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memorandum

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cc	Adrien Baudrimont and Heidi Nutters – San Francisco Estuary Partnership
from	Mark Lindley, PE; Scott Stoller, PE; Marisa Landicho, PE; and Matt Brennan, PhD, PE
subject	Horizontal Levee Conceptual Designs for Palo Alto Regional Water Quality Control Plant

INTRODUCTION

This memorandum describes conceptual designs for horizontal levees at three potential locations in the vicinity of the Palo Alto Regional Water Quality Control Plant (RWQCP). The horizontal levee concept is an innovative and experimental approach with the goals to 1) create habitat for special status species by replicating freshwater seeps that historically occurred on gently sloping transitional zones into tidal marshes, 2) provide sea-level rise adaptation through accretion of freshwater wetland plant biomass, and 3) provide polishing-level treatment of wastewater prior to discharge to the Bay. The conceptual design approach builds on the experience gained through design, construction, and monitoring of the Oro Loma Horizontal Levee Demonstration Project in San Lorenzo, California.

A horizontal levee is a flood control levee with a gently sloping berm along the Bay shoreline which provides key transitional habitat between tidal wetlands and terrestrial uplands. Its target vegetation consists of grassy wet meadow and riparian scrub. This type of habitat has been decimated by development along the shoreline, yet is a high restoration priority for resource agencies (Goals Project, 2015). The horizontal levee includes habitat for endangered species found only along the Bay shoreline, such as the saltmarsh harvest mouse and Ridgeway's rails, by providing refugia during high water and connectivity between marshes. These slopes also provide accommodation space for tidal wetlands to adapt to sea-level rise by shifting landward. Historically, natural transition zones would be fed by freshwater seeps from the surrounding watershed. In today's highly modified and developed shorelines with stormdrain systems designed to efficiently route rainfall from developed areas, transition zones are disconnected from the natural freshwater supply. To replicate the historic freshwater seep, the slope's vegetation can be irrigated with highly treated wastewater effluent. As the effluent percolates through the vegetation and soil, nutrients and pollutants are removed, thereby improving the effluent's water quality before discharge to the Bay. A horizontal levee can also contribute to flood management by attenuating waves, allowing for flood control levees to be constructed with crest elevations up to two feet lower than conventional levees. Additionally, the horizontal levee provides erosion protection on the front side of coastal levees, limiting the need for rip-rap (rock) protection on the levee face. By encouraging sediment and biomass accretion, the vegetation supported on the ecotone can build the ground surface elevation, contributing sea-level rise resilience to both the habitat and flood management functions.

The desirability for horizontal levees from the ecological viewpoint has been understood for some time (Goals Project, 1999) but these features have not been included in many restoration projects to date. The horizontal levee approach using treated wastewater effluent and its role in increasing resilience to sea-level rise is more recent, with the Oro Loma project serving as proof-of-concept and continuing to provide insight from ongoing monitoring. Designs for the Palo Alto sites will extend the Oro Loma Horizontal Levee Demonstration Project experience to typical Bayland settings. In addition to tailoring the designs to Palo Alto-specific considerations, the Palo Alto sites have been selected for greater habitat and hydrologic connectivity to tidal marsh and the Bay, as well as integration with regional coastal flood protection. Since this approach is new, these sites would likely undergo extensive regulatory review to secure permits.

Funding for the development of conceptual horizontal levee designs comes from an Integrated Regional Water Management Program (IRWMP) grant obtained by Oro Loma Sanitary District (OLSD) and administered by the San Francisco Estuary Partnership (SFEP). The bulk of this grant supported design and construction of a pilot horizontal levee at the OLSD wastewater treatment plant in San Lorenzo. With a remaining portion of the grant, Environmental Science Associates (ESA), the engineering firm that led design of the OLSD project, has developed conceptual designs of horizontal levee projects for the City of Palo Alto. ESA has been assisted by Peter Baye, the plant ecologist from the OLSD project, City staff, and other stakeholders.

This memorandum incorporates and expands on the information presented in the Ecotone Slope Opportunities memo in January, 2018 (ESA, 2018) and serves to memorialize the rationale for the conceptual design decisions and discuss important issues to resolve in order to bring the project(s) to fruition.

SETTING

Much of the Palo Alto shoreline, while highly developed and altered, continues to sustain tidal marsh along San Francisco Bay in particular at the former harbor and adjacent to the Palo Alto Airport. Harbor Marsh and the Baylands Nature preserve are backed by levees and a closed landfill (Figure 1). Just behind these levees are significant City of Palo Alto infrastructure, including the City's RWQCP, airport, the Palo Alto Flood Basin, roads and light development. The existing levees limit potential flooding from the Bay for the City infrastructure, as well as buildings and other development extending landward of Highway 101. Although the levees prevent flooding, they are not engineered to meet FEMA accreditation standards. To improve these levees, the City has partnered with nearby cities and county flood agencies as a member of the San Francisquito Creek Joint Powers Authority (SFCJPA). The SFCJPA is currently planning levee improvements, as well as habitat restoration and recreation enhancements under its Strategy to Advance Flood protection, Ecosystems, and Recreation along San Francisco Bay (SAFER Bay) project. The SAFER Bay project includes FEMA-accredited levees that can accommodate an additional three feet of sea-level rise. Still in its feasibility phase, the SAFER Bay project is considering several levee alignments along the Palo Alto shoreline. The City is also in the process of updating the Baylands Comprehensive Conservation Plan, which provides guidance for managing City-owned open space property along the Bay shoreline.

The City owns and operates the RWQCP to treat and dispose of wastewater from the City and surrounding communities. In 2016, the plant received approximately 19 million gallons per day (mgd) of average dry weather inflow (City, 2017), provided primary through tertiary treatment, and routed its effluent to recycled water uses (approximately 0.5 mgd), Renzel Marsh (approximately 1 mgd), and the Bay (the remaining 17.5 mgd) (City, 2017). The RWQCP's recycled water permit allows for up to 9 mgd of recycled water. Some of the RWQCP recycled water is piped to the northern shoreline section of the City of Mountain View for that city's recycled water program. The RWQCP is currently designing a redundant, parallel pipeline to carry effluent to the Bay, to improve capacity when Bay water levels are high, conditions that will become more frequent with sea-level rise. This new pipeline may offer opportunities for diverting effluent to a horizontal levee or enable re-purposing of the legacy emergency outfall.

Effluent from RWQCP currently meets water quality criteria from its National Pollutant Discharge Elimination System (NPDES) permits (City, 2017) that are issued by the Regional Water Quality Control Board. The City, along with other Bay-area water treatment operators, is assessing the capacity of the plant's current treatment process to meet more restrictive criteria for nutrients, particularly nitrogen, that may be implemented with a future permit renewal. To meet future nitrogen criteria, the City is planning upgrades to the existing treatment process including adding denitrification filters to reduce total nitrogen content to approximately 15 mg/l (Carollo, 2012). A horizontal levee can provide additional nitrogen removal capacity while also reducing concentrations of emerging contaminants of concern including trace pharmaceuticals.

ORO LOMA HORIZONTAL LEVEE - STATE OF THE ART

The horizontal levee demonstration project constructed at the Oro Loma wastewater treatment facility is a proof-of-concept project that incorporates several project elements, some that are common to future projects and some that are specific to the operational and research objectives of that particular facility. The essential elements of a horizontal levee include:

- Flood Control Levee – Comprised of compacted silt and clay soils with relatively low plasticity and low permeability to protect adjacent property from flood risks. Flood control levees typically incorporate relatively steep slopes to limit the amount of material required for levee construction.

- Horizontal Levee (i.e. Ecotone Slope) – A broad flat slope located adjacent to a flood control levee that is comprised of soil and planted with native wet meadow and/or riparian scrub vegetation and irrigated with freshwater seepage and/or shallow (approximately 1 mm) continuous or pulsed flow. Along a tidal marsh the horizontal levee above the marshplain (at ~MHHW) up to the 10-year or 100-year high water elevation. To provide high tide refugia habitat, the slope should be as flat as possible, generally a minimum of 10h:1v or ideally, flatter ranging from 30-100h:1v.

- Water Source – To support the habitat benefits of an ecotone, the slope requires some level of irrigation with freshwater. At minimum, irrigation during the rainy season into the spring would be required to mimic the fresh water seepage that historically supported this habitat. In the context of the Palo Alto RWQCP, a consistent source of treated (at least secondary-treated), nitrified, and disinfected wastewater can be used to irrigate the slope.

- Distribution System – Reliable system to deliver varied, but consistent flowrate and to evenly distribute water across the face of the ecotone slope. The distribution system could require controls to manage flow rates and to provide alternating periods of discharge and drawdown to vary saturation levels of surface soils.

- Treatment Zone – For wastewater polishing, a high permeability subsurface layer of gravel (or similar) substrate that extends for a specified width that provides a reducing environment for biologically-mediated processes to treat the constituents in the wastewater. Because the nitrate concentrations in the Palo Alto RWQCP effluent are anticipated to be below 15 mg/l (as N) following the planned treatment plant upgrade, nutrient polishing would not be a primary project goal. However, there are other polishing treatment benefits such as the reduction of emergent constituents of concern (i.e. pharmaceuticals) that may warrant research focus and could be important for the project. The treatment capacity of the horizontal levee could be adjusted to meet the agreed upon project goals.

- Segregated Treatment Cells – Hydraulically isolated cells that can allow for delivery to support varied saturated/unsaturated conditions and/or to implement various treatments to test and advance the state-of-the-art.

An overview of Oro Loma horizontal levee design:

- Pretreatment of secondary treated effluent prior to distribution to the horizontal levee includes nitrification and denitrification in free surface wetland. Disinfection is not currently included in the pretreatment process.

- A containment berm constructed to similar standards as a flood control levee. The containment berm forms a basin to contain up to 7.5 million gallons of primary treated effluent during extreme wet weather events.

- Total horizontal levee width is 456 linear feet, separated into 12 cells with 2-feet wide compacted clay berms. Each cell is 38 feet wide. The slope is approximately 3.3% (30h:1v) and length of ecotone and treatment zone is 150 linear feet. The length of the slope is divided into three (3) segments by a full-depth gravel mixing and sampling trench, every 50 feet to allow for flows to redistribute evenly across the cell to minimize preferential pathways.

- Horizontal levee substrate varies per cell for experimental purposes. The typical section is between two to three feet thick with 6-inches of drain rock for seepage at the bottom overlain with a 6-inch layer of sand and then one to two feet of top soil - either fine (clay loam) or coarse (layers of sand loam and clay loam). Drain rock and sand were blended with wood chips and the top soil was blended with wood fines to provide a carbon source to support biologic treatment processes.

- Horizontal levee cells were graded with two treatment approaches. Nine of the twelve cells incorporated a flat cross section to evenly spread water across the cell. Three of the fine-grained cells were graded to produce shallow swales and depressions to better mimic natural transitional ecotones with shallow freshwater wetlands.

- Vegetation communities also vary per cell for experimental purposes and encompass native wet meadow herbaceous, riparian scrub, and freshwater wetland species.

- Pump stations that allow for variable flow rates to be applied to the slope and that allow for greater flow rates to be applied on one or more days in three to four day cycles to mimic variable hydrologic conditions to support alternating periods of saturation and unsaturated conditions.

- Each cell is equipped with flow meters and valves to allow for fine tuning of flows delivered to specific cells.

Operations:

- The ecotone at Oro Loma was irrigated with freshwater pumped from a local well from early 2016 through the spring of 2017 to support plant establishment while construction of other project elements was completed.

- Beginning in April 2017 treated wastewater was routed through the free surface wetland and applied to the horizontal levee. Initial flow rates were approximately 70,000 gpd through November 2017 with flow applied consistently each day.

- In November 2017, flowrates were reduced to approximately 50,000 gpd to try to keep flows within the subsurface drain layers to the extent possible.

- From November 2017 through May 2018, flows to individual cells were adjusted to try to manage/maximize the ratio of subsurface flow to surface flow.

- Beginning in November 2017, Oro Loma implemented a bypass within the free surface treatment wetlands to deliver wastewater with nitrate concentrations ranging from 18 to 32 mg/l to test application of higher nitrate levels to the horizontal levee.

- June through August of 2018, flows were further reduced to approximately 30,000 gpd to maintain nearly 100% subsurface flows in the nine flat treatment cells.

At Oro Loma, removal of nitrate and trace organics has occurred primarily within the subsurface. Shallow surface flows have demonstrated relatively limited treatment efficiencies possibly due to the shorter residence times and relatively limited biological treatment. It's possible that as a surface layer of organic material develops surface treatment efficiencies may improve. Another important observation is that most of the removal has occurred in the upper portion of the high permeability drain layer within the horizontal levee. Even with the higher nitrate levels, very high treatment efficiencies have been demonstrated within the subsurface. Within the first 9-10 feet in the subsurface, nitrate levels are reduced by at least 90% (to non-detectable levels in many cells) and trace organics are reduced by 40% to greater than 90% depending on the constituent. This suggests that wastewater polishing could be spread over a longer and thicker, but narrower sub-surface treatment zone within the slope to achieve higher effluent throughput for the same total area.

