	24,600,000
Total – Unit Energy Demand(a)	kWh/MG Treated	1,100	1,300	1,300	1,200	1,300	1,300	1,300	1,200
Total – Annual Energy Cost(a)	$/yr	$2,980,000	$3,470,000	$3,600,000	$3,280,000	$3,590,000	$3,680,000	$3,500,000	$3,200,000

(a) Annual energy demands and associated costs are for new unit processes only.

Table 19. Annual Chemical Costs

Parameter	Units	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
CEPT									
Ferric - Annual Cost	$/yr	0	0	0	1,100,000	1,600,000	1,700,000	0	0
Polymer - Annual Cost	$/yr	0	0	0	190,000	190,000	190,000	0	0
Subtotal	$/yr	0	0	0	1,290,000	1,790, 000	1,890,000	0	0
BNR									
Methanol - Annual Cost	$/yr	0	800,000	800,000	0	400,000	400,000	0	0
Subtotal	$/yr	0	800,000	800,000	0	400,000	400,000	0	0
Filtration (Required for Tier II and III)									
Alum - Annual Cost	$/yr	0	250,000	270,000	0	220,000	410,000	0	0
Polymer - Annual Cost	$/yr	0	50,000	90,000	0	50,000	90,000	0	0
Methanol - Annual Cost	$/yr	0	0	1,510,000	0	0	1,510,000	0	0
Subtotal	$/yr	0	300,000	1,870,000	0	270,000	2,010,000	0	0
Total – Annual Chemical Costs(a)	$/yr	$0	$1,100,000	$2,670,000	$1,290,000	$2,460,000	$4,300,000	$0	$0

(a) Annual chemical costs are for new unit processes only.

Filtration. Only Tiers II (Alternatives 2 and 5) and III (Alternatives 3 and 6) require filtration. Of those, Tier II (Alternatives 2 and 5) has conventional granular media filters and Tier III (Alternatives 3 and 6) has denitrifying filters. The Tier III (Alternatives 3 and 6) denitrifying filters require more frequent backwash to account for biological growth. Thus, there is a larger annual power demand for the Tier III alternatives.

Summary. As summarized above, while the BNR process constitutes the main power demand for each of the alternatives, the difference is relatively small. Alternatives 3 and 6 have the highest annual energy costs at approximately $3.7 million and Alternative 1 has the lowest annual energy cost at approximately $3.0 million, representing a difference of approximately 20 percent.

Chemicals

The chemical requirements for each of the unit processes is described below.

CEPT. The chemical cost associated with CEPT is based on supplying ferric at a dosing range of about 25 mg FeCl/L and polymer at about 1.0 mg/L. The ferric dosing increases from Tier I to the more stringent Tier III for the alternatives with NDN and CEPT.

The use of ferric and polymer to implement CEPT in the primaries results in additional solids and organics capture of approximately 8 and 4 percentage points, respectively. Capturing more organics in the primaries will reduce the solids production in the downstream aeration basins.

The overall impact on the solids stream is still unknown. As stated in the NDN and CEPT section, CEPT can negatively impact solids treatment, in particular the MHF. The net overall impact of CEPT is site specific and should be evaluated in detail if CEPT appears to be the preferred alternative for the District.

BNR. Chemicals are required in the BNR to complement the biological process. There is insufficient BOD in the aeration basins to meet the nutrient requirements to meet the Tier II (Alternatives 2 and 5) and III (Alternatives 3 and 6) nutrient discharge limits. As a result, an external carbon source (e.g., methanol) is required to provide sufficient BOD.

Filtration. The alternatives that require filtration (Tiers II and III; Alternatives 2, 3, 5, and 6) also require alum and polymer addition. A higher chemical dose is required to meet lower nutrient discharge limits. Tier III (Alternatives 3 and 6) also requires the use of methanol for denitrification polishing.

Cost Summary

A summary of the capital, O&M and total annualized costs is presented in Table 20. As shown, the total annualized costs range from approximately $6.9 million for Alternative 8 to as high as $14.7 million for Alternative 6. As expected, the total annualized costs for Tiers IV and V (Alternatives 7 and 8) are the lowest. While the capital costs for the alternatives with NDN and CEPT (Alternatives 4, 5 and 6) are lower than their respective counterparts with NDN and EBPR (Alternatives 1, 2 and 3), the total annualized costs are higher due to the additional costs for power and chemicals associated with the NDN and CEPT alternatives.

Table 20. Capital, O&M, and Annualized Costs

Parameter	Units	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
Capital Costs									
Capital Cost(a)	$	$142,640,000	$199,850,000	$238,660,000	$111,600,000	$175,190,000	$211,040,000	$117,000,000	$115,010,000
Annualized Capital Costs(b)	$/yr	$4,539,000	$6,360,000	$7,595,000	$3,551,000	$5,575,000	$6,716,000	$3,723,000	$3,660,000
O&M Costs									
Power Costs(c)	$/yr	$2,980,000	$3,470,000	$3,600,000	$3,280,000	$3,590,000	$3,680,000	$3,500,000	$3,200,000
Chemical Costs(c)	$/yr	$0	$1,100,000	$2,670,000	$1,290,000	$2,460,000	$4,300,000	$0	$0
Subtotal Annual O&M Costs	$/yr	$2,980,000	$4,570,000	$6,270,000	$4,570,000	$6,050,000	$7,980,000	$3,500,000	$3,200,000
Total Annualized Costs	$/yr	$7,519,000	$10,930,000	$13,865,000	$8,121,000	$11,625,000	$14,696,000	$7,223,000	$6,860,000

(a) Capital costs are estimated to within -30 percent to +50 percent and are presented in current, 2013 dollars. Costs do not include the cost to clean up the contaminated soil adjacent to the plant where the new facilities would likely be located.

(b) Capital costs are amortized at 50 years and a 2 percent interest rate.

(c) Annual power and chemical costs are estimated for new unit processes only.

7 Site Footprint

Each of the eight alternatives would include expansion of the existing aeration basins. It is assumed that new tankage could be located east of the existing basins as shown in Figure 8. A range of footprints for the aeration basins is presented that overlays that smallest and largest footprints. The smallest footprint is for Tier I NDN and CEPT (Alternative 4) and the largest is for Tier III NDN and EBPR (Alternative 3). Tier I NDN and CEPT (Alternative 4) is slightly smaller (1 MG) than Tier V (Alternative 8) because the Alternative 8 treatment objectives are sized for the maximum month averaging period.

The proposed site contains contaminated soils that will increase construction costs. As described in the previous section, that additional cost is not included at this time. Once the District obtains site cleanup costs, the capital costs for each Alternative should be updated to reflect the total cost.

