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NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

OPPORTUNITIES & CONSTRAINTS ANALYSIS • JUNE 2023

BACWA
BAY AREA
CLEAN WATER
AGENCIES

SFEI | AQUATIC SCIENCE CENTER

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OVERVIEW

This report is a key output from the first phase of a project to assess the feasibility of nature-based solutions (NbS) for removal of nutrients from each of the Bay Area's wastewater treatment facilities, also known as water resource recovery facilities (WWRFs). The WWRF-specific fact sheets in this report are supported by a regional assessment reflecting stakeholder input. The information summarized on each sheet serve to inform Phases 2 & 3 (see next page), with the goal of identifying those facilities with the greatest potential to deploy NbS. Final outputs will include planning-level alternatives, cost estimates, and assessment of constraints to inform next steps and collaborations needed for complex multi-agency, multi-objective strategies.

Objectives of this Report

- Present a preliminary screening of potentially suitable areas for conversion to treatment wetlands or horizontal levees in close proximity to wastewater facilities in the Bay Area.
- Inform agency discussions and ground truthing of potentially suitable land for conversion to NbS.
- Does not constitute a plan and does not capture key constraints related to land ownership, regulations, existing planning processes, or governance challenges.

Key Assumptions

- Integrates existing geospatial data including physical opportunities (i.e. elevation, slope, habitat type) and general land use constraints (i.e. proximity to existing development or highly sensitive habitat types).
- Nutrient reduction estimates are based on a subset of potentially available sites in proximity to each facility and literature-based calculations.
- Does not reflect planned or implemented NbS.

Las Gallinas Wastewater Ponds. Photo by Melissa McMasters, CC BY 2.0

OVERARCHING PROJECT PHASES

1 ***This report: Identify opportunities & constraints***

- GIS-driven investigation of areas with potential opportunity for creation of treatment wetlands or horizontal levees, based on existing conditions
- Estimate of potential nitrate removal from a subset of nearby sites from literature-based treatment performance values
- Incorporate agency survey results & stakeholder feedback to select a subset of facilities for site-specific investigation (Phase 2)
- Anticipated completion in mid-2021

2 ***Next phase: perform site-specific investigations***

- Carry out agency outreach with a select group of facilities with high potential for NbS-based nutrient management
- Conduct site visits to discuss opportunities & constraints with agency staff or decision makers
- Assess issues of land ownership, agency interest and NbS feasibility to identify facilities with greatest opportunity and interest (Phase 3)
- Anticipated completion in mid-2022

3 ***Final phase: planning-level alternatives assessment***

- Develop a few alternatives for several facilities identified through consultation with BACWA and key stakeholders
- Develop planning-level designs to enable cost estimation, identification of regulatory and land use conflicts, and establish feasibility for agency-led planning
- Anticipated completion in mid-2023

INTRODUCTION

Partly driven by the Waste Discharge Requirements for Nutrients from Municipal Wastewater Dischargers to San Francisco Bay (Nutrient Watershed Permit), wastewater agencies in the SF Bay region are considering possible alternative strategies for nutrient reduction. A previous study evaluating the potential nutrient removal options using conventional nutrient reduction strategies (optimization of existing treatment processes and plant upgrades using gray infrastructure technologies) was completed for BACWA by HDR in 2018. The present study evaluates the potential to use of multi-benefit nature-based solutions (NbS) to assimilate nitrogen, as an alternative to or in combination with conventional technologies.

Constructed wastewater treatment wetlands have been successfully applied globally, but a key constraint for the SF Bay region is that most wastewater plants are situated near the Bay shoreline—often abutting sensitive ecological resources and susceptible to current and future flooding (for more information about susceptibility of wastewater plants to flooding, please see Appendix A). Land in the region is scarce and expensive, increasing the need for collaboration among public agencies capable of sharing land and resources to achieve multiple objectives.

The following fact sheets provide a synthesis of potential nutrient discharge reduction by NbS, as required by the Nutrient Watershed Permit, section VI.A.2.. The primary objective of this analysis is to evaluate opportunities and constraints associated with implementing NbS to reduce nutrient loading to San Francisco Bay at each of thirty-eight (38) wastewater treatment facilities. Two minor facilities (permitted discharge <1.0 mgd) are not considered here: the Port Costa Wastewater Treatment Plant and the Paradise Cove Wastewater Treatment Plant. Input into this process was provided by the Bay Area Clean Water Association's (BACWA) Contract Management Group (CMG), as well as staff from the San Francisco Bay Regional Water Quality Control Board (Water Board).

The first step in this analysis, the results of which are reported in the fact sheets, was a preliminary screening of physical possibilities for nature-based solutions to wastewater treatment based on a desktop analysis, and corresponding estimated nutrient load reductions for each facility. NbS types evaluated include open water wetlands and horizontal levees/ seepage slopes, which have differing site considerations. These NbS types do not characterize the full range of treatment wetlands or other types of NbS suitable for wastewater treatment, however, they comprise the main types of systems currently under consideration in the region.

To inform discharger-specific suitability assessments, two parallel assessment methods were used: one for horizontal levees and one for open water wetlands. Suitable horizontal levee locations were identified based on proximity to both marsh and development, where they may have the ability to provide multiple benefits, including flood protection and wildlife habitat in addition to nutrient reduction. Suitable open water wetland locations were identified using a range of physical criteria, including slope, elevation, land cover, etc, as described in the next section.

Results of the desktop analysis indicate that physical opportunities for NbS for nutrient management vary from facility to facility. At some facilities, NbS implemented at large opportunity sites close to the plant could reduce over 90% of total inorganic nitrogen

(TIN), while others have almost no opportunity for NbS due to steep slopes, high-intensity development surrounding the site, or other factors. Addition of a nitrification step upstream of new NbS will be required for implementation at some facilities.

The following fact sheets describe the results of this suitability and scoring analysis for each wastewater treatment facility in the region. Each fact sheet provides a suitability map for each site, as well as site-specific estimates of nutrient load reductions, from literature-based estimates of nitrate removal and based on a broad set of assumptions. These metrics are intended to provide a ballpark estimate of potential nutrient load reductions. Further analysis is required to refine these estimates once the most suitable sites have been selected.

These results do not constitute a plan, but rather report the results of a region-wide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities. As such, site-based ground-truthing will be critical for moving towards design and implementation.

The next steps in this process include the identification of ~10 facilities for site-specific alternatives analysis, including site inspections and interviews with key discharger staff. Based on that information, a subset of those facilities will be selected, in consultation with BACWA and the Water Board.

GIS MODELING METHODS

Horizontal Levees

This method was developed to expand and refine the range of opportunity sites for ecotone levees originally identified in the SF Bay Shoreline Adaptation Atlas.[1] Though the results of this analysis represent a more comprehensive set of opportunities than the Adaptation Atlas version, not every possible opportunity is identified, and some opportunities identified may not be feasible due to constraints not included in the modeling.

Ecotone slopes are ramps bayward of flood risk management levees and landward of a tidal marsh. Ecotone levees near wastewater treatment facilities present special opportunities for multi-benefit sea-level rise adaptation and nutrient load reduction projects, as they may be suitable for designs that include seepage slopes to treat effluent and create a fresh-to-brackish marsh habitat gradient. This type of ecotone levee is known as a "horizontal levee."

Areas mapped as suitable for horizontal levees were identified by selecting places where development is adjacent to tidal marsh (today or in the future). The "developed areas" layer and the "marsh" layer were expanded from the 2019 Adaptation Atlas analysis and included the layers listed below.

Included in the "developed areas" layer:

- National Land Cover Database 2016: low, medium, and high-intensity development [2]
- Wastewater facility footprints

- Bayfront landfills: SFEI analysis based on elevation, NLCD, and historical baylands, then cross-referenced using information from the SF Bay Regional Water Quality Control Board.
- Roads: 50m line buffer of interstate, state, and US highways [3]
- Railroads: 20m line buffer [4]
- Electric substations: Added any bayfront substation parcels not covered by NLCD [5]
- Superfund sites: National Priority List for Region 9

Included in the "marsh" layer:

- Areas at the suitable elevation for tidal marsh today (see Appendix 5 of the Adaptation Atlas p. 239)[1]
- Undeveloped areas at the suitable elevation for marsh migration with SLR (see methods in Appendix 5 (p. 242) of the Adaptation Atlas)
- Planned tidal marsh restoration, based on mapping completed for the 2015 Goals Project and updated for the SF Bay Shoreline Adaptation Atlas per interviews with several key landowners and stakeholders.[6]

A GIS layer delineating existing bayland habitats was used to clip the development layer and create a cleaner shoreline.[7] Next, opportunity sites were identified by buffering developed areas by a generous horizontal levee width (wide enough to support a levee with a 1:30 slope, assuming a crest height equal to the height of the 100-year storm surge plus 2.1 m of sea level rise). Necessary horizontal levee widths were calculated on an OLU-by-OLU basis as described in Appendix 5 (p. 241) of the Adaptation Atlas.[1] Buffered horizontal levee footprints (split at regular intervals of approximately 100 m) were selected if they mostly (>85%) overlapped existing marsh or potential future marsh and migration space (see "marsh" layers included above).

From this selection, we performed an extensive manual cleanup and addition process. The following procedures were used to modify the model output:

- Horizontal levees that had minimal connection to a marsh or potential future marsh were removed
- Horizontal levees that did not front buildings and infrastructure (e.g. fronting a salt pond berm) were removed
- Horizontal levees fronting road/rail with undeveloped area landward of the transportation corridor were removed, as other adaptation strategies such as raising the road could be more ecologically beneficial in these areas
- Horizontal levees crossing creek/slough channels were removed
- Horizontal levees conflicting with known restoration and enhancement plans were removed
- Horizontal/ecotone levees were added where they are currently planned or under construction
- Horizontal levees were edited by hand to reduce artifacts of the modeling process, to better align with marsh/development edges based on aerial imagery, and to fill gaps where there was no logical reason for a break in the levee.

To calculate treatment capacity and potential nutrient reductions, the lengths of the horizontal levees were calculated as half of the perimeter. These perimeters were based on the 30:1

slope used in the model identifying suitable sites. However, steeper 10:1 slopes were assumed for more conservative estimates of nutrient load reduction potential. A levee was included as a potential horizontal levee for a wastewater facility if it intersected a 3.2 km (2 mi) buffer ring from the facility location.

Open-Water Wetlands

Like horizontal levees, open-water wetlands use natural processes to achieve wastewater treatment objectives. Open water wetlands, including free water surface constructed wetlands and unit-cell open water wetlands, rely on physical, biological, and light-mediated processes to remove nutrients from wastewater. Suitability for open-water wetlands was determined using the Green Plan-IT Site Locator Tool, a product initially developed for determining optimal locations for stormwater green infrastructure.[8] The toolset was initially developed by SFEI and applied using state funding and collaborations with the cities of San Mateo and San Jose. The ArcGIS-based Site Locator tool allows the user to conduct a nested, weighted suitability analysis that produces maps of ranked opportunities and can be used for a range of applications.

Like any regional suitability analysis, this effort was limited by the resolution and quality of input data. In addition, not every relevant constraint could be included due to data limitations. Thus, the results of this analysis are meant to be a first-pass filter, not a final plan. For each site, identified opportunities for nature-based treatment using open-water wetlands need refinement using local-scale data and knowledge. Based on feedback from the BACWA's CMG for this project, the area of interest was a 3.2 km (2 mi) buffer around each treatment facility.

The following layers were included as "knockouts" in the analysis, meaning any location that fell in one of these categories was removed from consideration.

- Open water [9]
- Steep slopes: Areas with slope > 8%, based on the 10m resolution National Elevation Dataset[10]
- Low-lying areas: At or below mudflat elevation ($z^* < -0.14$) [1]
- Riparian areas: 50m buffer of Bay Area Aquatic Resource Inventory streams with Strahler order > 1. [7]
- Current and future tidal habitats and managed waterfowl ponds: Mapping completed for the 2015 Goals Project and updated for the SF Bay Shoreline Adaptation Atlas, then updated again by SFEI in 2020.
- South Bay Salt Pond Restoration Project ponds [11]
- Developed areas: National Land Cover Database 2016 - low, medium, and high-intensity development) [2,12]
- Parks with the following designation types: Local Park, Local Recreation Area, State Park, State Recreation Area, National Wildlife Refuge, State Historic or Cultural Area, National Parks, Recreation Management Area, Private Recreation or Education, Area of Critical Environmental Concern, Research or Educational Area, Local Historic or Cultural Area, Private Historic or Cultural, National Recreation Area, Historic or Cultural Area, Private Other or Unknown, Local Other or Unknown, National Monument or Landmark [13]
- Cemeteries, where known
- Schools [14]
- Landfills: SFEI analysis based on elevation, NLCD, and historical baylands, then cross-referenced using Water Board data.

- Airports [15]
- Residential areas: according to city/county general plans [16]

Next, several factors were used to rank areas that passed the knockout filtering stage according to their suitability. The five main factors were distance, elevation, site grade, land cover, and ownership. Rankings were assigned based on the weightings in Table 1, which were developed iteratively based on a review of outputs. Combined weights were summed to determine a polygon's relative suitability ranking compared to other polygons.

After the ranked results were determined using the Green Plan-IT suitability analysis, an additional factor of size was considered to reflect the fact that larger sites allow more flexibility in design and more treatment capacity. Contiguous sites over six acres were given an additional 0.04 ranking boost, contiguous sites over four acres an additional 0.04, contiguous sites over

Table 1. Nested factors included in ranking analysis for open-water wetland opportunities

Factor	Factor Weight	Layer	Layer Weight	Combined Weight
Distance	0.24	Less than 1 km from the facility	0.5	0.12
		1 -3 km from the facility	0.3	0.072
		3 - 6 km from the facility	0.15	0.036
		>6 km from the facility	0.05	0.012
Elevation	0.18	Less than 5 m higher than nearest WWRF	0.6	0.108
		5 - 15 m higher than nearest WWRF	0.3	0.054
		15 - 40 m higher than nearest WWRF	0.1	0.018
Slope	0.18	Less than 2% grade	0.6	0.108
		2 - 4% grade	0.3	0.054
		4 - 8% grade	0.1	0.018
Land Cover	0.3	Barren land	0.35	0.105
		Agriculture and undeveloped	0.25	0.075
		Developed open space	0.15	0.045
		Shrubland/grassland	0.1	0.03
		Forest	0.05	0.015
		Wetland	0.05	0.015
		Pond	0.05	0.015
Ownership	0.1	Public ownership	1	0.1

two acres an additional 0.02, and other sites 0.01. Sites less than one acre in size were removed from consideration.

To aid in the communication of results, a few opportunity sites for each wastewater facility were selected for calculation of summary statistics. First, opportunity sites were filtered to select contiguous patches over five acres. The three nearest contiguous patches over five acres to each wastewater facility (if there were three within the two-mile radius) were selected to perform the potential nutrient reduction analysis.

NUTRIENT REDUCTION ESTIMATION METHODS

To determine the potential efficacy of nature-based solutions if implemented at the opportunity sites identified by the suitability analysis, a set of metrics was calculated for each WWRF. Coarse estimates of potential flow capacity, total inorganic nitrogen (TIN) removal capacity, and potential facility-specific TIN reduction potential were calculated for both open water wetland and horizontal levee treatment opportunities at each WWRF.

Open Water Treatment Wetlands

Potential Flow Capacity

This indicator is an estimate of a theoretical volume of water available to route through a maximum area potentially suitable for conversion to open water treatment wetlands - which in many cases exceeds the average dry weather daily flow (ADWF) from a facility of interest.

For the purposes of this calculation, only the three (3) largest contiguous polygons located closest to the facility were considered suitable (see page 14 for more details). This assumption is useful for providing summary calculations, but likely does not reflect the sites representing the most feasible opportunities. This estimate generally characterizes the scale of potentially available land for a given facility, rather than assuming all potentially available lands could be converted to constructed treatment wetlands. This acreage was reduced by 20% to account for likely constraints and design considerations.

To remain consistent with recent literature regarding the performance of California-based open water treatment wetlands and the Oro Loma Horizontal Levee, the estimated wetland area needed to remove 90% of nitrate from 1 million gallons per day (mgd) of effluent was utilized to estimate flow capacity of the available acreage.[17,18,19] This value, termed the A_{90}, is considered a useful metric for wetland design, to enable comparison with technologies that offer the highest technically feasible level of treatment of municipal wastewater (i.e., effluent concentrations of <3 mg L^{-1} N).[17] In practice, a less conservative ratio of wetland area to flow may be chosen, driven by space constraints and water quality regulations.

The A_{90} varies considerably based on season and wetland type. Given the scarcity and cost of land in the region, the most efficient type of wetland was assumed, known as a unit-cell open water wetland, which is a shallow and unvegetated type that favors denitrification and photodegradation of organic contaminants.[20,18,21] Such systems have seasonal A_{90} values ranging from around 1.2 X 10^{-3} ha $(m^3\ d)^{-1}$ and 3.4 X 10^{-3} ha $(m^3\ d)^{-1}$, respectively in the summer to greater than 6 X 10^{-3} ha $(m^3\ d)^{-1}$ in the winter.[19] This corresponds to a summertime

A_{90} of 11.2 acres and an associated hydraulic retention time (HRT) of ~5.8 days. An HRT of this length is likely conservative based on recommended HRT values from the literature of constructed wetlands, though is intended only to inform conceptual opportunities and constraints.

Assuming these systems will be designed towards managing the ADWF, summer conditions were assumed, corresponding to a water temperature of 20°C, which approximates the dry weather temperatures of the Hayward Ponds, which have for decades received treated effluent from Union Sanitary District, based on data reported to the California Integrated Water Quality System (CIWQS).

TIN Reduction Potential

Based on the estimates of Total Potential Flow Capacity, for some facilities, land available for potential conversion to open water wetlands exceeds the area required for a given facility, which was estimated as the ADWF of a given facility divided by the A_{90} value. To estimate the theoretical total potential TIN load reductions available from lands near a given facility, the Total Potential Flow Capacity from above was used along with the dry weather TIN concentration to calculate the Total TIN Reduction Potential. This is a coarse indicator of whether lands surrounding a facility could be used in partnership with other wastewater facilities, and is subject to many constraints not evaluated here. Full nitrification of all effluent prior to NbS-based treatment is assumed, given the higher efficiency of removing nitrate vs. ammonia by these systems. For some facilities, the nitrification upgrades that would be required for implementation of NbS could be significant; these costs should be evaluated in future planning phases.

Facility-Specific TIN Reduction

It is assumed that individual facilities are not likely to construct excess acreage of constructed wetlands unless a larger regional facility is implemented in cooperation with other agencies. The 'Facility-Specific TIN Reduction' value is equivalent to the flow available from an individual facility that may be routed through the minimum required acreage available according to the A_{90} sizing criteria. Potentially available lands were limited to the three (3) largest contiguous polygons located closest to the facility (see page 14 for more details).

In practice, this means that ADWF for an individual facility was multiplied by an A_{90} value of 11.2 acres per mgd of flow. If less acreage is considered available, the lesser value is used. The corresponding load is assumed to be reduced by 90% in the dry season and this final load is compared to the average dry weather TIN load from the facility. Under this approach, the potential reduction value cannot exceed 90%, though additional acreage, longer retention time, or other optimizations could increase the removal efficiency during the summer beyond 90%.

Though not provided in the summary sheets, the estimated load reduction assuming full utilization of all Potentially Suitable Area was calculated using the tanks in series model.[22] Model parameters were based on values from Unit Cell Open Water Wetlands evaluated by UC Berkeley researchers and others at locations including Discovery Bay and Prado Wetlands in Riverside County, CA.[17] This exercise indicated that increasing the level of acreage beyond the A_{90} value yields marginal increases in nitrate load removal.

Horizontal Levees

Potential Flow Capacity

This indicator is an estimate of a theoretical volume of water available to route through the identified length of horizontal levee near a facility of interest.

Recently, results from the Oro Loma Horizontal levee project were published that indicate very high nutrient removal rates, with A_{90} values exceeding those estimated for unit-cell open water wetlands.[19] However, the substrate of the Oro Loma horizontal levee has low hydraulic conductivity that severely limits the flow rate - thus relatively low volumes of effluent can be treated through the Oro Loma horizontal levee. Managers and researchers involved in the Oro Loma project now believe that the media through which flows are routed in the subsurface can be optimized to permit higher flow, thus increasing total nitrate load removed. To estimate the potential volume and corresponding treatment rates, literature from woodchip bioreactor systems can be relied upon to estimate flow and nitrate removal potential.

Woodchip bioreactors are increasingly used to control nitrate from agricultural runoff and the Oro Loma system does incorporate wood chips as a carbon source but the soil mix inhibits flow. For this evaluation, a 0.5-meter thick layer of woodchips is assumed along a 10:1 slope of a 3.14-meter high levee. The flow of nitrate-rich effluent is assumed to only flow through this layer along the slope of the levee. A literature-based drainable porosity value of 0.41 was used, along with an assumed HRT of 24 hours, to estimate the potential flow capable of being routed through the system, while still optimizing for nitrate removal.[23,24] This provides a rough estimate of the maximum amount of flow that could likely be routed through the identified horizontal levee lengths.

TIN Reduction Potential

Researchers in 2016 published an analysis of woodchip bioreactor performance according to several design properties.[25] They found that temperature explained a substantial portion of the variation in nitrate removal across multiple studies of woodchip bioreactor performance. The removal rate of nitrate-N can be estimated by: N removal rate = $1.79e^{0.0766 \times \text{Temperature}}$. A temperature of 20°C was assumed, which would likely apply to year-round performance since such bioreactors maintain similar temperature ranges throughout the year. This results in an N-removal rate of 8.3 grams of nitrate-N per cubic meter of wood chips per day (g N m^{-3} d^{-1}) at 20°C. This rate was applied to the estimated volume of wood chips, per the dimensions above, to estimate a theoretical rate of TIN reduction. Consistent with the analysis for open water treatment wetlands, full nitrification of effluent prior to NbS treatment is assumed.

Facility-Specific TIN Reduction

To estimate the proportion of dry season TIN load potentially removed by horizontal levees identified in the GIS modeling procedure, total TIN Reduction Potential was compared to the load associated with the maximum ADWF from the facility of interest that could be routed through the horizontal levee. This flow rate is set to the lesser of the total ADWF from the facility or the Total Potential Flow Capacity, from above.

ACRONYMS

ADWF: Average Dry Weather Flow

BACWA: Bay Area Clean Water Agencies

CIWQS: California Integrated Water Quality System

EBDA: East Bay Dischargers Authority

kg N/d: kilograms of nitrogen per day

mgd: million gallons per day*

mg/L: milligrams per liter

NbS: Nature-based Solutions

SLR: sea level rise

TIN: Total Inorganic Nitrogen

WRRF: Water Resource Recovery Facility

**Note on units:* In general, SI units are used in this report. However, some English units commonly used in the wastewater industry (e.g. mgd, acres) are used for readability and ease of translation.

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READING THE FACT SHEETS

A guide for interpreting the facility-specific summaries

Overall Suitability for Nature-Based Treatment Solution

*The metrics for open-water wetlands are calculated for nearby sites over 5 acres. The 3 nearest sites to each facility over 5 acres (**"highlighted sites"**) were selected for further analysis and are highlighted in blue on the fact sheet maps. In some cases, just 1-2 opportunity sites were identified, and some facilities had no opportunities over 5 acres.*

Open water wetlands

- **High** if the highlighted sites are estimated to be capable of removing >70% of the nitrogen load from the facility, assuming full conversion to nitrate upstream of NbS. Also considered 'High' if >350 acres of land within a 3.2 km (2 mi) radius of the facility is mapped as potentially suitable for conversion to treatment wetlands.
- **Moderate** if 10-70% of the nitrogen load from a given facility can be removed by open water treatment wetlands, assuming full utilization of the highlighted sites.
- **Low** if less than 10% of total nitrogen load can be removed.

Horizontal levees

- **High** if potential horizontal levee opportunities within 2 miles of a facility are estimated to be capable of removing >70% of the nitrogen load from the facility, assuming full conversion to nitrate upstream of NbS. Also considered high if potential horizontal levee opportunities within 2 miles of a facility total more than 10 km in length.
- **Moderate** if 10-70% of the nitrogen load can be removed by potential horizontal levee opportunities within 2 miles of a facility.
- **Low** if less than 10% of total nitrogen load from a given facility can be removed.

Open Water Wetland Opportunities

Potentially suitable area within 2 miles of a facility: The sum of acreage within a 3.2 km (2 mi) radius of a given WRRF considered potentially suitable for conversion to treatment wetlands. The acreage listed represents 80% of the total modeled acreage to partially account for feasibility and design constraints.

Potentially suitable area: The lower end of the range is the acreage of the smallest of the highlighted sites. The upper end of the range is the acreage of all highlighted sites. The acreage listed represents 80% of the modeled acreage to partially account for design and feasibility constraints.

Potential flow capacity: The lower end of the range is the total estimated flow suitable for routing through the smallest highlighted site. The upper end of the range is the flow that could be treated using all highlighted sites. This is based on a relationship of 11.2 acres per mgd of flow, which is the estimated area required to remove 90% of nitrate from 1 mgd of typical municipal wastewater during spring and summer months (Jasper et. al. 2014 and Cecchetti et al., 2020).

Total TIN Reduction Potential: The range in TIN reduction capacity associated with the range of flows from above, assuming full conversion to nitrate prior to discharge to a treatment

wetland. The values represent the reduction in daily TIN load, calculated from the WRRF-specific average dry season TIN concentration and the potential flow capacity expressed above. In some instances, the total TIN reduction capacity is greater than the dry season daily load from the facility, indicating potential excess treatment capacity.

Facility-specific TIN Reduction: The percentage of daily average dry season TIN load from a given WRRF that could potentially be removed via open water treatment wetlands. The lower end of the range reflects the treatment capacity from the smallest of the highlighted sites, and the upper end of the range reflects the treatment capacity of all highlighted sites.

Horizontal Levee Opportunities

Potentially suitable length: The lower end of the range is the length of closest contiguous reach of shoreline to a facility considered potentially suitable for construction of a horizontal levee. The upper end of the range is the length of all identified horizontal levee opportunities intersecting a 2 mile-radius around a facility.

Potential flow capacity: The lower end of the range is the estimated flow suitable for routing through the modeled horizontal levee length nearest to the WRRF. The upper end of the range is the flow that could be treated using all potential horizontal levees within a 3.2 km (2 mi) radius. This assumes a conservative 24-hour retention time through a 0.5-meter thick woodchip media layer (porosity of 0.41) along a 3.14-meter high levee with a 10:1 slope.

Total TIN Reduction Potential: The range in TIN reduction capacity associated with the range of flows from above, assuming full conversion to nitrate prior to discharge to the horizontal levee. The nitrate removal rate is based on Addy et al. 2016, which provides an estimated nitrate removal rate as a function of woodchip volume from various experiments on woodchip bioreactor systems. In some instances, the total TIN reduction capacity is greater than the dry season daily load from the facility, indicating potential excess treatment capacity.

Facility-specific TIN Reduction: The percentage of daily average dry season TIN load from a given WRRF that could potentially be removed via horizontal levees, assuming a 0.5-meter thick denitrifying woodchip bioreactor layer. The lower end of the range reflects the treatment capacity from the nearest contiguous length of shoreline considered potentially suitable for a horizontal levee. The upper end of range reflects the sum of all potential opportunities within a 3.2 km (2 mi) radius of the WRRF of interest.

Site Opportunities and Constraints

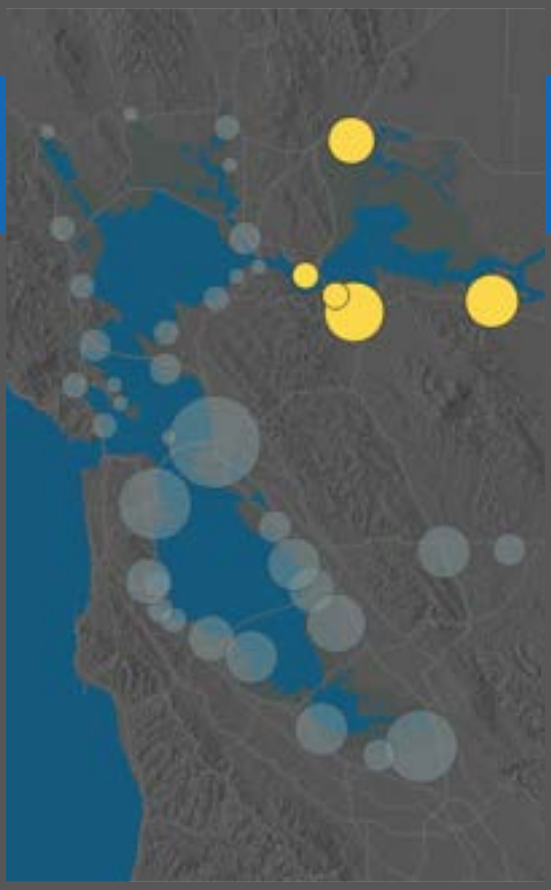
Excess Treatment Capacity: A relative ranking of whether potentially available land considered suitable for open water treatment wetlands or horizontal levees could treat municipal flows in excess of the average flow during the dry season from the WRRF of interest. This is a general indicator of whether potential may exist to partner with other WRRFs on NbS projects, without consideration of constraints, including flow distribution capacity.

Land Use/Regulatory Conflicts: A very coarse relative ranking estimating the likely conflicts associated with land use and ownership or environmental conflicts (e.g. sea level rise, wetlands, and sensitive species habitat) that could present regulatory constraints to implementation.

FACILITY-SPECIFIC FACT SHEETS

SUB-EMBAYMENT FOCUS

SUISUN BAY



Five water resource recovery facilities (WRRFs) discharge to Suisun Bay, which includes Carquinez Strait, according to boundaries from the San Francisco Bay Basin Water Quality Control Plan (Basin Plan). The combined ADWF from those WRRFs is ~55 mgd and the dry season TIN load is ~6,200 kg N/d.

This preliminary analysis indicates moderate opportunity exists in Suisun Bay to manage nutrients via nature-based solutions. On a cumulative basis, between 9% to 90% of the dry season TIN load could be managed with open water wetlands and horizontal levees could remove 13-75% of total TIN load from these five facilities. Refer to Introduction, Nutrient Reduction Estimation Methods.

A relatively large land area is potentially suitable for conversion to open water treatment wetlands or horizontal levees. Leveraging this area requires coordination among adjacent landowners, nearby WRRFs, and habitat restoration or flood control projects.

