Nature-based Solutions for Nutrient Removal

CONCEPT DESIGN & COST ESTIMATE:
SAN JOSÉ-SANTA CLARA

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IN PARTNERSHIP WITH
San José-Santa Clara Regional Wastewater Facility

PREPARED FOR
Bay Area Clean Water Agencies

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1. INTRODUCTION

In Phase I of the Nature-Based Solutions for Nutrient Reduction Study, the San Francisco Estuary Institute (SFEI) identified that the San José-Santa Clara Regional Wastewater Facility (San José-Santa Clara) has opportunities for both open-water treatment wetlands and horizontal levees. In Phase II of the study, SFEI and San José-Santa Clara explored several alternatives involving these two nature-based solutions (NbS) types. This memorandum and accompanying appendix represent Phase III of the study, which includes the following:

- Identification of the most feasible NbS alternatives to inform decision-making processes,
- Development of conceptual drawings to illustrate the most feasible NbS alternatives, and
- A preliminary cost estimate prepared by HDR, Inc. (Appendix A).

The conceptual design and accompanying cost estimates for the proposed treatment wetland are preliminary and subject to substantial refinement. There is significant uncertainty that should be further evaluated if these projects are pursued in the future. Important factors influencing the cost of all alternatives explored are the source of the fill material and the infrastructure required to deliver effluent to and from the NbS system. Additional considerations with major impacts on cost are the slope and height of the potential horizontal levee and the configuration of the interior earthen berm for the potential open-water treatment wetlands.

As San José-Santa Clara considers further evaluations, these variables must be taken into account. Input from facility staff and management will be crucial in identifying the reasons for adopting NbS as part of a long-term nutrient management strategy. These might include co-benefits such as habitat enhancement or sea-level rise protection in addition to the primary project objective of nutrient reduction. Detailed discussions with key stakeholders will provide critical insights that can significantly influence the design and functionality of the proposed treatment wetland.

2. SITE SPECIFIC ALTERNATIVES FOR NATURE-BASED SOLUTIONS

SFEI and San José-Santa Clara considered three options in the Phase II opportunities and constraints analysis, which were also considered for cost estimation purposes here:

- Option 1: Create a lined open water treatment wetland over consolidated fill area in 26 acres of former sludge lagoons.
- Option 2: Create an open water treatment wetland in an additional 81 acres of former sludge lagoons (107 acres total).
- Option 3: Incorporate seepage slope into future ecotone levee at the back of Pond A18.

Option 1: Conversion of remediated lagoons to treatment wetlands

Option 1 for a nature-based nutrient management alternative at San José-Santa Clara involves transforming several decommissioned sludge lagoons into a lined open water treatment wetland.

Before 1971, the Facility deposited biosolids into a series of 25 clay-lined lagoons, now known as the legacy biosolids lagoons, which contain an estimated total volume of 570,000 cubic yards of biosolid material. Constructed between 1962 and 1973, these lagoons each measure about 300 feet by 1,200 feet. They are separated from adjacent lagoons and other features by berms approximately 15 feet tall. In recent years, San José-Santa Clara initiated a cleanup project for these lagoons, referred to as the Legacy Biosolids Lagoons Site Cleanup project (Cleanup Project).[1]

Phase 1 of the Cleanup Project involves the consolidation and capping of material into four of the northwestern-most legacy lagoons. Phase 2 involves remediating the remaining legacy lagoons through consolidation and capping. Phase 1 has been largely completed and Phase 2 is planned to start before 2027.

Option 1 would convert 26 acres within the four consolidated lagoons considered in Phase 1 to a lined treatment wetland optimized for nutrient removal. The liner would prevent seepage into the underlying substrate. This option assumes the existing berms surrounding the ponds can support the new configuration, as shown in the layout provided in Figure 1. Additionally, a variant of this option (referred to as Alternative 1A in Appendix A) includes a cost estimate for constructing a new berm to better facilitate the proposed wetland.

Effluent from the San José-Santa Clara plant is suitable for polishing in treatment wetlands. For decades, the San José-Santa Clara treatment process has included nitrification, a step that converts ammonia to nitrate. Treatment wetlands are generally more effective at removing total inorganic nitrogen (TIN) loads when nitrate, rather than ammonia, is the predominant form of nitrogen. Nitrification also reduces the toxicity of effluent to wildlife - a significant concern in open water treatment wetlands, which provide habitat for fish and other forms of aquatic life.

Designing the treatment wetlands with variable topography could encourage the growth of emergent freshwater wetland vegetation along the shallower edges and riparian species along adjacent upland slopes. Deeper portions would discourage vegetation growth. Slopes adjacent to the open water portions could also be designed as irrigated areas or woodchip bioreactors to enhance denitrification. These vegetated areas would not only reduce nitrogen loads but also support diverse wildlife, including songbirds, wading birds, and other marsh species.

Water management would involve pumping from the treatment plant to the wetlands, with potential gravity flow to San José-Santa Clara's existing discharge point at Artesian Slough. The existing Capital Improvement Plan (CIP) includes building a final effluent pump station to adapt to sea level rise and other factors that could affect gravity-based flow to San Francisco Bay. It remains unclear if this new pump station could support a NbS treatment process, necessitating close coordination with the CIP implementation team to assess feasibility and integration with current plans.

1 San José-Santa Clara Regional Wastewater Facility. 2020. *Legacy Biosolids Lagoons Site Cleanup Addendum.* https://www.sanjoseca.gov/home/showpublisheddocument/57878/637239499962330000

Figure 1. Option 1, encompassing 26 acres of open water treatment wetlands on the remediated lagoons resulting from Phase 1 of the Cleanup Project.

Option 2: Conversion of lagoons planned for remediation to treatment wetlands

The second option proposes expanding lined treatment wetlands in approximately 81 additional acres in an area under Phase 2 of the Cleanup Project. This option is described in Alternatives 2 and 2A in Appendix A. The area for Option 2 is located to the south and southeast of the Option 1 area. Similar to Option 1, Alternative 2 assumes that the existing berm is adequate, whereas Alternative 2A requires designing and constructing a new berm for added strength (Appendix A).

Under this option, decommissioned lagoons scheduled for remediation under the Phase 2 of the Cleanup Project would be converted to treatment wetlands (Figure 2). Options 1 and 2 could be implemented simultaneously or in phases. Note that the drawing in Figure 2 shows Option 1 as a component of Option 2, while in Appendix A the additional 81-acre area is considered separately.

As in Option 1, these wetlands could feature a similar wetland design that might use either a unit-cell approach to optimize denitrification or a vegetated free-water surface wetland approach with varying depths for nutrient removal and additional benefits like wildlife habitat, aesthetics, and recreational use. The wetlands would be lined to prevent seepage, berms could be planted with native vegetation to support local wildlife, and the slopes of the berms could feature woodchip bioreactors to enhance denitrification.