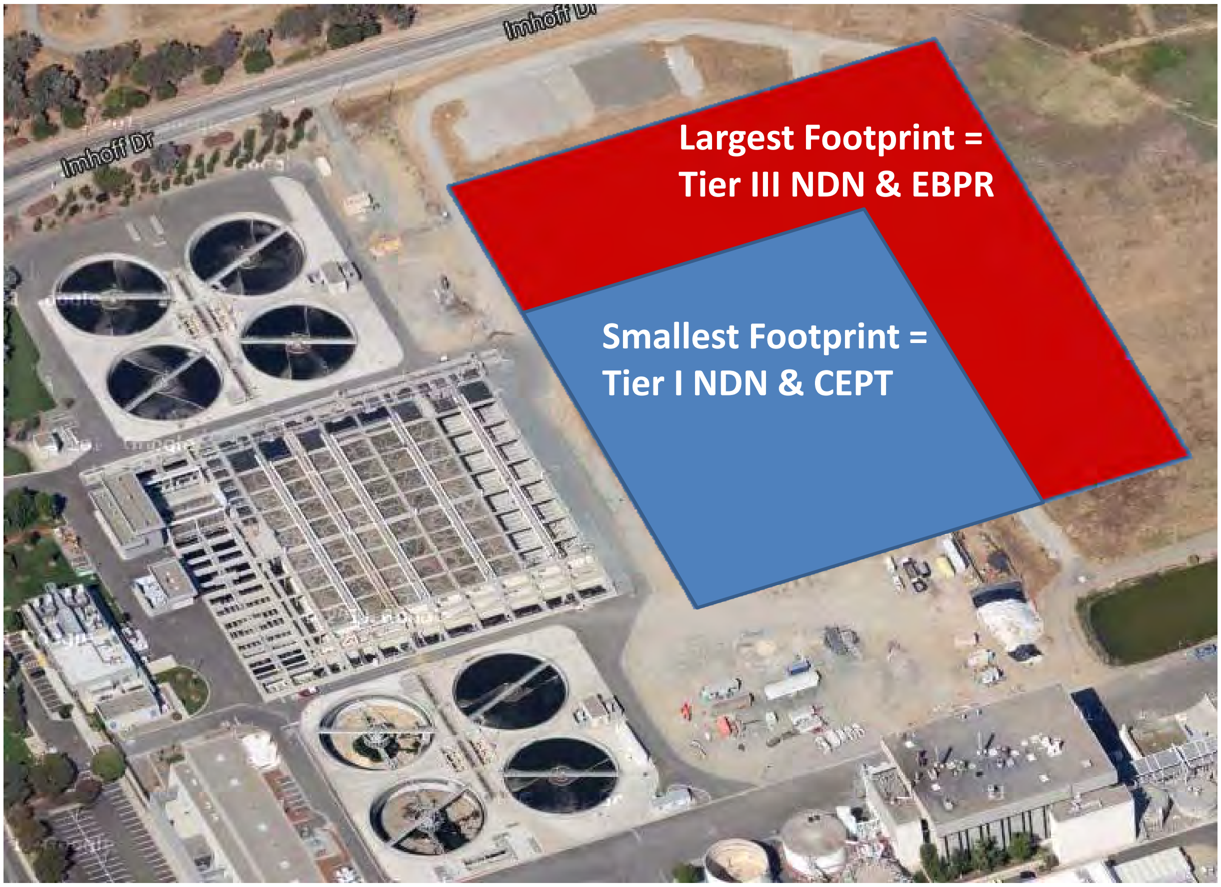

Figure 8. Aerial Photo of the Southern Portion of the District's Property – BNR Expansion

A summary of the footprint requirements for the activated sludge basin expansion and filters (if required) are provided in Table 21. The footprint listed is limited to the process basin requirements. It does not include the surrounding footprint for ancillary facilities. There is some flexibility where the filters can be located. For example, the filters could be located nearby the existing recycled water filters. However, the water would need to be conveyed to this location and then returned back to the disinfection facility.

Table 21. Footprint Requirements for Additional Activated Sludge Tankage and Filtration Facilities

Parameter[a]	Units	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
Activated Sludge Footprint (b)	sf	193,000	234,000	271,000	121,000	176,000	206,000	135,000	131,000
Filtration Footprint (c)	sf	0	11,000	23,000	0	11,000	23,000	0	0

(a) Footprint limited solely to process requirements. It does not include space for ancillary equipment, roads, etc.
(b) Footprint requirements for activated sludge are in addition to the existing footprint.
(c) Filtration facility location still undecided as there are a few different prospective locations.

8 Greenhouse Gas (GHG) Emissions

Assembly Bill 32 (AB 32) requires industrial facilities with greenhouse gas (GHG) emissions of more the 25,000 metric tons of carbon dioxide equivalent (CO2e) per year to participate in the California GHG emissions cap and trade program. The District is nearing that threshold and, as a result, the District is interested in quantifying the GHG emissions associated with upgrading the existing facility from secondary treatment to include nutrient removal. Additional GHG emissions would be created by the additional power and nitrous oxide (N2O) emissions associated with nutrient removal.

Any additional power requirements associated with transitioning from secondary treatment to nutrient removal treatment would be imported. As a result, no additional stationary source combustion greenhouse gas emissions would be incurred against the District under AB 32. This is significant as power requirements have been shown to represent the majority of GHG emissions for facilities transitioning from secondary to nutrient removal treatment.[4] This additional energy is from mixing, additional air requirements in the BNR, pumping in the BNR (e.g., IMLR), tertiary filtration feed and backwash pumping, etc.

Measuring N2O gases has gained recent attention because it is approximately 310 times more potent than carbon dioxide. While there are quantitative approaches to accurately calculating the GHG emissions associated with energy production, there is a lack of consensus on how to calculate N2O emissions from the treatment process. Table 22 illustrates the wide range of GHG emissions associated with N2O emissions production within the plant and leaving the plant as discharge, ranging from between 190 to greater than 700,000 million tons CO2e per year.

As a wastewater plant converts from secondary treatment to advanced nutrient removal the probability of N2O emissions production within the plant increases. This range is captured under the IPCC centralized WWTP row of Table 22. Given the uncertainty in N2O emissions production, the District performed their own calculations by assuming that a range of influent nitrogen load is converted to N2O emissions (1 to 15 percent). These values are listed as District Methodology in Table 22. This range is based on several well documented literature sources that highlight the variability in N2O emissions (e.g., Ahn et al., 2010).[5]

Despite potential N2O emission increases within the plant after converting the plant to a more advanced nutrient removal treatment, those emissions are off-set by less N2O emissions produced in receiving water. The N2O emission associated with the discharge on the receiving water is quantified in the lower portion of Table 22. The decrease in receiving water emissions range is directly related to a reduced effluent nitrogen load. There is uncertainty on whether

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

[5] Ahn, J.-H., Kim, S, Park, H., Rahm, B., Pagilla, K., Chandran, K. (2010b) N2O emissions from activated sludge processes, 2008-2009: Results of a national surveying program in the United States. Environ. Sci. Technol., 44(12):4505-4511.

future regulations will credit facilities with N2O emissions savings with discharge impact on receiving water.