The Oro Loma Ecotone Demonstration project was designed with capacity to deliver an average of up to 100,000 gpd to the horizontal levee with a daily maximum of up to 400,000 gpd. The project has been operated to deliver 30,000-70,000 gpd to 1.7 acres spread across a 456 LF horizontal levee. Delivery rates at the lower end of this range, 30,000 gpd (18,000 gpd/acre or 66 gpd/LF), have minimized overland flow and resulted in substantially higher removal rates.

It's possible that the hydraulic loading rate could be increased if the hydraulic conductivity and/or the depth of the drain layer substrate were increased or if the slope of the treatment zone was steepened. The drain rock treatment layer at Oro Loma is 0.5 feet thick. The conceptual design for Palo Alto proposes to increase the drain rock depth to one foot and to steepen the slope to 5% (20h:1v), which could increase the hydraulic loading rate up to 200 gpd/lf. Additionally, the design could be refined to improve hydraulic conductivity by incorporating separation fabric to limit intrusion of fines into the drain layer.

The vegetation establishment at Oro Loma has exceeded all expectations. Nearly 100% native cover has been observed and the vigor of the plants irrigated with the nitrogen content in the treated effluent has been beyond that seen on any other project. The revegetation leaders at Save the Bay have commented that the plants are growing as if on steroids due to the abundant water supply and high nutrient loads.

Moving forward to develop the next generation of the horizontal levee for Palo Alto, we would like to take into account the following lessons learned to advance or improve the process:

- Effective treatment is concentrated in the subsurface drain layer and correlated with hydraulic residence time requiring a relatively short distance of subsurface flow to achieve relatively high treatment efficiencies. Increasing the thickness of treatment media and steeping the slope of the treatment zone to increase subsurface flowrate should allow for increased volumes of treated wastewater.

- Since treatment volumes are also limited by hydraulic conductivity, increasing and/or maintaining the porosity of subsurface media could also increase treatment volumes.

- Vegetation for habitat creation and accretion – in particular willow have thrived at the Oro Loma demonstration with unforeseen impacts due to root growth into distribution pipes and potentially limiting the porosity of the subsurface drain layer. Planting of willow should be limited to maintain a sufficient distance from distribution lines and the upper portions of the treatment zone. Ecologists from Save the Bay indicate that willow roots can travel laterally up to 30 feet seeking water sources.

PALO ALTO PROJECT OBJECTIVES

The City of Palo Alto has identified the following objectives for the horizontal levee, in order of priority:

- Restore rare and historic ecotone transition slope habitat along the Bay's shoreline for special status species.

- Adapt to sea level rise by providing a transitional ecotone slope that will support freshwater plants to build organic soils to keep pace with some level of sea level rise and to allow wetland habitat bands to migrate up slope with rising water levels.

- Provide tertiary-treated wastewater to enhance ecological functionality of horizontal levee. The RWQCP intends to upgrade the treatment plant to denitrify all effluent and discharge at no more than 15 mg/l nitrate. Additional treatment by the horizontal levee would be an added benefit, but not relied upon to meet potential future permit requirements.

Additionally, the horizontal levee would advance the design of horizontal levees allowing for continued monitoring and research, including:

- Advance the state-of-the-art for horizontal levees for wastewater polishing, habitat creation, sea-level rise adaptation, and flood management.
- Advance the current permitting paradigm to allow for discharge of polished effluent from a horizontal levee into an adjacent tidal marsh connected to San Francisco Bay.
- Monitor effect of salt water at the toe of the horizontal levee on ecology and wastewater polishing.

SITE SELECTION

Several sites along the Palo Alto shoreline were considered as possibilities for a horizontal levee, but were not recommended for additional planning. Although a horizontal levee may be feasible at these sites, they are not as well-suited as the three recommended sites. In some instances, these other sites offer good opportunities for a horizontal levee, but will need to coordinate with the SAFER Bay project. As the SAFER Bay project advances, that project will likely include some of these other horizontal levee opportunities.

The pros and cons of these sites are summarized in Table 1 below.

Table 1. Sites considered for additional planning

Site Description	Pros	Cons
Embarcadero Road	• Proximity to RWQCP • Water availability (legacy emergency outfall connects to proposed levee) • SAFER levee permitting process will include project impacts	• Coordination with SAFER levee planning process could impact implementation schedule
Duck Pond	• Project size and complexity is limited • Proximity to RWQCP – could run new effluent line to site • Could provide plant nursery at existing Save the Bay location to support future horizontal levee implementation	• Limited benefit for SLR adaptation to protect infrastructure •
Pond A1	• Project proponent (South Bay Salt Ponds) currently designing ecotone slope that could be converted to a horizontal levee through the application of recycled water or treated wastewater • Would significantly increase habitat benefits of current restoration plan • Could tie in to Shoreline irrigation line and potentially rely on groundwater pumped from the nearby Shoreline complex	• Recycled water available adjacent to Pond A1 is not ideal water source (expensive, requires dechlorination, limited capacity) • Routing treated wastewater from RWQCP would require new pipeline and significant costs • Complicated implementation process with multiple agencies and jurisdictions

Site Description	Pros	Cons
Adjacent to existing RWQCP outfall	• Available wastewater effluent • Adjacent to shoreline and tidally-influenced	• Substantial impacts to jurisdictional tidal marsh wetlands – likely compensatory mitigation requirement under current regulatory policy • Adjacent to existing Palo Alto Airport which could limit habitat value and create conflicts with increased bird use
Seasonal wetlands between airport runway and existing levee	• Could tie into potential SAFER levee alignment along airport/runway creating horizontal levee connected to existing marsh habitat • Limits impacts to adjacent jurisdictional wetlands related to the RWQCP option (above)	• Adjacent to existing Palo Alto Airport which could limit habitat value and create conflicts with increased bird use
Palo Alto Flood Basin	• Large existing wetland area • Adjacent to Renzel Marsh and wastewater effluent pipeline	• Cross-jurisdictional (multiple cities and regulatory agencies involved) • SAFER levee alignment relative to the flood basin currently undetermined (location of levee determines if horizontal levee is connected to tides/shoreline and other parameters) • Substantial impacts to jurisdictional wetlands – likely compensatory mitigation requirement under current regulatory policy
Renzel Marsh	• City looking to enhance public access and habitat • Wastewater effluent currently feeding this marsh	• Isolated from shoreline and tides • Substantial impacts to jurisdictional wetlands – likely compensatory mitigation requirement under current regulatory policy requiring large mitigation efforts

The three alternative sites that warranted additional consideration were the Embarcadero Road Site, the Duck Pond Site, and the Pond A1 Site. Conceptual designs were developed for each of these sites as described in the following section and shown in the attached design figures.

Based on an initial review of these concepts, the Embarcadero Road site emerged as the most practical project tor the RWQCP to pursue in the near term. The primary drivers included:

- Proximity to the treatment plant, which reduces water supply costs, enables use of treated effluent and also simplifies operations and maintenance.

- The project would be primarily on uplands adjacent to existing tidal marsh allowing for implementation with minimal impact to existing marsh habitat.

- The project would be located on property that is owned by the City of Palo Alto, simplifying jurisdictional issues.
- The horizontal levee added to a comprehensive levee improvement project (SAFER Bay) would directly improve the flood protection for the RWQCP including protection from rising sea levels. Additionally, implementing a horizontal levee along the planned SAFER Bay levee improvements could allow the SAFER Bay levee to be constructed with a lower crest elevation due to the wave attenuation benefits associated with the horizontal levee.

The Duck Pond site also warrants serious consideration. This site has some of the same benefits as the Embarcadero Road Site such as proximity to the RWQCP and land ownership. However, this site is not adjacent to existing marsh habitat which limits its utility for meeting the City's primary objective of creating ecotone transition habitat for special status species. Additionally, the Duck Pond site would provide a limited benefit for sea level rise adaptation because the Duck Pond basin is connected to the Bay through a culvert/tide gate structure with muted tidal exchange. However, the potential for creating a native plant nursery that could support restoration of ecotone transitional habitat around the Bay provides a powerful driver for this site. The City indicated that Save the Bay, which operates the native plant nursery at the site, could function as a viable project sponsor at this location. The RWQCP would be willing to supply treated effluent to support a project at this site.

The Pond A1 Site also has good potential for implementing a horizontal levee. However, this site has a lower potential for direct involvement from the RWQCP primarily because it is further from the plant than the other two sites. The existing supply of treated effluent to this site is a recycled water line to the Shoreline Golf Course. This line has a limited capacity and recycled water would require dechlorination prior to application to the horizontal levee. There could be an opportunity to utilize groundwater pumped from the Shoreline Park as a water source for a Pond A1 project as discussed below. In addition, the South Bay Salt Ponds Project is currently pursuing an ecotone slope on the proposed levee at the site, and would be a viable sponsor for a potential project at this site.

CONCEPTUAL DESIGN

The conceptual designs for the potential Palo Alto horizontal levee alternatives integrate the design approach and the lessons learned from the Oro Loma Ecotone Demonstration Project.

The horizontal levee envisioned for this project consists of the following key design elements: a water supply system, site grading to create a broad transitional slope, a permeable treatment layer for wastewater polishing, and vegetation planting. Since these elements would be common across the possible project sites, design considerations for these elements are described in this section. The key design elements influence one another, so they also need to be integrated with one another. For example, the volume of water supply needs to be appropriate for conveyance capacity of the permeable treatment layer and to support the native vegetation. Other factors, such as, integration with existing and proposed infrastructure (such as trails and levees) scalability, environmental permitting, and monitoring, have been considered in developing conceptual designs.

Water Supply System

Water supplied to the horizontal levee provides irrigation to support target vegetation species, and as such, should meet the water quality needs for the vegetation. In addition, the water that leaves the slope needs to meet water quality requirements for discharge to the Bay.

For the Embarcadero Road and Duck Pond alternatives, final effluent from the Palo Alto RWQCP would supply the horizontal levee. At later stages of design, the water supply system will need to specify details such as connections to the existing RWQCP piping and the distribution system for plant irrigation. For purposes of the conceptual design, the focus is on water supply in terms of volumes, quality, and main pipeline alignment.

Design Flowrate

The quantity of water supplied to the horizontal levee will depend upon:

- **Available effluent** – The horizontal levee can be utilized to provide wastewater polishing under normal dry flow conditions. Alternatively, the horizontal levee and vegetation community can be designed around utilizing excess flows during the rainy season into spring to allow for other, higher uses of recycled water during the dry season. The supply should be achievable for sustained periods that can be integrated with the RWQCP's typical wastewater treatment process. We assume that the point of compliance will remain unchanged (i.e. at the treatment plant discharge up gradient from the horizontal levee), since this system is still experimental and in the developmental stage. At this time, the RWQCP has identified 3 MGD of environmental flows dedicated to improving nearshore habitat including horizontal levee(s), Renzel Marsh, and shallow water discharge. The 3 MGD of flow available for environmental flows is more than enough to support all of the three horizontal levee alternatives developed for Palo Alto (Embarcadero Road, Duck Pond and Pond A1).

- **Irrigation demand** – At minimum, this demand is a function of the irrigated area and the vegetation's evapotranspiration within the irrigated area. In general, the irrigation demand provides a lower limit on the required level of effluent to be applied to the slope and is not a limiting factor in the design. Typically, the design seeks to maximize the flowrate that can be effectively treated by the system which significantly exceeds the minimal irrigation demand required to maintain the vegetation community. The availability of excess treated wastewater significantly increases plant growth rates which can improve habitat quality.

- **Hydraulic Loading Rate –** The hydraulic loading rate refers to the maximum flowrate distributed along the top of the horizontal levee (i.e. gallons per day per linear foot) that can effectively be treated by the horizontal levee. Optimizing the loading rate is a secondary objective of this project. At Oro Loma, the horizontal levee's treatment capacity appears to be limited by the hydraulic conductivity (flowrate per unit area) of the subsurface treatment zone rather than hydraulic residence time required by the biological processes. Effective treatment of the wastewater has been limited to flows that pass through the subsurface treatment zone. Whereas, flows along the surface have had limited treatment efficiencies. The conceptual design seeks to incrementally increase the hydraulic loading rate by increasing both the hydraulic conductivity and the depth of the substrate, as well as, steepening the slope of the treatment zone.

