Sonoma Creek Baylands Strategy - Executive Summary

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Introduction

Prior to the 1850s, the Sonoma Creek baylands were a vast mosaic of tidal and seasonal wetlands. Fresh water, sediment, and nutrients were delivered from the upper watershed to mix with the tidal waters of San Pablo Bay, creating a small estuary teeming with life. Floods along Sonoma Creek and Schell Creek spread out in an alluvial fan in the region south of present-day State Route (SR) 121, creating distributary channels and depositing sediment.

During the late 19th and early 20th centuries, the Sonoma Creek baylands, along with 80 percent of wetlands around San Francisco Bay, were diked and drained for agriculture and other purposes. This created discrete parcels and simplified creek networks. Flow of water and sediment across the alluvial fans was blocked and confined to the creek channels. As a result, portions of Schellville and surrounding areas in southern Sonoma County are frequently flooded during relatively small winter storm events, when flows overtop the banks of Sonoma and Schell creeks, resulting in road closures at the junction of SR 121 and SR 12 that affect travel and public safety.

Much of what used to be tidal marsh has been transformed into other habitat types including diked agricultural fields. Narrow strips of tidal marsh have developed adjacent to the tidal slough channels that run between the diked agricultural baylands.

Development within the Sonoma Creek baylands continues despite the chronic flooding that is caused by filling and fragmentation of the floodplain. Flooding, and loss of habitat, species, and ecological function will increase with climate change-driven sea level rise and increased storm intensity.

Project Purpose

The purpose of this strategy is to provide Sonoma Land Trust and partners with a clear and comprehensive plan that:

- Coordinates the protection, acquisition, restoration, and enhancement of diverse baylands habitats,
- Integrates natural processes to increase climate resilience,
- Identifies opportunities for public access, and
- Provides recommendations for SR 37 and the SMART rail line.

Implementation of this strategy is intended to benefit species including the following special status species: California Ridgway's Rail, California black rail, salt marsh harvest mouse, Chinook salmon, and steelhead.

Background

The study area falls entirely within Sonoma County and includes the Sonoma Creek and Tolay Creek baylands between SR 121 and the bay and adjacent wetland-to-upland transition zones (Figure 1).

Figure 1. Study Area

This project was funded by San Francisco Bay Restoration Authority, U.S. Fish and Wildlife Service, Resources Legacy Fund, and the Dolby Family Fund. The project team included Sonoma Land Trust, San Francisco Estuary Institute, Environmental Science Associates, Ducks Unlimited, Point Blue Conservation Science, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, and Sonoma Water. The project was guided by a Science Advisory Panel. Public and private landowners throughout the study area were interviewed as part of the development of the strategy. The project team consulted with

Sonoma Water, Caltrans, Metropolitan Transportation Commission, Sonoma County Transportation Authority, and SMART.

This document provides a summary of the Sonoma Creek Baylands Strategy including future scenarios, opportunities and constraints, alternatives evaluated, key findings, and implementation.

Future Scenarios

The strategy considers a planning horizon of 100 years and incorporates predicted changing conditions within the planning area over time. The projected sea level rise in San Francisco Bay is 1.9 feet by 2050, and 5.7 feet by 2100. This projection is recommended by the Ocean Protection Council for medium to high risk aversion planning purposes.

Opportunities for Tidal Marsh Restoration

- Public and private landowners have expressed interest in completing conservation and restoration projects on their land.
- Fringing marsh habitat along the tidal creek and slough channels could provide a nucleus from which to build restorations.
- The alluvial fans of Sonoma and Tolay creeks could provide connectivity to upland habitats.
- There is adequate water from multiple sources including fresh water from the Sonoma Creek watershed and the North Bay Water Reuse Program recycled water pipeline, and tidal flows from San Pablo Bay.
- The natural sediment supply could be reestablished by reconnecting with inputs from the watershed and San Pablo Bay, and elevations of subsided parcels could be augmented through beneficial reuse of dredged sediment.
- Woody debris collects in the study area following big storms. Restoring the currently diked parcels would open new areas where woody debris could collect and provide habitat complexity.
- Tidal marsh restoration would result in restoration of tidal action through the diked baylands, which could reduce the depth, extent, and duration of flooding in the Schellville area around SR 121 by reducing backwater effects and enhancing drainage.

Constraints to Tidal Marsh Restoration

- Transportation infrastructure, including SR 37 and SR 121 and the Sonoma-Marin Area Rail Transit (SMART) rail line, presents a major constraint to restoration. Larger planning efforts to address congestion and flooding along the SR 37 corridor are underway, and restoration in the Sonoma Creek Baylands will need to be coordinated with these efforts. The major constraints presented by SR 37 are the channel crossings at Tolay and Sonoma creeks, which limit the width of the channel and thus the amount of tidal volume that can be accommodated when diked baylands are restored. At Tolay Creek, the current channel crossing is too small to accommodate any additional tidal volume, so the bridge would have to be lengthened to allow restoration in the Tolay Creek watershed.
- The SMART rail line runs through many of the diked properties, limiting future restoration options. The tracks, projected to be inundated by rising seas, are vulnerable to flooding and dependent on the aging system of berms and pumps that will be under increasing pressure as sea level rises.
- Sonoma Valley Airport is a small municipal airport with a single runway located along SR 121. The airport is surrounded by various safety zones as identified in the Sonoma County General Plan,

which constrain uses in the vicinity of the airport. Due to potential bird strike hazards, large water features including wetlands, may be prohibited in airport safety zones.

- The FAA requires that the VORTAC navigational aid on the eastern side of Skaggs Island and its access be maintained during and after restoration.
- Vector control can place a constraint on the range of design options available because restoration should not increase mosquito populations that can adversely impact human health.
- PG&E electric transmission lines and gas pipelines and Sonoma Water's North Bay Water Reuse Program pipeline run through the project area. Access to these utilities will need to be maintained and incorporated into site-specific restoration designs.
- One logistical constraint may be the piecemeal acquisition of properties from willing sellers, which could limit the potential to complete restorations as envisioned in this document. Therefore, project designs will need to carefully consider changes to hydrodynamics and tidal prism to ensure that the levees of adjacent properties are not undermined by the restorations.

Alternatives Evaluated

Four landscape-scale restoration alternatives were created to provide a mosaic of functional and resilient habitats. The alternatives were hydrologically modeled under various combinations of tidal and streamflow conditions, for the present day and the year 2050. The alternatives were also evaluated using a landscape evolution model to understand how well each succeeds at achieving habitat resilience up to the year 2100, based on their initial designs and response to sea level rise.

The alternatives incorporate current and predicted conditions in the region. Most of the diked baylands properties are at or below low water. This means the tidal flow volume following levee breaching is the maximum it can be and will not increase with future sea level rise. Therefore, alternatives that can accommodate this present-day potential flow volume can accommodate much higher flows associated with sea level rise. The alternatives are designed to maximize the balance of cut and fill within each parcel, reducing the need to import or export fill between parcels. In recognition of the relative lack of sediment in the San Francisco Bay, likely accretion rates relative to projected sea level rise, and the desire to reduce dependence on imported fill, the alternatives include significant shallow subtidal and mudflat habitats, mimicking historical conditions in the San Pablo baylands. The alternatives are summarized below:

- *No Restoration* alternative reflects current conditions with assumed foreseeable climate change-caused changes in the absence of new, large-scale wetland restoration. (Figure 2)
- *Alternative 1: Maximum Tidal* represents a broad scale tidal restoration. It was assumed that the diked baylands parcels would include a mix of habitat elevations including mudflat and low to high tidal marsh. It was also assumed that tidal volume would be routed through the existing channel network, which would adjust to the additional tidal volume from the restored parcels. (Figure 3)
- *Alternative 2: Avoid the Railroad* represents the least extensive tidal restoration and least amount of fill in the restored parcels. The purpose of this alternative was to evaluate a condition that minimizes impacts to SMART infrastructure, therefore reducing the need for and cost to protect the railroad. (Figure 4)
- *Alternative 3: Enhanced Maximum Tidal* represents a modification of Alternative 1 with the primary conveyance for tidal and stream flows routed through the center of the diked parcels. Whether through planned tidal marsh restoration projects or unplanned erosion and breaching of dikes caused by sea level rise, flow volumes within the tidal channels of Sonoma Creek have the potential to increase. If flow volumes increase, then channel size will increase as well, which could result in

the erosion of the linear strips of tidal marsh that have developed in the creek and slough channels, and scouring around SR 37 bridge abutments. This alternative is configured to protect existing marsh habitat in the channel network by focusing flow and tidal volume in newly graded channels rather than scouring the existing channels. (Figure 5)

Key Findings

SR 37 & SMART

The present bridge crossings and embankments disrupt hydrologic and habitat connectivity between the baylands and the bay, and inhibit the ability to implement restoration projects. To achieve a fully integrated design for maximizing hydrologic and habitat connectivity, SMART and SR 37 should be collocated on an elevated causeway (similar to the Yolo Bypass in the Sacramento Valley) adjacent to the existing SR 37 alignment, reducing the length of track and minimizing ecological disruption. Alternatively, SMART and SR 37 should be raised on piled causeways along their existing alignments.

SR 37

As an alternative to elevating SR 37 and SMART tracks on a causeway, SR 37 design should accommodate reconnecting baylands and tributaries, allowing for the passage of water, sediment, and species. These reconnections should center around the Sonoma and Tolay creek bridge crossings and surrounding marshes. Tolay Creek bridge should be lengthened and elevated sufficiently to accommodate the increased tidal volume that would result from restoration in the Tolay Creek baylands. Tidal volume beneath the Sonoma Creek bridge increases in all the alternatives, including the no-action alternative. A more detailed analysis along with close coordination with Caltrans will be required to investigate the scour potential of the concrete piles to ensure the structural integrity of the bridges required by the increased tidal exchange.

SMART

All alternatives except the no-action alternative require protection of the SMART railroad from tidal waters to maintain the existing level of flood protection. Potential protection measures include relocating the railroad outside of tidally influenced areas, raising the railroad embankment above tidal and floodwaters, raising the railroad on a pile-supported causeway, and isolating the existing embankment with levees. Currently, both Railroad and Wingo slough bridges constrain floodwater and are proposed to be modified. The legal obligations of landowners to protect the railroad from flooding were not investigated and require further examination. A more detailed analysis will be required along with close coordination with SMART.

Public Access

Public access to open space is vital to public health and the wellbeing of our community and will be provided to the maximum extent feasible. Public access and recreation in the planning area is and will continue to be limited and access in the diked baylands should be considered temporary given the anticipated change over time as sea level rise and other ecological changes alter the landscape. The project team and Science Advisory Panel developed the following guiding principles for new public access:

1. Options for public access should be considered during every project phase.

2. Before access is included in site design, ensure that resources, including funding and the entity responsible for the design, construction, maintenance, law enforcement, and ownership of the access facility have been identified.
3. Build trails from natural, soft materials that may deteriorate with sea level rise, flooding, and inundation without harm to surrounding habitat.
4. Access should be adaptable to ensure on-going facility safety and maintenance. Facility safety and maintenance needs may change with anticipated changing landscape conditions.
5. Improve signage at existing access facilities (e.g. Eliot Trail) to increase awareness of existing public access opportunities.

Implementation

Alternative 3 emerged as the most feasible alternative overall, as it ranked the highest for meeting project goals, followed by Alternative 1 and Alternative 2. Alternatives 1 and 3 are similar in terms of infrastructure impacts, while Alternative 2 emerged as most feasible regarding infrastructure impacts because interactions with the railroad were avoided. Alternative 2 could be implemented on the shortest timeline due to infrastructure avoidance, smaller restoration area, and the need to acquire fewer properties.

It is likely that Alternative 2 will be implemented in the process of implementing Alternative 3. Alternative 3 provided the greatest level of resource protection and restoration, highest rate of carbon sequestration, greatest sea level rise adaptability, and maximized environmental benefits, mainly due to the protection of existing outboard marshes and the species that rely on them.

Feasibility level opinions of probable construction costs were developed for the three restoration alternatives (Table 1). The costs of acquisition were not included.

Table 1. Feasibility level opinion of probable cost

		Construction (includes admin and management)		
Alternative	Design & Permitting	Restoration	Infrastructure Protection	Total
1	$23.6M	$154.0M	$171.8M	**$349.4M**
2	$18.5M	$124.8M	$82.6M	**$225.9M**
3	$23.6M	$185.7M	$171.8M	**$381.1M**

Sonoma Land Trust and project partners will continue to coordinate with the SR 37 redesign and SMART to envision and implement an integrated transportation and restoration project. Simultaneously, Sonoma Land Trust and partners will continue to develop site-specific conservation and restoration projects moving toward implementation of Alternative 3. Sonoma Land Trust is committed to an accelerated implementation of the strategy, following guidance from the Bay Ecosystem Habitat Goals Project that wetland habitats restored and established prior to 2030 will be most resilient to and best able to buffer the impacts of sea level rise as it increases toward the middle of the century[1].

[1] Goals Project. 2015. The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015 prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

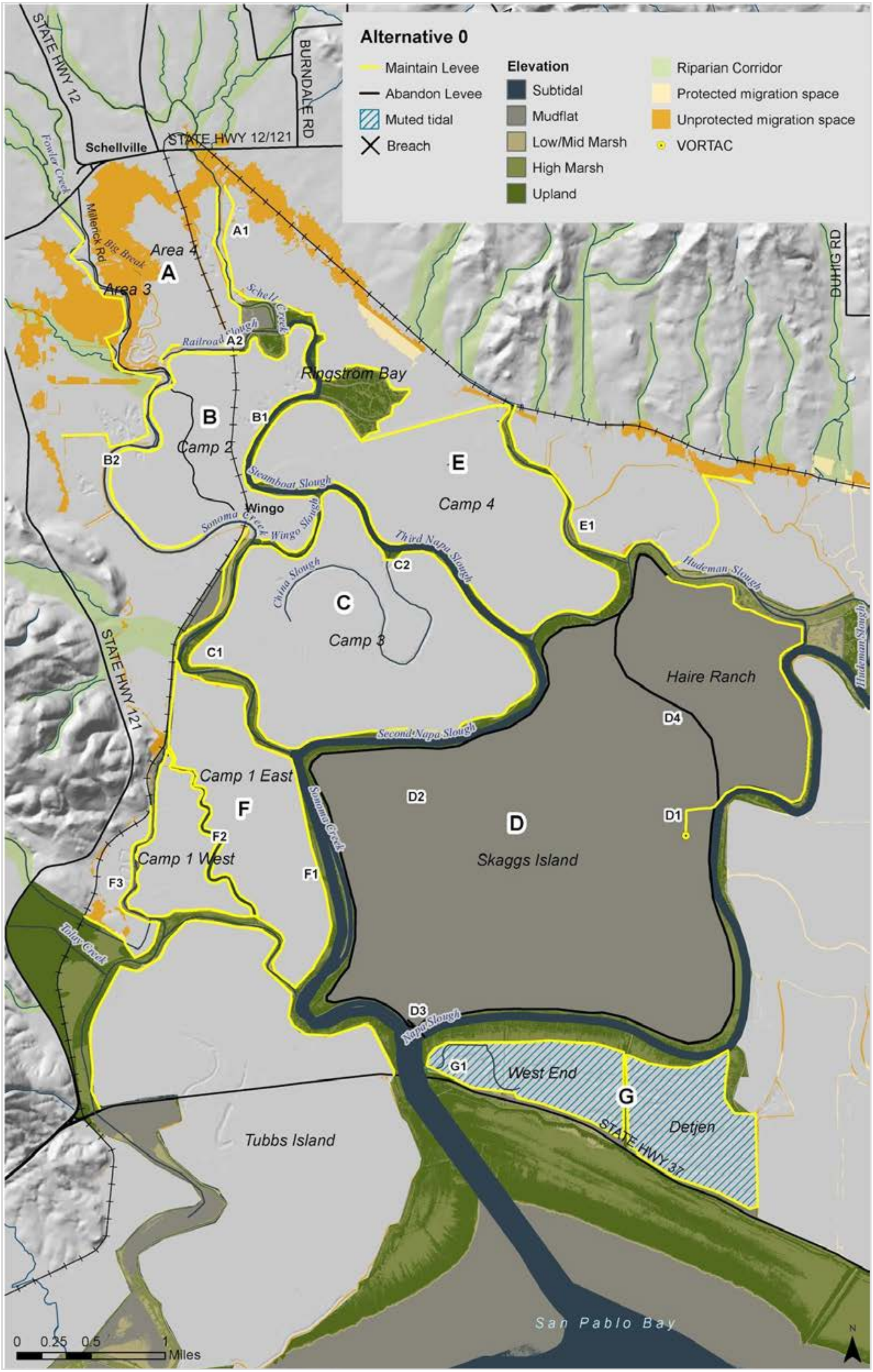

Figure 2. No Action

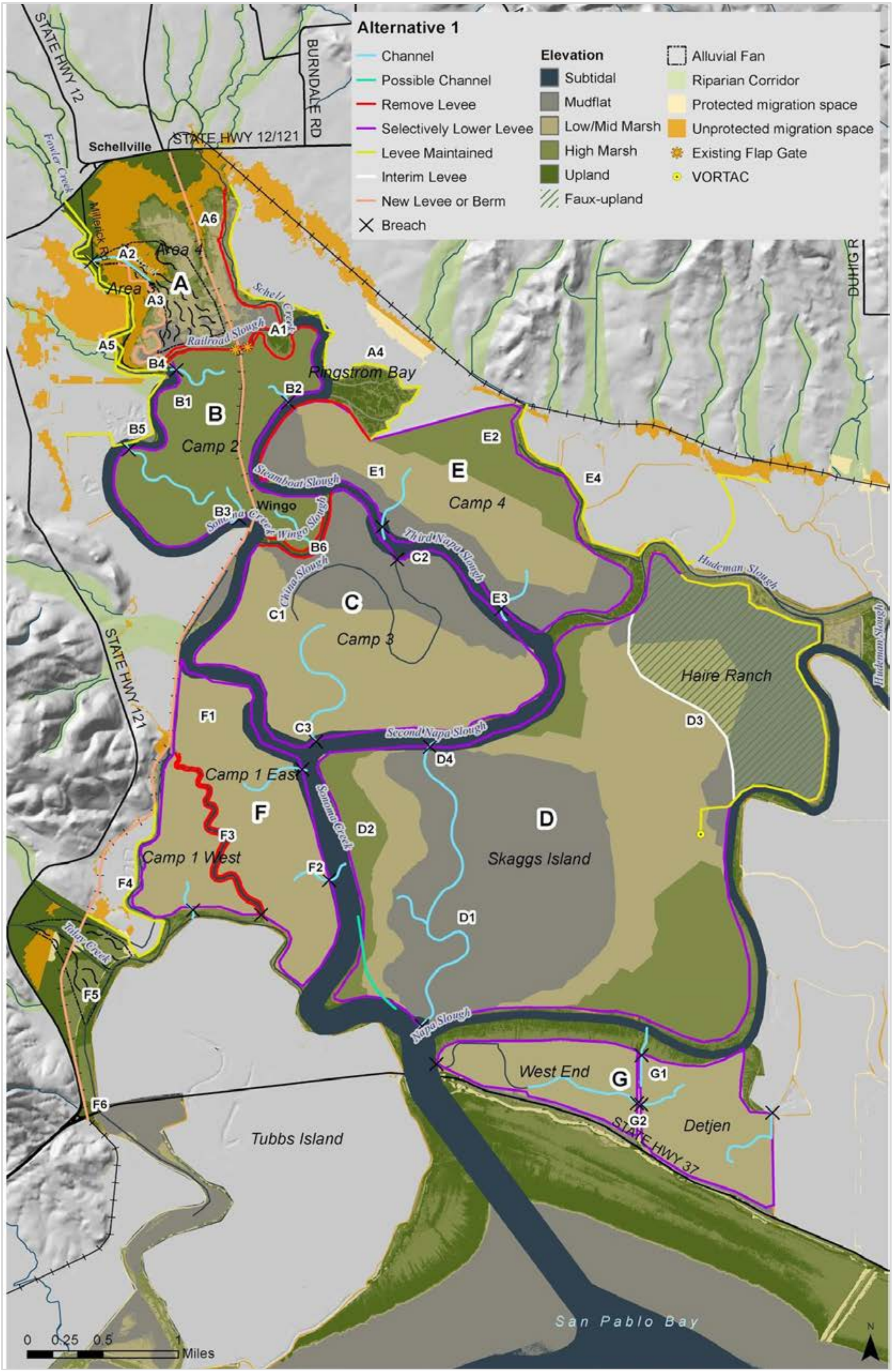

Figure 3. Alternative 1 Maximum Tidal

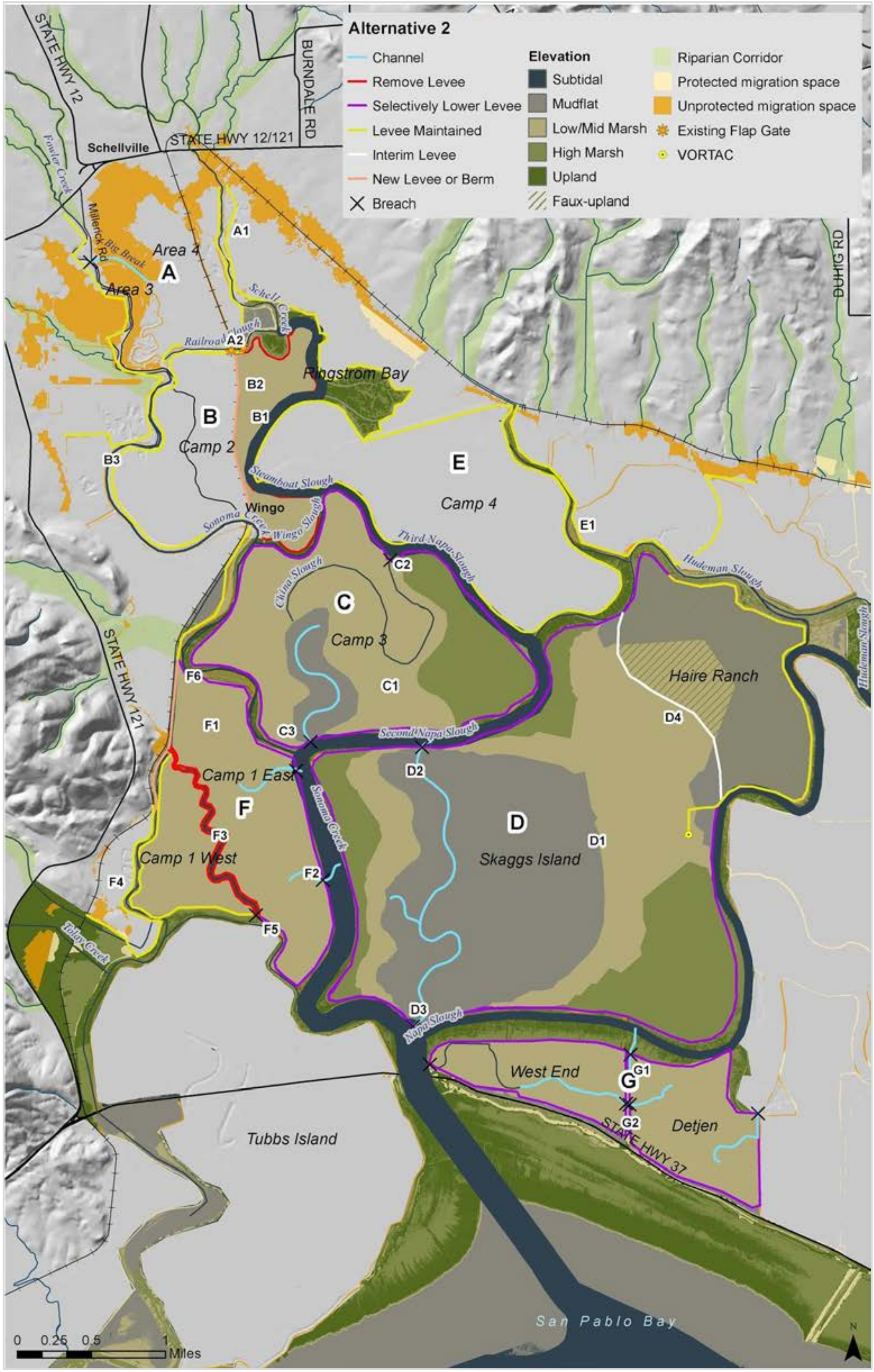

Figure 4. Alternative 2 Avoid the Railroad

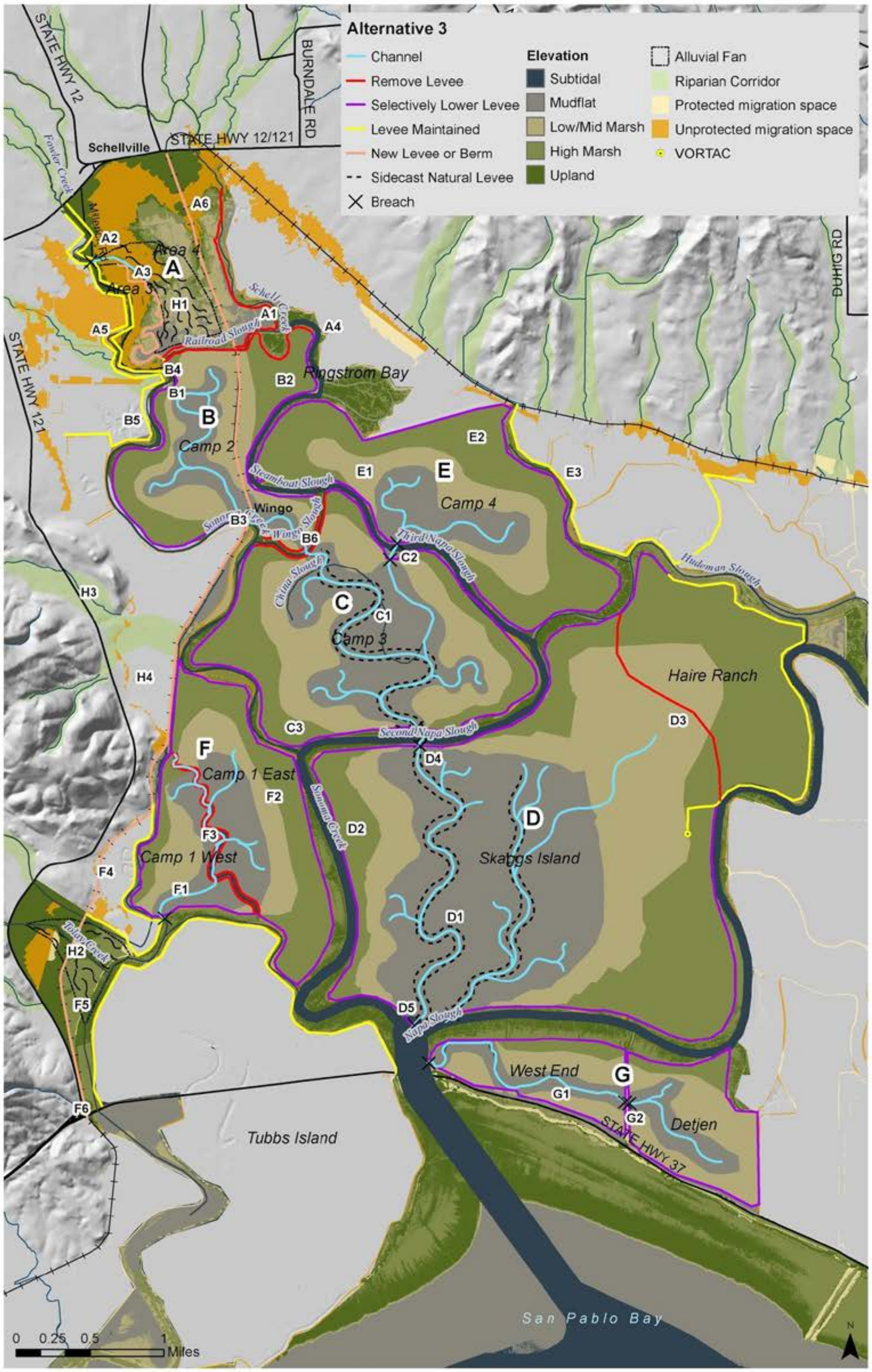

Figure 5. Alternative 3 Enhanced Maximum Tidal

Sonoma Creek Baylands Strategy

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Acknowledgements

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Figures

Acronyms and Abbreviations

ALUC - Sonoma County Airport Land Use Commission
BCDC - Bay Conservation and Development Commission
Caltrans - California Department of Transportation
CDFW - California Department of Fish and Wildlife
CEMAR – Center for Ecosystem Management and Restoration
CNPS - California Native Plant Society
CNRA-OPC - California Natural Resources Agency/California Ocean Protection Council
ESA - Environmental Science Associates
FAA - Federal Aviation Administration
HAT - Highest Astronomical Tide
MHHW - Mean Higher High Water
MLLW - Mean Lower Low Water
NMFS - NOAA National Marine Fisheries Service
OPC – Ocean Protection Council
RWQCB - California Regional Water Quality Control Board
SCC - California State Coastal Conservancy
SFEI - San Francisco Estuary Institute
SMART – Sonoma-Marin Area Rail Transit
SPBNWR - San Pablo Bay National Wildlife Refuge
SR - State Route
USFWS - United States Fish and Wildlife Service

CHAPTER 1

Introduction

1.1 Background

The diked agricultural areas of the Sonoma Creek Baylands were once a vast mosaic of tidal and seasonal wetlands. The Sonoma Creek Baylands sits where multiple tributaries delivered fresh water, sediment and nutrients which mixed with the tidal waters of San Pablo Bay, the northern extent of San Francisco Bay, to create a small estuary teeming with life (**Figure 1.1**). Diverse salinity and topographic gradients would have supported an abundant and diverse flora while bears and eagles might have fed on steelhead and chinook salmon navigating Sonoma Creek. The Swampland Act of 1850 ushered in an era of reclamation and more than eighty percent of San Pablo Bay's wetlands, including in Sonoma Creek Baylands, were reclaimed resulting in loss of habitat, species and ecological function. Development within the Sonoma Creek watershed continues today amidst constrained floodplains and subsided baylands isolated by levees, resulting in chronic flooding of infrastructure. These challenges will worsen with sea level rise and increased storm intensity, both associated with climate change. While broad strategies exist for the region (Goals Project 2015), no plans exist which specifically target the protection, restoration and adaptation of the Sonoma Creek Baylands in anticipation of climate change.

A flood management and ecosystem enhancement study for lower Sonoma Creek was completed in 2012 (ESA PWA and SSRCD 2012). Hydrodynamic modeling indicated that although individual projects will not effectively reduce flooding, a broader watershed-wide approach may provide more significant flood reduction and habitat restoration opportunities. The study recommended a shift to flood-compatible land uses within the Sonoma Creek Baylands, such as through the acquisition of easements on flood-prone lands for seasonal flooding, and acquisition of flood-prone lands for restoration to tidal wetlands.

The Sonoma Creek Baylands Strategy (Strategy) builds on the recommendations of the 2012 study and provides a plan for landscape-scale restoration, flood protection, and public access in the Sonoma Creek Baylands. It also provides recommendations for the State Route (SR) 37 redesign project and the SMART rail line.

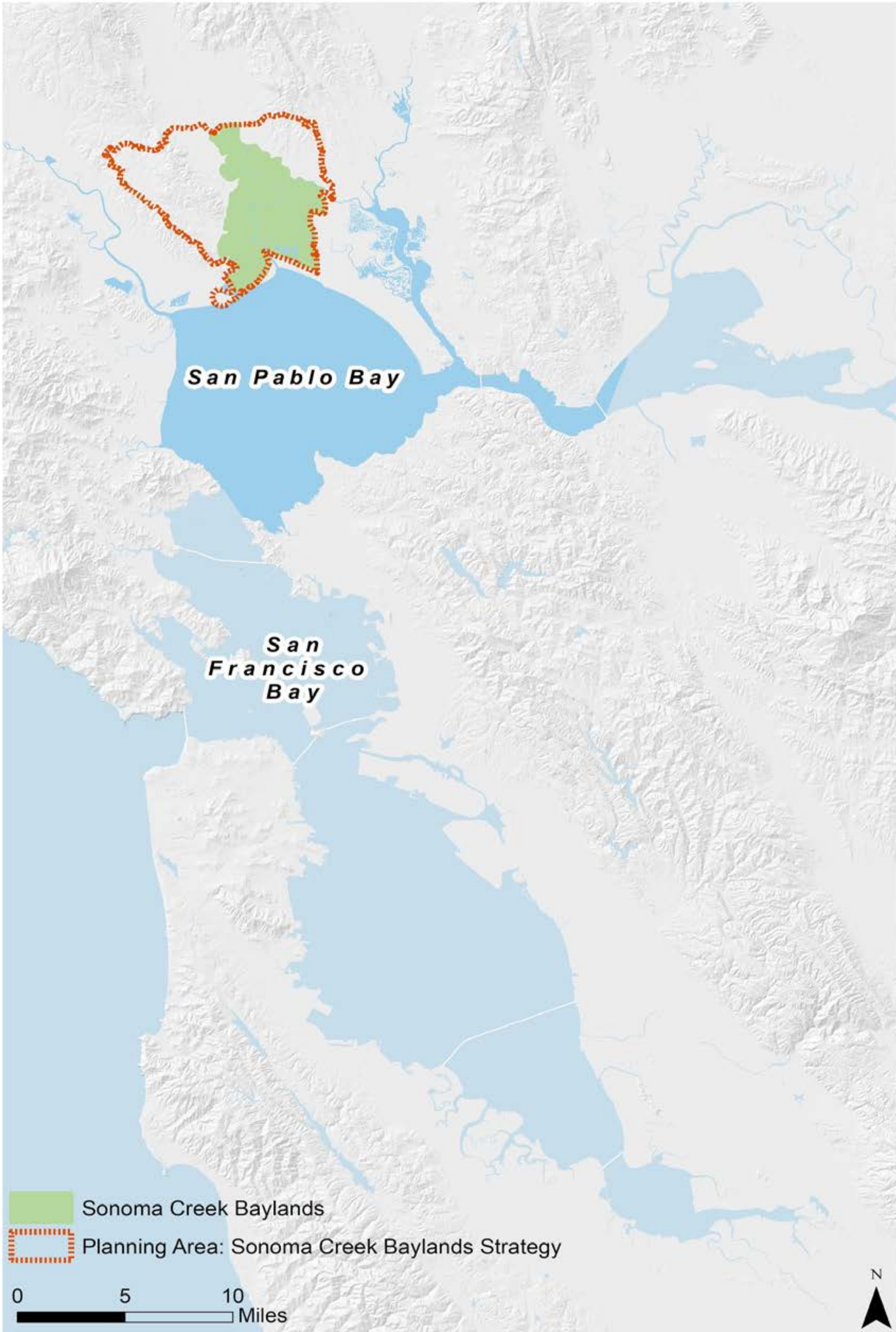

Figure 1.1 The planning area in context.

1.2 Purpose and Goals

The purpose of the Strategy is to provide Sonoma Land Trust and partners with a clear and comprehensive plan that coordinates the protection, acquisition, restoration, and enhancement of diverse baylands habitats (e.g., subtidal, mudflat, tidal marsh, brackish marsh, freshwater marsh, upland-wetland transition), integrates natural processes to increase climate resilience of the Sonoma Creek Baylands, identifies appropriate public access, and provides recommendations for the redesign of SR 37 and increased connectivity under and across the SMART rail line where they pass through the Sonoma Creek Baylands.

The goals of the Strategy broadly reflect those of the widely adopted Baylands Ecosystem Habitat Goals Update (2015). Specific Strategy goals include:

1. Adhere to the guiding principles developed by the State Route 37 - Baylands Group.
2. Prioritize existing acquisition opportunities from willing sellers.
3. Maximize appropriate habitat restoration.
4. Identify important marsh migration zones and watershed connections.
5. Identify opportunities and constraints for reduction of chronic flooding.
6. Identify opportunities for public access.
7. Provide recommendations for the redesign of SR 37 relative to the preferred alternative for the Sonoma Creek Baylands.
8. Provide quantifiable metrics to evaluate Strategy alternatives, where possible.
9. Gain stakeholder buy-in through targeted outreach.

1.3 Guiding Principles

At the beginning of the study, principles to guide development of the Strategy were determined through a series of workshop-style meetings between the project team and key agency stakeholders.

1. The planning area of the Strategy is defined as land within Sonoma County and the very western tip of Solano County that includes the Tolay Creek watershed (within the Petaluma watershed), the baylands and fluvial floodplain of Sonoma Creek up to the flood breakout area just north of SR 12 and SR 121, and the adjacent upland-wetland transition zone. Sonoma Creek Baylands lies within the planning area, which includes the lands around San Pablo Bay that are now or were historically submerged by the estuary's tides (**Figure 1.2**).

2. Sonoma Creek Baylands is dominated by agricultural uses with roads, rail, and utilities running within and adjacent to the baylands. The Strategy must be informed by and should provide findings for the relative risks of worsening flooding of diked lands, roads or railroads, erosion of levees, and saline intrusion into groundwater in the Sonoma Valley and Sonoma Creek Baylands.

3. The Strategy will be informed by processes and inputs outside the planning area – north in the Sonoma Creek watershed, east in the Napa-Sonoma marshes, and south in San Pablo Bay.

4. The Strategy will consider a planning horizon of 100 years, acknowledging that conditions within the planning area will change over time. Within this period, environmental conditions such as relative sea level rise, sediment supply, subsidence, etc. will be based on the latest scientific information and state projections, where applicable. The Strategy must coordinate with other stakeholders' activities and plans in the baylands and local watersheds, while taking natural geomorphic processes into account.

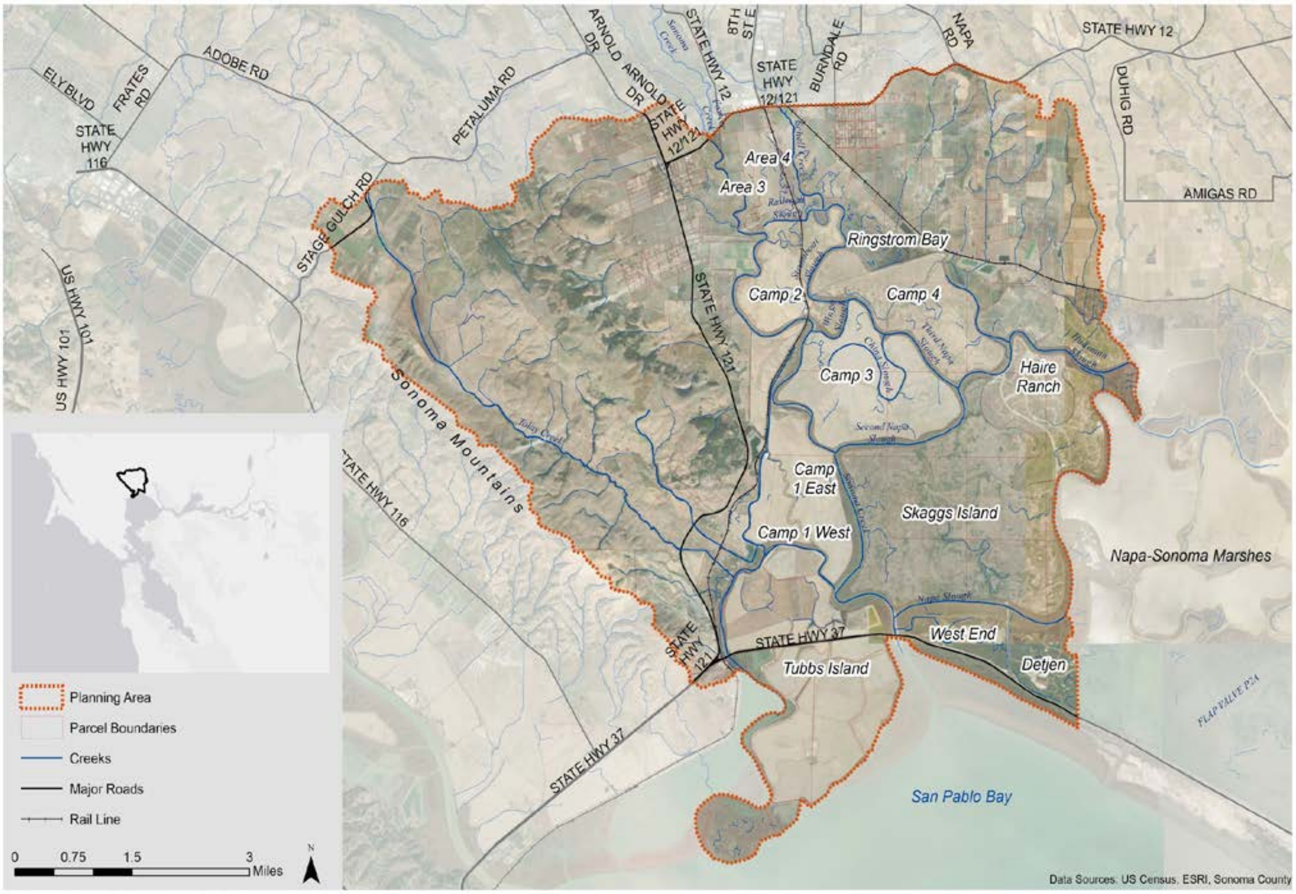

Figure 1.2 Planning area and surrounding areas. Labeled parcels constitute the Sonoma Creek Baylands portion of the planning area.