Key Opportunities & Constraints

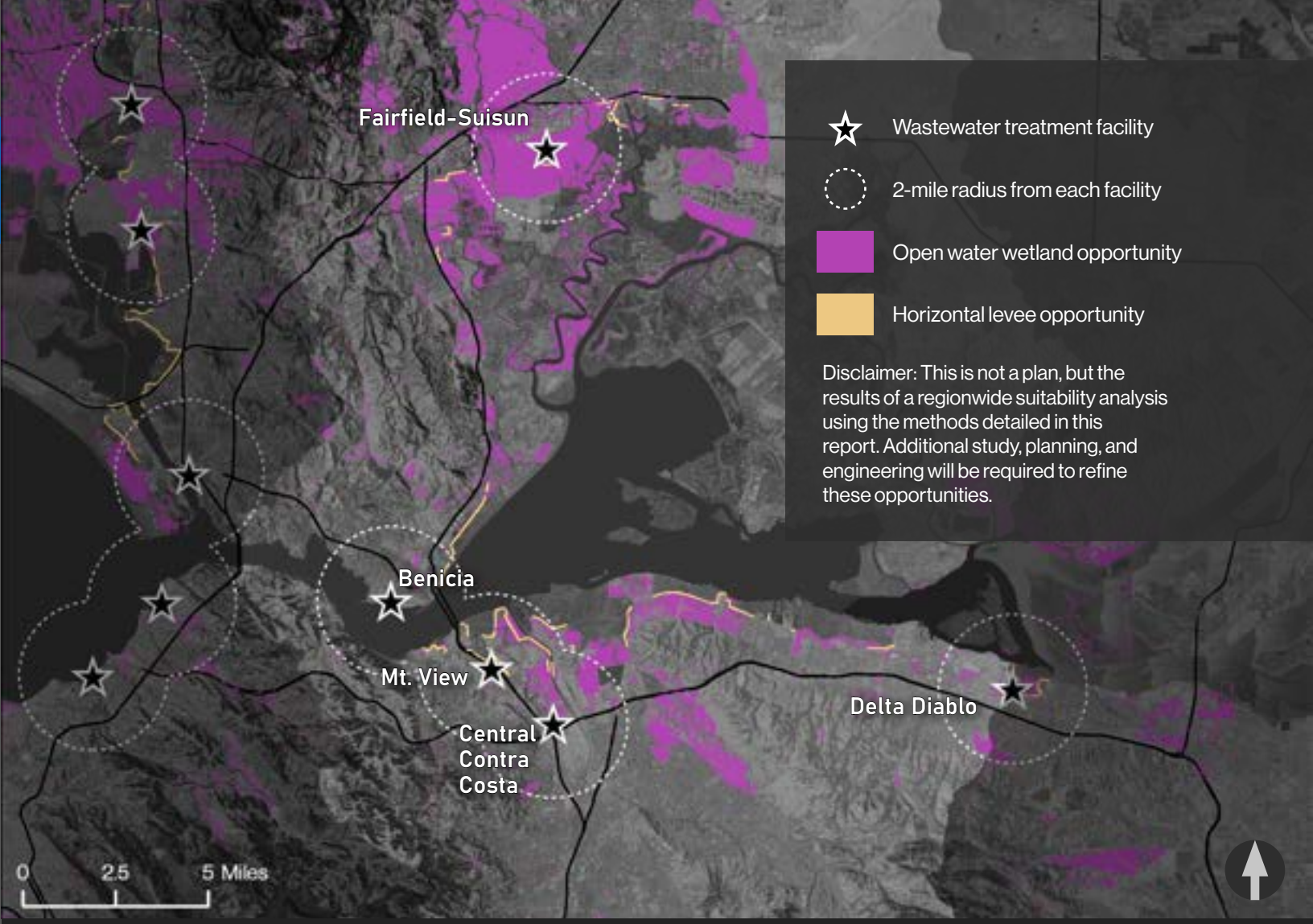
This analysis integrates existing geospatial data including physical opportunities (i.e. elevation, slope, habitat type) and general land use constraints (i.e. proximity to existing development or highly sensitive habitat types).

- On a subembayment scale, significant potential exists to convert lands to NbS interventions for nutrient removal. However, some facilities are isolated and partnership among facilities may be impractical.
- Mt. View Sanitary District was one of the first West Coast WRRFs to utilize open water treatment wetlands and their system removes between 15-50% of TIN, based on the time of year.
- Fairfield-Suisun nitrifies its effluent and areas in proximity to the facility may be suitable for open water treatment systems. Given its relative isolation, partnership opportunities may be limited.
- The Central Contra Costa Sanitary District and Delta Diablo WRRFs discharge the greatest TIN loads and hold moderate potential to deploy either open water wetlands or horizontal levees. Conflicting land uses and environmental restrictions likely requires considerable coordination to design and quantify the multiple benefits available to bring such projects to fruition.

Map (above, top)
Wastewater treatment facilities that discharge to Suisun Bay, in yellow, sized relative to average daily total inorganic nitrogen loads in the region.

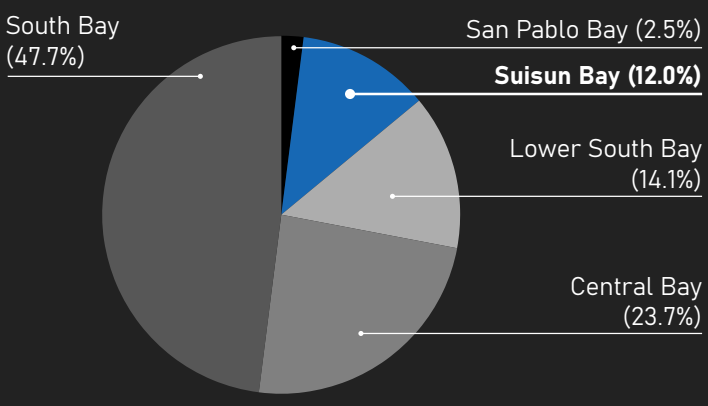
Photo (above, bottom)
View of Moorhen Marsh, an open water treatment wetland managed by Mt. View Sanitary District. Photo courtesy of Mt. View Sanitary District.

Map (facing page)
Overview of WRRFs discharging to Suisun Bay, including modeled outputs of areas potentially suitable for conversion to open water treatment wetlands or horizontal levees.



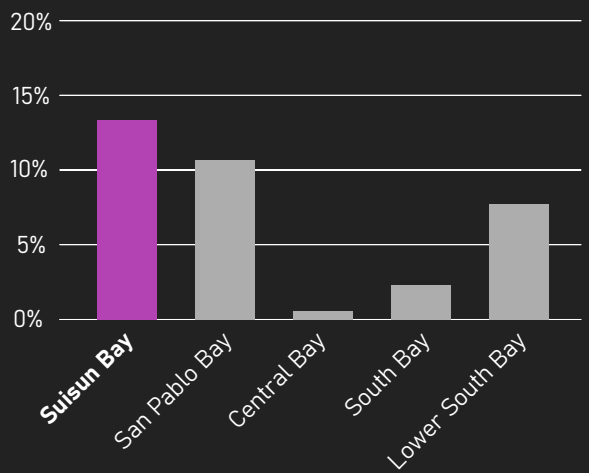
SUMMARY STATISTICS: SUISUN BAY

Total Inorganic Nitrogen Load*



*total average dry season daily TIN load

Percent of area within 2 mi of a facility suitable for open water wetlands



6 - 36 km** of shoreline in Suisun Bay were identified as potentially suitable for **horizontal levees**, corresponding to a potential treatment capacity of **11 - 61 mgd****

**lower end of range: closest opportunity to each facility; higher end of range: all oppportunities within 2 miles of a facility

CITY OF BENICIA

NATURE-BASED TREATMENT SOLUTIONS

The Benicia Wastewater Treatment Plant discharges non-nitrified effluent to Carquinez Strait. The facility serves the City of Benicia (pop. ~28,000) - with a dry weather permitted capacity of 4.5 mgd and average dry season flow of 1.9 mgd. Limited opportunities for nature-based treatment are available in close proximity to the facility.

Preliminary Findings

Opportunities for NbS-based treatment are limited by surrounding geography and the challenge of piping flows across the Carquinez Strait. Potential areas for open water treatment wetlands and horizontal levees were identified. If horizontal levees to the east were pursued for treatment, over 70% of TIN as nitrate could be removed.

Opportunities & Constraints

Opportunities shown across the Carquinez Strait are excluded from the values shown here. Opportunities for NbS could be explored in conjunction with potential outfall improvements. Given the facility's exposure to sea level rise, a horizontal levee to the south of the plant may be worth further investigation. Additionally, future partnership opportunities may involve recycled water projects for industrial and/or municipal use.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High*
Horizontal levees	High*

*Model may overestimate opportunity, as local constraints are not accounted for

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	56 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	5 - 36 acres
Total Potential Flow Capacity	0.4 - 3.1 mgd
Total TIN Reduction Potential	50 - 360 kg/day
Facility-Specific TIN Reduction	19% - over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.2 - 4.7 km
Total Potential Flow Capacity	2.1 - 7.9 mgd
Total TIN Reduction Potential	160 - 610 kg/day
Facility-Specific TIN Reduction	73% - over 90%

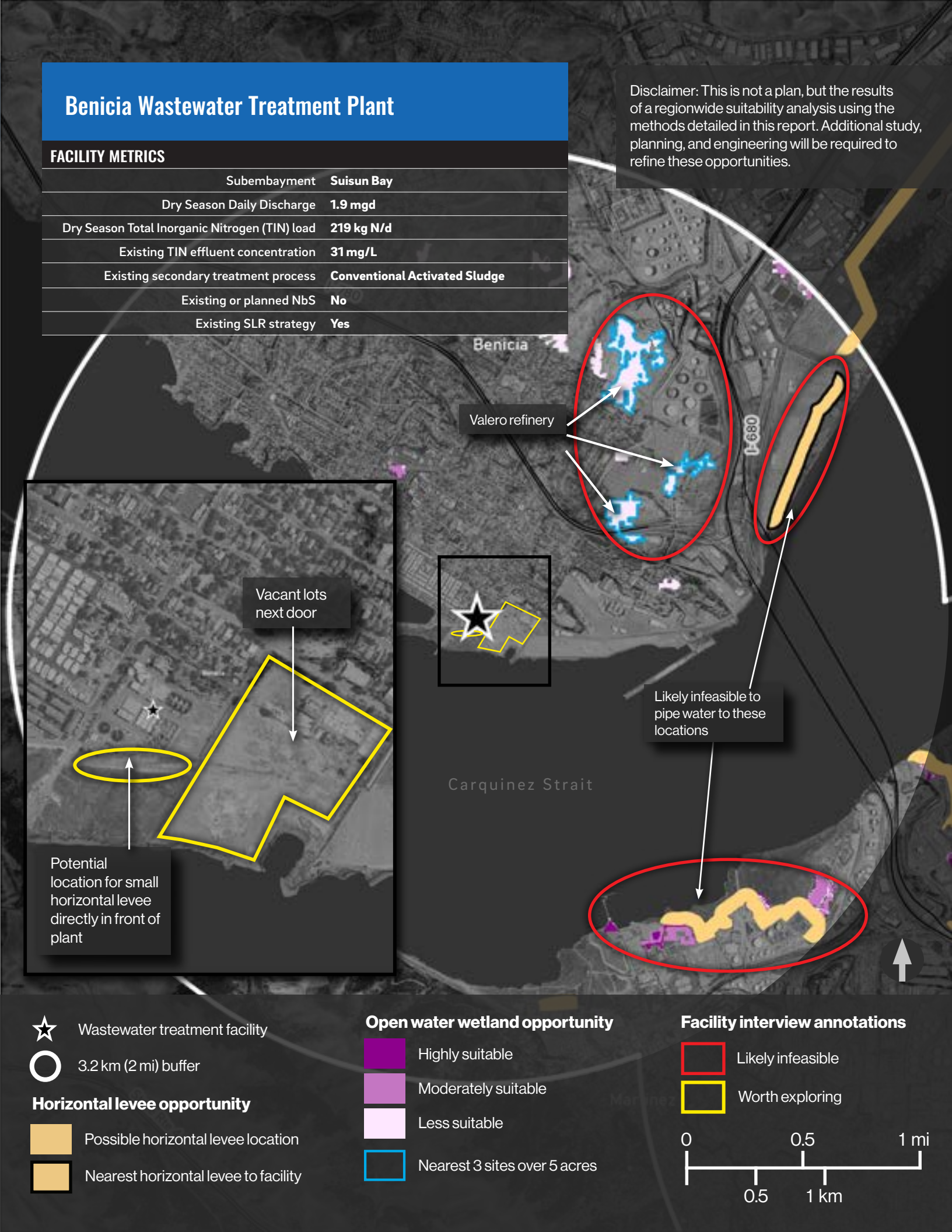
Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	Moderate

Benicia Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Suisun Bay**
Dry Season Daily Discharge	**1.9 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**219 kg N/d**
Existing TIN effluent concentration	**31 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Likely infeasible

Worth exploring

0 0.5 1 mi

0.5 1 km

CENTRAL CONTRA COSTA SANITARY DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Central San Wastewater Treatment Plant discharges non-nitrified effluent to Suisun Bay. The facility serves ~118,000 service connections in Contra Costa Co. and a population of nearly 500,000, with a dry weather permitted capacity of 53.8 mgd and average dry weather flows of ~32 mgd. Central San has indicated on-site options for NbS are limited given space requirements for wet weather storage. Habitat restoration and flood control projects in the area represent potential partnership opportunities.

Preliminary Findings

Multiple opportunities for open water wetlands were identified, including some adjacent to the facility. If open water wetlands were implemented at all three highlighted sites, nitrified dry season TIN loads could be reduced by about 30%. If the nearest horizontal levee opportunity was implemented, TIN loads could be reduced by about 3%.

Opportunities & Constraints

An opportunity for Central San is a potential partnership with the Lower Walnut Creek Restoration Project. Alternatively, options for hybrid wet weather storage and NbS-based nutrient removal in the summer may be possible. The need for split-stream nitrification represents a significant hurdle to supplying nitrified effluent to NbS.

Photo courtesy of Google Earth

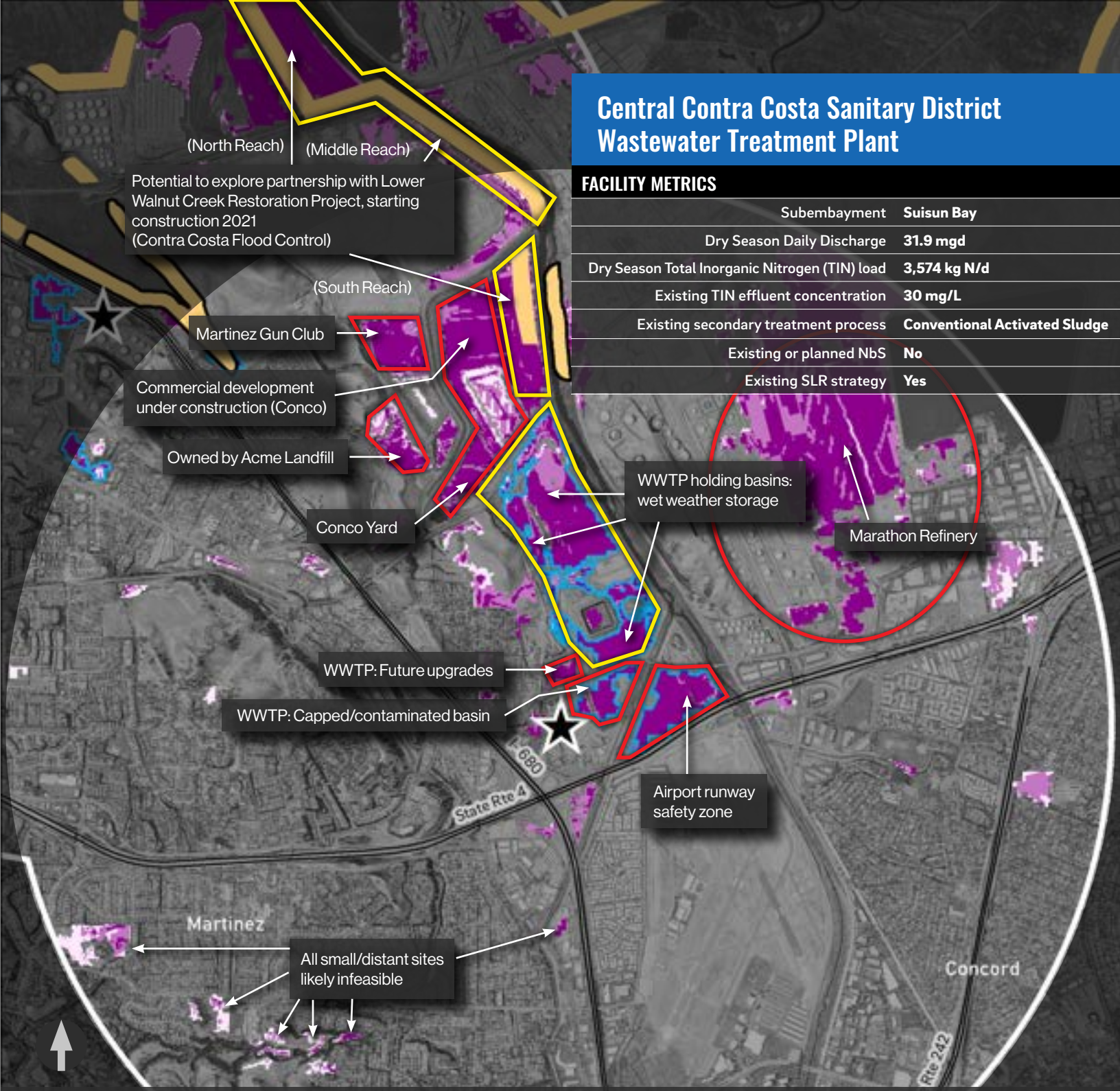
Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Moderate

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	685 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	4 - 37 acres
Total Potential Flow Capacity	0.3 - 10.9 mgd
Total TIN Reduction Potential	30 - 1,230 kg/day
Facility-Specific TIN Reduction	1% - 31%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.7 - 8.3 km
Total Potential Flow Capacity	1.3 - 14.2 mgd
Total TIN Reduction Potential	100 - 1,090 kg/day
Facility-Specific TIN Reduction	3% - 30%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	Moderate



Central Contra Costa Sanitary District Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Suisun Bay**
Dry Season Daily Discharge	**31.9 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**3,574 kg N/d**
Existing TIN effluent concentration	**30 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

0 0.5 1 mi

0.5 1 km

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres*

*Selected sites were manually modified to capture larger opportunity sites that were nearly as close as smaller ones.

Facility interview annotations

Likely infeasible

Worth exploring

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

DELTA DIABLO

NATURE-BASED TREATMENT SOLUTIONS

The Delta Diablo Wastewater Treatment Plant discharges primarily non-nitrified effluent to New York Slough, which feeds into Suisun Bay at the confluence with the San Joaquin River. The facility serves ~57,000 connections in Antioch, Pittsburg, and Bay Point, with a dry weather permitted capacity of 19.5 mgd. In 2014, a conceptual assessment of NbS opportunities was performed identifying potential sites and options for partial treatment and nutrient removal.

Preliminary Findings

Several opportunities for both treatment types were identified, including some in close proximity to the Delta Diablo facility. Together, the three highlighted open water wetland opportunities could reduce the nitrified TIN load by over 90%. The nearest horizontal levee opportunity could reduce TIN loads by 12%.

Opportunities & Constraints

Candidate NbS sites include upland areas adjacent to existing wetlands and a ~20-ac undeveloped property owned by Delta Diablo. Delta Diablo has pilot tested emerging nutrient removal processes and is evaluating water recycling challenges and opportunities as part of a current long-term master planning effort.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Moderate

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	488 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	25 - 92 acres
Total Potential Flow Capacity	2.2 - 8.1 mgd
Total TIN Reduction Potential	420 - 1,560 kg/day
Facility-Specific TIN Reduction	29.% - over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.2 - 4.1 km
Total Potential Flow Capacity	2.1 - 6.9 mgd
Total TIN Reduction Potential	160 - 530 kg/day
Facility-Specific TIN Reduction	12% - 41%

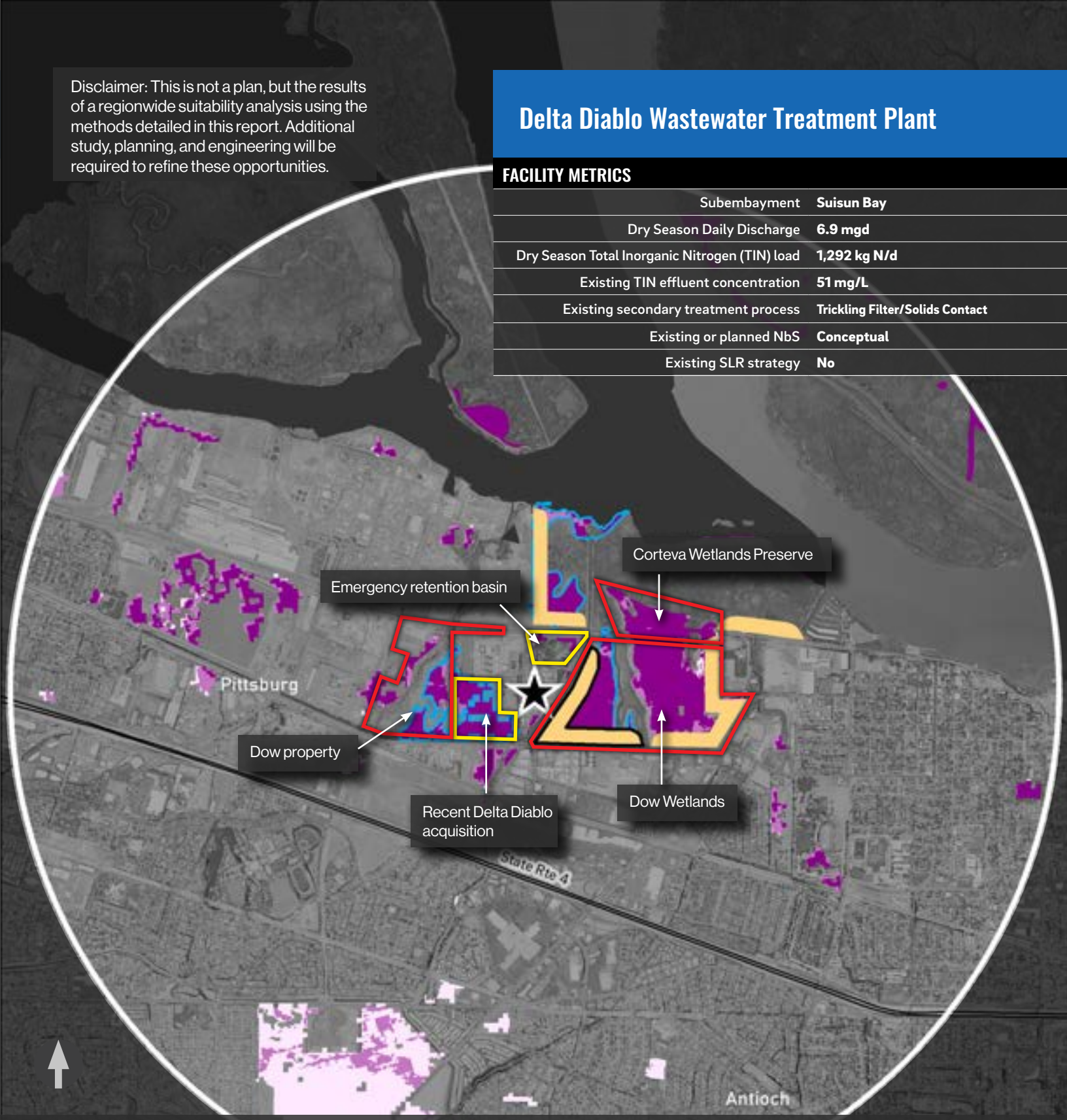
Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	Moderate

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

Delta Diablo Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Suisun Bay**
Dry Season Daily Discharge	**6.9 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**1,292 kg N/d**
Existing TIN effluent concentration	**51 mg/L**
Existing secondary treatment process	**Trickling Filter/Solids Contact**
Existing or planned NbS	**Conceptual**
Existing SLR strategy	**No**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Likely infeasible

Worth exploring

0 0.5 1 mi

0.5 1 km

FAIRFIELD-SUISUN SEWER DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Fairfield-Suisun Wastewater Treatment Plant discharges nitrified effluent to Suisun Bay via Boynton Slough. The facility serves ~58,000 connections in and around Fairfield - with a dry weather permitted capacity of 23.7 mgd and actual dry weather flow of ~11 mgd. Nitrified tertiary treated effluent is discharged to wetlands and recycled water users. The Sewer District has interest in exploring NbS to take advantage of existing discharge pathways and adjacent locations.

Preliminary Findings

More opportunity for open water wetlands than horizontal levees was identified. Opportunities for open water wetlands are widespread near the facility. If implemented, open water wetlands would have the capacity to remove more than 90% of total inorganic nitrogen discharged by the Fairfield-Suisun plant.

Opportunities & Constraints

This mapping exercise suggests significant opportunity due to the presence of open space, though much of this is privately held and not readily available. The greatest opportunities likely lie in creation of open water wetlands adjacent to existing discharge pathways, and increased recycled water allocation for agricultural uses.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Moderate

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	3,540 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	4 - 2,958 acres
Total Potential Flow Capacity	0.3 - 263.5 mgd
Total TIN Reduction Potential	30 - 24,940 kg/day
Facility-Specific TIN Reduction	2% - over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.6 - 3.7 km
Total Potential Flow Capacity	1.1 - 6.4 mgd
Total TIN Reduction Potential	80 - 490 kg/day
Facility-Specific TIN Reduction	8% - 47%

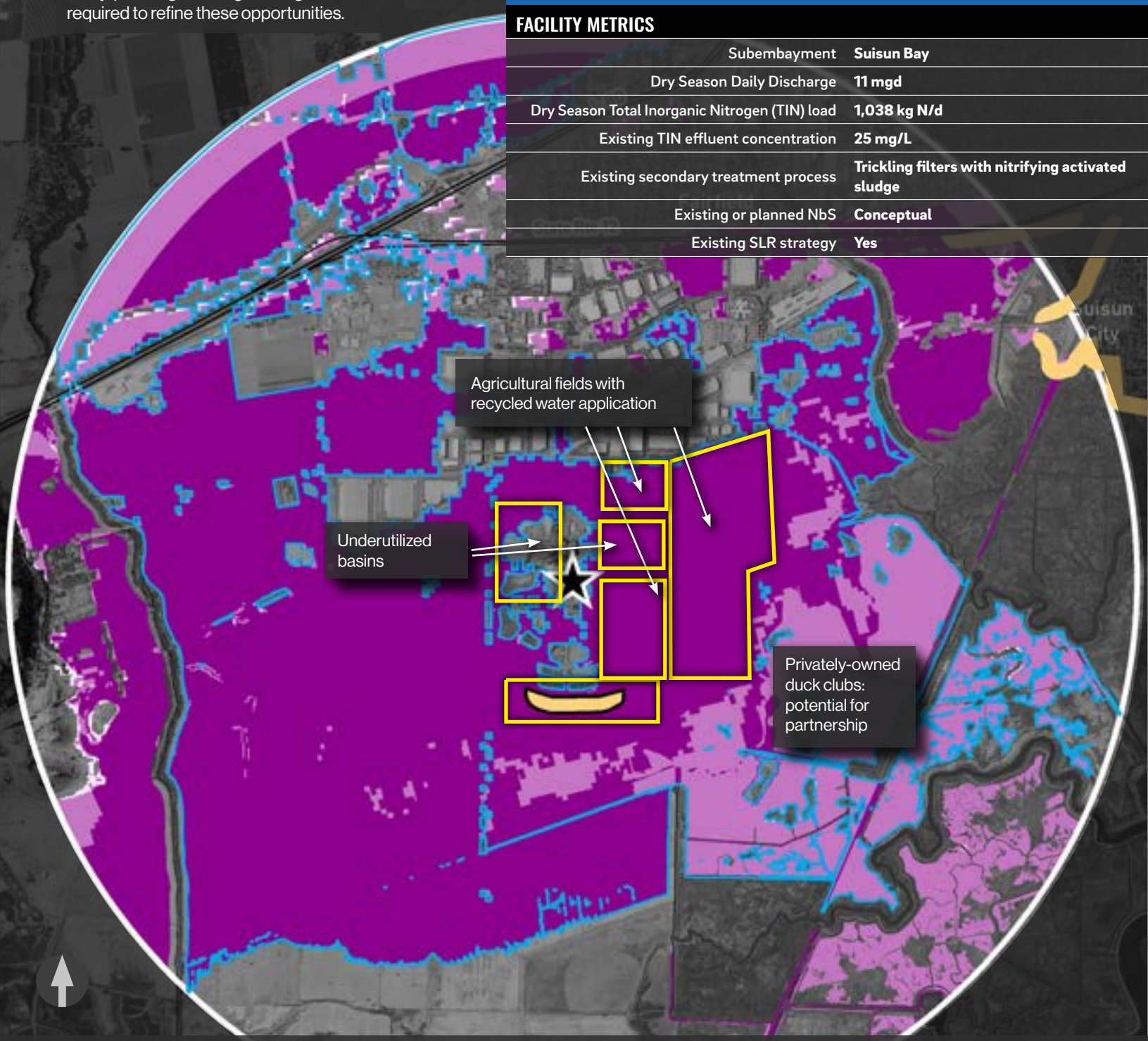
Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Moderate

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

Fairfield-Suisun Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Suisun Bay**
Dry Season Daily Discharge	**11 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**1,038 kg N/d**
Existing TIN effluent concentration	**25 mg/L**
Existing secondary treatment process	**Trickling filters with nitrifying activated sludge**
Existing or planned NbS	**Conceptual**
Existing SLR strategy	**Yes**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Likely infeasible

Worth exploring

0 0.5 1 mi

0.5 1 km

MT. VIEW SANITARY DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Mt. View Sanitary District discharges nitrified effluent to Carquinez Strait via Peyton Slough. The facility serves a population of ~22,00 in and around Martinez - with a dry weather permitted capacity of 3.2 mgd. This facility was one of the first on the West Coast to adopt NbS for wastewater treatment. Moorhen Marsh was created in 1973 and continues to serve as a polishing system to provide habitat and enhance water quality prior to discharge to Peyton Slough.

Preliminary Findings

Several opportunities for both treatment types were identified, including some in close proximity to the Mt. View facility. Together, the three highlighted open water wetland opportunities could reduce nitrified TIN loads by over 90%. The nearest horizontal levee opportunity could reduce TIN loads by over 90%.

Opportunities & Constraints

Available data indicates Moorhen Marsh removes between 15-50% of total nitrogen, depending on time of year. The facility is considering expansion of floating wetlands for contaminant removal, based on pilot tests. Future opportunities may involve partnerships on horizontal levees given the facility's exposure to future flood risk.