- **Seasonality** – Treatment removal rates and evapotranspiration rates also have a seasonal component, with evapotranspiration and, to a lesser extent, treatment efficiency, decreasing with cooler temperatures. During the wet season, precipitation can deliver enough water that may affect peak conditions, particularly if it causes above-ground flow of wastewater. For reference, at OLSD, 1 inch of rain/day approximately matches the daily effluent volume and 4 inches rain/month (wet season average) is 12% of monthly effluent volume; 8 inches rain/month (wet season extreme) is 25% of monthly effluent volume). While the native vegetation that would establish on the horizontal levee are adapted shallow surface flows, the extra water delivered by rainfall could impact treatment efficiencies for polishing treated effluent within the subsurface.

- **Design Flowrate –** The Palo Alto project would be designed to supply a variable flowrate to the horizontal levee with lower and upper bounds used to experimentally evaluate performance and advance the state-of-the-art. The lower bound should be at or above the irrigation demand and the upper bound should be moderately above the hydraulic conductivity of the treatment media. The flowrate will be a function of the hydraulic loading rate and the length of the horizontal levee. Additionally, since the primary goals for the Palo Alto project would be related to creating habitat for special status species and sea level rise adaptation, delivery of treated effluent should also be tailored to support a complex, heterogeneous native plant community by fluctuating between saturated and unsaturated conditions in the upper soil layers.

Water Quality

The water applied to the horizontal levee would need to have a suitable quality for the slope's vegetation and also need to comply with effluent discharge requirements set by the regulatory agencies. The water quality criteria will be determined in collaboration with regulatory agencies, primarily the Regional Water Quality Control Board, as well as the wildlife agencies. These criteria will consider effluent quality that is tolerable to the ecotone vegetation and beneficial uses of the receiving waters.

The horizontal levee will receive influent which has undergone tertiary treatment including nitrification, partial denitrification in the future, dual media filtration, and disinfection within RWQCP's facilities. Even with this advanced level of treatment, there are several constituents that could pose a risk to the treatment effectiveness and vegetation health.

Extremely high nitrate concentrations can impair vegetation growth and may impact the nitrate removal capacity of the gravel treatment layer. As discussed above, nitrate concentrations up to 30 mg/l have not adversely impacted either the vegetation communities or the nitrogen removal effectiveness of the system at Oro Loma. However, higher nitrate levels have only been applied for a limited period during the winter and spring of 2018 and additional monitoring through the summer months are required. We recommend data from Oro Loma be evaluated and future recommendations be incorporated into the Palo Alto horizontal levee design. RWQCP effluent currently has average nitrogen concentrations at just over 30 mg/L (HDR, 2016). The RWQCP is planning an upgrade including partial denitrification to reduce total nitrogen levels to about 15 mg/l. These improvements are planned to be implemented as early as 2021 which could align with implementation of a horizontal levee project. If lower nitrate levels are preferable for the horizontal levee, options to reduce nitrate concentrations could include: blending with other water sources and/or additional treatment for the effluent stream routed to the horizontal levee.

While higher salinity levels (as measured by total dissolved solids or TDS), concentrations of 800-900 mg/l, can damage foliage for a number of native upland plant species (City, 2017), vegetation species intended for the horizontal levee typically have some salinity tolerance and are not likely to be affected by these relatively low salinity levels. The RWQCP is planning to upgrades to the treatment facility that may include removal of TDS through advanced filtration methods.

The recycled water that is delivered to the Shoreline complex adjacent to the Pond A1 alternative (tertiary treated meeting Title 22 standards) is chlorinated prior to discharge from the RWQCP. While chlorine is not considered toxic to plants, it does interact with organic matter to form chemicals collectively known as disinfection byproducts that are known to adversely affect aquatic ecosystems. It is anticipated that recycled water would need to be dechlorinated prior to application to a horizontal levee. The RWQCP has limited capacity to supply recycled water which is relatively expensive to produce, and it should be directed to the highest and best use.

Distribution System

The main pipeline will deliver effluent from existing RWQCP piping to the horizontal levee project site(s). As shown in Figures 1 and 5, two main pipe networks already convey effluent from the RWQCP and could be the starting point for a connection to the horizontal levee. These networks include:

- two existing Bay outfalls and a third proposed Bay outfall heading northeast from the RWQCP
- recycled water pipelines, primarily configured to serve the Shoreline area in the City of Mountain View

A new main pipeline to the horizontal levee will need to consider the physical connection to existing pipelines, pipeline capacity, right-of-way, and potential conflicts with other utilities and infrastructure (such as the proposed SAFER coastal levee).

Horizontal levee Design

The conceptual design for the Palo Alto horizontal levee integrates the successes and the lessons learned from experience at the Oro Loma site. There are three sites that are being considered for implementation as shown in Figure 1 – Embarcadero Road (Figures 2-6), Duck Pond (Figures 7-8), and Pond A1 (Figure 9-12), which are described in greater detail below. The design elements described in this section are common to each location. The horizontal levee will consist of 1) a levee (or berm) on the landward side for flood protection, 2) a treatment zone, and 3) a habitat transition zone. The conceptual design of each of these elements was based on several factors including tidal inundation and datums, adjacent land use and topography, and proposed future use of the area.

Datums

Using data from the NOAA station at Coyote Creek (NOAA 9414575) and the Palo Alto Yacht Harbor, the following tidal datums were used for the Embarcadero Road Shoreline, Duck Pond and USFWS Pond A1 sites. Since the Duck Pond experiences a muted tide signal, tidal datums were estimated with professional judgement for the conceptual design effort. We recommend that a tide gage be set up to measure the tide range and surveys of existing vegetation at the site be performed if design at the Duck Pond proceeds.

Table 2 – Tidal Datums

Tidal Datum	Embarcadero Road Shoreline/ USFWS Pond A1 (feet NAVD)	Duck Pond (feet NAVD)
Mean higher high water (MHHW)	7.5	5.5-6.5
Mean high water (MHW)	6.9	
Mean tide level (MTL)	3.3	
Mean low water (MLW)	-0.3	
Mean lower low water (MLLW)	-1.5	-1.0-0.0
Diurnal Tide Range (MHHW – MLLW)	9.0	5.5-7.5
100-yr flood stage **	10.8	10.8
10-yr flood stage **	10.2	9.5
Note: Tidal Datums are from Coyote Creek with the exception of the 10- and 100-yr flood stage, which are from the Palo Alto Yacht Harbor		

The tidal datums were used to set the horizontal levee elevations. The horizontal levee is designed to be a freshwater transitional zone to the tidal marsh. For the Embarcadero Road and Pond A1 locations, the lower end of the treatment area is situated between elevation 8.0 and 9.5 feet NAVD, which is 0.5 to 2.0 feet above MHHW. For the Duck Pond location, the lower end of the treatment area is situated at approximately elevation 7 feet NAVD to account for the muted tide that this site experiences. These elevations will be refined through the design process to incorporate appropriate sea-level rise projections and other considerations. For instance, the treatment zone could be raised or possibly flattened to 30h:1v to raise the lower end further above MHHW depending on concerns related to salt water impacts on biological treatment efficiency.

Embarcadero Road Horizontal levee

The Embarcadero Road site has been identified by the City of Palo Alto as the preferred location to move forward for additional study and design to support ultimate implementation. The full build out vision is presented in Figure 2 which shows the project including three main sections of horizontal levee and irrigated ecotone slope:

1. The preferred Phase 1 project is located in the central portion of the Embarcadero Road site just south of the Environmental Volunteer’s Center and includes about 800 LF of horizontal levee and irrigated ecotone slope along the planned SAFER levee alignment.

2. The Harbor Road leg south of the central Phase 1 reach includes about 940 LF of horizontal levee and irrigated ecotone along the planned SAFER levee alignment.

3. The northeast leg includes about 860 LF of horizontal levee and irrigated ecotone along Embarcadero Road northeast of the Environmental Volunteer's Center.

This conceptual alternative includes sections of horizontal levee in areas with wider existing uplands that include a permeable treatment zone and flatter slopes that can provide wastewater polishing in addition to the transitional habitat benefits. In areas with a relatively narrow band of uplands, this concept includes irrigated ecotone slopes which are designed around a steeper 10h:1v slope to provide some habitat benefits while limiting fill in existing wetlands.

The Embarcadero Road project can be supplied with treated wastewater that could be delivered either directly from the legacy emergency outfall or with smaller pipe connected to the RWQCP that could be sleeved through the legacy outfall alignment shown in plan view on Figures 2 & 3.

The preferred Phase 1 project includes about 590 LF of horizontal levee and an additional 210 LF of irrigated ecotone as shown in more detail on Figure 3. Conceptual cross sections for the horizontal levee portions of the Phase 1 project are presented on Figure 4. This portion of the Embarcadero Road site offers the widest upland corridor, which can support a horizontal levee with a relatively flat 20-30h:1v treatment zone and a 30-50h:1v high marsh ecotone below the treatment zone which would create relatively wide transitional slope along the adjacent Harbor Marsh. The landward side of the horizontal levee and ecotone slope is bounded by the planned SAFER levee backed by Embarcadero Road (Figure 4, Sections A-B). In Sections A-B, the full height of the SAFER levee is shown along with the potential to lower the height of the levee by up to 2 feet accounting for the wave attenuation from the existing Harbor Marsh and proposed horizontal levee. As the upland band in this area narrows to the north near the Environmental Engineer's center and to the south towards Harbor Road the horizontal levee would transition to a steeper irrigated ecotone designed to provide habitat benefits while forgoing the wastewater polishing function offered by the horizontal levee. The 590 LF of horizontal levee is anticipated to be able to polish up to 118,000 gpd of treated wastewater. The irrigated ecotone would require up to about 400 gpd on average to support vigorous plant growth which could be supplied by either treated wastewater or a separate water source.

The Harbor Road leg of the project as shown on Figure 2 also abuts the planned SAFER levee and includes about 210 LF of horizontal levee with about 730 LF of irrigated ecotone along areas with a relatively narrow band of existing upland habitat. Conceptual cross sections for this reach of the project are presented on Figure 5, Section C and D. Section C shows a representation of the horizontal levee along this reach with a lower and steeper treatment zone at 20h:1v and a steeper transitional slope along the Harbor Marsh to limit fill within the existing wetlands. Section D provides a representation of the irrigated ecotone slope with a 10h:1v slope extending down and filling a portion of the Harbor Marsh. Along this reach, the SAFER levee would require fill within the existing wetlands, and the ecotone would require additional fill in the marsh. However, we anticipate that the ecotone would allow for the SAFER levee to be built with a lower overall height and section due to the wind wave attenuation provided by the ecotone slope. The ecotone section would require up to about 2.5 feet of fill in the existing marsh beyond the steeper proposed SAFER levee section and most of the marsh fill would support native high marsh transitional vegetation. The 210 LF of horizontal levee along Harbor Road is anticipated to have a treated wastewater polishing capacity of up to 42,000 gpd and the irrigated ecotone would require up to about 1,200 gpd of treated wastewater or a separate water source to support vigorous native vegetation.

The northeast leg of the project along Embarcadero Road includes a short 130 LF section of horizontal levee and about 730 LF of irrigated ecotone as shown on Figure 2. Conceptual sections for this reach are presented on Figure 6. This reach is north of the proposed SAFER levee alignments in an area of relatively low ground at about the 10-year water level. The conceptual sections illustrate two potential options to improve flood protection along this reach including either construction of a low berm along Embarcadero Road or raising Embarcadero Road to just above the 100-year water level. The short section of horizontal levee would also incorporate relatively steep slopes of 20h:1v within the treatment zone with a somewhat flatter transitional section to meet the adjacent Harbor Marsh. Raising Embarcadero Road would allow for the horizontal levee and irrigated ecotone to be somewhat flatter and could allow for a longer stretch of horizontal levee as areas that would only support a steeper 10h:1v irrigated ecotone could be expanded to support a horizontal levee allowing for increased habitat benefits and wastewater polishing. As shown, the 130 LF of horizontal levee could polish up to 26,000 gpd, and the 730 LF of irrigated ecotone would require up to about 1,200 gpd of treated wastewater or a separate source for irrigation.

In total, the full build out Embarcadero Road alternative could polish up to 186,000 gpd of treated wastewater along 930 LF of horizontal levee and require up to 2,800 gpd of treated wastewater or a separate source for irrigation. Well below the 3 MGD of treated wastewater available from the RWQCP.

The Embarcadero Road alternative would also require relocating existing public access trails. The conceptual cross sections show the existing trail moved upslope to the upper limit of the ecotone/horizontal levee slope adjacent to the planned SAFER levee or the berm/raised Embarcadero Road in the northeast leg. Alternatively, it could be possible to locate the trail along the SAFER levee top or perhaps allow the trail to jog up and down slope between the levee and upper edge of the ecotone to provide some variation of elevation and views. The relocated trail is shown as an 8 feet wide corridor that would be paved with aggregate base or a decomposed granite surface. One concern would be the close proximity of the public access to the habitat supported by treated wastewater and the potential for the public to go off trail. Public access could be controlled by incorporating strategic plantings along the trail that would restrict access to the treatment areas and sensitive habitat. Other projects have also utilized fencing – either a chicken wire fence to limit dog access or a two cable fence to demarcate the limit of the public access while allowing more open access for endangered species and other wildlife.