5. The Strategy will propose solutions that are feasible, affordable, potentially permittable, and that minimize maintenance and risk.

6. In light of sea level rise, the Strategy will emphasize rapid implementation of restoration projects to increase the success of marsh development and will identify intermediate implementation steps.

7. The Strategy will align with the Groundwater Sustainability Plans for Sonoma Valley and Petaluma River and Southern Sonoma Stormwater Resource Plan.

8. The Strategy will be informed by and help meet the goals of multiple regional plans, such as:

- Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (USFWS, 2013b)
- Baylands Ecosystem Habitat Goals (Goals Project 1999) and update (Goals Project 2015)
- California State Wildlife Action Plan – 2015 Update (CDFW 2015)
- San Pablo Bay National Wildlife Refuge Comprehensive Conservation Plan (USFWS 2011)
- San Pablo Bay National Wildlife Refuge Climate Adaptation Plan (Veloz et al. 2016)
- Napa-Sonoma Marshes Wildlife Area Land Management Plan (URS 2011)
- Sonoma Creek Watershed Enhancement Plan (Southern Sonoma County RCD 1997)
- San Francisco Bay Shoreline Adaptation Atlas (SFEI and SPUR 2019)

- Natural Resource Management Plan for the San Francisco Bay National Wildlife Refuge Complex (USFWS, 2019)

9. Outreach to stakeholders will be undertaken at all stages of the Strategy to gather information, develop alternatives, and communicate findings, as appropriate.

10. The Strategy will be guided by the findings and applicable general recommendations made in the Baylands Ecosystem Habitat Goals Science Update (Goals Project 2015) for restoration and management in response to climate change, quoted verbatim below:

- Establish tidal marsh restorations by 2030 to prepare for accelerated sea level rise and projected impacts on tidal marshes
- Restore estuary – watershed connections
- Design complexity and connectivity into the baylands
- Restore and protect complete tidal wetland systems
- Restore the baylands [as appropriate] to full tidal action
- Plan for the baylands to migrate

These principles were revisited throughout the development of the Strategy to guide the modeling, alternatives, feasibility analysis, and restoration recommendations for the planning area.

1.4 Stakeholder Outreach

During the winter of 2019, Sonoma Land Trust and Sonoma Water conducted interviews with property owners throughout the planning area. Sonoma Land Trust is also working with SMART and Caltrans to coordinate this project with the transportation infrastructure. More extensive stakeholder outreach will occur during site-specific restoration design as required by CEQA.

The Science Advisory Panel (SAP) for this project includes public property owners and staff from SPBNWR and CDFW. Alternatives were developed in partnership with Sonoma Water, Sonoma Resources Conservation District, San Francisco Bay Restoration Authority, CDFW and USFWS.

1.5 Organization of This Report

Chapter 1 of this report provides the background to the region, the purpose and goals of this work, guiding principles for the evaluation, and background on the stakeholder outreach that was completed. Chapter 2 describes existing conditions of the project area including the geographical setting, habitats and species, environmental conditions including geomorphology, past restorations, hydrology, sediment supply, contamination, current land uses, and future environmental conditions under climate change. Chapter 3 describes the development of the future scenarios used to evaluate restoration alternatives. Chapter 4 describes considerations for the feasibility of landscape-scale tidal marsh restoration including existing resources, co-benefits, habitat, rail and road, Sonoma Valley Airport, utilities, land use, regulatory jurisdictions, public access, these feasibility considerations for each of the diked baylands parcels, and uncertainties. Chapter 5 describes each of the four alternatives. Chapter 6 walks through a feasibility analysis to evaluate how well each of the alternatives performs in meeting project goals, then provides discussion of constructability, sequencing, implications for public access and infrastructure including road and rail, cost of implementation, regulatory requirements, and groundwater implications of the restoration alternatives. Chapter 7 provides the conclusion. Chapter 8 includes references.

CHAPTER 2

Existing Conditions

2.1 Setting

The planning area of the Sonoma Creek Baylands Strategy (Strategy) is defined as the Sonoma Creek watershed south of SR 121 (Carneros Highway), Tolay Creek watershed, and adjacent upland-wetland transition zones, within Sonoma County. The Strategy is informed by processes and inputs from outside the planning area – to the north in the Sonoma Creek watershed, to the east in the Napa-Sonoma marshes, and to the south in San Pablo Bay (**Figure 1.2**). The planning area is bounded on the west by the Sonoma Mountains and on the east by the Mayacamas Mountains. To the north, the planning area extends to SR 121. Downstream of SR 121, Schell and Sonoma Creeks enter a complex network of tidal slough channels before draining to San Pablo Bay. Tolay Creek runs parallel to the west boundary of the planning area and enters San Pablo Bay west of Tubbs Island. At the southern end of the basin, the Sonoma and Mayacamas Mountains end at the flat baylands that form the Napa-Sonoma Marsh. The north and west portions of the planning area contain uplands and developed areas, while the central and southern portions contain public and privately owned diked baylands. Although the west, north, and east periphery of the planning area includes large upland areas, the Strategy concentrates on the bayland parcels in the center of the planning area. This concentration on the baylands is represented in many of the maps in this document. Site names are adapted from the Lower Sonoma Creek Flood Management and Ecosystem Enhancement Plan (ESA 2012) and are shown in **Figure 2.1**.

2.2 Habitats and Species

The planning area supports a range of habitats. Much of what used to be tidal marsh has been transformed into other habitat types. The main habitat types in areas that were historically tidal marsh include agricultural baylands (hayfields and vineyards) and diked wetlands with linear strips of tidal marsh, adjacent to tidal sloughs, between these parcels. Surrounding these areas to the west and north the main habitat types include grassland and agriculture (**Figure 2.2**).

Tidal Waters

Tidal creeks and sloughs meander throughout the Sonoma Creek Baylands providing mudflat and subtidal habitats. Downstream of SR 121, Schell and Sonoma Creeks enter a complex network of tidal slough channels before draining to San Pablo Bay. Tolay Creek runs parallel to the west boundary of the planning area and enters San Pablo Bay west of Tubbs Island. Open water and mudflat habitat also exists at newly restored tidal restoration sites in the southwest corner of the planning area along Tolay Creek and at Tubbs Setback.

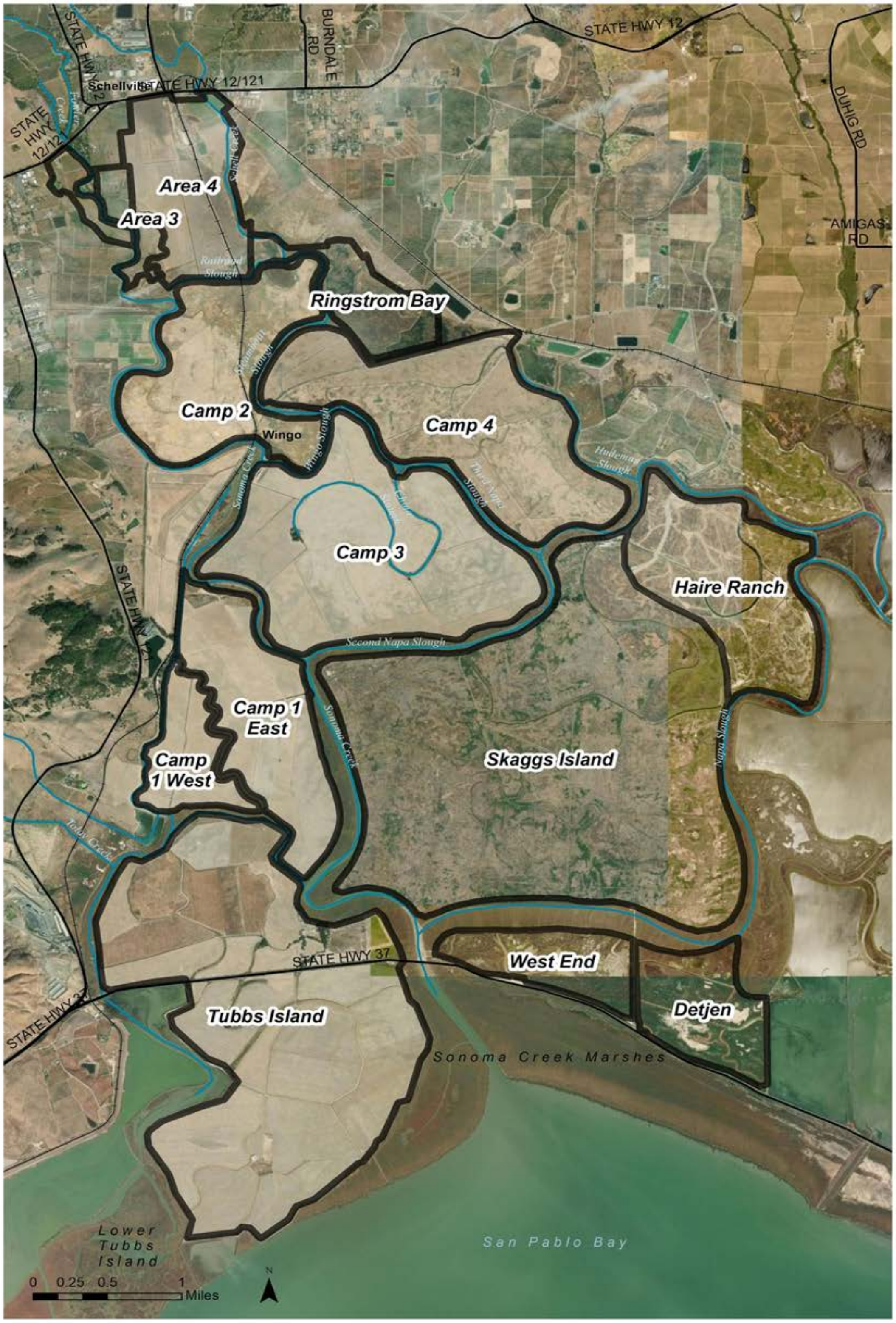

Figure 2.1 Site Names used in this report, adapted from the Lower Sonoma Creek Flood Management and Ecosystem Enhancement Plan (ESA 2012).

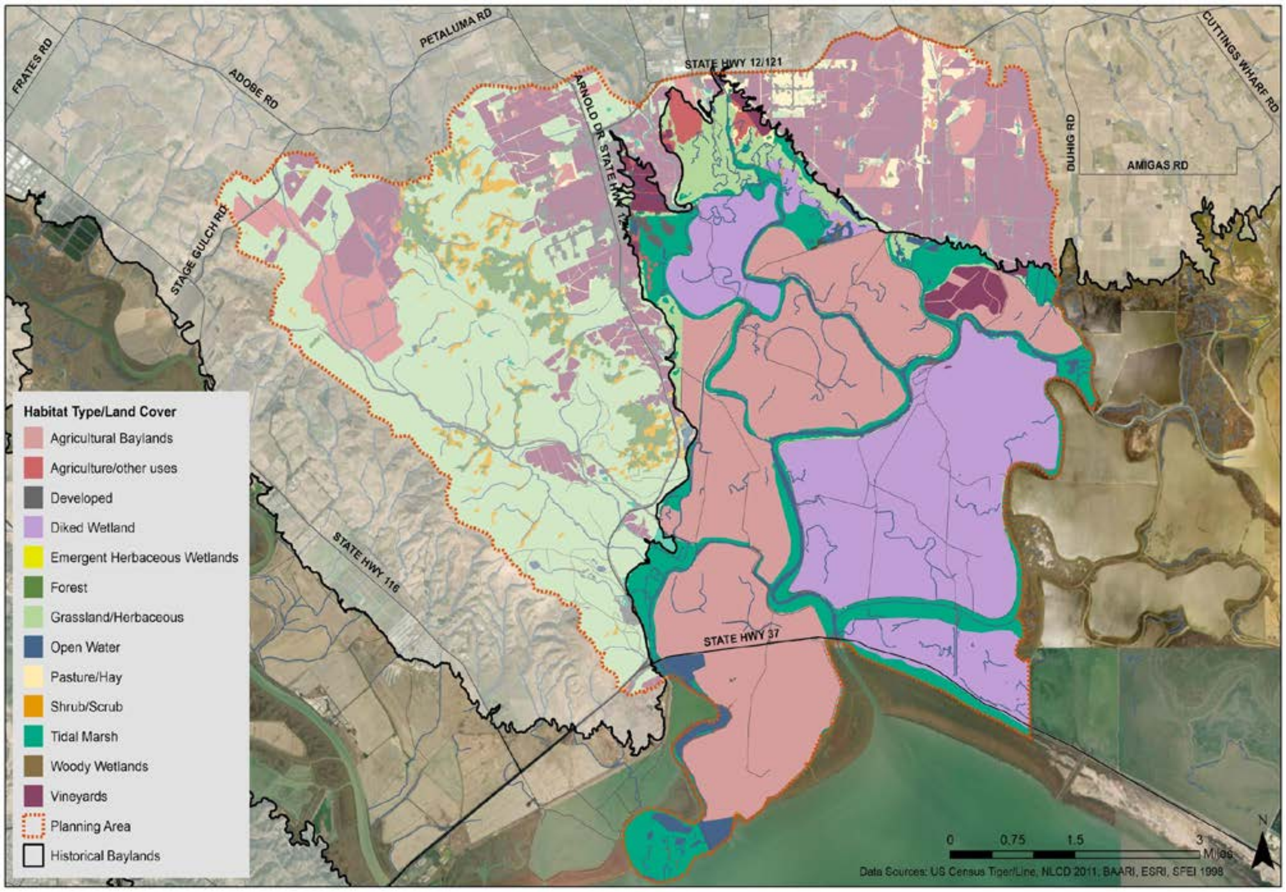

Figure 2.2 Habitat types.

Tidal Marsh

Tidal marsh exists mostly in linear strips along tidal slough channels in the Sonoma Creek Baylands and along the shoreline of San Pablo Bay. Tidal marsh is generally stratified in "zones" of low, mid, and high marsh, depending on its elevation relative to the reach of the tides. The tidal marsh vegetation is dominated by California cordgrass (*Spartina foliosa*) in the low marsh and perennial pickleweed (*Sarcocornia pacifica*), salt grass (*Distichlis spicata*), and alkali bulrush (*Bolboschoenus maritimus*) in the mid and high marsh. Other common native plants found within mid and high marsh include gumplant (*Grindelia stricta*), jaumea (*Jaumea carnosa*) and alkali heath (*Frankenia salina*). Perennial pepperweed (*Lepidium latifolium*) is the most common non-native invasive plant found within tidal marshes in the planning area.

Tidal marshes in San Francisco Bay can generally be classified into different evolutionary stages or age classes based on a variety of important physical and biological attributes. Large millennial tidal marshes, which are high value wetlands that were formed 2,000 to 5,000 years ago, are no longer found within the Sonoma Creek Baylands. The other two evolutionary stages that are found within the Sonoma Creek Baylands are new tidal marshes and centennial tidal marshes.

New tidal marshes are generally immature, low-elevation marshes, at the early stages of evolution, and are most often found at recent restoration and mitigation projects aimed at recovering tidal wetland acreage. However, they can also be observed at areas along prograding shorelines (where sediments have naturally accumulated at high enough elevations to support colonization by wetland vegetation) and in areas along the upland-estuarine transition zone (where tidal wetland habitats prograde over adjacent terrestrial habitats due to sea level rise). Characteristics of new tidal wetlands often include extensive subtidal and/or intertidal mudflats, an immature tidal channel network, a general lack of high tide refugia, and vegetation dominated by low marsh species such as California cordgrass. New tidal wetlands within the planning area include Tolay Creek and Tubbs Setback.

Centennial tidal marshes is a large category of tidal wetlands which are mostly between 50 and 150 years old. The functions and services provided by centennial wetlands vary according to their age, morphology, and position along the salinity gradients of the estuary. Three main types of centennial tidal marshes are found within the Sonoma Creek Baylands: fringing overwash wetlands, fringing infill wetlands, and reverted wetlands.

Fringing overwash wetlands form along the shorelines of San Pablo Bay due to the deposition of inorganic sediment and organic debris by currents and wind-waves. This type of wetland tends to exist high in the intertidal zone. They can be supratidal at some locations where abundant sediment and debris is entrained by especially high waves and deposited in a splash zone above the tides. They generally lack extensive tidal channel networks and tend to retain tidal and wave-driven flood waters on their plains. Fringing overwash wetlands can be found at the mouth of Sonoma Creek along San Pablo Bay and the strip marsh south of SR 37.

Fringing infill wetlands are generally narrow, linear wetlands that formed along tidal channels between reclamation levees as the channels shoaled and narrowed in response to the decreases in their tidal prism. Tidal prism is the volume of water entering and existing the Sonoma Creek Baylands between Mean Lower Low Water (MLLW) and Mean Higher High Water (MHHW). Many of these channels have equilibrated to the historical changes in tidal prism, and their fringing infill wetlands have matured with high marsh plains and dense channel networks. A special characteristic of these marshes is the parallel arrangement of the networks, owing to the uniform slope of the marsh plains toward the larger channels they fringe. The tidal marsh found along Sonoma Creek would be considered fringing infill wetlands.

Reverted wetlands exist where tidal action has been restored to formerly reclaimed millennial wetlands due to unplanned levee failures. The accidental or passive breaching of their levees distinguishes reverted wetlands from restoration projects, where the breaches are intentional and carefully planned. Reverted wetlands tend to pre-date the laws and regulations governing levee work, and therefore include many older, more mature centennial wetlands. These older reverted centennial marshes can resemble millennial wetlands in some obvious ways. For example, many of the oldest reverted wetlands have dense dendritic channel networks that serve broad, high-elevation marsh plains, and they can support similar assemblages of plants and animals. It is possible that Ringstrom Bay, Lower Tubbs Island, or other small pockets of tidal marshes within the Sonoma Creek Baylands are reverted wetlands.

Diked Wetland

Non-tidal seasonal and perennial wetlands and waters occur in diked areas in the Sonoma Creek Baylands. The majority of diked wetland occurs at Skaggs Island. Other large diked wetlands include Haire Ranch, Camp 2, West End, Detjen, and Ringstrom Bay (**Figure 2.2**). Diked wetlands contain an array of different wetlands and habitats, most of which were created after the area was diked and are managed in some way. However, the majority of each diked wetland site is dominated by some form of non-tidal wetlands.

Many seasonal wetland depressions occur throughout Skaggs Island in drainage ditches and water basins. Skaggs Island was historically tidal marsh but was diked and drained for agricultural production. The seasonal wetlands developed after farming operations ceased in the 1990s. The vegetation in the seasonal wetland depressions is dominated by non-native herbs and grasses. The most frequently observed species include common velvet grass (*Holcus lanatus*), Italian ryegrass (*Festuca perennis*), brass buttons (*Cotula coronopifolia*), and bird's-foot trefoil (*Lotus corniculatus*). Infrequently, deeper portions of depressions are dominated by native stalked popcornflower (*Plagiobothrys stipitatu*s var. *micranthus*), but very little is present in these wetlands (WRA 2015).

Haire Ranch, Camp 2, West End, and Detjen are currently managed as diked wetlands. Haire Ranch forms the northeastern corner of Skaggs Island and was converted to a diked wetland from agricultural bayland in 2018. Haire Ranch currently provides seasonal wetland habitat with a long-term goal of becoming tidal wetlands connected to the rest of Skaggs Island when it is fully restored. Camp 2 consists mostly of freshwater perennial pond and seasonal wetlands which were constructed in 2003. West End and Detjen are comprised of non-tidal and muted tidal salt marsh and seasonal ponds/salt pannes. West End, which used to be managed as a private duck hunting club, is currently a muted tidal marsh, operated with tide gates to allow tidal exchange (URS 2011). The site is dominated by annual pickleweed (*Salicornia depressa*) and contains other common tidal marsh vegetation (URS 2011). Detjen was also previously operated as a duck club and contains habitat similar to West End that is dominated by perennial pickleweed.

Agricultural Baylands

Agricultural baylands currently occur over much of the planning area in historically tidal marsh areas that were diked, drained and converted to agricultural fields and pasture lands beginning in the late 19th century. Due to the highly acidic soils of the former tidal marshes, crop selection in agricultural baylands is limited. The dominant crop is oat hay which is primarily used for dairy cattle feed. Agricultural baylands are also subsided below Mean Sea Level and rainwater is pumped out in winter, so the land is dry enough for crops to grow. Vineyards are also found within the agricultural baylands. Other uses include a hunt club.

Habitats Surrounding the Baylands

North and west of the agricultural baylands and diked wetlands are a mix of grasslands, forest, scrub/shrub, vineyards, hay/pasture, other agricultural uses, and developed areas.

Wetland-Upland Transition Zone

The wetland-upland transition zone (transition zone) is important for restoration planning and includes a mix of different habitat types and land uses. The transition zone, which is dynamic in time and space, is defined in multiple ways. In this report, we use the Upper Boundary Mapping Approach defined in Robinson et al. (2017), in which the transition zone is defined as a 1,640-foot (500-meter) buffer area above the current highest astronomical tide, or HAT, which is approximately MHHW + 1 foot (**Figure 2.3**). The transition zone extends farther inland (1,640 feet inland from the head of tide) where it intersects stream corridors. This area encompasses most of the ecosystem services provided by the transition zone including sea level rise accommodation, flood control, and wildlife refuge habitat (**Figure 2.4**, Goals Project 2015).

Due to low elevations in the south and center portions of the planning area, the majority of potential transition zone area is along the north, west, and east edges of the Sonoma Creek Baylands (**Figure 2.5**). While much of the area within the transition zone is developed in vineyards, large swaths of annual grassland and pockets of native and non-native forest and freshwater wetlands are also present. Throughout the agricultural baylands and diked wetlands, minimal strips of land occur above HAT along levee and berm slopes. Vegetation on these levee slopes consists mainly of non-native and invasive plant species including invasive perennial pepperweed (*Lepidium latifolium*), yellow starthistle (*Centaurea solstitialis*), fennel (*Foeniculum vulgare*), mustard (*Brassica* spp.), and annual grasses. Coyote brush (*Baccharis pilularis*) is the only native dominant plant commonly found along levee slopes within the transition zone.

Migration Space

The migration space for tidal marsh within the planning area refers to areas expected to be inundated with 6.6 feet (2 meters) of sea level rise above the HAT excluding areas of existing tidal marsh (SFEI and SPUR, 2019). Migration space is mainly found on the Sonoma Creek and Tolay Creek alluvial fans which are relatively flat, compared to the steeper hillsides of the Sonoma and Mayacamas Mountains. Migration space occurs primarily on unprotected lands and is mostly comprised of vineyards and hay/pasture. The migration space also contains some infrastructure such as roads and buildings, and some grassland habitat.

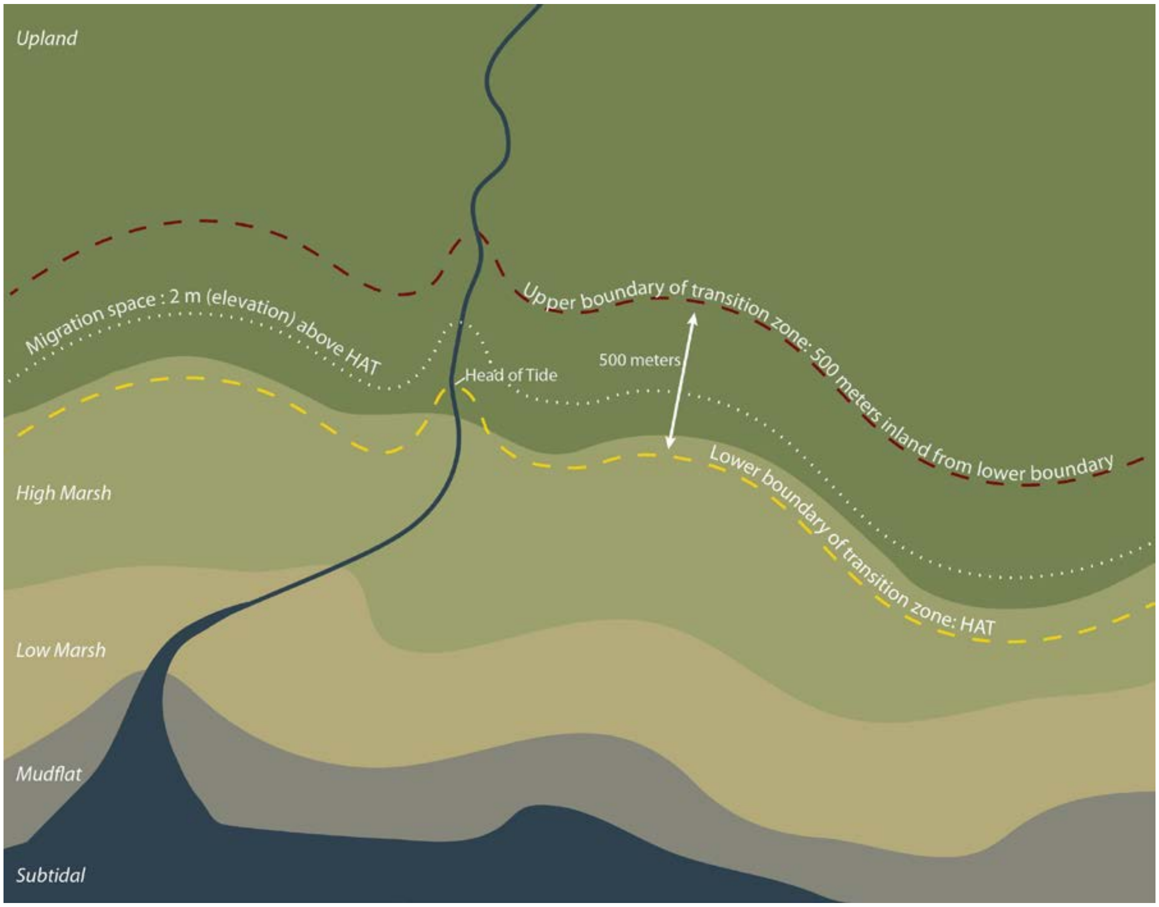

Figure 2.3. Upper boundary approach to transition zone mapping, overlaid with habitat types.

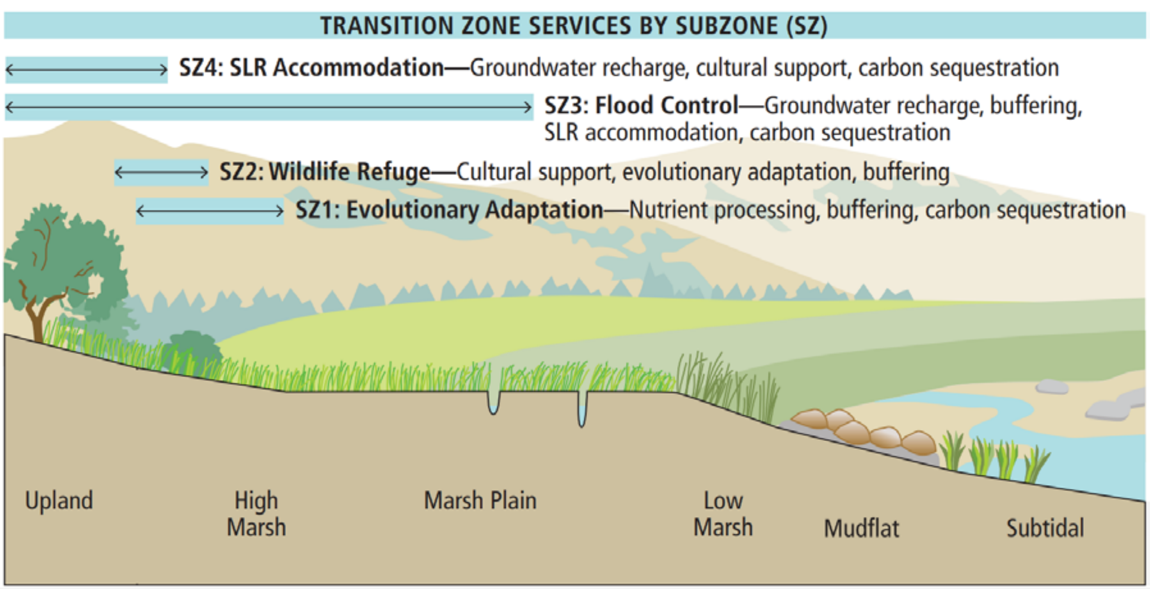

Figure 2.4. Transition zone services (Goals Project 2015).

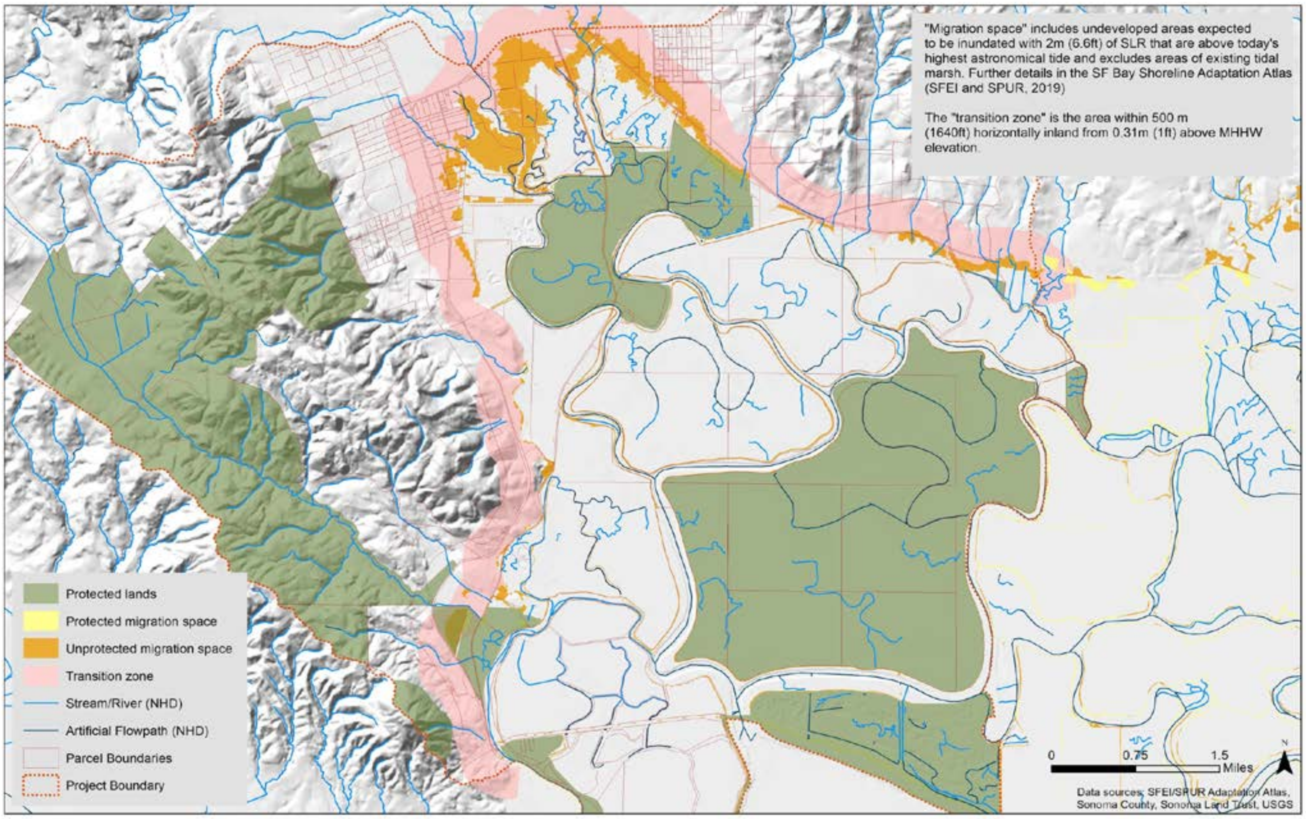

Figure 2.5. Transition zone, migration space, and protected lands within the planning area.

Special-Status Plants and Important Plant Species

Few rare plants are documented within the Sonoma Creek Baylands. Species that may be found in the planning area include:

- Pappose tarplant (*Centromadia parryi* ssp. *parryi*)
- Point Reyes bird's-beak (*Chloropyron maritimum* ssp. *palustre*)
- Soft bird's-beak (*Chloropyron molle* ssp. *molle*)
- Mason's lilaeoposis (*Lilaeopsis masonii*)
- Suisun Marsh aster (*Symphyotrichum lentum*)

These plants are rare throughout the San Francisco Estuary due to the conversion of tidal marsh habitats to agriculture and other land uses. All are listed as rare or endangered in California by the California Rare Plant Ranking System (CNPS Rare Plant Program 2020). Soft bird's-beak is also federally listed as endangered.

Alkali vernal pool flora of adjacent terrestrial lowlands also have potential to establish populations in downstream seasonal wetland pools and seasonally flooded flats in diked wetlands and agricultural baylands. State-listed or regionally or locally uncommon vernal pool plant species that may be found in the planning area include:

- Johnny nip (*Castilleja ambigua* subsp. *ambigua*)
- Flatface downingia (*Downingia pulchella*)

- Contra Costa goldfields (*Lasthenia conjugens*)
- Yellowray goldfields (*Lasthenia glabrata* subsp. *glabrata*)
- Lemmon's canarygrass *(Phalaris lemmonii)*
- Popcorn flower *(Plagiobothrys* spp.)
- Coastal plantain *(Plantago elongata)*
- Saline clover (*Trifolium hydrophilum*)
- Flowering-quillwort *(Triglochin scilloides)*

All are listed as rare, endangered, or vulnerable in California and Contra Costa goldfields is also federally listed as endangered (CNPS Rare Plant Program 2020). Other locally or regionally declining or uncommon plants with ecological or cultural significance that may be found in seasonal wetlands, salt marsh pools, or tidal marsh transition zones in the planning area include Santa Barbara sedge (*Carex barbarae*) and wigeon grass (*Ruppia maritima*).

Invasive Plant Species

Invasive plants occur throughout the planning area as they do throughout the baylands in the San Francisco Estuary. A few key invasive plants that occur within wetland and transition zones include invasive cordgrass (*Spartina alterniflora* and invasive hybrids), perennial pepperweed (*Lepidium latifolium*), Pacific bentgrass (*Agrostis avenacea*), and stinkwort (*Dittrichia graveolens*) (Goals Project 2015). Invasive cordgrass and perennial pepperweed are both actively monitored and controlled within the San Pablo Bay National Wildlife Refuge (USFWS 2013a). Invasive cordgrass grows at low marsh elevations while perennial pepperweed occurs at high marsh and transition zone elevations. Only a single small population of invasive cordgrass is known to be present in the Sonoma Creek Baylands due in part to continued eradication efforts of this species and its hybrids throughout tidal marshes in San Francisco Bay (Olofson Environmental 2014, 2018).

Many other invasive species occur throughout the agricultural baylands, diked wetlands, and non-native grasslands in the planning area including many herbaceous and annual grassland species such as yellow starthistle (*Centaurea solstitialis*), fennel (*Foeniculum vulgare*), wild radish (*Raphanus sativus*), ripgut brome (*Bromus diandrus*), and Italian ryegrass (*Festuca perennis*).

It is possible for invasive plant species to establish in newly restored or disturbed areas in the planning area. One species known to invade salt marsh edges recently is the Southeastern annual saltmarsh aster (*Symphyotrichum subulatum* var. *squamatum*). It has been observed just southwest of the planning area and is invasive in other salt marshes in San Francisco Bay (Peter Baye, personal communication).

Wildlife

Focal Species

California Ridgway's rail, California black rail, salt marsh harvest mouse, Chinook salmon and steelhead are endangered, threatened, or species of special concern that occur within tidal marshes in the Sonoma Creek watershed. These are the focal species for potential habitat benefits from future restoration in the planning area. **Table 2.1** lists habitat functions of these five species within the tidal marsh.

California Ridgway's Rail

The California Ridgway's rail (formerly known as the California clapper rail and hereafter Ridgway's rail) is a secretive waterbird that looks like a small chicken and lives in salt and brackish tidal marshes in the

San Francisco Bay Estuary. It once occupied coastal California tidal marshes from Humboldt Bay southward to Morro Bay, and estuarine marshes of San Francisco Bay and San Pablo Bay to the Carquinez Strait (Grinnell and Miller 1944). Resident populations are currently limited to San Francisco Bay, San Pablo Bay, and associated tidal marshes. This sub-species is listed as Endangered at both the federal and state levels and is also a Fully Protected species under the State Fish and Game Code.

Ridgway's rail occurs almost exclusively in mature and restored salt and, to a lesser extent, brackish marshes with direct tidal flows, adequate invertebrate prey food supply, well developed tidal channel networks, and suitable nesting and escape cover during extreme high tides (Eddleman and Conway 2018). Preferred Ridgway's rail habitat is characterized by intricate networks of tidal sloughs with taller plant material that provides cover from predators. They rely on marsh plants such as Pacific cordgrass (*Spartina foliosa*), bulrush (*Bolboschoenus maritimus*), and pickleweed for breeding, where the vegetation structure allows nests to be built above high tides and wave action and still provides cover from above.

USFWS has surveyed for rails within the planning area in the tidal marshes at Tolay Creek, Lower Tubbs Island, and Tubbs Setback, and within Sonoma Creek Marsh west of the mouth of Sonoma Creek. Based on survey results, Ridgway's rails are present within tidal marshes in the southern portion of the Sonoma Creek Baylands, specifically within Tolay Creek, Lower Tubbs Island, and the marsh west of the mouth of Sonoma Creek (USFWS 2020). Because recent surveys have not been completed throughout tidal marshes within the central or northern parts of the Sonoma Creek Baylands it is difficult to determine the density of Ridgway's rails in the Sonoma Creek Baylands compared to other tidal marshes in the bay. However, marshes enhanced and restored south and southwest of the planning area have been continuously surveyed and do have dense Ridgway's rail populations (J. McBroom and M. Marriott, personal communication). Tidal marsh restoration within the Sonoma Creek Baylands would provide ecologically connected habitat to tidal marshes with existing dense Ridgway's rail populations to expand habitat for Ridgway's rail and other marsh dwelling wildlife species.