Option 3: Seepage slope in future ecotone levee

Option 3 explores modifying part of the future ecotone levee being constructed under the South San Francisco Bay Shoreline Project (Shoreline Project) to incorporate a woodchip bioreactor-based seepage slope. This alternative would involve extensive collaboration with external partners. The Shoreline Project is led by the United States Army Corps of Engineers (USACE) in collaboration with local partners Valley Water and the State Coastal Conservancy. As part of the Shoreline Project, Pond A18, owned by the City of San José, is planned to be breached and restored to tidal marsh in collaboration with the South Bay Salt Ponds Restoration Project.

In October 2020, 60% designs for the Shoreline Project levee were completed for this reach (Artesian Slough East to Coyote Creek). However, implementation is on hold out of consideration for construction details and cost. The design includes an ecotone slope that would create transition zone habitat at the back of the future restored marsh in Pond A18 (Figures 3 and 4). As the ecotone levee is already planned directly adjacent to the San José-Santa Clara facility, it is a logical location to incorporate a horizontal levee seepage slope (Figure 5). Unlike other locations proposed around the Bay for horizontal levees, construction in this location would not impact any existing tidal marsh as it could be constructed in the pond prior to breaching.

Based on discussions with stakeholders like the California State Coastal Conservancy and the City of San José, there is tentative interest in incorporating a seepage slope into the ecotone levee at the back of Pond A18. However, there are numerous hurdles to achieving this goal. There have already been extensive construction delays on this phase of the shoreline levee, and further changes to the design could delay the timeline further. USACE has strict design requirements

Figure 2. Option 2, including the 26-acre open water treatment unit from Option 1 plus an additional 81 acres of treatment wetlands on top of the consolidated lagoons considered under Phase 2 of the Cleanup Project. Option 1 is shown here as a component of Option 2, while in Appendix A the additional 81-acre area is considered separately.

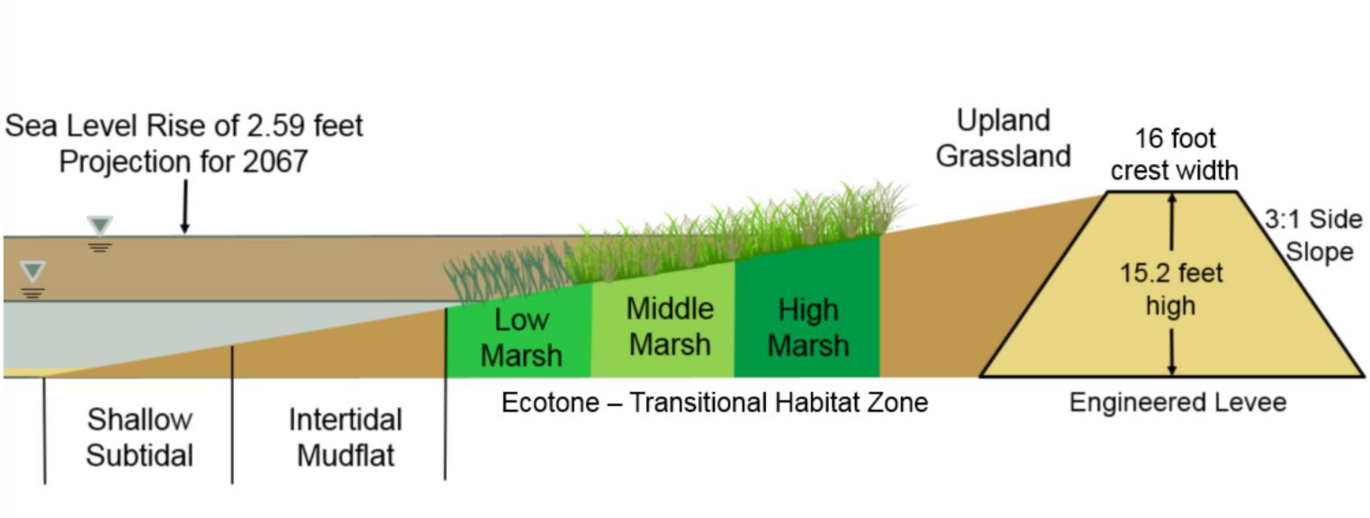

Figure 3. An ecotone levee (without seepage slope) is already planned at Pond A18 as part of the South San Francisco Bay Shoreline Project (USACE with local partners Santa Clara Valley Water District and California State Coastal Conservancy).
Image credit: Valley Water.

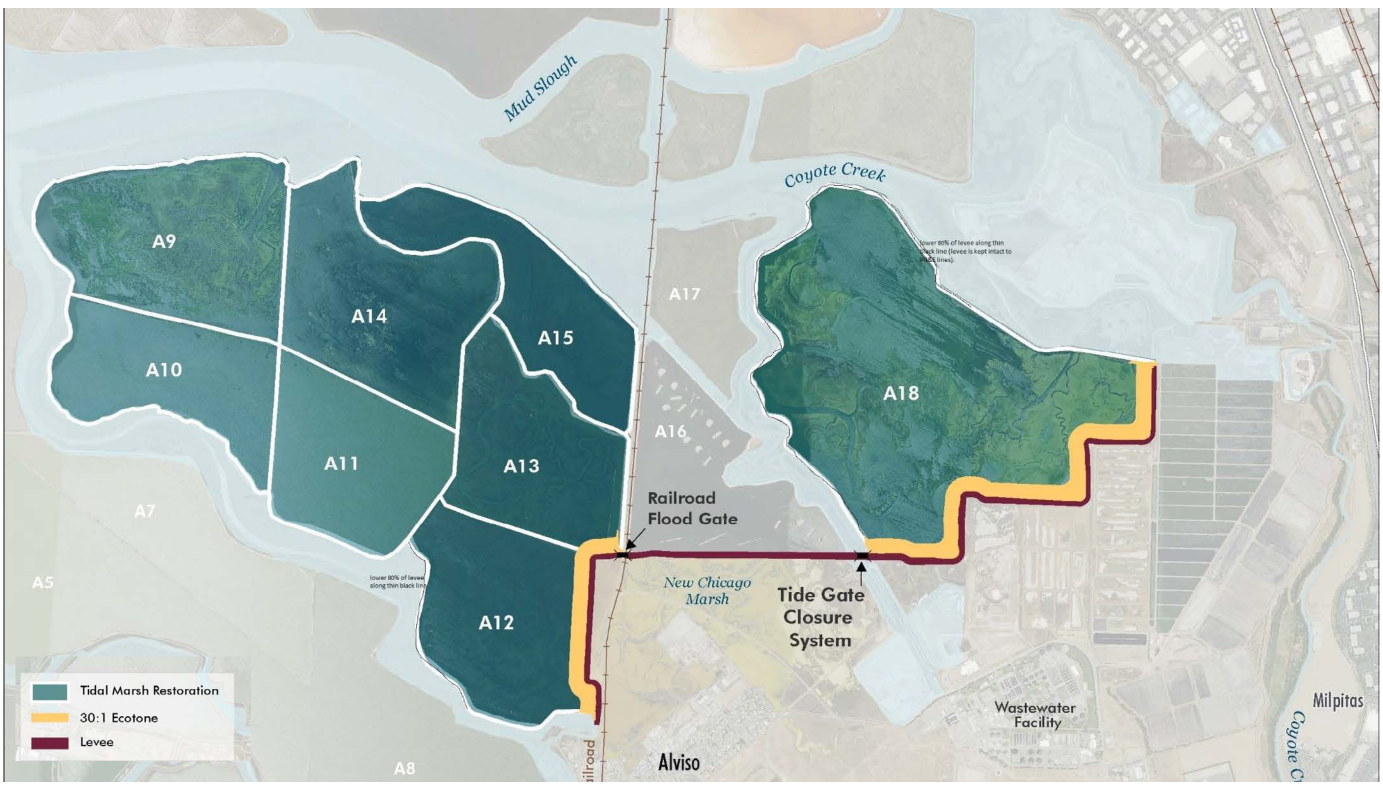

Figure 4. A map showing the planned levee alignment for the South San Francisco Bay Shoreline Project.
Image credit: State Coastal Conservancy.