Research is advancing on the mechanisms of N2O production and how best to apply multipliers to real world situations. As this field continues to advance, the wide range of N2O production estimates is expected to narrow. Once fine-tuned, actual N2O emissions from treatment plants will be better characterized, which will put the District in a position to better quantify the actual contribution in GHG emissions created by N2O.

Table 22. Nitrous Oxide Emissions within the Plant and Leaving as Discharge

Parameter	Metric Tons CO2e Per Year								
	Baseline (Existing Plant)	Alternative 1 Tier I (NDN&EBPR)	Alternative 2 Tier II (NDN&EBPR)	Alternative 3 Tier III (NDN&EBPR)	Alternative 4 Tier I (NDN&CEPT)	Alternative 5 Tier II (NDN&CEPT)	Alternative 6 Tier III (NDN&CEPT)	Alternative 7 Tier IV (NDN)	Alternative 8 Tier V (Nitrification)
Centralized N2O Emissions within the Plant									
IPCC Centralized WWTP(a)	807	920	920	920	920	920	920	920	920
District Methodology (b)	8,740	8,740	8,740	8,740	8,740	8,740	8,740	8,740	8,740
District Methodology (c)	131,150	131,150	131,150	131,150	131,150	131,150	131,150	131,150	131,150
Discharge Impact on Receiving Water N2O Emissions									
IPCC Multiplier - Low End(d)	1,450	500	320	190	500	320	190	820	1,450
IPCC Multiplier - High End(d)	752,148	252,230	157,640	94,580	252,230	157,640	94,580	409,870	725,150
IPCC Multiplier - Average(d)	363,299	126,360	78,980	47,390	126,360	78,980	47,390	205,340	363,300

(a) Centralized N20 emissions calculated based on the International Panel on Climate Change (IPCC) methodology using Eqn 6.9 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf).

(b) Based on District methodology, assuming 1 percent of influent load is converted to N20.

(c) Based on District methodology, assuming 15 percent of influent load is converted to N20.

(d) Discharge impact on receiving water N20 emissions, calculated based on the IPCC multiplier methodology using Eqn 6.7 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf).

9 Summary

In anticipation of future nutrient discharge limitations, it is important for the District to understand and plan for the potential costs associated with upgrading its wastewater treatment plant to meet a range of future, potential discharge requirements.

A previous study prepared for the District in 2009 evaluated the feasibility of achieving total nitrification (i.e., ammonia removal) at the treatment plant. In that study, eight potential nitrification technologies were screened and four were selected for detailed evaluation, including conventional nitrification, integrated fixed film activated sludge (IFAS), moving bed biofilm reactor (MBBR), and a biological aerated filter (BAF). Although both IFAS and MBBR technologies provide a reliable nitrification technology, their selection over conventional nitrification is typically driven by space constraints and lower wastewater temperatures than those encountered at the District. In addition, the use of fixed film technologies was relatively unproven, particularly at plants with high flows similar to the District's. Lastly, BAFs had higher capital costs and were also relatively unproven. As a result, conventional nitrification was recommended as the preferred treatment process to achieve the potential nutrient discharge limits. The purpose of this study was to update the 2009 Study and develop recommended facilities and costs to achieve a range of discharge requirements. Five potential discharge requirements were considered. The discharge requirements for Tiers I, II and III were based on the petition filed by the NRDC in November 2007, while Tiers IV and V are based on the recently adopted NPDES permits for SRCSD and the City of Stockton, respectively. Eight alternatives based on conventional nitrification were developed to meet the discharge requirements. A summary of the capital and O&M costs for each alternative is presented in Table 23.

Table 23. Summary of Capital, O&M and Annualized Costs

Alternative	Capital Cost ($ Millions)[a]	Annual O&M Cost ($ Millions / Year)[b]	Total Annualized Cost ($ Millions / Year) [c]
Alternative 1, NDN with EBPR Tier I: TN = 8.0 mg N/L; TP = 1.0 mg P/L	$142.6	$2.98	$7.52
Alternative 2, NDN with EBPR Tier I: TN = 5.0 mg N/L; TP = 0.5 mg P/L	$199.9	$4.57	$10.93
Alternative 3, NDN with EBPR Tier II: TN = 3.0 mg N/L; TP = 0.3 mg P/L	$238.7	$6.27	$13.87
Alternative 4, NDN with CEPT Tier II: TN = 8.0 mg N/L; TP = 1.0 mg P/L	$111.6	$4.57	$8.12
Alternative 5, NDN with CEPT Tier III: TN = 5.0 mg N/L; TP = 0.5 mg P/L	$175.2	$6.05	$11.63
Alternative 6, NDN with CEPT Tier III: TN = 3.0 mg N/L; TP = 0.3 mg P/L	$211.0	$7.98	$14.70
Alternative 7, NDN Tier IV: NH3-N = 2.4 mg N/L; NOx-N = 10.0 mg N/L	$117.0	$3.50	$7.22
Alternative 8, Nitrification Tier V: NH3-N = 2.0 mg N/L	$115.0	$3.20	$6.86

(a) Capital costs are estimated to within -30 percent to +50 percent and are presented in current, 2013 dollars. Costs do not include the cost to clean up the contaminated soil adjacent to the plant where the new facilities would likely be located.
(b) Annual O&M costs include power and chemicals for new unit processes only.
(c) Capital costs are amortized over 50 years and 2 percent interest.

As illustrated in Table 23, as the nutrient discharge limits become more restrictive, the capital costs increase. The lowest capital cost alternatives are Alternatives 4, 7, and 8, which have the least stringent discharge limits and associated process requirements. The highest capital costs are associated with the alternatives that were developed to meet the Tier III treatment objectives. In addition, the alternatives with biological nitrogen and phosphorus removal (Alternatives 1, 2 and 3) have higher capital costs than those with biological nitrogen and chemical phosphorus removal (Alternatives 4, 5, and 6) to meet the same respective treatment objective.

The capital costs presented in Table 23 do not include construction of additional secondary clarifiers or the clean up and removal of the contaminated soil adjacent to the District's plant where the new treatment facilities would likely be located. Once the soil contamination cleanup cost is quantified, it should be added to the estimated capital costs for each of the alternatives to present a complete picture of the expected total cost. Costs were not included for the construction of additional secondary clarifiers because the existing clarifiers are rated to handle the design maximum month overflow conditions, regardless of the discharge limit. However, stress testing of the existing secondary clarifiers is recommended to confirm that additional secondary clarifiers are not needed.

Similar to the capital costs, and as expected, the O&M costs also increase as the discharge limits become more restrictive. However, the alternatives with biological nitrogen and chemical phosphorus removal (Alternatives 4, 5 and 6) have greater O&M costs than their respective counterparts with biological nitrogen removal and biological phosphorus removal (Alternatives 1, 2 and 3). As a result of the higher O&M costs associated with Alternatives 4, 5 and 6, the total annualized costs, including annualized capital costs, are also higher than their respective counterparts (Alternatives 1, 2 and 3). The alternatives for Tiers IV and V, Alternatives 7 and 8, have the lowest total annualized costs.