California Black Rail

California black rail (black rail) is a small secretive waterbird that is difficult to detect, complicating the study of its natural history. The historic distribution and abundance of black rail is poorly understood since systematic surveys and population estimates for the species were not completed until the 1970s (Evens et al. 1991). Black rail resides in a variety of wetland habitats across its range in California and Arizona (Evens et al. 1991). The most geographically extensive occupied habitats exist in the San Francisco Estuary, specifically in tidal marshes along the Petaluma and Napa rivers, San Pablo Bay, Suisun Bay, and Suisun Marsh, which supports a large proportion of the subspecies (Evens et al. 1991, Spautz et al. 2005). Black rail is listed as threatened in the State of California because of population declines attributed in large part to loss of more than 90 percent of historic wetland habitat in California (Tsao et al. 2015). It is also a Fully Protected species under the State Fish and Game Code.

Black rail occur almost exclusively in tidal marsh habitat in San Francisco Bay. The highest concentrations are in marshes associated with large rivers and sloughs (Evens et al. 1991, Nur and Spautz 2002). Restored marshes as young as eight years can support breeding black rail (e.g. Pond 2A in Napa Sonoma Marsh, Point Blue unpublished data). A factor that may explain why the largest populations of black rail are in the North Bay of the San Francisco Estuary is an abundance of emergent marsh vegetation with freshwater influence (Evens et al. 1991), which probably affects the factors that define habitat suitability, such as high food abundance, nest site availability, and access to high tide refugia habitat (Raabe et al. 2010). Tidal marshes within the Sonoma Creek Baylands are thought to have a high density of black rail compared to other tidal marsh sites not associated with large rivers in San Pablo Bay (Evens and Nur 2002). Black rail surveys taken over the past 10 years in and adjacent to the southwest portion of the planning area have found relatively few black rail individuals (M. Marriott pers. comm., USFWS 2020). However, surveys in nearby areas (Napa River Salt Marsh Restoration Project) found an increasing trend for black rail populations between 2013 and 2019 (K. Taylor pers. comm., CDFW 2020).

Salt Marsh Harvest Mouse

Salt marsh harvest mouse is endemic to the greater San Francisco Bay. There are two subspecies of SMHM: the northern subspecies (*Reithrodontomys raviventris halicoetes*) is found in the Marin Peninsula and San Pablo and Suisun Bays (Shellhammer and Barthman-Thompson 2015). Salt marsh harvest mouse has become endangered because approximately 80 percent of the historical tidal marshes in San Francisco Bay Estuary have been filled or otherwise highly modified (Jones and Stokes et al. 1979). Most of the tidal marshes that remain support few or no mice because of backfilling, subsidence, or vegetation changes (Shellhammer 1982). Salt marsh harvest mouse is listed as an Endangered Species at both the federal and state levels and is also a Fully Protected species under the State Fish and Game Code.

The salt marsh harvest mouse is dependent on dense and tall vegetation cover, usually in the form of pickleweed (*Sarcocornia pacifica*, the dominant salt marsh vegetation in the San Francisco Bay) and other salt dependent or salt tolerant vegetation in both tidal and diked salt and brackish marshes. The mice move into wetland-upland transition zones or tall vegetation that is exposed within the marsh for escape cover during high tides or floods. Marshes in San Francisco Bay without this important refuge habitat usually do not have salt marsh harvest mouse, as individual mice without such cover are easily detected by predators (particularly birds).

Salt marsh harvest mouse has been trapped in the planning area south of Skaggs Island, Tolay Creek, Lower Tubbs Island, and Tubbs Setback (USFWS 2009, SFEI 2009, USFWS 2020). Populations have been found to have average to good densities within these marshes (M. Marriott pers. comm). Dense populations have also been found in the marshes just south of the planning area within Sonoma Creek marsh and the strip marsh (USFWS 2020). Future tidal restoration within the planning area would provide additional habitat and connectivity to existing dense populations of salt marsh harvest mouse.

Steelhead

Sonoma Creek and many streams in Sonoma Valley historically supported large numbers of steelhead (*Oncorhynchus mykiss*) and chinook salmon (*Oncorhynchus tshawytscha*). Their populations have declined sharply in the past several decades. The steelhead population is currently estimated at over 13,000 over-summering juveniles on average in the Sonoma Creek watershed (Sonoma Ecology Center 2013). Steelhead spawning has been observed in several tributaries to Sonoma Creek, and most of these tributaries appear to be well-seeded with juvenile steelhead by summer (Leidy et al. 2005). The Central California Coast steelhead Distinct Population Segment (DPS) includes all naturally-spawned populations of steelhead (and their progeny) in coastal streams from the Russian River to Aptos Creek, and the drainages of San Francisco and San Pablo Bays eastward to the Napa River. This steelhead DPS was listed as threatened under the Federal Endangered Species Act in 1997. Sonoma Creek still supports a small steelhead run and is designated as Critical Habitat for the run (Leidy et al. 2005). Steelhead typically migrate to marine waters after spending up to two years rearing in freshwater habitat, and typically reside in marine waters for two or three years prior to returning to their natal stream to spawn. Within San Francisco Bay, steelhead adults typically spawn between December and April. Unlike other salmonids, steelhead may spawn multiple times before dying. Preferred spawning habitat for steelhead is in perennial streams with cool to cold water temperatures, high dissolved oxygen levels, and fast-flowing water (Moyle, 2002). Steelhead are known to spawn upstream of the planning area within Sonoma Creek (CEMAR, 2013).

Table 1. Focal Species Conservation Status and Habitat Functions

Species		Listing Status		Habitat					
Common Name	Scientific Name	Federal	State	Large Channels	Small Channels	Low Intertidal	Low Marsh	High Marsh	Upland Transition
California Ridgway's rail	*Rallus obsoletus*	E	E (FP)	A/F, J/F (channel edges)	A/F, J/F (channel edges)	A/F, J/F	A/F, J/F	A/F, J/F, B, R	A/F, J/F
California black rail	*Laterallus jamaicensis coturniculus*	none	T (FP)		A/F, J/F (channel edges)	A/F, J/F	A/F, J/F	A/F, J/F, B, R	A/F, J/F, R
Salt marsh harvest mouse	*Reithrodontomys raviventris haliocoetes*	E	E (FP)					A/F, J/F, B, R	A/F, J/F, R
Central California Coast steelhead DPS	*Oncorhynchus mykiss*	T	none	A/M, A/F, J/M, J/F	J/M, J/F	J/M, J/F	J/M, J/F	J/M, J/F	
Chinook salmon fall-run ESU	*Oncorhynchus tshawytscha*	none	SSC	A/M, A/F, J/M, J/F	J/M, J/F	J/M, J/F	J/M, J/F	J/M, J/F	

Life Stage: (A) – Adult, (J) = Juvenile
Listing Status: (E) – Endangered, (T) – Threatened, (FP) – Fully Protected
Habitat Function: (B) = Breeding, (R) = Rearing, (F) = Foraging, (M) = Migrating

Chinook salmon

A small chinook salmon run still exists in Sonoma Creek, but it is not known whether these are wild fish or strays from hatcheries in the Sacramento and San Joaquin River systems (Sonoma Ecology Center 2006). Chinook within Sonoma Creek likely belong to the Central Valley fall-run Evolutionarily Significant Unit (ESU) that includes all naturally spawned spring-run populations from the Sacramento-San Joaquin River main stems and their tributaries. Chinook have been sporadically reported in Sonoma Valley since the 1980s and spawning has been observed within Nathanson Creek in downtown Sonoma, the upper reaches of Sonoma Creek, and in Calabazas Creek. As such, a small, self-sustaining population of chinook salmon is probably present in the Sonoma Creek watershed (Sonoma Ecology Center, 2013).

Other Important Wildlife Species

Birds

Bird species that could occur within the planning area include shorebirds, ducks, passerines, raptors, herons, and egrets. The extensive intertidal mudflats surrounding San Pablo Bay are considered a key migratory staging and refueling area for over-wintering shorebirds or the Pacific Flyway (Goals Project 2000). Dabbling and diving ducks utilize tidal creeks and sloughs and tidal marsh habitat for foraging. Dabbling ducks also may breed in upland areas adjacent to tidal marshes. San Pablo song sparrow

(*Melospiza melodia samuelis*) and salt marsh common yellowthroat (*Geothlypis trichas sinuosa*) are CDFW species of special concern and USFWS birds of conservation concern that could occur in tidal marshes within the planning area.

Many raptor species, some of which are special-status, use habitats within and around Sonoma Creek Baylands for foraging, nesting, and roosting. Species such as the golden eagle (*Aquila chrysaetos*) and Swainson's hawk (*Buteo swainsoni*) hunt in upland grasslands and nest in large trees near wetlands, grasslands, and along the edges of ephemeral creeks. Burrowing owls (*Athene cunicularia*) occupy burrows excavated by ground squirrels. Species such as northern harrier (*Circus hudsonius*) and white-tailed kite (*Elanus leucurus*) forage over wetland and grassland areas. Osprey use San Pablo Bay and tidal creeks for foraging and nest in perches near their foraging grounds.

Herons and egrets use tidal marshes and other wetlands for foraging. Although known nesting colonies previously existed in Skaggs Island and Schellville, mostly within groves of eucalyptus trees, no nesting colonies have been observed for approximately 10 years (Kelly et al. 2006, USFWS 2009, M. Marriott pers comm.).

Fish

Other special-status fish species that may use the tidal portions of lower Sonoma Creek include the federally threatened southern DPS of North American green sturgeon, state threatened longfin smelt, and the State Species of Special Concern, Sacramento splittail. All tidal portions of San Francisco and San Pablo Bay are designated as critical habitat for green sturgeon, which spawn within the upper reaches of the Sacramento River watershed. Green sturgeon may spend considerable time foraging within San Francisco Bay during immigration and emigration to the Pacific Ocean (Brown, 2007). Suitable foraging habitat exists within the tidal portions of lower Sonoma Creek (e.g., soft bottom substrates with benthic fish and invertebrate species) and green sturgeon may use the tidal portions of the planning area as foraging habitat. Longfin smelt are consistently observed within the open water habitat of Central San Francisco Bay, including tidal water adjacent to lower Sonoma Creek. Longfin smelt have a two-year lifecycle and reside as juveniles and pre-spawning adults in the more saline habitats within San Pablo Bay and Central Bay during most of their life. Longfin smelt are most likely to occur within Central San Francisco Bay during the late summer months before migrating upstream to the Delta in fall and winter. However, during the winter months, when fish are moving upstream to spawn, high outflows may push many back into San Francisco Bay. Sacramento splittail depend on both brackish-water rearing habitats in the San Francisco Bay Estuary and on floodplain and river-edge spawning habitats immediately above the estuary (Sommer et al. 2007). Most migrate between these two habitat types on a near-annual basis. The tidal portions of lower Sonoma Creek may provide rearing habitat for Sacramento splittail.

2.3 Environmental Conditions

Geomorphology

The San Francisco Estuary is a drowned, tectonically reshaped river valley lying between the parallel ridges of the Coast Ranges. It has been shaped by the San Andreas fault to the west and the Hayward fault to the east, which caused the intervening block of crust to be overridden and forced downward, resulting in a broad region of low topography between segments of the coast range (Atwater 1979). The Golden Gate and Carquinez Straits, where the Bay penetrates the Coast Range, are constricted and deep. These constrictions separate the estuary into four broad, shallow embayments of South, Central, San Pablo, and Suisun Bays, each with one or two deeper natural channels.

The evolution of the baylands is closely related to the shape of the shallow embayments and the history of changes in sea level. At the end of the last glacial period, some 15,000 to 18,000 years ago, the seas began their most recent rise, and about 10,000 years ago, ocean waters began to flood the valleys now occupied by the Estuary. Sea level rise slowed over time, from an initial rate of about 0.8 inch per year, to the current rate of about 0.1 inch per year, beginning about 6,000 years ago. Between 2,000 and 3,000 years ago, mudflats and tidal marshes began to form around the edges of the broad shallow embayments (Goals Project 1999).

Sonoma Creek, its watershed and its baylands, lies on the northern side of the San Pablo Bay basin in a wide alluvial valley characterized by large watersheds, gradual slopes, and historically extensive wetlands and mudflats, characteristics that it shares with the Napa and Petaluma Rivers (**Figure 2.6**).

Fluvial-dominated Sonoma Creek and alluvial fan

Sonoma Creek extends 33 miles from Sugarloaf Ridge to San Pablo Bay. The creek drains the western slopes of the Mayacamas Mountains and the eastern slopes of the Sonoma Mountains, an area of about 170 square miles (**Figure 2.7**). Schell Creek empties 19 square miles of land and joins Sonoma Creek within the zone of tidal influence (ESA 2018). Tolay Creek is a third-order channel that flows for 12.5 miles from Tolay Lake, once the largest freshwater lake in Sonoma County, to Sonoma Creek. Historically, Tolay Creek drained the marshes of the western half of the planning area (Camp 1). Sonoma Creek and Napa Slough drained the eastern part (**Figure 2.8**). Now, Tolay Creek no longer drains Camp 1 and only flows to the west of Tubbs Island.

The head of tide on Sonoma Creek is about 5,000 ft upstream of SR 121. North and west of SR 121, the creeks are fluvially-dominated with a relatively steep longitudinal slope (600:1 H:V) driving the hydraulic conditions. South of SR 121, the longitudinal slope decreases significantly (5,300:1 H:V) as the fluvial Sonoma Creek meets the bay and becomes tidally-dominated. As the longitudinal slope decreases, the velocity of the water and its ability to convey sediment is also reduced. Under historic conditions, sediment from the creek was deposited between SR 121 and Railroad Slough in the form of an alluvial fan across a series of distributary channels, which were perched higher than the surrounding marshes (ESA 2012). A smaller alluvial fan is located on Tolay Creek where there is a similar change from upland to bayland gradient.

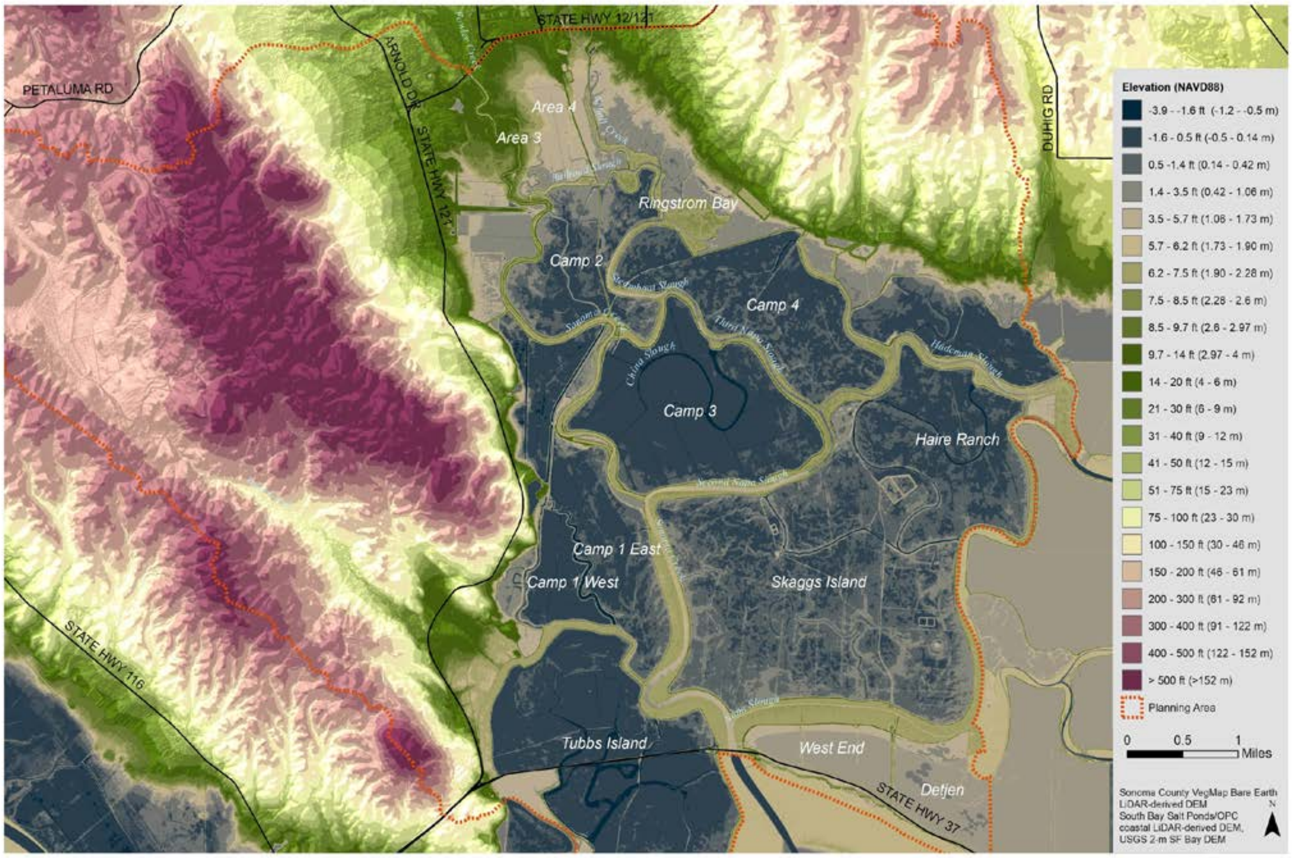

Figure 2.6. Present day topography of the broader Sonoma Creek area following diking. Digital elevation model sources: South Bay Salt Pond/OPC coastal Lidar-derived DEM, USGS 2-m SF Bay DEM.

Alluvial fans build up at the mouth of streams as sediment erodes from the hills and is carried downstream (**Figure 2.9, a**). Channels shift as sediment builds up and blocks the water's path, resulting in deposition in a fan pattern (**Figure 2.9, b**).

From 1850 onwards, the upper watershed has changed dramatically. Farming in the Sonoma Valley intensified, freshwater marshes were drained, roads constructed, and the area of impervious surfaces increased. These changes in the watershed decreased the infiltration capacity and increased runoff directly to the stream channels. During the same period, Sonoma Creek's floodplain was significantly reduced due to the construction of levees and development close to the channel. Distributary channels on the alluvial fan were combined and ditched. The reduced connectivity with the floodplain and concentration of flows within the channel have increased the amount and the rate at which water and sediment is delivered to the Baylands from the upper watershed over time. Today, steep slopes surround much of the Sonoma Creek Baylands area except at the shallow sloping alluvial plains that have formed at the mouths of tributary and distributary creeks. Marshes cannot migrate inland where there are steep slopes abutting them, so alluvial plains are a particularly important feature to target for protection and restoration as sea level rises.

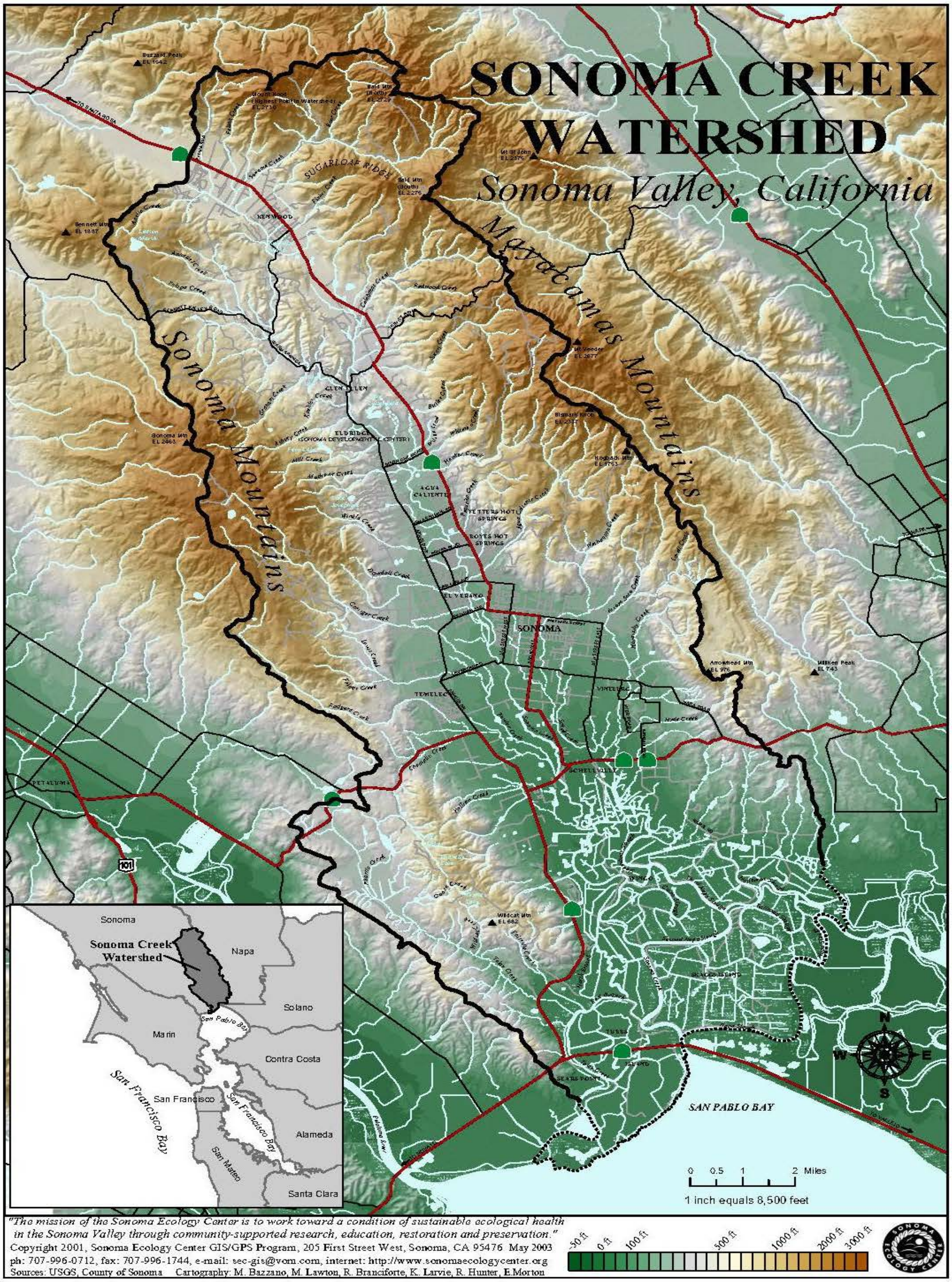

Figure 2.7. Sonoma Creek Watershed (Sonoma Ecology Center, 2003)

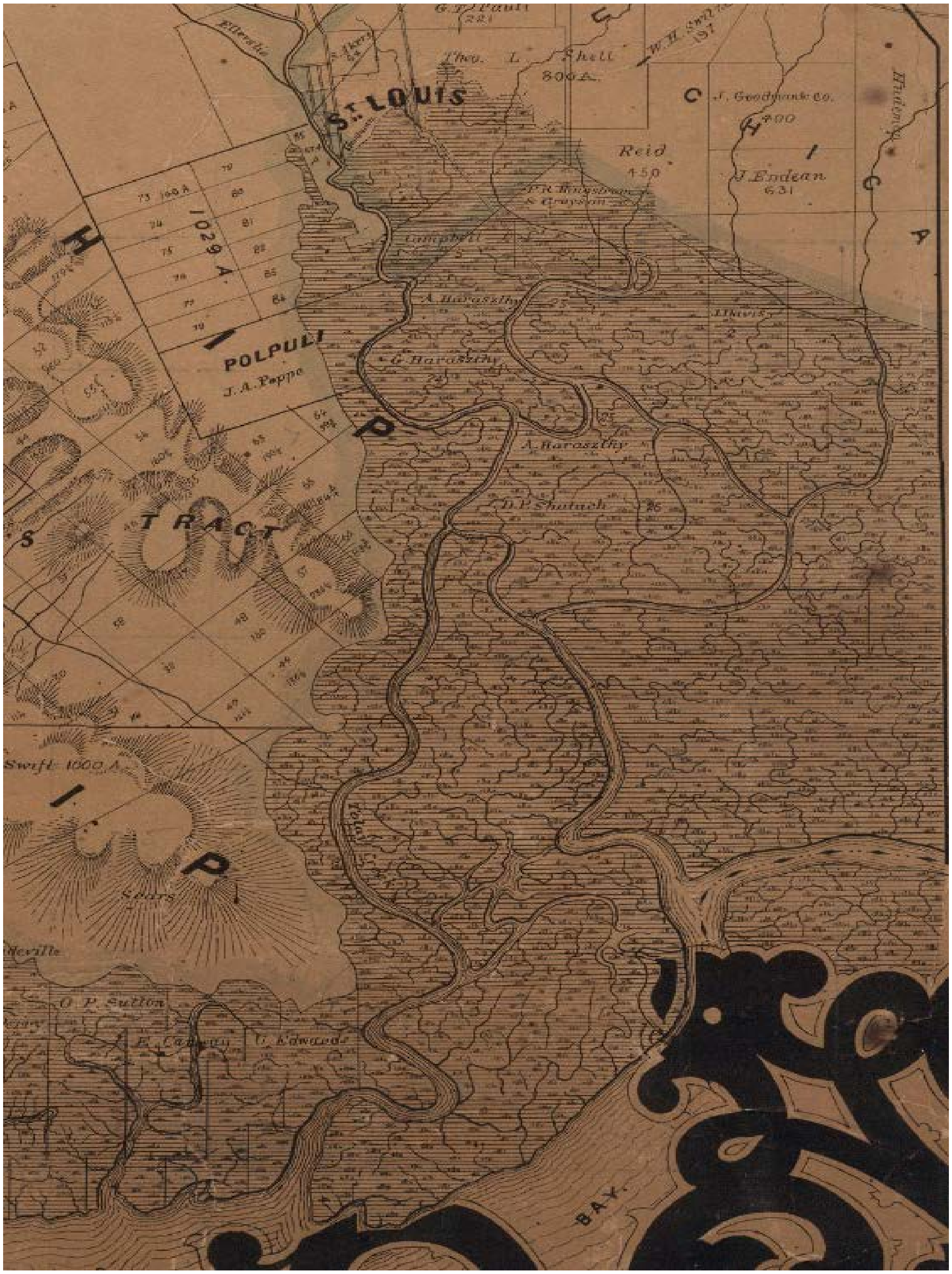

Figure 2.8. Bowers Map of 1866 showing the historical configuration of tidal sloughs prior to the diking and draining of the camps following the Swampland Act of 1850.

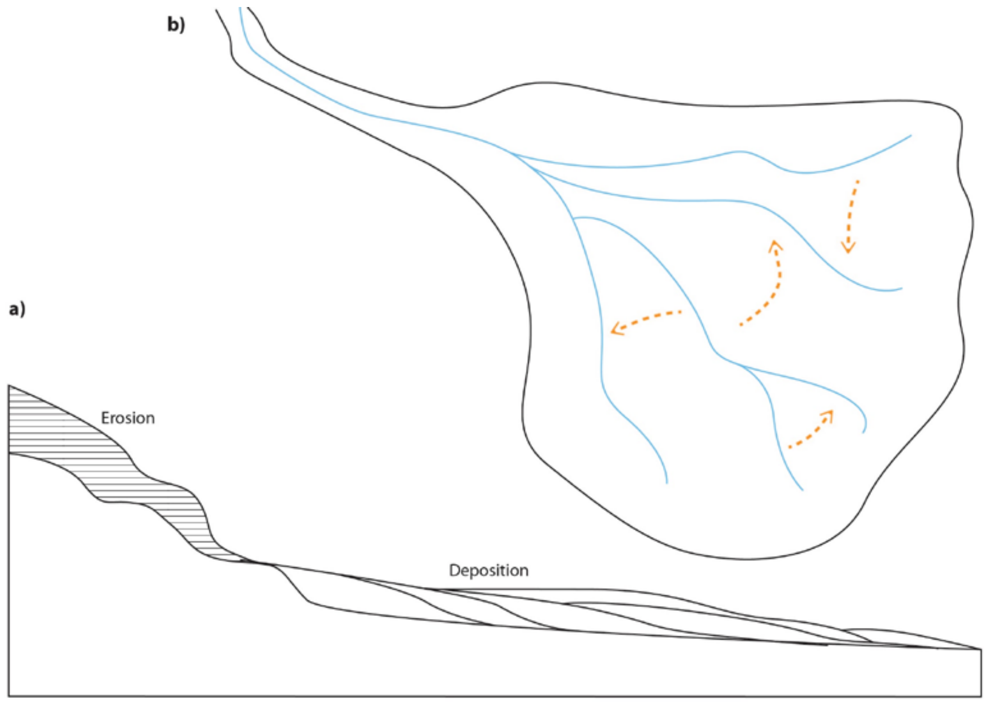

Figure 2.9. (a) Cross section showing stream-driven erosion of hillslope and deposition on alluvial plain. (b) Plan view of alluvial fan showing lobe-shaped pattern that develops as sediment builds up and forces channels to shift across the fan.

Tidally-dominated Sonoma Creek

The Sonoma Creek Baylands are a Holocene tidal marsh platform, relatively flat except at the terrestrial edges and at the bayward natural marsh berm. The tidal wetlands comprise a range of estuarine habitat types including tidal salt or brackish marsh, intertidal flats and subtidal channels. The marshes were subject to regular inundation by tidal water from the bay as well as fluvial flows during periods of high runoff, and extensive marshes formed, bounded to the west by Sonoma Mountain and to the east by the southern end of the Mayacamas Mountains and occupying about 20,000 acres along lower Sonoma Creek (**Figure 2.10**). Wetland-upland transition zones bordered the estuary, forming a link between the tidal wetlands and the adjacent upland and fluvial habitats. There were limited areas of moist grasslands to the north and west, along upper Sonoma Creek and in the drainages around and below Tolay Lake. A large area of vernal pool soils existed on the western side of upper Sonoma Creek.

In the historical Sonoma Creek Baylands there were several distinct areas of tidal marsh (**Figure 2.8**). The most expansive zone consisted of well-drained tidal marsh, indicated by a high density of tidal channels. Bayward of this marsh, a natural wave-built berm at the edge of the bay ran along much of the shoreline east of Sonoma Creek's mouth, restricting the tidal channel connection to the Bay. The historical toll-road and the present SR 37 followed this berm. The wide, high saltmarsh terrace bayward of the berm is a 20th century marsh that lies above MHHW (Atwater et al. 1979) and is relatively stable in position (SFEI-ASC 2020). Tidal channels in the marshes landward of the berm drained westward to either Sonoma or Tolay Creek or eastward connecting to the Napa River rather than draining directly to San Pablo Bay. Further inland, freshwater inflow from Sonoma Creek and smaller creeks enters the tidal marsh, creating brackish conditions and depositing sediment from their respective local watersheds. The extent of freshwater influence would have varied annually and seasonally based on streamflow. Ecologically, the zone of freshwater influence was a transition zone between tidal and fluvial habitats.

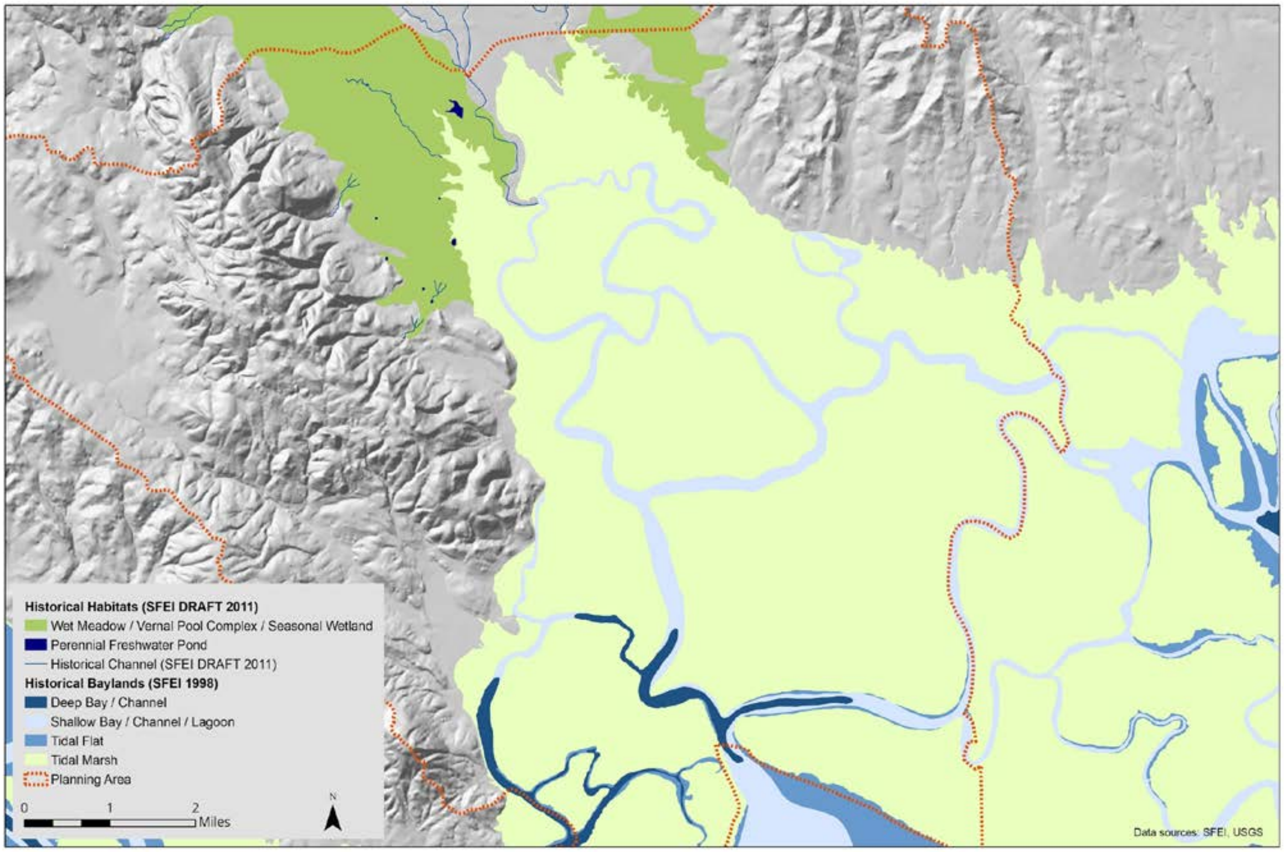

Figure 2.10. Historical Habitats.

Over the past 150 years, diking and draining for flood control and agriculture purposes have eliminated most of the historical baylands. The federal Swampland Act of 1850 provided an incentive for individuals and companies to dike and drain wetlands below the high tide line. The diking occurred in discrete units called “camps” (e.g. Camp 1, Camp 2), each camp being diked as a unit and reflecting the pattern of historical channels. At first, levees were built by hand, but by the late 1880s, the task was mechanized with steam dredgers. Ditches and floodgates were constructed to drain the camps, and pumps were installed as land conversion progressed (Dawson 2016). Levee construction in the Sonoma Creek Baylands and the rerouting of Tolay Creek began in the late 19th century and was completed by the early 1920s.

Diking and draining caused a dramatic loss of tidal marsh habitat, the creation of discrete diked bayland parcels, a significant reduction in tidal prism, and the creation of a significant sediment trap in the historical channels. The fluvial and tidal channels have been confined by levees, simplifying the historical tidal channel network that connected lower Sonoma Creek to its surrounding baylands and blocking the movement of sediment from the uplands and into the marshes. The loss of tidal prism has caused the tidal channels, including the tidal reaches of local rivers and streams, to fill in and become much more narrow and shallow creating marsh within the leveed channels and decreasing flood capacity (Goals

Project 1999). The former marshes have subsided by several feet below MHHW (**Figure 2.11**), and the whole area is dependent upon levees and pumping to prevent flooding.

Although a larger, comprehensive strategy is needed, the nature of the reclamation in the form of discrete diked baylands means that the area may also need to be managed and planned for as a series of discrete units. If the dikes around a single diked bayland parcel fail, large areas of the former Sonoma marsh will be inundated by tidal waters, creating significant amounts of tidal prism and opening up large sediment sinks (**Figure 2.12**). The increased tidal prism will also have significant impacts on the channels, levees and parcels downstream.

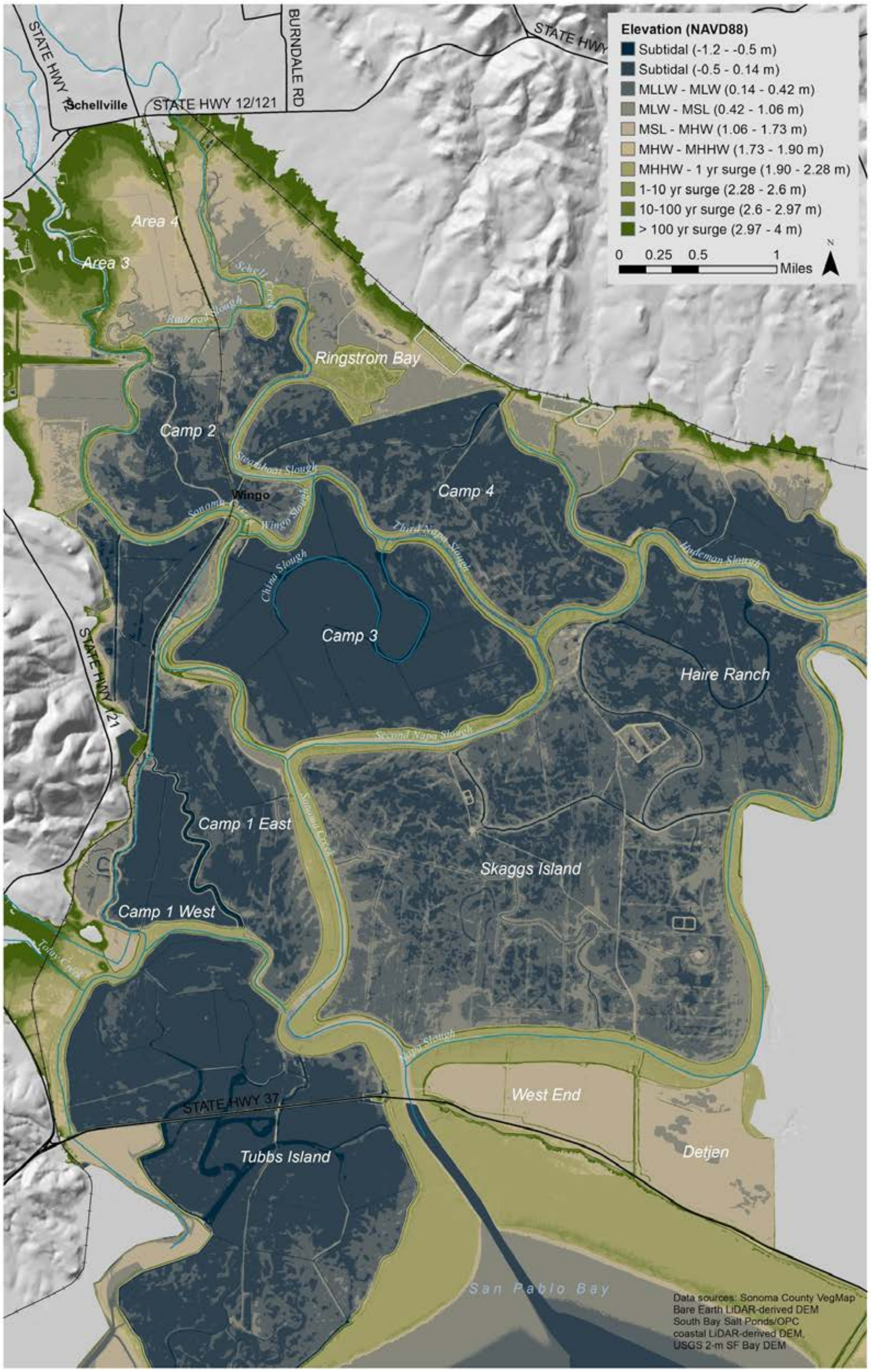

Figure 2.11. Present day topography of the lower Sonoma Creek watershed (baylands only) following diking.