Photo courtesy of Google Earth

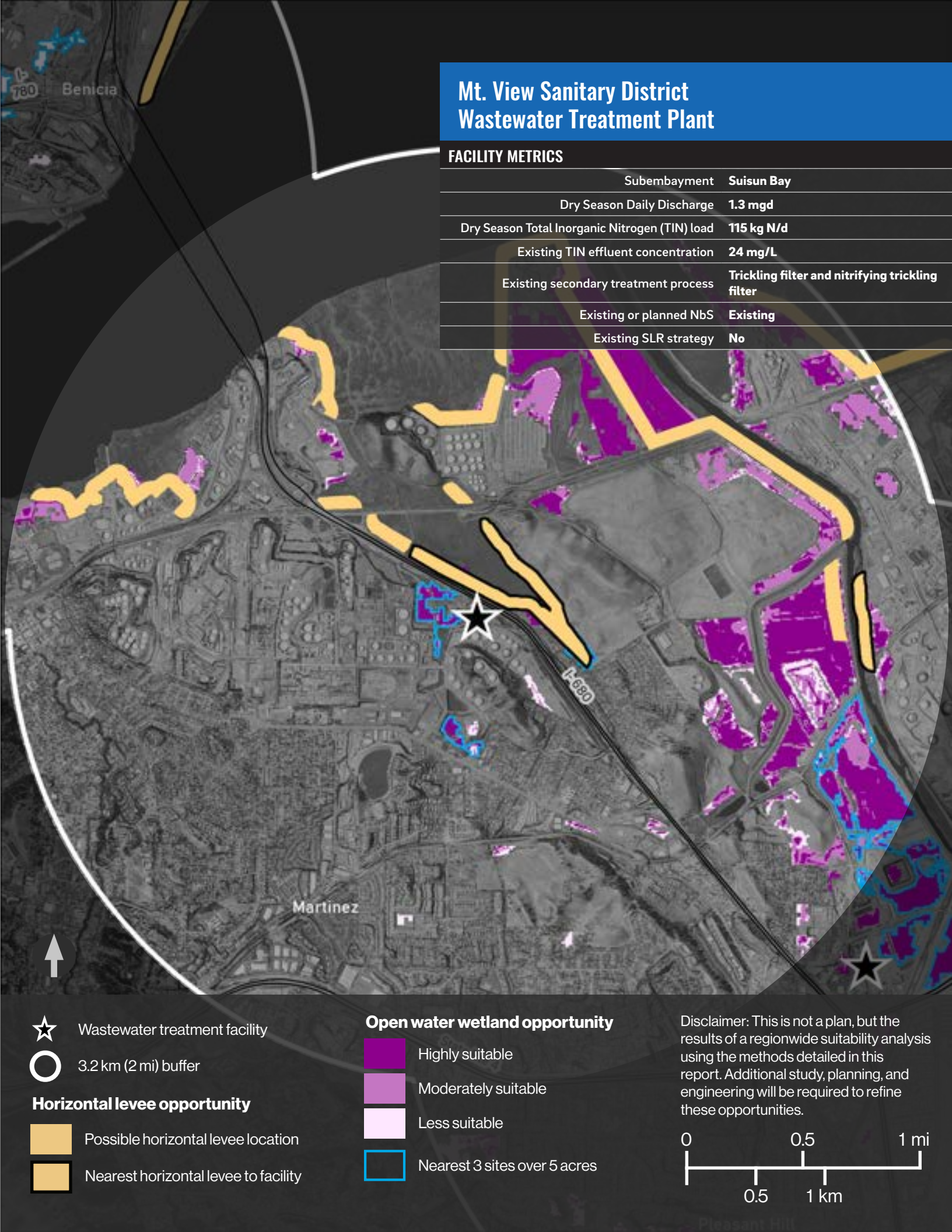
Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	546 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	5 - 20 acres
Total Potential Flow Capacity	0.4 - 1.7 mgd
Total TIN Reduction Potential	40 - 160 kg/day
Facility-Specific TIN Reduction	28.% - over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	2.4 - 14.9 km
Total Potential Flow Capacity	4.1 - 25.3 mgd
Total TIN Reduction Potential	310 - 1,940 kg/day
Facility-Specific TIN Reduction	over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Moderate



Mt. View Sanitary District Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Suisun Bay**
Dry Season Daily Discharge	**1.3 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**115 kg N/d**
Existing TIN effluent concentration	**24 mg/L**
Existing secondary treatment process	**Trickling filter and nitrifying trickling filter**
Existing or planned NbS	**Existing**
Existing SLR strategy	**No**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SUB-EMBAYMENT FOCUS

SAN PABLO BAY

Ten (10) water resource recovery facilities (WRRF) discharge to San Pablo Bay and its tributaries, according to boundaries from the San Francisco Bay Basin Plan. The combined ADWF from those WRRFs is ~15 mgd and the dry season TIN load is ~1,300 kg N/d.

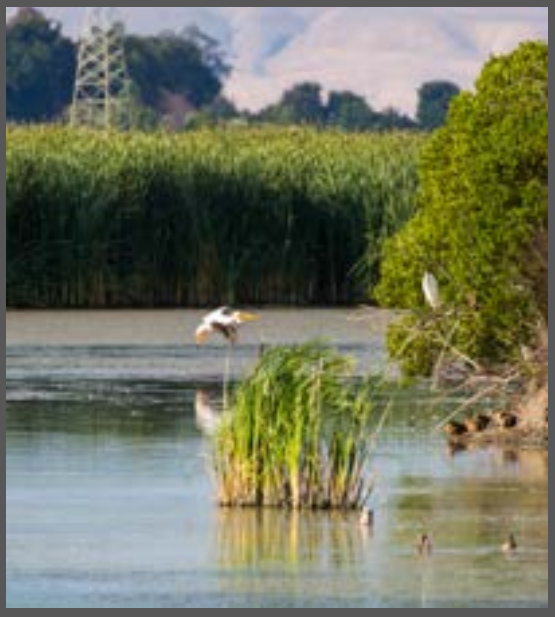
This preliminary analysis indicates that high opportunity exists in San Pablo Bay to manage nutrients via nature-based solutions. On a cumulative basis, between 50% to 90% of the dry season TIN load could be managed with open water wetlands and horizontal levees could remove up to 90% of total TIN load from these ten facilities. Refer to Introduction, Nutrient Reduction Estimation Methods.

Despite high opportunity in terms of land area potentially suitable for conversion to nature-based treatment solutions, the need for large-scale reduction is relatively small given existing dry season discharge prohibitions to tributaries and high rates of water reclamation for municipal and agricultural irrigation.

Key Opportunities & Constraints

This analysis integrates existing geospatial data including physical opportunities (i.e. elevation, slope, habitat type) and general land use constraints (i.e. proximity to existing development or highly sensitive habitat types).

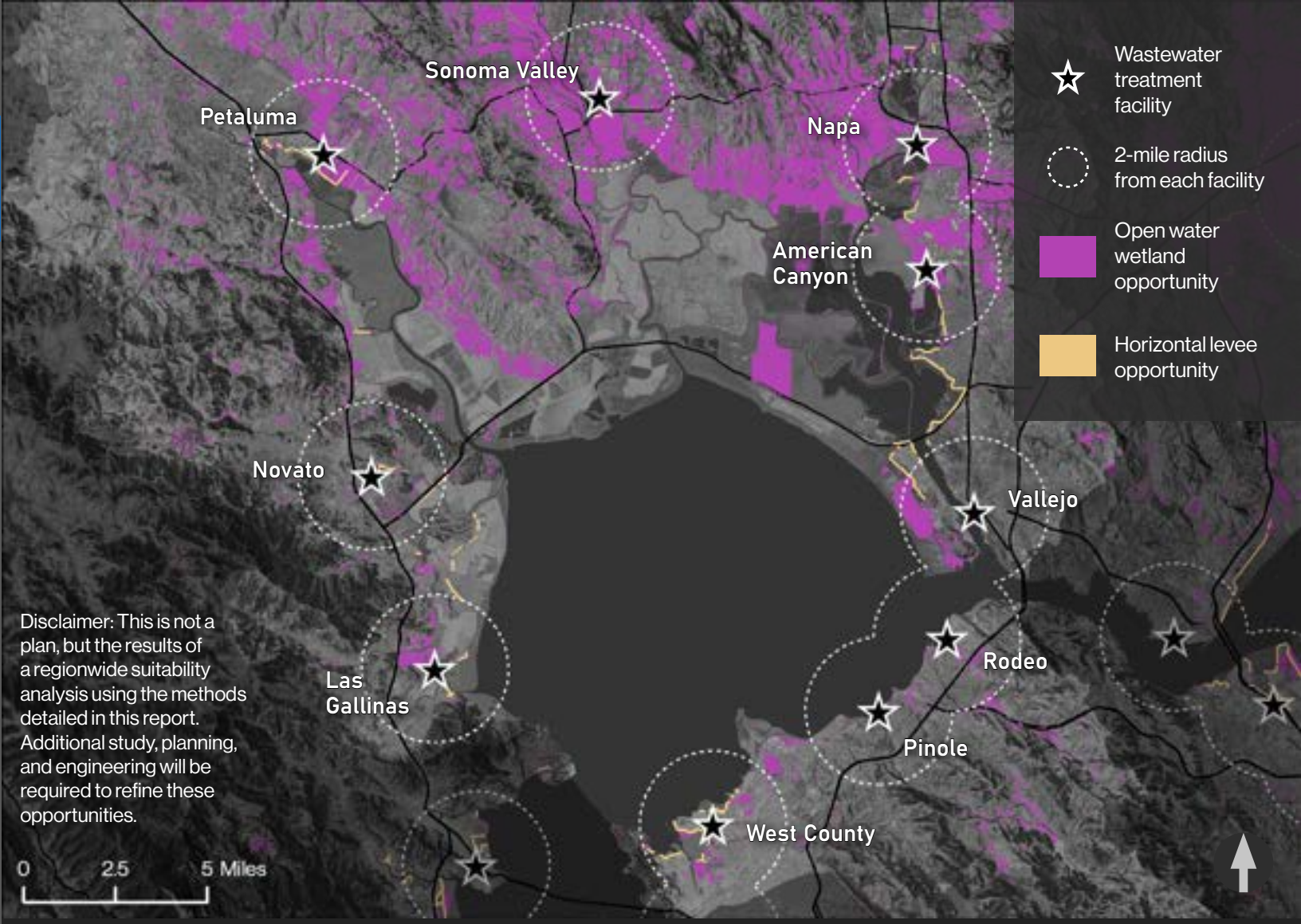
- Most of the Marin, Sonoma and Napa Co. dischargers to San Pablo Bay are subject to longstanding dry weather discharge prohibitions. This has led to large-scale water reclamation - primarily involving agricultural irrigation and other forms of land application that could fall under the classification of nature-based solutions to wastewater treatment.
- The Las Gallinas and Novato WRRFs are considering partnerships with habitat restoration and flood control projects to irrigate ecotone slopes with treated effluent.
- The Pinole, Vallejo, and Rodeo WWRFs are not subject to discharge prohibitions and have limited opportunities to deploy NbS for nutrient removal under current conditions. Partnerships with flood control agencies on multi-benefit horizontal levees may increase the viability of deploying NbS to manage nutrients from these facilties.



Map (above, top)
Wastewater treatment facilities that discharge to San Pablo Bay, in yellow, sized relative to average daily total inorganic nitrogen loads in the region.

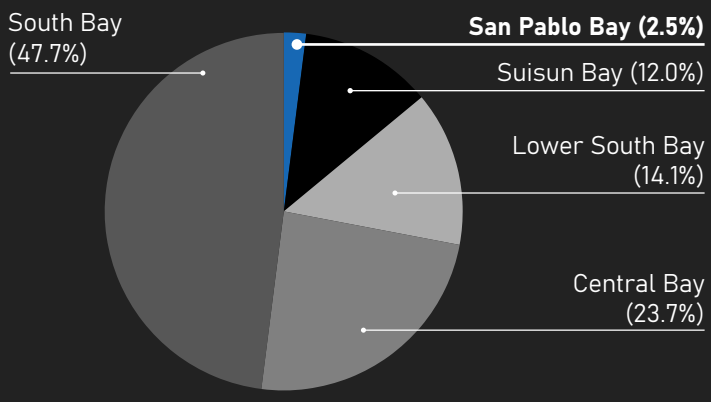
Photo (above, bottom)
Wastewater storage and wildlife ponds managed by Las Gallinas Valley Sanitary District. Photo by Melissa McMasters, CC BY 2.0

Map (facing page)
Overview of WRRFs discharging to San Pablo Bay, including modeled outputs of areas potentially suitable for conversion to open water treatment wetlands or horizontal levees.



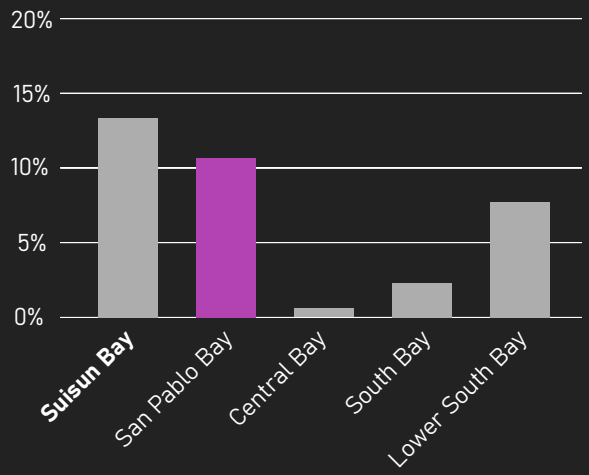
SUMMARY STATISTICS: SAN PABLO BAY

Total Inorganic Nitrogen Load*



*total average dry season daily TIN load

Percent of area within 2 mi of a facility suitable for open water wetlands



15 - 28 km** of shoreline in San Pablo Bay were identified as potentially suitable for **horizontal levees**, corresponding to a potential treatment capacity of **25 - 48 mgd****

**lower end of range: closest opportunity to each facility; higher end of range: all oppportunities within 2 miles of a facility

CITY OF AMERICAN CANYON

NATURE-BASED TREATMENT SOLUTIONS

The American Canyon Water Reclamation Facility discharges nitrified effluent directly to North Slough during the wet season. During the dry season, a large proportion of flow is recycled. The remaining is routed through on-site ponds following UV treatment. The facility serves the City of American Canyon (pop. ~20,000) and industrial dischargers from the food and beverage industry - with a dry weather permitted capacity of 2.5 mgd and average dry season flow of 1.1 mgd.

Preliminary Findings

There are a number of opportunity sites for both open-water treatment wetlands and horizontal levees near the American Canyon facility, including some areas directly adjacent to the plant. Nature-based treatment systems could have the capacity to reduce the nitrified TIN load at American Canyon by over 90%.

Opportunities & Constraints

Though not recognized as such, American Canyon employs NbS treatment in the dry season. Influent and effluent ammonia levels are monitored from the wetland pond, but not nitrate - limiting ability to assess TIN removal from the ponds. Opportunities exist for optimization of the existing pond and use of horizontal levees.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	1,264 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	38 - 841 acres
Total Potential Flow Capacity	3.4 - 74.9 mgd
Total TIN Reduction Potential	110 - 2,380 kg/day
Facility-Specific TIN Reduction	over 90%

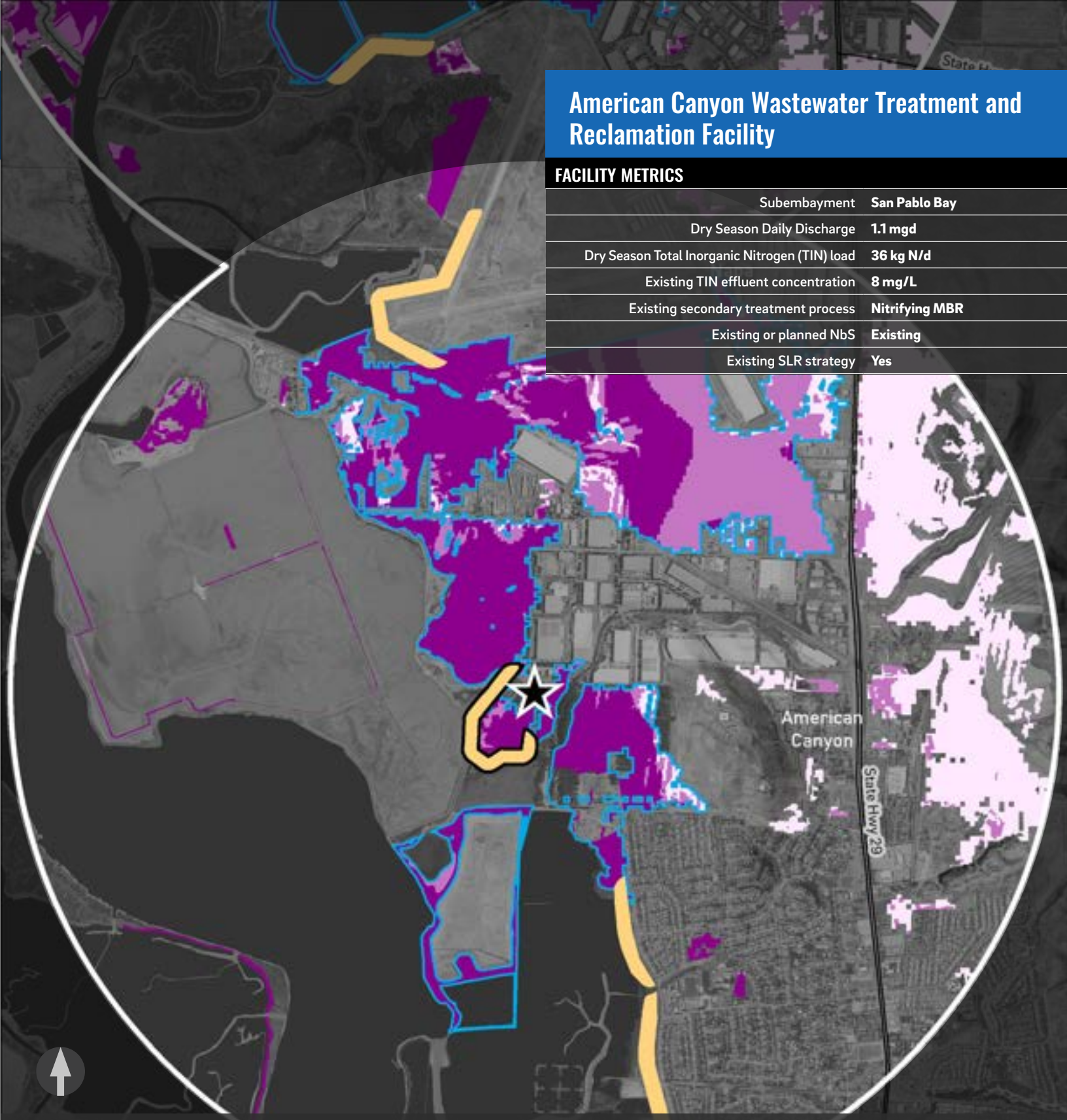
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.3 - 4.9 km
Total Potential Flow Capacity	2.1 - 8.3 mgd
Total TIN Reduction Potential	160 - 630 kg/day
Facility-Specific TIN Reduction	over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Low

American Canyon Wastewater Treatment and Reclamation Facility

FACILITY METRICS

Subembayment	**San Pablo Bay**
Dry Season Daily Discharge	**1.1 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**36 kg N/d**
Existing TIN effluent concentration	**8 mg/L**
Existing secondary treatment process	**Nitrifying MBR**
Existing or planned NbS	**Existing**
Existing SLR strategy	**Yes**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

LAS GALLINAS VALLEY SANITARY DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Las Gallinas Valley Sanitary District Sewage Treatment Plant reclaims most of its dry season flows. Remaining flow is discharged to San Pablo Bay. The facility serves a population of ~30,000 - with a dry weather permitted capacity of 2.9 mgd and average dry weather discharge flow of ~0.2 mgd. The facility already relies on NbS, with two 20-acre storage ponds, a 20-acre freshwater marsh/ pond, 200 acres of irrigated pasture, and provision of disinfected teriary recycled water to two local water agencies.

Preliminary Findings

Several opportunities for both treatment types were identified, including some very near the Las Gallinas facility. Together, the three highlighted open water wetland opportunities could reduce TIN loads by over 90%. The nearest horizontal levee could reduce TIN loads by over 90%.

Opportunities & Constraints

Las Gallinas maintains considerable capacity to manage dry season flows via NbS and distributing tertiary treated water for irrigation. Partnership opportunities include irrigation of horizontal levees and sea level rise protections proposed via the McInnis Marsh Restoration Project, with Marin Co Parks/Flood Control District and others.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	334 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	6 - 205 acres
Total Potential Flow Capacity	0.4 - 18.2 mgd
Total TIN Reduction Potential	20 - 830 kg/day
Facility-Specific TIN Reduction	over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	2.5 - 5.1 km
Total Potential Flow Capacity	4.3 - 8.6 mgd
Total TIN Reduction Potential	330 - 660 kg/day
Facility-Specific TIN Reduction	over 90%

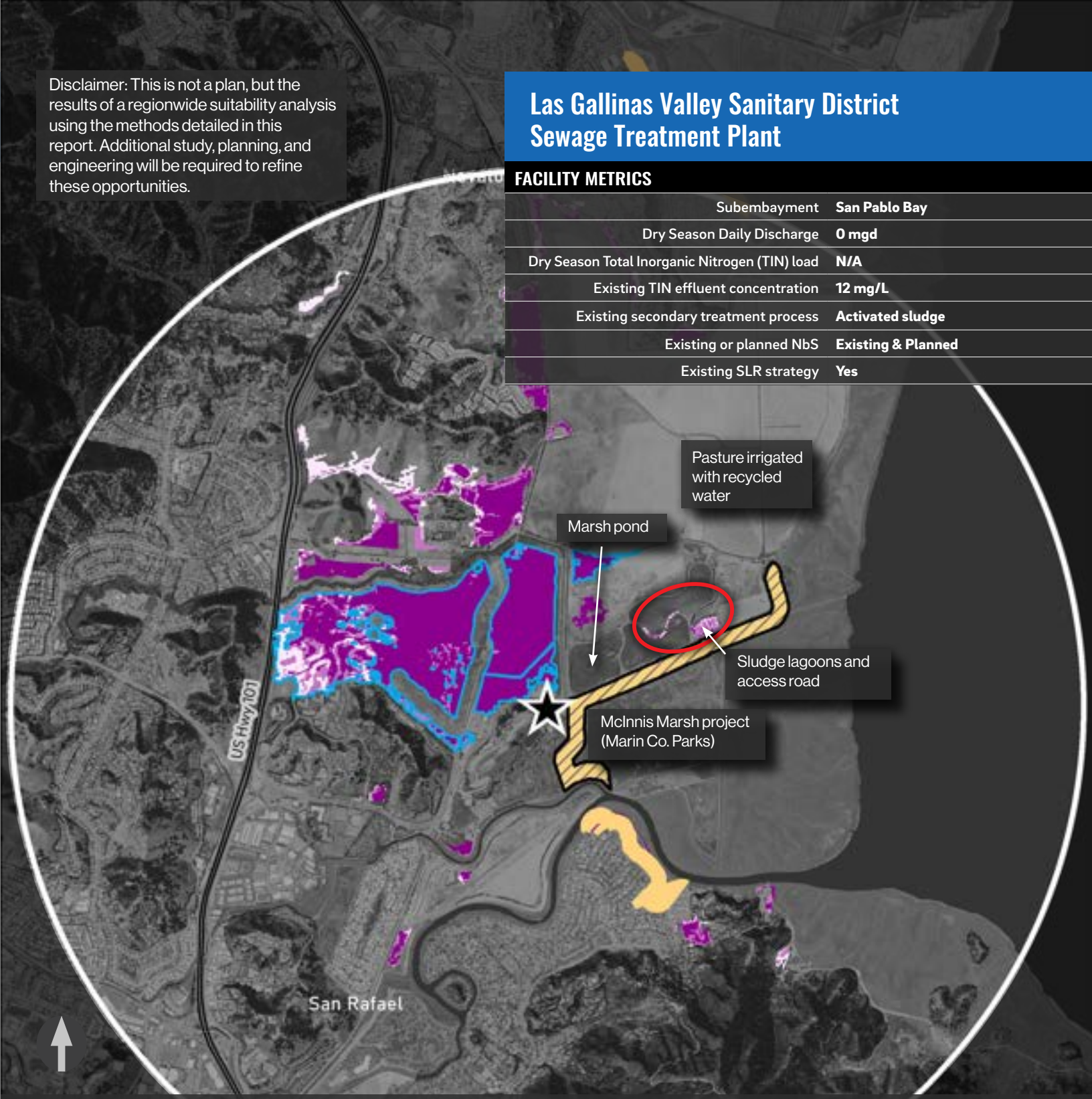
Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Moderate

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

Las Gallinas Valley Sanitary District Sewage Treatment Plant

FACILITY METRICS

Subembayment	**San Pablo Bay**
Dry Season Daily Discharge	**0 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**N/A**
Existing TIN effluent concentration	**12 mg/L**
Existing secondary treatment process	**Activated sludge**
Existing or planned NbS	**Existing & Planned**
Existing SLR strategy	**Yes**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Ecotone levee planned or constructed*
*at least part of length

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Likely infeasible

Worth exploring

0 0.5 1 mi

0.5 1 km

NAPA SANITATION DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Soscol Water Recycling Facility reclaims the vast majority of its dry season flows. Wet season flow is discharged to the Napa River. The facility serves a population of ~83,000 – with a dry weather permitted capacity of 15.4 mgd and average dry weather flow of 6.0 mgd. The facility relies on 340 acres of oxidation ponds for storage and additional treatment. Dry season flows are recycled for landscaping and irrigation and the facility expects to increase recycling volume.

Preliminary Findings

Several opportunities for both treatment types were identified, including some in close proximity to the Napa Sanitation facility. An open water wetland at just one of the three highlighted sites could reduce the nitrified TIN load by over 90%. The nearest horizontal levee opportunity could also reduce TIN loads by over 90%.

Opportunities & Constraints

Due to NapaSan's robust recycled water program wet season TIN discharge is minimized. Additional opportunities may exist for open water wetlands and horizontal levees, however NapaSan's existing reclamation activities make expansion of recycled water opportunities more attractive in the long term.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	1,869 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	33 - 402 acres
Total Potential Flow Capacity	2.9 - 35.8 mgd
Total TIN Reduction Potential	120 - 1,520 kg/day
Facility-Specific TIN Reduction	over 90%

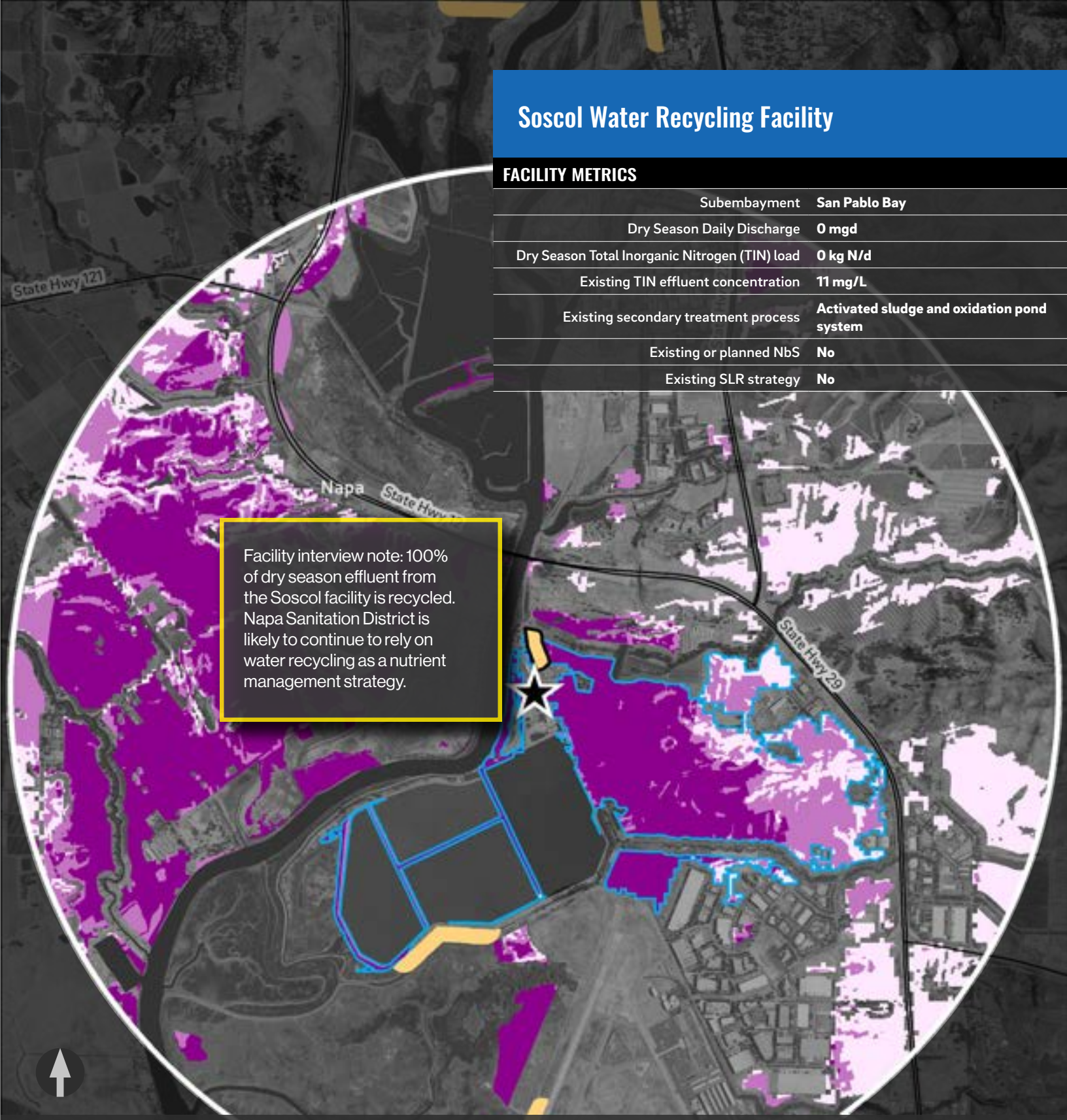
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.3 - 2.8 km
Total Potential Flow Capacity	0.6 - 4.7 mgd
Total TIN Reduction Potential	40 - 360 kg/day
Facility-Specific TIN Reduction	over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Moderate

Soscol Water Recycling Facility

FACILITY METRICS

Subembayment	**San Pablo Bay**
Dry Season Daily Discharge	**0 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**0 kg N/d**
Existing TIN effluent concentration	**11 mg/L**
Existing secondary treatment process	**Activated sludge and oxidation pond system**
Existing or planned NbS	**No**
Existing SLR strategy	**No**



Facility interview note: 100% of dry season effluent from the Soscol facility is recycled. Napa Sanitation District is likely to continue to rely on water recycling as a nutrient management strategy.

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

NOVATO SANITARY DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Novato Sanitary District Wastewater Treatment Plant reclaims the vast majority of its dry season flows. Remaining flow is discharged to San Pablo Bay. The facility serves a population of ~60,000 - with a dry weather permitted capacity of 7.0 mgd and actual dry weather flow of ~1.3 mgd. Though not called such, the facility relies on NbS via 180 million gallon storage ponds, a wildlife pond, and 820 acres of irrigated pasturelands. Additional recycled water users also exist.