Since the District does not yet have direction regarding its future effluent discharge requirements, and because it could be one or two permit cycles before discharge limits are imposed, the District should continue to evaluate advances in nutrient removal technologies, particularly emerging technologies.

Appendix A

Flows and Loads Technical Memorandum

INFLUENT FLOWS AND LOADS

CCCSD Ammonia Removal Study-
Technical Memorandum 2 ***March 3, 2009***

Reviewed by: Hany Gerges, Ph.D., P.E.
Prepared by: Michael Falk, Ph.D.

Chapter 1 - Background

The National Pollutant Discharge Elimination System (NPDES) permit issued to Central Contra Costa Sanitation District (District) is listed in Table . The existing permit does not require nitrification within the District's wastewater treatment facility. However, loads (e.g., ammonia) discharged to receiving water bodies are subjected to monitoring and permit regulations.

Table 1 The District's NPDES Permit of Conventional Pollutants

Parameter	Units	Average Monthly	Average Weekly	Maximum Daily	Instantaneous Minimum	Instantaneous Maximum
cBOD	mg/L	25	40	50	-	-
TSS	mg/L	30	45	60	-	-
Entero-cocci	CFU/ 100 ml	35	-	-	-	-
Oil & Grease	mg/L	10	-	20	-	-
pH	s.u.	-	-	-	6.0	9.0

cBOD = Carboneous biochemical oxygen demand
TSS = Total suspended solids

Potential future regulations coupled with ensuring low ammonia levels in the receiving water bodies have spurred interest by the District in nitrifying to nitrogen levels of 0.5 mg/L (annual median) and 3.1 mg/L (maximum day).

Chapter 2 - Analysis of Historical Data

A statistical analysis of the District influent data was performed. Influent flows and loads for the period between December 2004 and December 2008 were used. The main purpose of the analysis was to determine the annual average (AA), maximum month (MM), maximum day (MD) and peak hours (PH) values for the influent flows and main process parameters such as BOD, TSS, Ammonia NH_3, and phosphorus. These values will be used in developing a mass balance model of the wastewater treatment plant using an HDR's software called Envision.

The model will then be used to evaluate different nitrification technologies and identify the most cost effective one.

Influent Flows and Loads

The relationship between influent flow and constituents concentrations is an important element in estimating the hydraulic and biological loading on the treatment plant. In the following sub-sections, the relationship between influent flow rate and TSS and BOD concentrations and loadings is presented.

Total Suspended Solids

Figure 1 compares the variability in the influent TSS concentration (primary y-axis) and influent Flow (secondary y-axis) with respect to time (x-axis) .

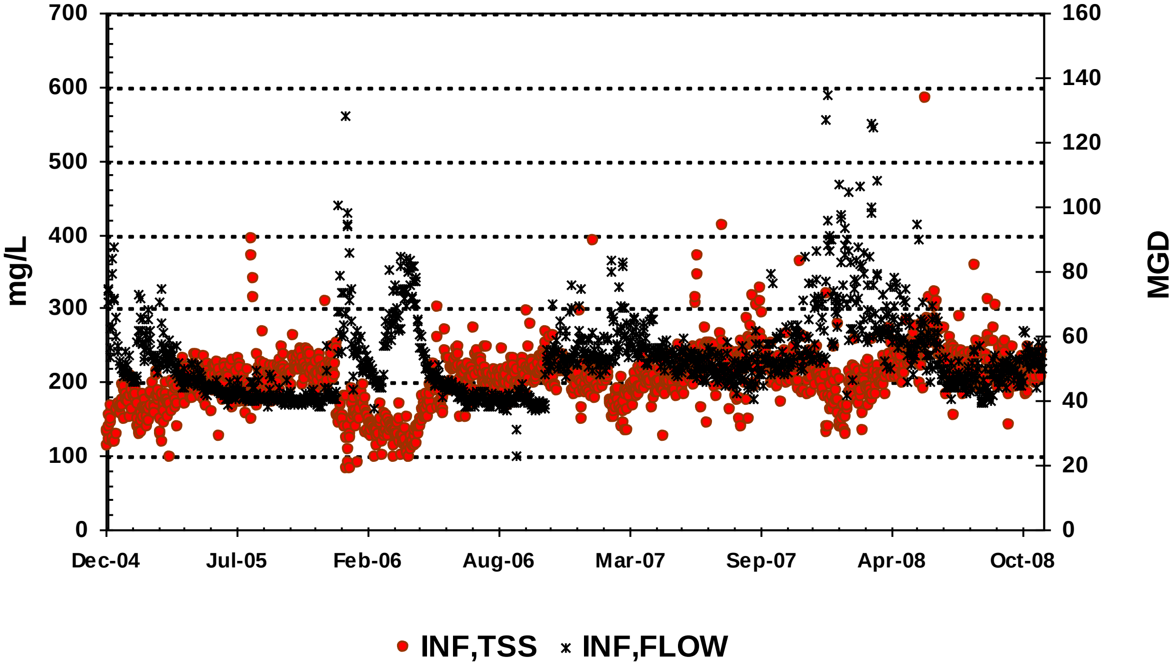

Figure 1. Influent Flows and TSS Concentrations over Time

Figure 1 shows that for flows up to 80 mgd, TSS levels become diluted with increased flow. In contrast, as flows exceed 80 mgd the direct relationship between flow and TSS ceases to exist.

For example, the average flow rate during the storm event on January 4 and 5, 2008 was approximately 131 mgd and corresponded with TSS concentrations of 221 and 320 mg/L, respectively. In contrast, the flow rate during the storm event on March 15, 2008 was 125 mgd and corresponded to to 176 mg/L TSS.

In order to determine the effect of dilution of TSS loading on the plant, a more detailed analysis was performed by plotting the relationship between flows and TSS concentrations based on flow range as shown in Figure 2. A trend line was inserted into each data series that are governed by flow ranges. Figure 2 shows that for flows up to 49 mgd, the influent suspended solids concentration remain the same and no dilution occurs. For flows between 49 and 80 mgd, some dilution occurs. For flows higher than 80 mgd, the influent TSS concentration increases as the flow increases.