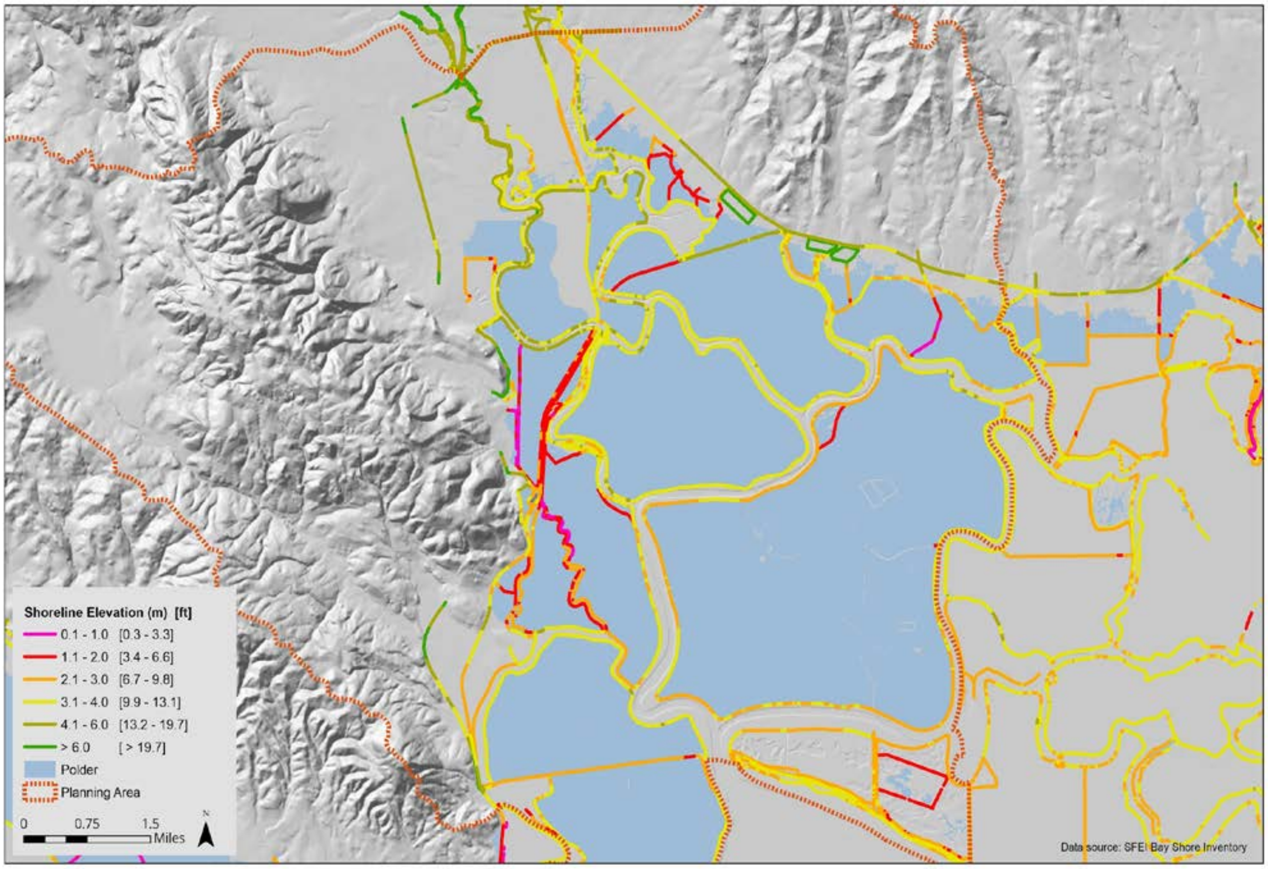

Figure 2.12. Elevations of levees surrounding diked parcels

Grading and Channels

The historical marsh channels in the planning area support high-quality fringing infill marsh habitat and are the most likely to remain viable marsh habitat as sea level rises, given their existing elevation relative to the subsided baylands. Restoring tidal action to diked parcels while protecting the existing fringing infill wetlands is one challenge to overall restoration of this area. **Figure 2.13** is a conceptual drawing of two options for restoring tidal action to a parcel given existing conditions (a). In Option (b), the historical channels are used as conduits to connect the Bay to the newly restored parcel. Given the large increase in tidal prism that results from opening up the low-lying parcel to tidal action, existing marsh adjacent to the channels is eroded downstream of the levee breach. In Option (c), a new channel is cut through the center of the newly restored parcel. Cut and fill reduces the increase in tidal prism introduced by restoring tidal action to the parcel.

In the context of climate change, the difference between options (b) and (c) is important. Given the low elevation of many parcels in the planning area, it will be difficult to reach marsh elevations if tidal action is restored without the addition of fill material. Relying on vertical accretion alone after existing marsh is eroded is likely to result in a net loss of marsh area. A long-term gain in marsh could occur with option (b), if a large amount of fill material is imported, which would be costly and time consuming. Even if this did occur, it is unlikely that the restored marshes could rival the complexity and diversity found in existing high marshes. Strategies that prioritize protection and augmentation of existing high marsh and migration space for lateral transgression (option (c)), while relying on local fill material, are more likely to be feasible and successful in the long term. Imported material may be an important method of increasing and sustaining tidal marshes in this region into the future, particularly if delivery methods can be developed that are cost-effective.

Restoration Efforts

Recent tidal and non-tidal wetland restoration and enhancement has occurred within and adjacent to the planning area, mostly in areas southwest and east of it (**Figure 2.14**). Enhancements include hydrologic or other modifications to increase wetland quality and function such as improving tidal exchange in order for marsh vegetation to grow more vigorously. These restored and enhanced tidal and non-tidal wetlands are providing wildlife habitat and other important wetland functions that will provide adjacent habitat and founding plant populations to future tidal restoration sites.

Tidal restoration sites include the Tolay Creek Restoration Project initiated in 1997 and completed in 1999 which increased tidal flow to 435 acres of the lower Tolay Creek watershed between SR 37 and San Pablo Bay. In 2009, the Lower Tubbs Island/Lower Tolay Creek Enhancement Project improved function to 65 acres of existing, but poorly functioning and muted, marsh units, creating connection between them. The Lower Tubbs Island unit itself is 249 acres and has undergone multiple projects over the years including dike improvement and water control structure removal and replacement. Tubbs Setback Restoration restored 71 acres to tidal action in 2002. The 400-acre marsh at the mouth of Sonoma Creek and east of Tubbs Island was also enhanced in 2015 by improving tidal exchange and drainage to the marsh. Other important tidal wetland restoration projects west of the planning area include Sears Point, which restored 960 acres of tidal habitat in 2015 (now called the Dickson unit), and the Sonoma Baylands Restoration Project, which restored 305 acres in 1996. East of the planning area, over 6,000 acres have been restored to tidal action, including Ponds 3, 4, and 5 of Napa-Sonoma Marshes (3,500 acres), the former Napa Plant Site (1,360 acres), and Cullinan Ranch (1,250 acres). Restoring tidal influence within the planning area will expand the growing mosaic of tidal habitats along the northern extent of San Pablo Bay.

Non-tidal wetland restoration and enhancement has also occurred within diked parcels in the planning area (**Figure 2.11**). In 2004, 313 acres of non-tidal wetlands were enhanced by increasing habitat diversity and improving drainage at Ringstrom Bay. A project was also completed on 608 acres at Camp 2 to improve water management and flooding capabilities and enhance freshwater wetlands and associated upland. Additional enhancements are anticipated at Camp 2 to improve the function of the wetlands. Vintage wine estates (previously Viansa winery) restored 97 acres of seasonal wetlands in 1993. Conversion of 782 acres of former agricultural fields to seasonal wetlands and open water was completed at Haire Ranch in 2019. Some enhanced diked wetlands are anticipated to remain non-tidal; others, such as Haire Ranch, are slated for future long-term tidal restoration.

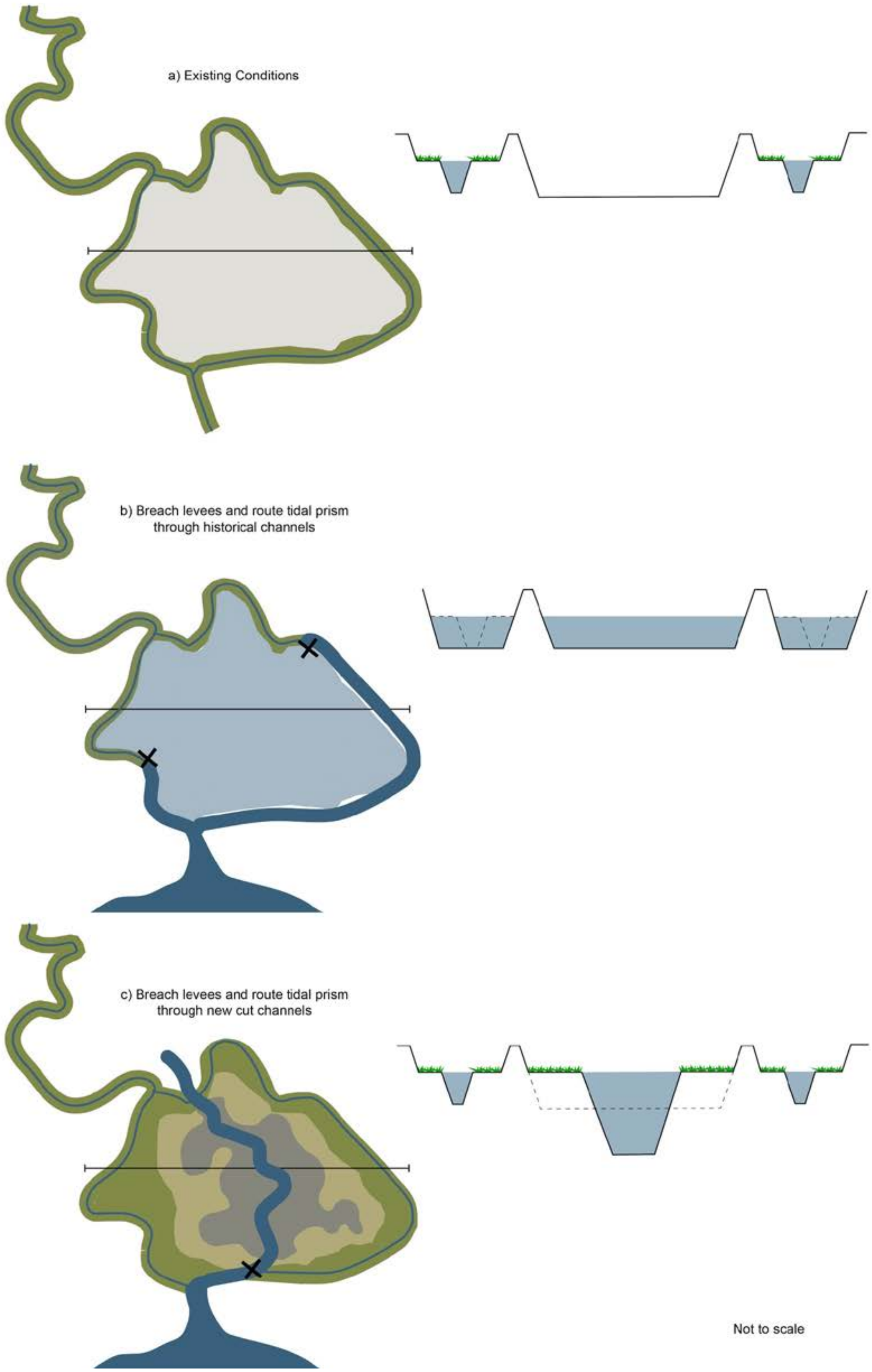

Figure 2.13. Conceptual model of options for grading and channels in plan view (left) and cross section (right).

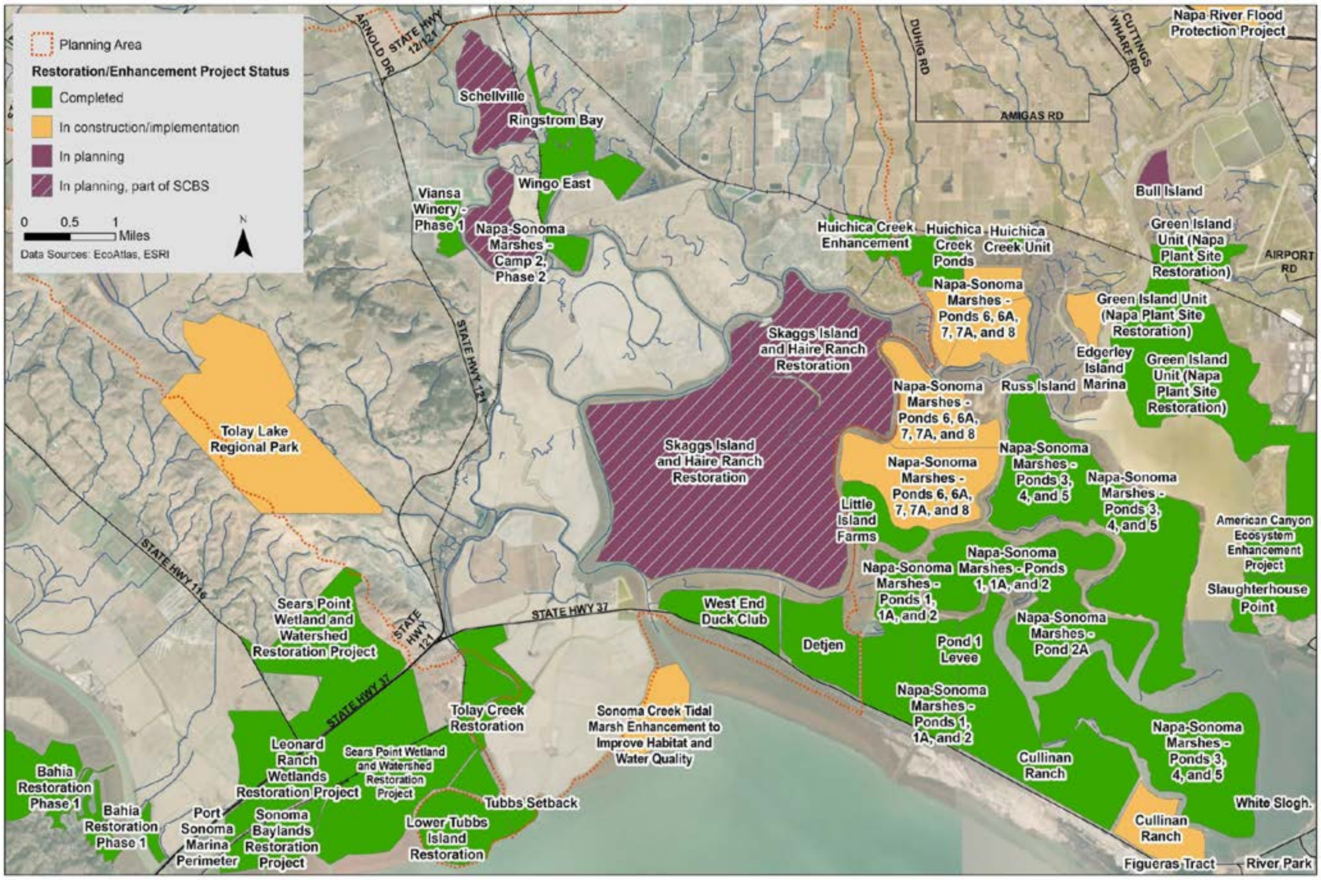

Figure 2.14. Restoration and enhancement projects. (EcoAtlas, California Wetlands Monitoring Workgroup, 2020).

Hydrology

Fluvial Hydrology

Historically, floods along Sonoma Creek and Schell Creek spread over the alluvial fan south of SR 121 creating distributary channels and depositing sediment. The creation of discrete parcels and simplification of the creek network, by diking and draining the camps, blocked the flow of sediment and water across the alluvial fans and confined them to the creek channels. However, these channels have filled in due to lack of tidal prism and now lack capacity. As a result, portions of Schellville and surrounding areas in southern Sonoma County are frequently flooded during relatively minor winter storm events that cause flows to overtop the banks of Sonoma and Schell Creeks. Floodwater that breaks out of the channels is then trapped behind the dikes surrounding the camps and remains impounded, flooding the camps for considerable periods of time (weeks or months). Recurrent flooding has caused economic loss and considerable damage to private property and roadways. In essence, most flooding below SR 121 is controlled by San Pablo Bay water levels. Flooding above SR 121 is controlled by a combination of creek flood flows and high water levels downstream (ESA 2012).

The dikes along Camp 2 have failed in large flood events including the New Year's Eve 2005 event and a large flood which occurred in late February 2019. The dikes along Camp 4 are low enough that this parcel also flooded during those events. Camp 1 experienced a moderate degree of flooding during the

New Year's Eve 2005 event. Some degree of flooding is observed on Skaggs Island during such large floods which is likely a combination of direct precipitation and, potentially, minor overtopping. Camp 3 has not flooded during these events (ESA 2019).

The very flat topography of the lower watershed, the blocking of natural flood paths, the creation of large flood cells, the sedimentation of the historical channels caused by the diking of the camps, considerable tidal influence extending above SR 121, and low ground elevations aggravated by land subsidence have all contributed to the existing flooding issues and the challenges of addressing them. Flood reduction alternatives have been evaluated including options such as expanding the Sonoma Creek channel at the SR 121 bridge, creating an overflow channel at Schell Creek, and creating a floodplain terrace downstream of SR 121 (see ESA 2012 for all alternatives that were evaluated).

Bay Hydrology

The astronomical tides, wind waves, and freshwater flows from local tributaries and from the Delta determine water levels and salinities in the Bay. The hydrologic processes vary around the estuary as each interacts with the shape and size of the shallow embayments that make up San Francisco Bay.

Tides generated in the ocean typically have a range of about 7.5 feet at the Golden Gate. When the tide enters the Bay, it splits between the north and south bay. As the tidal wave propagates into the South Bay it is amplified by the funnel shape of the embayment and the wave that reaches the head of the embayment is reflected and interacts with the incoming wave - both effects amplify the tide range. The North Bay is much longer and not funnel-shaped, so the amplification effects on the tide are not so pronounced. Instead the tidal wave is propagating in shallow water where friction dissipates tidal energy and reduces the tidal range. In the North Bay the tide is characterized by a progressive tidal wave with a tide range of about 6 feet in San Pablo Bay.

Shape and size of the embayments also influence wind waves. The longer the fetch the larger the wave that can be generated for the same wind speed and duration. The shape of the embayments is important as it determines the fetch length relative to the direction of dominant winds. Shallow embayments will dissipate wave energy and reduce wave heights. The generation of individual wind waves will also raise the local water surface elevation close to the shore (known as wave setup) as wave momentum is transferred to the breaker zone close to the shore.

The Sacramento-San Joaquin River flows into the San Francisco Estuary, draining about 40% of the area of California. This significant riverine input, together with the tide and wave regime described above, creates two distinct hydrodynamic regimes within the San Francisco Estuary: the South Bay is a weakly-mixed lagoon in contrast to the river-dominated estuary of the North Bay.

Bay Water Levels

San Pablo Bay has mixed semi-diurnal tides, meaning that there are two unequal high tides and two unequal low tides each day. The average elevation of the highest daily tide is called Mean Higher High Water (MHHW); the average elevation of the lowest low water is called Mean Lower Low Water (MLLW). The difference between MHHW and MLLW is the tide range. The tides are caused by the gravitational pull of the moon and the sun and are very predictable. The highest astronomical tides occur a few times per year, generally between December and February, and are called King Tides. These very high tides are an early indication of the extent of inundation of future average tides with sea level rise.

In addition to the regular astronomical tides, the Bay experiences elevated water levels of varying duration due to El Niño, storm surge and waves, and (depending on location) freshwater discharge from rivers during storm events. Alone or in combination, these factors result in temporary higher water levels, particularly at high tide, referred to as extreme water levels. El Niños can elevate the Bay water levels by up to a foot for 9-12 months every two to seven years. Storm surges occur due to low pressure associated with storm systems passing over the Bay, allowing the Bay water levels to rise. In the Bay the surges are limited to about 3.5 feet above normal tide levels and last for a few hours. Extreme water levels are usually characterized in terms of probability: a 1-percent-annual-chance tide (or 100-year extreme water level) is the water level elevation in the Bay that has a 1% chance of being reached (or exceeded) in any given year. Waves are similarly characterized by probability.

Table 2.2 shows the tidal datum and extreme total water levels for Sonoma Creek calculated as part of their recent FEMA remapping of the Bay (AECOM 2016).

Table 2.2 Present (2000) tidal datum and extreme water surface elevations for Sonoma Creek.

		Elevation ft (m) NAVD88	
Extreme water levels	100-year total water level	9.74 (2.97)	100-year storm surge is 3.5ft (1.07m)
	10-year total water level	8.53 (2.60)	
	1-year total water level	7.48 (2.28)	
Daily Tides	Highest Astronomical Tide (HAT)	7.71 (2.35)	Tide range is 5.8ft (1.76m)
	Mean Higher High Water (MHHW)	6.23 (1.90)	
	Mean Sea Level (MSL)	3.48 (1.06)	
	Mean Lower Low Water (MLLW)	0.46 (0.14)	

While the Bay is sheltered from oceanic waves, local winds blowing over relatively long fetches do generate waves in San Pablo Bay. Waves in shallow water resuspend sediment to be circulated by tidal currents, erode marsh edges and dikes, and can cause flooding due to runup and overtopping on dikes. The wave height at a structure depends on location of the structure on the shoreline and how much marsh and mudflat is (or expected to be) between the structure and the Bay. For the mouth of Sonoma Creek, the 100-year inshore significant wave height (average of the highest one-third of waves) is about 2.7ft (0.82m), and the maximum wave height is 3.1ft (0.95m) (AECOM 2016).

The same wind wave generation processes that occur in the embayments will also occur in large ponded areas of water although the waves generated will be smaller due to the shorter fetch. In addition, it is possible for seiches to be generated by strong winds that push water from one end of a body of water to the other, with the water then oscillating back and forth. Seiches will increase the local water depth for a period, allowing generation of larger wind.

Tidal Circulation

The Sonoma Creek Baylands is a network of tidal sloughs connected to Sonoma Creek to the west and the Napa River to the east, which drain into San Pablo Bay. The tidal wave propagating landward through San Pablo Bay enters the marsh from the west (Sonoma Creek) and the east (Napa River). For example, during a flood tide, water on the west side of South Slough (which connects Napa Slough to the Napa River) is flowing to the east and water on the east side of the Slough is flowing to the west. In the approximate middle of the slough and marsh, these flood currents converge, and the water velocity is negligible. Warner et al. (2003) called this area the barotropic convergence zone.

A sill at the mouth of Sonoma Creek becomes exposed during low spring tides, truncating the tide on the west side of the marsh (Warner et al. 2003). During spring tides, tidally averaged water-surface elevations are higher on the west side, which causes easterly, tidally averaged fluxes of water and sediment. During neap tides, the sill is not exposed at low tide and the west side of the marsh experiences the full tide range, creating tidally averaged fluxes in the opposite direction.

Elevations and volumes

Average elevations for each parcel of interest are shown in **Figure 2.15** and show a north-south gradient from the alluvial fan south of SR 121 to the diked marshes further south. Most of the diked marshes have subsided from historical marsh elevations (presumably around MHW to MHHW) to their present elevations around MLLW. West End and Detjen stand out because while they are diked, they have muted tidal connections to the Bay and soils have remained saturated rather than being farmed and turned over, which oxidizes organic material. Therefore, the parcels have maintained higher elevations (see Appendix 2). Most of the diked baylands have subsided to an elevation at about MLLW. The Ringstrom Bay, West End, and Detjen units have average elevations equivalent to low marsh. On the alluvial fan, south of SR 121, Area 4 is at high marsh elevation, and Area 3 has an average elevation above the tidal range.

Volumes of sediment required to raise each parcel to each habitat zone are shown in **Figure 2.16**. These volumes were calculated for void space and do not account for sediment compaction over time, and therefore are underestimates. The volumes were approximated based on hypsometric curves generated for each parcel using Sonoma County Veg Map's 2013 3ft bare earth LiDAR-derived DEM (and OPC's 1m LiDAR-derived DEM (2010) for West End and Detjen) and are estimates only. As a large area at relatively low existing elevation (an average of 0.99 ft/0.30m NAVD88), Skaggs Island requires the most sediment to reach marsh elevation. Camps 3 and 4, other large and low-lying parcels, would also require large volumes of sediment to reach marsh elevation. In comparison, smaller and higher parcels like Camps 1-2, Detjen, and West End, require smaller volumes of sediment to reach the same elevations.

Groundwater

Declining groundwater levels indicate groundwater withdrawals in excess of recharge in the southern portion of the Sonoma Valley. The net loss of groundwater is due to a combination of increasing groundwater demands and declining levels of precipitation over the last few decades. These declining groundwater levels, which have fallen below sea level in some areas, could exacerbate the intrusion of poor quality water (either from brackish water or geothermal fluids) into the deeper aquifers (ESA 2018). According to Farrar (as cited in ESA 2012) salinity intrusion is already a problem in the groundwater of the Schellville area. Groundwater pumping depressions near El Verano and the City of Sonoma could induce salinity intrusion in the groundwater (Goals Project 2015). According to Sonoma Water (as cited in ESA 2018), reversing the declining trends and recovering groundwater levels in the deeper aquifers is necessary to protect and preserve groundwater uses in these areas and will require a number of management actions in the near future.

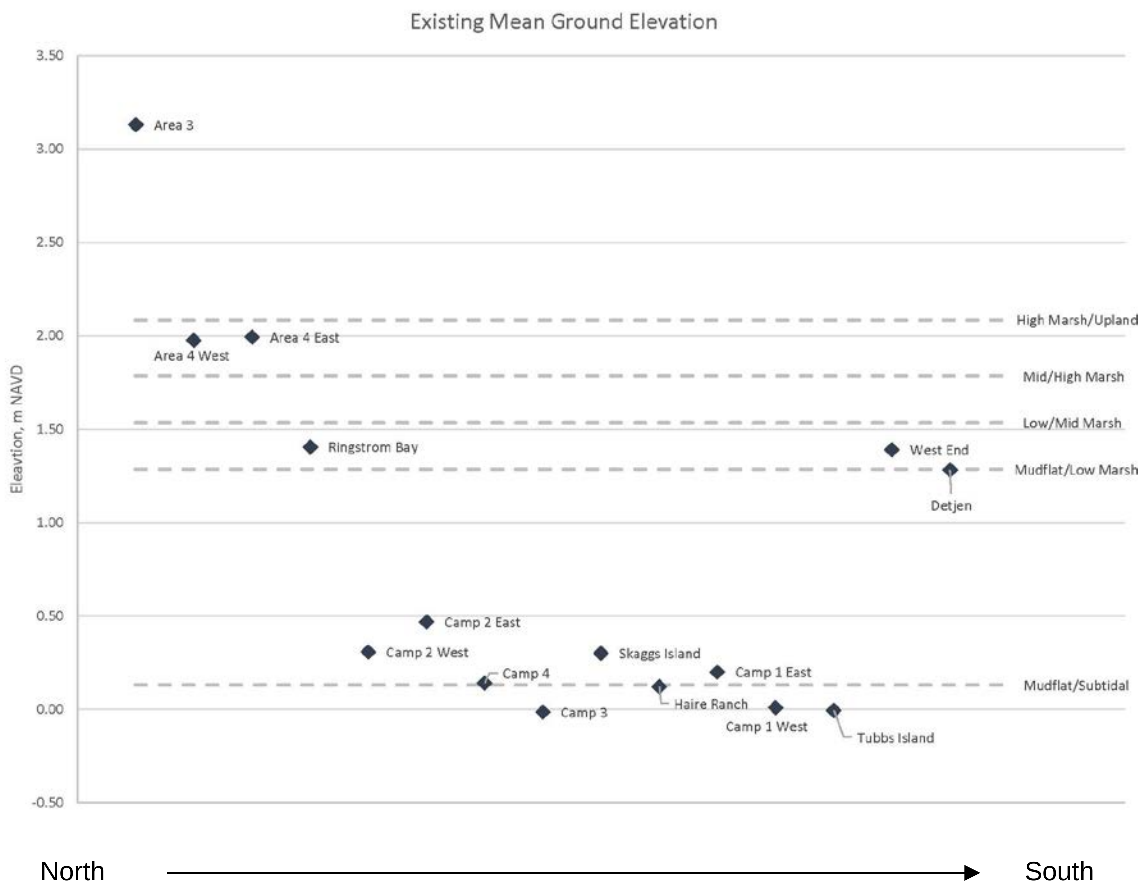

Figure 2.15. Existing mean ground elevations (data from Sonoma County Veg Map and CA OPC LiDAR-derived DEM).

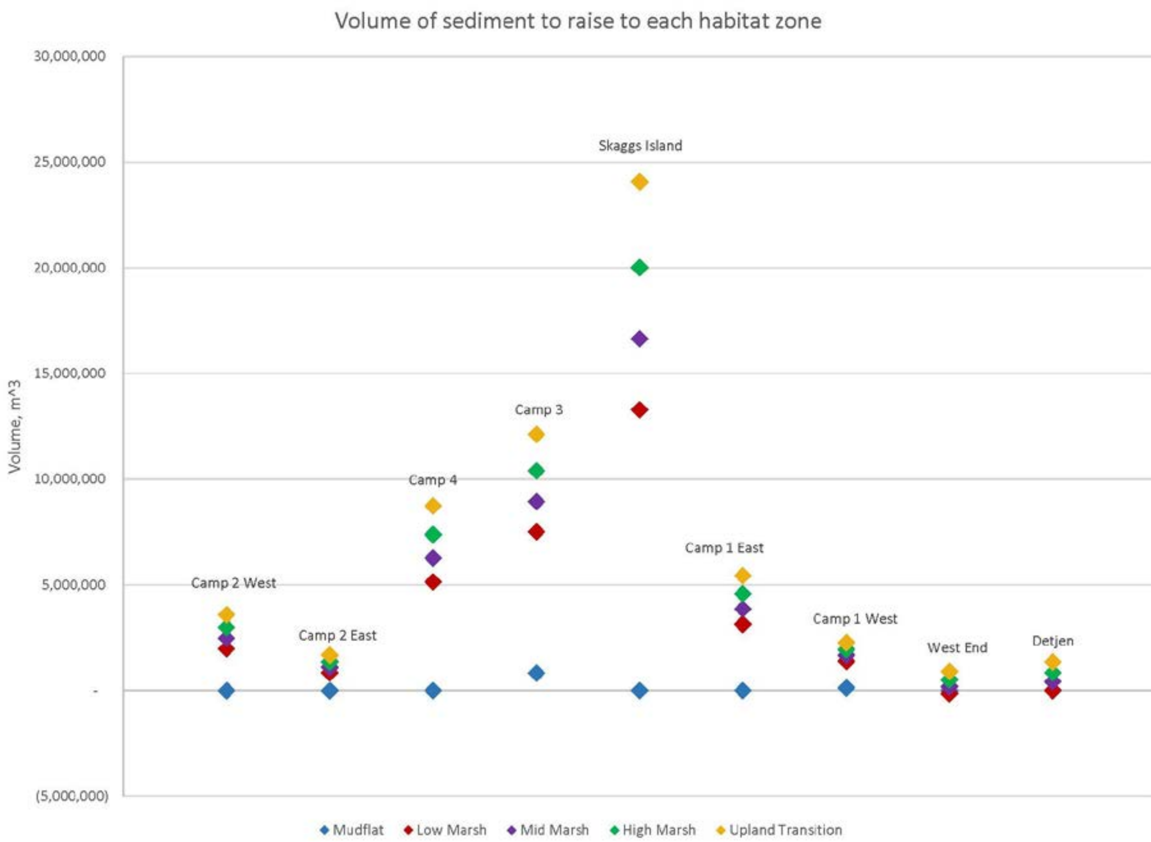

Figure 2.16. Void space volumes of sediment needed to raise diked bayland elevations to each habitat zone (data from Sonoma County Veg Map and CA OPC LiDAR-derived DEM).

The Sonoma Valley Groundwater Basin was originally listed as medium priority by the California Department of Water Resources and was elevated to high priority in 2018 (ESA 2018). The Sonoma Valley Groundwater Sustainability Agency was formed in 2017 consistent with the implementation of the Sustainable Groundwater Management Act. Local stakeholders representing diverse groundwater users and interests continue to guide development and implementation of the Sonoma Valley Groundwater Sustainability Plan through a Board of Directors and an Advisory Committee (ESA 2018).

Recycled Water

Recycled water is treated to tertiary standards at the Sonoma Valley Wastewater Treatment Plant and is used for crop and landscape irrigation on some baylands properties in lieu of groundwater or imported water. According to Sonoma Water, recycled water deliveries are estimated to represent less than 10% of the total water demand in the subbasin and contributing watershed areas (Sonoma Valley Groundwater Sustainability Agency *in Progress*). In southern Sonoma Valley, recycled water is primarily relied upon for agricultural purposes to irrigate vineyards, dairies, and pasturelands. A significant portion of the total recycled water available from the Wastewater Treatment Plant is currently delivered for wetlands enhancement at the Napa-Sonoma Salt Marsh Restoration Project (Sonoma Valley Groundwater Sustainability Agency *in Progress*).

Sediment Supply

Watershed Supply

Although the size of watershed is a key factor in determining overall annual average loads, yield (load divided by the area of contributing watershed) varies considerably between watersheds and over time. Long-term yields of 558 t/km^2 per year have been estimated for the period 1995-2016 in Sonoma Creek (Schoellhamer et al. 2018). Year-by-year variability is demonstrated by the Sonoma Creek TMDL, which estimated a total sediment yield of 248 t/km^2 for 2005 (106,503 t/year from a total watershed area of 430 km^2).

Schoellhamer et al. (2018) found that between 1995 and 2016, of all San Francisco Bay tributaries, Sonoma Creek and Napa River supplied the most sediment. These two tributaries are estimated to account for 22% of the small tributary load and 14% of the total load. Net supply from the Delta was 37% of the total supply for this 22-year period. Sonoma Creek's mean annual total suspended load to the Bay was estimated to be 0.13 Mt/year (with a range of 0.10 to 0.17 Mt/year). Bedload from Sonoma Creek was two orders of magnitude smaller with a range of -0.0071 to 0.0071 Mt/yr.

Bay Supply

Krone (1979) suggests that suspended-sediment transport within San Pablo Bay follows a seasonal cycle: the majority of suspended sediment is delivered through the Delta during the heavy winter freshwater flows, creating a large pool of erodible sediment within the channels and shallows. During the following summer months, persistent onshore winds generate wind waves, resuspending bed sediments in the shallows for transport by tidal currents. Sediment is likely transported away from the mudflats and shallow subtidal areas where energy is high, to lower energy areas such as Sonoma Creek and its marshes. As the summer progresses, the finer fraction of this erodible pool is reduced. In the fall, when neither wind nor freshwater flow is significant, suspended sediment concentration is at its lowest. As the winter wet season commences, the cycle repeats itself.

It is highly probable that the sediment budget in the Bay will shift toward a deficit. Reduction in supply and continual removal of sediment from the Bay has impacted suspended sediment concentrations in a measurable way. Schoellhamer (2011) showed from observations at deep channel sites in the Bay that there was a 36% decrease in suspended sediment concentrations between the early 1990s and the early 2000s. Sediment demand and retention in old and restored marshes in the Bay and Delta will also increase with sea level rise. The sediment supply to the estuary may decrease further, particularly if more instream storage is built, although that trend is uncertain (McKee et al. 2006, Cloern et al. 2011).

Sediment Trapping

Tides propagate through San Pablo Bay and up into the lower reaches of tributary streams such as Sonoma Creek. Sills with short excursion lengths, however, can limit the amount of sediment that the tides transport between the Bay and tributary streams and some of the tributaries that supply sediment to the Bay during high flows act as sediment traps during low flows. Sediment accumulates in the barotropic convergence zone. The zone is within one tidal excursion from San Pablo Bay and most of the sloughs have narrowed due to advection of sediment from San Pablo Bay during flood tide, deposition of the sediment, and subsequent lack of shear stress on the ebb sufficient to resuspend the sediment (Warner et al. 2003). Most of the sloughs in the barotropic convergence zone are shallow, narrow, vegetation-choked channels compared to the sloughs closer to Sonoma Creek and Napa River outside the zone. In addition to sediment accumulation, Swanson et al. (2003) found that after the breach of a salt pond widened in December 2002, a pulse of saline water remained in the barotropic convergence zone for 10 days while salinity was lower elsewhere.

Ganju et al. (2004) also identified an oscillating sediment mass in Sonoma Creek. The geometry and tidal currents in the area create a process of sediment erosion and deposition that repeats with each ebb and flood cycle. As water flows seaward on ebb tides, the tidal currents apply force to the riverbed. Recent deposits of sediment on the bed erode and are resuspended into the water column. Once the suspended-sediment mass reaches the Bay, slack tide and the unconfined flow allow sediment to drop out of the water, forming an ebb delta. As water begins flowing landward immediately after the tide turns from slack to flood, these deposits are resuspended and transported landward. This process then repeats, with the same sediment mass oscillating back and forth between Sonoma Creek and San Pablo Bay. Sediment is effectively trapped within these areas, except during large freshwater flows from the rivers.

Contamination

The Sonoma Creek Baylands may include contaminants from watershed inputs such as mercury, selenium, other agricultural runoff, and possible contaminants from former military land use. Compared to other areas in San Francisco Bay, the planning area is generally thought to have fewer contaminants due to the low industrial use in the area.

Total daily maximum loads (TMDLs) have been developed for Sonoma Creek to establish water quality objectives for pathogens and sediment. TMDLs have been established due to concerns regarding the decline of native fish and to reduce health risks to recreational users. Sonoma Creek has been officially designated as impaired by sediment since 1996 due to channel incision, urban stormwater runoff, vineyards, and livestock grazing (RWQCB 2008). Significant sources of pathogens include septic systems, sanitary sewer systems, municipal runoff, grazing lands, dairies, and municipal wastewater treatment facilities (RWQCB 2006). Since action plans have been adopted to address these issues, education and restoration projects have been implemented to reduce sediment and pathogen pollution in Sonoma Creek.

Although most areas in the planning area have not yet been assessed for contaminants, site assessments were completed at Skaggs Island in 1988, 1992, and 2003 by the U.S. Navy, USFWS, and other agencies (Ducks Unlimited 2018). Multiple sites required removal of material contaminated by pesticides, PCBs, metals, lead, and DDT (Ducks Unlimited 2018). The Navy concluded that the site is now stable and poses no human or ecological threat. However, restoration activities in the vicinity of known contaminant sites at Skaggs Island should be planned and carried out in a way that prevents re-mobilization of potential harmful contaminants. During restoration activities appropriate mitigation measures should be taken to minimize the risk of contaminants at any site within the planning area.

2.4 Current Land Uses

Aside from the relatively small developed area of Schellville adjacent to SRs 121 and 12, land use in most of the planning area is a mix of agriculture, rural residential, and open space (**Figure 2.2**). Agricultural space is dominated by hay production with smaller plots of land devoted to wine grape and dairy cow production. Residential properties are concentrated along Millerick Road, south of its junction with SR 121. Open space is typically tidal wetland and fresh or saltwater marsh.