Preliminary Findings

There are multiple opportunities for nature-based systems near the plant, though it's unlikely they will all be utilized as the open water opportunity is located bayward of the levee opportunity. If implemented, the horizontal levees identified would have the capacity to remove over 90% of the nitrified TIN load.

Opportunities & Constraints

Novato's facility maintains low nutrient discharges yet has explored options for routing flow to an horizontal levee, in partnership with the Coastal Conservancy on the Bel Marin Keys Restoration Project. Future flooding may limit the ability to use existing pasturelands and levees for flood control and discharge may represent a long-term solution.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	199 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	9 - 47 acres
Total Potential Flow Capacity	0.7 - 4.2 mgd
Total TIN Reduction Potential	30 - 200 kg/day
Facility-Specific TIN Reduction	48% - over 90%

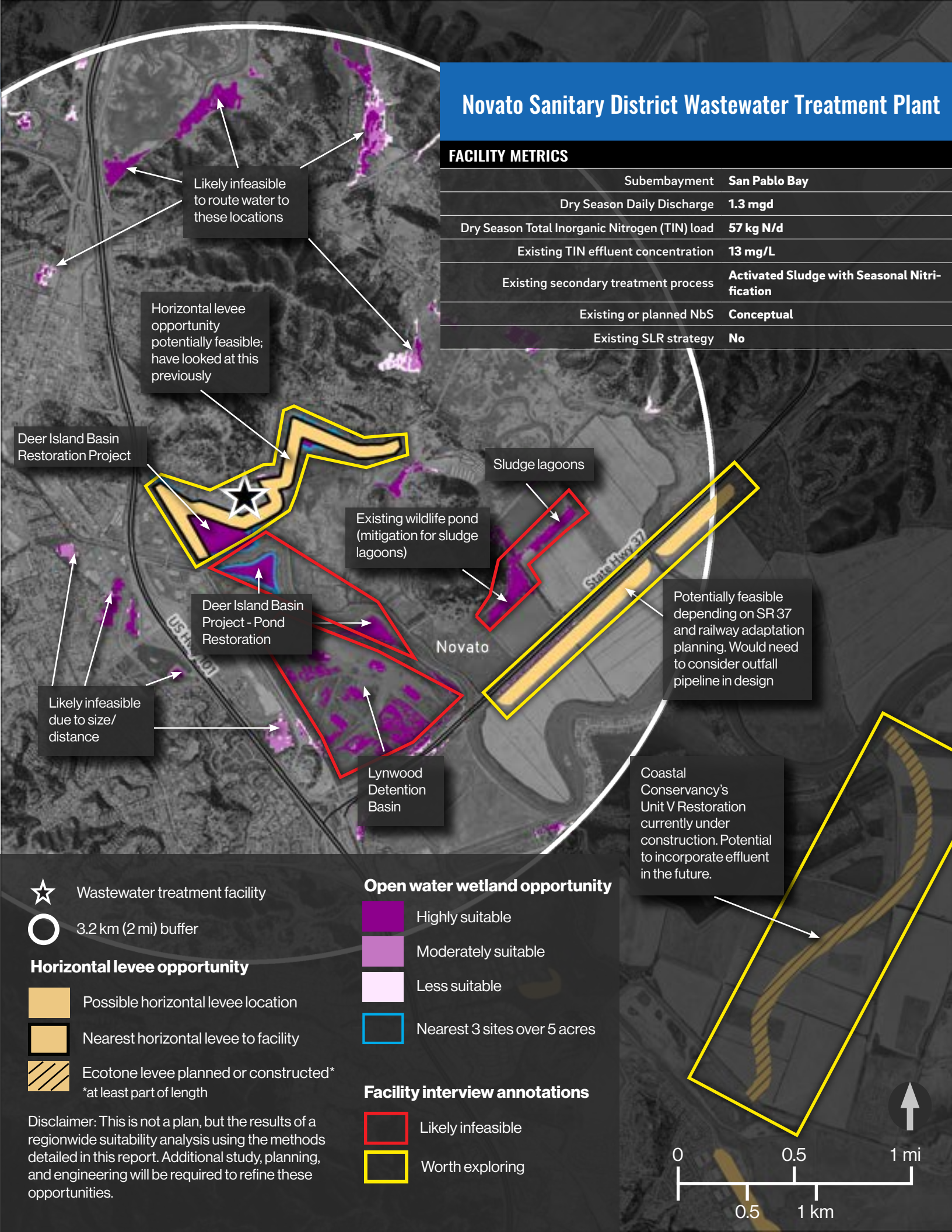
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	2.8 - 5 km
Total Potential Flow Capacity	4.7 - 8.5 mgd
Total TIN Reduction Potential	360 - 650 kg/day
Facility-Specific TIN Reduction	over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Moderate

Novato Sanitary District Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**San Pablo Bay**
Dry Season Daily Discharge	**1.3 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**57 kg N/d**
Existing TIN effluent concentration	**13 mg/L**
Existing secondary treatment process	**Activated Sludge with Seasonal Nitrification**
Existing or planned NbS	**Conceptual**
Existing SLR strategy	**No**



Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

CITY OF PETALUMA

NATURE-BASED TREATMENT SOLUTIONS

The Ellis Creek Water Recycling Facility reclaims virtually all dry season flows. Remaining flow is discharged to the Petaluma River following treatment in oxidation ponds (146-ac), treatment wetlands (16-ac) and polishing wetlands (31-ac). The facility serves ~25,300 service connections in and around Petaluma - with a dry weather design capacity of 6.7 mgd. Approximately 35% of total annual flows are recycled via landscaping and agricultural irrigation.

Preliminary Findings

Modeling indicates considerable potential to expand Petaluma's existing acreage of open water treatment wetlands, as well as options for deploying horizontal levees for multiple benefits. Currently, however, SLR does not pose a significant threat and the WWRF discharges very little during the dry season.

Opportunities & Constraints

Additional potential opportunities for NbS creation likely exists here, though there is currently no need for nutrient reduction during the dry season. Sea level rise may raise the groundwater table to a level that impacts ongoing operations and other upland options for open water wetlands or land application may become attractive or necessary.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	1,521 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	8 - 313 acres
Total Potential Flow Capacity	0.7 - 27.8 mgd
Total TIN Reduction Potential	no dry weather discharge
Facility-Specific TIN Reduction	no dry weather discharge

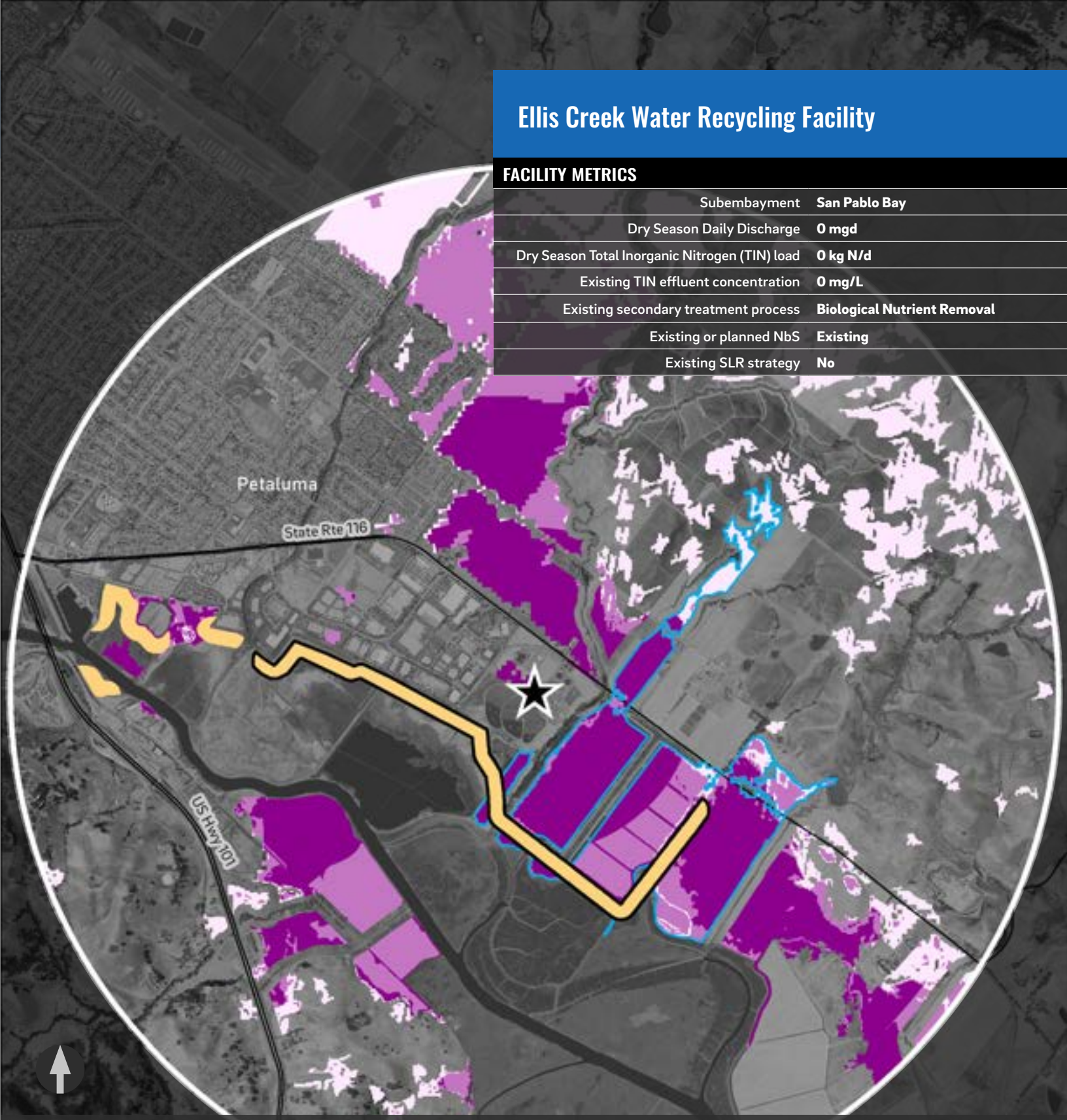
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	4 - 5.8 km
Total Potential Flow Capacity	6.9 - 9.8 mgd
Total TIN Reduction Potential	520 - 750 kg/day
Facility-Specific TIN Reduction	no dry weather discharge

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Moderate

Ellis Creek Water Recycling Facility

FACILITY METRICS

Subembayment	**San Pablo Bay**
Dry Season Daily Discharge	**0 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**0 kg N/d**
Existing TIN effluent concentration	**0 mg/L**
Existing secondary treatment process	**Biological Nutrient Removal**
Existing or planned NbS	**Existing**
Existing SLR strategy	**No**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

CITY OF PINOLE

NATURE-BASED TREATMENT SOLUTIONS

The Pinole-Hercules Water Pollution Control Plant discharges effluent to San Pablo Bay. The facility serves ~11,200 service connections in Pinole and Hercules - with a dry weather permitted capacity of 4.06 mgd. In 2019, the facility completed a major upgrade involving nitrification and reduction in total inorganic nitrogen loads. The agency has not considered NbS for nutrient management and is located on the immediate shoreline, thus subject to future flood risk.

Preliminary Findings

Several opportunities for both treatment types were identified, including some in close proximity to the Pinole facility. Together, the three highlighted open water wetland opportunities could reduce the nitrified TIN load by over 90%. The nearest horizontal levee opportunity could reduce TIN loads by 18%.

Opportunities & Constraints

The facility recently invested ~$45 million in treatment upgrades and data trends indicate decreasing TIN loading. Projected sea level rise impacts may present opportunities to partner on horizontal levees for flood risk reduction and additional water quality improvements, but are not under consideration at this time.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Moderate

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	86 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	8 - 30 acres
Total Potential Flow Capacity	0.7 - 2.6 mgd
Total TIN Reduction Potential	80 - 310 kg/day
Facility-Specific TIN Reduction	27% - over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.4 - 0.8 km
Total Potential Flow Capacity	0.7 - 1.4 mgd
Total TIN Reduction Potential	50 - 110 kg/day
Facility-Specific TIN Reduction	18% - 39%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	Moderate to High

Pinole-Hercules Water Pollution Control Plant

FACILITY METRICS

Subembayment	**San Pablo Bay**
Dry Season Daily Discharge	**2.3 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**280 kg N/d**
Existing TIN effluent concentration	**32 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**No**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

RODEO SANITARY DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Rodeo Sanitary District Water Pollution Control Facility discharges nitrified effluent to San Pablo Bay via an outfall shared with the cities of Pinole and Hercules. The facility serves a population of ~9,000 in Rodeo - with a dry weather permitted capacity of 1.14 mgd and average dry weather flows of ~0.5 mgd. The facility performs partial nitrification via activated sludge processes involving a high solids retention time. Despite its close proximity to the shoreline, modeling indicates the facility faces low future flood risk.

Preliminary Findings

Opportunities for open water wetlands were identified, though none in direct proximity to the Rodeo plant. Any one of the three highlighted open water wetland opportunities could reduce the nitrified TIN load by over 90%. No opportunities for horizontal levees were identified.

Opportunities & Constraints

This facility features limited opportunities for open water treatment wetlands or horizontal levees. Given its small size and low nutrient loading, significant nutrient reductions are unlikely in the near term. Future partnership opportunities may involve discharges to horizontal levees or recycled water projects for industrial or municipal use.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	169 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	9 - 58 acres
Total Potential Flow Capacity	0.7 - 5.2 mgd
Total TIN Reduction Potential	40 - 280 kg/day
Facility-Specific TIN Reduction	over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0 km
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	Moderate

Rodeo Sanitary District
Water Pollution Control Facility

FACILITY METRICS

Subembayment	**San Pablo Bay**
Dry Season Daily Discharge	**0.5 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**29 kg N/d**
Existing TIN effluent concentration	**14 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No response**
Existing SLR strategy	**No response**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SONOMA VALLEY COUNTY SANITATION DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Sonoma Valley County Sanitation District Wastewater Treatment Plant discharges to San Pablo Bay via Schell Slough or Hudeman Slough during the wet season. The facility serves ~17,500 connections in the City of Sonoma and surrounding communities - with average dry weather influent flow of ~2.7 mgd. During the dry season, virtually all flow is recycled. This a fully nitrifying plant and recycles dry season flows in partnership with vineyards and other farms.

Preliminary Findings

Several opportunities for both treatment types were identified, including some in close proximity to the facility. Any one of the three highlighted open water wetland opportunities could reduce total inorganic nitrogen (TIN) loads by over 90%. The horizontal levee opportunity could also reduce TIN loads by over 90%.

Opportunities & Constraints

This mapping and modeling exercise identified substantial opportunities to deploy NbS for wastewater treatment near this facility. Given that all dry weather flows are currently applied to land, the need for additional NbS strategies arises only if year-round nutrient removal was required and additional land application was not possible.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	3,122 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	16 - 66 acres
Total Potential Flow Capacity	1.4 - 5.8 mgd
Total TIN Reduction Potential	110 - 450 kg/day
Facility-Specific TIN Reduction	over 90%

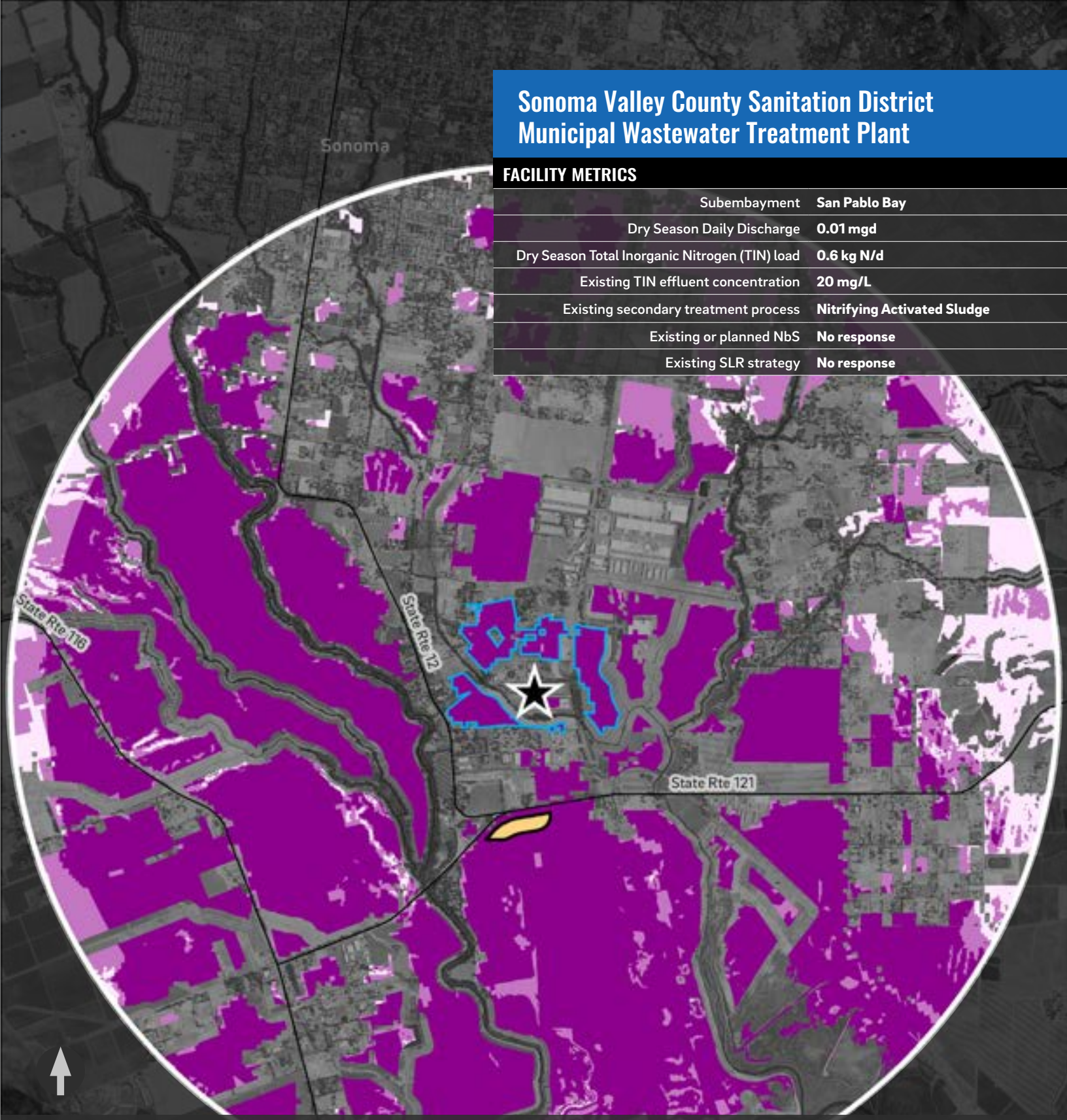
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.5 km
Total Potential Flow Capacity	0.8 mgd
Total TIN Reduction Potential	60 kg/day
Facility-Specific TIN Reduction	over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Moderate

Sonoma Valley County Sanitation District Municipal Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**San Pablo Bay**
Dry Season Daily Discharge	**0.01 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**0.6 kg N/d**
Existing TIN effluent concentration	**20 mg/L**
Existing secondary treatment process	**Nitrifying Activated Sludge**
Existing or planned NbS	**No response**
Existing SLR strategy	**No response**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

VALLEJO FLOOD AND WASTEWATER DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Vallejo Flood and Wastewater District Wastewater Treatment Plant discharges mostly non-nitrified effluent to San Pablo Bay. The facility serves ~38,000 connections in Vallejo and has a permitted dry weather capacity of 15.5 mgd and average dry season flows of ~8.5 mgd. Limited NbS options present themselves near this facility, though the redevelopment of Mare Island may present opportunities for implementation of nature-based solutions.

Preliminary Findings

A few opportunities for both treatment types were identified, though none in close proximity to the facility. Together, the three highlighted open water wetland opportunities could reduce the nitrified TIN load by about 25%. The nearest horizontal levee opportunity could reduce TIN loads by about 45%.

Opportunities & Constraints

It is not known whether opportunities on Mare Island are viable, based on existing infrastructure and hydraulics. Using horizontal levees for treatment could be viable, though nitrification requires capital intensive investments, based on the recommendations contained in the 2018 Nutrient Reduction Study by HDR.

Photo courtesy of Google Earth

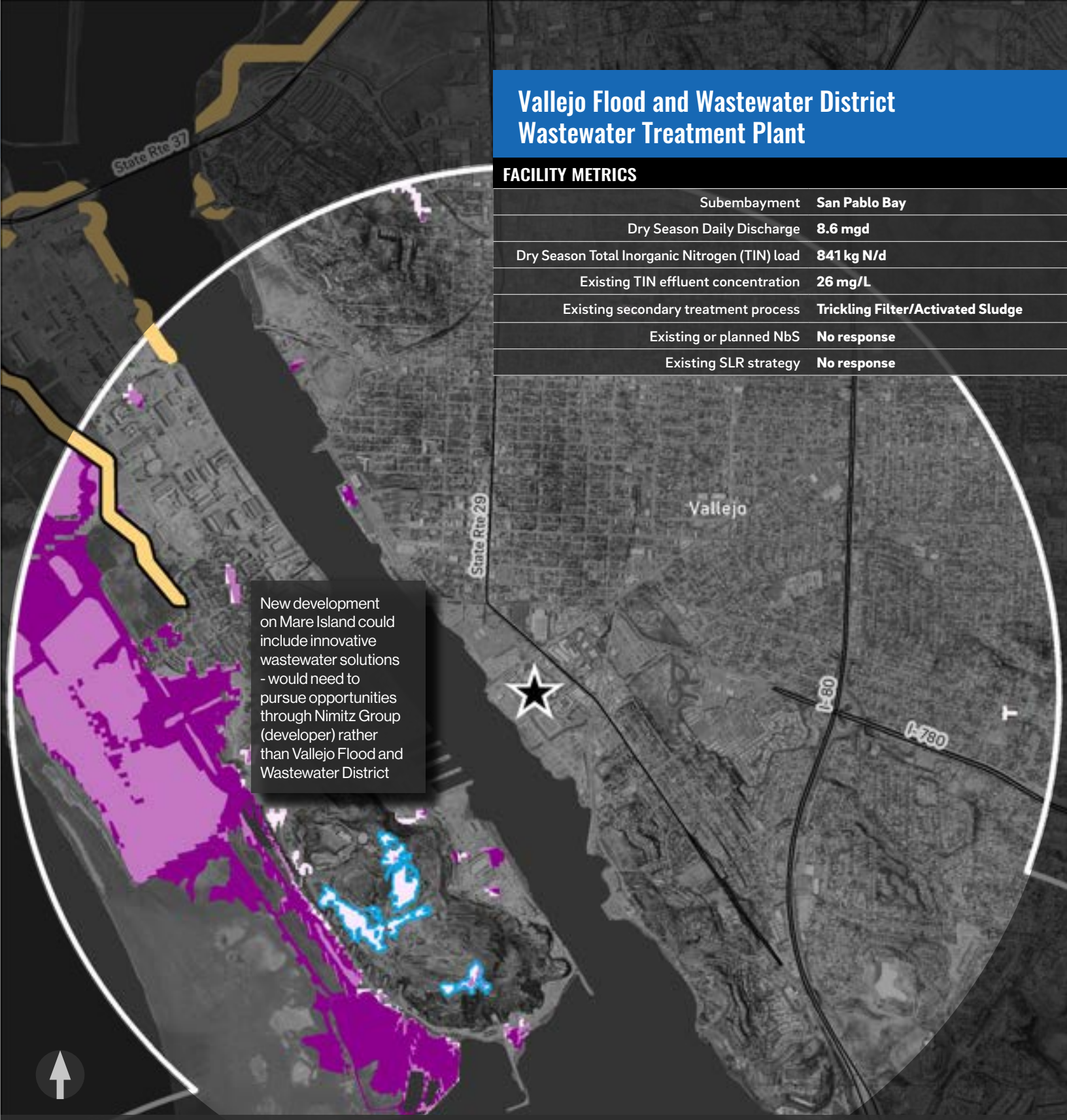
Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Moderate

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	550 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	4 - 27 acres
Total Potential Flow Capacity	0.3 - 2.3 mgd
Total TIN Reduction Potential	30 - 230 kg/day
Facility-Specific TIN Reduction	3% - 25%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	2.9 - 3.4 km
Total Potential Flow Capacity	4.9 - 5.8 mgd
Total TIN Reduction Potential	380 - 450 kg/day
Facility-Specific TIN Reduction	45% - 54%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	High



Vallejo Flood and Wastewater District Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**San Pablo Bay**
Dry Season Daily Discharge	**8.6 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**841 kg N/d**
Existing TIN effluent concentration	**26 mg/L**
Existing secondary treatment process	**Trickling Filter/Activated Sludge**
Existing or planned NbS	**No response**
Existing SLR strategy	**No response**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

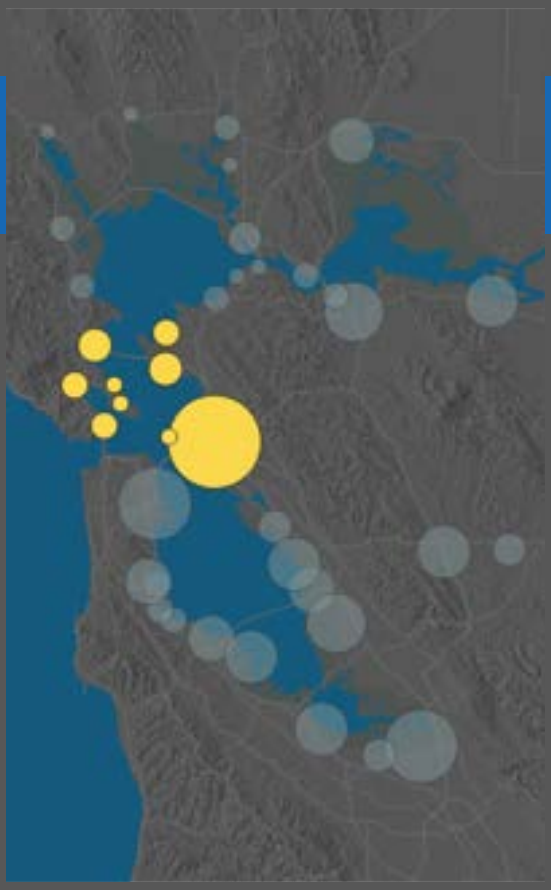
Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SUB-EMBAYMENT FOCUS

CENTRAL SF BAY



Nine water resource recovery facilities (WRRFs) discharge to Central San Francisco Bay, which roughly extends from the Richmond–San Rafael Bridge to the Bay Bridge, according to boundaries from the San Francisco Bay Basin Plan. The combined ADWF from those WRRFs is ~70 mgd and the dry season TIN load is ~12,300 kg N/d.

This preliminary analysis indicates low opportunity exists in the Central Bay to manage nutrients via nature-based solutions. On a cumulative basis, between 2% to 12% of the dry season TIN load could be managed with open water wetlands and horizontal levees could remove 7-23% of total TIN load from these nine facilities. Refer to Introduction, Nutrient Reduction Estimation Methods.

Despite geographic constraints, targeted projects and parternships could yield significant nutrient reductions in both the East Bay and Marin County.

Key Opportunities & Constraints

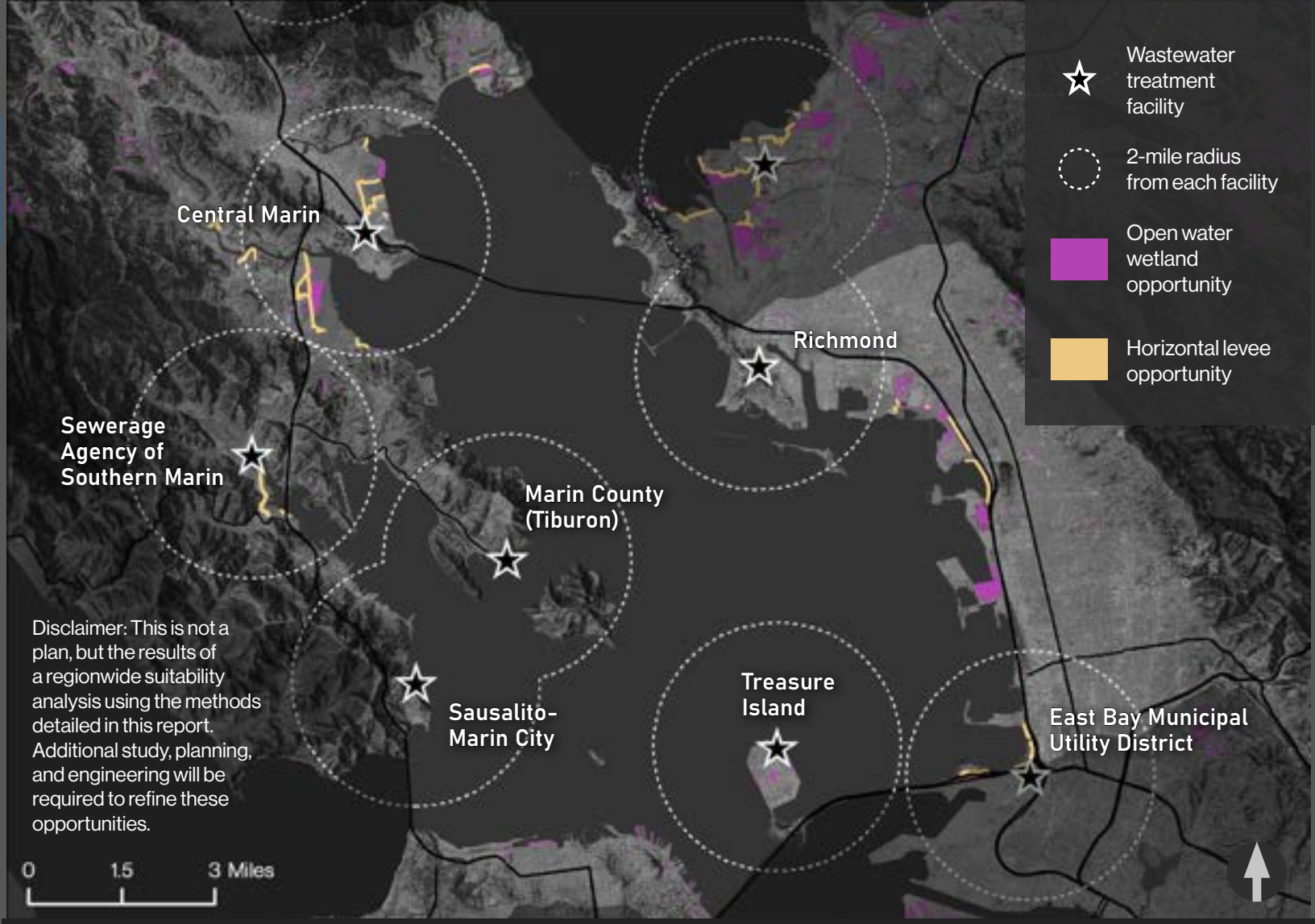
This analysis integrates existing geospatial data including physical opportunities (i.e. elevation, slope, habitat type) and general land use constraints (i.e. proximity to existing development or highly sensitive habitat types).