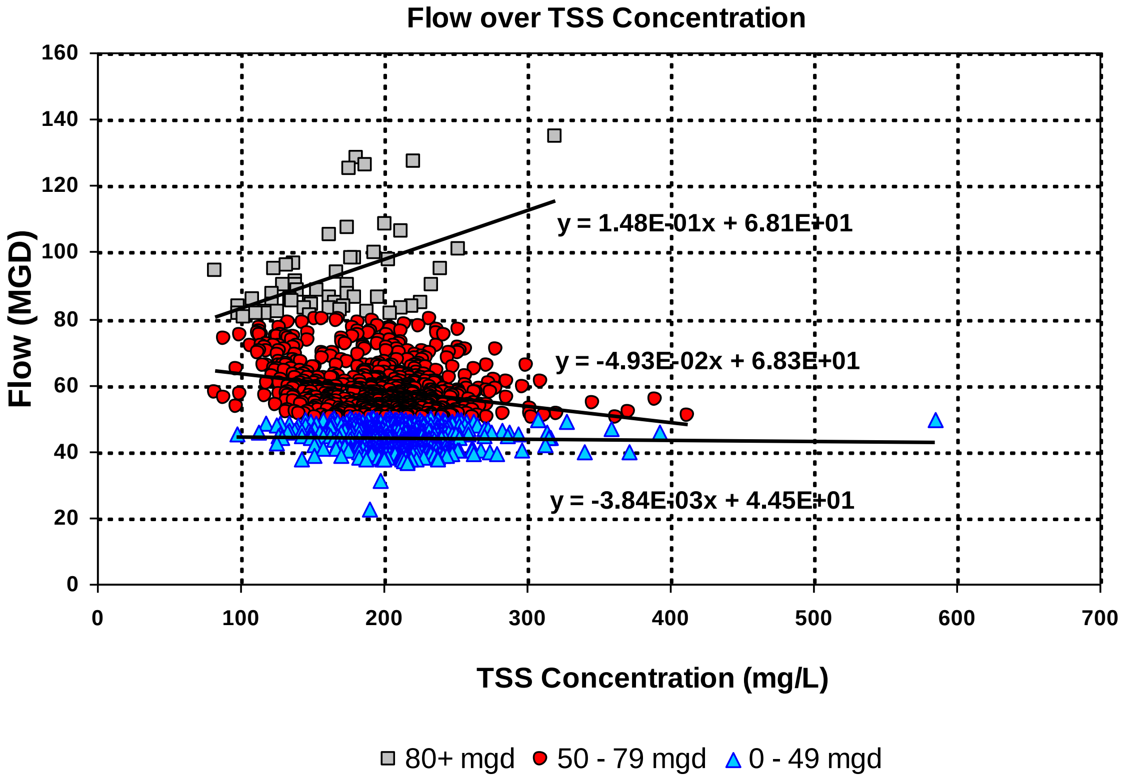

Figure 2. Influent Flow over TSS Concentration

Design of wastewater unit processes is usually based on loadings rather than concentrations. The best way for analyzing loadings is to develop log normal distribution plots. A plot similar to Figure 2 was constructed using flows over loads as illustrated in Figure 3. As expected, as the flows exceed 80 mgd, the load increase is most pronounced in comparison with the other two flow ranges.

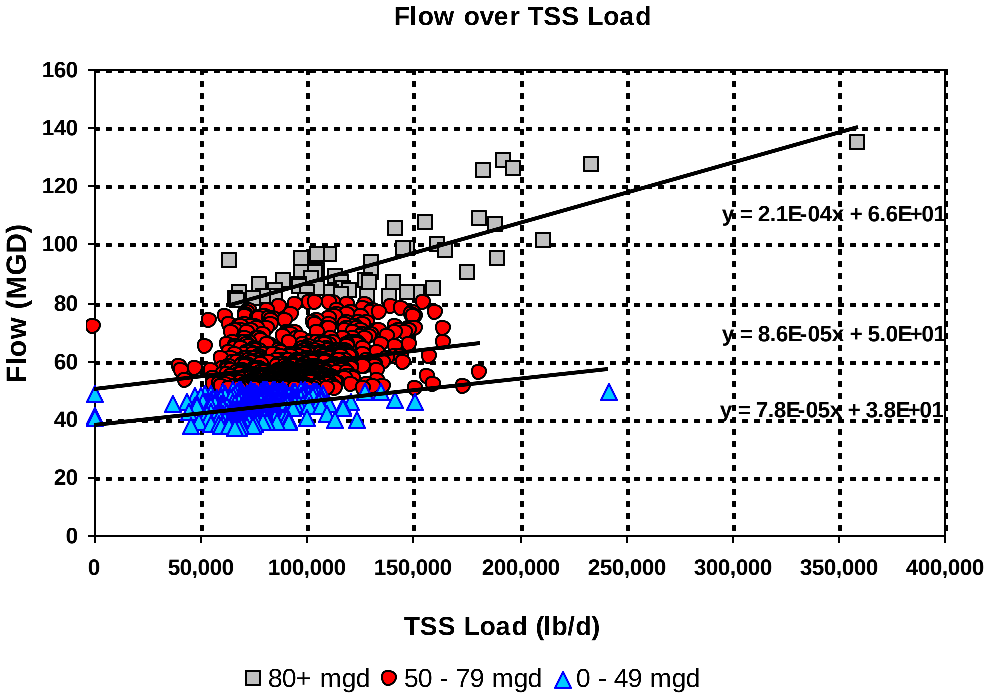

Figure 3. Influent Flow over TSS Load

For either flows or loads, the log-normal distribution plot typically provides best representation of data distribution for wastewater treatment plants. For example, Figure 4 and Figure 5 illustrate log-normal and normal distribution plots, respectively, for influent TSS load at the District. The log-normal distribution in Figure 4 is more in agreement with the data than the normal distribution plot in Figure 5.