Land Ownership

The planning area is approximately 35,000 acres, of which approximately 11,000 acres are under permanent conservation. This conserved acreage includes portions of Tolay Lake Regional Park, Tubbs Island Setback and Tolay Creek (leased by USFWS), Gravelly Lake conservation easement (held by SCAPOSD), Tolay Creek Riparian conservation easement (held by SLT), Tolay Creek Lagoons and Camp 2 (owned by CDFW), West End (owned by CDFW), and Lower Tubbs Island, Skaggs Island, Haire Ranch and Detjen (owned by USFWS). The Tubbs Island Setback, Tolay Creek, Lower Tubbs Island, Skaggs Island, Haire Ranch and Detjen are all part of the larger San Pablo Bay National Wildlife Refuge (SPBNWR), managed by USFWS (**Figure 2.17**). The 20,450-acre Refuge contains 11,200 acres of tidal habitats, including open bay and mudflats, which occur either within or near the planning area (Veloz et al. 2016). The approximately 15,200-acre Napa-Sonoma Marshes Wildlife Area is owned by the State of California and managed by CDFW. While most of the acreage is east of the planning area, some units are within the planning area (**Figure 2.18**).

The remaining acreage is privately owned or owned by public agencies, such as Sonoma Water and Vallejo Sanitation District, for purposes other than conservation.

Future restoration to tidal marsh of an additional 6,350 acres of publicly owned land, including Camp 2 (590 acres) and Skaggs Island (3,150-acres), is possible. Creation of tidal connections between Skaggs Island and Haire Ranch is possible as well. The majority of acreage adjacent to Sonoma Creek south of SR 121 could be available for acquisition except for the west bank south of SR 37, which is owned by Wing and Barrel Hunt Club and the Vallejo Flood and Wastewater District. There are also thousands of acres of private property adjacent to and in the vicinity of Sonoma Creek that may be available for conservation and restoration to tidal marsh and other wetland habitat, and marsh migration, transition zone, and upland habitats. Public and private conservation organizations work only with willing landowners to purchase private land.

Both public and private lands in the Sonoma Creek Baylands are vulnerable to dike failure and flooding. Most properties rely on pumps and repeated dike repairs to keep the land dry, although entire parcels can be inundated for weeks and sometimes months.

Table 2.3. Property Ownership and Easements

Property Name	Owner	Fee or Conservation Easement (CE)	Acres
Tolay Lake Regional Park	Sonoma County Regional Parks	Fee	3,070
Tubbs Island Setback and Tolay Creek	CDFW	Fee	180
Gravelly Lake Conservation Easement	Private	CE held by SCAPOSD	970
Tolay Creek Riparian Conservation Easement	Private	CE held by SLT	30

Lower Tubbs Island	USFWS	Fee	150
Skaggs Island	USFWS	Fee	3,150
Haire Ranch	USFWS	Fee	1,080
Detjen	USFWS	Fee	530
Tolay Creek Unit (North)	CDFW	Fee	180
Tolay Creek Unit (Tubbs Island)	CDFW	Fee	60
Tolay Creek Unit (Midshipman Slough)	CDFW	Fee	110
Wingo Unit (Camp 2)	CDFW	Fee	590
Wingo Unit	CDFW	Fee	170
Ringstrom Bay	CDFW	Fee	440
Sonoma Creek Unit (West End)	CDFW	Fee	470
		Total	11,180

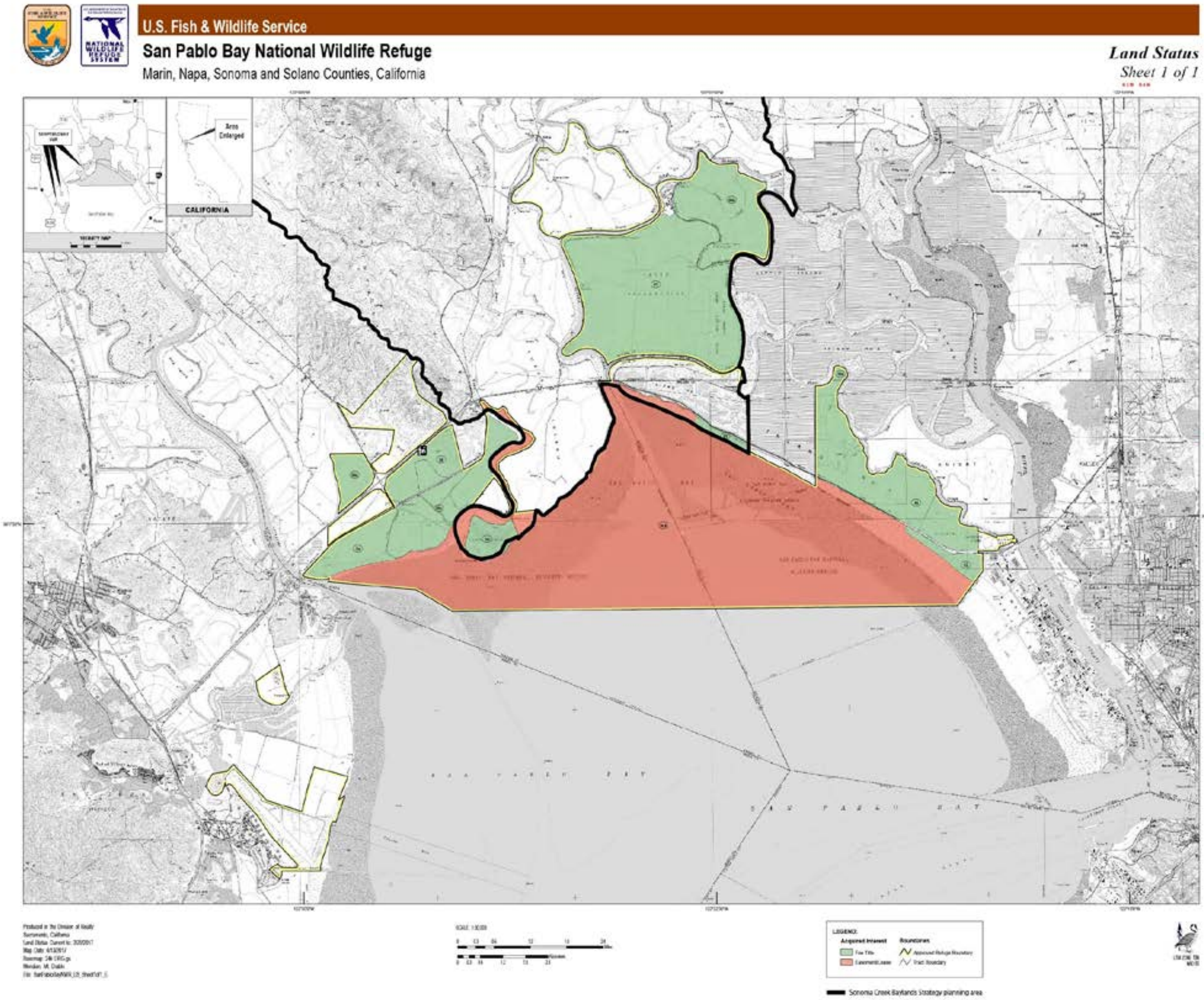

Figure 2.17. Land managed by USFWS (courtesy of USFWS, planning area added for this report).

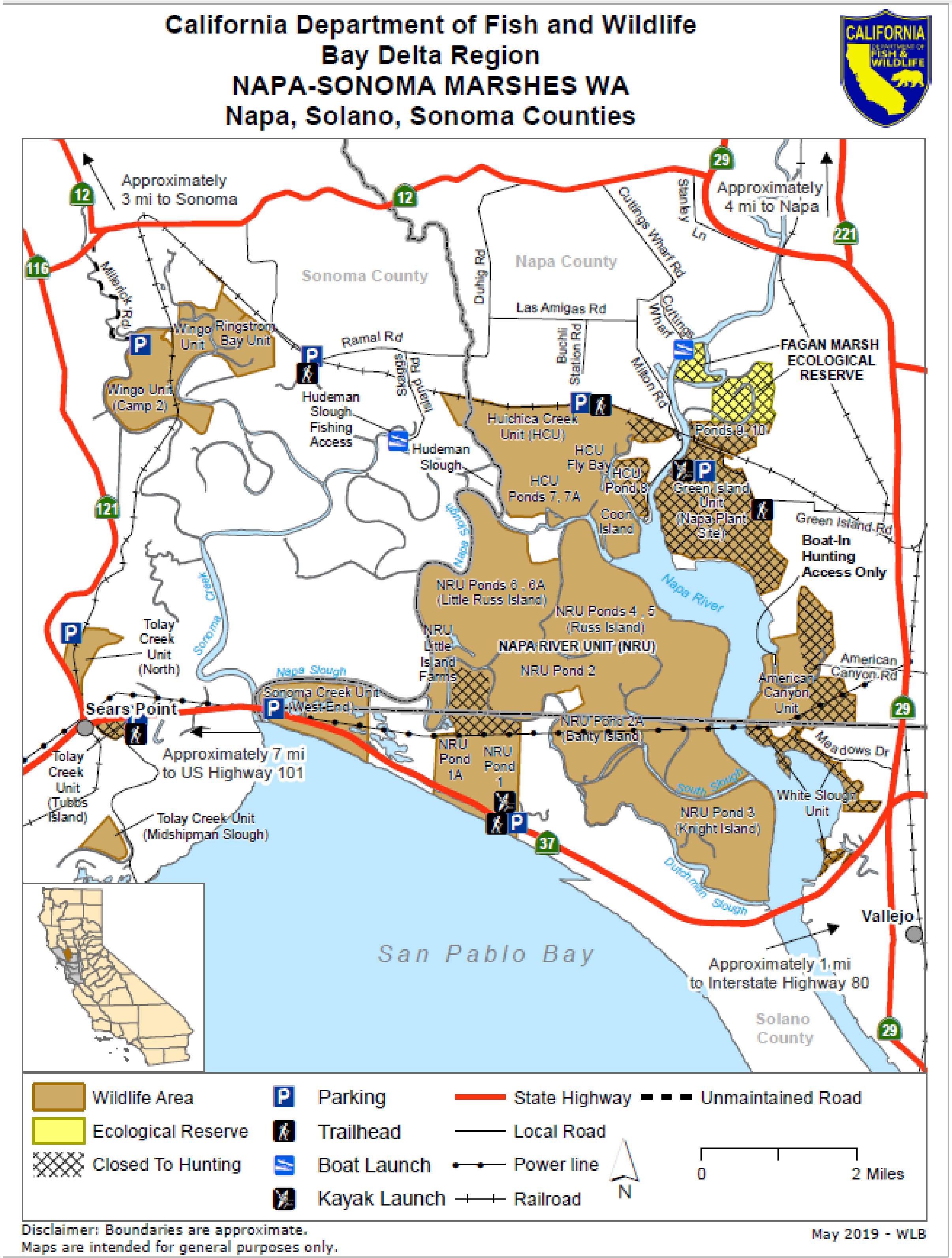

Figure 2.18. Land managed by CDFW (courtesy of CDFW).

2.5 Future Environmental Conditions

Sea Level Rise

Sea level rise guidance for California has been revised following recent updates in projections (CNRA-OPC 2018). The guidance provides probabilistic decadal projections of sea level rise, with respect to a baseline of the year 2000, based on high and low emission scenarios, and location on the California coast. The recommended projections for San Francisco are shown in **Figure 2.19**.

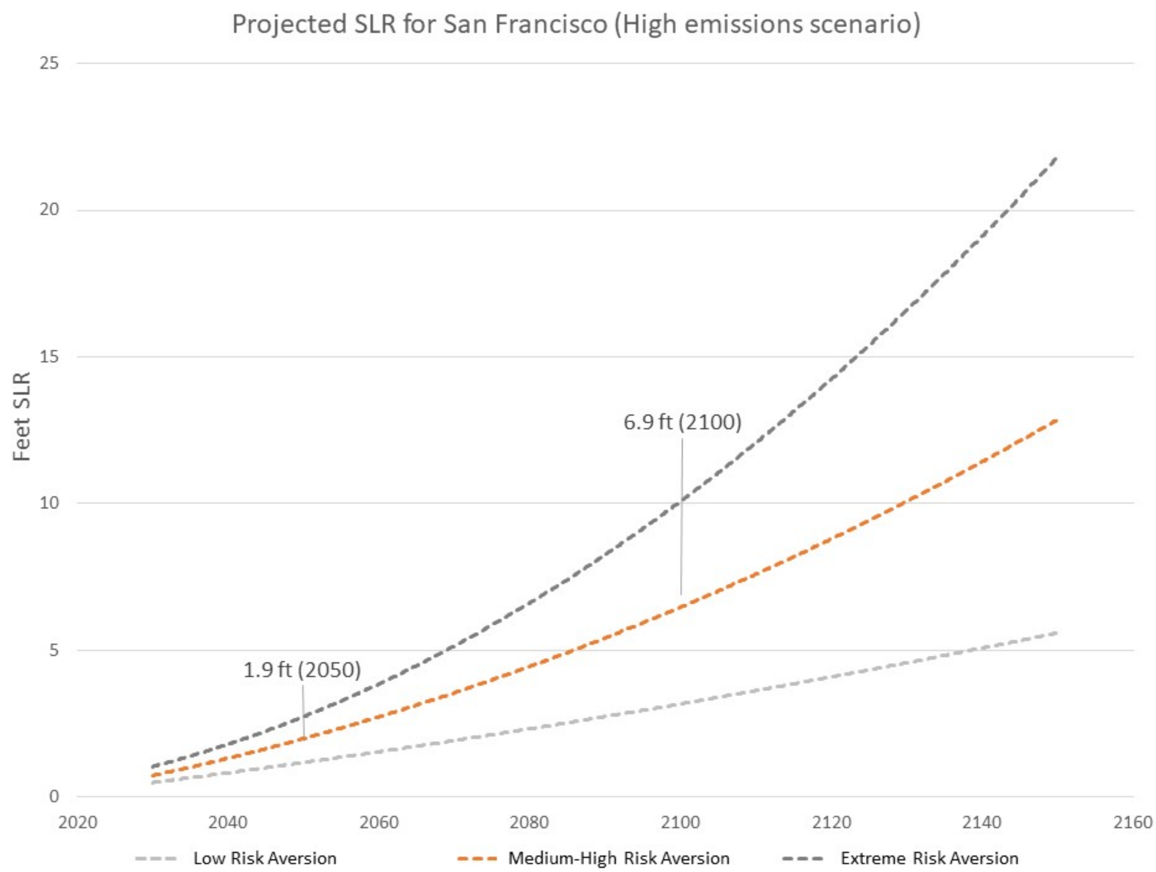

Figure 2.19. Projected Sea Level Rise (in feet) for San Francisco (adapted from Table 1, pg 18, CNRA-OPC 2018). All three curves shown on the chart are for a high-emissions scenario. The orange line shows the 0.5% probability sea level rise curve, which is recommended for medium-high risk aversion planning purposes. Projections used for modeling in this report are 1.9 feet in 2050 and 6.9 feet in 2100.

Assuming medium to high-risk aversion for most land uses in the Sonoma Creek planning area, the projected sea level rise in San Francisco Bay by 2050 is 1.9 feet (0.58m. Between the years 2000 and 2100, sea level is projected to rise by 5.7 to 6.9 feet (1.74 to 2.10m). This would raise the present-day tidal datum and extreme water levels by a similar amount as shown in **Table 2.4.**

Table 2.4. Current and Projected Water Levels

Projected total water levels	Today	2050	2100	
		ft NAVD	ft NAVD	
+ 1:100-year storm surge of 3.6 ft.	9.74	11.64	15.44	16.64
+ Mean High Water (MHHW)	6.23	8.13	11.93	13.13
+ Mean Sea Level (MSL)	3.48	5.38	9.18	10.38
+ Mean Lower Low Water (MLLW)	0.46	2.36	6.16	7.36
Sea Level Rise	0.0	1.9	5.7	6.9

Future Geomorphic Changes

With significant sea level rise projected in San Francisco Bay by 2100 under existing emissions trajectories (CNRA-OPC 2018), existing wetlands in the Sonoma Creek Baylands are at risk and land uses in low-lying surrounding areas are jeopardized. Dike overtopping will become more frequent in diked, subsided baylands, while the increased frequency of inundation may accelerate bank erosion and habitat conversion in tidal wetlands (Goals Project 2015). Climate change will also alter precipitation and streamflow patterns and vegetation distribution throughout the watershed. Countywide, climate change is projected to increase the frequency and severity of floods, droughts and extreme weather events (Cornwall et al. 2014).

The impacts of sea level rise on Sonoma Creek marshes are not merely submergence of existing marshes and overtopping of dikes. Horizontal retreat due to marsh shoreline erosion poses an equal or greater threat, particularly for SR 37, which is at risk of increased exposure to higher bay wave energy and increased wave runup, contributing to significantly higher total water levels than still-water tidal elevations.

Of particular concern is the potential increase in flow rates along the tidal channels of Sonoma Creek as tidal action is restored to diked areas either by design through restoration projects, or by accident due to erosion and breaching of dikes. The presently diked baylands are very large areas of subsided land which, since they lie within the tidal range, will fill and empty on each tide. The volume of water that enters on the flood and leaves on the ebb is called the tidal prism and is conveyed to and from the marsh by the remaining tidal channels. The present tidal prism is relatively small, since most areas are protected by dikes, and so many of the channels have been filling in. If the tidal prism increases, then these channels will erode to a size that allows them to convey the increased volume of water. Erosion of the channels to convey water may result in erosion to the existing fringing infill wetlands and dikes, and scouring around bridge piles. It is imperative to estimate the future widths of the main channels if tidal prism is increased.

The relationship between channel size at a particular cross-section of a tidal channel and the tidal prism upstream of that cross-section is known as hydraulic geometry and has been investigated by Williams et al (2002) for marshes in San Francisco Bay. The historical width of Sonoma Creek prior to diking, measured from the earliest accurate surveys of these marshes taken in 1856 by the U.S. Coast and Geodetic Survey, was about 1,194 ft at the SR 37 bridge which corresponds to a tidal prism of approximately 30 million yd^3 (**Table 2.5**). Subsequent diking and draining as described above has reduced the channel at the bridge to its present width of about 387 ft for a tidal prism of about 2.6 million yd^3.

Table 2.5. Historical, present, and future Sonoma Creek Channel dimensions based on hydraulic geometry described in Williams et al. (2002).

	Historical	Current	With all restored
Tidal Prism (yd^3)	33.0M	2.6M	75.8M
Width (ft)	1,194	387	1,829
Depth (ft)	26	16	30
Area (ft)	16,000	3,279	29,000

In the future, an accidental breach on the east bank of the Sonoma Creek could inundate the whole of Skaggs Island including the former subtidal and mudflat areas. Such a breach could increase the tidal prism passing under the SR 37 bridge to as much as 28 million yd^3 (more than it was historically due to the subsidence of former marshes) and increase the present width of 387 feet to about 1170 feet. In the past, such breaches have been repaired relatively promptly, and the Sonoma Creek channel has not been significantly eroded. But with rising sea levels in the future, it may not be cost-effective to maintain these dikes, and the inundation could become permanent. In the extreme case, tidal action could be restored to all the former marshes either as planned marsh restoration projects or by accidental breaching. In this case, the maximum tidal prism of the Sonoma Creek is about 75 million yd^3 giving a potential maximum width of about 1800 feet. In addition to the channel to accommodate normal tidal flows, allowance would have to be made to maintain the adjacent creek marsh which at present is about 500 feet wide.

CHAPTER 3

Scenario Development

3.1 Hydrologic Scenarios

Each of five landscape condition scenarios (outlined in Chapter 5) was evaluated under the following hydrologic scenarios, for present day and year 2050 conditions.

Three hydrologic scenarios were selected to bracket the range of conditions relevant to assessing the hydraulic impact of restoration scenarios. The hydrologic scenarios reflect various combinations of tidal conditions and streamflow in the primary channels. The hydrologic scenarios, which are described in more detail in Appendix 1, include: (1) 1% annual chance flow, typical tides; (2) 1% annual chance flow, storm surge tide; and (3) 1% annual chance flow at 2050, storm surge tide with 2050 sea level rise. The peak flows on Sonoma Creek and Schell Creek and the peak tide level for each of these scenarios is summarized in Table 2 of Appendix 1.

The first scenario (1% annual chance flow, typical tides) reflects a large flood from the Sonoma Creek watershed and a tide signal ranging between typical MHHW and MLLW. The second (1% annual chance flow, storm surge tide) reflects a large flood condition coincident with a storm surge in San Pablo Bay. The third (1% annual chance flow in 2050, storm surge with 2050 sea level rise) reflects extreme fluvial and coastal flooding including future climate change impacts on precipitation and sea level. In addition to these 1% flood scenarios, a typical tide condition with base flow was modeled for existing and sea level rise conditions to assess parcel inundation extents and tidal muting under typical tidal cycles with background watershed flow contribution.

The 2050 hydrologic scenarios reflect assumptions for the influence of climate change on coastal water levels and future rainfall intensity. The approach and assumptions made in characterizing climate change impacts to these variables are summarized in the following section.

Climate change analysis

Climate change impacts to sea level rise and watershed hydrology were characterized for mid-century (2050) conditions. A sea level increase of 1.9 feet by 2050 was used for modeling, based on California statewide guidance (see Section 2.5, Future Environmental Conditions).

For future discharge conditions, downscaled rainfall data was used as input to the hydrologic model developed by PWA for estimating design discharges. ESA used extreme value analysis with the daily rainfall totals from a downscaled climate model (6km x 6km grid cell; Pierce, 2014) to estimate rainfall depths for the 1% annual chance event at 2050, under the medium-high emissions (RCP 8.5) scenario. The climate grids overlaid with the watershed model subbasins is shown in Figure 2 of Appendix 1.

Data from 29 climate models was processed to generate an estimate of future design rainfall. Using this methodology, an average increase of 7% over the Sonoma Creek watershed was estimated for 2050. The rainfall depth for the 2050 1% annual chance event was increased by 7% and run through the hydrologic model for the Sonoma Creek watershed. The peak flow increased by 11% from 24,360 to 27,100 cfs. More details on the development of hydrologic scenarios are available in Appendix 1.

CHAPTER 4

Feasibility Considerations

4.1 Existing Resources and Landscape

Many of the essential resources required for tidal restoration are already present within the planning area. For example, there are adequate flows of water into the site from multiple sources: freshwater flows from the Sonoma Creek watershed and tidal flows from San Pablo Bay. The recycled water pipeline (North Bay Water Reuse Program) provides another opportunity to introduce freshwater inputs to the system to create a more varied gradient of habitats from freshwater to brackish to saline.

Sediment inputs will be required for restored marshes to accrete and build elevation to keep up with sea level rise. The planning area also provides an opportunity for long-term sediment supply, with inputs of both coarse sediment from the watershed and fine suspended sediment from San Pablo Bay. While the multiple sources of sediment are an asset for restoration, the quantities and spatial distribution of sediment supply in the future cannot be predicted. Beneficial reuse of dredged sediment in this region may be possible.

Woody debris present on site may provide future habitat complexity and erosion control. Woody debris currently accumulates at Big Break and upstream of the Wingo Bridge. Restoring some of the large, currently diked parcels would open new areas where the woody debris could collect, adding habitat complexity rather than impeding flow in the existing channels. The combination of the space available in the currently underused diked baylands and the existing water, sediment, and woody debris that can fill this space presents a valuable opportunity.

The existing historical tidal channels present another opportunity. The fringing wetlands along these channels (north of SR 37) total approximately 1,300 acres. Restoration of these channels and their adjacent marshes would provide a nucleus of mature, complex marsh habitat, including populations of valuable wetland species, that restorations can build out from. They also present an opportunity as conveyance channels, although increasing tidal prism in these channels would result in erosion of their banks which are the existing fringing wetlands.

As stated in Section 2.4 above, thousands of acres of private land are potentially available for acquisition to add to existing public properties already in conservation, creating the opportunity to restore tidal action to parcels from SR 37 to SR 12.

4.2 Co-Benefits

Restoring tidal action to the planning area creates the possibility of associated benefits that are not direct goals of restoration but may be incorporated into the design. One such benefit is alleviation of the duration and depth of flooding in adjacent properties. Currently, stormwater flooding is of particular concern for properties around SR 12 in Schellville, and also in other parts of the planning area. Lack of efficient drainage pathways can pond floodwater several feet deep in these areas for several weeks following a large flood event. Restoration of tidal action in the downstream baylands can reduce backwater effects in fluvial channels and enhance drainage, lowering flood depths, extent, and duration higher in the system, and reducing flooding upstream.

Another co-benefit may be to reduce mosquito populations that may cause a public nuisance or human health threat through careful design of restoration projects that increase water movement and reduce ponding. Vector control can also place a constraint on the range of design options available, because restoration should not increase mosquito populations that can adversely impact human health. In general, restoration alternatives with more tidal area, more wave action, and less vegetation are likely to be preferable from a vector control standpoint to alternatives with more freshwater/brackish water, muted tidal or seasonal wetlands, and more vegetation.

4.3 Habitat

The many opportunities associated with tidal habitat restoration are described in detail in the 1999 and 2015 Bayland Goals documents (Goals Project 1999, Goals Project 2015). The following section describes considerations that are most pertinent to the planning area.

One major opportunity is potential connection with existing tidal habitat, including the Napa-Sonoma marshes, Ringstrom Bay Unit, strip marsh at the mouth of Sonoma Creek in San Pablo Bay, Tolay Creek marsh and Lower Tubbs Island units, and the existing fringing marshes in the historical tidal channels. Expanding these existing tidal habitats by restoring adjacent tidal habitats in the Sonoma Creek Baylands would enhance connectivity and create larger patches that can support more robust populations of species.

Adjacent tidal habitats provide numerous benefits for restoration, due to the populations of marsh and tidal flat species that already inhabit the region. One such benefit is a local seed source, which reduces the need for planting in the restoration process. Another is an established food web for species that will eventually inhabit the restored area. The existing food web in the Bay, tidal flats, marsh, and upland areas provides a base from which to build after habitat is restored.

Adjacent uplands also provide valuable opportunities. In the Sonoma Creek Baylands, upland connectivity exists primarily at the alluvial fans at Tolay Creek and Area 4. Elsewhere, steep topography and infrastructure (primarily the rail line) inhibit connectivity between the baylands and uplands. Transition zone connections between the baylands and uplands are important for both upland and wetland species. These zones are becoming more important as they are where marshes can migrate inland as sea level rises.

Another design consideration will be the preservation of existing marsh habitat, both the fringing marsh in the existing historical tidal channels and the strip marsh along San Pablo Bay. Given climate change, preservation of existing high marsh habitat is essential, as sediment accretion in restored areas will be gradual and may not be able to keep pace with sea level rise (Appendix 3). Because restored habitat will take time to build up to the level of habitat quality that already exists in the strip marsh and channel marshes, it is important to reduce impacts to this mature habitat in the interim. Existing high marsh has better potential to persist late into the century and to provide high value habitat in the nearer term. Restoring more tidal prism to the site using the existing historical channels will inevitably mean erosion and loss of existing mature fringing wetlands, so restoration designs need to consider these impacts and weigh them against the value of using the existing channel network to direct flows.

4.4 Rail and Road

Transportation infrastructure presents one major constraint to restoration in the planning area. The Sonoma-Marin Area Rail Transit (SMART) line runs along the western edge of the planning area (west of

Camps 1 and 3 and through the middle of Camp 2 and Area 4) (**Figure 4.1**). The existing line goes through Schellville, and there is also a railroad right-of-way across the northern edge of Camp 4, where future development of the rail bed might occur. Other railroad-related constraints include the existing bridges at Railroad Slough and Wingo Slough, which limit the flow that can travel through these sloughs and trap woody debris. Additionally, railroad easements over the diked baylands properties require that the property owners maintain levees and reduce flooding around the tracks to ensure the railroad infrastructure (levees, tracks, etc.) is kept dry, placing the burden of flood prevention on property owners. The segments of SMART rail that were constructed within historical tidal marshes and areas projected to be inundated by rising seas are vulnerable to flooding and dependent on the aging system of berms and pumps that will be under increasing pressure as sea level rises.

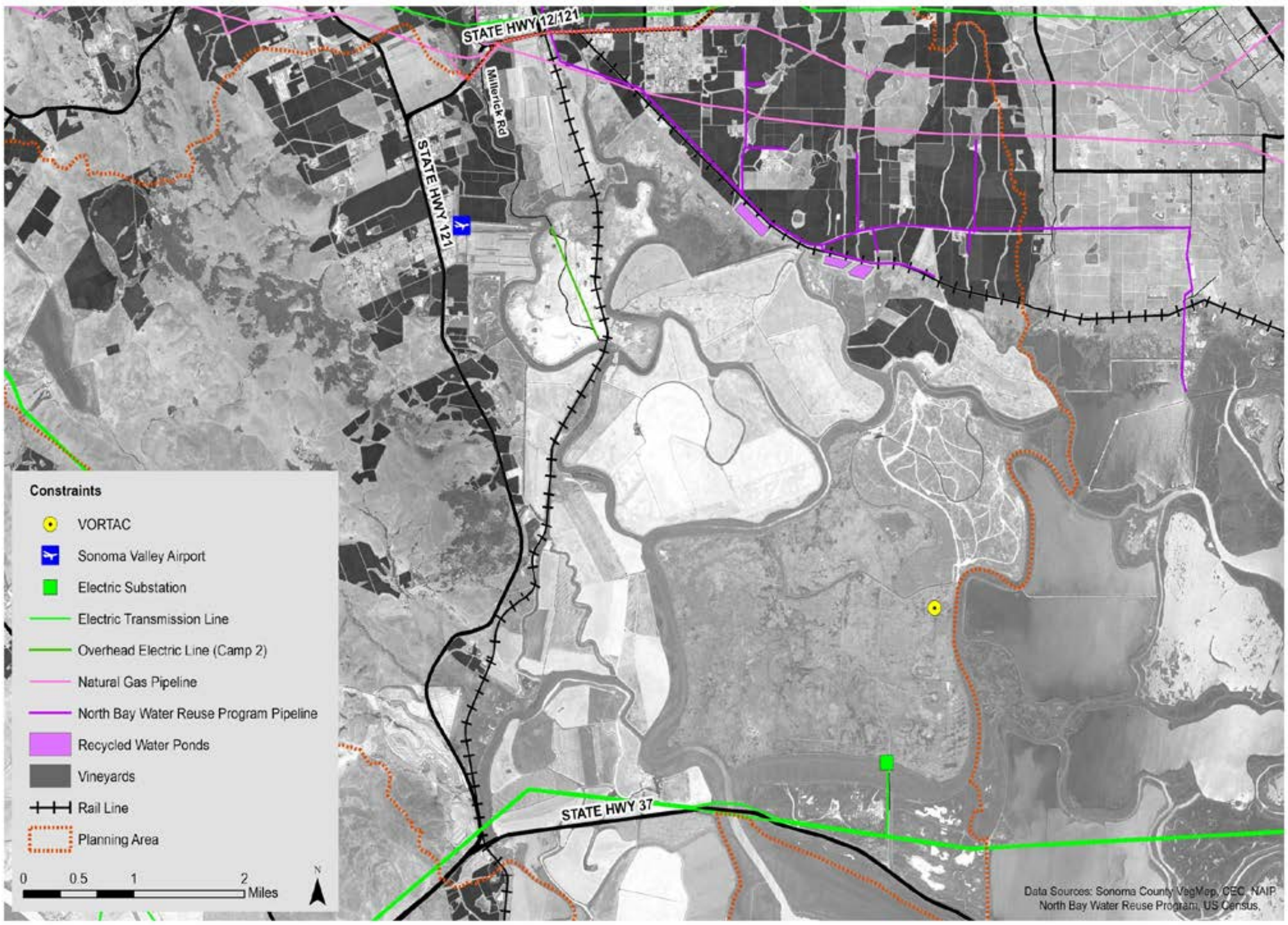

Figure 4.1. Spatial distribution of infrastructure and land use constraints in the planning area.

SR 37 is another transportation infrastructure constraint to consider. The highway runs along the southern edge of the planning area, through Tubbs Island and south of West End and Detjen (**Figure 4.1**). Larger planning efforts to address congestion and flooding along the SR 37 corridor are underway, and restorations in the Sonoma Creek Baylands will need to be coordinated with these efforts. The major constraints presented by SR 37 are the channel crossings at Tolay and Sonoma Creeks, which limit the width of the channel and so the amount of tidal prism that can be accommodated when diked baylands are restored. If too much tidal prism is added to the Sonoma Creek channel, the bridge abutments and dikes on Tubbs Island and at West End could be undermined. At Tolay Creek, the current channel crossing is too small to accommodate any additional tidal prism, so the bridge would have to be lengthened to allow restoration in the Tolay watershed. SR 37 flooding and congestion relief planning efforts provide the opportunity to reconnect the baylands to the Bay if the roadway is elevated and/or modified with wider crossings that allow for increased tidal flow.

SR 121 is a heavily traveled east-west route connecting the lower Sonoma and Napa Valleys. Upstream of SR 121 flooding overtops the highway during most Sonoma Creek flood events greater than approximately a 2- to 5-year peak flow (ESA 2012). This flooding near the highway's junction with SR 12 typically results in road closure, affecting both travel and public safety.

Millerick Road, a county-owned road, travels south from SR 12 through several properties in the northern portion of the planning area and is often closed due to flooding and levee failure, creating access challenges for property owners to the south of SR 12.

4.5 Sonoma Valley Airport

Sonoma Valley Airport is a small municipal airport with a single runway located along SR 121 (**Figure 4.1**). The airport is surrounded by various safety zones as identified in the Sonoma County General Plan, which constrain uses in the vicinity of the airport. Due to potential bird strike hazards, large water features, including wetlands, may be prohibited in all airport safety zones (**Figure 4.2**). In addition, the airport may hold avigation easements over some adjacent lands that may further constrain land use options. Avigation easements will need to be evaluated and additional conversation with the county will be needed during site-specific restoration design to determine appropriate habitat types within the airport safety zones.

4.6 Utilities

PG&E electric transmission lines and gas pipelines run through the northern and southern portion of the planning area (**Figure 4.1**). Constraints created by these utility lines, the need to maintain access, and opportunities to partner with utility companies will be addressed during site-specific restoration planning. Sonoma Water's North Bay Water Reuse Program Pipeline runs through the northern portion of the planning area delivering tertiary treated water to some properties. Sonoma Water has indicated that this fresh water supply may be available to restoration projects; however, the recycled water would likely be available only during the winter or wet season since there is high demand for it for agricultural purposes during the dry summer months.

Other infrastructure constraints center primarily around preserving access to specific sites to allow maintenance of infrastructure after restoration. For example, a Pacific Gas and Electric (PG&E) electric transmission line runs along the southern edge of the site, with an electric substation at the southeast corner of Skaggs Island. Access to this PG&E substation will need to be maintained during and after restoration. Road access to Wingo Bridge will be needed to allow for maintenance of the railroad and another PG&E transmission line that runs south from SR 12 roughly along the same path as the railroad; access for maintenance is technically from the north via Millerick Road, but given that Millerick Road is often washed away by flooding caused by berm failure and overtopping, the railroad, Wingo Bridge, Camp 2 and the transmission line must be accessed from the south over private properties with permission from these owners.

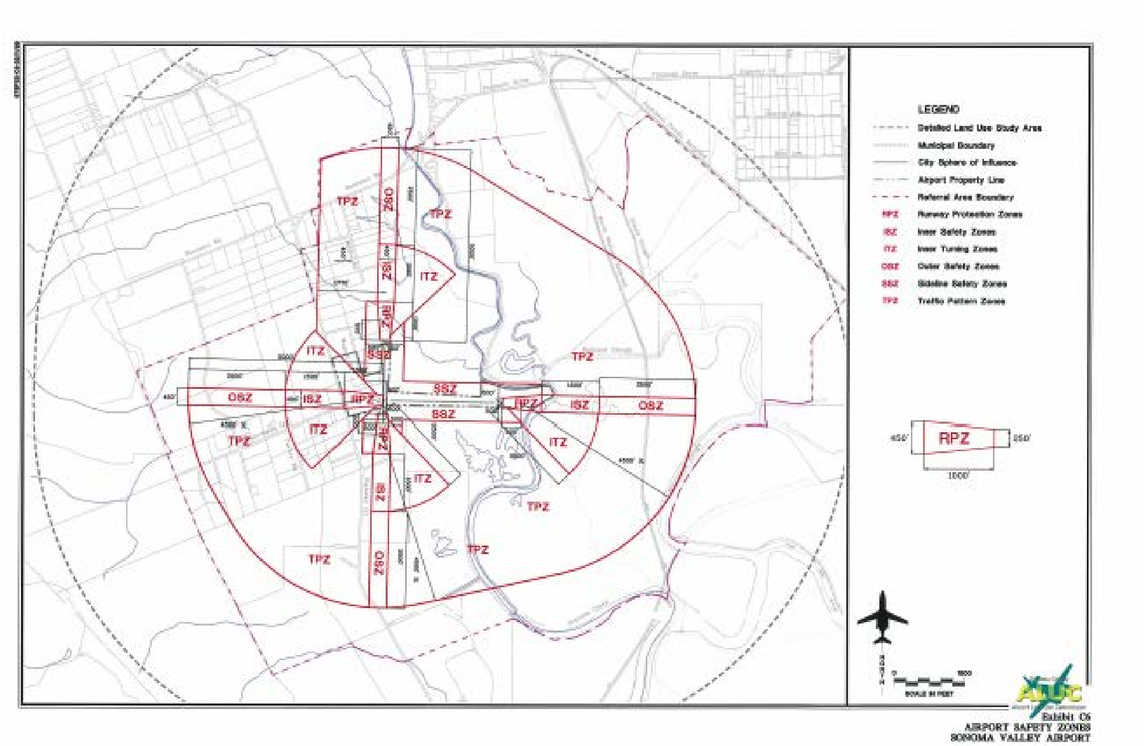

Figure 4.2. Airport safety zone (Sonoma County Airport Land Use Commission).

The VORTAC navigational site on the eastern side of Skaggs Island is also a constraint. The VORTAC is a collocated radio beacon and tactical air navigation beacon that aids aircraft pilots in navigation. The FAA requires that the site and access to it are both maintained during and after restoration. A raised berm leading to the site may need to be constructed to allow maintenance of the VORTAC if tidal action is restored to Skaggs Island.

4.7 Land Use

Agriculture is the predominant land use in the transition zone and upland area just outside the baylands. Vineyards are becoming more common in the region and are a high-value agricultural land use that may present a constraint to the design of restoration in the planning area. Design of the restoration will need to consider ways to minimize impacts to neighboring vineyards, including increased flooding, access restrictions, and changes to groundwater, particularly increased saltwater intrusion. One area that may require early considerations to avoid impacts is the existing Area 3 vineyards, which are directly adjacent to Area 4, a high-opportunity site for tidal and transition zone restoration on the alluvial fan.

One logistical constraint may be the piecemeal acquisition of properties from willing sellers, which could limit the potential to complete restorations as envisioned in this document. Not all parcels in the planning area will be immediately converted to restored habitat from their present land uses, at least in the early phases. Therefore, project designs will need to carefully consider changes to hydrodynamics and tidal prism to ensure that the levees of those properties remaining in their current uses are not undermined by restoration of neighboring properties. For example, the portion of Tubbs Island that is currently used by the Vallejo Sanitation District for biosolids application is unlikely to be converted from its current land use in the near future, so any changes to tidal prism in Sonoma Creek and Tolay Creek will need to avoid undermining the Tubbs Island levees.