for their flood risk management levees, and the seepage slope would be a new design element to consider. The planned ecotone levee (without seepage slope) has already been permitted, and permit amendments would be required to implement such a project. These challenges would not be simple to overcome; however, preliminary conversations with various stakeholders indicate interest in continuing the discussion.

The horizontal levee could potentially treat concentrated flows coming from future recycled water projects aimed at boosting potable water supply for the San José-Santa Clara service area. Practically, Option 3 gains attractiveness as a nutrient management strategy as TIN concentrations rise. The high-concentration waste products from the reverse osmosis process (known as reverse osmosis concentrate or ROC), used in advanced water purification, are particularly suitable for treatment wetlands. Research at Oro Loma Sanitary District demonstrates that the experimental horizontal levee effectively removes nutrients from ROC, despite its high concentrations.[2] Typically, wetlands face challenges in treating wastewater efficiently due to the extensive area required relative to the volume of water treated. Utilizing a concentrated waste stream like ROC enhances treatment efficiency within constrained spaces. Moreover, as San José potentially increases wastewater recycling for potable use, it will require more extensive ROC treatment and disposal options, making the use of horizontal levees and woodchip-based seepage slopes more viable.

2 Stiegler, A. N. 2022. Trace Organic Contaminant Removal in Subsurface Flow Treatment Wetlands. Dissertation, University of California, Berkeley.

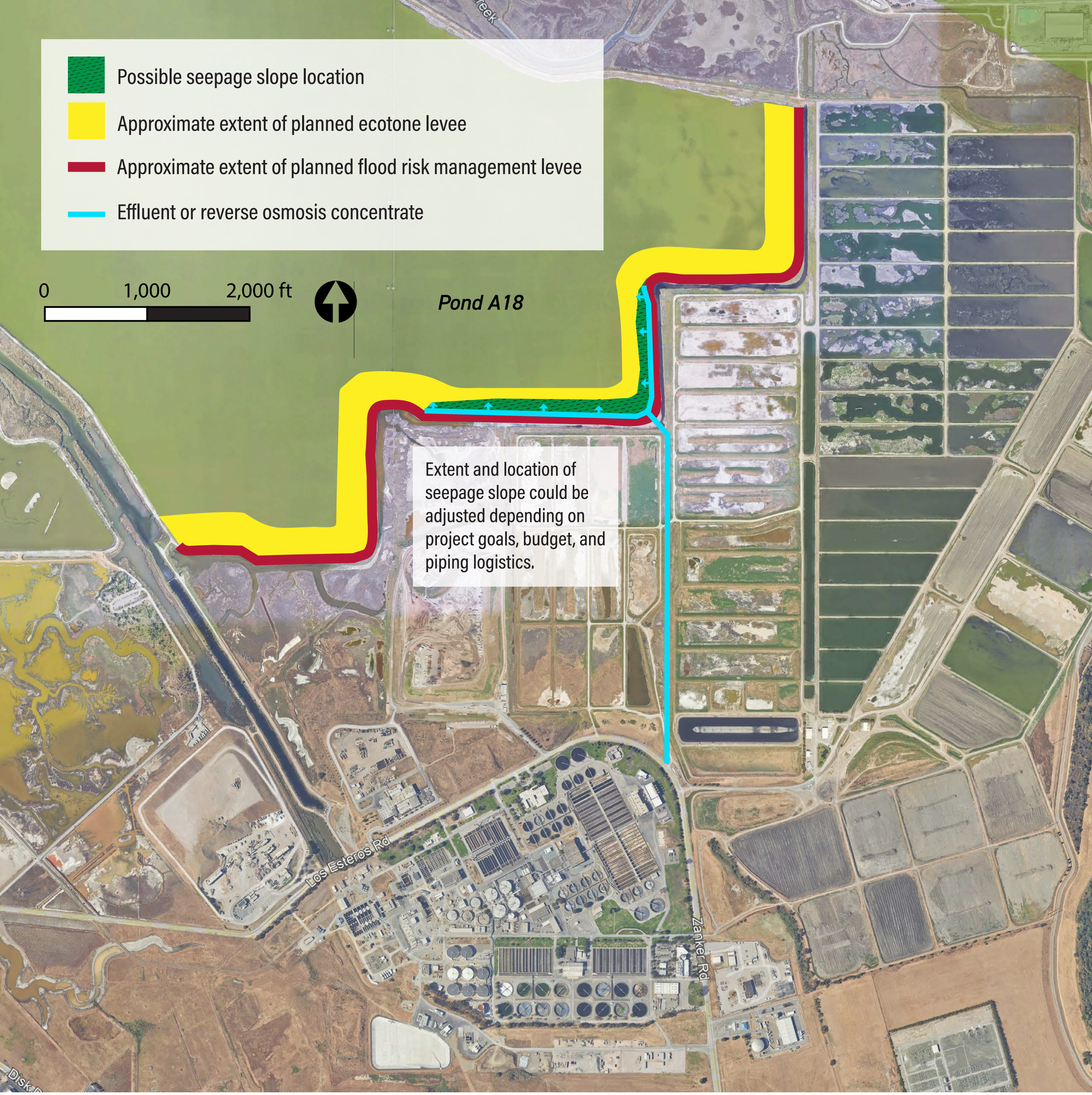

Figure 5. Option 3, including a possible configuration for a horizontal levee and associated seepage slope for nutrient removal. Treatment effectiveness is based on the extent of the seepage slope and TIN concentrations of the incoming flow.

3. ESTIMATED PERFORMANCE SUMMARY

Appendix A outlines the assumptions underlying the performance of treatment wetlands in managing TIN levels. Options 1 and 2 propose constructing open water treatment wetlands spanning 26 acres and 107 acres, respectively. Conservative estimates suggest that Option 1 could process at least 3.4 million gallons per day (mgd), reducing TIN loads by at least 230 pounds per day (100 kg/day). This equates to a 6% decrease in TIN loads. Option 2 (Appendix A Alternatives 1 and 2 combined) could treat a minimum of 14 mgd, removing at least 970 pounds per day of TIN (435 kg), or over 25% of dry season loads, according to recent data.[3] Higher removal rates may be possible through optimization and site-specific assessment.