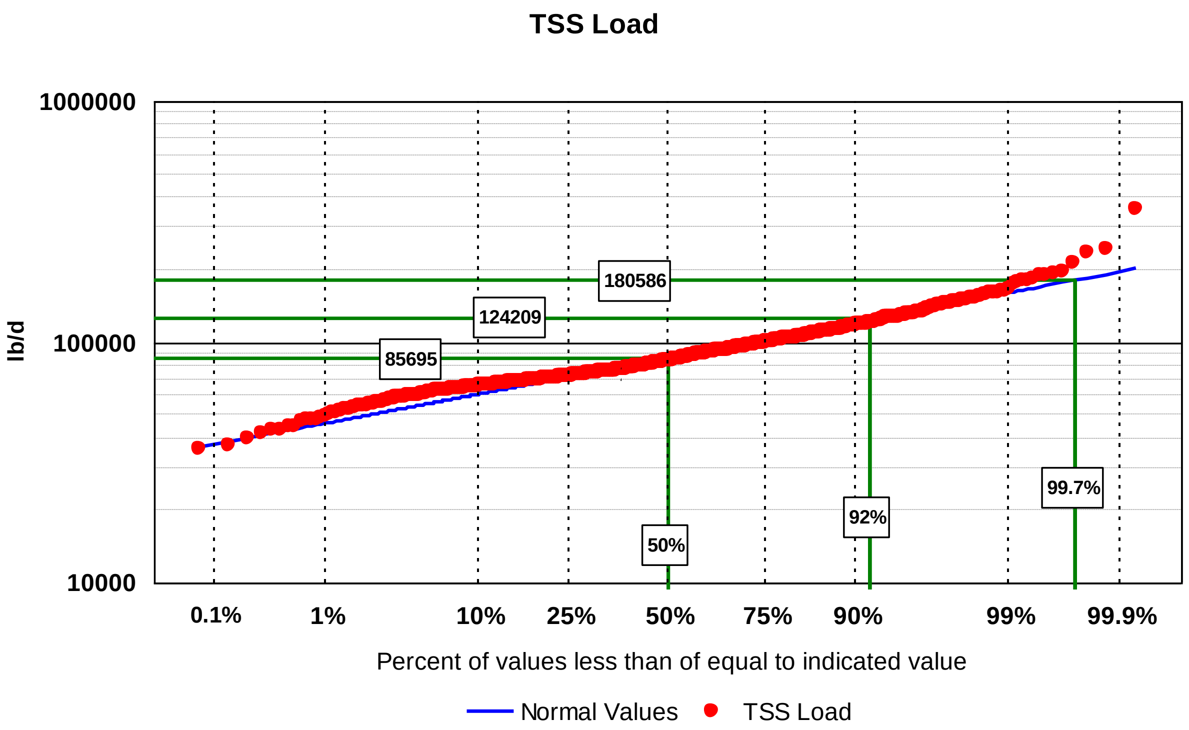

Figure 4. Log-Normal Distribution of TSS Load

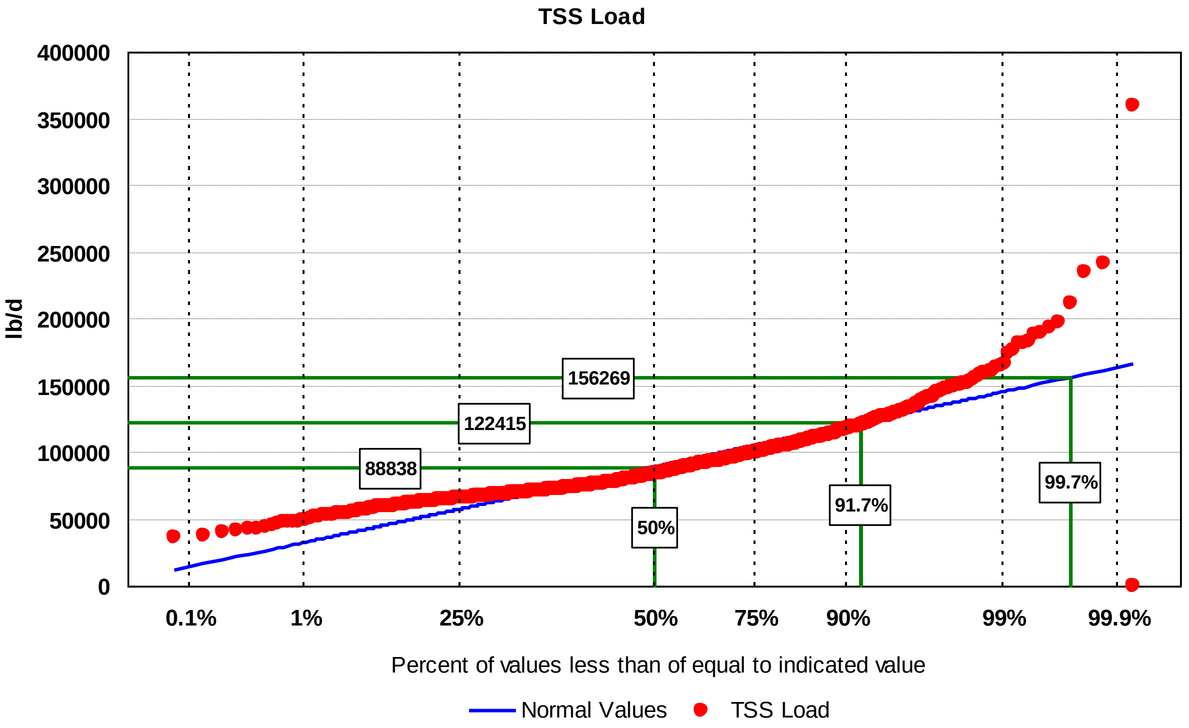

Figure 5. Normal Distribution of TSS Load

Biochemical Oxygen Demand

The assessment of BOD is similar to the approach employed for TSS. Figure 6 presents the influent BOD concentration (primary y-axis) and influent Flows (secondary y-axis) over time. As with TSS (Figure 1), Figure 6 illustrates that there is an indirect relationship between BOD concentration and flow up until roughly 80 mgd. Like TSS, once the flow exceeds 80 mgd, the BOD concentration relationship with flow seen at lower flows ceases to exist.

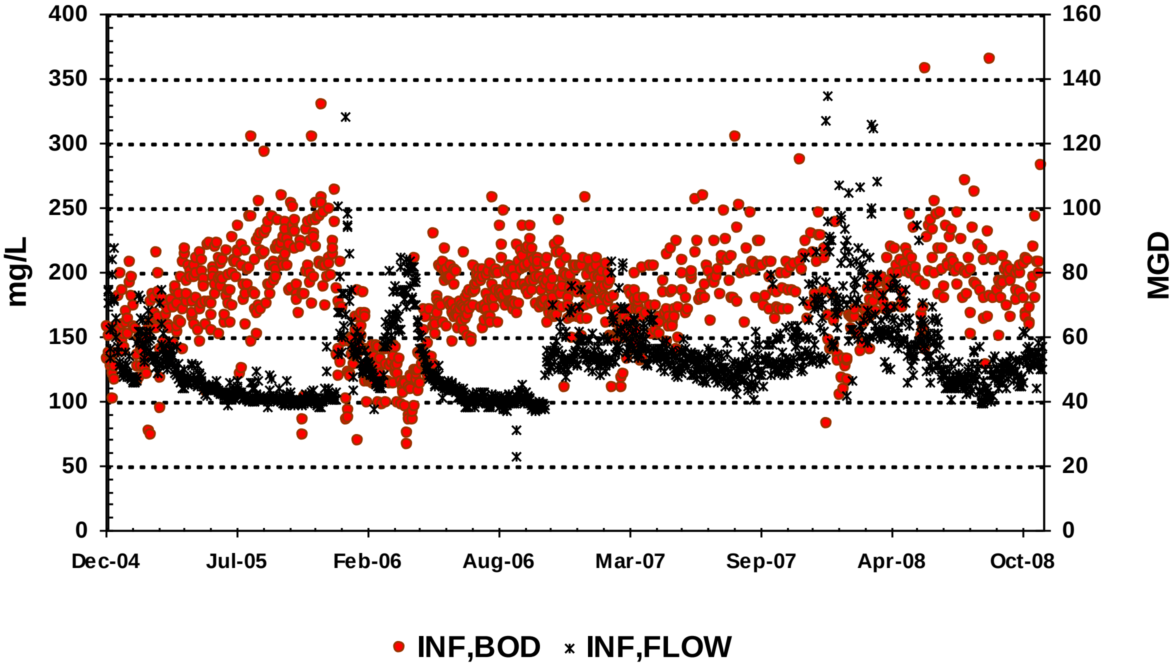

Figure 6. Influent Flows and BOD Concentrations over Time

As with TSS, the attempt was made to reconcile the discrepancies associated with Figure 6 by plotting the flow over BOD concentration and flow over BOD load with data series based on grouped flows as shown in Figure 7 and Figure 8. As with Figure 2 and Figure 3, the largest increase for BOD concentration and load occurs at flows greater than 80 mgd, signaling increased concentration and loads with flow.