Duck Pond Horizontal levee

The Duck Pond site would allow for a horizontal levee project that could support a nursery for Save the Bay to provide native plant material for future high marsh and riparian scrub transitional revegetation efforts throughout the Bay Area.

The conceptual design is presented in plan view on Figure 7 and sections on Figure 8. The site has the capacity to construct two segments of horizontal levee of approximately 525 linear feet combined, with an anticipated treatment capacity of up to 105,000 gpd. The horizontal levees were limited to areas that did not impact existing marsh and could achieve a 50-foot long treatment zone at a 20-30h:1v slope above elevation 7 feet NAVD. The concept as shown on Figure 7 represents a fairly large project footprint that could be adjusted as needed to avoid existing buildings or other valuable infrastructure.

To achieve the necessary horizontal levee dimensions, a new berm would be built up to elevation 10 feet NAVD or possibly higher depending upon revised tidal datums and goals for flood protection in this area. The treatment zone would extend from approximately elevation 9.5 down to 7.0 feet NAVD. Below the treatment zone, the horizontal levee would extend at a 30h:1v slope or flatter to match local MHW or MHHW within the muted tidal basin (assumed at elevation 6 feet NAVD).

The Duck Pond site could be supplied with treated wastewater routed from either the legacy emergency outfall as described for the Embarcadero Road alternative or from the proposed primary outfall that will be routed around the Palo Alto Airport as referenced in the plan view Figure 1.

The existing access trail could be moved to the top of the proposed berm to maintain existing public access.

Pond A1 Horizontal levee

The Pond A1 site is considerably larger than the Embarcadero Road or Duck Pond sites as shown on Figure 1. Given the current 60% design for the Pond A1 restoration under development by the South Bay Salt Ponds Project, the site has the capacity to construct two long segments of horizontal levee as shown on Figures 9-11. The Pond A1 60% grading plans include construction of an ecotone transitional slope up to elevation 9.0 feet NAVD which would represent the lowest potential elevation to support high tide refugia habitat. The horizontal levees were limited to areas in the 60% grading plan that included transitional slopes that were 30h:1v or flatter as shown in the conceptual cross sections on Figure 12. To build upon this design while improving habitat values and keeping the treatment zone above MHHW, the concept proposes to extend the treatment zone up to elevation 11 feet NAVD. Below the treatment zone, the ecotone would continue at a 20:1 slope until it matches the proposed ecotone grade. Pond A1 West and East offer a combined horizontal levee of about 1,850 LF with an anticipated treatment volume of up to 407,000 gpd.

The Pond A1 site has several recycled water pipelines in the vicinity that could supply the horizontal levee as referenced in the plan view Figure 9. The RWQCP currently supplies water for the City of Mountain View's recycled water system (Carollo, 2012). This recycled water is used in buildings and to irrigate a golf course and other areas of Shoreline Park. Even accounting for other plans to expand recycled water use, both the RWQCP and the City of Mountain View believe there is unallocated recycled water supply that could be used for the Pond A1 horizontal levee. The actual amount of unallocated supply, as well as the existing pipeline's capacity to deliver this supply will need to be determined. However, since recycled water is relatively expensive to produce and has a high market value, the RWQCP may want to reserve this water for paying customers. Additionally, using recycled water would require adding a dechlorination process prior to application to a horizontal levee.

The existing recycled water supply system to Mountain View includes several sections that approach the Pond A1 shoreline, as shown in Figure 9 and briefly described below:

- **Primary Supply Pipeline** – The 24-inch main pipeline follows East Bayshore Road and then Garcia Avenue. A new extension of approximately 2,500 feet could connect to the west side of Pond A1 (off Figure 9 to the southeast).
- **Marine Way Spur** – An existing 6-inch diversion from the primary supply pipeline extends to the corner of Casey Avenue and Broderick Way. A new extension of approximately 1,250 feet could connect to the west side of Pond A1.

- **Shoreline Irrigation System** – This system, which is pressurized by its own pump and can also draw from potable and pond storage, includes an existing 10-inch water main that approaches Pond A1. A new extension of approximately 800 feet could connect to the east side of Pond A1.

- **Historical Shoreline Pipeline** - A historical recycled water pipeline, which is currently de-commissioned, runs from the primary supply pipeline and then along the Pond A1 shoreline. New extensions of approximately 100 feet could connect to most of the Pond A1 shoreline.

Further discussion with the City of Mountain View is needed to identify the condition and capacity in these pipes.

An alternative water supply for the horizontal levee could be groundwater pumped from Shoreline Park. Shoreline Park is constructed on a closed landfill site. Normal operation is for groundwater to be pumped from the perimeter outside of the landfill footprint. Depending on water quality, the groundwater is either sent to the RWQCP for processing or discharged to surface water (City of Mountain View, 2013). The City of Mountain View Department of Public Works is responsible for the landfill operation and could be approached regarding interest and capacity in supplying groundwater to the horizontal levee.

Wastewater Treatment Zone

All three conceptual alternatives include a similar wastewater treatment zone that has been developed to account for the lessons learned at Oro Loma to allow for an incremental increase in treatment volumes per linear foot of horizontal levee. The proposed treatment zone is presented on Figure 13. At this early stage, the proposed treatment zone incorporates the following elements (described from the highest elevation to the lowest):

- A distribution channel & trench offset about 10 feet from the relocated trail or tie in with the levee/berm core. The offset limits reducing the prism of the levee/berm core to help maintain the flood control functions of the core. Additionally, the offset provides a buffer between public access and the distribution of treated wastewater.

- A 5-feet wide distribution channel & trench backfilled with drain rock to route treated effluent to the subsurface treatment layer. The shallow channel (~0.25-foot deep) would allow for treated effluent to be distributed across the ecotone via open channel and subsurface gravity flow to help limit the need for perforated distribution pipes which have experienced problems related to clogging at Oro Loma. Oro Loma utilized a 2-feet wide distribution trench, and the wider trench proposed here would allow for distribution of increased effluent volumes.

- A 1-foot thick sub-surface drain layer separated top and bottom with a geotextile separator fabric to limit intrusion of fines into the drain layer. The drain layer is anticipated to include a mix of drain rock (or other highly permeable material) and wood chips to provide a carbon source. The 1-foot thick drain layer is twice as thick as the drain layer incorporated at Oro Loma, and is anticipated to allow for at least double treatment volume per linear foot due to the increased thickness and more resilient separation barrier.

- A 1.5-feet thick ecotone soil layer to support native vegetation underlain by a 0.5 feet thick sand filter layer to further help limit migration of fines into the subsurface drain layer. The ecotone soil and sand filter layers would be blended with composted wood fines for labile carbon to help support biological treatment.

- A 5-feet wide discharge trench to allow the subsurface flows to migrate from the drain layer into the ecotone soils down gradient from the treatment zone and as shallow surface flows.

- The subsurface treatment zone is currently shown as 40 feet long plus 5 feet wide trenches at the upper and lower limits for a total treatment length of 50 feet. Current monitoring results show that the subsurface treatment reaches maximum efficiencies at 10 feet in total flow length. As we understand more about the residence time and how the Oro Loma demonstration evolves regarding treatment efficiency, it's possible that the length of the treatment zone can be reduced to optimize the design for cost effectiveness.

- Below the treatment zone, the ecotone habitat zone would incorporate a 2 feet thick layer of ecotone soil blended with composted wood fines to provide a source of labile carbon.

Project Site Grading

To facilitate implementation of a horizontal levee pilot at Palo Alto, the sites considered in this memo avoid or limit adding fill in existing wetlands. This approach will help streamline implementation by simplifying the permitting process. Factors to consider when designing grading include:

- Where needed for the target vegetation, grading would position the horizontal levee at appropriate elevations relative to and just above the Bay tide range, and be sloped to provide gravity drainage.

- In addition to adjusting the ground surface, grading may include replacing or amending the top two to three feet of soil. This would provide appropriate substrate conditions (e.g. organic/nonorganic composition, grain size, hydraulic conductivity) to support the native vegetation and water treatment.

- The grading also needs to integrate with current and planned flood management strategies. For example, the horizontal levee should be planned to not interfere with existing or proposed coastal flood protection levees (including the SAFER levee and/or Pond A1 levee) nor to impair existing drainage pathways.

Additionally, the grading plans could include some complexity similar to natural upland to tidal marsh transitions. It could be possible to incorporate coarser soils along wider, higher sections of the ecotone, and finer grained soils within valleys or coves that drain into swales with depressional wetlands to better mimic natural ecotones and freshwater seeps.

Ecotone Vegetation Planting

Based on observations at remaining ecotone reference sites on the Bay shoreline, the target plant community is a mix of wet meadow and riparian scrub/shrub habitat. Eighteen species were planted and have mostly flourished at the OLSD pilot project. These species can serve as an initial planting palette with demonstrated capacity to provide the preferred habitat and treatment. In addition, reference sites local to Palo Alto, such as the area just west of Harbor Point parking lot, may provide additional insight for selecting and propagating plant species. At OLSD, this vegetation palette has yielded plant heights ranging from two feet to more than twelve feet high, with some species likely to grow higher. When placing specific species, the plant layout should consider proximity to public access, such that taller vegetation does not unduly impact views, space, and safety for recreational users.

These ecotone vegetation species require physical conditions which are largely determined by the water supply and grading design elements, as discussed in those sections above. In turn, the planting extent and capacity to process effluent needs to be coordinated with the water supply rate and quantity. To thrive and outcompete terrestrial non-native species, the wet meadow and riparian species benefit from more water than just precipitation alone. Along natural transitional slopes, incidental rainfall is augmented by surface runoff and shallow ground water flow originating in the surrounding watershed. Although initial data from OLSD indicates that ecotone vegetation thrives at an irrigation rate on the order of 18,000 gpd/acre and 66 gpd/LF, alternate irrigation rates may be achievable, depending on such factors as site geometry (length, width, slope) and subsurface hydraulic conductivity.

Since refinements for vegetation planting design are still evolving, the planting may consider different treatments across the project area. These treatment variations could include different vegetation types and substrates integrated into a more complex topographic grading plan, such that questions related to water treatment (e.g. nitrogen removal rates) or habitat (e.g. preferences of special status bird species) could be monitored and evaluated. Additional monitoring might also assess alternate irrigation cycles, removal rates as a function of flow path length, slope width, and potential habitat changes in downstream salt marsh due to increased freshwater discharge.

Thus far, the plantings at Oro Loma have not required significant maintenance. However, the Oro Loma horizontal levee was planted at a 1-foot on center plant spacing. This high-density spacing was implemented to allow the Oro Loma experiment to proceed as soon as possible by allowing near complete aerial coverage within the first year of planting. This high density also allowed for the native plants to generally out compete non-native species. At Oro Loma, with a continuously saturated hydrologic regime, willow and bulrush/cattail are beginning to out compete many of the other planted native species, and some non-native species including pampas grass have begun to colonize the site. With a primary goal to provide critical habitat for special status species, the Palo Alto horizontal levee may try to target a more varied hydrologic regime with alternating cycles of saturated and unsaturated surface soils to support a greater variety of native transitional plant species and to help limit non-native plants. Additionally, occasional inundation with salt water from the Bay during king tides and storm surges will also help to limit non-native plants along the ecotone.

Planting methods

OLSD was successfully planted using seeds and seedlings collected from wild plants, propagated in nurseries and raised beds, and then planted with some assistance from volunteers. Assuming sufficient nursery capacity is identified, these methods should be transferable and scalable to other sites. Possible improvements to these planting methods which may achieve similar results at greater scale and lower cost include reduced lower planting density augmented with hydroseeding or drill seeding to infill the remaining area and mechanical distribution.

Although the planting is anticipated for irrigated areas above regular tidal inundation, the vegetation is close enough to the Bay to be exposed to salinity, in the form of spray, seepage from saline soils, or infrequent flooding. So, plants selected for the ecotone should have some tolerance for salt or brackish inundation. Planting would be likely limited to elevations above monthly tidal inundation. Below this elevation, the vegetation would transition to tidal marsh species that can accommodate regular saltwater inundation (e.g. cordgrass, pickleweed). These species are already present adjacent to the proposed horizontal levee project areas and typically establish on their own from sources conveyed by the tides and do not usually require planting. To transition between the lower edge of the horizontal levee and adjacent existing tidal marsh, the planting palette might be expanded to include high marsh vegetation such as gumplant (Grindelia stricta) and saltgrass (Distichlis spicata).