4.8 Regulatory

Several key state and federal regulatory requirements will apply to restoration projects within the planning area. These regulatory requirements will also provide guidance and standards for project planning, implementation, and post-project monitoring. Some of the laws governing these programs include the:

- California Environmental Quality Act,
- National Environmental Policy Act
- Federal Clean Water Act (Sections 401, 402 and 404),
- Federal Rivers and Harbors Act (Section 10),
- Federal and California Endangered Species Acts,
- Magnuson-Stevens Act,
- State Fish and Game Code,
- California Title 23 and United States Code Section 408 for flood protection,
- Porter-Cologne Water Quality Control Act,
- McAteer-Petris Act
- Coastal Zone Management Act (Section 307)
- Williamson Act, and
- National Historic Preservation Act.

Agencies governing these laws include the:

- U.S. Army Corps of Engineers,
- U.S. Fish and Wildlife Service,
- National Oceanic and Atmospheric Administration (NOAA) Fisheries
- California Department of Fish and Wildlife,
- State Water Resources Control Board,
- San Francisco Bay Conservation and Development Commission (BCDC),
- California State Lands Commission
- Sonoma County Board of Supervisors, and
- Native American Heritage Commission.

Jurisdictional seasonal wetlands may exist in the diked baylands, placing a constraint on tidal restoration in these areas. Project design should avoid the possibility of mobilizing mercury-laden sediments, which may have been deposited from the watershed in historical channels. Alternatives that reduce increases in tidal prism through historical channels are less likely to increase mobilization of mercury from sediment.

Some recent regulatory developments may provide a streamlined permitting approach for large tidal wetland restoration projects in San Francisco Bay. The Bay Restoration Regulatory Integration Team (BRRIT) was recently developed to collaboratively process permit applications for multi-benefit wetland restoration projects. The BRRIT consists of six state and federal regulatory agencies and is designed to work closely together, identify challenges that can cause permitting delays between and among regulatory and resource agencies, and to resolve those delays quickly. BCDC's revised San Francisco Bay Plan policies which modify the language for a "minor amount of fill" for habitat restoration projects will also take effect in 2020 (BCDC 2019). Habitat restoration projects will now be allowed to use larger amounts of Bay fill for the “minimum amount necessary for the project purpose” to restore and enhance habitat in light of sea level rise impacts on Bay habitats. BCDC jurisdiction under the McAteer-Petris Act occurs in the southern portion of the Sonoma Creek Baylands along Sonoma Creek to its confluence with Second Napa Slough (BCDC 2008).

4.9 Public Access

During the plan development process, Sonoma Land Trust staff met with San Francisco Bay Trail, San Francisco Bay Area Water Trail, and Sonoma County Regional Park staff to share information about the planning process, review existing and proposed public access facilities and plans, and solicit input on the strategy. Sonoma Land Trust and other project partners also participated in the development of the Grand Bayway SR 37 Public Access Scoping Report. A variety of public access opportunities exist in the planning area.

Within and near to the planning area, the San Francisco Bay Trail has been constructed on levee tops in conjunction with construction of wetlands restoration projects. Bay Trail segments have been constructed at Port Sonoma, on the levee-top at the Sonoma Baylands, and Sears Point (Eliot and Dickson Trails) tidal wetland restoration projects. Trail segments also exist along Tolay Creek, Tubbs Island, and at Hudeman Slough. San Francisco Bay Trail has identified additional segments needed to complete a continuous Bay Trail through and beyond the planning area. These planned segments include Tolay Creek Road / SR 37 to Tubbs Tolay Trailhead (Sears Point Bay Trail Gap Closure) and SR 37 from Sonoma Creek east to Mare Island (See the San Francisco Bay Trail website for more info). In addition to the Bay Trail, public access facilities within the planning area include the boat launch at Hudeman Slough Wetlands and trails at Tolay Lake Regional Park. On CDFW’s Camp 2 property, hunting, fishing, wildlife viewing, boating, environmental and scientific programs, nature observations, photography, and hiking are allowed.

The San Francisco Bay Area Water Trail (Bay Area Water Trail) is a growing network of non-motorized small boat launching and landing sites across the San Francisco Bay Estuary. Within the planning area, Hudeman Slough offers the only formal water access site. Boaters may also access the waterways within the planning area from nearby Bay Area Water Trail launch sites, including Cullinan Ranch and Cuttings Wharf.

Sonoma Land Trust, STRAW (Students and Teachers Restoring a Watershed) and other organizations offer a variety of targeted education and learning opportunities in and around the planning area. Sonoma Land Trust’s Bay Camp is a bilingual summer day camp at Sears Point which serves at least 100 children annually and offers scholarships to 50 percent of the participants to include children who would not otherwise have access to summer camp. Sonoma Land Trust is implementing a field trip program to SPBNWR for 3rd and 4th graders focused on exploring the ecosystem through curriculum that includes conservation and restoration, marshland ecosystems and ecology, and climate change resilience. Additionally, through it’s On the Land Program, Sonoma Land Trust offers guided hikes and outings at Sears Point to hundreds of members and non-members each year. STRAW provides classroom and field programs, aligned with science standards, preparing students to restore streams and wetlands. Teachers attend annual training events and are given resources and technical support to integrate watershed science into their classroom year-round. Ducks Unlimited recently received funding from Cargill to work with Friends of San Pablo Bay National Wildlife Refuge to bring students from Mare Island Technology Academy for environmental education and recreation activities.

Many of the Strategy project partners are engaged with the development of the Grand Bayway SR 37 Public Access Scoping Report, funded by the Bay Area Regional Collaborative with a Caltrans SB1 Climate Adaptation grant. The scoping report considers mobility, public access and environmental education options along the SR 37 corridor. The long-term goal of this project is to locate a future bay trail alignment along the reconstructed elevated SR 37. In the short-term, the project has identified opportunities for recreation, public access and education in the planning area in the Sears Point/Tolay Lake Regional Park/Tubbs Island area, including closing the 4,300-foot gap in the Bay Trail between the end of the Eliot Trail and the Tubbs / Tolay trailhead, assuming approval by Caltrans who owns the right-of-way, and around the Ramal Road/Skaggs Island area. The project has also identified opportunities in Petaluma and Novato, along the Napa River, and on Mare Island in Vallejo.

Public Access Opportunities and Challenges

SLT, Point Blue, USFWS and CDFW have included public access as a part of our conservation activities in the Sonoma Creek baylands to build support for our work, foster a sense of place, improve public health through open space recreation, and contribute to the welfare of our community. Opportunities exist for improving public access and recreation in and around the planning area. For example, current proposals supported by USFWS include adding signage for existing Bay Trail segments, adding a shade structure to the outdoor area next to an existing education center, and expanding programming for underserved youth.

There may also be opportunities to add sites to the San Francisco Bay Area Water Trail, a regional program that encourages the use of non-motorized small boats, such as kayaks and canoes. The San Francisco Bay Area Water Trail Plan ultimately seeks to facilitate a network of launch sites every three to four miles and boat-in overnight opportunities every eight miles. The Bay Area Water Trail network primarily focuses use and seeks enhancements to existing boat launch locations, and encourages appropriate development of new facilities designed to meet regional access needs. Sonoma County Regional Parks plans to improve its boating facilities at Hudeman Slough by renovating the boat launch to accommodate more types of water recreation, adding a permanent restroom, resurfacing the parking area, providing six campsites and a camp host site, and providing an ADA accessible path between campsites, parking lot, restroom and boat launch. Sonoma Creek, Napa Sloughs, and Hudeman Slough retain sufficient water at low tides to allow paddling, making them important routes on the Water Trail in the planning area. Resilient facilities could be designed appropriate to the site context, ranging from more fully developed facilities (i.e., Hudeman Slough) to destination sites only accessible to the public by boat.

The top priority for the Bay Trail in the planning area is closing the 4,300-foot gap between the end of the Eliot Trail and the Tubbs / Tolay Trailhead. This gap is on a Caltrans right-of-way and constructing the Bay Trail there requires Caltrans' approval. Closing this gap would provide nearly nine miles of continuous Bay Trail between Petaluma River and Tubbs / Tolay. Sonoma County Regional Parks is working with Caltrans, Bay Trail, and the SR 37 Project Leadership Team to advance an interim trail alignment as part of the Caltrans State Highway Operation and Protection Program and MTC Interim Congestion Relief projects. Eventually this segment will be incorporated into the ultimate SR 37 project.

Grants for public access are available, including from the San Francisco Bay Trail and the San Francisco Bay Area Water Trail. Over $800,000 in Bay Trail grants have been expended in the planning area over the past two decades, contributing to the design and construction of the Sonoma Baylands and Eliot Trails, as well as a feasibility study on the above-referenced Eliot/Tubbs-Tolay gap closure.

There are, however, significant constraints to implementing public access objectives outlined in the various public access plans. Some public access improvement and facilities are proposed on privately held land, which is generally not available for this purpose, but may be the only feasible location. Obstacles on public land (e.g., CDFW, USFWS) include limited resources available to fund and implement design and construction of access facilities and to provide the ongoing maintenance and law enforcement required to maintain and manage public access facilities. Additional constraints include the risk of future flooding and/or the prohibitive cost of protecting potential public access sites from sea level rise, fluvial flooding events, and tidal inundation of restored areas, and the need to protect wildlife nesting and foraging areas from human disturbance.

Plans for public access in the planning area can be found in several existing documents including the Sonoma County Bicycle and Pedestrian Plan, San Francisco Bay Trail Plan and San Francisco Water Trail Plan. Some of these plans have already been partially implemented and their full implementation is dependent on securing necessary properties and easements, allocation of resources for design and construction, resourcing agencies and organizations to maintain access infrastructure and ensure public safety, and science-based assessment and selection of sites that will be defensible and secure from sea level rise inundation. Moving forward, strategic implementation of public access could be evaluated with the following guiding principles.

1. Options for public access should be considered during every project phase.

2. Before access is included in site design, ensure that resources, including funding and the entity responsible for the design, construction, maintenance, law enforcement and ownership of the access facility, have been identified.

3. Build trails from natural materials that may deteriorate with sea level rise, flooding, and inundation without harm to surrounding habitat.

4. All access should be adaptable to ensure ongoing facility safety and maintenance. Facility safety and maintenance needs may change with anticipated changing landscape conditions.

5. Improve signage at existing access facilities (e.g. Eliot Trail) to increase awareness of existing public access opportunities.

The Future

Public access and recreation in the planning area is and will continue to be limited for a variety of reasons including the remote location of the Sonoma Creek baylands relative to urban centers, transportation and parking constraints along SR 37, potential conflicts between habitat for threatened and endangered species and recreation, and tidal inundation. All access, except for trails and other facilities located in surrounding upland areas or on an elevated causeway built for road and/or rail, should be considered temporary given the anticipated change over time as sea level rise and other ecological changes alter the landscape.

Public access to open space is vital to public health and the wellbeing of our community, and will be provided to the maximum extent feasible and by a variety of means (e.g. on land, on water) that is consistent with the project. Sonoma Land Trust, Point Blue, Ducks Unlimited, and Friends of the San Pablo Bay National Wildlife Refuge will continue to provide targeted public access and education opportunities in concert with our restoration work.

Current and future USFWS-owned parcels will be managed as part of the San Pablo Bay National Wildlife Refuge, pursuant to the National Wildlife Refuge System Administration Act of 1966 and the Refuge Recreation Act of 1962 as well as other laws, executive orders, regulations and policies. The National Wildlife Refuge System Improvement Act of 1997 established six wildlife-oriented public uses that take priority over all others (wildlife observation, wildlife photography, environmental interpretation, environmental education, hunting and fishing). All uses of a national wildlife refuge must be compatible with and not materially interfere with or detract from the fulfillment of the National Wildlife Refuge System mission or the purposes of the national wildlife refuge.

Current and future CDFW owned parcels will be managed in accordance with the Land Management Plan and will include recreation and public use including hunting, fishing, wildlife viewing, boating, environmental, and scientific programs, nature observations, photography, and hiking (URS 2011). Because established trails provide predators easier access to the wildlife, CDFW is striving to protect certain sensitive areas that are not suitable for this type of access.

4.10 Feasibility Considerations by Parcel

Areas 3 and 4

The primary use of Areas 3 and 4 is agriculture, consisting of dryland farmed oat hay, dairy farming, and vineyards. Private residences and a winery are located on the east side of Sonoma Creek. Portions of the property near Sonoma Creek are allowed to flood and are farmed less intensively. These are isolated from Sonoma Creek by low berms of variable height. Millerick Road, located on the east side of Sonoma Creek, is a County-maintained road from SR 12/121 to CDFW property near Camp 2. Area 4 has elevations that could support high marsh and wetland-upland transition zone elevations (about 6.6 feet NAVD) and is part of the former alluvial fan of Fowler and Schell Creeks. Two existing breaches (Big Break and Little Break) on the east side of Sonoma Creek frequently flood Millerick Road south of the winery. This flooding extends into the adjacent agricultural lands of the former alluvial fan. The SMART railroad bisects Area 3 and 4 on a berm which has some poorly functioning culverts and flap gates. During floods, water crosses the Area 3 property from Sonoma Creek at Big Break and enters the Area 4 property by crossing the railroad. Flood water from Schell Creek also crosses SR 121. Flood water currently ponds on Area 4 due to the constraints of the Railroad Slough levee and the railroad berm, logjam at Big Break, and poorly performing flap gates. Because they are the alluvial fans of multiple creeks, ground elevations of Areas 3 and 4 are increasing during floods. Anecdotal evidence suggests that elevations at Area 4 have increased by 22 inches since the 1970s.

Camp 2

Camp 2 is managed as seasonal wetlands for waterbird habitat and is lower than Area 4 by about 1-2 feet NAVD. It is presently protected by levees with flap gates. The condition of Camp 2 levees vary. In general, the levees range in elevation from 13-feet (NAVD 88) on the north to 9-feet on the south. Levee top widths range between 10 feet to less than 4 feet near Steamboat Slough. The levee system has been repeatedly breached in the past. While repair and maintenance efforts have improved some reaches, other portions are in poor condition, un-engineered. The SMART railroad crosses from Camp 2 to Area 4 at Railroad Slough (Railroad Slough Bridge). The crossing is lower than the surrounding levee system and has proven to be a vulnerability. The railroad uses a k-rail to partially block the crossing during flood stages. The SMART railroad then bisects Camp 2 from north to south on a berm. Millerick Road crosses Camp 2 on a low berm, west of the railroad, from Area 3 to Wingo. There are seasonal wetlands with occasional flooding of prolonged duration. Flood water can enter Camp 2 from Sonoma Creek by low spots on the levee, especially at breaks in the levee at the confluence of Railroad Slough and Sonoma Creek, at the Wingo Bridge, and at levee breach locations on the east side of the property. This flood water is ponded by the levees and poorly performing flap gates. Accidental breaches and levee overtopping have occurred in the 2005/2006 winter and in the 2019/2020 winter, resulting in erosion along the railroad embankment, primarily the west side. The Millerick Road berm acts as a dam across the parcel. Relocating the road adjacent to the railroad, and removing the road berm, would simplify the drainage patterns.

Camp 3

Camp 3 is lower in elevation than Camp 2 and Skaggs Island (about 0 feet NAVD), which would be low mudflat or subtidal if tidal. It is presently farmed and protected by well-maintained levees and efficient pumps. This parcel is not normally flooded during storms. Tidal habitats could be restored in Camp 3, although it is low and would require high natural accretion rates or import of sediment to raise to marsh elevations. Historically, the main hydraulic connection was to Third Napa Slough through China Slough. Since Camp 3 will initially have a large tidal prism, breach locations and corresponding erosion will need to be carefully considered. A breach at the confluence of Sonoma Creek and Second Napa Slough would provide a more direct connection with the Bay and more sediment deposition.

Skaggs Island

The general elevation of Skaggs Island is about 1 foot NAVD. Protected by dikes, much of the existing habitat is similar to uplands because excess water is pumped off. Levees vary in degree of condition; some being recently reconstructed, above the 100-year floodplain elevation with flat stable side slopes. Others are in poor condition, un-engineered, below flood plain elevation and with near-vertical slope faces. Many of these levees have already failed or are likely to fail without future maintenance or improvements. There is an extensive sheet pile wall along the northwestern levee. The Haire Ranch project in the northeast corner of the island includes a subsidence reversal element with a seasonal freshwater wetland modeled on the Viansa restoration, which relies on rainfall from Skaggs Island for its water source (Ducks Unlimited 2017). As Skaggs Island is restored, this water source will disappear. There is a low dike separating Haire Ranch from the rest of Skaggs Island; the dike will be lowered if tidal action is restored to the western portion of the island. The VORTAC navigation aid in the southeast corner of the island is requires maintenance by the Federal Aviation Administration (FAA) and must be protected and accessible for the foreseeable future. Skaggs Island is a major opportunity site given that it is already under public ownership and restoration of the site is a priority for USFWS Refuge managers.

Camp 4

Camp 4 is at an elevation of about 0.3 feet NAVD, which would be low mudflat if tidal. It is presently dryland farmed oat hay and protected by levees that vary in condition. This parcel floods from Ringstrom Bay and Steamboat Slough during storm events. East of Camp 4 is Hudeman Slough and higher ground. The adjacent upland areas include vineyards and water storage ponds. The railroad in this area follows the historical marsh edge contour and may require protection from flooding in the future. Tidal habitats could be restored on the western side of Camp 4, adjacent to Third Napa Slough, although it is low and would require high natural accretion rates and/or import of sediment to raise to marsh elevations. Breaches could be made to Third Napa Slough. On the eastern side of the property adjacent to Hudeman Slough and rising ground, more fill could be placed to create an elevation gradient up to high marsh/upland transition. As an alternative, a cutoff levee could be constructed similar to that at Haire Ranch that would allow seasonal wetlands/faux uplands to be managed following breaching of the western half of the parcel.

Camp 1

Camp 1 is divided into two properties by dikes on either side of Bush Slough: Camp 1 West and Camp 1 East. The general elevation is low, about 0-0.7 feet NAVD, which would be low mudflat if tidal. The berm of the SMART railroad is located on the western edge of Camp 1, which reduces hydrologic connectivity with the Tolay Creek watershed and acts as a physical barrier to the wetland-upland transition zone. From 19th-century surveys at the time of diking, it appears that the majority of the area drained through Tolay Creek. This drainage was altered by the cutting of the East Branch which formerly connected Tolay Creek to Sonoma Creek. Following the diking of Camp 1 and Tubbs Island the channels filled in due to the lack of tidal prism.

Tidal habitats could be restored to Camp 1 East, adjacent to Sonoma Creek, although it is low and would require high natural accretion rates and/or import of sediment to raise to marsh elevations. Breaches could be made to Sonoma Creek. If the Bush Slough levees were lowered, the slough could be restored as a tidal channel that connects Camp 1 East and West to either Sonoma Creek or to Tolay Creek. Connecting any parcel to Tolay Creek will require the widening of the Tolay Creek bridge at SR 37 and a consideration of how to protect the SMART railroad berm from flooding.

Detjen and West End

West End is primarily used for habitat and waterfowl hunting. Detjen was historically a duck club, but the club has not been in operation for well over a decade. The Detjen and West End parcels are at relatively high elevation compared to other diked bayland parcels (mean elevation 4.3 feet and 4.6 feet NAVD respectively, about the elevation of the mudflat/low marsh habitat transition). The higher elevation of these parcels means they will be easier to raise to high marsh elevation and to enhance marsh functions because they will require less imported sediment, less cut and fill, and/or less time to accrete naturally than the more subsided parcels. West End levees are in poor condition and since the area has already breached through failed tide gates, the levees no longer serve a function. These parcels already have muted tidal flows, so the change to full tidal restoration is less drastic than in parcels that are currently managed in a dry condition. These sites are also good opportunity areas for restoration because they are already under public ownership and can be restored sooner than parcels that must be acquired in the future. Salt marsh harvest mouse and black rail already inhabit the site, so restoration designs will need to take this into consideration.

Other feasibility considerations for restoration at Detjen and West End may include: (1) flooding of SR 37 by changes to tidal action at West End and Detjen must be prevented; (2) the Solano/Napa County line, which runs horizontally through the middle of both sites; (3) access to the PG&E substation between the two parcels; (4) access to a private inholding in the northeast corner of the Detjen property; and (5) PG&E transmission towers that cross both properties.

4.11 Uncertainties

Some environmental conditions that will impact the restoration have not been thoroughly studied and would be better understood with more investment of time and resources. One example is the sediment supply from the watershed, including the volume of material, type of material, and locations of sedimentation over time. Another example is current and future accretion rates of Bay sediment in different parts of the marsh. This report includes some analysis of tidal prism and tidal circulation changes that will accompany restoration, but the local impacts of these changes are not yet fully understood. Changes to groundwater conditions are also not well-understood now but may be better illuminated with more research. The central question is how groundwater conditions in the watershed might change due to sea level rise, both in the presence and absence of restoration (i.e. does restoration have an impact on future depth and quality of groundwater given the larger impact of sea level rise on the aquifer?). Environmental conditions at the planning area (including some of those listed here, e.g. sea level rise, precipitation-driven sediment supply) are dependent on the rate of global greenhouse gas emissions and global climate change, so uncertainty will always be present in local projections of these factors.

While some opportunities and constraints are well-understood, other considerations have not been defined or are difficult to forecast because they depend on future decisions by neighbors and landowners. Whether or not certain parcels can be included in the restoration plan depends on whether owners are willing to sell, which may change over time. Decisions about sale of parcels may depend on future suitability for agriculture, which is dependent on economic conditions and environmental conditions that will change with the climate (e.g. temperature, precipitation and flooding, saltwater intrusion). Uncertainty about future land use and land availability makes planning challenging, so developing flexible options may be valuable.

Other socio-political and economy-dependent uncertainties include the future use and maintenance of the SMART rail line, the redesign of SR 37, and the maintenance of levees on neighboring parcels. All three will need to adapt to rising sea level over time, with continued maintenance and reinforcement, realignment, redesign, or abandonment. Changes to the two transportation corridors and the levees on neighboring parcels will influence the extent and types of restoration that are possible in the planning area. Decisions about changes to and maintenance of levees, roads, and rail will depend on larger forces, including but not limited to changes in development, land use, and transportation networks and technology in the region at large.

CHAPTER 5

Alternative Strategy Development

Four future alternative strategies are summarized here and described in more detail in the following sections and in **Figures 5.1-5.4**. Appendix 1 provides flood model results for each future alternative strategy described below, as well as a baseline scenario that reflects current physical conditions.

No Restoration - The No Restoration scenario reflects conditions with assumed foreseeable changes in the absence of new large-scale wetland restoration. For this scenario, it was assumed that, due to intentional intervention or levee degradation, Skaggs Island is fully tidal. Levees included in the restoration alternatives (below) to protect private land on the east side of Schell Creek and west side of Sonoma Creek were assumed in place. All other levee locations were expected to be maintained at present conditions as reflected in the 2014 LiDAR. The Sonoma Creek channel downstream of Skaggs Island was assumed to be scoured to accommodate the additional tidal prism from Skaggs.

Alternative 1: Maximum Tidal - This alternative represents a broad scale tidal restoration condition for the project site and assumes that Skaggs Island and Camps 1-4 are fully tidal. Levees along Railroad Slough were removed to allow conveyance from Sonoma Creek into Camp 2 and downstream areas. Additionally, levees along the right bank of Schell Creek north of Camp 2 were removed to allow floodwater to escape this channel earlier than current conditions and reduce water levels in Schell Creek. Levees along Wingo Slough were removed to increase flow exchange from Camp 2 to Camp 3 for fluvial and tidal conditions. The Camps 1-4 and Skaggs Island parcels were assumed to be filled to a mix of habitat elevations from mudflat to low to high tidal marsh. It was assumed that the channel network had adjusted to the additional tidal prism from the restored parcels.

Alternative 2: Avoid Railroad – This alternative represents less tidal restoration and less fill in the restored parcels. The purpose of this alternative was to evaluate a condition that has less impact on existing infrastructure and would require less imported fill to construct. Under this alternative, the Railroad Slough berms are left intact, as is the right (west) levee on Schell Creek upstream of Camp 2. The portion of Camp 2 west of the Railroad is not restored to tidal action while the portion to the east is. Camp 4 is left at current conditions and is not restored to tidal action. It was assumed that the channel network had adjusted to the additional tidal prism from the restored parcels.

Alternative 3: Enhanced Maximum Tidal - This alternative represents a modification of Alternative 1 with the primary conveyance in the system for tidal and fluvial flows routed through Camp 2, Camp 3, and Skaggs Island. The Railroad Slough berms are removed for this alternative. Levee breaches and tidal channels in Camps 1-4 and Skaggs Island allow tidal action in those parcels. This alternative is configured to protect existing marsh habitat in the channel network by focusing flow and tidal prism in newly graded channels rather than scouring the existing channels. It was assumed that the mouth of Sonoma Creek had scoured to accommodate the increase in tidal prism under this alternative. All other channels were assumed to match baseline conditions.

5.1 Alternative 0: No Restoration (Figure 5.1)

Rationale

This alternative provides a reference point for the restoration alternatives, which assumes no future action is taken other than maintaining existing levees as sea level rises (except for Skaggs Island). This is in contrast to Alternatives 1-3, which assume active intervention in the planning area to promote tidal habitat development.

In Alternative 0, it is assumed that the Skaggs Island levees are not maintained and will fail. The Haire Ranch levee is left at its current elevation, meaning Haire Ranch is flooded at high tide. For the remainder of parcels, it is assumed that levees are maintained and kept well above flood elevations.

This alternative assumes minimal changes overall in the planning area (other than the failure of the Skaggs Island levee); therefore, the hydrodynamic model results demonstrate the impacts of future flooding on the current landscape.

Description

A. Areas 3 and 4

Existing levees north and east of Ringstrom Bay on either side of Schell Creek (A1) and along Railroad Slough (A2) would be maintained and raised so the amount of freeboard relative to sea level remains unchanged.

B. Camp 2

Existing levees east and west of the railroad (B1) and west of Sonoma Creek south of Sonoma Skypark (B2) would be maintained and raised so the amount of freeboard relative to sea level remains unchanged.

C. Camp 3

Existing levees along Sonoma Creek (C1) and along Second and Third Napa Sloughs (C2) would be maintained and raised so the amount of freeboard relative to sea level remains unchanged.

D. Skaggs Island

Access would be maintained to the VORTAC navigational site on a berm (D1). At current elevation, a breach of the Skaggs Island dike that restored tidal action to the site would result in mudflat habitat (D2). The dike might breach at the confluence of Napa Slough and Sonoma Creek (D3). The dike between Haire Ranch and Skaggs Island would be abandoned and left at its current elevation of approximately four feet (D4).

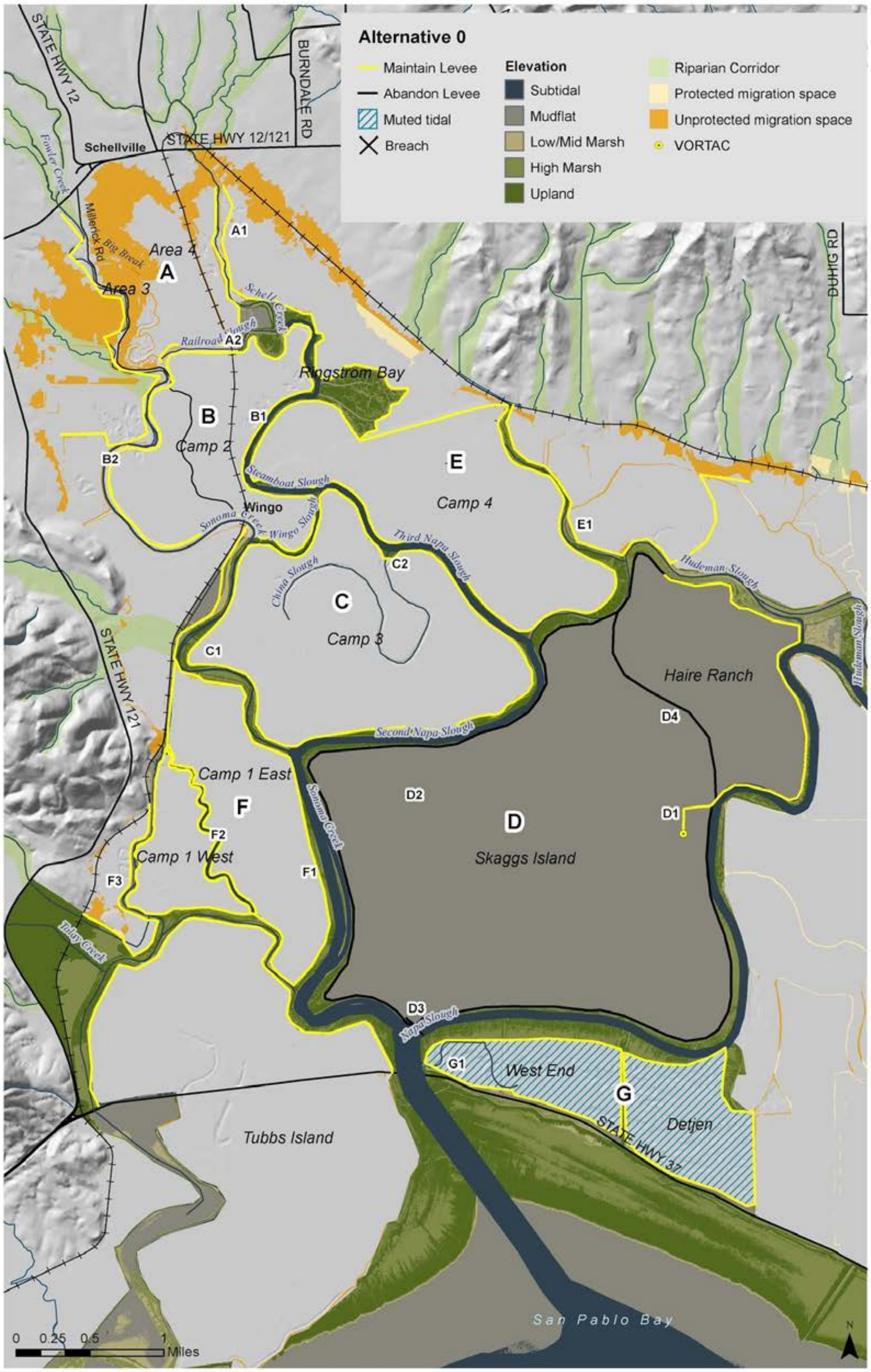

Figure 5.1. Alternative 0: No Restoration.

E. Camp 4

All existing levees, including levees east of Hudeman Slough (E1), would be maintained and raised so the amount of freeboard relative to sea level remains unchanged.

F. Camp 1

Existing levees along Sonoma Creek (F1) and Bush Slough (F2) and west of Camp 1 West (F3) would be maintained and raised so the amount of freeboard relative to sea level remains unchanged.

G. Detjen and West End Duck Club

Existing levees would be maintained and raised so the amount of freeboard relative to sea level remains unchanged. Muted tidal flows would continue to be allowed into both properties (G1).

H. Tubbs Island

It is assumed the Wing and Barrel Hunt Club and the Vallejo Flood and Wastewater District will maintain their existing levees and raise them so the amount of freeboard relative to sea level remains unchanged.

I. Sonoma Creek and Tolay Creek bridges (SR 37)

Both bridges would be kept at their current lengths. Tidal prism would remain unchanged in Tolay Creek and increase in Sonoma Creek due to the breach of the Skaggs Island levee (approximate channel widths shown in Table 5.1). However, the increased tidal prism in Sonoma Creek would not undermine the bridge abutments or the Tubbs Island levee.

Table 5.1 Approximate widths at SR 37 Sonoma and Tolay Creek crossings under current conditions and Alternative 0

	Current channel width (ft)	Current width between levees (ft)	Alternative 0 channel width (ft)
Sonoma Creek	492	1,188	928
Tolay Creek		656 (narrower upstream)	No change

J. Railroad

The railroad would be protected by existing levees, which would be maintained and raised so the amount of freeboard relative to sea level remains unchanged.

5.2 Alternative 1: Maximum Tidal (Figure 5.2)

Rationale

The existing elevation gradient from SR 12/121 at Schellville to the diked baylands could be used to create a transition between tidal habitats and upland habitats. Connecting across the elevation gradient would require the removal of levees along Railroad Slough. In parts of the planning area, existing flooding impacts are exacerbated by the prolonged ponding of water behind levees. These levees are no longer required for the parcels being restored to tidal action and can be breached, removed, or lowered.

In the southern part of the planning area, the diked parcels generally get larger and deeper, so the tidal prism following tidal restoration will open the existing creeks and erode the remaining fringing infill wetlands. To prevent the additional tidal prism from eroding the levees that protect adjacent parcels, tidal prism in excess of the capacity of the eroded tidal channels was routed through the restored parcels. Lower marsh and mudflat elevations are most attainable in deeper diked parcels. In these larger parcels in the southern part of the planning area, more sediment is likely to come from the Bay than from the watershed. However, passive restoration from natural sources may be slow (Appendix 3). It may be necessary to augment with placed sediment from other sources or to cut shallow subtidal areas and place the subsequent fill material to create mid-low marsh. Grading to low-marsh elevation does not guarantee immediate colonization by marsh species, and when colonization does occur it will initially be single-species cordgrass marsh (new tidal wetland). Over time, sediment deposition and colonization by other species tend to create a more diverse mid- to high-marsh habitat that is consistent with restoration goals. However, sea level rise limits the time available for marsh habitat to reach these higher elevations (Appendix 3).

If the existing dikes are breached and lowered, the railroad berm will need to be raised, perhaps armored with rip rap, or levees constructed on either side. The Wingo bridge will need to be raised. Lengthening the Wingo bridge would allow more conveyance of tidal prism upstream. Collocating Millerick Road with the railroad would reduce the infrastructure to be maintained. Physically raising the tracks may be necessary if groundwater flooding is a problem.

Description

A. Areas 3 and 4

Tidal habitat could be restored in the lower half of the Area 4 property on either side of the railroad berm by removing levees along Railroad Slough and Schell Creek (A1), allowing tidal connection to Schell Creek, Steamboat Slough, Sonoma Creek, and Camp 2. Elevations here could reach high marsh and transition zone habitat levels. The existing railroad berm would have to be raised or protected by new levees (A6). The upper half of the Area 4 property would be transitional habitat with seasonal wetlands. During floods, water from the north would continue to flow over the Area 4 property through a defined channel leading from Big Break (A2), avoiding the Area 3 vineyards, but would drain more rapidly to the south to Camp 2 at low tide. This could reduce the duration and depth of flood inundation north of Railroad Slough, allowing more rapid draining of the Schellville area. The Area 3 vineyards may require a levee along the boundary with the Area 4 property (A3). Sediment from Big Break would be expected to deposit in the Area 4 property and into Camp 2. The defined channel from Big Break should be large enough to carry large woody debris into the Area 4 property. The levees north and east of

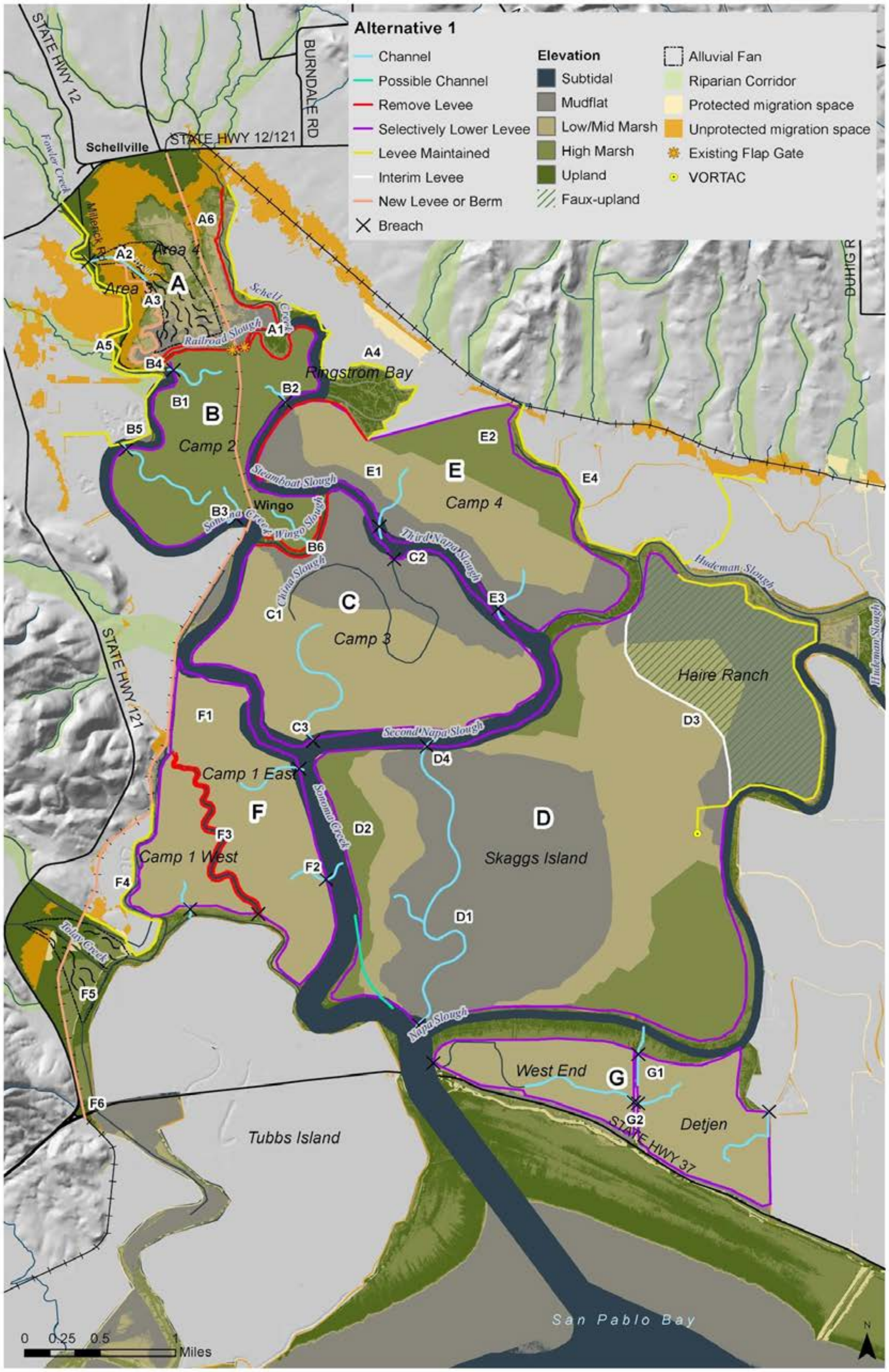

Figure 5.2. Alternative 1: Maximum Tidal.

Ringstrom Bay (A4) and on both sides of Sonoma Creek north of Sonoma Skypark (A5) would need to be maintained.

B. Camp 2 (Wingo Unit)

Tidal habitat could be restored in Camp 2 on either side of the railroad berm by breaching and lowering levees along Sonoma Creek and Steamboat Slough (B2). The levee would be breached at Wingo to drain parcels on either side of the railroad into Sonoma Creek (B3). Areas within Camp 2 could be graded by importing dredged sediment and cutting channels to promote sedimentation from the creeks to accelerate attainment of marsh elevation (B1). The target would be mid-marsh elevation to form contiguous marsh with Ringstrom Bay. During floods, sediment and water would flow south from the Area 4 property and the creeks, extending the alluvial fan south. Sediment would also accrete in Camp 2 as Sonoma Creek and Steamboat Slough are scoured out by increased tidal prism. Elevations are low and will take time to accrete to colonization elevation by natural processes. The import of sediment would accelerate the establishment of marsh.

Millerick Road would terminate at the southern end of Area 3 (B4) and be deconstructed in Camp 2. Existing levees west of Sonoma Creek and south of Sonoma Skypark would be maintained and improved (B5). Levees on both sides of Wingo Slough would be removed (B6).