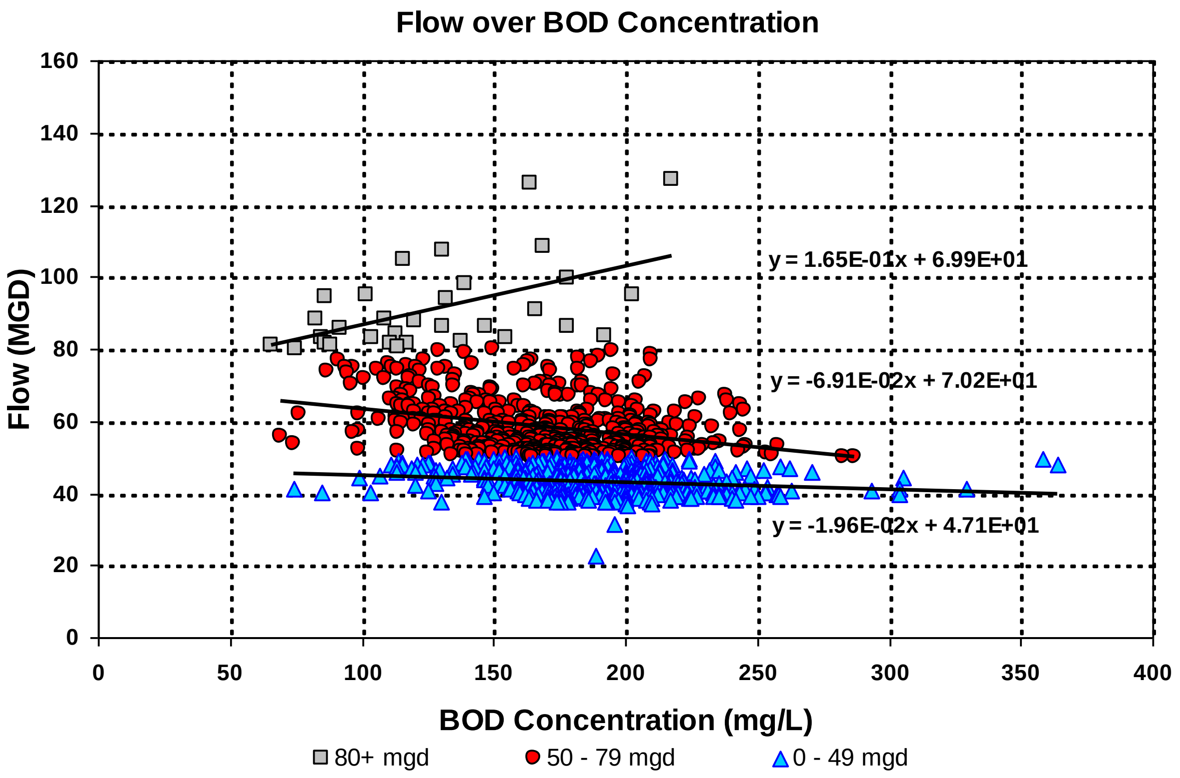

Figure 7. Influent Flow versus BOD Concentration

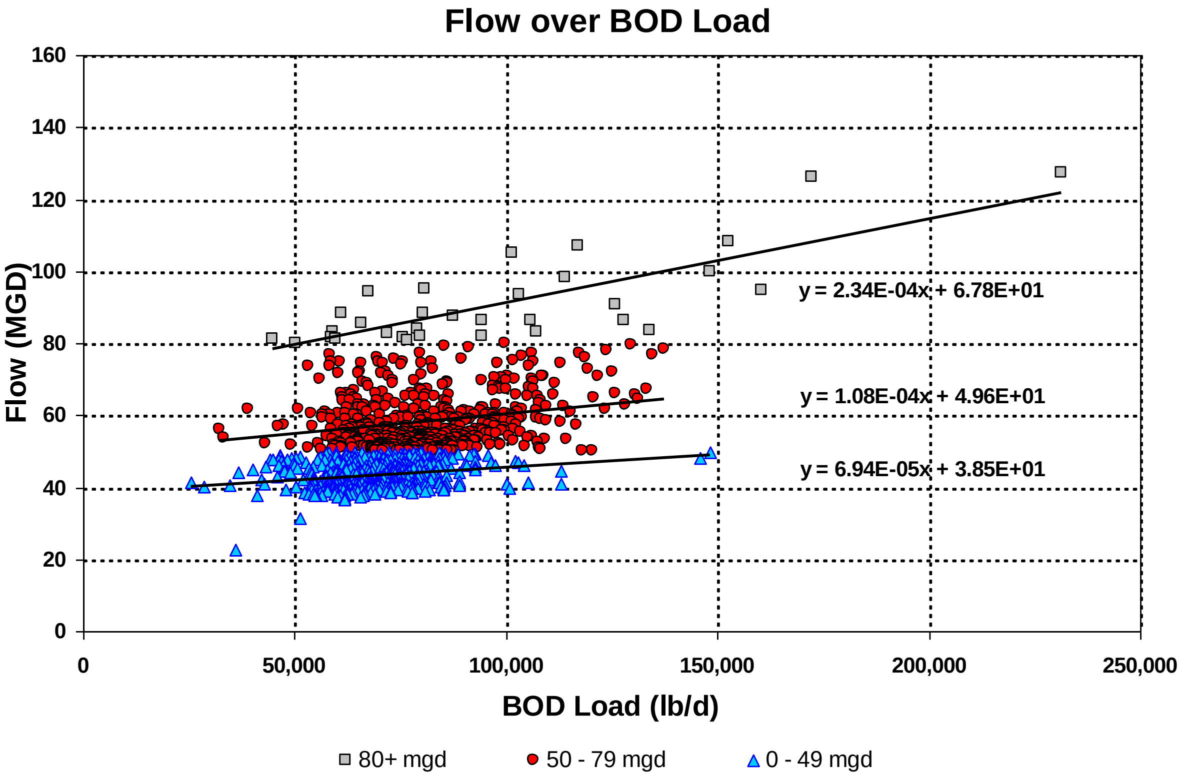

Figure 8. Influent Flow versus BOD Concentration

Summary

Although concentrations associated with maximum monthly and maximum day flows and loads are typically diluted, that does not appear to be the case for the District. A more detailed evaluation might be required to accurately address why this phenomenon is occurring at the District. For the purpose of evaluating nitrification alternatives for the District, it was assumed that statistical analysis described in this technical memorandum is sufficient to determine wastewater characteristics of the influent.