CONCEPTUAL DESIGN COST ESTIMATES

Construction cost estimates for each conceptual alternative were prepared based on our experience at Oro Loma and on other wetland restoration projects. The cost estimates considered critical construction components related to mobilization, SWPPP (environmental compliance), earthwork (cut, fill, placement, compaction), import of rock and other materials, infrastructure improvements (pump stations, pipelines, and discharge appurtenances), trail relocation, and revegetation (seeding and planting). At the conceptual level these costs are relatively rough "ball park" estimates as many details related to each conceptual alternative are not well defined, and as designs are further developed unanticipated constraints and requirements could significantly change (usually increase) potential project construction costs. In particular, details related to connections to the RWQCP including required turnouts, pump stations, controls, etc. and pipelines to potential horizontal levee sites are roughly estimated, but the actual details of the work required are not known at this conceptual level.

Additionally, the cost estimates include projected construction costs and do not include engineering (restoration design, geotechnical, MEP), permitting and CEQA related costs or costs related to staff time by a project proponent. Finally, operation and maintenance costs for RWQCP staff to operate the treated wastewater distribution system, parks staff for trail maintenance, and revegetation maintenance are not included at this stage. These costs should be mainly used to compare alternatives with the understanding that the costs will likely change as designs progress.

The estimated costs are provided in 2018 and 2021 dollars in summary in Table 3 below and in detail on the attached Table 4.

Table 3 – Estimate Construction Costs for Conceptual Alternatives

Conceptual Alternative	2018 Construction Costs	2021 Construction Costs
Embarcadero Road – Phase 1	$1,465,000	$1,650,000
Embarcadero Road – Build Out (including Phase 1)	$2,869,000	$3,230,000
Duck Pond	$2,306,000	$2,590,000
Pond A1	$3,231,000	$3,630,000
Notes: Cost Estimates include a 35% contingency. 2021 estimate includes a 4% per year escalation over the 2018 estimate. Cost estimates should be considered as a +/-30-50% level of accuracy at this conceptual stage. Pond A1 costs reflect tie in to the existing recycled water supply lines and does not reflect the costs of recycled water or dechlorination. If a dedicated line is required, the costs for Pond A1 would increase significantly.		

PERMITTING STRATEGY

As noted in the 2018 Basin Plan Triennial Review, the receiving waters downstream of many Bay Area wastewater treatment plants include recently restored wetlands or areas that will be restored to wetland habitat in coming years. In many circumstances, using the treated wastewater as a source of freshwater for restored wetlands and ecotone transitional areas would provide a net environmental benefit by increasing the amount of freshwater and brackish wetlands and supporting vigorous native transitional vegetation for birds and wildlife dependent on such habitats. Using treated wastewater in this fashion as a source of freshwater was identified as an important climate change response strategy in the Baylands Ecosystem Habitat Goals 2015 Science Update to "restore estuary-watershed connections that nourish the Baylands with sediment and freshwater" (2018 Basin Plan Triennial Review - San Francisco Bay Region Brief Issue Descriptions April 2018, pp. 10-11).

As part of the review, RWQCB staff are exploring an update of Regional Board Resolution No. 94-086 "Policy on the Use of Wastewater to Create, Restore, and/or Enhance Wetlands." The current Resolution 94-086 policy is now over 20 years old. Much has been learned about wetland restoration over the intervening years and the hydrology and topography of the San Francisco Bay has been changing as vast areas of former salt evaporation ponds are being restored to marsh under the San Francisco Bay Salt Pond Restoration Project.

This review is anticipated to also clarify permitting requirements for wastewater discharges into wetlands, develop near-shore permitting strategies for discharges to wetlands and sloughs. RWQCB would also evaluate and provide guidance about what level of treatment is appropriate for effluent discharged into wetland habitats, including consideration of contaminants of emerging concern (e.g., flame retardants, personal care products, microbeads and nano particles).

Establishing NPDES permits for discharging wastewater in wetlands is complicated by a variety of regulatory issues; RWQCB would explore those regulatory issues and identify policy options, and potentially evaluate issues associated with discharge prohibition exemptions in the Basin Plan and could address Beneficial Use designation associated with creation of new wetlands. A discussion of regulatory interpretations to be explored with RWQCB is provided below, as well as a specific discussion of key issues to be addressed for amending existing wastewater treatment plant NDPES permits to accommodate horizontal levee projects.

Regulatory Interpretations

From a regulatory standpoint, it would be most conservative to assume that an NPDES permit (or amendment to an existing NPDES permit) would be required. However, the issue of Clean Water Act (CWA) applicability to pollutant discharges to groundwater that ultimately reach surface water, in more that de minimis quantities, is currently being litigated and being investigated by USEPA (see excerpt below):

SUMMARY: *The Environmental Protection Agency (EPA) is requesting comment on the Agency's previous statements regarding the Clean Water Act (CWA) and whether pollutant discharges from point sources that reach jurisdictional surface waters via groundwater or other subsurface flow that has a direct hydrologic connection to the jurisdictional surface water may be subject to CWA regulation. EPA is requesting comment on whether the Agency should consider clarification or revision of those statements and if so, comment on how clarification or revision should be provided.*

A more creative permitting interpretation would be that application of secondary effluent to a horizontal levee is simply a land application or land disposal project, subject to simple water reclamation or waste discharge requirements. The discharge may just be subject to various BMPs, such as: how much flow can be applied, where, and when. This approach would need further investigation and discussion with RWQCB, as Title 22 prohibits the discharge to receiving water of recycled water use for irrigation (other than "incidental" runoff as can occur with other irrigation systems). Another approach could be the establishment of a Low Threat Discharge General Permit within San Francisco Bay Region 2; several other RWQCBs have this General Permit in place, and it could be applied to horizontal levee projects. Finally, one could potentially make a case that the secondary or tertiary treated effluent, applied at specified rates and conditions, after a period traveling through the subsurface environment, contains de minimis levels of constituents of concern, and does not need further monitoring and/or permitting (like a septic tank and leach field). These potential regulatory interpretations should be explored with RWQCB.

Existing NPDES Permit Amendment: Key Issues and Approaches

The most expedient permitting approach would be the modification of a wastewater treatment plant's existing NPDES permit to accommodate releases via the horizontal levee slope. There are several approaches or key issues that would need to be addressed for successful permit modification, and these would be negotiated with RWQCB on a case by case basis. However, central to permit modification would be the use of the Basin Plan's exemption to the shallow water discharge prohibition. RWQCB's review should focus on: 1) the overall environmental benefits of these projects, and 2) review of potential incremental impacts (if any) that could occur to beneficial uses identified in the Basin Plan related to shifting from an existing shallow water discharge to discharge to a horizontal levee. The treated effluent will continue to meet the requirements associated with the RWQCP's permitted shallow water discharge prior to application to the horizontal levee.

The regulatory issues would revolve around what if any additional limitations would be required to allow for a near-shore shallow water seepage type discharge. As such, the applicant would need to work with RWQCB to demonstrate that water quality released to/from horizontal levee slope would continue to: 1) meet California Toxic Rule (CTR) requirements; 2) meet applicable toxicity requirements; 3) meet Basin Plan Anti-Degradation requirements; 4) provide an equivalent level of protection; 5) and/or provide a net environmental benefit.

Horizontal Levee projects at Palo Alto can expect to go through similar review and negotiations with RWQCB about application of the exception to the Basin Plan Discharge Prohibitions. It would appear that framing a holistic description of a horizontal levee type project should qualify for an exception given that it should truly provide a "net environmental benefit." A net environmental benefit (NEB) is probably the broadest and most highly regarded exemption. Demonstrating a NEB may also help minimize/offset the need for other regulatory/permitting requirements. Once more data are available on the Oro Loma Horizontal Levee effluent quality, it can likely be demonstrated that in general horizontal levees would provide a higher level of treatment, and therefore an equivalent level of protection, which would comply with the lowest hurdle: an exemption from the Basin Plan discharge prohibitions.

It is anticipated that monitoring data from Oro Loma will demonstrate that that nitrate can be treated with exceptionally high efficiencies and that other constituents are similarly reduced in concentration compared to those in the secondary effluent applied to the Horizontal Levee. Soil microbes would probably degrade many of the other organics in the secondary effluent before it would reach the Bay, again reducing loadings compared to a direct discharge of secondary effluent at the currently permitted levels for a shallow water discharge. There is also the argument to be made that the mass of pollutants discharged via the horizontal levee slope is at most the same, and almost certainly lower, than the mass that would have been discharged to the Bay via a direct secondary effluent shallow water outfall discharge.

With respect to the need for effluent limits, potentially mass limits or de minimis mass loading findings could be applicable to address the Water Quality Based Effluent Limitations (WQBEL) issues. Due to the dispersed nature of the discharge from horizontal levee slopes, it is anticipated that mixing zones/initial dilution approaches would not be appropriate. For the first few horizontal levee projects, it is likely that RWQCB would require a Reasonable Potential Analysis (RPA) to be completed to confirm that remaining concentrations are below California Toxic Rule (CTR) Water Quality Objectives (WQOs) such that effluent limits would not be required. These key issues would need to be reviewed with RWQCB staff as part of the case-by-case review and permit negotiation previously noted.

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ATTACHMENTS

DWG: K:\projects_2012\D120042.03 - Oro Loma IRWMP Support\09 CAD\Dwgs\OVERVIEW.dwg USER: Marisa Landicho PLOT DATE: 8/7/2018 1:57:11 PM

NOTE: AERIAL ORTHOIMAGERY FROM NORTHROP GRUMMAN (2015), AS DOWNLOADED FROM USGS EARTH EXPLORER DATABASE. IMAGERY WAS COLLECTED BY NORTHROP GRUMMAN BETWEEN FEBRUARY 20 TO FEBRUARY 24, 2015.

ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 1
SITE LOCATION MAP

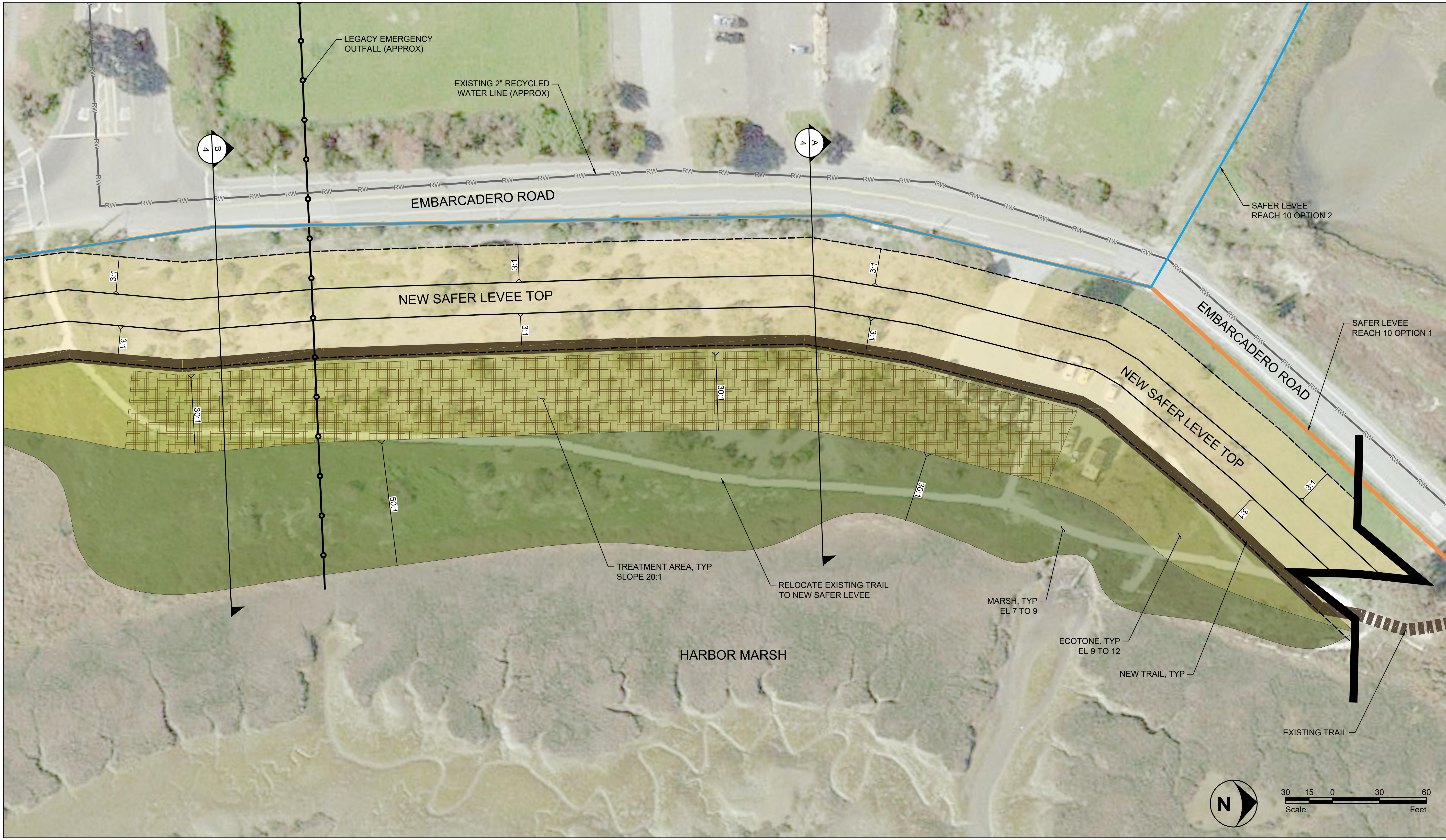
ESA

NOTE: AERIAL ORTHOIMAGERY FROM NORTHROP GRUMMAN (2015), AS DOWNLOADED FROM USGS EARTH EXPLORER DATABASE. IMAGERY WAS COLLECTED BY NORTHROP GRUMMAN BETWEEN FEBRUARY 20 TO FEBRUARY 24, 2015.