C. Camp 3

Tidal habitats could be restored in Camp 3, although it is low and would require high natural accretion rates and/or import of sediment to raise to marsh elevations. The target would be low-marsh elevation. Historically, the main hydraulic connection into Camp 3 was to Third Napa Slough through China Slough. In Alternative 1, levees would be breached and lowered at the confluence of Sonoma Creek with Second Napa Slough, and areas within Camp 3 graded to promote sedimentation from the creeks and Bay (C1). In addition, since Camp 3 will initially have a large tidal prism, it may be better to have two breaches: one at the confluence of Sonoma Creek with Second Napa Slough and one at the confluence of China Slough with Third Napa Slough (C2) to distribute erosion across the two creeks. In addition, a breach at the confluence of Sonoma Creek and Second Napa Slough (C3) would provide a more direct connection with the Bay and more sediment deposition. Levees would be selectively lowered all around Camp 3.

D. Skaggs Island

The low elevation and large size of Skaggs Island mean that restoring a tidal marsh will be difficult. Creating subtidal lagoon habitat by grading (D1) may be a more feasible option for the western portion of the island. The cut material could then be placed to the east adjacent to the VORTAC and to the west adjacent to Sonoma Creek to create low-mid marsh and some transition zone areas (D2). Access to the VORTAC would be maintained from the Hudeman Slough bridge southward along the levee on the east side of Skaggs Island. To reduce the erosion of Sonoma Creek by tidal prism from Skaggs Island and the upstream parcels, the subtidal lagoon could be used to convey tidal flows and floodwater through the island from a breach at Second Napa Slough (D4) to a breach at the confluence of Sonoma Creek and Napa Slough. A cutoff channel could be constructed to reduce erosion in the U-shaped bend of Sonoma Creek at the southwest corner of the island. Sediment is expected to come mainly from the Bay. The dike between Haire Ranch and Skaggs Island would need to be raised and maintained as an interim dike until full tidal action could be restored (D3).

E. Camp 4

Tidal habitats could be restored on the western side of Camp 4, adjacent to Third Napa Slough, although it is low and would require high natural accretion rates and/or import of sediment to raise to marsh elevations. The target would be low-marsh elevations. Breaches would be made to connect the western portion of the property to Third Napa Slough (E3) and material placed to create low-mid marsh and some transition zone areas (E1). On the eastern side of the property adjacent to Hudeman Slough, more fill could be placed to create an elevation gradient up to high marsh/transition zone (E2). As an alternative, a cutoff berm could be constructed similar to that at Haire Ranch that would allow seasonal wetlands/faux uplands to be managed following breaching of the western half of the parcel. Existing levees east of Hudeman Slough would need to be maintained and improved (E4).

F. Camp 1 (East and West)

Tidal habitats could be restored at Camp 1 East, adjacent to Sonoma Creek, although it is low and would require high natural accretion rates and/or import of sediment to raise to marsh elevations (F1). Bush Slough levees would be lowered or removed, and the slough restored as a tidal channel to connect Camp 1 West and Camp 1 East to either Sonoma Creek or to Tolay Creek (F3). Levees could be breached to connect Camp 1 East to Sonoma Creek if flows are routed in that direction (F2). Connecting any parcel to Tolay Creek will require the lengthening of the Tolay Creek bridge at SR 37 (F6) and dredging Tolay Creek to SR 37 (F5). Routing Camp 1 flows to Tolay Creek may be preferable if all parcels proposed for restoration in Alternative 1 are restored, as this maximum additional tidal prism to Sonoma Creek would exceed capacity between the levees in the lower reach. This alternative would also require maintaining and improving existing levees west of Camp 1 West (F4).

G. Detjen and West End Duck Club

The Detjen and West End parcels are at higher existing elevation relative to nearby parcels, so they will require less sediment to reach marsh elevation. In Alternative 1, channels connecting the Detjen Property to Napa Slough and South Slough would be widened (G1) and the gates removed. The Detjen property would be connected to West End Duck Club with a box culvert between the two properties (G2). The existing connection of the West End Duck Club to Sonoma Creek would be improved by removing the existing tide gates and leaving as an open breach.

H. Tubbs Island

It is assumed the Wing and Barrel Hunt Club and the Vallejo Flood and Wastewater District will maintain their existing levees and raise them so the amount of freeboard relative to sea level remains unchanged.

I. Sonoma Creek and Tolay Creek bridges (SR 37)

Routing all the tidal prism from the proposed restorations under the Sonoma Creek bridge would result in a channel significantly wider than the width between the levees, which suggest the levees would be eroded, and potentially, the bridge abutments scoured. The tidal prism under the Sonoma Creek bridge could be reduced to fit between the existing levees if the portion of tidal prism from Camp 1 was removed (by routing the Camp 1 tidal prism under the Tolay Creek bridge). While the distance between levees at SR 37 is sufficient to accommodate the Camp 1 tidal prism, the Tolay Creek bridge is not long enough. Further upstream the Tolay Creek levee in the CDFW Tolay Creek Unit North may have to be set back about 250 feet to accommodate the increased tidal prism. Approximate channel widths for both the Camp 1 to Tolay Creek and Camp 1 to Sonoma Creek options are shown in Table 5.2.

Table 5.2. Approximate widths at SR 37 Sonoma and Tolay Creek crossings under current conditions and Alternative 1.

	Current channel width (ft)	Current width between levees (ft)	Alternative 1 channel width of Camp 1 to Tolay Crk (ft)	Alternative 1 channel width of Camp 1 to Sonoma Crk (ft)
Sonoma Creek	492	1,188	1,201	1,358
Tolay Creek		656 (narrower upstream)	696	No change

J. Railroad

The railroad is assumed to be a barrier to restoration and would be raised on a berm or protected by adjacent levees. Wingo Bridge would be lengthened. Railroad Slough Bridge would remain unchanged because the restoration of flows is oriented in the north-south direction, and east-west flows in this slough would not be expected.

5.3 Alternative 2: Avoid Railroad (Figure 5.3)

Rationale

The railroad is a significant impediment to restoration. If tidal action is restored to Camp 2 and Area 4, the railroad would have to be raised on a berm or levees would need to be constructed on either side. This alternative assumes that minimum changes to the railroad are made. Where possible, existing levees are used to protect the railroad. The levees around Area 4 and Camp 2 are maintained and there is no hydraulic connection between Area 4 and Camp 2. The levees on the narrow northern section of Camp 1 East are maintained, and the railroad in the southern main section of the Camp 1 East and Camp 1 West properties is protected by a levee offset to the east.

In Alternative 2, Area 4 and Camp 2 would be seasonal wetlands, perhaps with improved drainage to prevent the prolonged flooding that occurs now. Millerick Road would be left in place. Camp 4 would be maintained as a diked bayland, as it is unlikely to be available for acquisition in the foreseeable future. This would require the future maintenance of the eastern levees from SR 12/121 to Hudeman Slough. Tidal action would be restored to Camp 3 and Skaggs Island. Material would be cut and filled in Camp 3 and Skaggs Island to create more low-mid marsh in these parcels. The Haire Ranch levee would be raised to allow tidal action to be restored to the western side of Skaggs Island.

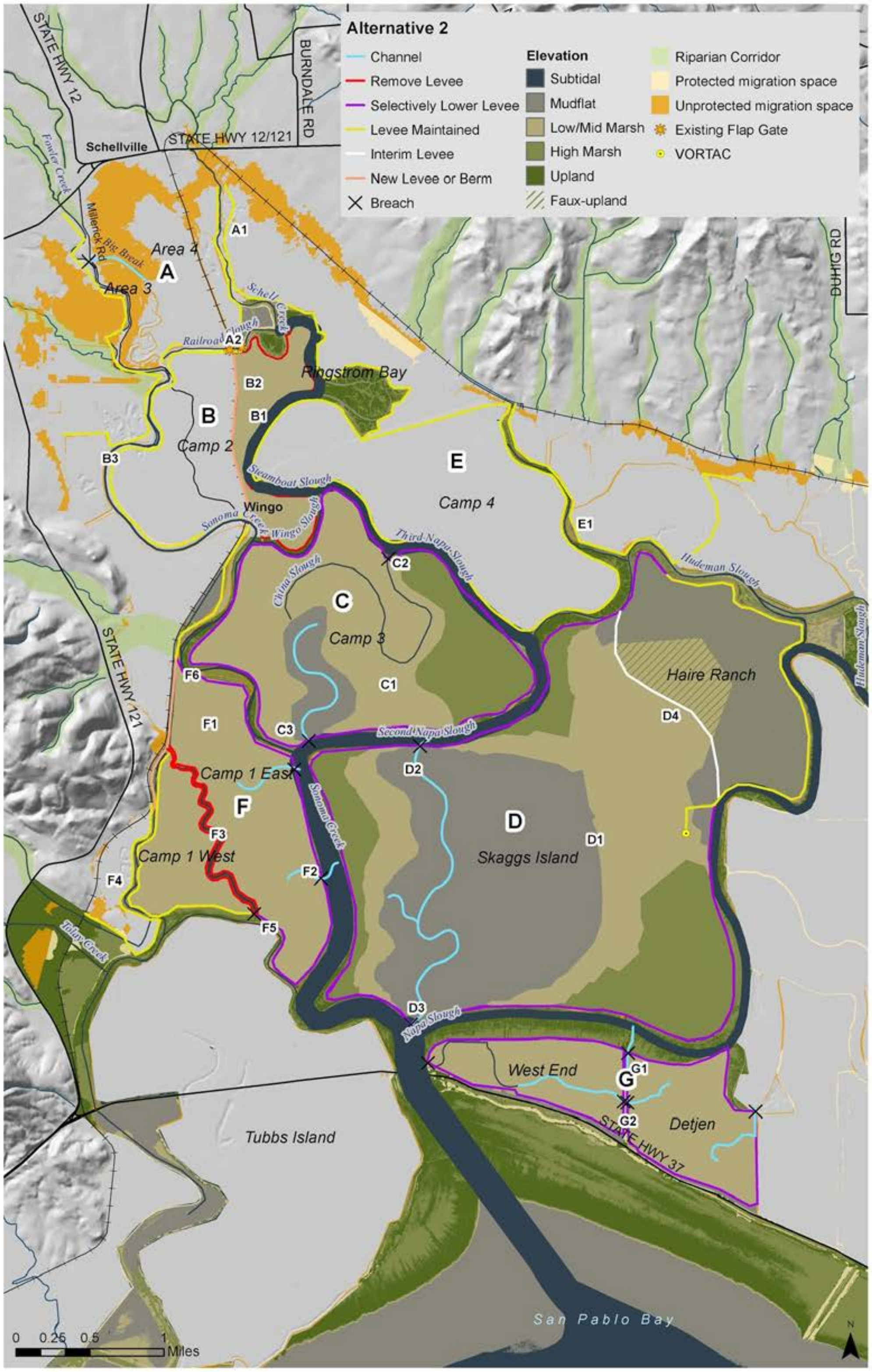

Figure 5.3. Alternative 2: Avoid Railroad.

Actions for Camp 1 East, Camp 1 West, Detjen, and West End would be the same as in Alternative 1. Initial habitat elevations would be graded to low marsh elevations. Tidal prism from Camp 1 West would be routed through East Branch rather than Tolay Creek if Tolay Creek bridge is not lengthened.

Description

A. Area 4

Existing levees surrounding the Area 4 property would be maintained (A1). The function of the existing tide gates to Railroad Slough would be improved to reduce flooding (A2).

B. Camp 2 (Wingo Unit)

Levees would be removed along Steamboat Slough, Wingo Slough, and the eastern half of Railroad Slough (B1). The railroad berm would be protected on the eastern side to allow tidal restoration on the eastern portion of the parcel (B2). Levees along the western half of Railroad Slough and Sonoma Creek would be maintained (B3).

C. *Camp* 3

Levees along Sonoma Creek and Third Napa Slough would be selectively breached and lowered (C2). The levee at the confluence of Sonoma Creek and Second Napa Slough would be breached (C3). The parcel would be graded to promote sedimentation from the creeks and Bay to accelerate attainment of marsh elevation (C1).

D. Skaggs Island

Levees along Sonoma Creek and Second Napa Slough would be selectively breached and lowered (D2). The levee would be breached at the confluence of Sonoma Creek and Napa Slough (D3). The Haire Ranch levee would be maintained in an interim state, without a commitment to long-term maintenance (D4). A subtidal lagoon would be excavated in the middle of the property. Low/mid marsh and upland transitional habitat would be created with onsite fill east of Sonoma Creek. Access to the VORTAC would be maintained from the Hudeman Slough bridge southward along the levee on the east side of Skaggs Island

E. Camp 4

Levees surrounding Camp 4 would be maintained (E1).

F. Camp 1 (East and West)

Material would be placed on the parcels, up to low-mid marsh elevation (F1). Levees would be breached and channels constructed to connect Camp 1 East to Sonoma Creek (F2). The levees along Bush Slough would be removed (F3). The levees west of Camp 1 West would be maintained and improved (F4). The levee at the southern end of Bush Slough would be breached to connect Camp 1 to the East Branch of Tolay Creek; the East Branch would be dredged to Sonoma Creek (F5). A levee would be constructed west of Camp 1 to protect the railroad (F6). No additional flows are routed westward from Camp 1 to Tolay Creek.

G. Detjen and West End Duck Club

Channels connecting the Detjen Property to Napa Slough and South Slough would be widened and the gates removed (G1). The Detjen property would be connected to the West End property with a box culvert under the road (G2). The existing connection of the West End Duck Club to Sonoma Creek would be improved by removing the existing tide gates and leaving as an open breach.

H. Tubbs Island

It is assumed the Wing and Barrel Hunt Club and the Vallejo Flood and Wastewater District will maintain their existing levees and raise them so the amount of freeboard relative to sea level remains unchanged.

I. Sonoma Creek and Tolay Creek bridges (SR 37)

Both bridges would be kept at their current lengths. Tidal prism would remain unchanged in Tolay Creek and would increase in Sonoma Creek due to restoration. Approximate channel widths for current conditions and Alternative 2 are shown in Table 5.3. The grading of the restored parcels can be designed to reduce the increase to tidal prism and corresponding channel widths shown in the table, so as not to undermine the bridge abutments or the Tubbs Island levee.

Table 5.3. Approximate widths at SR 37 Sonoma and Tolay Creek crossings under current conditions and Alternative 2

	Current channel width (ft)	Current width between levees (ft)	Alternative 2 channel width (ft)
Sonoma Creek	492	1,188	1,237
Tolay Creek		656 (narrower upstream)	No change

J. Railroad

While impacts to the railroad are minimized in this alternative, some interventions are required to prevent flooding of the tracks. No changes to Wingo Bridge or Railroad Slough Bridge would be required. In Camp 2, levees would be maintained west of the railroad tracks and lowered east of the tracks. A levee would be built adjacent to the tracks in Camp 2 or the tracks would be raised on a berm. Levees protecting the tracks through Area 4 would be maintained.

5.4 Alternative 3: Enhanced Maximum Tidal (Figure 5.4)

Rationale

The existing condition is large parcels of diked baylands at about MLLW with a lot of potential tidal prism. The only high marsh is the fringing infill wetlands of the historical channels (about 1,300 acres of marsh, approximately the size of Camp 4). The historical channels today are sized to serve the remaining marsh and are now effectively tidal marsh channels rather than tidal sloughs or creeks. Restoring tidal action to the diked baylands using the historical channels would result in the rapid loss of the fringing wetlands (and undesired impacts to existing populations of endangered Ridgway's rail and salt marsh harvest mouse), to be eventually replaced with new marsh of lower elevation and less complexity.

The goals of Alternative 3 are to: (1) reduce erosion of the existing fringing wetlands by routing tidal prism through the center of the diked baylands as much as possible; (2) route flood water from Schellville to the Bay in an efficient manner with reduced depths and durations of ponding; (3) minimize future tidal prism at the Sonoma Creek bridge and Tolay Creek bridge as much as possible; (4) minimize import of sediment and maximize balance of cut and fill; and (5) minimize marsh edge wind wave erosion of marsh edges.

To reduce erosion of the existing marsh as much as possible, both tidal prism and flood water are routed through the diked baylands. New channels would be cut through the diked baylands connecting Sonoma Creek to Skaggs Island, Camp 3, Camp 2 and the Area 4 property. The existing high marsh along the historical channels would serve as nucleus for new marshes. Fill created by cutting channels could be placed adjacent to the existing historical marsh channels to raise the outer edges of the diked baylands to marsh colonization elevation. While marsh vegetation would establish mainly by natural recruitment, some seeding and revegetation would occur to stabilize slopes in the upland transition zone. Some small areas of existing marsh vegetation could also be excavated and transplanted at the correct elevation in the restored tidal marsh to help jump start vegetation colonization.

Since the diked parcels are at about MLLW, opening them to tidal action without grading them first results in the maximum increase in tidal prism (volume between MLLW and MHHW). If they are graded, most channel cuts will be below MLLW and will not increase tidal prism. Any fill placed within the diked parcel will be above MLLW and will reduce tidal prism. The net result of maximizing cut/fill within each diked parcel is to reduce tidal prism and reduce the import of sediment. If the total tidal prism can be reduced by a strategy of cut/fill in individual parcels, widening of Sonoma Creek at SR 37 should also be reduced.

Large areas of low marsh, mudflat and shallow subtidal are likely to be within the restored diked parcels. Wind waves generated within the parcels could erode the adjacent marsh edges, an issue that has been observed during other restoration projects. The fill from the channels could be sidecast to create berms adjacent to the channels to reduce fetch lengths and corresponding wave heights.

Space adjacent to the restored wetland areas is needed for the wetland-upland transition zone and to allow marsh migration as sea level rises. Much of the transition zone is under cultivation as vineyards or is separated by road or rail. Protecting and enhancing transition zones in the Tolay Creek alluvial fan and Sonoma and Schell Creek alluvial fans across the Area 3 and Area 4 parcels allows connections to the Tolay, Sonoma, and Schell Creek watersheds. The alluvial fans of Tolay, Sonoma and Schell Creeks are relatively flat and offer the best opportunities for marsh migration. Away from the alluvial fans, the hillslopes are steep, and the migration zone constrained. In these areas, there may be more opportunities to establish protected riparian corridors along the minor streams that drain the hillsides to the wetlands.

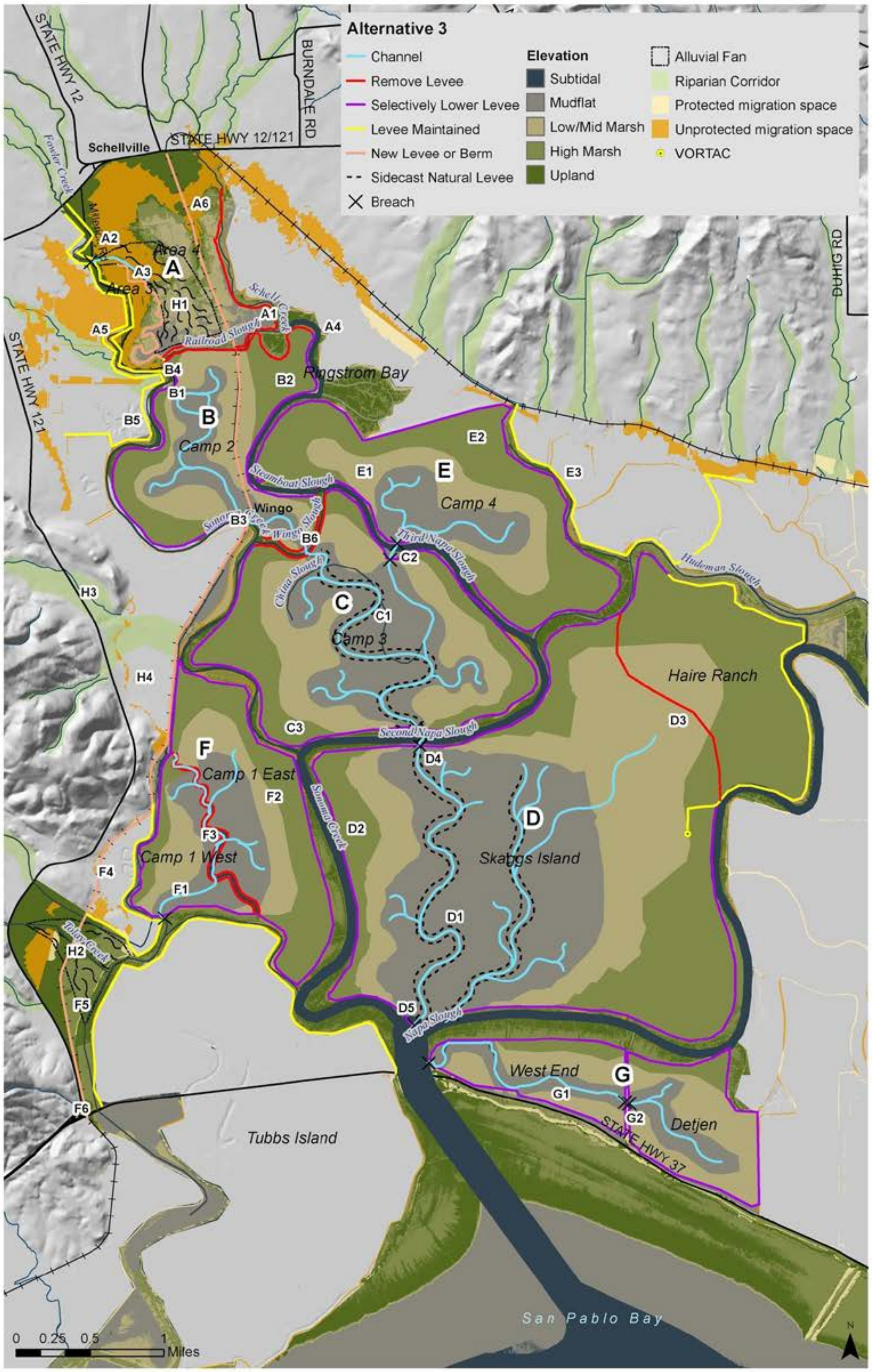

Figure 5.4. Alternative 3: Enhanced Maximum Tidal.

Description

A. Areas 3 and 4

Levees would be removed on both sides of Railroad Slough and on the western bank of Schell Creek (A1). A permanent high-level flood channel would be created for Big Break (A2). A new levee would be constructed along the border between the Area 4 property and the Area 3 vineyards (A3). The existing levees north and east of Ringstrom Bay would be maintained and improved (A4), as would the existing levees on both sides of Sonoma Creek north of Sonoma Skypark (A5). The railroad berm would be protected (A6).

B. Camp 2

Camp 2 would be graded to allow flows from the Area 4 property to Camp 3 (B1). Low berms would be sidecast adjacent to the channel to reduce wave fetch. Fill would be placed to create marsh adjacent to historical channels (B2). A channel connecting Camp 2 to Camp 3 would be routed under the existing Wingo Bridge (B3). Millerick Road would terminate at the southern end of Area 3 and be deconstructed in Camp 2 (B4). The existing levees west of Sonoma Creek and south of Sonoma Skypark would be maintained and improved to protect the Skypark (B5). The levees on both sides of Wingo Slough would be removed to allow the channel connection to Camp 3 (B6). Levees along Sonoma Creek and Steamboat Slough would be selectively lowered.

C. Camp 3

Camp 3 would be graded to create channels from Camp 2 to Skaggs Island and connect Camp 3 to Camp 4 (C1). Low berms would be sidecast adjacent to channels. Levees would be breached on both sides of Third Napa Slough to allow the channel connection to Camp 4 (C2). Fill would be placed to create marsh elevations adjacent to historical channels (C3).

D. Skaggs Island

Skaggs Island would be graded to create a channel from Camp 3 to Sonoma Creek (D1), including a subtidal lagoon in the middle of the property. Low berms would be sidecast adjacent to the channel. Fill would be placed to create marsh around the perimeter of the property adjacent to historical channels (D2). The Haire Ranch levee would be removed to reconnect this area to the rest of Skaggs Island (D3). Levees on both sides of Second Napa Slough would be breached to allow the channel connection to Skaggs Island (D4). The levee would be breached at the confluence of Sonoma Creek and Napa Slough (D5). Access to the VORTAC would be maintained from the Hudeman Slough bridge southward along the levee on the east side of Skaggs Island

E. Camp 4

Camp 4 would be graded to create a channel from Camp 4 to Camp 3 (E1). Fill would be placed on the outer edges of the parcel to create marsh adjacent to historical channels (E2). Existing levees east of Hudeman Slough would be maintained and improved (E3).

F. Camp 1 (East and West)

Camp 1 would be graded to create a channel connecting to Tolay Creek (F1). Fill would be placed to create marsh adjacent to historical channels (F2). Levees along Bush Slough would be removed (F3). The existing levees west of Camp 1 West would be maintained and improved (F4). Tolay Creek would be dredged to the SR 37 bridge (F5). A levee would be constructed to protect the railroad unless the railroad could be raised. The Tolay Creek bridge on SR 37 would be lengthened (F6).

G. Detjen and West End Duck Club

The channel connecting the West End property to Sonoma Creek would be widened (G1) and the Detjen property would be connected to West End with a box culvert under the road (G2). The existing connection of the West End Duck Club to Sonoma Creek would be improved by removing the existing tide gates and leaving as an open breach.

H. Alluvial Fans, Riparian Corridor, Transition Zone

Distributary channels would be allowed to flow over Areas 3 and 4 from Big Break (H1). Distributary channels would also be allowed to flow over the Tolay Creek alluvial fan (H2). Riparian corridors would be established and enhanced along the minor streams that drain the hillsides to the wetlands (H3). Transition zones on the outer edges of Camp 4, Haire Ranch, and Camp 1 would be protected and restored (H4).

I. Tubbs Island

It is assumed the Wing and Barrel Hunt Club and the Vallejo Flood and Wastewater District will maintain their existing levees and raise them so the amount of freeboard relative to sea level remains unchanged.

J. Sonoma Creek and Tolay Creek bridges (SR 37)

Tolay Creek bridge would be lengthened to accommodate increased tidal prism from the restoration of Camp 1. Sonoma Creek Bridge would remain at its current length since the grading of restorations is designed so the increase in tidal prism would not undermine the bridge abutments or the Tubbs Island levee. While the distance between the Tolay Creek levees at SR 37 is sufficient to accommodate the Camp 1 tidal prism, the Tolay Creek bridge is not long enough. Further upstream the Tolay Creek levee in the CDFW Tolay Creek Unit: North may have to be set back about 250 feet to accommodate the extra tidal prism. Approximate channel widths for current conditions and Alternative 3 are shown in Table 5.4.

Table 5.4. Approximate widths at SR 37 Sonoma and Tolay Creek crossings under current conditions and Alternative 3.

	Current channel width (ft)	**Current width between levees (ft)**	**Alt 3 channel width (ft)**
Sonoma Creek	492	1,188	1,201
Tolay Creek		656 (narrower upstream)	696

K. Railroad

The railroad is assumed to be a barrier to restoration and would be raised on a berm or protected by adjacent levees. Wingo Bridge would be lengthened. Railroad Slough Bridge would remain unchanged because the restoration of flows is oriented in the north-south direction, and east-west flows in this slough would not be expected. Culverts under the railroad berm would need to be widened at Tolay Creek to accommodate increased tidal prism.

CHAPTER 6

Alternative Strategies Feasibility Analysis

6.1 Evaluation of Alternatives

The project team performed a high-level review and evaluated each alternative according to how well each alternative would meet the strategy's goals and objectives (Table 6.1), and according to the following feasibility criteria: infrastructure encroachment complexity, implementation complexity, resource protection and restoration, and environmental outcomes (Table 6.2).

The following section provides descriptions of the meanings behind the ratings shown in the goals rating matrix (Table 6.1). For many of the goals, quantitative metrics (e.g. hydrodynamic modeling results) were used to help rate the alternatives. The ratings themselves are qualitative and are meant to give a relative evaluation of the alternatives, not to be interpreted as definitive values. For instance, a rating of "2" does not necessarily mean that alternative will perform twice as well as an alternative with a rating of "1", but rather that it better achieves the stated goal. The weighting factors were assigned based on relative importance and number of similar goals (for instance, reducing flooding was an important overarching goal, but Goals 4-7 were each weighted at 0.5 because they pertained to the same overarching goal).

Goal 1: Prioritizes already acquired lands, then existing acquisition opportunities

Alternatives 1 (Maximum Tidal) and 3 (Enhanced Maximum Tidal) best achieve this goal because they restore 4 out of 4 already-acquired parcels (Camp 2, Skaggs Island/Haire Ranch, Detjen, and West End properties). Alternatives 1 and 3 also take advantage of opportunities that may arise if Areas 3 and 4 and/or Camps 1, 3, and 4 are acquired. **Alternative 2 (Avoid Railroad) mostly achieves this goal**, with 3 out of 4 already-acquired parcels restored (Skaggs Island/Haire Ranch, Detjen, and West End). Alternative 2 also takes advantage of opportunities that may arise if Camps 1 and 3 are acquired. **Alternative 0 (No Restoration) does not achieve this goal** because it does not take advantage of restoration opportunities on already acquired lands nor on properties where acquisition is possible.

Goal 2: Maximizes appropriate habitat restoration

Alternative 3 (Enhanced Maximum Tidal) best achieves this goal because it preserves mature high marsh in fringing infill wetlands along creeks, restores a range of habitat types (shallow subtidal, mudflat, low-mid marsh, and some upland transition areas) in existing diked parcels, and connects to existing upland areas. This alternative provides the best habitat connectivity from shallow subtidal habitat to the upland transition zone. **Alternative 1 (Maximum Tidal) mostly achieves this goal** by restoring mudflat, low-mid marsh, and some upland transition areas in existing diked parcels. However, mature high marsh in fringing infill wetlands along creeks is eroded in Alternative 1. **Alternative 2 (Avoid Railroad) partially achieves this goal** by restoring mudflat and low-mid marsh habitat, though in fewer areas than Alternatives 1 and 3. Fringing infill wetlands in creeks closer to the Bay are eroded in Alternative 2. **Alternative 0 (No Restoration) does not achieve this goal**, with some passive restoration of mudflat habitat in Skaggs Island but no active restoration in the planning area.

Table 6.1. Summary Matrix Evaluating how well each alternative achieves Sonoma Creek Baylands Strategy Goals

GOALS		Weighting Factor	Alternative 0: No Restoration	Alternative 1: Maximum Tidal	Alternative 2: Avoid Railroad	Alternative 3: Enhanced Max. Tidal
G1	Prioritizes already acquired lands, then existing acquisition opportunities	1	0	3	2	3
G2	Maximizes appropriate habitat restoration	1	0	2	1	3
G3	Includes marsh migration zones and watershed connections	1	0	2	1	3
G4	Reduces peak water surface elevation on Sonoma Creek and/or Schell Creek during flood ev ents	0.5	0	3	2	3
G5	Reduces chronic flooding depth	0.5	0	2	1	3
G6	Reduces flooding extent	0.5	0	2	2	3
G7	Reduces chronic flooding duration	0.5	0	2	1	3
G8	Includes opportunities for public access	1	1	3	2	3
G9	Accommodates increased tidal prism at SR 37 crossings	1	2	2	2	2
G10	Minimizes scour to private levees	1	3	1	2	3
G11	Does not worsen salinity intrusion into groundwater in the Sonoma Valley and Sonoma Creek Baylands	2	Unknown	Unknown	Unknown	Unknown
ACHIEVES SCBS GOALS		30	20%	58%	43%	77%

Goal 3: Includes marsh migration zones and watershed connections

Alternative 3 (Enhanced Maximum Tidal) best achieves this goal because it emphasizes restoration of alluvial fan function at Tolay Creek and at Sonoma and Schell Creeks. It is the only alternative that involves restoring tidal action to all of Camp 1 through Tolay Creek. Camp 4 and Haire Ranch are restored, connecting the baylands to upland habitat on the eastern side of the planning area. **Alternative 1 (Maximum Tidal) mostly achieves this goa**l by reconnecting the alluvial fans at Sonoma and Schell Creeks and at Tolay Creek, though the connection at Tolay Creek is minimal relative to Alternative 3. As in Alternative 3, Camp 4 and Haire Ranch are restored, providing a connection to uplands on the east side of the planning area. **Alternative 2 (Avoid Railroad) partially achieves this goal** by reconnecting Haire Ranch, though Camp 4 and Area 4 are not restored, and Camp 1 is restored but with less tidal connection to Tolay Creek as in Alternative 3. **Alternative 0 (No Restoration) does not achieve this goal** because no transition zone habitat nor watershed connections are restored.

Goal 4: Reduces peak water surface elevation during flood events

Alternatives 1 (Maximum Tidal) and 3 (Enhanced Maximum Tidal) best achieve this goal. In Alternative 1, water surface elevation on Sonoma Creek is lowered downstream of Big Break and is similar to existing conditions upstream of Big Break. In Alternative 3, water surface elevation on Sonoma Creek is lowered from the mouth to about 1 mile upstream of SR 121. Alternative 3 reduces peak elevations on Sonoma Creek most of all the alternatives. In Alternative 1, water surface elevation on Schell Creek is lowered downstream of SR 121 and unchanged upstream of SR 121. Similarly, for Alternative 3, water surface elevations are lowered downstream of SR 121 and are slightly lower than existing conditions upstream of SR 121. Alternative 1 reduces peak elevations on Schell Creek most of all the alternatives. **Alternative 2 (Avoid Railroad) partially achieves this goal.** Water surface elevation on Sonoma Creek is lowered downstream of Camp 2, though there is a slight increase between Camp 2 and Big Break, a result of constraining flow on both Schell and Sonoma Creeks without compensating by increasing conveyance across Railroad Slough as in the other alternatives. Upstream of Big Break, peak water surface elevations in Sonoma Creek are similar to existing conditions. In Schell Creek, water surface elevations are reduced downstream of SR 121 but unchanged upstream. Overall, Alternative 2 reduces peak surface elevations on both creeks, but not as much as Alternatives 1 and 3 do. **Alternative 0 (No Restoration) does not achieve this goal.** Water levels on Sonoma Creek are increased from Big Break to midway through Camp 2 under the 2050 1% flood scenario (relative to existing conditions under the same flood scenario). Upstream of Big Break, water levels are consistent with existing conditions. On Schell Creek, water levels are higher than existing conditions from Camp 2 upstream, increasing flood extent and depths upstream of SR 121. In sum, future flooding would worsen under Alternative 0.

Goal 5: Reduces chronic flooding depth

Alternative 3 (Enhanced Maximum Tidal) best achieves this goal with the most widespread flood depth reduction. Under this alternative, flood depth is reduced by 0.1' or more in 400 of 500 flooded acres, and flood depth is reduced in 90% of the flooded area. **Alternative 1 (Maximum Tidal) mostly achieves this goal**, with flood depth reduced in about 40% of the flooded area. Alternative 2 (Avoid Railroad) partially achieves this goal; as in Alternative 1, flood depth is reduced in about 40% of the flooded area, but there are also localized increases in flood depth that may require additional landscape modifications to mitigate. **Alternative 0 (No Restoration) does not achieve this goal**, with increased flood depth relative to existing conditions in about 20% of the flooded area.

Goal 6: Reduces flooding extent

Alternative 3 (Enhanced Maximum Tidal) best achieves this goal, with the peak flooded area upstream of SR 121 reduced by 50 acres relative to current conditions under the 2050 1% flow, elevated tide scenario. **Alternatives 1 (Maximum Tidal) and 2 (Avoid Railroad) mostly achieve this goal** with peak flooded area upstream of SR 121 reduced by about 10 acres in each alternative under the same scenario. In Alternatives 1, 2, and 3, restoration reduces flooding east and west of the restored parcels. **Alternative 0 (No Restoration) does not achieve this goal** because peak flooded area upstream of SR 121 is increased by 9 acres relative to current conditions.

Goal 7: Reduces chronic flooding duration

Alternative 3 (Enhanced Maximum Tidal) best achieves this goal. Peak water level at Railroad Slough in Alternative 3 is about 11', approximately 2' lower than existing conditions, and drains much faster (dropping to about 4' after 33 hours rather than to 10' after 51 hours). The simulation does not continue past this point; however, water levels are known to persist for several weeks in these areas after a flood event under existing conditions. Upstream of SR 121, there is a lower peak water level (0.7' lower) and faster drainage under Alternative 3 than under existing conditions. **Alternative 1 (Maximum Tidal) mostly achieves this goal.** Peak water level in Area 4 at Railroad Slough is substantially lower (2.6' under the 1% elevated tide scenario relative to existing conditions). There is a slightly lower peak than in Alternative 3, but drainage is slightly slower and less complete. Upstream of SR 121, flood duration is similar to existing conditions, with a decrease of 0.2' in peak water level and an average decrease of 0.05' over the 30-hour inundation period. **Alternative 2 (Avoid Railroad) partially achieves this goal.** Under Alternative 2, water levels in Area 4 are increased by 0.6' at peak flow because the railroad constrains overflows from Sonoma Creek. However, Area 4 does drain faster than under existing conditions. Upstream of SR 121, flood duration is similar to existing conditions, with a decrease of 0.2' in peak water level and an average decrease of 0.05' over the 30-hour inundation period. **Alternative 0 (No Restoration) does not achieve this goal.** While flood durations were not modeled for this alternative, flooding is presumably worsened by raising levees without increasing downstream drainage opportunities through restoration as in Alternatives 1-3.

Goal 8: Includes opportunities for public access

The restoration alternatives (Alternatives 1-3) achieve this goal better than Alternative 0 (No Restoration) because they move privately owned land that is not open to the public to public ownership. While creating new trails on restored land will be difficult due to the constraints listed in the Public Access section above, there will be opportunities associated with the restoration alternatives to improve and expand public access in and around the planning area. The restoration alternatives rate more or less equally when it comes to improving access and education opportunities, with Alternative 1 and 3 scoring slightly higher, assuming that more publicly available land would result in more public access. The type of future public access also varies with the future owner. As described in the Public Access section above, USFWS and CDFW have adopted plans that allow for varying levels of access on their properties. It is likely that Sonoma Land Trust and its partners will continue to expand public access and education programs throughout the planning area, no matter which restoration alternative is implemented.

Goal 9: Accommodates increased tidal prism at SR 37 crossings

All alternatives mostly achieve this goal. In each alternative, restorations can be designed to ensure increased tidal prism is accommodated**. Alternative 0 (No Restoration)** has the least restoration and therefore least change to tidal prism at bridge crossings. The channel width at the Sonoma Creek bridge on SR 37 increases from about 490' (150m) under existing conditions to about 928' (283m) under Alternative 0. Under **Alternative 2 (Avoid Railroad)**, channel width at the Sonoma Creek bridge increases to 1,237' (377 m). Under **Alternatives 1 (Maximum Tidal) and 3 (Enhanced Maximum Tidal)**, tidal prism from the restoration of Camp 1 could be routed through Tolay Creek. This would require lengthening the Tolay Creek bridge and, further upstream, setting back a portion of the CDFW Tolay Creek Unit: North levee about 250 feet to accommodate the extra tidal prism, but would reduce tidal prism in Sonoma Creek and may avoid impacts to levees and bridge abutments there. Further investigation is warranted in relation to the bridge abutments and pilings and allowable depth of scour. Alternatively, changes could be made at the Sonoma Creek crossing to accommodate more tidal prism.

For all restoration alternatives, grading of restored parcels can help limit increase in tidal prism. See Chapter 5 for details on channel widths.