The calculations for Option 3 in Appendix A assume that only a small section of the total ecotone levee is enhanced with a woodchip bioreactor seepage slope for denitrification of tertiary-treated wastewater. Further analysis reveals that if the entire 3.1-kilometer levee segment proposed under Option 3 were to incorporate a more extensive woodchip-based seepage slope, it could eliminate approximately 880 pounds of TIN daily (400 kg), representing more than 20% of the dry season load.[4] As discussed above, treatment of nutrient-rich ROC could result in high rates of TIN removal with a smaller project footprint, though additional research is likely needed to establish feasibility and effectiveness.

The nutrient removal calculations for these treatment wetland design options are estimates, and real-world conditions may result in better performance due to higher than anticipated TIN concentrations during dry seasons. It is crucial to validate these assumptions with actual data and consider necessary adjustments to the design or management strategies.

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3 Nutrient Reduction Study Group Annual Report, 2023. February 2024. Prepared by HDR inc., on behalf of the Bay Area Clean Water Agencies. https://bacwa.org/nutrients-2/

4 Estimate based on the estimated 3.1 km length of the levee segment, which will be used to treat tertiary effluent, with a horizontal levee height of 3.1 meters, 10:1 slope, bed temperature of 20° C, 24-hr retention time, and woodchip media depth of 0.5 meters. Treatment of RO concentrate could result in higher TIN removal rates. Addy, K., Gold, A.J., Christianson, L.E., David, M.B., Schipper, L.A. and Ratigan, N.A., 2016. Denitrifying bioreactors for nitrate removal: A meta-analysis. Journal of Environmental Quality, 45(3), pp.873-881.

4. PRELIMINARY COST ESTIMATE

The engineering firm HDR Inc. has prepared high-level cost estimates for Options 1, 2 and 3 (Appendix A). The planning-level cost estimates for Option 1, in 2023 dollars, range from $19.1 Mil - $33.7 Mil, and from $58 to $94 Mil for Option 2. Option 3 has an estimated cost of $1.3 Mil.

The cost estimate for Option 3 assumes a small footprint for the seepage slope relative to the entire length of the levee. If higher load reduction is desired, the seepage slope size could increase. While the cost should increase proportionally with the bioreactor footprint, it is highly dependent on fill availability. Appendix A contains more details on the high-level cost estimates.

5. NEXT STEPS

The next steps for project evaluation include defining project goals and objectives in alignment with San José-Santa Clara's existing CIP process, selecting a preferred design, refining cost estimates, and initiating preliminary discussions with permitting agencies. It is critical that Options 1 and 2 are closely aligned with and support the objectives of the Cleanup Project. Option 3's feasibility depends on forming agreements with partners involved in the South San Francisco Bay Shoreline Project and it may emerge as a viable strategy for treating ROC as Santa Clara County expands its potable reuse capabilities. Lastly, San José-Santa Clara should coordinate early on with the mosquito abatement district to address potential concerns before progressing with the design and development process.

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Appendix A

Bay Area Clean Water Agencies
Nature-based Solutions Study

San Jose/Santa Clara Regional Wastewater Facility: Nature-based Solutions Evaluation for Nutrient Management

Individual Plant Report

San Jose, CA
June 6, 2023
March 4, 2024
July 27, 2024
FINAL Report

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1 Overview

HDR was retained by San Francisco Estuarine Institute (SFEI) to support a high-level analysis on the feasibility and layouts for Nature-Based solutions (NbS) at the Delta Diablo Wastewater Treatment Plant, the Fairfield-Suisun Sewer District Wastewater Treatment Plant, and the San Jose/Santa Clara Regional Wastewater Facility (San Jose RWF). This effort supports the on-going NbS efforts under the Second Nutrient Watershed Permit (R2-2019-0017) to evaluate nutrient management strategies at treatment plants across the Bay Area.

Several alternatives and layouts were reviewed at San Jose RWF, as well as a planning level cost estimate to implement each of the listed NbS projects. The cost estimates were based off a blend of previous HDR projects and engineering judgment based on geographic location. The quantities calculations are provided in Appendix A.

2 Methods

The methods section includes a brief description on San Jose RWF and the potential siting locations, details on the cost estimating approach, and the approach for total inorganic nitrogen (TIN) load reduction with NbS technologies.

2.1 San Jose/Santa Clara Regional Wastewater Facility

The Cities of San Jose and Santa Clara own the San Jose RWF, which is operated by the City of San Jose (City). The Facility discharges treated effluent to the Lower South San Francisco Bay. It is located at 700 Los Esteros Road, San Jose, CA 95134, and it serves approximately 1.5 million people throughout the region (Cities of San Jose, Santa Clara, Milpitas, Burbank, Cupertino, West Valley and Sunol). The plant has an average dry weather flow (ADWF) permitted capacity of 167 million gallons per day (mgd) and a peak permitted wet weather flow of 261 mgd. The current plant average annual discharge flows to the Bay are approximately 85 mgd.

The San Jose RWF currently fully nitrifies (i.e., reliably biologically converts ammonia to nitrite/nitrate). A portion of the produced nitrite/nitrate is denitrified (i.e., biologically reduces formed nitrite/nitrate to nitrogen gas). Such biological processes are fundamental to any NbS technology as NbS technologies are typically designed to remove nitrite/nitrate with limited ammonia load reduction.

HDR was provided with the total property space as well as the location of easements around the plant. An aerial view that includes the various layouts is provided in Figure 1. The largest section of space for a potential NbS technology would be located on the western side of the plant. In this space HDR was asked to review three separate alternatives including:

- Lined open water treatment wetland,
- Expanding existing wetlands by repurposing the former sludge lagoons, and

- Wood chip bioreactor along a portion of a horizontal levee or ecotone project

There are three separate areas under consideration as noted in Figure 1. Note: the San Jose RWF is susceptible to sea level rise as it sits at the southern end of San Francisco Bay. Immediately to the north of the facility there are decommissioned salt ponds that are not owned by the San Jose RWF. The United State Army Corps of Engineers (USACE) is evaluating sea level rise alternatives as part of the Shoreline Program.

Figure 1. San Jose RWF: Property and Easements (Source: SFEI, 2019)

The initial phasing would consider the blue colored 26 acres presented in Figure 1, which would be a wetland. The second phase would expand upon the initial phasing by an additional 81 acres of wetland (purple colors, 62 acres and 19 acres, in Figure 1). A key feature for both phases is whether the existing berms are sufficient. Costs are included for both leaving the berms as is, as well as strengthening the berms.

The final third phase considers the 92 acres (orange color in Figure 1) for a horizontal levee or ecotone. The horizontal levee would be used for further nutrient polishing, sea level rise, and habitat restoration. The USACE is evaluating the horizontal levee as part of the Shoreline Program. As such, HDR was instructed to limit their cost estimate for the horizontal levee to a wood chips bioreactor and pumping/conveyance.