ESA

ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 2
EMBARCADERO
ROAD OVERVIEW

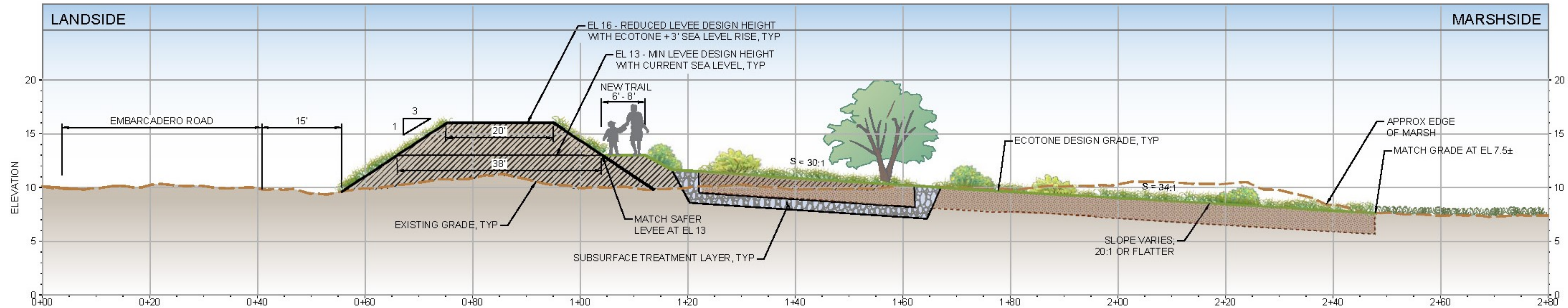


DWG: K:\projects_2012\D120042.03 - Oro Loma IRWMP Support\09 CAD\Dwgs\EMBARCADERO DETAIL.dwg USER: Marisa Landicho PLOT DATE: 8/7/2018 1:57:31 PM

NOTE: AERIAL ORTHOIMAGERY FROM NORTHROP GRUMMAN (2015), AS DOWNLOADED FROM USGS EARTH EXPLORER DATABASE. IMAGERY WAS COLLECTED BY NORTHROP GRUMMAN BETWEEN FEBRUARY 20 TO FEBRUARY 24, 2015.

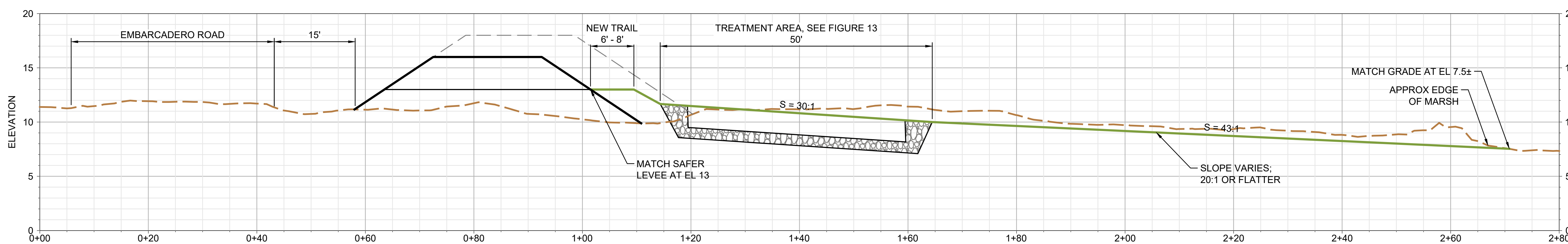
ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 3
EMBARADERO ROAD
PHASE 1 PLAN VIEW



A 2.3 **SECTION** EMBARCADERO ROAD

VERT: 1" = 10'
HORIZ: 1" = 20'



B 2.3 **SECTION** EMBARCADERO ROAD

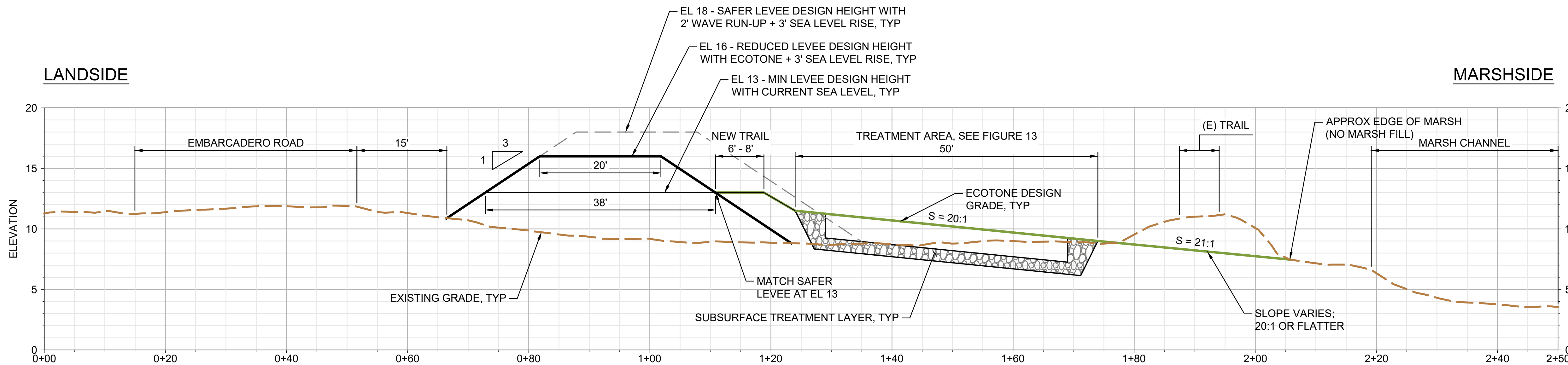
VERT: 1" = 10'
HORIZ: 1" = 20'

NOTE: EXISTING GRADE SURFACE IS APPROXIMATE AND BASED ON USGS TOPOGRAPHIC LIDAR (USGS, 2010), AS DOWNLOADED FROM THE NOAA OFFICE FOR COASTAL MANAGEMENT. ELEVATIONS ARE PRESENTED IN NORTH AMERICAN VERTICAL DATUM OF 1988.

10 5 0 10 20
Scale Feet

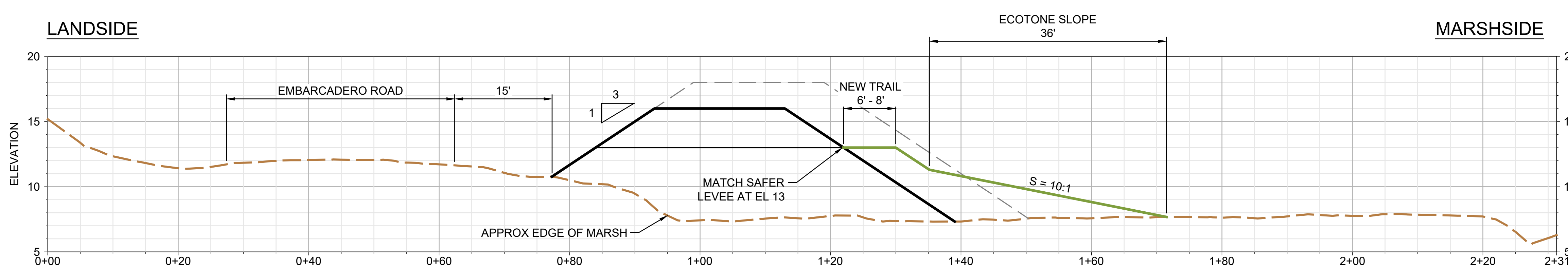
ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 4
EMBARCADERO PHASE 1
CROSS SECTIONS



C
2
SECTION
EMBARCADERO ROAD

VERT: 1" = 10'
HORIZ: 1" = 20'



D
2
SECTION
EMBARCADERO ROAD

VERT: 1" = 10'
HORIZ: 1" = 20'

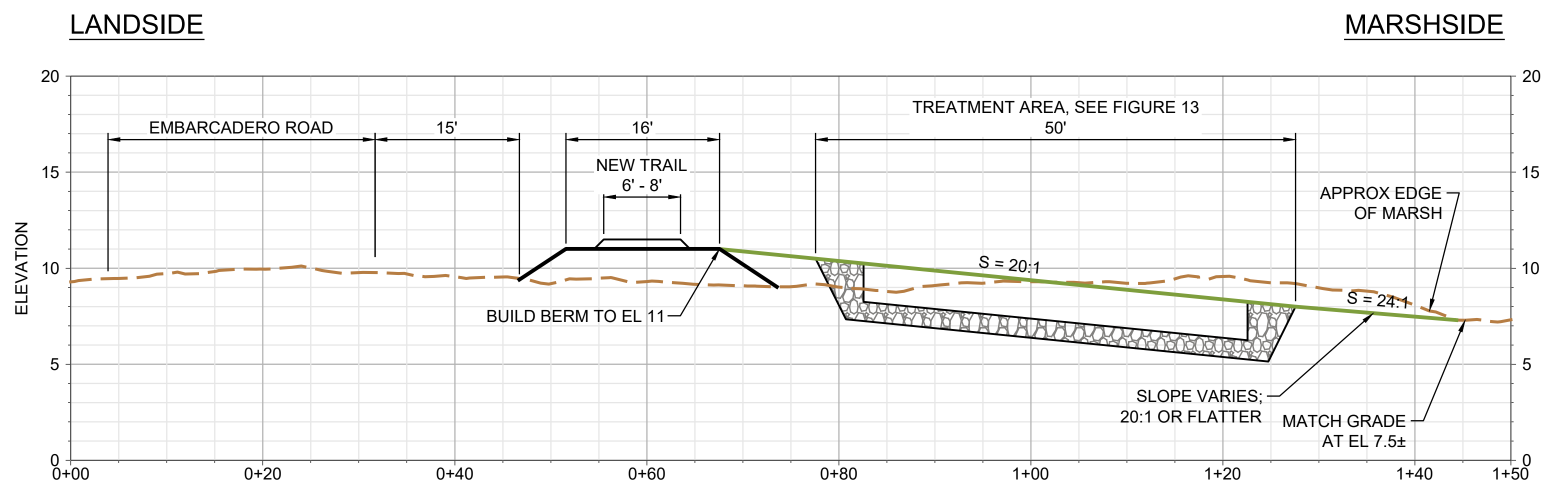
NOTE: EXISTING GRADE SURFACE IS APPROXIMATE AND BASED ON USGS TOPOGRAPHIC LIDAR (USGS, 2010), AS DOWNLOADED FROM THE NOAA OFFICE FOR COASTAL MANAGEMENT. ELEVATIONS ARE PRESENTED IN NORTH AMERICAN VERTICAL DATUM OF 1988.