Appendix B

Modeling Assumptions

BioWin® Modeling Assumptions
Prepared by Hazen and Sawyer

1.0 Introduction – Background

This memo summarizes the assumptions made during the modeling efforts to support the update to the 2010 Nitrification Study for the Central Contra Costa Sanitation District, CCCSD. The following table, **Table 1 – Treatment Options**, were modeled to provide costs for the update for various tiers of treatment.

Table 1 - Treatment Options

Treatment Options	NDN & EBPR	NDN & CEPT	Nitrification	NDN
Tier I: 8 mg N/L; 1 mg P/L	X	X		
Tier II: 5 mg N/L; 0.5 mg P/L	X	X		
Tier III: 3 mg N/L; 0.3 mg P/L	X	X		
Tier IV (Sac Reg): 2.4 mg NH3-N/L for MM; 3.3 mg NH3-N/L for MD; 10 mg NOx-N/L for MM				X
Tier V (Stockton): 2 mg NH3-N/L for MM; 5 mg NH3-N/L for MD			X	

2.0 Influent Flows and Design Loads

Influent Flows and loads were provided by CCCSD. Scenarios were undertaken for Average Annual and Maximum month loading. The modeled conditions are highlighted in **Table 2 – Design Conditions – Influent Wastewater**.

Table 2 - Design Conditions – Influent Wastewater

	Design Conditions - Influent Wastewater					
Condition	Flow mgd	BOD lb/day	TSS lb/day	NH3-N lb/day	TKN-N lb/day	TP lb/day
ADWF	54					
AA	57	85,000	98,000	11,000	17,000	3,000
MM	78	116,000	140,000	14,000	23,000	4,000
MD	107	158,000	201,000	18,000	31,000	5,000

3.0 Wastewater Characterization

Wastewater characteristics were determined previously by others (August 2013 Report and BioWin Model). The influent wastewater characteristics from this previously calibrated model were used for this effort and are summarized in **Table 3 – Influent Wastewater characterization**.

Table 3 - Influent Wastewater Characterization

Influent Wastewater Fractions	Biowin Default	CCCSD Model August 2013
Fbs - Readily biodegradable (including Acetate) [gCOD/g of total COD]	0.16	0.16
Fac - Acetate [gCOD/g of readily biodegradable COD]	0.15	**0.25**
Fxsp - Non-colloidal slowly biodegradable [gCOD/g of slowly degradable COD]	0.75	0.75
Fus - Unbiodegradable soluble [gCOD/g of total COD]	0.05	0.05

Fup - Unbiodegradable particulate [gCOD/g of total COD]	0.13	0.13
Fna - Ammonia [gNH3-N/gTKN]	0.66	**0.68**
Fnox - Particulate organic nitrogen [gN/g Organic N]	0.5	0.5
Fnus - Soluble unbiodegradable TKN [gN/gTKN]	0.02	**0.015**
FupN - N:COD ratio for unbiodegradable part. COD [gN/gCOD]	0.035	0.035
Fpo4 - Phosphate [gPO4-P/gTP]	0.5	0.5
FupP - P:COD ratio for unbiodegradable part. COD [gP/gCOD]	0.011	0.011
FZbh - OHO COD fraction [gCOD/g of total COD]	1.00E-04	1.00E-04
FZbm - Methylotroph COD fraction [gCOD/g of total COD]	1.00E-04	1.00E-04
FZaob - AOB COD fraction [gCOD/g of total COD]	1.00E-04	1.00E-04
FZnob - NOB COD fraction [gCOD/g of total COD]	1.00E-04	1.00E-04
FZamob - ANAMMOX COD fraction [gCOD/g of total COD]	1.00E-04	1.00E-04
FZbp - PAO COD fraction [gCOD/g of total COD]	1.00E-04	1.00E-04
FZbpa - Propionic acetogens COD fraction [gCOD/g of total COD]	1.00E-04	1.00E-04
FZbam - Acetoclastic methanogens COD fraction [gCOD/g of total COD]	1.00E-04	1.00E-04
FZbhm - H2-utilizing methanogens COD fraction [gCOD/g of total COD]	1.00E-04	1.00E-04
Influent Stoichiometric Parameter		
Particulate substrate COD:VSS ratio [mgCOD/mgVSS]	1.6	1.6
Particulate inert COD:VSS ratio [mgCOD/mgVSS]	1.6	1.6

4.0 Assumptions

4.1 COD/BOD Ratio

The existing CCCSD BioWin model uses a COD input for raw wastewater. Design loads were described in terms of BOD5 and TSS. Therefore, a COD/BOD5 ratio of 2.3 was used to determine the COD input values for the model based on the design basis BOD5 values. The COD input for AA and MM design conditions are listed in the **Table 4 – COD Input below**.

Table 4 - COD input

	Flow MGD	COD mg/L
AA	58	411
MM	79	413

4.2 Primary clarifiers

Primary clarifier total suspended solids (TSS) removal for chemically enhanced primary treatment (CEPT) were assumed per the schedule outlined in **Table 5 – Primary Clarifiers Performance, TSS Removal**. These removals were provided by CCCSD.

Table 5 - Primary Clarifiers Performance, TSS Removal

Scenario	Primary Clarifiers Performance, TSS Removal	
	Ave Annual	Max Month
BASELINE - No Baffles, No CEPT	54%	45%

Baffles, No CEPT	65%	50%
Baffles, CEPT	73%	55%

4.3 Cyanide Inhibition

All scenarios assumed cyanide inhibition of ammonia oxidizing bacteria, AOB, and nitrogen oxidizing bacteria, NOB, growth rates due to the recycle of untreated sidestream from incineration. Inhibited growth rates for AOBs and NOBs were determined by others via batch testing. These growth rates for AOBs and NOBs are summarized in **Table 5 – Cyanide Inhibited Maximum Specific Growth Rates**.

Table 6 – Cyanide Inhibited Maximum Specific Growth Rates

Scenario	Maximum Specific Growth Rate	
	AOB	NOB
	1/day	1/day
w/ Cyanide inhibition	0.67	0.58

4.4 Temperature

The min week temperature of 18.0 °C was assumed for the modeling.

4.5 Sludge Blend Tank Operations – For all EBPR options, it is assumed that the sludge blend tank operation will be modified to separate the primary sludge and WAS or that the detention time will be limited to less than 15 minutes. Otherwise, substantial release of P occurs due to EBPR releasing P in the presence of the primary sludge.

4.6 Simulation Approach

Steady state simulations using conservative minimum aerobic SRTs for minimum winter temperature and maximum month load conditions were used for all unit process sizing. Sizing based on this approach should be adequate to meet the max day limits under Tier 4 and 5, assuming adequate aeration during peak load events and design aerobic SRTs are achieved prior to the peak load event.