2.2 Cost Estimate Basis

The cost estimate prepared for these projects combines historical unit pricing in Northern California (emphasis on the Bay Area) escalated to an equivalent present cost and task-based estimates. Task-based estimating is based on the following variables:

- Construction method,
- Equipment,
- Labor classifications,
- Material pricing appropriate for the scope of work,
- Site conditions, and
- Level of design detail

The basis of historical unit pricing was primarily derived from the Caltrans Contract Cost Database, available online at: [EM 1110-2-1304, Civil Works Construction Cost Index System (CWCCIS), Tables 1-4, 30 September 2022 (oclc.org)]

These tables provide historical information for inflation and the cost data herein is considered appropriate for such planning-level cost estimates. All cost values are in 2023 dollars.

2.2.1 Key Variables Governing the Estimates: Slope and Fill

The key drivers for cost in each of the alternatives are fill and slope. The slope governs the overall footprint, whereas fill represents the primary quantity that makes up the cost for each alternative. Slope selection is typically governed by available land and desired outcomes (e.g., ecological benefits). Fill constitutes the largest portion of cost. As such, the quality of fill can have a profound impact on overall costs. To account for this, HDR has provided a “High”, “Medium”, and “Low” pricing for fill.

The calculations that informed quantities for each alternative were calculated based on the current conceptual design with assumptions made for the extent of impact to existing features, foundation over-excavation and stabilization, dewatering, and other items necessary to quantify the work.

Details on quantities for each alternative is provided in Appendix A.

2.2.2 Carbon Source for TIN Load Reduction

The polishing of total inorganic nitrogen (TIN = ammonia + nitrite + nitrate) that is fed to any of the NbS alternatives requires a carbon source to facilitate the biological denitrification process (i.e., reduction of nitrite/nitrate to nitrogen gas). In most NbS scenarios, a natural carbon source, such as wood chips, are incorporated into the design. Horizontal levees can have a woodchip layer; woodchip-filled seepage slopes can be situated where the treatment plant discharges to an open water wetland; and unit-cell treatment wetlands can incorporate horizontal-flow woodchip bioreactors in one or several open water treatment cells. Wood chips were selected as they are relatively easy to obtain, are safe, and they have a relatively long replacement horizon (decadal timescales). The addition of an external carbon source does not necessarily enhance the nitrogen loading rate criteria; rather, it improves the nitrogen removal performance within the NbS.

As noted in the previous section, details on the carbon source quantity and unit cost are provided in Appendix A.

2.3 Total Inorganic Nitrogen Polishing

The extent of TIN load reduction varies by NbS alternative. For San Jose RWF, three different NbS alternatives were evaluated as presented in Figure 1:

- Lined open water treatment wetland,
- Expand existing wetlands by repurposing the former sludge lagoons, and
- Wood chip bioreactor along the length of the proposed San Jose RWF Horizontal Levee Project

Estimating the TIN load reduction polishing for the various NbS systems are all predicated on a tanks-in-series model based on available literature (Crites et al, 2014; Kadlek and Wallace, 2008; Wren, 2019). The tanks-in-series model is as follows:

$$\frac{Nitrate\ Concentration\ as\ N\ Exiting\ Wetland}{Nitrate\ Concentration\ as\ N\ Entering\ Wetland} = \left(1 + \frac{kA}{NQ}\right)^{-N}$$

where:

k = areal removal rate (m per yr)

A = wetland area (m^2)

Q = influent flow rate (m^3 per year)

N = number of tanks-in-series

As previously discussed in the BACWA NbS Scoping and Evaluation Plan (Wren, 2019), research at the nearby Town of Discovery Bay's wastewater treatment plant revealed that k is equal to 59.4 (at 20 degrees C) (Wren, 2019). Given the proximity to San Jose RWF, using a similar value is deemed reasonable and used for this analysis. A more detailed evaluation is recommended to verify the k value. Given that the TIN load reduction is currently focused on dry season reductions (i.e., May through September), the 20 degrees C value is considered a conservative and the 59.4 k value is thus left as is (i.e., not increased to account for likely warmer temperatures).

Besides having the capacity to polish TIN loads, NbS systems must be able to accommodate the hydraulic loading rate. A literature review was performed that yielded the information presented in Table 1. Those listed in Table 1 are more representative of unit cell wetlands. Given that the San Jose RWF already provides provide biological nitrification/denitrification and filtration, a high-quality product water is anticipated which should enhance hydraulic loading potential (most critical for the subsurface bioreactor along the horizontal levee). For comparative purposes, the Prado Wetlands hydraulic loading rate in Table 1 is deemed a conservative hydraulic loading rate (0.41 ft/d; 0.13 mgd/acre) for the NbS alternatives considered at the San Jose RWF.

Table 1. Literature Review of NbS Hydraulic Loading Rates (Adapted from Jasper et al., 2013)

Wetland Name	Location (Year Started)	Size	Flow	Hydraulic Loading rate	Comment
Easterly	Orlando, FL (1987)	1,170 ac	21 mgd	0.06 ft/d (0.02 mgd/acre)	Wildlife habitat; nutrient polishing of treated wastewater. Florida Department of Environmental Protection (2012)
Prado	Riverside, CA (1992)	494 ac	66 mgd	0.41 ft/d (0.13 mgd/acre)	Wildlife habitat; nitrate polishing from effluent-dominated Santa Ana River prior to aquifer recharge. Orange County Water District (2012)
George W Shannon	Tarrant County, TX (2002)	445 ac	106 mgd	0.73 ft/d (0.24 mgd/acre)	Wildlife habitat; nutrient and solids polishing from effluent-dominated Trinity River. Tarrant Regional Water District (2012)

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3 Results

SFEI/HDR engaged with the City and reached consensus on the most attractive potential NbS solution(s). HDR was tasked with providing layouts and planning-level cost estimates for three (3) alternatives that include:

1) Lined open water treatment wetland over consolidated fill in several of the decommissioned sludge lagoons (Alternative 1 & 1A),
2) Expanding existing wetlands by repurposing the former sludge lagoons (Alternatives (2 & 2A), and
3) Wood chip bioreactor along the length of the proposed San Jose RWF Horizontal Levee Project (Alternative 3)

The "A" variations for alternatives 1 and 2 represent design/construction of a new berm for strengthening purposes.

Alternatives 1 and 1A propose the creation of a lined open water treatment wetland over consolidated fill that would be sited in several of the decommissioned sludge lagoons. An approximate layout of this alternative is provided in Figure 2. As previously stated, Alternative 1 assumes that the existing berm surround the ponds is sufficient, while Alternative 1A estimates a cost for creating a new berm to facilitate this new wetland.

Alternatives 2 and 2A consider expanding this wetland to include an additional 81 acres of wetlands. The expanded wetlands would be sited in the former sludge lagoons which are located immediately to the south and southeast of the Alternative 1 pond. Similar to Alternative 1, Alternative 2 assumes that the existing berm is sufficient. Alternative 2A assumes that a new berm would need to be designed/constructed for strengthening purposes. An aerial layout presenting this is provided in Figure 3.