10 5 0 10 20
Scale Feet

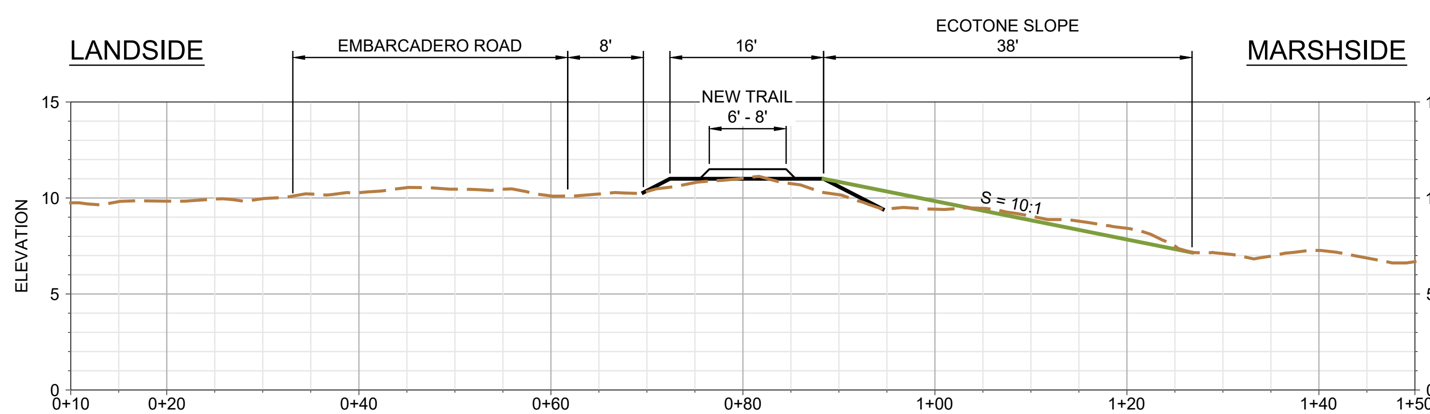
ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 5
EMBARCADERO SOUTH
CROSS SECTION

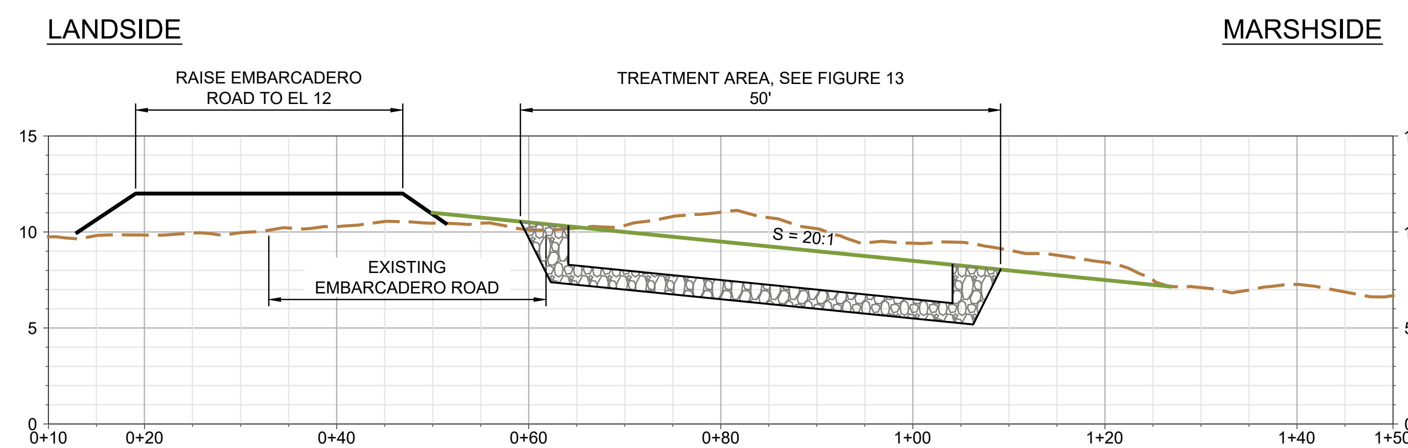
ESA



E
2
SECTION
EMBARCADERO ROAD
VERT: 1" = 10'
HORIZ: 1" = 20'



F1
2
SECTION (WITH BERM)
EMBARCADERO ROAD
VERT: 1" = 10'
HORIZ: 1" = 20'



F2
2
SECTION (RAISE ROAD)
EMBARCADERO ROAD
VERT: 1" = 10'
HORIZ: 1" = 20'

NOTE: EXISTING GRADE SURFACE IS APPROXIMATE AND BASED ON USGS TOPOGRAPHIC LIDAR (USGS, 2010), AS DOWNLOADED FROM THE NOAA OFFICE FOR COASTAL MANAGEMENT. ELEVATIONS ARE PRESENTED IN NORTH AMERICAN VERTICAL DATUM OF 1988.

10 5 0 10 20
Scale Feet

FIGURE 6
EMBARCADERO NORTH
CROSS SECTIONS

ESA

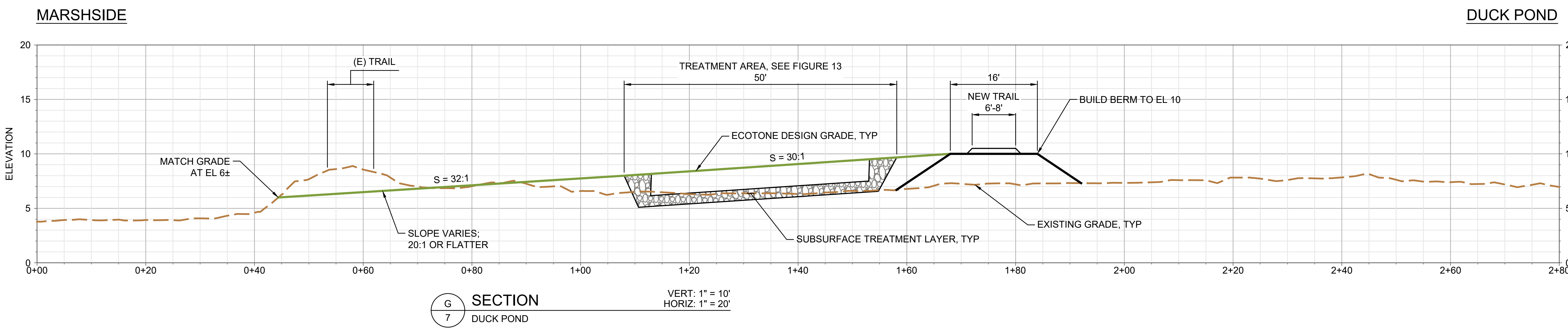
DWG: K:\projects_2012\D120042.03 - Oro Loma IRWMP Support\09 CAD\Dwgs\DUCK POND.dwg USER: Marisa Landicho PLOT DATE: 8/7/2018 1:57:48 PM

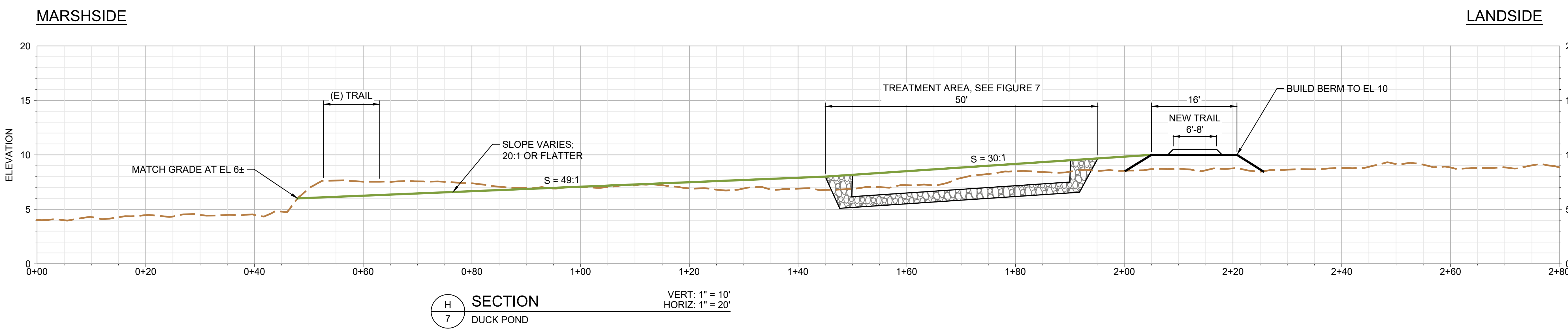
NOTE: AERIAL ORTHOIMAGERY FROM NORTHROP GRUMMAN (2015), AS DOWNLOADED FROM USGS EARTH EXPLORER DATABASE. IMAGERY WAS COLLECTED BY NORTHROP GRUMMAN BETWEEN FEBRUARY 20 TO FEBRUARY 24, 2015.

ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 7
DUCK POND
PLAN VIEW

ESA





NOTE: EXISTING GRADE SURFACE IS APPROXIMATE AND BASED ON USGS TOPOGRAPHIC LIDAR (USGS, 2010), AS DOWNLOADED FROM THE NOAA OFFICE FOR COASTAL MANAGEMENT. ELEVATIONS ARE PRESENTED IN NORTH AMERICAN VERTICAL DATUM OF 1988.

10 5 0 10 20
Scale Feet

DWG: K:\projects_2012\D120042.03 - Oro Loma IRWMP Support\09 CAD\Dwgs\SECTIONS.dwg USER: Marisa Landicho PLOT DATE: 8/7/2018 1:57:52 PM

ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 8
DUCK POND
CROSS SECTIONS

ESA

NOTE: AERIAL ORTHOIMAGERY FROM NORTHROP GRUMMAN (2015), AS DOWNLOADED FROM USGS EARTH EXPLORER DATABASE. IMAGERY WAS COLLECTED BY NORTHROP GRUMMAN BETWEEN FEBRUARY 20 TO FEBRUARY 24, 2015. SOUTH BAY SALT PONDS RESTORATION (60% DESIGN) BY DUCKS UNLIMITED (2017).

DWG: K:\projects_2012\D120042.03 - Oro Loma IRWMP Support\09 CAD\Dwgs\SBSP.dwg USER: Marisa Landicho PLOT DATE: 8/7/2018 1:57:58 PM

ESA

ORO LOMA IRWMP SUPPORT . D120042.03

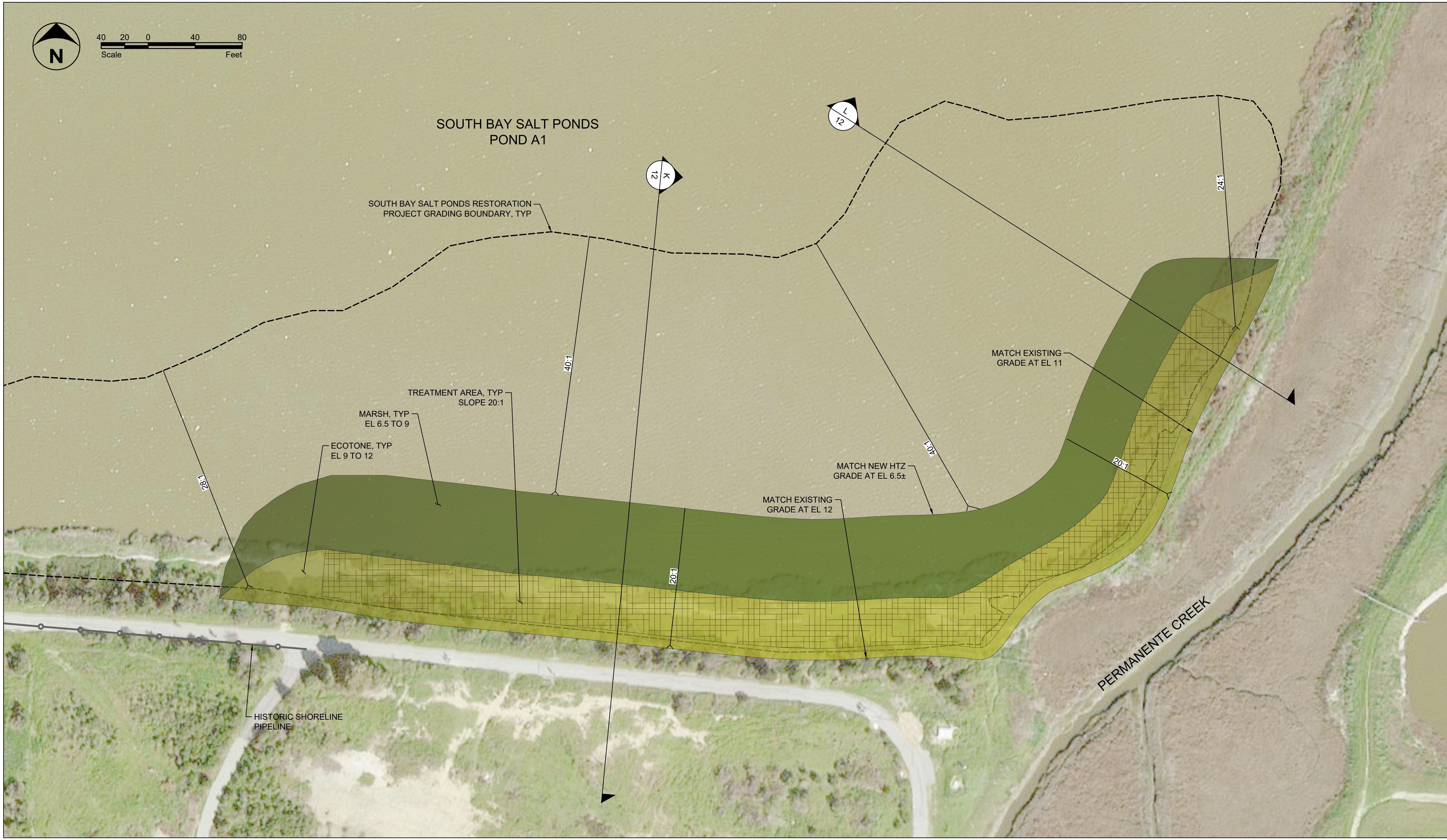
FIGURE 9
POND A-1 OVERVIEW

NOTE: AERIAL ORTHOIMAGERY FROM NORTHROP GRUMMAN (2015), AS DOWNLOADED FROM USGS EARTH EXPLORER DATABASE. IMAGERY WAS COLLECTED BY NORTHROP GRUMMAN BETWEEN FEBRUARY 20 TO FEBRUARY 24, 2015. SOUTH BAY SALT PONDS RESTORATION (60% DESIGN) BY DUCKS UNLIMITED (2017).

ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 10
POND A-1 WEST
PLAN VIEW

ESA

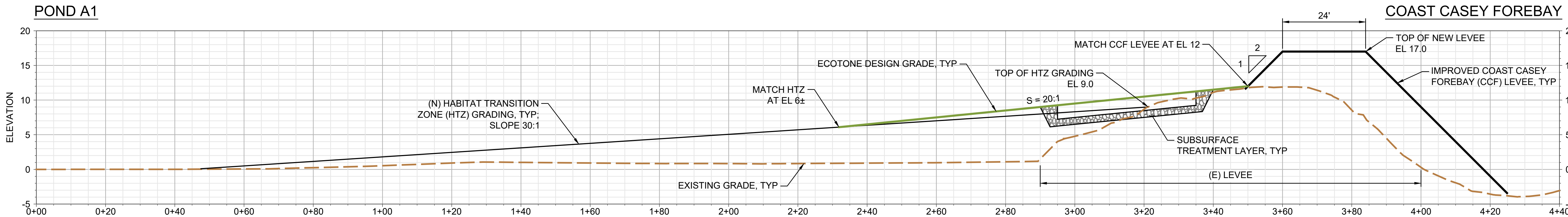


NOTE: AERIAL ORTHOIMAGERY FROM NORTHROP GRUMMAN (2015), AS DOWNLOADED FROM USGS EARTH EXPLORER DATABASE. IMAGERY WAS COLLECTED BY NORTHROP GRUMMAN BETWEEN FEBRUARY 20 TO FEBRUARY 24, 2015. SOUTH BAY SALT PONDS RESTORATION (60% DESIGN) BY DUCKS UNLIMITED (2017).

ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 11
POND A-1 EAST
PLAN VIEW

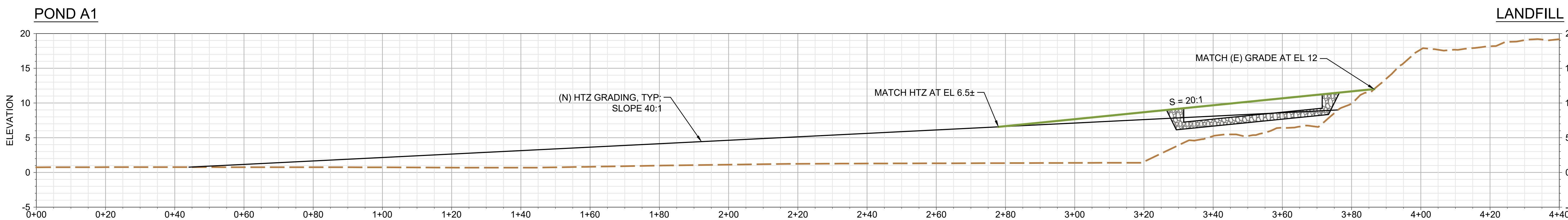
ESA



SECTION J / 10

POND A1

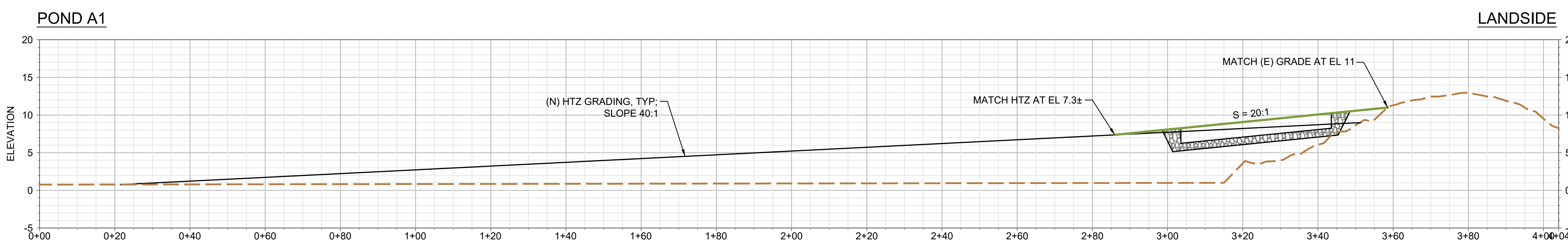
VERT: 1" = 7.5'
HORIZ: 1" = 15'



SECTION K / 11

POND A1

VERT: 1" = 7.5'
HORIZ: 1" = 15'



SECTION L / 11

POND A1

VERT: 1" = 7.5'
HORIZ: 1" = 15'

NOTE: EXISTING GRADE SURFACE IS APPROXIMATE AND BASED ON DUCKS UNLIMITED (2017) 60% DESIGN FOR SOUTH BAY SALT PONDS RESTORATION PROJECT. ELEVATIONS ARE PRESENTED IN NORTH AMERICAN VERTICAL DATUM OF 1988.

15 7.5 0 15 30
Scale Feet

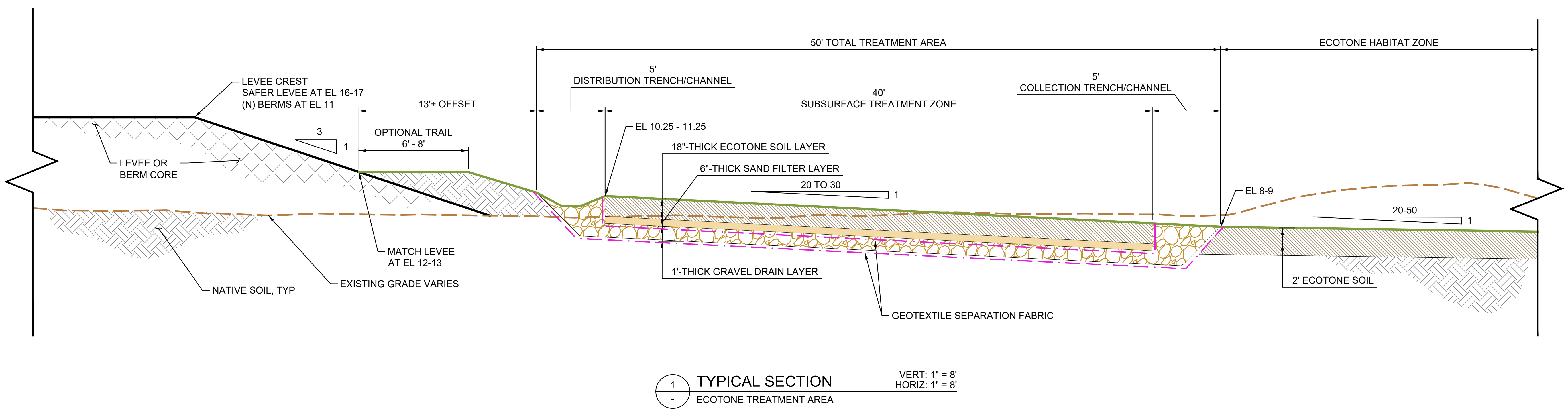
DWG: K:\projects_2012\D120042.03 - Oro Loma IRWMP Support\09 CAD\Dwgs\SECTIONS.dwg USER: Marisa Landicho PLOT DATE: 8/7/2018 1:58:11 PM

ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 12

POND A-1 CROSS SECTIONS

ESA



DWG: K:\projects_2012\D120042.03 - Oro Loma IRWMP Support\09 CAD\Dwgs\SECTIONS.dwg USER: Marisa Landicho PLOT DATE: 8/7/2018 1:58:12 PM

ORO LOMA IRWMP SUPPORT . D120042.03

FIGURE 13
ECOTONE TREATMENT
AREA TYPICAL SECTION

ESA

TABLE 4
PALO ALTO
CONCEPTUAL DESIGN - OPINION OF PROBABLE COSTS

ITEM NO.	ITEM	Phase 1 Embacadero ESTIMATED QUANTITY	Embarcadero Build-Out ESTIMATED QUANTITY	South Bay Salt Ponds ESTIMATED QUANTITY	Duck Ponds ESTIMATED QUANTITY	UNIT OF MEASURE	UNIT PRICE	Phase 1 Embacadero TOTAL	Embarcadero Build-Out TOTAL	South Bay Salt Ponds TOTAL	Duck Ponds TOTAL
0	Treatment Length	590	930	1,845	820	LF	---	---	---	---	---
1	Mobilization & Demobilization (7%)	1	1	1	1	LS	10%	$ 98,700	$ 193,200	$ 217,600	$ 155,400
2	SWPPP Implementation	2.3	4.3	5.4	3.6	AC	$ 10,000	$ 23,000	$ 43,000	$ 54,000	$ 36,000
Clearing & Grubbing											
3	Disc Grading Area	2.3	4.3	5.4	3.6	AC	$ 1,000	$ 2,300	$ 4,300	$ 5,400	$ 3,600
Earthwork											
4	Remove & Stockpile Topsoil (Upper 1')	3,700	7,000	8,700	5,800	CY	$ 15	$ 55,500	$ 105,000	$ 130,500	$ 87,000
5	Excavation to Ecotone Subgrade	9,700	22,600	0	10,900	CY	$ 10	$ 97,000	$ 226,000	$ -	$ 109,000
6	Furnish & Install Geotextile Fabric	6,700	10,500	16,400	9,900	SY	$ 5	$ 33,500	$ 52,500	$ 82,000	$ 49,500
7	Import & Place Gravel	1,400	2,100	4,200	1,900	CY	$ 50	$ 70,000	$ 105,000	$ 210,000	$ 95,000
8	Import & Place Sand	440	690	1,370	610	CY	$ 50	$ 22,000	$ 34,500	$ 68,500	$ 30,500
9	Import, Mix, & Place Blended Ecotone Soil	6,800	13,000	16,000	10,800	CY	$ 30	$ 204,000	$ 390,000	$ 480,000	$ 324,000
Revegetation											
10	Drill Seeding	2.3	4.3	5.4	3.6	AC	$ 8,000	$ 18,400	$ 34,400	$ 43,200	$ 28,800
11	Plantings (per acre, assuming 2' O.C.)	2.3	4.3	5.4	3.6	AC	$ 40,000	$ 92,000	$ 172,000	$ 216,000	$ 144,000
Infrastructure											
11	WWTP Connection (pump station, turnout, controls, etc.)	1	1	1	1	LS	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000
13	Pipeline Connection to WWTP or Ex Irr Line	660	660	2,850	2,210	LF	$ 175	$ 115,500	$ 115,500	$ 498,750	$ 386,750
14	Distribution Line to Treatment Area	700	2,500	1,450	670	LF	$ 150	$ 105,000	$ 375,000	$ 217,500	$ 100,500
15	Discharge (box, valves, flow meters, etc)	4	13	8	4	EA	$ 10,000	$ 40,000	$ 130,000	$ 80,000	$ 40,000
Public Access											
16	New Trail (8' Wide)	900	2,710	0	1,420	LF	$ 20	$ 18,000	$ 54,200	$ -	$ 28,400
	SUBTOTAL:							$ 1,085,000	$ 2,125,000	$ 2,393,000	$ 1,708,000
	CONTINGENCY:						35%	$ 380,000	$ 744,000	$ 838,000	$ 598,000
	TOTAL ESTIMATE OF PROBABLE CONSTRUCTION COST (2018 DOLLARS):							**$ 1,465,000**	**$ 2,869,000**	**$3,231,000**	**$2,306,000**
	ESCALATED TOTAL ESTIMATE OF PROBABLE CONSTRUCTION COST (2021 DOLLARS):						4%/yr	**$ 1,650,000**	**$ 3,230,000**	**$3,630,000**	**$2,590,000**

1 For planning purposes we have provided order of magnitude estimates to allow cost comparison of alternatives. These cost estimates are intended to provide an approximation of total projects construction costs appropriate for the conceptual level of design. These cost estimates are considered to be approximately -30% to +50% accurate and include a 35% contingency to account for project uncertainties (such as final design, permitting restrictions and bidding climate).

2 These estimates are subject to refinement and revisions as the design is developed in future stages of the project.

3 This table does not include estimated project costs for permitting, design, monitoring, or ongoing maintenance.

4 Estimated costs are developed in 2018 dollars, and escalated to 2021 dollars assuming a 4% annual escalation.

5 This opinion of probable construction cost is based on ESA's previous project experience and bid prices from similar projects.

6 This estimate does not include earthwork associated with building levees designed by others (i.e. SAFER levee or the South Bay Salt Ponds restoration). We assume excess material will be mixed within the ecotone soil, or used for levee construction. Earthwork units costs assume no off-haul.