- Topography and urbanization represent key constraints for Central Bay facilities in Marin Co and the East Bay.
- The main discharger to the Central Bay, EBMUD, is highly constrained by its urban locale. The agency could rely on its extensive distribution system to partner on projects to the south and north. Closer options include horizontal levees in proximity to the Bay Bridge toll station and Emeryville Crescent.
- Marin County agencies have generally not explored nature-based treatment strategies. The topography around most Marin Co WRRFs, coupled with future flood risk, could increase future interest in partnerships with flood control agencies to deploy horizontal levees.
- West County, which faces considerable flood risk in the future, received Measure AA funding to design a 'living levee' project, using treated effluent for irrigation.
- Treasure Island is planning to install a polishing wetland as part of their WRRF replacement project.

Map (above, top)
Wastewater treatment facilities that discharge to Central SF Bay, in yellow, sized relative to average daily total inorganic nitrogen loads in the region.

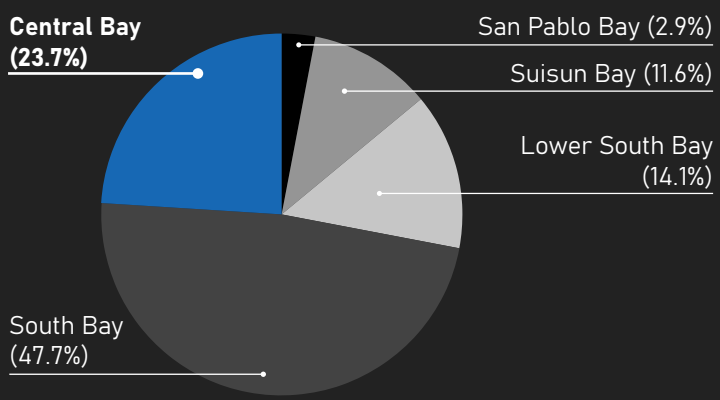
Photo (above, bottom)
View of the Bay Bridge on-ramp and EBMUD in the background during a King Tide event. Urbanization and future flood risk constrains opportunities for NbS deployment in the Central Bay. Photo courtesy Baykeeper and Lighthawk.

Map (facing page)
Overview of WRRFs discharging to Central SF Bay, including modeled outputs of areas potentially suitable for conversion to open water treatment wetlands or horizontal levees.



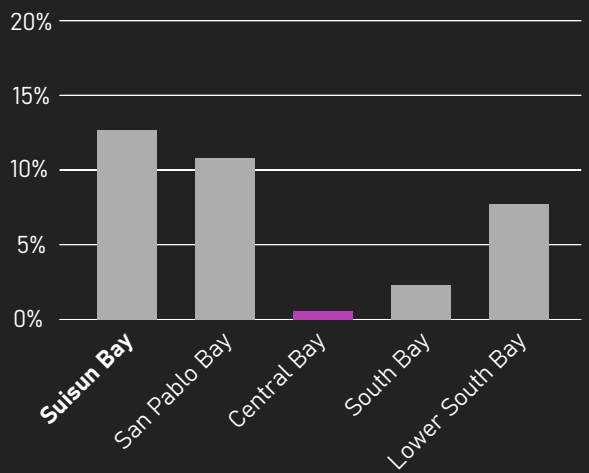
SUMMARY STATISTICS: CENTRAL SF BAY

Total Inorganic Nitrogen Load*



*total average dry season daily TIN load

Percent of area within 2 mi of a facility suitable for open water wetlands



7 - 22 km** of shoreline in Central SF Bay were identified as potentially suitable for **horizontal levees**, corresponding to a potential treatment capacity of **12 - 37 mgd****

**lower end of range: closest opportunity to each facility; higher end of range: all oppportunities within 2 miles of a facility

CENTRAL MARIN SANITATION AGENCY

NATURE-BASED TREATMENT SOLUTIONS

The Central Marin Sanitation Agency Wastewater Treatment Plant discharges non-nitrified effluent to Central SF Bay. The facility serves ~115,000 service connections in Marin Co. - with a dry weather permitted capacity of 10 mgd and average dry weather flow of ~6 mgd. This agency has not considered NbS for nutrient control and has some recycled water capacity. Opportunities for plant optimization for enhanced nitrification were identified in HDR's 2018 Nutrient Reduction Study.

Preliminary Findings

Several opportunities were identified for both horizontal levees and open water wetlands, though none are in direct proximity to the Central Marin facility. If multiple identified opportunities for NbS were implemented, nitrified TIN loads could be reduced by over 90%.

Opportunities & Constraints

This mapping exercise identified some locations likely infeasible due to distance from the facility. The potential horizontal levees shown to the north could hold promise if the Canalways site were to be restored to tidal marsh. Possibilities exist for future flood control partnerships and the likely need for nitrification could be addressed via optimization.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	79 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	9 - 66 acres
Total Potential Flow Capacity	0.7 - 5.9 mgd
Total TIN Reduction Potential	110 - 920 kg/day
Facility-Specific TIN Reduction	10% - 86%

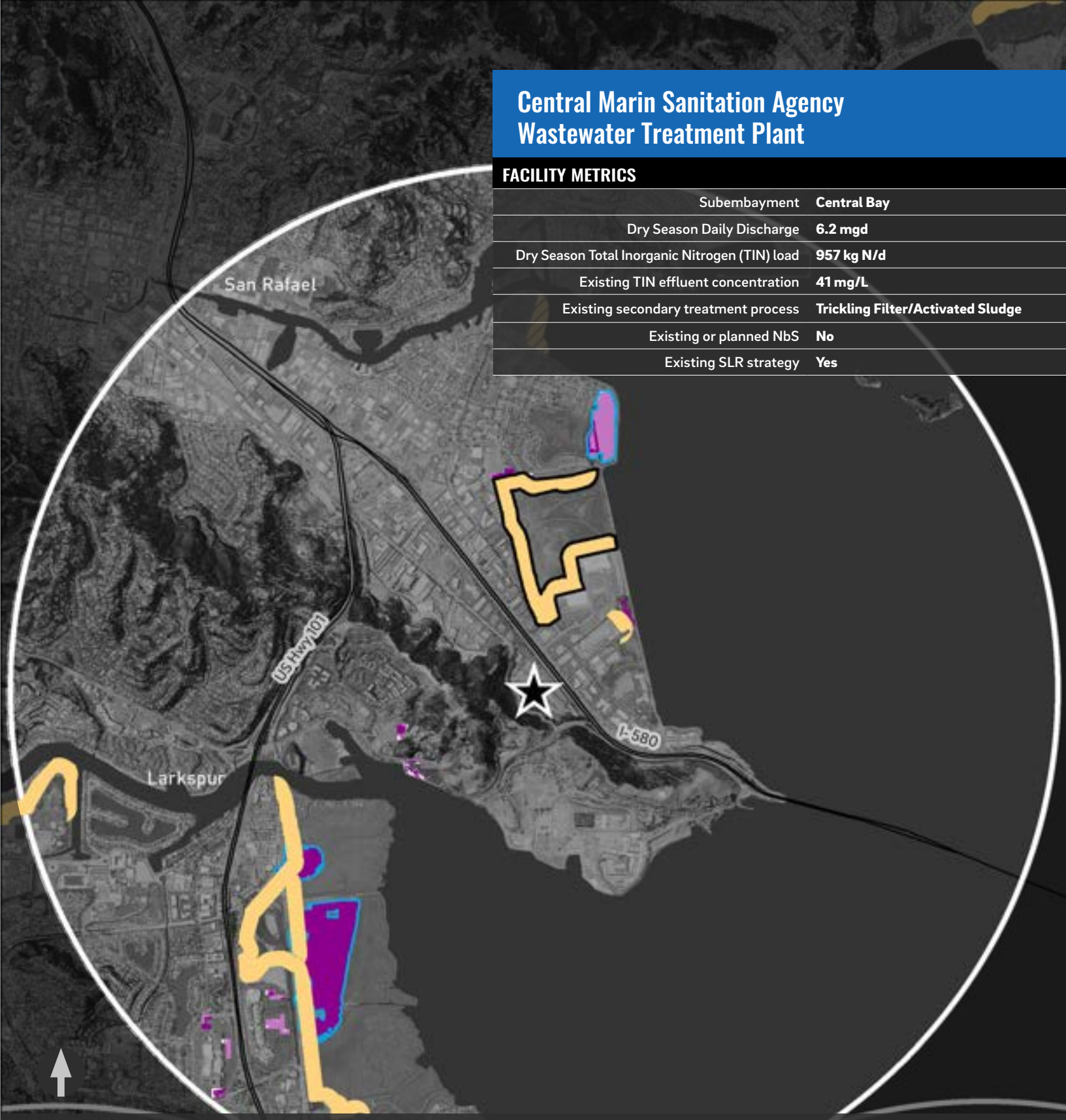
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	2.3 - 8.3 km
Total Potential Flow Capacity	4 - 14.2 mgd
Total TIN Reduction Potential	300 - 1080 kg/day
Facility-Specific TIN Reduction	31% - over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	Moderate - High

Central Marin Sanitation Agency Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Central Bay**
Dry Season Daily Discharge	**6.2 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**957 kg N/d**
Existing TIN effluent concentration	**41 mg/L**
Existing secondary treatment process	**Trickling Filter/Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

EAST BAY MUNICIPAL UTILITY DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The EBMUD Wastewater Treatment Plant discharges non-nitrified effluent to Central SF Bay. The facility serves ~685,000 connections in Alameda and Contra Costa County, including industrial dischargers - with a dry weather permitted capacity of 120 mgd and ADWF of ~50 mgd. EBMUD is evaluating nutrient management options and has piloted emerging technologies. Opportunities for NbS are limited by the urban footprint though partnership opportunities likely exist.

Preliminary Findings

Few opportunities for open water wetlands were identified in the highly urban area around the EBMUD plant, though there may be opportunity for horizontal levees in close proximity to the facility. If these horizontal levees were constructed, nitrified TIN loads could be reduced by about 3%.

Opportunities & Constraints

EBMUD's facility is extremely constrained by its geography. Yet its distribution network for recycled and wet weather flows opens the possibility to partner with agencies to the north and south. Levees at Emeryville Crescent may be a viable flood protection strategy and collaboration with EBDA agencies could prove beneficial.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Low
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	6 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	0 acres
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.1 - 2.5 km
Total Potential Flow Capacity	1.9 - 4.2 mgd
Total TIN Reduction Potential	140 - 320 kg/day
Facility-Specific TIN Reduction	1% - 3%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	High

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

East Bay Municipal Utility District, Special District No. 1 Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Central Bay**
Dry Season Daily Discharge	**47.0 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**9,442 kg N/d**
Existing TIN effluent concentration	**53 mg/L**
Existing secondary treatment process	**High Purity Oxygen Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**

EBMUD is willing to pursue partnerships with Caltrans, MTC, the Port of Oakland, and/or other agencies on multibenefit sea-level rise adaptation projects in the area

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Worth exploring

0 0.5 1 mi

0.5 1 km

MARIN COUNTY, TIBURON

NATURE-BASED TREATMENT SOLUTIONS

Sanitary District No.5 of Marin County's Tiburon Wastewater Treatment Plan discharges non-nitrified effluent to Central SF Bay. The facility serves ~3,500 connections from the Tiburon Peninsula and City of Belvedere - with a dry weather permitted capacity of 0.98 mgd and average dry season flow of ~0.5 mgd. The facility is designated as a minor discharger (permitted capacity <1.0 mgd) and given the topography of the site is not exposed to projected sea level rise-related flooding.

Preliminary Findings

Few opportunities for nature-based treatment systems were identified. One acre of potentially available area for an open-water treatment wetland was identified to the northwest of the facility.

Opportunities & Constraints

This facility does not feature any significant NbS opportunities for treatment largely due to the steep gradients of the surrounding area on the Tiburon Peninsula. Future opportunities may involve partnerships on flood protection levees or land application to nearby open space areas, yet agencies have not identified projects.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Low
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	1 acre
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	0 acres
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

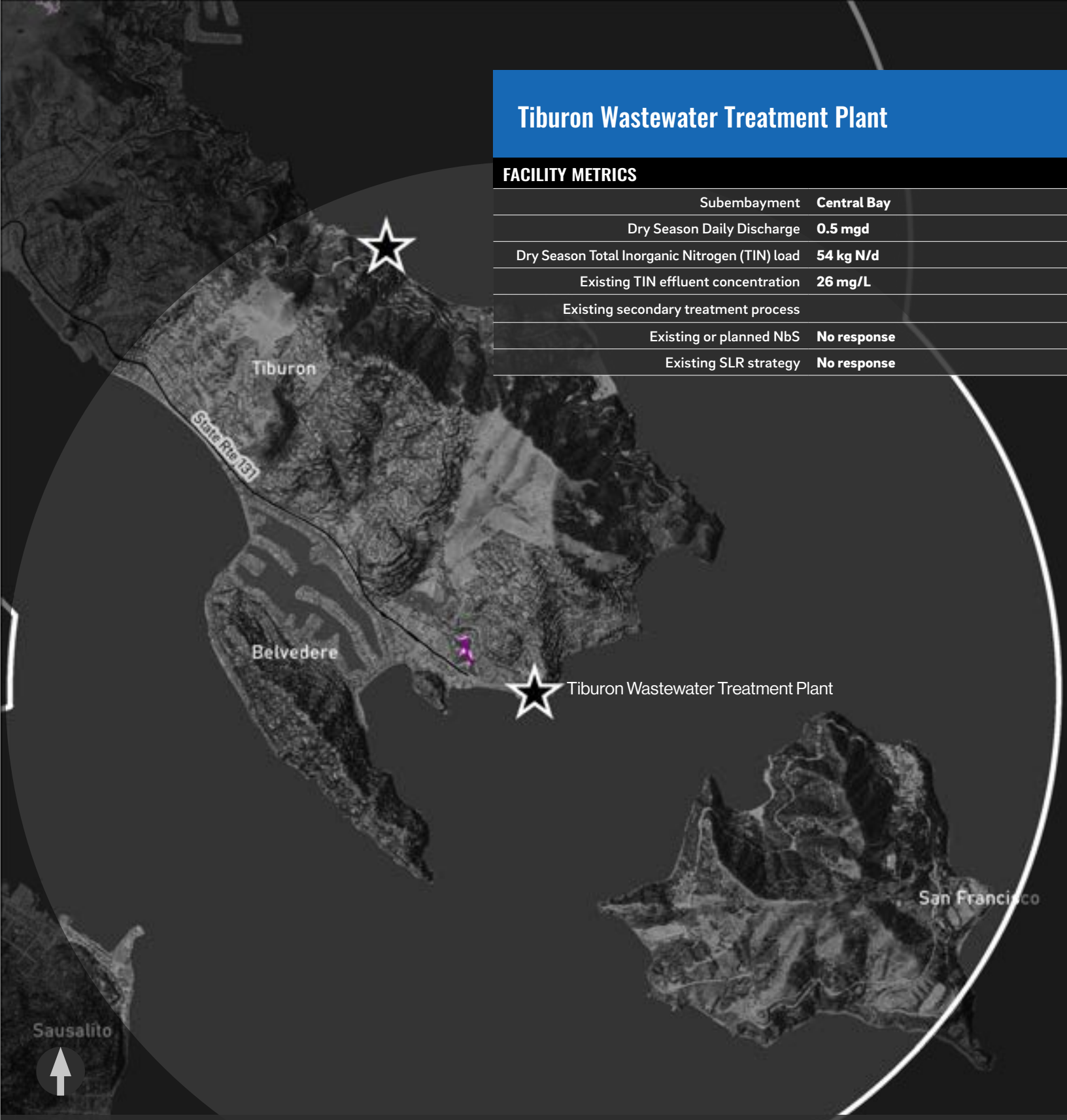
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0 km
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	None
Land Use/Regulatory Conflicts	N/A

Tiburon Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Central Bay**
Dry Season Daily Discharge	**0.5 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**54 kg N/d**
Existing TIN effluent concentration	**26 mg/L**
Existing secondary treatment process	
Existing or planned NbS	**No response**
Existing SLR strategy	**No response**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

RICHMOND MUNICIPAL SEWER DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Richmond Municipal Sewer District Water Pollution Control Plant discharges non-nitrified effluent to Central SF Bay via a common Outfall with West County Wastewater District. The facility serves ~20,000 connections in the City of Richmond - with a dry weather permitted capacity of 16 mgd and recent average dry weather flows of ~4.8 mgd. This facility has not considered NbS for wastewater treatment, yet has expressed interest in potential partnerships.

Preliminary Findings

Opportunities for open water wetlands were identified, though at quite a distance from the Richmond plant. Together, the three highlighted open water wetland opportunities could reduce the nitrified TIN load by about 55%. No opportunities for horizontal levees were identified.

Opportunities & Constraints

Significant NbS opportunities for treatment were not found, largely due to the steep gradients of the surrounding area on Point Potrero. Potential partnership opportunities involve discharge to horizontal levees closer to West County's facility, or possible collaboration with Chevron, which owns the areas of open water wetland opportunities.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Moderate
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	54 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	8 - 33 acres
Total Potential Flow Capacity	0.7 - 2.9 mgd
Total TIN Reduction Potential	90 - 370 kg/day
Facility-Specific TIN Reduction	13% - 55.%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0 km
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	Moderate

Richmond Municipal Sewer District Water Pollution Control Plant

FACILITY METRICS

Subembayment	**Central Bay**
Dry Season Daily Discharge	**4.8 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**649 kg N/d**
Existing TIN effluent concentration	**34**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**No**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SAUSALITO-MARIN CITY SANITARY DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Sausalito-Marin City Sanitary District Wastewater Treatment Plant discharges partially nitrified effluent to Central SF Bay. The facility serves ~6,500 connections in Sausalito and surrounding areas - with a permitted dry weather capacity of 1.8 mgd and average dry season flow of ~1.1 mgd. The facility has not evaluated NbS to date and is highly constrained due to adjacent topography its position between SF Bay and the Golden Gate National Recreation Area.

Preliminary Findings

No opportunities for nature-based treatment systems were identified.

Opportunities & Constraints

This facility does not feature any significant NbS opportunities for treatment based largely on the steep gradients of the surrounding area between Sausalito and Pt. Cavallo. Potential future partnership opportunities may involve discharge to horizontal levees along Richardson Bay, yet agencies have not identified projects to date.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Low
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	0 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	0 acres
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0 km
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	None
Land Use/Regulatory Conflicts	N/A

Sausalito-Marin City Sanitary District Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Central Bay**
Dry Season Daily Discharge	**1.1 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**140 kg N/d**
Existing TIN effluent concentration	**34 mg/L**
Existing secondary treatment process	**Trickling Filter**
Existing or planned NbS	**No**
Existing SLR strategy	**No**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SEWERAGE AGENCY OF SOUTHERN MARIN

NATURE-BASED TREATMENT SOLUTIONS

The Sewerage Agency of Southern Marin (SASM) Wastewater Treatment Plant discharges partially nitrified effluent to Central SF Bay. The facility serves ~29,000 people through six member agencies in S. Marin Co. - with a dry weather permitted capacity of 3.6 mgd ADWF and average dry weather flow of ~2.0 mgd. The facility has not evaluated NbS to date and is subject to considerable risk of future flooding. SASM recently completed a rehabilitation project.

Preliminary Findings

Opportunities for horizontal levees were identified near the facility. The nearest horizontal levee opportunity could reduce nitrified TIN loads by 57%. If all horizontal levees opportunities shown were implemented, TIN loads could be reduced by over 90%. No opportunities for open water wetlands over 5 acres were identified.

Opportunities & Constraints

The recently completed rehabilitation project reportedly improved nitrification capacity, which reduces a hurdle of preparing effluent for NbS application. Implementation of horizontal levees along Richardson Bay could yield significant nutrient removal benefits and reduce sea level rise related flood risk in Mill Valley and adjacent areas.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Low
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	7 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	0 acres
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.8 - 2 km
Total Potential Flow Capacity	1.4 - 3.4 mgd
Total TIN Reduction Potential	100 - 260 kg/day
Facility-Specific TIN Reduction	57% - over 90%

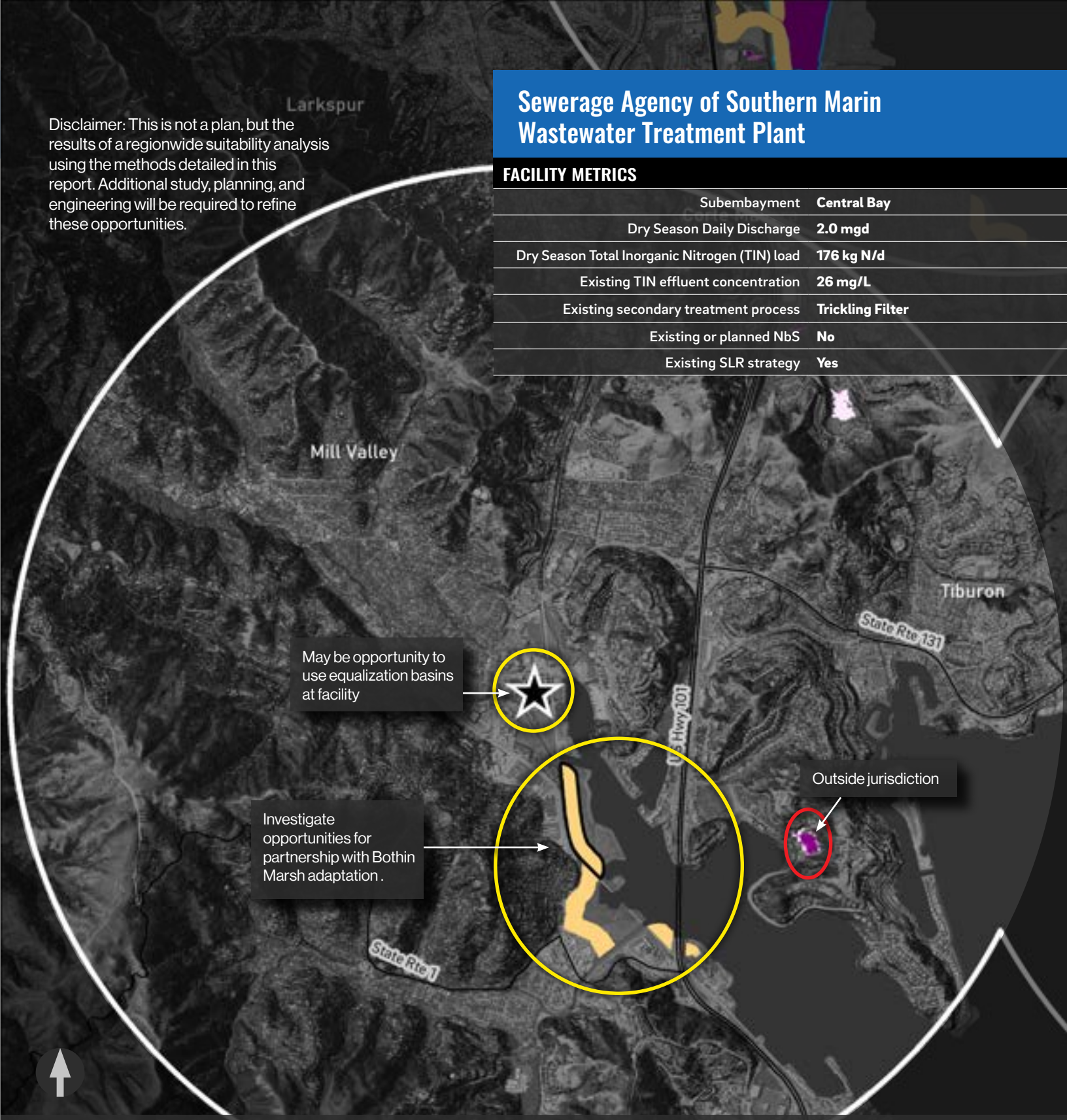
Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	High

Sewerage Agency of Southern Marin Wastewater Treatment Plant

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

FACILITY METRICS

Subembayment	**Central Bay**
Dry Season Daily Discharge	**2.0 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**176 kg N/d**
Existing TIN effluent concentration	**26 mg/L**
Existing secondary treatment process	**Trickling Filter**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Likely infeasible

Worth exploring

0 0.5 1 mi

0.5 1 km

TREASURE ISLAND

NATURE-BASED TREATMENT SOLUTIONS

The Navy plans to transfer ownership of Treasure Island's wastewater facility to the City and County of San Francisco. The SFPUC is currently the contract operator of the facility. Redevelopment of Treasure Island involves construction of a new facility, the Treasure Island Water Resource Recovery Facility, which is planned to provide secondary treatment by means of a membrane bioreactor (MBR) for average dry weather flow of 1.3 mgd. Effluent in excess of recycled water demands will be routed through constructed polishing wetlands.

Preliminary Findings

A few opportunities for open water wetlands were identified. If implemented, the largest open water wetland opportunity could reduce the nitrified TIN load by over 90%. No opportunities for horizontal levees were identified.

Opportunities & Constraints

The Treasure Island Redevelopment Agency and SFPUC is constructing a new plant that includes provision for an open water polishing wetland. Details are not available to inform projected nutrient load reduction, yet expansion of recycled water and polishing wetlands are projected to manage loads as redevelopment progresses.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	14 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	7 acres
Total Potential Flow Capacity	0.6 mgd
Total TIN Reduction Potential	30 kg/day
Facility-Specific TIN Reduction	over 90%

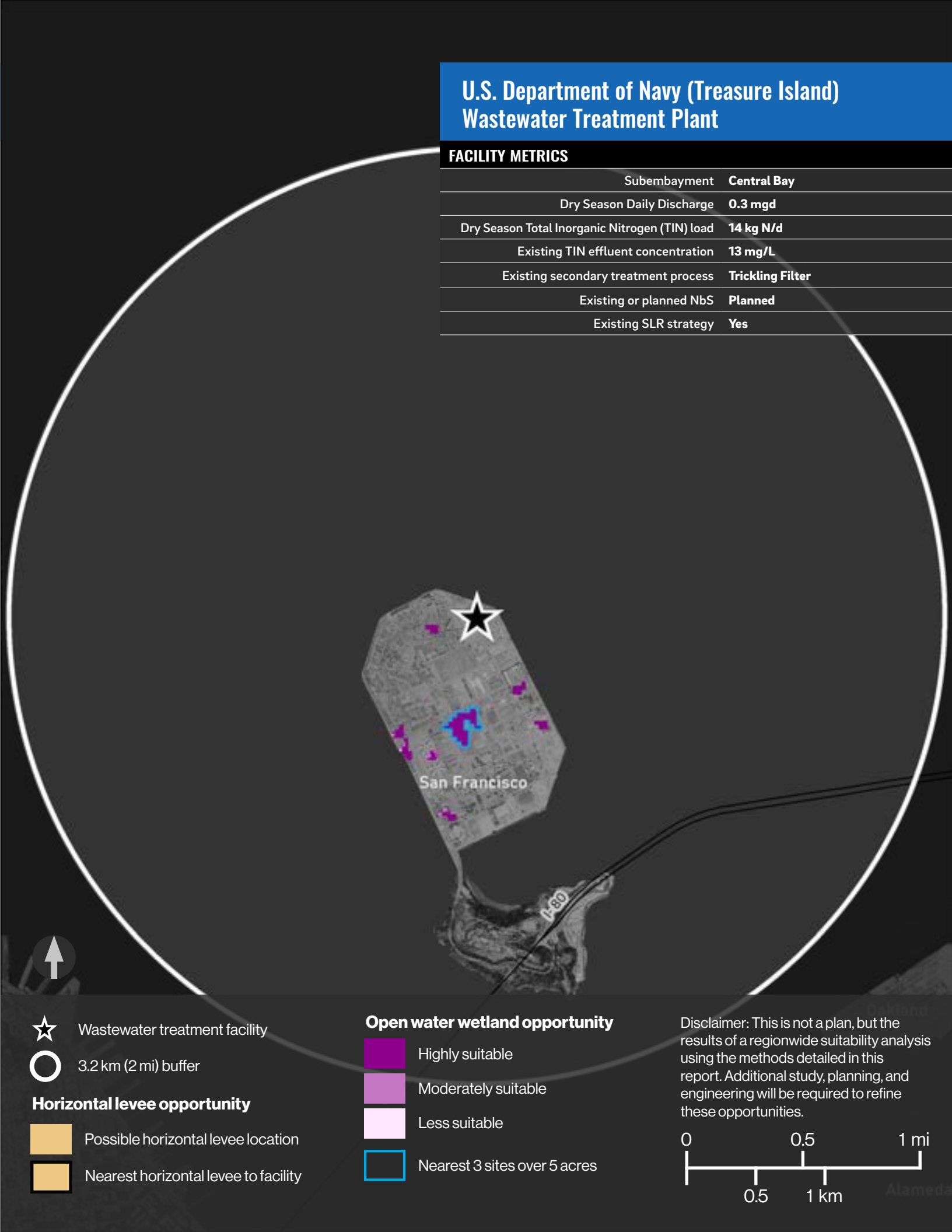
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0 km
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	Low

U.S. Department of Navy (Treasure Island) Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**Central Bay**
Dry Season Daily Discharge	**0.3 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**14 kg N/d**
Existing TIN effluent concentration	**13 mg/L**
Existing secondary treatment process	**Trickling Filter**
Existing or planned NbS	**Planned**
Existing SLR strategy	**Yes**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

WEST COUNTY WASTEWATER DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The West County Wastewater District Treatment Plant discharges partially nitrified effluent to Central SF Bay via a common Outfall with Richmond Municipal Sewer District. The facility serves ~32,300 connections in San Pablo, Richmond and adjacent areas - with a dry weather permitted capacity of 12.5 mgd and recent average dry weather flow of ~6.5 mgd. Recent upgrades have improved nitrification, nutrient removal, and wastewater recycling capacities.

Preliminary Findings

Several opportunities for both treatment types were identified, including some adjacent to the West County facility. Together, the three highlighted open water wetland opportunities nearest the plant could reduce the nitrified TIN load by about 80%. The nearest horizontal levee opportunity could reduce TIN loads by 43%.