Alternative 3 involves creating a horizontal levee along the boundary of these legacy lagoons/salt ponds. This option is currently being evaluated by the USACE as part of their Shoreline Program. As such, HDR's effort was limited to preparing a cost estimate related to the TIN load reduction component (wood chip bioreactor layer and the associated plumbing).

For all three alternatives, any future designs should focus on minimizing hydraulic short-circuiting and maximizing contact time in the NbS. In most cases, natural baffles would be included to foster a serpentine pathway through the system. Inclusion of such baffles would foster plug-flow hydraulic conditions and support the notion of using an 'N' value of 4.4 while estimating the TIN load reduction (refer to Section 2.3). The overall layout options are vast, as any of the open water systems could include a terraced system with interior dike(s), inlet terrace with relatively flat interior berms, etc. Such details can be addressed at detailed design.

Figure 2. San Jose RWF: Layout for Alternatives 1 & 1A

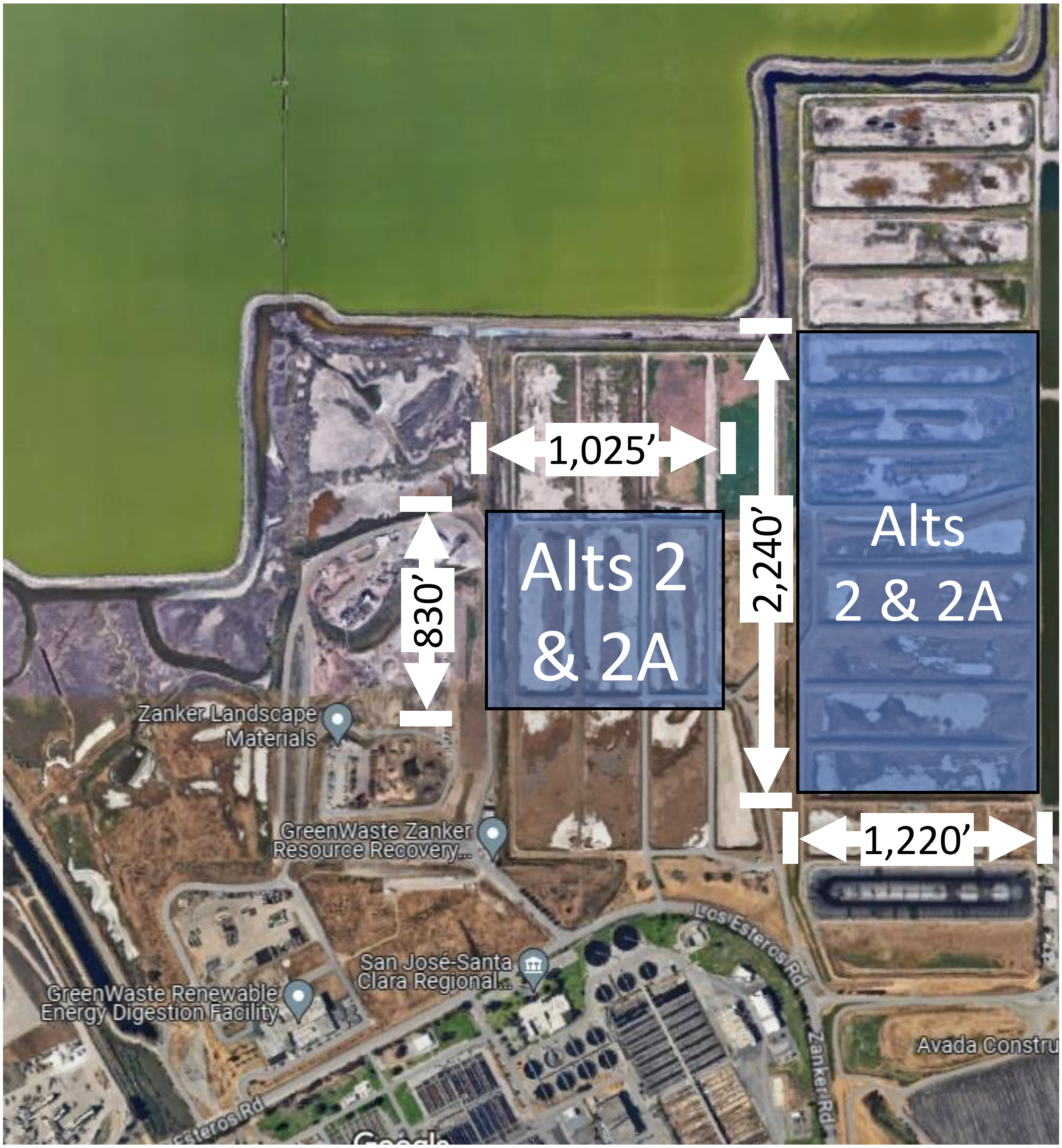

Figure 3. San Jose RWF: Layout for Alternatives 2 & 2A

A summary of the planning-level cost estimates, footprint, anticipated feed flow, and potential nitrogen load reduction is provided in Table 2. For the initial projects (Alternatives 1 & 1A), it is anticipated that upwards of 3.4 mgd of feed flow would be able to polish San Jose RWF effluent (translates to approximately 100 kg N/d (230 lb N/d) removed daily in the NbS). This load reduction represents approximately 6 percent of the current San Jose RWF effluent discharged to the Bay. Further expanding the initial project into Alternatives 2 & 2A provides additional NbS footprint for polishing more San Jose RWF effluent (an additional 10.8 mgd that translates to 335 kg N/d (740 lb N/d) beyond that captured in Alternatives 1 & 1A). Such values represent a combined total feed flow of 14.2 mgd and upwards of 435 kg N/d (970 lb N/d) TIN load reduction for Alternatives 1 through 2A. The combined load reduction for Alternatives 1 through 2A represents approximately 25 percent of the Current San Jose RWF effluent discharged to the Bay.

The horizontal levee (Alternative 3) could be phased after Alternatives 1 through 2A or pursued independently. The additional TIN load reduction is predicated on how much of the horizontal levee includes a bioreactor with supplemental carbon (assumed wood chips in this example). Based on conversations with San Jose RWF, the analysis assumed that 0.9 acres would be used for such a bioreactor. As such, the extent of TIN load reduction associated with the horizontal levee (<10 kg N/d (<20 lb N/d)) pales in comparison to Alternatives 1 through 2A (combined total of upwards of 435 kg N/d (970 lb N/d)). Note: the bioreactor within the horizontal levee could be increased in size to further polish TIN loads.

The planning level costs for Alternative 1, 1A, 2, 2A, and 3 are $19.1 Mil, $33.7 Mil, $58.1 Mil, $94.1 Mil, and $1.3 Mil, respectively. As previously noted, the “A” alternatives are based on a berm rebuild which has additional costs associated with it. The costs increase from Alternatives 1 to 2 due to additional available acreage. As previously noted, the cost for Alternative 3 is limited to the wood chip bioreactor (0.9 acres) and the associated hydraulic conveyance. The other costs would be included as part of the ongoing Shoreline Program by the USACE.