Opportunities & Constraints

The facility recently implemented biological nutrient removal, reducing nutrient concentrations, and routes ~80% of its flow to Chevron. With Measure AA funding, this agency is currently planning and designing horizontal levee alternatives, with potential for cooperation with flood control agencies, industry and other wastewater agencies.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	277 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	8 - 64 acres
Total Potential Flow Capacity	0.7 - 5.7 mgd
Total TIN Reduction Potential	20 - 170 kg/day
Facility-Specific TIN Reduction	10% - 79%

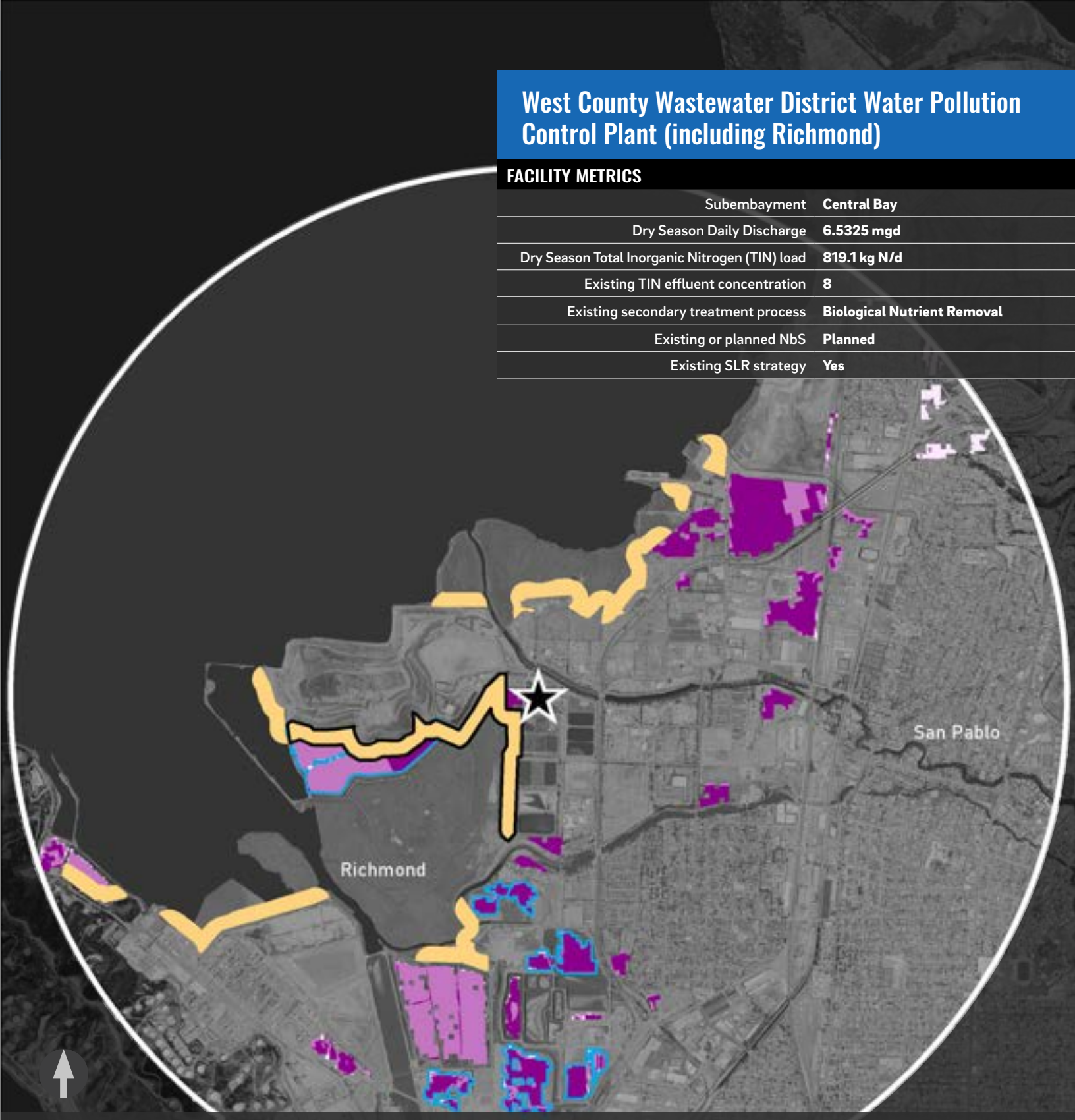
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	2.7 - 8.7 km
Total Potential Flow Capacity	4.6 - 14.8 mgd
Total TIN Reduction Potential	350 - 1,130 kg/day
Facility-Specific TIN Reduction	43% - over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	HIgh
Land Use/Regulatory Conflicts	High

West County Wastewater District Water Pollution Control Plant (including Richmond)

FACILITY METRICS

Subembayment	**Central Bay**
Dry Season Daily Discharge	**6.5325 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**819.1 kg N/d**
Existing TIN effluent concentration	**8**
Existing secondary treatment process	**Biological Nutrient Removal**
Existing or planned NbS	**Planned**
Existing SLR strategy	**Yes**



☆ Wastewater treatment facility

○ 3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SUB-EMBAYMENT FOCUS

SOUTH SF BAY

Thirteen water resource recovery facilities (WRRFs) discharge to South San Francisco Bay, which roughly extends from the Bay Bridge to the Dumbarton Bridge, according to boundaries from the San Francisco Bay Basin Plan. The combined ADWF is ~150 mgd and the dry season TIN load is ~24,700 kg N/d.

This preliminary analysis indicates moderate opportunity in the South Bay to manage nutrients via nature-based solutions. On a cumulative basis, between 8% to 55% of the dry season TIN load could be managed with open water wetlands and horizontal levees could remove 7-25% of total TIN load from these thirteen facilities. Refer to Introduction, Nutrient Reduction Estimation Methods.

Most of the potentially suitable land for conversion to nature-based treatment solutions is located in the East Bay. Options in San Francisco and San Mateo County are quite limited and likely requires partnerships to facilitate water transfers to areas with the greatest opportunity.

Key Opportunities & Constraints

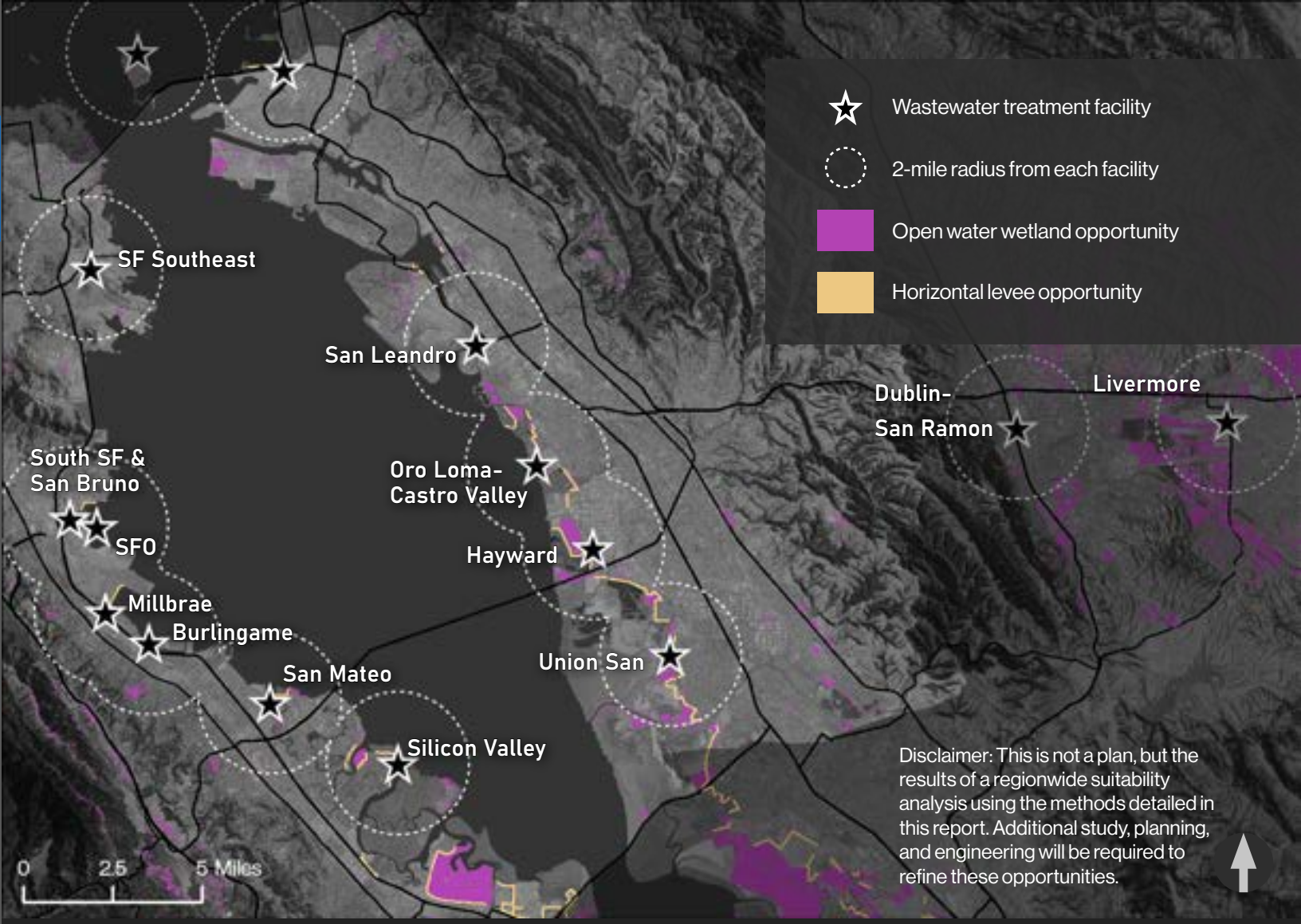
This analysis integrates existing geospatial data including physical opportunities (i.e. elevation, slope) and general land use constraints (i.e. proximity to existing development or highly sensitive habitat).

- Many South Bay cities are threatened by current and future flooding - prompting several several flood risk reduction and sea level rise adaptation projects. Cooperation among participating agencies represents a significant barrier to discharging wastewater to horizontal levees for treatment. This is particularly the case in San Mateo Co, where traditional levees and sea walls are in the advanced planning or implementation phases.
- East Bay Dischargers Authority agencies carry high potential for both open water wetlands and horizontal levees. Existing distribution infrastructure makes them well suited for partnership, potentially including EBMUD.
- Oro Loma was the first to pilot horizontal levees for treatment and is evaluating significant expansion. San Leandro is in advanced planning for a hybrid open water and seepage slope treatment system.
- Union Sanitary was among the first WRRFs to pursue NbS for wastewater discharge but recently ceased discharge to Hayward Marsh.

Map (above, top)
Wastewater treatment facilities that discharge to South SF Bay, in yellow, sized relative to average daily total inorganic nitrogen loads in the region.

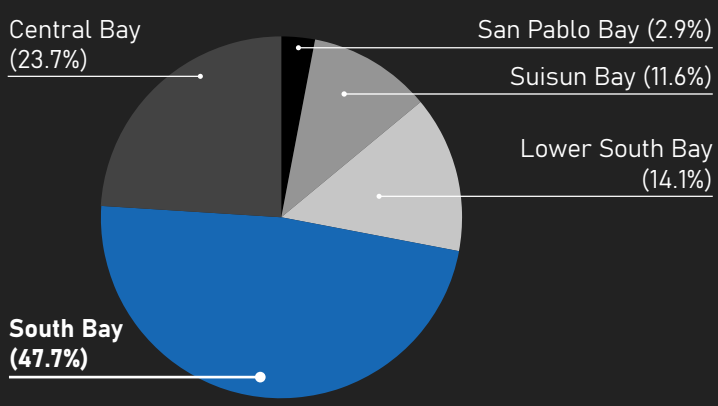
Photo (above, bottom)
View of Oro Loma Sanitary District's horizontal levee pilot project and experimental system to evaluate optimal design configurations.

Map (facing page)
Overview of WRRFs discharging to South SF Bay, including modeled outputs of areas potentially suitable for conversion to open water treatment wetlands or horizontal levees.



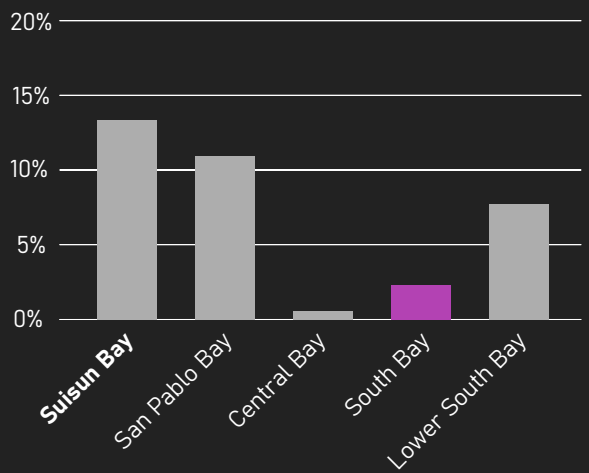
SUMMARY STATISTICS: SOUTH SF BAY

Total Inorganic Nitrogen Load*



*total average dry season daily TIN load

Percent of area within 2 mi of a facility suitable for open water wetlands



12 - 47 km** of shoreline in South SF Bay were identified as potentially suitable for **horizontal levees**, corresponding to a potential treatment capacity of **21 - 81 mgd****

**lower end of range: closest opportunity to each facility; higher end of range: all oppportunities within 2 miles of a facility

CITY OF BURLINGAME

NATURE-BASED TREATMENT SOLUTIONS

The Burlingame Wastewater Treatment Facility discharges non-nitrified effluent to South San Francisco Bay. The facility serves a population of ~37,000 in Burlingame and a portion of Hillsborough - with a dry weather permitted capacity of 5.5 mgd and average dry season flow of 2.6 mgd. Given the urban density of surrounding lands, limited opportunities for nature-based treatment exist, though horizontal levees may be viable, in coordination with surrounding agencies.

Preliminary Findings

Few opportunities for nature-based treatment systems were identified, and none in direct proximity to the facility. However, if logistical hurdles were overcome to implement either of the identified opportunities, each would have the capacity to greatly reduce total inorganic nitrogen discharges at the Burlingame plant.

Opportunities & Constraints

Opportunity for horizontal levees are shown adjacent to SFO, near the Millbrae facility, though the airport has indicated it will pursue traditional sea walls in an effort to minimize habitat expansion and associated bird strike risk. Open water wetland areas shown here are likely impractical given the distance to the facility.

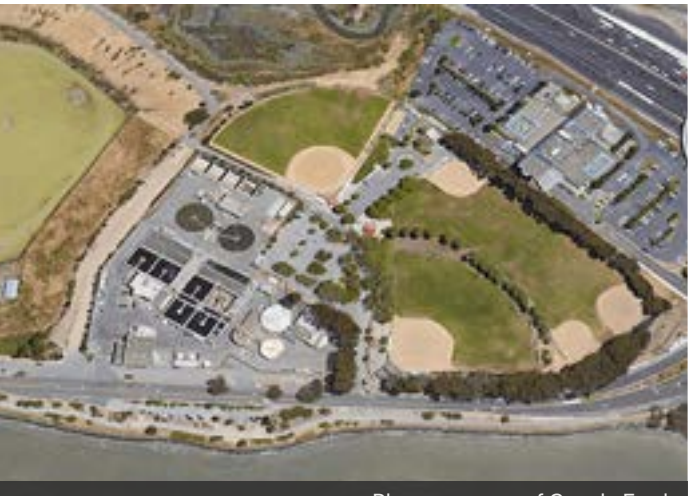


Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Moderate

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	74 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	55 acres
Total Potential Flow Capacity	4.9 mgd
Total TIN Reduction Potential	640 kg/day
Facility-Specific TIN Reduction	over 90%

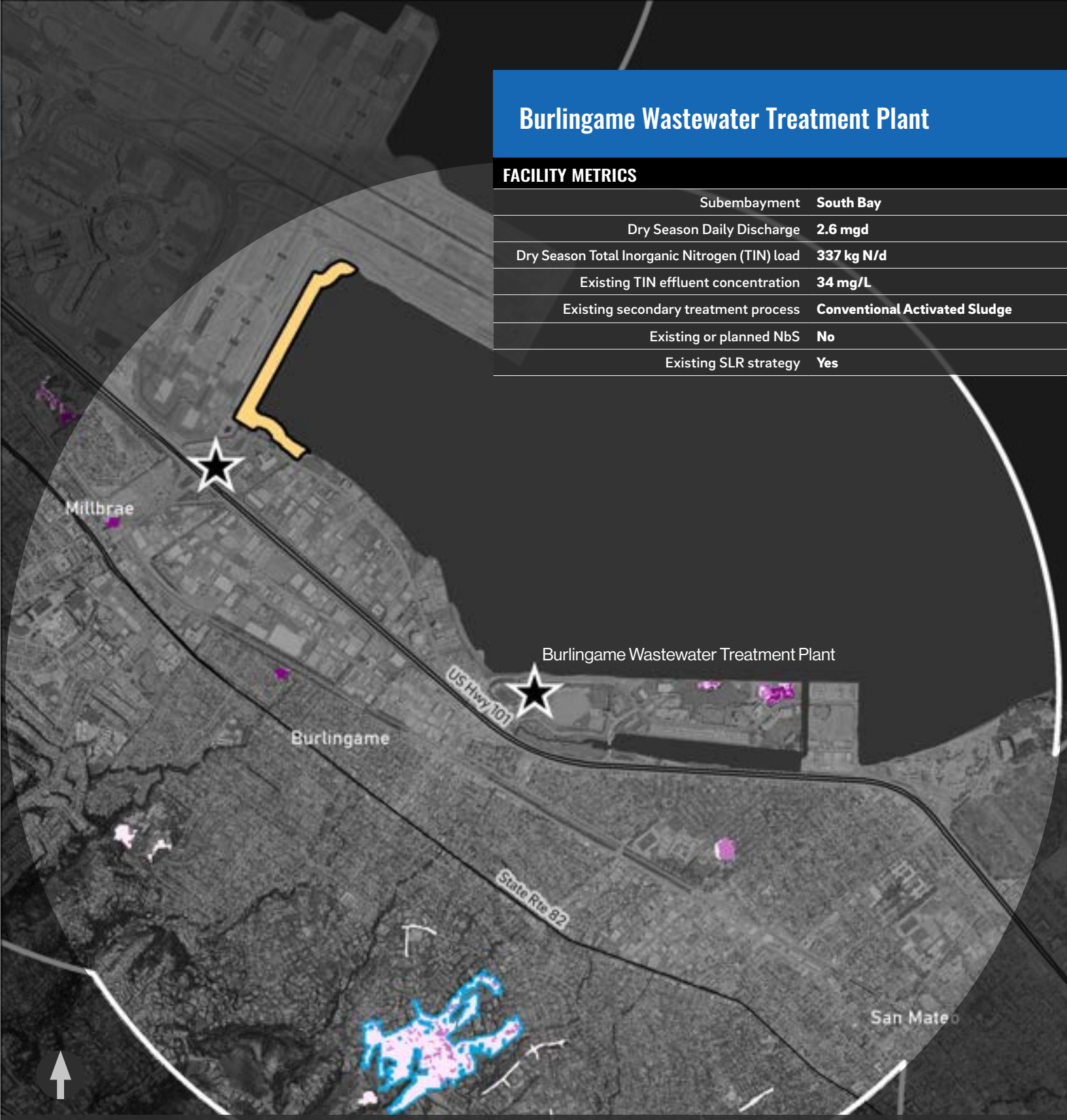
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.7 km
Total Potential Flow Capacity	3 mgd
Total TIN Reduction Potential	230 kg/day
Facility-Specific TIN Reduction	68%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	High

Burlingame Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**2.6 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**337 kg N/d**
Existing TIN effluent concentration	**34 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

DUBLIN-SAN RAMON SERVICES DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Dublin San Ramon Sanitary District Wastewater Treatment Plant discharges to South SF Bay via EBDA's common outfall. The facility serves 53,500 service connections in San Ramon, Dublin and Pleasanton - with a dry weather permitted capacity of 23.9 mgd. The facility has not considered NbS for wastewater treatment to date. The facility recycles and annual average of ~2 mgd for landscape irrigation and plans to double this volume over the next decade.

Preliminary Findings

Several opportunities for open water wetlands were identified, though none are in close proximity to the Dublin-San Ramon facility. The smallest of the three highlighted open water wetland opportunities could reduce the nitrified TIN load by about 11%. Together, the three highlighted sites could reduce TIN loads by about 37%.

Opportunities & Constraints

Given its inland location, sea level rise is not an issue for this facility and locations potentially suitable for open water wetlands are distributed. Increased wastewater recycling for land application or potable use may represent sustainable options in the future, given the distance to discharge via LAVWMA and EBDA.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Moderate
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	167 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	14 - 43 acres
Total Potential Flow Capacity	1.2 - 3.8 mgd
Total TIN Reduction Potential	260 - 810 kg/day
Facility-Specific TIN Reduction	11% - 37%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0 km
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	Moderate

Dublin San Ramon Services District Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**9.5 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**1,292 kg N/d**
Existing TIN effluent concentration	**56 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No response**
Existing SLR strategy	**No**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

CITY OF HAYWARD

NATURE-BASED TREATMENT SOLUTIONS

The Hayward Pollution Control Facility discharges non-nitrified effluent to South SF Bay via EBDA. The facility serves the majority of Hayward (pop ~159,000) - with a dry weather permitted capacity of 18.5 mgd and permitted peak flows of 35 mgd. Hayward has recently completed a conceptual SLR adaptation plan and is exploring NbS through an EPA grant. EBDA agencies may leverage existing infrastructure to explore partnership opportunities in EBDA's service area.

Preliminary Findings

Multiple opportunities for nature-based treatment systems were identified, including both horizontal levee and open-water wetland opportunities in close proximity to the facility. If implemented, nature-based strategies could reduce the nitrified TIN load by over 90%.

Opportunities & Constraints

Hayward is actively exploring the conversion of existing oxidation ponds to open water wetlands - representing a significant stand alone strategy. Levee potential suggests opportunities to partner with EBDA agencies and others. HDR's 2018 Nutrient Reduction Report indicates nitrification of requires significant investment at this facility.

Photo courtesy of City of Hayward

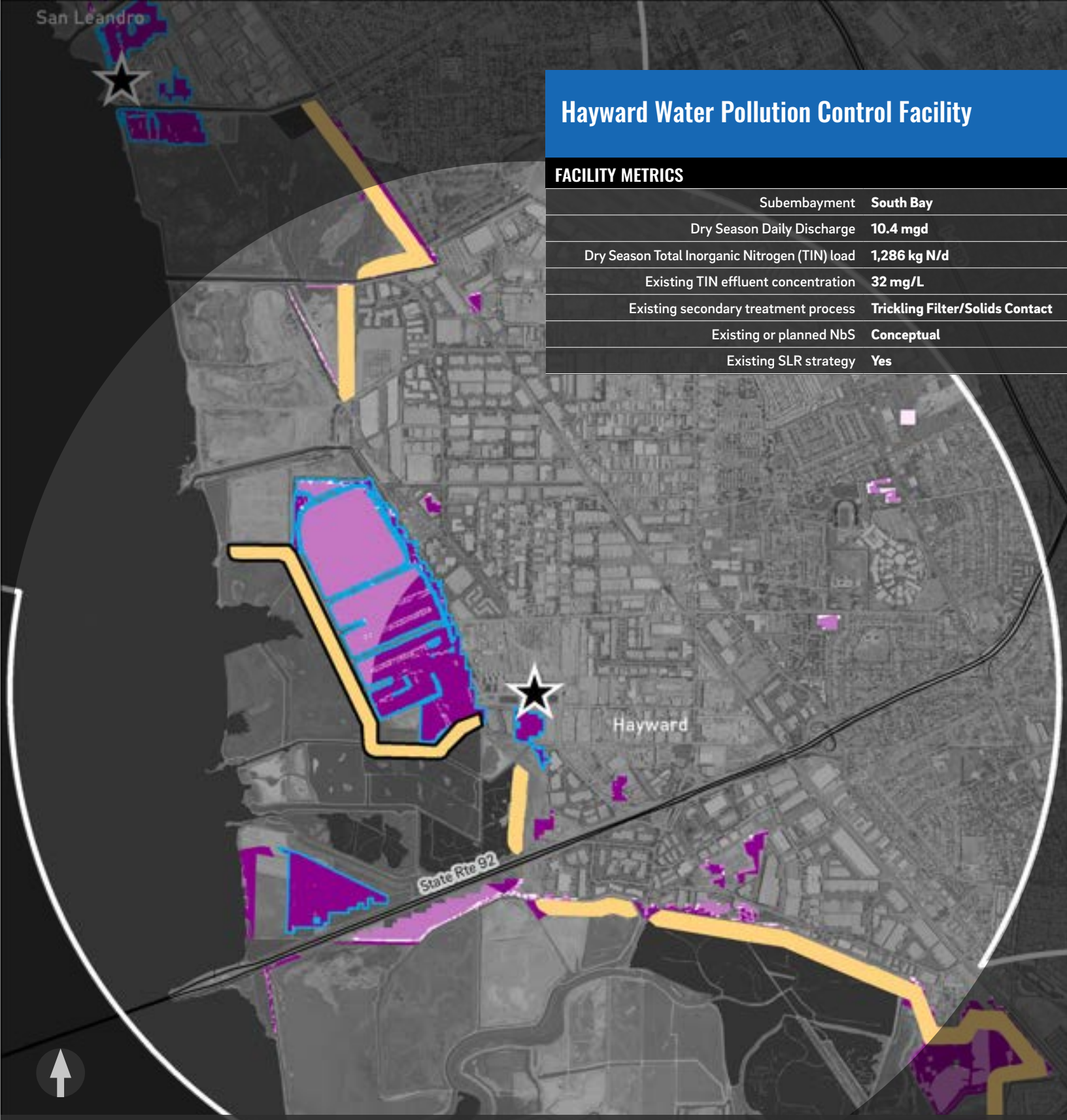
Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	308 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	7 - 222 acres
Total Potential Flow Capacity	0.6 - 19.7 mgd
Total TIN Reduction Potential	70 - 2,390 kg/day
Facility-Specific TIN Reduction	5% - over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	2.5 - 10.9 km
Total Potential Flow Capacity	4.3 - 18.6 mgd
Total TIN Reduction Potential	330 - 1,420 kg/day
Facility-Specific TIN Reduction	26% - over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	High



Hayward Water Pollution Control Facility

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**10.4 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**1,286 kg N/d**
Existing TIN effluent concentration	**32 mg/L**
Existing secondary treatment process	**Trickling Filter/Solids Contact**
Existing or planned NbS	**Conceptual**
Existing SLR strategy	**Yes**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

CITY OF LIVERMORE

NATURE-BASED TREATMENT SOLUTIONS

The Livermore Water Reclamation Plant discharges to South SF Bay via EBDA's common outfall. The facility serves Livermore, with a population of ~90,000 and a dry weather permitted capacity of 8.5 mgd. The facility has not considered NbS for wastewater treatment to date. Given its inland location, sea level rise is not a consideration. Livermore recycles ~6 mgd for landscape irrigation and fire protection applications and may increase this amount.

Preliminary Findings

Several opportunities for open water wetlands were identified, including some in close proximity to the Livermore facility. The smallest of the three highlighted open water wetland opportunities could reduce the nitrified TIN load by about 11%. Together, the three highlighted sites could reduce TIN loads by over 90%.

Opportunities & Constraints

This mapping exercise identified opportunities at nearby quarry ponds, though the viability of this option is unknown. Increased wastewater recycling for land application or potable use may represent sustainable options in the future, given the distance required to discharge via LAVWMA and EBDA to SF Bay.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	1,006 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	5 - 232 acres
Total Potential Flow Capacity	0.4 - 20.6 mgd
Total TIN Reduction Potential	70 - 3,690 kg/day
Facility-Specific TIN Reduction	11% - over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0 km
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

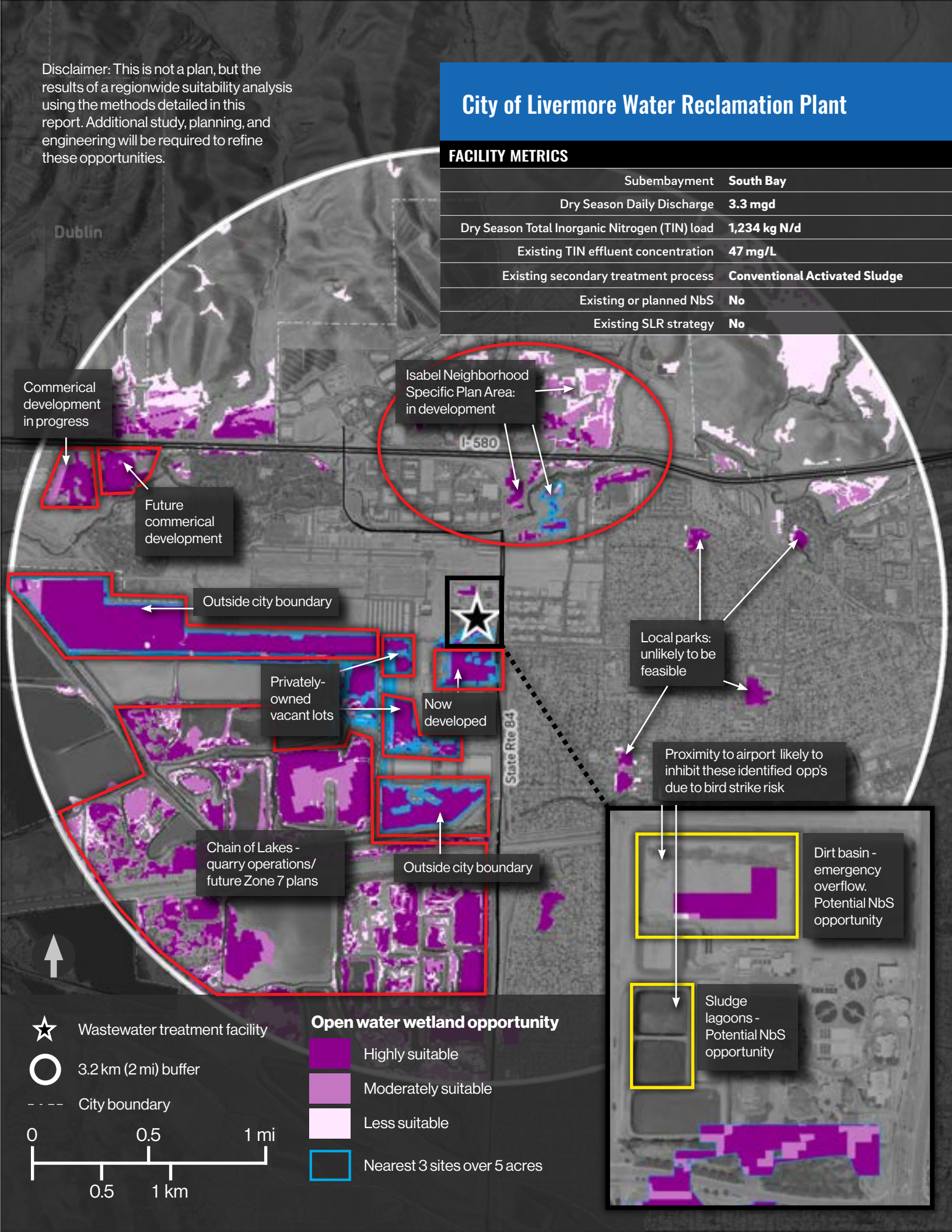
Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Moderate

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

City of Livermore Water Reclamation Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**3.3 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**1,234 kg N/d**
Existing TIN effluent concentration	**47 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**No**



CITY OF MILLBRAE

NATURE-BASED TREATMENT SOLUTIONS

The Millbrae Water Pollution Control Plant discharges non-nitrified effluent to South SF Bay. The facility serves ~6,550 connections in Millbrae - with a dry weather permitted capacity of 3.0 mgd and average dry season flow of 1.4 mgd. The facility maintains considerable exposure to sea level rise-related flooding and is highly constrained, geographically due to its proximity to Highway 101 and SFO airport, as discussed in HDR's 2018 Nutrient Reduction Study.

Preliminary Findings

One horizontal levee opportunity in close proximity to the facility was identified. If implemented, this horizontal levee could reduce the nitrified TIN load by nearly 90%. One site over 5 acres was identified as a possible open water wetland location; if implemented, this site could reduce TIN loads by more than 90%.

Opportunities & Constraints

Opportunity for horizontal levees are shown adjacent to SFO, though the airport has indicated it will pursue traditional sea walls in an effort to minimize habitat expansion and associated bird strike risk. Open water wetland areas shown here are likely impractical given the constrained conditions and distance to the facility.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

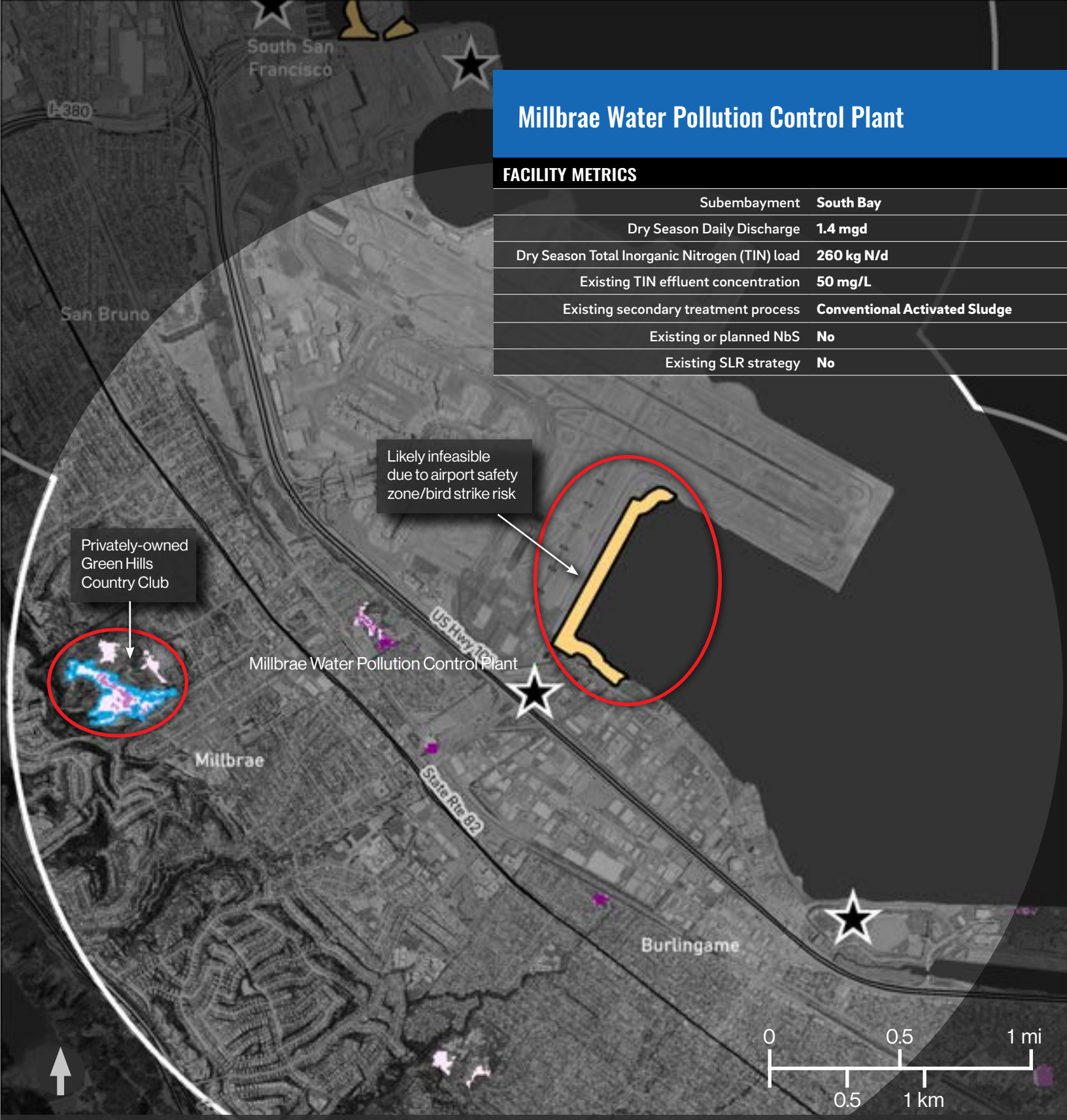
Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

*Model may overestimate opportunity, as local constraints are not accounted for

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	29 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	16 acres
Total Potential Flow Capacity	1.4 mgd
Total TIN Reduction Potential	270 kg/day
Facility-Specific TIN Reduction	over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.7 km
Total Potential Flow Capacity	3 mgd
Total TIN Reduction Potential	230 kg/day
Facility-Specific TIN Reduction	89%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	High



Millbrae Water Pollution Control Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**1.4 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**260 kg N/d**
Existing TIN effluent concentration	**50 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**No**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Likely infeasible

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

ORO LOMA-CASTRO VALLEY SANITARY DISTRICTS

NATURE-BASED TREATMENT SOLUTIONS

The Oro Loma/Castro Valley Wastewater Treatment Plant discharges to South SF Bay via EBDA. The facility serves ~47,000 connections in San Lorenzo, Castro Valley & surrounding areas - with a dry weather permitted capacity of 20 mgd. The facility piloted the region's first horizontal levee and completed a project in 2019 to fully nitrify its effluent. Planning efforts include significant expansion of horizontal levees.

Preliminary Findings

Several opportunities for both treatment types were identified, including some in close proximity to the Oro Loma facility. Together, the three highlighted open water wetland opportunities could reduce the nitrified TIN load by about 30%. The nearest horizontal levee opportunity could reduce TIN loads by 13%.

Opportunities & Constraints

Oro Loma is an early adopter of NbS and nutrient management efforts in the region. Significant potential for treatment via horizontal levees exists and plant-scale nitrification removes a significant hurdle to implementation. Land ownership, public perception, and environmental conflicts represent significant but not insurmountable constraints.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Moderate
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	193 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	4 - 41 acres
Total Potential Flow Capacity	0.3 - 3.6 mgd
Total TIN Reduction Potential	50 - 560 kg/day
Facility-Specific TIN Reduction	3% - 30%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.7 - 9 km
Total Potential Flow Capacity	2.8 - 15.3 mgd
Total TIN Reduction Potential	220 - 1,170 kg/day
Facility-Specific TIN Reduction	13% - 71%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	High

Oro Loma-Castro Valley Sanitary Districts Water Pollution Control Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**10.8 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**1,639 kg N/d**
Existing TIN effluent concentration	**41 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**Existing**
Existing SLR strategy	**No**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SAN FRANCISCO INTL. AIRPORT

NATURE-BASED TREATMENT SOLUTIONS

The Mel Leong Treatment Plant discharges non-nitrified effluent to South SF Bay. This facility serves SFO and includes industrial wastewater and stormwater - with a dry weather permitted capacity of 3.4 mgd and average dry weather flow of ~1.1 mgd. The 2018 Nutrient Reduction Report by HDR identified limited opportunities for optimization and costly upgrade options. NbS opportunity is limited by available land area and SFO policy regarding bird strike risk.

Preliminary Findings

Horizontal levee opportunities were identified near the Mel Leong plant. The nearest horizontal levee opportunity could reduce the nitrified TIN load by 14%. If all three horizontal levees opportunities shown were implemented, TIN loads could be reduced by over 90%. No opportunities for open water wetlands were identified.

Opportunities & Constraints

Opportunity for horizontal levees are shown adjacent to SFO, though the airport has indicated it will pursue traditional sea walls to minimize habitat creation and associated bird strike risk. Future potential partnerships may lie to the north in the event horizontal levees are considered. Opportunities for open water wetlands are limited.

Photo courtesy of Google Earth

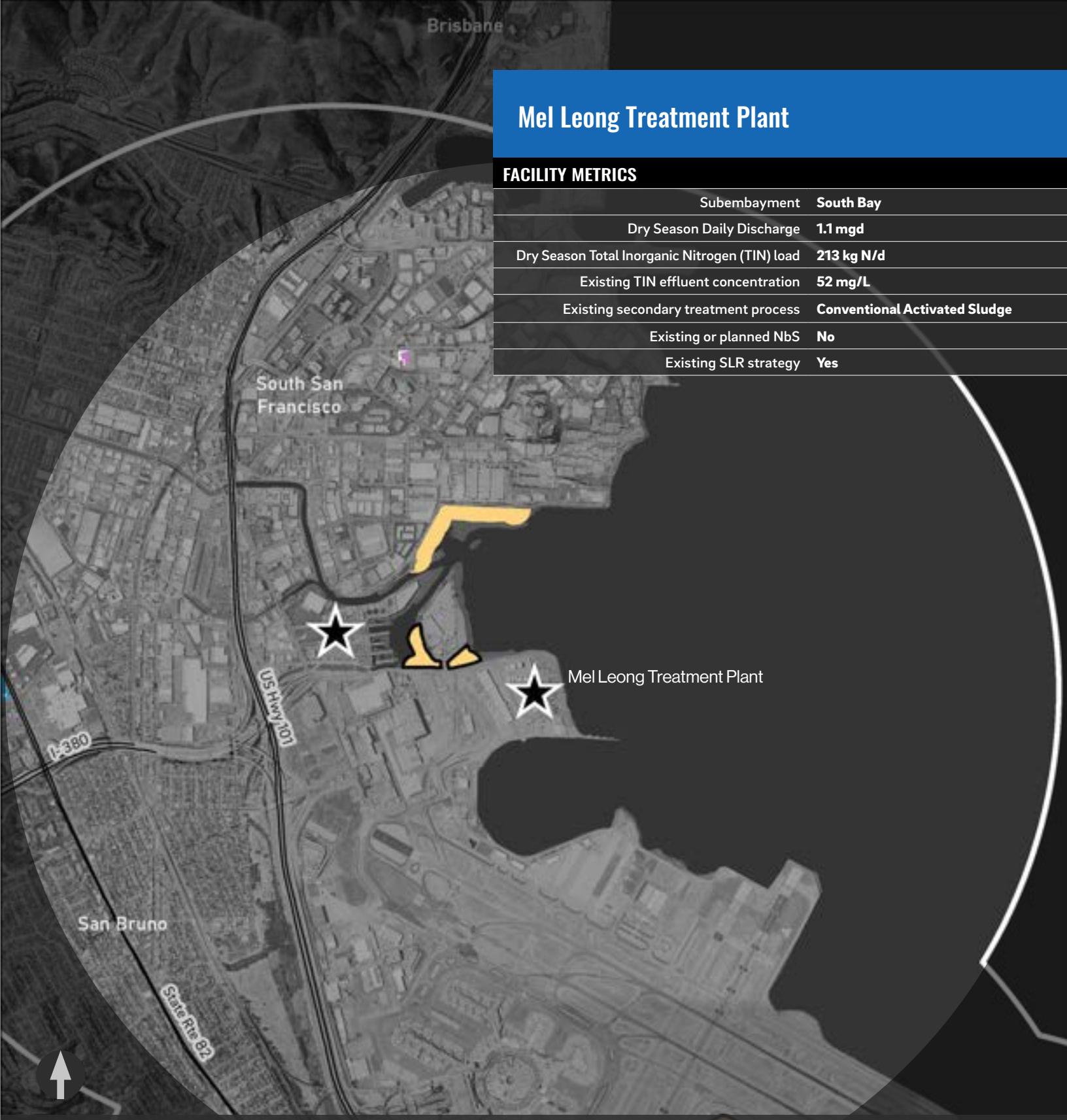
Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Low
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	1 acre
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	0 acres
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.3 - 3.5 km
Total Potential Flow Capacity	0.5 - 5.9 mgd
Total TIN Reduction Potential	30 - 450 kg/day
Facility-Specific TIN Reduction	14% - over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	High



Mel Leong Treatment Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**1.1 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**213 kg N/d**
Existing TIN effluent concentration	**52 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SAN FRANCISCO PUBLIC UTILITIES COMMISSION SOUTHEAST PLANT

NATURE-BASED TREATMENT SOLUTIONS

SFPUC has a combined sewer system that discharges non-nitrified effluent to the South Bay and has a service area population of approximately 58,000. The Southeast Plant has a permitted dry weather capacity of 85.4 mgd, with actual 2019 average dry weather flows of ~48 mgd. The urban geography and high land value surrounding the facility represent key constraints to deploying NbS at scales necessary for meaningful nutrient reductions at one of the region's largest facilities.

Preliminary Findings

A few opportunities for open water wetlands were identified, though none in close proximity to the SFPUC Southeast Plant. If implemented, the largest open water wetland opportunity could reduce the nitrified TIN load by 1%. No opportunities for horizontal levees were identified.

Opportunities & Constraints

San Francisco's geography severely limits NbS opportunities for wastewater treatment. Horizontal levees may be considered at some point. However, regional initiatives offering opportunities to distribute flow, sidestream, or reverse osmosis concentrate may be needed for SFPUC to leverage NbS for discharge and treatment at scale.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Low
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	12 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	9 acres
Total Potential Flow Capacity	0.7 mgd
Total TIN Reduction Potential	120 kg/day
Facility-Specific TIN Reduction	1%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0 km
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	None
Land Use/Regulatory Conflicts	High

Southeast Water Pollution Control Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**53.6 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**9,414 kg N/d**
Existing TIN effluent concentration	**46 mg/L**
Existing secondary treatment process	**High Purity Oxygen Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

CITY OF SAN LEANDRO

NATURE-BASED TREATMENT SOLUTIONS

The San Leandro Water Pollution Control Plant discharges non-nitrified effluent to South SF Bay via EBDA. The facility serves ~15,300 municipal and industrial connections in the majority of San Leandro - with a dry weather permitted capacity of 7.6 mgd. San Leandro is in the process of designing and permitting a 6-ac open water treatment wetland and seepage slopes to treat 0.5-0.95 mgd if nitrified effluent and may consider partnerships with other EBDA agencies.

Preliminary Findings

A few opportunities for open water wetlands were identified, though none in close proximity to the plant. Together, the highlighted open water wetland opportunities could reduce the nitrified TIN load by over 90%. The nearest horizontal levee opportunity, between the Oro Loma and San Leandro facilities, could reduce TIN load by 14%.

Opportunities & Constraints

Although not displayed on the map here, an existing 6.9-ac retention basin is planned for conversion to a NbS treatment unit immediately west of the facility. Surrounding areas are highly industrial and built out. Existing infrastructure exists to help facilitate partnerships, south of the 3.2 km (2 mi) radius, with other EBDA agencies.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	Moderate

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	59 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	23 - 118 acres
Total Potential Flow Capacity	2 - 10.5 mgd
Total TIN Reduction Potential	310 - 1,630 kg/day
Facility-Specific TIN Reduction	38% - over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.8 km
Total Potential Flow Capacity	1.4 mgd
Total TIN Reduction Potential	110 kg/day
Facility-Specific TIN Reduction	14%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	Moderate

San Leandro Water Pollution Control Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**4.8 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**762 kg N/d**
Existing TIN effluent concentration	**41 mg/L**
Existing secondary treatment process	**Trickling Filter/Activated Sludge**
Existing or planned NbS	**Implementation**
Existing SLR strategy	**No**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

CITY OF SAN MATEO

NATURE-BASED TREATMENT SOLUTIONS

The San Mateo Wastewater Treatment Plant discharges to South SF Bay and serves a population of ~170,000 in San Mateo, Foster City, Hillsborough and surrounding areas. The facility is currently undergoing a major upgrade that includes a five-stage biological nutrient removal/ membrane bioreactor to reduce nitrogen to ~15 mg/L. The project will reduce TIN by 50% to 60%.

Preliminary Findings

Opportunities for both treatment types were identified, including some in close proximity to the San Mateo facility. Together, the three highlighted open water wetland opportunities could reduce the nitrified TIN load by about 23%. The horizontal levee opportunity could reduce TIN loads by 10%.

Opportunities & Constraints

Major upgrades are underway and San Mateo does not envision deploying NbS. Surrounding areas are densely built out and models indicate future flood risk vulnerability is high. San Mateo has a FEMA certified levee system that protects the facility. Partnership with Foster City on a horizontal levee could prove beneficial.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Moderate
Horizontal levees	Low

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	53 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	4 - 27 acres
Total Potential Flow Capacity	0.3 - 2.4 mgd
Total TIN Reduction Potential	50 - 360 kg/day
Facility-Specific TIN Reduction	3% - 23%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.1 km
Total Potential Flow Capacity	1.8 mgd
Total TIN Reduction Potential	140 kg/day
Facility-Specific TIN Reduction	10%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Low
Land Use/Regulatory Conflicts	High

City of San Mateo Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**9.5 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**1,423 kg N/d**
Existing TIN effluent concentration	**40 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**

☆ Wastewater treatment facility

○ 3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SILICON VALLEY CLEAN WATER

NATURE-BASED TREATMENT SOLUTIONS

Silicon Valley Clean Water discharges non-nitrified effluent to the South Bay. The plant serves a population of ~200,000 from West Bay Sanitary District and the cities of Belmont, San Carlos, and Redwood City. The Facility has a permitted dry weather capacity of 29 mgd and average dry weather flow of ~12.3 mgd. The facility recycles ~0.5 mgd for irrigation and industry, with plans to increase to ~1.5 mgd by 2040. Future flood exposure is high given the facility's proximity to SF Bay.

Preliminary Findings

Several opportunities for both treatment types were identified, including some in close proximity to the facility. Together, the three highlighted open water wetland opportunities could reduce the nitrified TIN load by about 56%. The nearest horizontal levee opportunity could reduce TIN loads by 7%.

Opportunities & Constraints

The 2018 Nutrient Reduction Study indicates nitrification is capital-intensive at this facility, representing a hurdle to preparing effluent for NbS application. Future flood risk for this site is high, suggesting opportunities for discharge to horizontal levees, which appears more feasible than open water wetlands given geographic constraints.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Moderate
Horizontal levees	Moderate

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	148 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	4 - 86 acres
Total Potential Flow Capacity	0.3 - 7.6 mgd
Total TIN Reduction Potential	60 - 1,400 kg/day
Facility-Specific TIN Reduction	2% - 56%

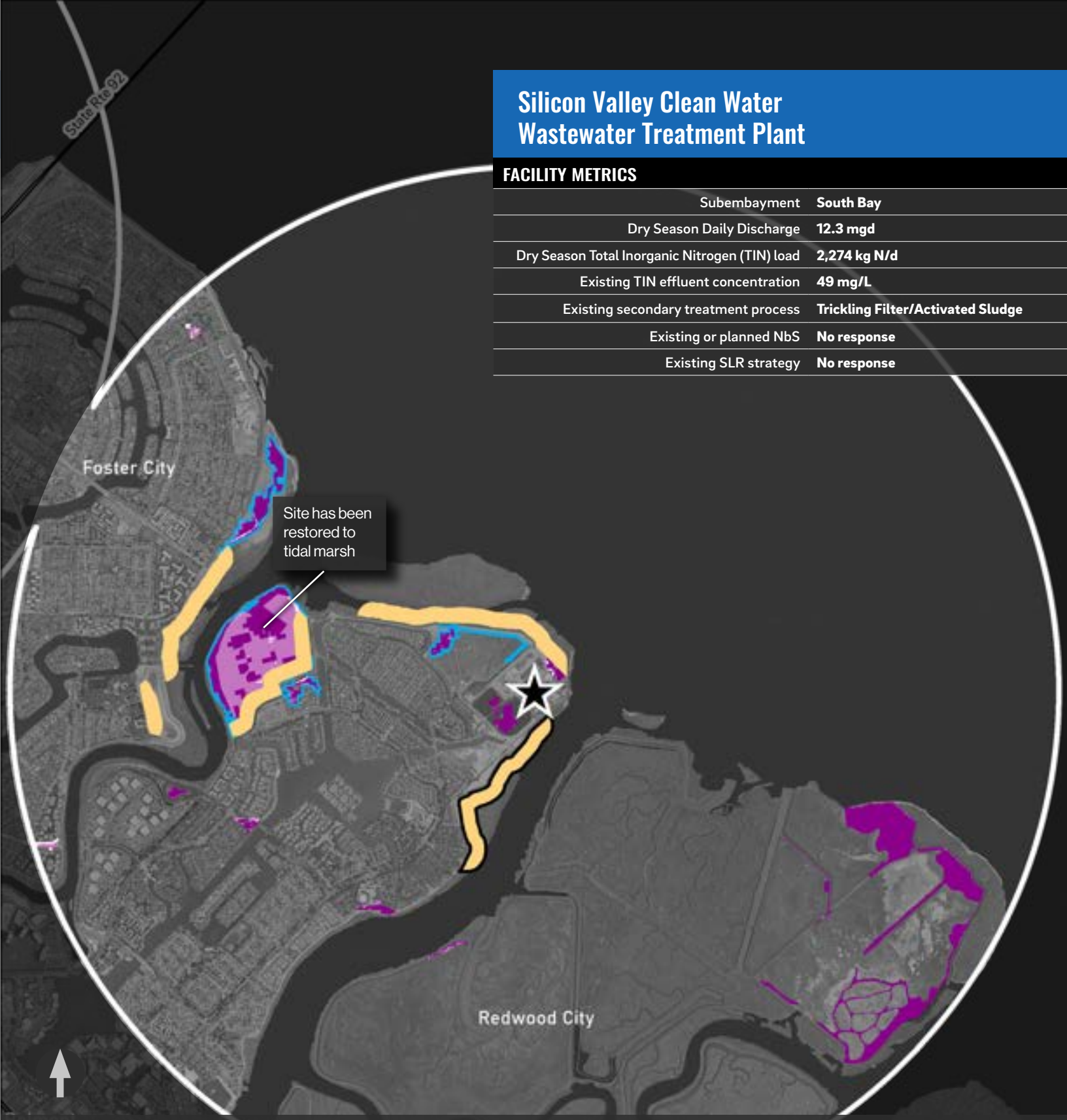
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.3 - 5.3 km
Total Potential Flow Capacity	2.2 - 8.9 mgd
Total TIN Reduction Potential	170 - 680 kg/day
Facility-Specific TIN Reduction	7% - 30%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	High

Silicon Valley Clean Water Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**12.3 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**2,274 kg N/d**
Existing TIN effluent concentration	**49 mg/L**
Existing secondary treatment process	**Trickling Filter/Activated Sludge**
Existing or planned NbS	**No response**
Existing SLR strategy	**No response**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

SOUTH SAN FRANCISCO AND SAN BRUNO

NATURE-BASED TREATMENT SOLUTIONS

The South San Francisco - San Bruno Water Quality Control Plant discharges non-nitrified effluent to South SF Bay. The facility serves a population of ~110,000, including commercial and industrial connections in and around South SF, Colma and San Bruno - with a dry weather permitted capacity of 13 mgd and average dry weather flow of ~7.7 mgd. Future flood risk threatens the facility, which is physically constrained by its proximity to Highway 101 and SFO airport.

Preliminary Findings

Opportunities for horizontal levees were identified near the facility. The nearest horizontal levee opportunity could reduce the nitrified TIN load by 6%. If all horizontal levees opportunities shown were implemented, TIN loads could be reduced by 24%. No opportunities for open water wetland treatment were identified.

Opportunities & Constraints

Staff are currently exploring flood protection options in partnership with the US Army Corps of Engineers. Opportunity may exist to implement NBS at disused former Navy wharves adjacent to the plant. Addition of an upstream nitrification step would be required prior to implementation of any NBS.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Low
Horizontal levees	Moderate

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	2 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	0 acres
Total Potential Flow Capacity	0 mgd
Total TIN Reduction Potential	0 kg/day
Facility-Specific TIN Reduction	0%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.5 - 1.7 km
Total Potential Flow Capacity	0.8 - 3 mgd
Total TIN Reduction Potential	60 - 230 kg/day
Facility-Specific TIN Reduction	6% - 24%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	High

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

South San Francisco and San Bruno Water Quality Control Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**7.7 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**942 kg N/d**
Existing TIN effluent concentration	**33 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Likely infeasible

Worth exploring

0 0.5 1 mi

0.5 1 km

UNION SANITARY DISTRICT

NATURE-BASED TREATMENT SOLUTIONS

The Union Sanitary Wastewater Treatment Plant discharges non-nitrified effluent to South SF Bay via EBDA. The facility serves the cities of Newark, Union City & Fremont (pop. ~350,000) and industrial dischargers - with a dry weather permitted capacity of 33 mgd and actual dry weather flows of ~23 mgd. Starting in 1988 Union San discharged to Hayward Marsh yet recently ceased this practice and is interested in expanding NbS for treatment and sea level rise adaptation.

Preliminary Findings

Multiple opportunities for both treatment types were identified, including several adjacent to the facility. Either the horizontal levees or the open water wetlands could reduce nearly half of the nitrified TIN load if all opportunities shown were implemented, though it is unlikely all will be feasible.

Opportunities & Constraints

HDR's 2018 Nutrient Reduction Report indicates limited opportunity to nitrify and meet potential nutrient regulations within its current footprint. Potential opportunities include partnership with the South SF Bay Salt Pond Restoration Project on horizontal levees and Alameda Co Flood Control District given high SLR-related flood risk.

Photo courtesy of Google Earth

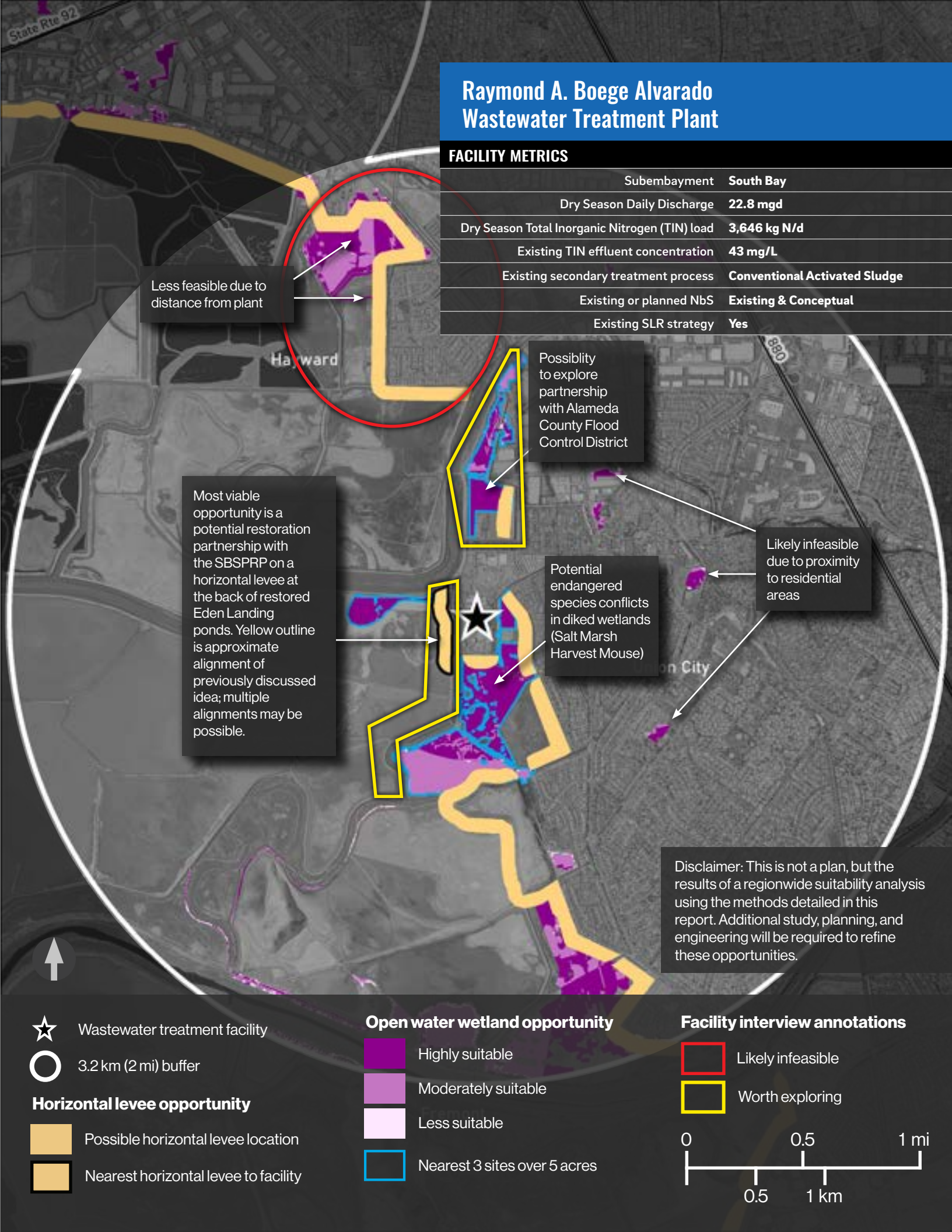
Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	375 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	13 - 142 acres
Total Potential Flow Capacity	1.1 - 12.5 mgd
Total TIN Reduction Potential	180 - 2,040 kg/day
Facility-Specific TIN Reduction	4% - 50%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	0.7 - 11.5 km
Total Potential Flow Capacity	1.2 - 19.6 mgd
Total TIN Reduction Potential	90 - 1,500 kg/day
Facility-Specific TIN Reduction	2% - 41%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	High



Raymond A. Boege Alvarado Wastewater Treatment Plant

FACILITY METRICS

Subembayment	**South Bay**
Dry Season Daily Discharge	**22.8 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**3,646 kg N/d**
Existing TIN effluent concentration	**43 mg/L**
Existing secondary treatment process	**Conventional Activated Sludge**
Existing or planned NbS	**Existing & Conceptual**
Existing SLR strategy	**Yes**

Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Likely infeasible

Worth exploring

0 0.5 1 mi

0.5 1 km

SUB-EMBAYMENT FOCUS

LOWER SOUTH SF BAY

Three water resource recovery facilities (WRRFs) discharge to Lower South San Francisco Bay, which encompasses areas south of the Dumbarton Bridge, according to boundaries from the San Francisco Bay Basin Plan. The combined ADWF from those WRRFs is ~110 mgd and the dry season TIN load is ~7,300 kg N/d.

This preliminary analysis indicates moderate opportunity exists in Lower South Bay to manage nutrients via nature-based solutions. On a cumulative basis, between 2% to 90% of the dry season TIN load could be managed with open water wetlands and horizontal levees could remove 15-65% of total TIN load from these three facilities. Refer to Introduction, Nutrient Reduction Estimation Methods.

A relatively large land area is potentially suitable for conversion to open water treatment wetlands or horizontal levees. Leveraging this area requires coordination with the South SF Bay Shoreline Project (flood protection), adjacent landowners, and habitat restoration projects.