Some examples of what a treatment wetland and horizontal levee could resemble are provided in Figure 4 and Figure 5.

Details on the quantities that informed the planning-level cost estimates is provided in Appendix A.

Table 2. San Jose RWF: Summary of the Alternatives

Alternative	Technology Description	Footprint, Acres	Feed Flow, mgd	Potential TIN Load Reduction, kg N/d*	Construction Cost, $ Mil	Comments
1	Wetland	26 acres	Upwards of 3.4	Upwards of 100 kg N/d (230 lb N/d)	$19.1 Mil	• Assumes existing berm is sufficient. • Need to verify that the wetlands can accommodate the hydraulic loading (site specific) and minimize short-circuiting. Based on a hydraulic loading rate of 0.41 ft/d (0.13 mgd/acre), the system would be nearing hydraulic limitations. Note: a free water surface wetlands should have less stringent hydraulic constraints compared to a horizontal levee, so this is considered less of a constraint. • On-site fill might be an option to reduce and/or eliminate cost; however, there are concerns over availability at San Jose RWF, as well as potential fill quality (on-site bay mud quality). For planning-level purposes, off-site fill was assumed.
1A	Wetland that includes a berm rebuild	26 acres	Upwards of 3.4	Upwards of 100 kg N/d (230 lb N/d)	$33.7 Mil	• A berm rebuild might be required. • Need to verify that the wetlands can accommodate the hydraulic loading (site specific) and minimize short-circuiting. Based on a hydraulic loading rate of 0.41 ft/d (0.13 mgd/acre), the system would be nearing hydraulic limitations. Note: a free water surface wetlands should have less stringent hydraulic constraints compared to a horizontal levee, so this is considered less of a constraint. • On-site fill might be an option to reduce and/or eliminate cost; however, there are concerns over availability at San Jose RWF, as well as potential fill quality (on-site bay mud quality). For planning-level purposes, off-site fill was assumed.
2	Additional Wetland	81 combined acres (19 acre and 62 acre plots)	Upwards of 10.8	Upwards of 335 kg N/d (740 lb N/d)	$58.1 Mil	• Assumes existing berm is sufficient. • Need to verify that the wetlands can accommodate the hydraulic loading (site specific) and minimize short-circuiting. Based on a hydraulic loading rate of 0.41 ft/d (0.13 mgd/acre), the system would be nearing hydraulic limitations. Note: a free water surface wetlands should have less stringent hydraulic constraints compared to a horizontal levee, so this is considered less of a constraint. • On-site fill might be an option to reduce and/or eliminate cost; however, there are concerns over availability at San Jose RWF, as well as potential fill quality (on-site bay mud quality). For planning-level purposes, off-site fill was assumed.
2A	Additional wetland that includes a berm rebuild	81 combined acres (19 acre and 62 acre plots)	Upwards of 10.8	Upwards of 335 kg N/d (740 lb N/d)	$94.1 Mil	• A berm rebuild might be required. • Need to verify that the wetlands can accommodate the hydraulic loading (site specific) and minimize short-circuiting. Based on a hydraulic loading rate of 0.41 ft/d (0.13 mgd/acre), the system would be nearing hydraulic limitations. Note: a free water surface wetlands should have less stringent hydraulic constraints compared to a horizontal levee, so this is considered less of a constraint. • On-site fill might be an option to reduce and/or eliminate cost; however, there are concerns over availability at San Jose RWF, as well as potential fill quality (on-site bay mud quality). For planning-level purposes, off-site fill was assumed.
3	Horizontal Levee 30:1 - Bioreactor	0.9 acres for the bioreactor (92 acres for the overall horizontal levee) **	Less than <0.1 **	Upwards of 10 kg N/d (20 lb N/d) **	$1.3 Mil ***	• Is limited to the wood chip bioreactor, The primary cost contributors are demolition (e.g., clearing/ grubbing), native plantings, and erosion/ stormwater control. • Need to verify that such a bioreactor can accommodate the hydraulic loading (site specific) and minimize short-circuiting. Based on the hydraulic loading rate of 0.41 ft/d (0.13 mgd/acre), the system would be nearing hydraulic limitations. Of the three alternatives, a horizontal levee would have the most pronounced hydraulic constraints. • The bioreactor footprint could be expanded as a means to further polish effluent loads.

* San Jose RWF discharge currently averages approximately 3,800 kg TIN/d

** For perspective, the bioreactor footprint required to treat upwards of 5 mgd flow to the horizontal levee bioreactor would be on the order of 60 acres (i.e., nearly two-thirds of the horizontal levee)

*** If higher load reduction is desired with the horizontal levee, the bioreactor size could increase. While the cost should increase proportionally with the bioreactor footprint, it is highly dependent on fill availability as access typically diminishes as quantity demands increase.

Figure 4. Picture of Discovery Bay Open-Water Wetland Cell Located in Discovery Bay, CA) (Jasper et al., 2013)

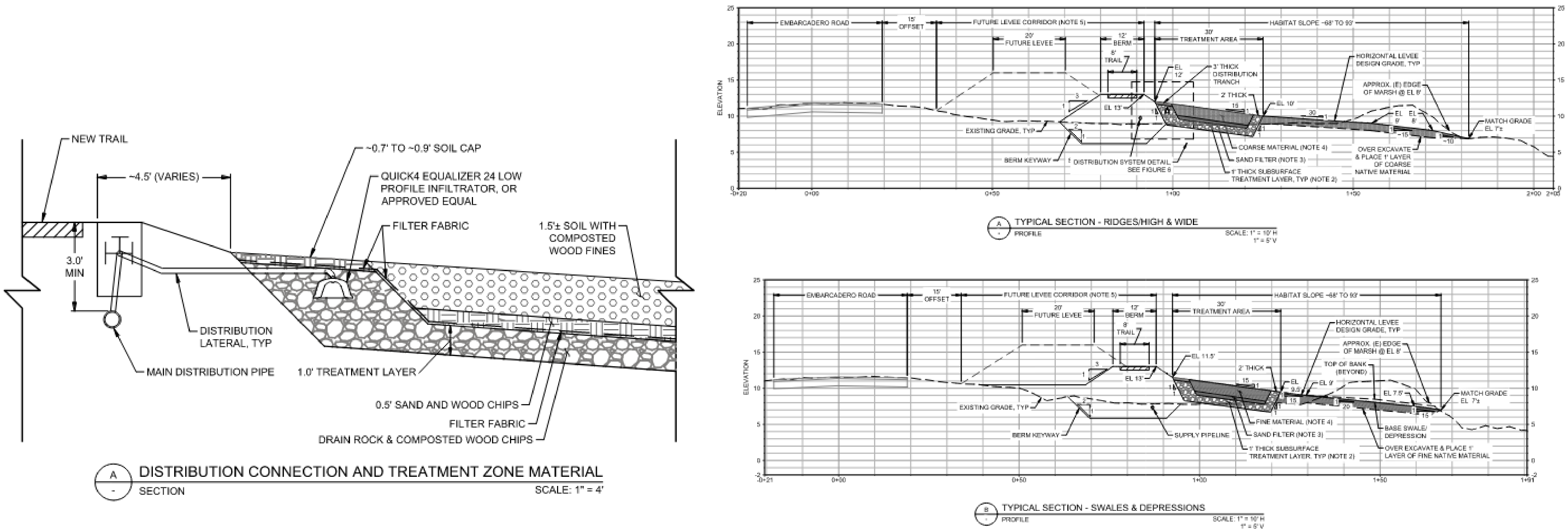

Figure 5. Representative Horizontal Levee Overview (Left-Hand Side) and Typical Sections (Right-Hand Side) (Source: Palo Alto Horizontal Levee Demonstration: https://www.sfestuary.org/truw-pahlp/)