Key Opportunities & Constraints

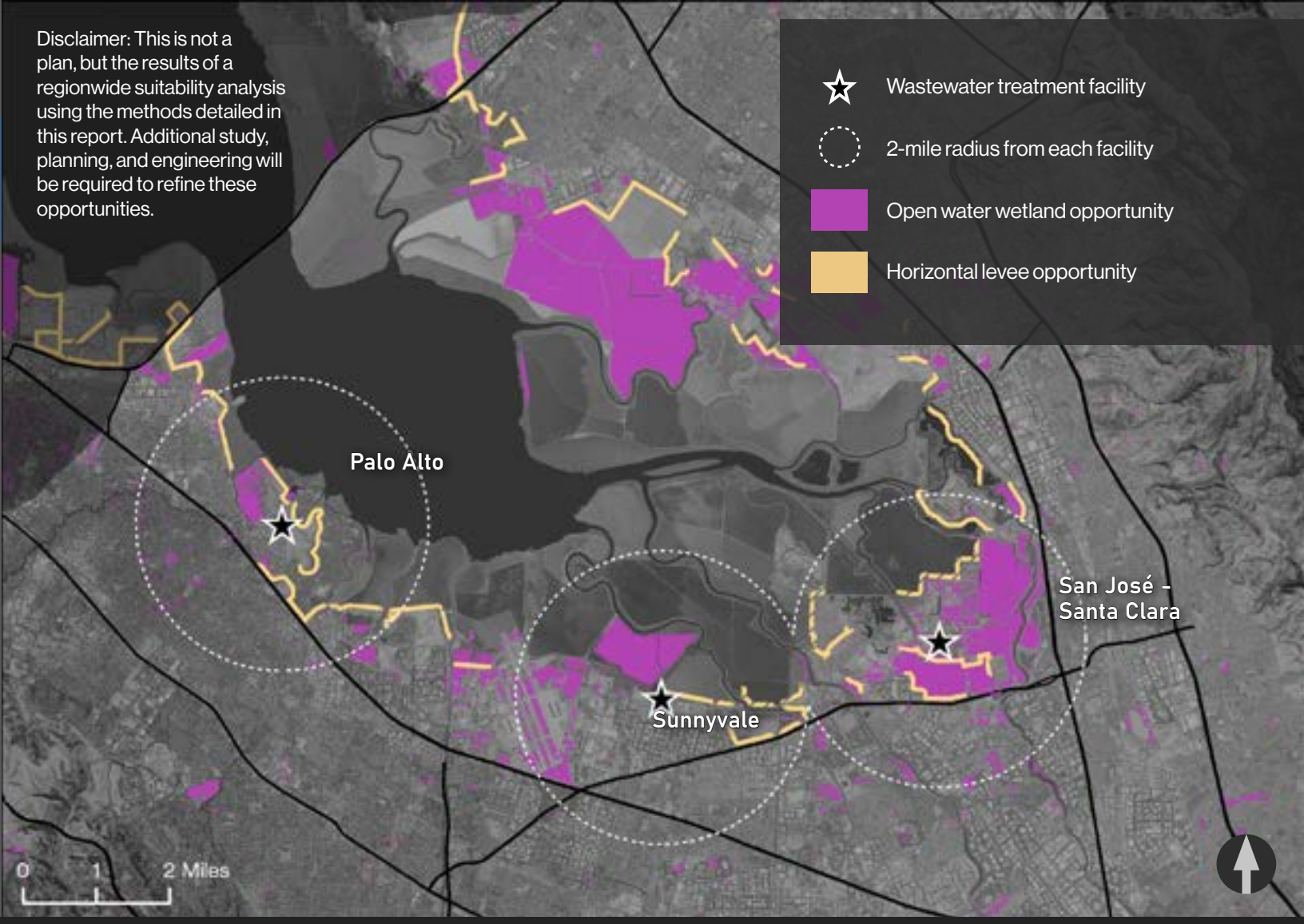
This analysis integrates existing geospatial data to inform physical opportunities (i.e. elevation, slope) and general land use constraints (i.e. proximity to existing development or highly sensitive habitat).

- Much of the shoreline in the Lower South Bay is susceptible to current and future flooding and the South SF Bay Shoreline Project is proceeding with levees. Cooperation among participating agencies represents a significant barrier to discharging wastewater to horizontal levees for treatment. Facility-specific summaries show potential levee alignments at Palo Alto and San José.
- Opportunities for open water treatment wetlands is greatest at the San José-Santa Clara Regional Wastewater Facility, which is currently evaluating options for remediation of former biosolid holding areas and other areas suitable for conversion to open water treatment.
- Palo Alto is currently designing a pilot-scale horizontal levee project that will receive treated effluent, and has a long-running 14-acre open water treatment system.
- Though not addressed here, Valley Water is evaluating nature-based options for treating reverse osmosis concentrate, in cooperation with San José, Oro Loma, academic researchers, and others.

Map (above, top)
Wastewater treatment facilities that discharge to Lower South SF Bay, in yellow, sized relative to average daily total inorganic nitrogen loads in the region.

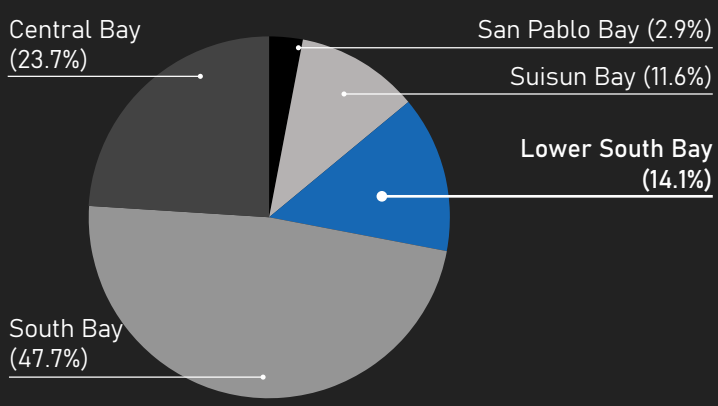
Photo (above, bottom)
View of Renzel Marsh, a 14-acre open water system receiving advanced treated wastewater from the Palo Alto Regional Water Quality Control Plant. Photo courtesy of Google Earth.

Map (facing page)
Overview of WRRFs discharging to Lower South SF Bay, including modeled outputs of areas potentially suitable for conversion to open water treatment wetlands or horizontal levees.



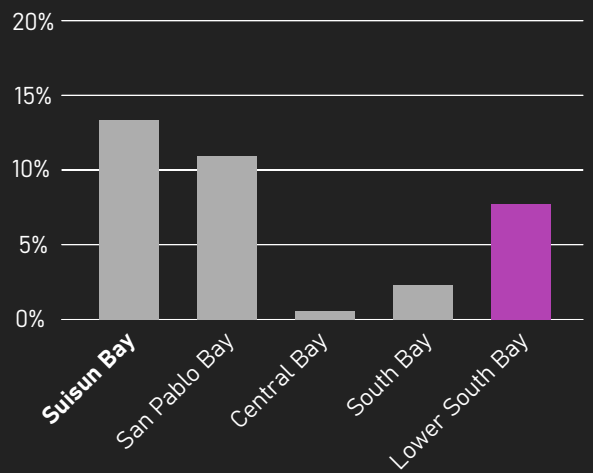
SUMMARY STATISTICS: LOWER SOUTH SF BAY

Total Inorganic Nitrogen Load*



*total average dry season daily TIN load

Percent of area within 2 mi of a facility suitable for open water wetlands



8 - 37 km** of shoreline in Lower South SF Bay were identified as potentially suitable for **horizontal levees**, corresponding to a potential treatment capacity of **14 - 63 mgd****

**lower end of range: closest opportunity to each facility; higher end of range: all oppportunities within 2 miles of a facility

CITY OF PALO ALTO

NATURE-BASED TREATMENT SOLUTIONS

The Palo Alto Wastewater Treatment Plant discharges nitrified effluent to Lower SF Bay. The facility serves a population of ~220,000 - with a dry weather permitted capacity of 39 mgd and average dry weather flow of ~20 mgd. The facility's existing 14-ac freshwater marsh receives treated effluent. Palo Alto has expressed interest in expanding NbS and recycled water deliveries to meet sustainability objectives.

Preliminary Findings

Several opportunities for both treatment types were identified, including some in close proximity to the Palo Alto facility. Together, the three highlighted open water wetland opportunities could reduce the nitrified TIN load by about 45%. The nearest horizontal levee opportunity could reduce TIN loads by about 19%. Preliminary findings require further evaluation for compatibility with current land uses.

Opportunities & Constraints

As a nitrifying facility with a high degree of future flood vulnerability, potential exists to partner on horizontal levees. Constraints include the adjacent airport, the dense urban landscape, and need for cooperation among diverse stakeholders and landowners. Lessons being learned through the current levee project will aid in future planning.

Photo courtesy of Google Earth

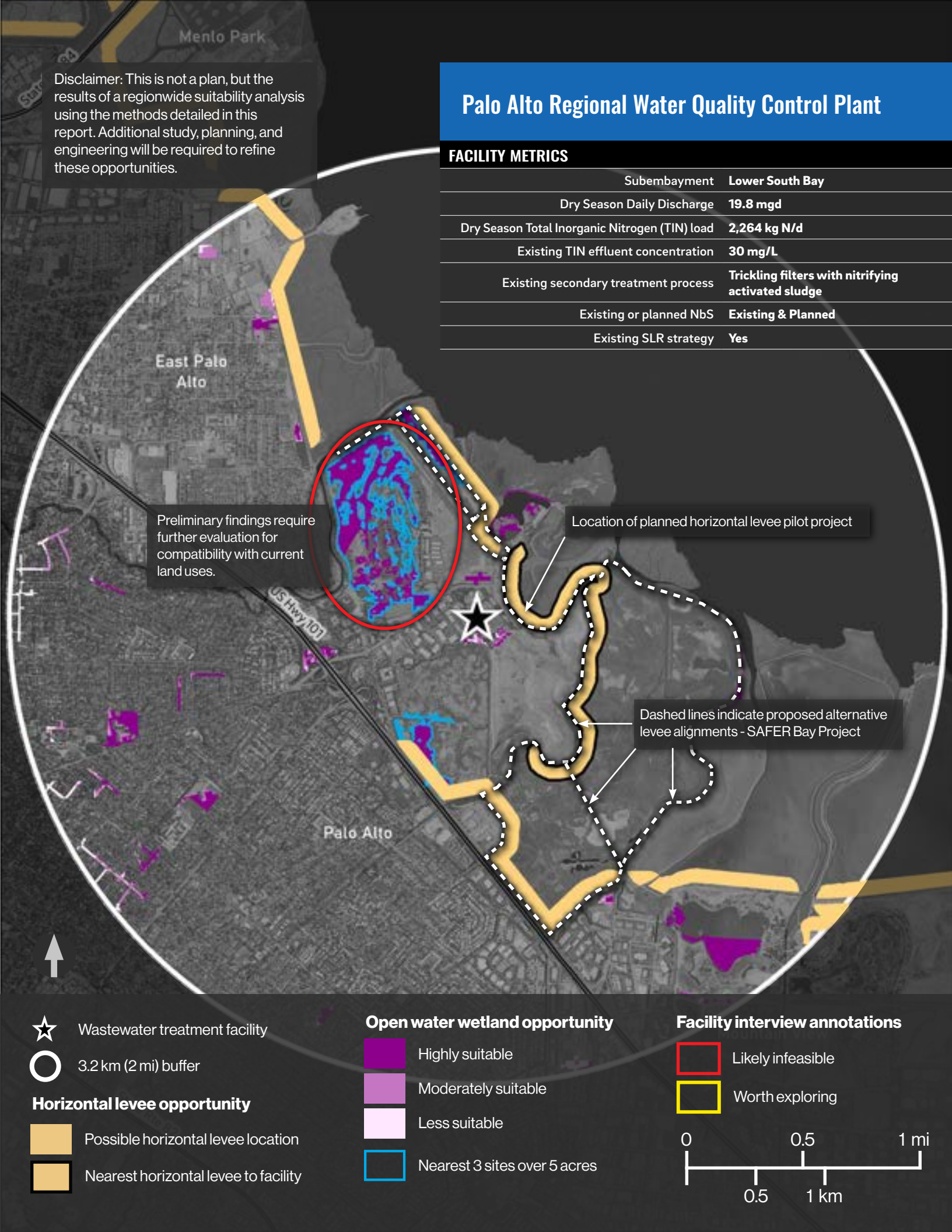
Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Moderate
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	182 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	8 - 111 acres
Total Potential Flow Capacity	0.7 - 9.9 mgd
Total TIN Reduction Potential	80 - 1,130 kg/day
Facility-Specific TIN Reduction	3% - 45%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	3.3 - 12.8 km
Total Potential Flow Capacity	5.6 - 21.8 mgd
Total TIN Reduction Potential	430 - 1,660 kg/day
Facility-Specific TIN Reduction	19% - 73%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	Moderate
Land Use/Regulatory Conflicts	High



Palo Alto Regional Water Quality Control Plant

FACILITY METRICS

Subembayment	**Lower South Bay**
Dry Season Daily Discharge	**19.8 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**2,264 kg N/d**
Existing TIN effluent concentration	**30 mg/L**
Existing secondary treatment process	**Trickling filters with nitrifying activated sludge**
Existing or planned NbS	**Existing & Planned**
Existing SLR strategy	**Yes**

SAN JOSÉ-SANTA CLARA REGIONAL WASTEWATER FACILITY

NATURE-BASED TREATMENT SOLUTIONS

The City of San José's facility discharges nitrified effluent to Lower South Bay. It serves a population of ~1.4 million, representing a significant proportion of Santa Clara Co. - with a dry weather permitted capacity of 167 mgd and average dry weather flow of ~80 mgd. Potential NbS treatment opportunities include supplying the South SF Bay Shoreline Project with treated effluent along ecotone levees and converting former biosolids ponds to open water wetlands.

Preliminary Findings

Several opportunities for both treatment types were identified near the San Jose-Santa Clara facility. Together, the highlighted open water wetland opportunities could reduce the nitrified TIN load by over 90%. The nearest horizontal levee opportunity could reduce TIN loads by 9%.

Opportunities & Constraints

This mapping exercise yielded multiple levee alignments in addition to the one currently being constructed. The South SF Bay Shoreline Project is progressing and there are currently no plans to irrigate the slopes with existing nitrified effluent. San José is also considering options for remediation of legacy biosolids ponds, including conversion to open water wetlands.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	High
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	1,128 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	5 - 940 acres
Total Potential Flow Capacity	0.4 - 83.7 mgd
Total TIN Reduction Potential	20 - 4,880 kg/day
Facility-Specific TIN Reduction	0% - over 90%

Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	3 - 16 km
Total Potential Flow Capacity	5.1 - 27.2 mgd
Total TIN Reduction Potential	390 - 2,080 kg/day
Facility-Specific TIN Reduction	9% - 45%

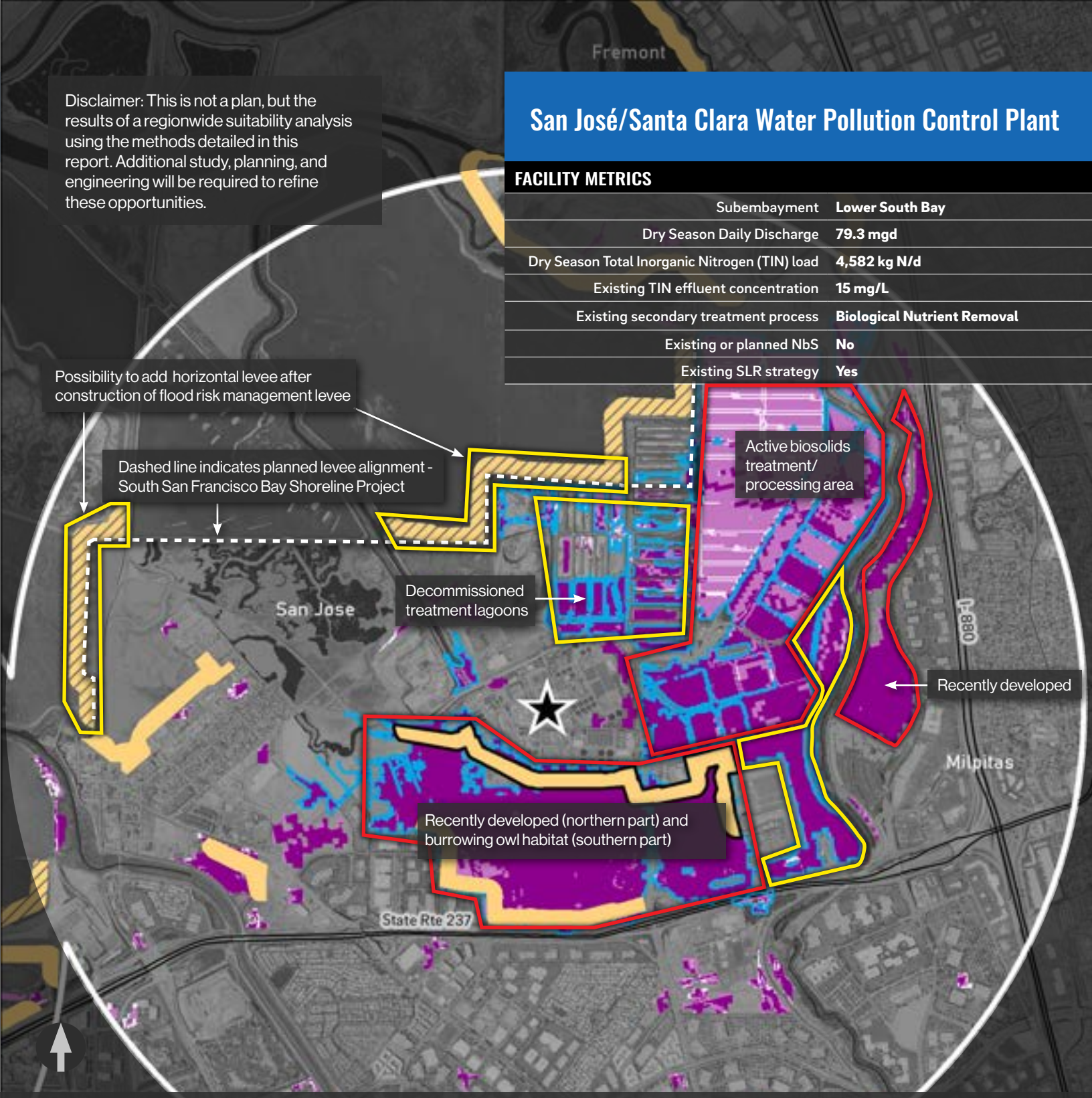
Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	Moderate

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

San José/Santa Clara Water Pollution Control Plant

FACILITY METRICS

Subembayment	**Lower South Bay**
Dry Season Daily Discharge	**79.3 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**4,582 kg N/d**
Existing TIN effluent concentration	**15 mg/L**
Existing secondary treatment process	**Biological Nutrient Removal**
Existing or planned NbS	**No**
Existing SLR strategy	**Yes**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Ecotone levee planned or constructed*
*at least part of length

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Facility interview annotations

Likely infeasible

Worth exploring

0 0.5 1 mi

0.5 1 km

CITY OF SUNNYVALE

NATURE-BASED TREATMENT SOLUTIONS

The Sunnyvale Water Pollution Control Plant discharges nitrified effluent to Lower South SF Bay via Guadalupe Slough. The facility serves ~28,000 connections in and around Sunnyvale - with a dry weather permitted capacity of 29.5 mgd and actual dry weather flow of ~9 mgd. Sunnyvale has conceptually evaluated ecotone levees to address SLR-based flood risk & remove nitrate. Sunnyvale's Plant Master Plan calls for enhancing recycled water production steadily over time.

Preliminary Findings

While opportunities for NbS are limited by high-intensity urban development, there are several potential sites to explore near the shoreline. If multiple opportunities were implemented, horizontal levees could reduce the nitrified TIN load by over 90%.

Opportunities & Constraints

Possible locations to implement NBS include the existing Cargill Channel (landward of oxidation ponds) and at the back of Pond A4. Implementation depends on future tidal marsh restorations and the alignment of a future shoreline levee. Coordination with Valley Water and USFWS will be key.

Photo courtesy of Google Earth

Refer to pages 14-15 for a key to interpreting the metrics in the following tables:

Overall suitability for nature-based treatment solutions	
Measure	**Suitability**
Open water wetlands	Moderate
Horizontal levees	High

Open water wetland opportunities	*open water wetlands on map*
Within 2 miles of facility	
Total Potentially Suitable Area	58 acres
Nearby sites over 5 acres (outlined in blue on map)	
Potentially Suitable Area	4 - 42 acres
Total Potential Flow Capacity	0.3 - 3.7 mgd
Total TIN Reduction Potential	20 - 190 kg/day
Facility-Specific TIN Reduction	3% - 38%

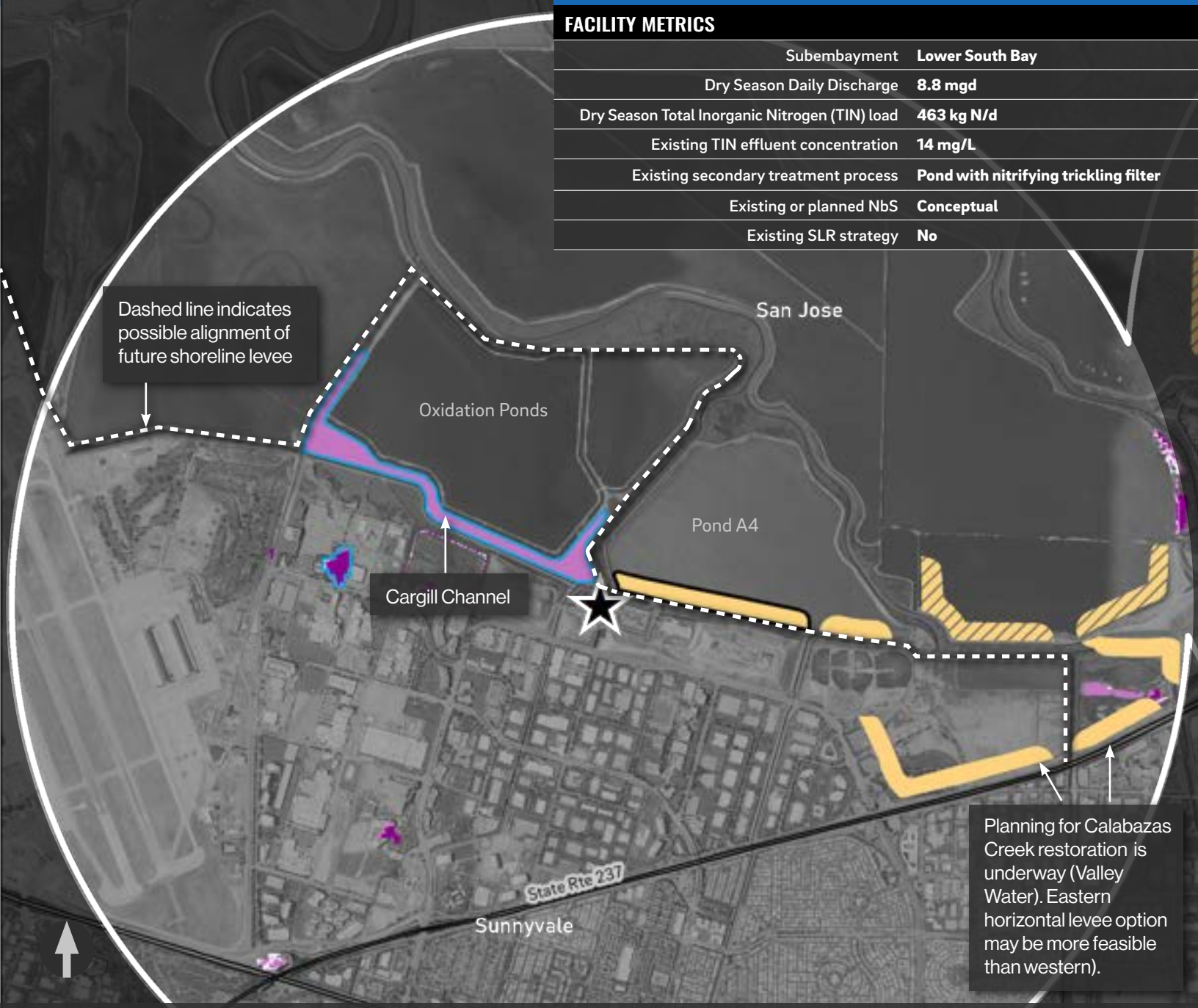
Horizontal levee opportunities	*horizontal levees on map*
Potentially Suitable Length	1.2 - 6.2 km
Total Potential Flow Capacity	2.0 - 10.5 mgd
Total TIN Reduction Potential	150 - 800 kg/day
Facility-Specific TIN Reduction	32% - over 90%

Site opportunities and constraints	
Consideration	**Relative Magnitude**
Excess Treatment Capacity	High
Land Use/Regulatory Conflicts	High

Sunnyvale Water Pollution Control Plant

FACILITY METRICS

Subembayment	**Lower South Bay**
Dry Season Daily Discharge	**8.8 mgd**
Dry Season Total Inorganic Nitrogen (TIN) load	**463 kg N/d**
Existing TIN effluent concentration	**14 mg/L**
Existing secondary treatment process	**Pond with nitrifying trickling filter**
Existing or planned NbS	**Conceptual**
Existing SLR strategy	**No**



Wastewater treatment facility

3.2 km (2 mi) buffer

Horizontal levee opportunity

Possible horizontal levee location

Nearest horizontal levee to facility

Ecotone levee planned or constructed*

*at least part of length

Open water wetland opportunity

Highly suitable

Moderately suitable

Less suitable

Nearest 3 sites over 5 acres

Disclaimer: This is not a plan, but the results of a regionwide suitability analysis using the methods detailed in this report. Additional study, planning, and engineering will be required to refine these opportunities.

0 0.5 1 mi

0.5 1 km

APPENDIX A: SEA-LEVEL RISE AND GROUNDWATER RISE EXPOSURE

Many of the wastewater facilities around the Bay are exposed to flooding from sea-level rise (SLR), and a number of facilities are actively developing adaptation plans to address this climate change threat. Nature based solutions for nutrient reduction may be designed as multi-benefit projects that also reduce flood risk for treatment facilities as sea levels rise. Horizontal levees constructed bayward of flood risk management levees can attenuate waves and reduce the potential for levee overtopping.

Another flooding risk to plan for is emergent groundwater: a secondary impact of rising sea levels. Where the shallow aquifer is unconfined, SLR will cause a lift in the level of the overlying shallow aquifer, resulting in higher groundwater tables in many areas around the Bay where groundwater is already near the surface during the wet season (Plane, Hill, and May 2019). Rising groundwater is likely to impact subsurface infrastructure and remobilize soil contaminants even before it emerges above the ground surface. Future changes in the water table should be considered as new nature-based treatment systems are sited and designed.

Understanding exposure to these two flooding threats may help guide decision making for the implementation of nature-based solutions, which may require land use changes for large areas near wastewater facilities. Integrating planning for nutrient management with planning for climate change is likely to lead to more resilient long-term solutions.

Projected sea-level rise flooding and groundwater emergence flooding estimates for each facility (Table 1) are from Hummel et al. (2018), and report the estimated percentage of the facility's footprint affected by each type of flooding with one and two meters of sea-level rise. The authors estimated the percent of each facility impacted by surface water flooding from sea-level rise using projections from the USGS's CoSMoS model, accessible from the Our Coast Our Future website (USGS, Point Blue). Groundwater flooding is based on projections of water table rise developed from an interpolated groundwater surface that was constructed using data aggregated by Plane and Hill (2017). More details about the method are available in Hummel et al. (2018). These numbers are preliminary and provide a general sense of the scope of exposure for each facility, but further study is needed for refinement. For instance, this analysis only includes exposure within facility footprints, but other vulnerabilities (e.g. inhibited access to pipes running through the baylands) may exist outside these footprints.

References

Hummel, M.; Matthew Berry; Stacey, M. Sea Level Rise Impacts on Wastewater Treatment Systems Along the U.S. Coasts. Earths Future 2018, 6 (4), 622–633. https://doi.org/10.1002/2017EF000805.

Plane, E.; Hill, K. Minimum Depth to Groundwater for the Coastal San Francisco Bay Area, v6 [Data File]. Retrieved from Https://Doi. Org/10.6078/D1W01Q; 2017.

Plane, E.; Hill, K.; May, C. A Rapid Assessment Method to Identify Potential Groundwater Flooding Hotspots as Sea Levels Rise in Coastal Cities. Water 2019, 11(11), 2228. https://doi.org/10.3390/w11112228.

USGS; Point Blue Conservation Science. Our Coast, Our Future Flood Map http://data.pointblue.org/apps/ocof/cms/index.php?page=flood-map.

Table A1. Relative exposure of wastewater facilities to flooding from sea-level rise and groundwater rise, from Hummel et al. (2018)

Discharger	Percent of plant footprint flooded with 1m SLR (surface flooding only)	Percent of plant footprint flooded with 2m SLR (surface flooding only)	Percent of plant footprint flooded with 1m groundwater rise	Percent of plant footprint flooded with 2m groundwater rise
American Canyon, City of	0	0	0	6
Benicia, City of	67	87	23	74
Burlingame, City of	0	0	5	46
Central Contra Costa Sanitary District	0	0	0	0
Central Marin Sanitation Agency	3	3	24	59
East Bay Municipal Utility District	0	10	5	34
Fairfield-Suisun Sewer District	0	0	0	1
Hayward, City of	0	5	27	81
Las Gallinas Valley Sanitary District	0	0	0	1
Marin County, Paradise Cove	45	45	0	12
Marin County, Tiburon	0	0	0	0
Millbrae, City of	64	100	34	74
Mt. View Sanitary District	38	43	88	93
Napa Sanitation District	0	2	2	9
Novato Sanitary District	14	52	13	53
Oro Loma-Castro Valley Sanitary Districts	0	100	42	82
Palo Alto, City of	64	91	1	9
Petaluma, City of	0	0	20	71
Pinole, City of	0	36	0	2
Richmond Municipal Sewer District	0	0	0	2
Rodeo Sanitary District	0	0	0	1
San Francisco Intl. Airport	7	99	27	79
SFPUC Southeast Plant	0	3	2	27
San José-Santa Clara RWF	0	89	3	40
San Leandro, City of	0	28	24	41
San Mateo, City of	100	100	59	99
Sausalito-Marin City Sanitary District	0	0	0	0
Sewerage Agency of Southern Marin	0	65	0	31
Silicon Valley Clean Water	100	100	92	100
Sonoma Valley County Sanitary District	0	0	27	50
South San Francisco and San Bruno	0	12	7	42
Sunnyvale, City of	66	97	38	77
Treasure Island	0	99	1	14
Union Sanitary District	99	100	70	98
Vallejo Flood and Wastewater District	0	100	5	56
West County Wastewater District	0	98	1	79