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Appendix A. Quantities and Take-Offs

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San Jose NbS Treatment
Updated: 2/22/24

Component/ Discipline	Item to be Quantified	Quantity	Unit	Price	Unit	Notes	Calculation Method Used	Total
Alternative 1								
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$ 1,243,000
General	Stormwater Pollution Prevention Plan/ Erosion/ Stormwater Control	24	Month	$ 13,601	Month			$ 330,000
Demoliton	Clearing/Grubbing	26	Ac	$ 5,440	Ac		Hand Calc	$ 140,000
Civil	Excavation	167,787	CY	$ 25	CY	Based on HDR's engineer's best judgment from other excavation efforts in the Bay Area.		$ 4,190,000
	Wetlands							
Civil	Wetlands Fill	26	Ac	$ 287,707	Ac	Using total line price for other unit cell wetlands pricing and dividing by area to scale it per acre. Note 1: the sample unit cell wetland was 27 acres which is within the same magnitude as FSSD and thus deemed reasonable. Note: the most conservative high quality fill was used (unit cost ranged from $263,000 - $288,000 depending on fill quality). The unit cost per acre includes a compact clay liner, specified earthen fill (purchase, haul, and placement), miscellaneous excavation (purchase, haul, placement), plantings, and miscellaneous 8" pipes.		$ 7,480,000
	Miscellaneous							
Misc	Native plantings	26	Acre	$ 5,000	Acre		Hand Calc	$ 130,000
Misc	8" Pipe	4,000	LF	$ 40	LF	Approximate. Roughly distance from Tokar Locks and Security on Los Esteros Road to the edge of the legacy lagoons	Hand Calc	$ 160,000
							Base Total	$ 13,673,000
							Contingency (30%)	$ 4,100,000
							Contractor Profit (8%)	$ 1,090,000
							Insurance and Bonds (2%)	$ 270,000
							Total:	**$ 19,133,000**
Berm Rebuild - Alternative 1A								
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$ 2,186,000
Civil	**FEMA Fill**							
Civil	Fill Purchase, Haul, and placement	4,268	LF	$ 2,209	LF	Based on BACWA NbS engineer's unit cost estimate for a 6' tall, 12' crest width, and 45' levee bottom (i.e., 171 sf cross-sectional area) levee for an approximately 3,100' levee perimeter. The unit cost for fill and compact clay are $215/cy and $107/cy, respectively, for purchase, haul, and placement.		$ 9,430,000
							Base Total	$ 24,046,000
							Contingency (30%)	$ 7,210,000
							Contractor Profit (8%)	$ 1,920,000
							Insurance and Bonds (2%)	$ 480,000
							Total:	**$ 33,656,000**

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Component/ Discipline	Item to be Quantified	Quantity	Unit	Price	Unit	Notes	Calculation Method Used	Total
Alternative 2								
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$ 3,771,000
General	Stormwater Pollution Prevention Plan/ Erosion/ Stormwater Control	24	Month	$ 13,601	Month			$ 330,000
Demoliton	Clearing/Grubbing	81	Ac	$ 5,440	Ac		Hand Calc	$ 440,000
Civil	Excavation	522,720	CY	$ 25	CY	Based on HDR's engineer's best judgment from other excavation efforts in the Bay Area.		$ 13,070,000
	Wetlands							
Civil	Wetlands Fill	81	Ac	$ 287,707	Ac	Using total line price for other unit cell wetlands pricing and dividing by area to scale it per acre. Note 1: the sample unit cell wetland was 27 acres which is within the same magnitude as FSSD and thus deemed reasonable. Note: the most conservative high quality fill was used (unit cost ranged from $263,000 - $288,000 depending on fill quality). The unit cost per acre includes a compact clay liner, specified earthen fill (purchase, haul, and placement), miscellaneous excavation (purchase, haul, placement), plantings, and miscellaneous 8" pipes.		$ 23,300,000
	Miscellaneous							
Misc	Native plantings	81	Acre	$ 5,000	Acre		Hand Calc	$ 410,000
Misc	8" Pipe	4,000	LF	$ 40	LF	Approximate. Roughly distance from Tokar Locks and Security on Los Esteros Road to the edge of the legacy lagoons	Hand Calc	$ 160,000
							Base Total	$ 41,481,000
							Contingency (30%)	$ 12,440,000
							Contractor Profit (8%)	$ 3,320,000
							Insurance and Bonds (2%)	$ 830,000
							Total:	**$ 58,071,000**
Berm Rebuild - Alternative 2A								
General	Mobilization/Demobilization	1.00	LS	From Total	LS	Estimate about 10% of the total		$ 6,112,000
Civil	**FEMA Fill**							
Civil	Fill Purchase, Haul, and placement	10,598	LF	$ 2,209	LF	Based on BACWA NbS engineer's unit cost estimate for a 6' tall, 12' crest width, and 45' levee bottom (i.e., 171 sf cross-sectional area) levee for an approximately 3,100' levee perimeter. The unit cost for fill and compact clay are $215/cy and $107/cy, respectively, for purchase, haul, and placement.		$ 23,410,000
							Base Total	$ 67,232,000
							Contingency (30%)	$ 20,170,000
							Contractor Profit (8%)	$ 5,380,000
							Insurance and Bonds (2%)	$ 1,340,000
							Total:	**$ 94,122,000**

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Horizontal Levee Wood Chip Bioreactor								
Component/ Discipline	**Item to be Quantified**	**Quantity**	**Unit**	**Price**	**Unit**	**Notes**	**Calculation Method Used**	**Total**
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$ 81,000
General	Stormwater Pollution Prevention Plan/ Erosion/ Stormwater Control	24	Month	$ 13,601	Month			$ 330,000
	Horizontal Levee							
Civil	Wood Chip	5,722	CY	$ 10	CY			$ 60,000
	Miscellaneous							
Misc	Native plantings	1	Acre	$ 5,000	Acre		Hand Calc	$ -
Misc	8" Pipe	10,473	LF	$ 40	LF	In San Jose Levee Piping Plan. Approximate	Hand Calc	$ 420,000
							Base Total	$ 891,000
							Contingency (30%)	$ 270,000
							Contractor Profit (8%)	$ 70,000
							Insurance and Bonds (2%)	$ 20,000
							Total:	**$ 1,251,000**