Goal 10: Minimizes scour to private levees

Alternatives 0 (No Restoration) and 3 (Enhanced Maximum Tidal) best achieve this goal. In Alternative 0, there is no change to tidal prism in existing channels (except south of Skaggs Island) and therefore no increased impact on private levees. In Alternative 3, scour to private levees along historical channels is avoided by routing tidal prism through the center of the diked parcels. However, there may be some erosion on the back side of levees in Alternative 3, and as in Alternative 0, there is increased tidal prism south of Skaggs Island. **Alternative 2 (Avoid Railroad) mostly achieves this goal**; there is less overall tidal prism because less area is restored. However, there is some scour potential on private levees because the conveyance is through existing historical channels between these levees. **Alternative 1 (Maximum Tidal) partially achieves this goal**; grading is used to reduce tidal prism in restored parcels, but more area is restored than in Alternative 2 and water is routed as much as possible through existing channels between levees, increasing potential for scour.

Goal 11: Does not worsen salinity intrusion into groundwater in the Sonoma Valley and Sonoma Creek Baylands

While this is an extremely important consideration, **at this time it is unknown what the difference between the alternatives may be in terms of impacts on groundwater.** All three restoration alternatives and the no-restoration alternative involve opening currently diked parcel(s) to tidal action, which may impact groundwater conditions. Monitoring of any changes to groundwater conditions (depth to water and salinity) should accompany restoration efforts. Additional discussion of groundwater is included in Section 6.9.

Summary of Goals Evaluation

Alternative 3 (Enhanced Maximum Tidal) received the highest ranking for the most goals, evaluated to "best achieve goal" for nine of the ten goals for which rankings were assigned. **Alternative 1 (Maximum Tidal) received the next highest combined score**; it performs nearly as well as Alternative 3 in reducing flooding and also prioritizes restoration of already-acquired lands. However, it did not score as highly as Alternative 3 for the habitat restoration goals, mostly because of the scour of mature high marsh that would result from routing more tidal prism through existing channels. **Alternative 2 (Avoid Railroad) achieves or partially achieves many of the goals** but is less successful than Alternatives 1 and 3 in reducing flooding and improving habitat because less area is restored in this alternative. **Alternative 0 (No Restoration) predictably does not perform well in the habitat restoration goals nor the flood reduction goals**. Because no restorations are implemented, there is no change to tidal prism, so Alternative 0 does not achieve the goals of minimizing scour to private levees and reducing tidal prism at the Sonoma Creek bridge.

6.2 Availability of Properties

Over the course of preparing this document, prospects of acquiring one or more of these parcels have changed from likely to unlikely and vice versa. Properties in public ownership (Skaggs Island, Haire Ranch, West End, Detjen and Camp 2) are available for restoration based on discussions with USFWS and CDFW. The remaining properties will be evaluated for acquisition and restoration when they become available. Since availability and sequencing are intertwined, ultimate restoration design needs to be flexible to take advantage of opportunities as they become available. Starting with restoration design, permitting and construction on publicly owned properties will provide a strong core to restore the Sonoma Creek baylands, which future actions will build upon. An evaluation of logical restoration sequencing is provided in Section 6.4. Property-specific restoration design will be planned to accommodate the eventual future implementation of the full Strategy; therefore, sequencing of acquisition and restoration will be conducted so as not preclude full implementation of the Strategy and will likely be completed on large independent parcels or on large geographically clustered parcels.

Examples of potential geographical clusters of parcels to be opportunistically implemented beginning with parcels in public ownership:

- Design and implement restoration on Skaggs and Haire, as one unit (Figure 5.4 - C and D)
- Design and implement restoration on West End and Detjen (Figure 5.4 - G)
- Acquire Camp 1 East and Camp 1 West (Figure 5.4 - F); Design and implement restoration for Camp 1 East and Camp 1 West (Figure 5.4 - F)
- Acquire Area 4 (Figure 5.4 - A); Design and implement restoration of Area 4 and Camp 2 (Figure 5.4 - A and B)
- Acquire conservation easements over the transition zone properties and those in the alluvial fans

6.3 Constructability

This section provides an assessment of the constructability of the three action alternatives, which were developed using different configurations of similar design elements. While there will be some variation in construction approach due to the specific settings and constraints of the proposed restoration sites, the means and methods used to construct these elements will generally be the same. The means and methods identified herein have been implemented successfully on numerous tidal restoration projects. All of the alternatives are constructible, although the final design should consider the value provided by specific elements in light of that element's construction cost.

The properties included in this study consist mainly of active and fallow agricultural lands and the restoration actions (design elements) will occur mainly in areas that are accessible to farm equipment. Equipment mobilization for all planning areas will be from land and it is anticipated that standard (non-specialized) construction equipment will be used in all restoration actions, with the exception of the West End and Detjen properties, which are managed wetland systems. The use of specialized amphibious equipment may be required to construct the interior channels on these properties. In general, the work interior to the properties would be seasonally constrained to dry weather when fields are most accessible. Perimeter levee work would be best conducted during periods of sustained moderate tides with no runoff.

Levee Lowering and Removal

Levee lowering consists of decreasing the existing levee height to a specified elevation, often mean higher high water (MHHW). This allows water to overtop the system somewhat frequently, which controls invasive vegetation and provides some containment to the restoration area that promotes sediment accretion. Variations to levee lowering include the complete removal of some levee sections to match the elevation of adjacent ground (sometimes used as a means of terrestrial predator control) or leaving sections at the original height to provide upland refugia habitat for native species. In hard soil areas levee removal may extend below the adjacent ground or the soil may be loosened. The excavated material from levee removal would be repurposed at other locations onsite. In contrast, excavated material from levee lowering is typically used in the immediate vicinity (side cast) to flatten the remaining levee slopes.

Levee removal and lowering is typically performed with excavators, bulldozers, and small dump trucks (if material is to be repurposed at other locations). The equipment operates from the levee top as the restoration area becomes inaccessible once the operation commences. This constraint limits production and may necessitate temporary fills along the levee to accommodate equipment. Levee removal and lowering operations can be lengthy to complete and equipment is typically left and fueled at the worksite. Following is a summary of the levee removal and lowering activities associated with each property in the planning area:

- Areas 3 & 4: The elevations of these properties are the highest in the planning area, generally at or above MHHW. Given these elevations, material generated from the Railroad Slough and Schell Creek levee lowering could be readily incorporated into the protective elements for the railroad or the new levee to protect Area 3. The low-lying portions of these features would need to be constructed with other material prior to initiating the lowering operations.

- Camp 2: The ground elevation of Camp 2 is below mean sea level which makes the reuse of levee removal material within the site difficult. This site is unique in that it is bisected by the railroad embankment. Most likely Camp 2 would be restored in two phases as defined by the railroad and levee material from the “phase 1” side, which could be used to create topography on the “phase 2” side. This would require hauling material across the railroad tracks. Alternatively, removed material could be used to expand the higher elevation parts of transitional areas associated with levee lowering operations. Some reaches of Camp 2 levees have top widths on the order of 4 feet. These levees would require preparatory work to enable equipment access to the area.

- Camp 3, Camp 4, and Skaggs Island: As with Camp 2, these sites are below mean sea level and material generated from levee lowering and removal operations would need to be placed as transitional habitats along the interiors of remaining levee systems. This would require working along the perimeter levee tops which are limited in width to about 12 feet. Some of the Skaggs Island levees are paved and, where this exists, the pavement would need to be demolished prior to levee lowering.

- Camp 1: The Bush Slough levees are internal to the site and could be removed and used to create habitat within Camp 1. Material from perimeter levees would be used to flatten levee slopes as stated previously.

- West End and Detjen: No levee lowering or removal is proposed.

Created Topography

Created topography consists of placing and contouring soil to create ground elevations suitable to support the desired habitat types, creating islands and ridges adjacent to tidal channels for habitat and wave attenuation, constructing tidal channels to convey water within the sites, and constructing levee breaches to connect the sites to adjacent slough systems. Creating habitat by raising broad regions within the individual sites would require a substantial quantity of soil due to their size and low ground elevations. Some potential sources of fill are described below.

- Onsite soil: Fill would be generated within the restoration sites by the excavation of subtidal basins, tidal channels, and levee lowering and removal. Material generated from levee lowering, removal, and breaching would not be a significant source of fill and is best suited for adjacent uses such as flattening levee side slopes. Subtidal basin and large channel excavations could create a large volume of material. To the extent possible, fill sites should be located in reasonable proximity to the excavation site in order to limit hauling distance and manage construction duration and cost. Onsite soil is expected to be suitable as habitat fill: moisture content is not a concern since minimal compaction is desired, undesirable grain sizes or soil lenses could be blended with the predominantly clayey and silty soils, and while deep excavations could produce soils with low pH and/or unbalanced nutrients, these conditions could be remedied by burring, blending, or amending the soil. If contaminated material is encountered at the sites, it would need to be encapsulated, removed, or otherwise remediated (contaminant testing would occur prior to restoration actions).

- Import of upland soil: Soil could be imported from offsite by truck or railroad at a significant effort and cost. Upland soil typically comes from construction sites where excavations are required ("basement digs"); such projects are not common in the region and would not produce a significant or reliable supply of material. The restoration effort could accept material opportunistically but should not rely on such sources.

- Import of dredged soil: The San Francisco Bay Area dredges approximately 3 million cubic yards of material annually, 30 to 40 percent of which is typically used for beneficial use such as wetland restoration projects. However, creating infrastructure to import dredge material would be challenging and extremely expensive. In addition, there are active restoration projects in San Francisco Bay that are already set up to receive dredged material. These projects would be in direct competition with the Lower Sonoma Creek restoration effort. While this source presents several significant challenges, it is the most likely means for importing offsite soil to the area. Hydraulically importing sediment to the planning area would require infrastructure that extended well into San Pablo Bay, similar to that of the Hamilton Wetland Restoration project in the early 2000's. The sites themselves are suitable for placement of dredged material and the PG&E substation as Skaggs Island could be a potential power source. If such infrastructure were in place, it would be reasonable to assume that the project could import ½ million cubic yards of sediment per year on average (Montezuma Wetlands, for comparison, imports anywhere from ½ to 1 ½ million cubic yards annually).

Channels internal to proposed restoration sites would be excavated prior to the reintroduction of tidal water (levee lowering, removal, and breaching). The high groundwater table in the area could necessitate localized dewatering to facilitate the work. Excavating channels with scrapers would be the most efficient means. Excavators and trucks would be used if conditions proved too soft for scrapers. A combination of both methods is likely to occur at most sites. Excavated material would be hauled to the placement area and shaped with bulldozers and/or graders. The appropriate compaction for habitat fill would be achieved with the hauling equipment. The new channels would be aligned to the extent possible with historical/remnant channels to take advantage of natural hydrology and minimize excavation. Channels on larger properties could be lined with side cast ridges created out of the excavated material. These ridges would be quite large and would require a significant quantity of material given the low ground elevation of the properties (up to 6 feet below MHHW).

West End and Detjen are currently managed wetlands connected to tidal sloughs through water control structures. The most efficient means to construct channels in these properties is to drain and dry them prior to the work. However, it is likely that the sites would be too soft for most equipment and channels would be constructed using excavators on crane mats or possibly amphibious equipment. The excavated material would likely be placed near the channels to create habitat topography such as side cast ridges and islands. The construction or expansion of the large interior channels associated with Alternative 3 could be completed with excavators on mats, but the material would be handled multiple times to place it as created topography. Small low ground pressure trucks could potentially operate at these sites, which would expedite the work and reduce construction costs.

Tolay Creek would be dredged as part of the Camp 1 restoration alternatives, with the dredged material used within Camp 1 as created topography. The western reach of Tolay Creek extends from SR 37 to the southwestern edge of Camp 1, approximately 1.75 miles. This reach consists of a broad vegetated high marsh with a small channel less than 5 feet wide. The eastern reach extends from Bush Slough to Sonoma Creek (approximately 0.75 mile in length) and consists of a narrower high marsh with a channel 10-20 feet wide. This channel becomes divided for the last 1,600 feet prior to its confluence with Sonoma Creek. A remnant berm overgrown with brush is in the marsh along the entire eastern reach.

Both reaches are too confined for dredging equipment. The most likely construction scenario would be to utilize low ground pressure equipment consisting of long reach excavators, either amphibious or on mats, and tracked or balloon-tired haul trucks. For the western reach, a temporary haul road would be constructed within the marsh along or adjacent to the alignment of the future channel. Excavators would construct the channel and load the trucks, which would then carry the material to the placement area within Camp 1. Bulldozers would place and shape the fill into created topography. The haul road would quickly deteriorate and require frequent maintenance. It may be more efficient to construct intermittent crossings from the channel to the western edge of the marsh where soils are firmer, making the haul route more reliable. Hauling material along SR 121 should be avoided due to the congestion caused by number of trips (potentially on the order of 10,000, depending on channel size) and the difficulty in keeping public roads clean. Creating the channel on the eastern reach would be more straightforward. The abandoned berm in the marsh could be cleared of brush and used as a temporary haul road. Excavators would be positioned in the marsh between the future channel and berm. Material would be excavated, placed in dump trucks, and transported to Camp 1. Some sections of the berm would need to be widened to provide passing opportunities for trucks (the berm could be removed upon completion of the channel). Both reaches are densely vegetated. While this vegetation provides support to construction equipment, permits typically require the hand removal of pickleweed to minimize the potential for take of salt marsh harvest mouse. Pickleweed is the dominant vegetation in the marsh and hand clearing for this effort would be a monumental task.

Breaches would be constructed with excavators and bulldozers working from the levee top. Fill would be placed adjacent to the breach on the interior of the site. This operation would be sequenced with levee lowering and the elements completed as the equipment backed it way out of the work area. Breaching would normally occur during a low rising tide to minimize the discharge of turbidity.

Levee Construction

Alternatives 1 and 3 propose a new levee along the east side of Area 3 and all alternatives require the construction of levees (or other protection measures) for SR 37 and the railroad to ensure that the current level of flood protection is retained post restoration. These levees could be constructed with onsite material if sufficient quantities could be identified. U.S. Army Corps of Engineers methodologies are required for levee construction; material would need to meet specific geotechnical requirements and the footprint of the proposed levee investigated for permeable layers. These investigations would include soil borings. Local soil conditions and levee configurations will determine the speed at which the levees can be constructed. It is likely that several may need to be built over multiple construction seasons.

Infrastructure

Various elements are present in the planning area that need to be either protected or removed prior to restoration. These are briefly discussed below.

Removed

- Bituminous roads: Skaggs Island contains an extensive system of paved roads within the site and on perimeter levees. The West End and Detjen properties are bisected by the paved Skaggs Island Road. These roads would need to be demolished and hauled to a recycle facility.
- Gravel roads: All areas contain untreated gravel roads which may contain geotextile fabric under the surfacing. Roads within the restoration areas may be abandoned in place, depending on their location and elevation. Some roads might require breaching and conversion into wave breaks or islands.
- Unsurfaced roads: All areas contain unsurfaced dirt roads. These roads may be abandoned in places or ripped to loosen the soils that have been compacted through their use. Typically, these roads are at an elevation where they would become subtidal habitats and buried through sediment accretion.
- Building and barns: Buildings, barns, and other structures are present on actively farmed parcels. These structures will need to be removed prior to restoration.
- Wells and septic systems: Wells and septic systems must be demolished in accordance with County standards. Specific permits would be required.
- Fences, stockpiles, other debris piles.
- Pumps and water control structures: Located on all properties.
- Power poles and lines: Located on all properties.

Protected

- Transmission Towers: Transmission towers cross West End and Detjen properties. The concrete protecting the tower footings may need to be raised to protect the tower bases. PG&E access boardwalks may need to be raised to maintain access.
- Electrical substation: A PG&E substation is located at the north side of the Skaggs Island bridge, in the perimeter marsh south of the Skaggs Island levee. It formerly powered the U.S. Naval communication station but now serves only the VORTAC.

6.4 Sequencing

The sequencing of the restoration actions will be largely driven by the availability of the various properties within the planning area. West End, Detjen, Skaggs Island, Haire Ranch and Camp 2 are in public ownership. These properties are situated where they could be tidally restored without further property acquisition and implemented in a manner that would allow future connection to adjacent parcels when or if these parcels became available. Restoration of Camp 2 as an initial step would require further analysis. Accidental levee breaches temporarily converted the property to a tidal system in 2018 with no identified impacts to the region’s tidal sloughs. One caveat for West End and Detjen - while both are in public ownership and seem low-hanging fruit for enhancement, they are the only properties directly adjacent to SR 37. Cost of improvements to SR 37 to maintain existing levels of flood protection following enhancement should be evaluated against the anticipated timeline for SR 37 improvements. Skaggs Island, Haire Ranch and Camp 2 could be restored independently.

The restoration of any given property should be implemented in a manner that does not limit options for future connection with the remainder of the planning area. For instance, the restoration of Skaggs Island and Haire Ranch as an initial step should be implemented such that the conveyance of the tidal prism could be extended into either Camp 3 or Camp 4 (for alternatives 1 and 3). In this way the regional restoration effort could continue without causing undue scour along privately held parcels or of the fringing marshes of the historical channels, in the event that a particular property (either Camp 3 or Camp 4 in this case) was not available.

The planning area could be broken into the following subregions under this larger conceptual framework: Tolay Creek and Camp 1; Areas 3 & 4 and Camp 2; West End and Detjen; and Skaggs Island, Haire Ranch, Camp 3 and Camp 4. Restoration within each of these subregions is largely independent from the others. For instance, actions could be taken to improve the hydraulic connectivity of Tolay Creek from SR 37 through Camp 1 without significantly altering the conditions within the rest of the planning area. Similarly, steps could be taken in the northern portions of the planning area in an effort to alleviate the flooding that currently occurs near State SR 12/121. Areas 3 & 4 and Camp 2 could be restored as in Alternatives 1 and 3, which would improve the conveyance of flood water from Sonoma Creek through Railroad Slough to Steamboat Slough. West End and Detjen, and Skaggs Island and Haire Ranch could be restored without affecting other properties. Restoration of these subregions could occur in parallel or in series. Other planned restoration elements have no impact on water conveyances within the planning area and could occur at any time. These include restoration efforts at the alluvial fans, riparian corridors, and transition zones located at the small creeks and drainages within the planning area's watershed.

Restoration of the properties within the planning area will increase the tidal prism within the lower Sonoma Creek region; therefore, the logical sequence for restoration actions is from the bay northward. Following this approach, new tidal channels and baylands designed to accommodate the increased tidal flow would be created in step with the region's exposure to that flow. This would minimize erosion of the existing perimeter marsh and facilitate deposition of suspended sediments from the bay. Such a sequence could consist of restoring Skaggs Island, then Camp 3 and/or Camp 4, then Camp 2, and finally Areas 3 and 4. This would restore the region without creating hydraulic constrictions within the existing sloughs.

6.5 Implications for Public Access

Implementation of Alternatives 1, 2, or 3 would almost certainly increase opportunities for public access to the Sonoma Creek baylands since these parcels are currently in private ownership and public access is limited to the overlook at Viansa Winery and the Caltrans access at SR 37/Sonoma Creek bridge. Access opportunities would be evaluated based on the guiding principles laid out in Chapter 4, consistent with the landowners' access goals and mission. The primary mission in the Sonoma Creek baylands is conservation and restoration of fish and wildlife habitat. Public access will be provided to the maximum extent feasible and with a variety of options (e.g. on land, on water) that are consistent with the project and in a way that accounts for sea level rise.

6.6 Infrastructure Considerations

The Strategy seeks to work with natural processes and the existing landscape to restore a range of subtidal, intertidal, and upland-connected habitats. Where possible, SR 37 and SMART railroad design should accommodate reconnection of baylands and tributaries allowing the passage of water, sediment, and species. The Strategy is primarily concerned with Sonoma Creek, Tolay Creek, and the baylands surrounding them. The Sonoma Creek watershed is approximately 140 square miles and all tributaries drain to San Pablo Bay and the baylands. Sonoma Creek and Tolay Creek are important sources of sediment supply for the San Pablo baylands. Reconnection of tributaries and their alluvial deposition to the landward side of our restored baylands is imperative to increase the capacity of the marshes to keep pace with sea level rise.

Equally important for water, sediment, and species is the connection of the baylands to the Bay, primarily at the Sonoma Creek and Tolay Creek bridge crossings. The mudflats of San Pablo Bay are important estuarine sediment sources that are re-suspended by waves and nourish subsided baylands, helping accelerate restoration, particularly for parcels in the southern half of the planning area such as Skaggs Island.

Both SR 37 and SMART Railroad are major elements of infrastructure that bisect the Sonoma Creek baylands east-west and north-south, respectively. The railroad then curves eastward to bisect vital transition and upland areas. While this transportation infrastructure must be protected, it is in a landscape of high habitat value and even greater restoration potential. Both of these factors led non-profit conservation organizations, landowners, and the California State Coastal Conservancy to form a collaborative working group to provide restoration and sea level rise adaptation recommendations for the SR 37 corridor to the Metropolitan Transportation Commission that will integrate restoration planning with transportation infrastructure planning to achieve both restoration and transportation objectives while increasing resilience of the marshes and the infrastructure. Resilience planning for this infrastructure creates a tremendous opportunity to reimagine how this infrastructure should be located and how it should integrate with the surrounding critically important baylands.

SR 37: Implications of and recommendations for State Route 37, Sonoma Creek Bridge, Tolay Creek Bridge

The original toll road, which later became SR 37, was opened in 1928, and much of its alignment took advantage of the higher ground created by waves building up a berm at the edge of San Pablo Bay. The road was and remains a substantial impediment to the movement of nutrients, sediment, and wildlife. The pressing need for both short-term and intermediate term improvements to SR 37 also creates opportunities to integrate transportation and conservation goals into a more resilient outcome for both transportation and conservation. The timing and preferred alternatives that emerge from these planning processes have tremendous implications for the entire San Pablo baylands, including the Strategy planning area.

SR 37 poses three distinct challenges for implementation of the Strategy: Tolay Creek Bridge, Sonoma Creek Bridge, and direct frontage of SR 37 with the Strategy planning area. Caltrans is in the process of evaluating both interim and long-term improvements to SR 37. Because of the ecological values of this area, the conservation-focused State Route 37-Baylands Group has collaborated with planners at Metropolitan Transportation Commission, Caltrans, and the four County Congestion Management Agencies to develop infrastructure alternatives that minimize impacts to resources, accommodate planned restoration activities, and achieve these dual goals.

The State Route 37-Baylands Group is composed of North Bay wetland land managers, ecological restoration practitioners, and other stakeholders interested in the conservation and restoration of the San Pablo Baylands. The Group was formed in June 2017 in response to accelerated action by the SR 37 Policy Committee following the flooding and subsequent closure of SR 37. The State Route 37-Baylands Group developed mutually agreed upon guiding principles as a foundation for engagement with transportation planners. The guiding principles are to integrate improvements to SR 37 with habitat goals, to improve ecological connectivity when reconstructing SR 37, to incorporate landscape-appropriate design solutions that consider historical ecology and sea level rise, to use most recent OPC or more current sea level rise projections, to protect wetland resources and leave options open for future restoration, to minimize financial impacts to low-income commuters, and to include multi-modal transportation options and recreational opportunities. These recommendations are consistent with the Baylands Ecosystem Habitat Goals Science Update (2015) to elevate SR 37 "to allow the full passage of sediment, water, and wildlife." The State Route 37-Baylands Group will continue to advocate for incorporation of conservation goals into infrastructure improvements in accordance with these guiding principles.

Tolay Creek Bridge

Caltrans is actively planning an interim project to widen the Tolay Creek Bridge. To integrate the interim SR 37 improvements to Tolay Creek Bridge with the Strategy, the Tolay Creek Bridge must be lengthened and elevated sufficiently to accommodate the increased tidal prism that would result from the identified restoration opportunities herein. Alternatives 1 and 2 have Camp 1 West draining to Tolay Creek. Alternative 3 has both Camp 1 East and Camp 1 West draining to Tolay Creek. To achieve these dual goals, both the interim and long-term SR 37 projects should be planned to accommodate the increased tidal prism at Tolay Creek Bridge that will result from Alternative 3.

Sonoma Creek Bridge

Sonoma Creek Bridge spans the mouth of Sonoma Creek along SR 37 (**Figure 6.1**) and is owned and operated by Caltrans. The structure is a concrete deck supported on concrete piles and spans 1,865 feet. Wooden fenders demarcate the deepest portion of the channel to aid in navigation for vessels. The bridge was built in 1969 and widened in 2002. Because Sonoma Creek drains the majority of the tidal sloughs connecting the lower Sonoma Creek Baylands, restoring tidal action could directly impact this structure.

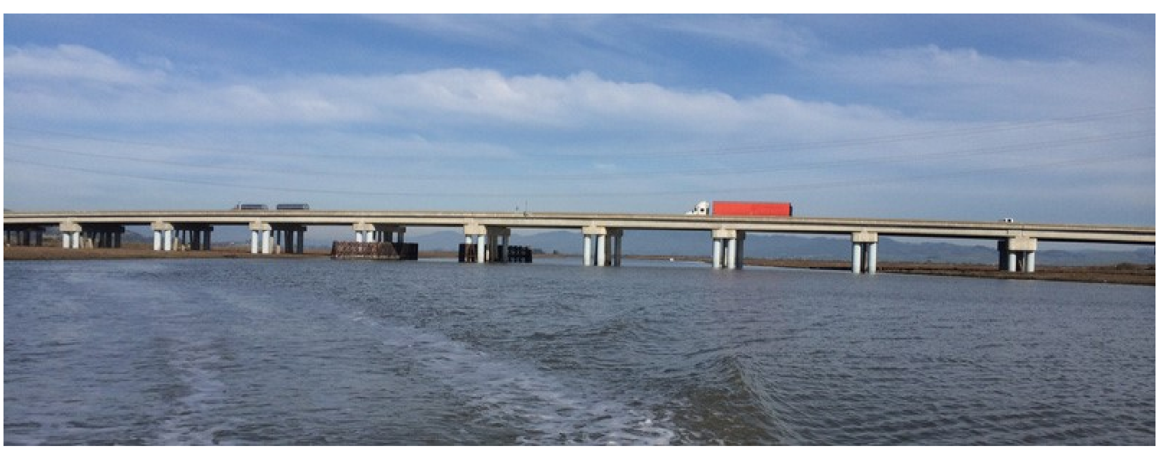

Figure 6.1. Sonoma Creek Bridge

Implementation of the no-action alternative (where Skaggs Island breaches on its own) or any of Alternatives 1, 2, or 3 would increase tidal prism at the Sonoma Creek Bridge. Options to be explored include sizing and location of levee breaches, and grading and import of fill material to decrease tidal prism. If all subsided parcels in Alternative 1 are restored to tidal action and all tidal prism is routed through Sonoma Creek, Sonoma Creek Bridge would need to be lengthened and the levees along West End and/or Tubbs Island set back. However, if tidal prism from the restoration of Camp 1 is instead routed through Tolay Creek, as in Alternative 3, these changes may not be needed. Grading of restored parcels and import of sediment can also decrease the amount of tidal prism in Sonoma Creek. A design for SR 37 that would accommodate tidal restoration would also be compatible with interim management strategies to halt and reverse subsidence and to achieve interim habitat values for waterfowl and shorebirds. A more detailed analysis will be required along with close coordination with Caltrans to investigate the scour potential of the concrete piles to protect the structural integrity of the bridge from increased tidal exchange. If Sonoma Creek Bridge is not lengthened, then it should be evaluated for serviceability under future conditions.

Existing Embankments

Three main properties have direct frontage on embankment within the planning area: Tubbs Island, West End, and Detjen. Vallejo Flood and Wastewater District (VFWD) has verified plans to use Tubbs Island for the foreseeable future for biosolid placement on the north and south sides of SR 37 between Tolay Creek and Sonoma Creek. It is also likely that as sea level rise rates accelerate, continued operation of biosolid placement in the baylands will become more challenging as unengineered earthen berms require maintenance and improvements.

The West End and Detjen properties are directly adjacent to SR 37 and collectively have nearly 2.5 miles of frontage along SR 37. The action alternatives propose the tidal restoration of the West End and Detjen properties (currently muted tidal and managed wetlands, respectively). Both properties are isolated from the adjacent tidal sloughs (Sonoma Creek and Napa Slough) by a perimeter levee that has an elevation of approximately 12 feet (NAVD88) at West End and between 6 and 11 feet at Detjen. Breaching these levees would allow the full tidal range to enter the properties and would potentially expose approximately 2.5 miles of SR 37 to flood conditions that could reach a still water elevation of 10.5 feet (under the modeled scenario of 1% Sonoma Creek flow combined with high tide and 2050 sea level rise). The elevation of the SR 37 embankment varies between 3 and 8 feet at the Detjen property and generally between 5 and 8 feet at the West End property (elevation of the embankment increases to 13 feet near the approach to the Sonoma Creek Bridge). The cross slope of the traveled way (which controls the direction of runoff) varies continuously along this stretch of highway, ranging from sloping entirely to the south, being crowned in the center (sloping both north and south), and sloping entirely to the north. The Detjen and West End properties are separated from the highway embankment by an isolated ditch with a width that varies between 12 and 70 feet. The ditch terminates at the east side of the SR 37 public access area (the overlook at West End). Both properties are isolated from the ditch by a small berm, ranging in elevation between 3 to 4 feet at Detjen and 4 to 6 feet at West End.

Ideally locations where SR 37 traverses historical baylands should be elevated on a causeway from existing high ground on the toes of Cougar Mountain near the SR 121 interchange extending east through the planning area. SR 37 road base and topping should be removed but the existing earthen berm beneath the road base should be left in place and selectively lowered to marsh plain elevation to recreate the historical wave-built berm at the north edge of San Pablo Bay and restore hydrologic and ecologic connectivity. Restoring these deeply subsided lands will increase tidal prism at Sonoma Creek.

The project would need to provide the same level of flood protection that is currently afforded by the West End and Detjen properties. Flood protection options for SR 37 include raising the highway embankment, elevating the roadway on a pile-supported causeway, constructing a levee against the northern shoulder of the highway, or improving the existing berms on the southern edge of Tubbs Island, West End and Detjen properties. Elevating the roadway 15 feet above its current elevation to accommodate sea level rise and storm surge on a combination of pile-supported causeway and embankment is the ultimate goal of transportation planners. However, this "ultimate project" may not be completed until 2050, and baylands habitat restoration projects need to be completed or at least underway by 2030. If the timeline of the ultimate project could be accelerated, the transportation and restoration elements could become more integrated, resulting in better outcomes and time and cost savings for both.

As an interim (rather than “ultimate”) project, raising the roadway is impractical due to the degree of raising required and the disruption to traffic. Constructing a levee against the highway embankment would require filling the adjacent ditch, which represents a substantial quantity of fill and would put a heavy geotechnical load on the existing highway embankment. In addition, the varying cross slope creates drainage issues which could be difficult to resolve. The most practical approach would be to improve the berms on the south side of the northern part of Tubbs Island, West End and Detjen properties. The advantages of this option are that the highway embankment would not be subjected to additional geotechnical loads, the highway drainage concerns are avoided, and the improvements would be located largely outside of the Caltrans right-of-way. Disadvantages are that the stagnant ditch would remain as is and the levee improvements would encroach into the restored wetlands. A tide gate would be needed to drain the ditch but would only function at low tide. However, the berm improvements could be configured such that they provide habitat transition areas (**Figure 6.2**), or the berm improvements could be built with steeper side slopes to provide an interim solution while the longer term road raising project is completed.

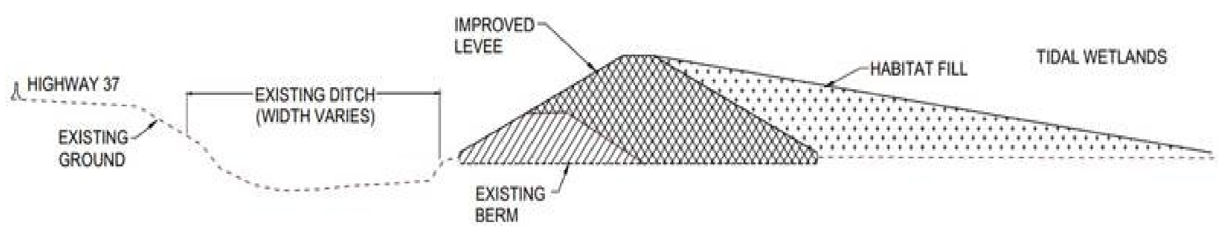

Figure 6.2. Schematic showing the concept of improving existing berms north of the SR 37 embankment.

Railroad: Recommendations for Railroad

All action alternatives require the protection of the railroad from tidal waters to some extent to maintain the level of flood protection that currently exists within the region. The legal obligation of landowners to protect the railroad from flooding on their properties was not investigated in the present study and will require further examination. Potential protection measures include relocating the railroad outside of tidally-influenced areas, raising the railroad embankment above tidal/flood waters, raising the railroad on a pile-supported causeway (potentially collocated with the SR 37 causeway), and isolating the existing embankment from tidal/flood waters.

- Relocating the railroad is not considered under this study.
- Raising the railroad would be an enormous undertaking given the need to maintain railroad gradients at a maximum of about 100:1. Under Alternatives 1 and 3 the railroad would be raised from near SR 37 to SR 121, a length of approximately 7 miles, and would include the Wingo and Railroad Slough bridges. Raising the railroad would require the construction of a temporary bypass track to allow the railroad to operate during construction. Raising the embankment would require removal of the rail and ties, widening of the existing embankment, import of ballast rock, reinstallation of the rail line, and deconstruction of the temporary track. The raised embankment would need to be protected from wave erosion, possibly by rip rap or habitat fill (horizontal levee).
- Isolating the railroad would require the construction of a levee on one or both sides of the existing railroad embankment, depending on the footprint of the restoration. The new levee system would expand the footprint of the railroad corridor through the planning area. It may be possible to construct levees against the railroad embankment, but this approach would need to be evaluated for settlement and stability. Site conditions may dictate that levees be offset from the existing embankment. As with the raising of the embankment, the levees would need to be protected from erosion. In addition, a means to remove precipitation and groundwater that is contained within the levees is required. This approach would not protect the railroad from flood that occurred at the Wingo or Railroad Slough bridges. These areas could be protected by installing flood gates across the railroad tracks, similar to those being installed in South San Francisco Bay at Alviso, that could be closed during high water events.

The 2018 California State Rail Plan drafted by Caltrans includes a proposed extension of passenger rail service, known as the Novato-Solano Hub, which would add passenger service from Novato as a goal for 2040. The rail service is proposed to run on the existing rail line which parallels the western portion of SR 37, then north along SR 121 to Schellville, where it turns east over the Napa River, then south to Vallejo. The State Rail Plan calls for evaluating expansion of service to Solano County, considering rail service primarily on existing rail alignments, with potential connections near Vallejo or at Fairfield-Suisun. The location and configuration of this rail line relative to the planning area provide an opportunity to consider how to integrate resilience planning for the rail line with conservation goals and objectives of the Strategy. The existing rail line is low-lying relative to existing mean sea level, and much of its length is protected by unengineered earthen berms that are maintained by individual property owners. As described in Chapter 2 (Existing Conditions), the rail line rests on an earthen embankment which bisects the western and northern edges of the lower Sonoma Creek Baylands. The rail line poses three distinct challenges for implementation of the Strategy: the Railroad Slough Bridge, the Wingo Slough Bridge, and the alignment running west of Camps 1 and 3 and through the middle of Camps 2 and 4. The rail line is singular in minimizing grade changes.

Railroad Slough Bridge: Railroad Slough levee and the railroad berm currently constrain floodwater. Restoring tidal action is expected to have minimal impact on this structure because Railroad Slough is oriented east-west, and the restoration of flows is oriented north-south. Alternatives 1 and 3 propose removal of levees along Railroad Slough to allow conveyance from Sonoma Creek to Camp 2 and points downstream. Alternative 2 proposes that most of these levees remain intact with restoration west of the rail line only, and levee removal occurring at Camp 2 East only. A more detailed analysis will be required along with close coordination with the North Coast Rail Authority.

Wingo Slough Bridge: Alternatives 1 and 3 include removal of levees along both sides of Wingo Slough. Alternative 2 includes removal of the levees only along the Camp 2 East section of Wingo Slough. A more detailed analysis will be required along with close coordination with the North Coast Rail Authority.

Alignment west of Camps 1 and 3 and through Camps 2 and 4: This alignment is primarily within the historical bay margin and in diked baylands. Railroad easements over the diked bayland properties that require property owners to maintain levees and protect the railroad infrastructure (levees, tracks, etc.) from flooding transfers the burden of flood prevention to property owners. This infrastructure is currently low-lying relative to surrounding marsh elevations. As sea level rises, this burden will become increasingly costly and challenging. Protecting this rail line provides an opportunity to reimagine it with a view to resilience, to achieve both transportation and conservation goals. The guiding principles for a resilient rail line match those for SR 37: to improve ecological connectivity, to incorporate landscape-appropriate design solutions that consider historical ecology and sea level rise, to use most recent OPC or more current sea level rise projections, to protect wetland resources and leave options open for future restoration, to minimize financial impacts to low-income commuters, to include multi-modal transportation options and recreational opportunities. Co-locating the rail line south of SR 37 on a causeway would reduce the length of track requiring improvements and maintenance, and would achieve infrastructure, resilience, and conservation goals. Alternatively, raising the rail line on a causeway would also achieve these three goals, although a longer length of track would be required.

Summary Recommendations for the redesign of SR 37 and SMART to ensure hydrologic and habitat connectivity

A fully integrated design for transportation infrastructure to maximize hydrologic and habitat connectivity in the Sonoma Creek baylands would:

- Collocate SMART with SR 37 on a piled causeway on the SR 37 alignment to reduce length of track and minimize ecological disruption with sufficient bridge lengths at Sonoma Creek and Tolay Creek to accommodate increased tidal prism associated with the Strategy.
- Alternatively, raise both SMART and SR 37 on piled causeways above their existing alignments, with sufficient bridge lengths at Sonoma Creek and Tolay Creek (for SR 37) and Wingo and Railroad Slough bridges (for SMART).

A partially integrated design to benefit hydrologic and habitat connectivity would:

- Lengthen bridges to accommodate increased tidal prism associated with restoration (includes SMART bridges at Wingo and Railroad Slough and SR 37 bridges at Tolay Creek and Sonoma Creek).
- Raise SR 37 and SMART to accommodate sea level rise with costs of infrastructure improvements borne by the respective infrastructure owners, rather than as part of the cost of implementing the Strategy.

A status quo design that would continue to disrupt hydrologic and habitat connectivity would:

- Raise the existing earthen embankments for SR 37 and SMART and armor the embankments to protect against erosion.

Discussion of range of outcomes if land stays in private ownership

The Sonoma Creek baylands are subsided several feet and are protected by levees in varied conditions. If land stays in private ownership, individual landowners would be likely to maintain the existing levees in the near term. Compared to other properties, the levees at Camp 3 in the best condition. The other parcels have levees ranging from fair to near failing, and several have accidentally breached in the past, sometimes on multiple occasions and in multiple locations. Unplanned levee breaches will become increasingly common because of the cost and regulatory complexity of private levee maintenance, existing poor condition of many of the levees, the added elevation needed to keep pace with sea level rise, and the scarcity of suitable levee material as it becomes less available and more costly to import or place by clamshell. These levee breaches will put additional stress on adjacent levees as tidal prism increases, flow velocity increases, and flow patterns change. Late 2019, when multiple levees were breached, was a harbinger of worsening future conditions which will be exacerbated by continued poor condition of levees, higher sea level, and more severe winter storms. If properties are acquired for conservation purposes, and/or in public ownership, restoration would maintain current or improved levels of flood protection for adjacent lands while restoring ecological functions and values. It will also allow management of increased tidal prism which is inevitable either due to planned restoration or unplanned levee failure.

6.7 Cost of Implementation

Acquisition

Historically, land values in the Sonoma Creek baylands have been relatively low due to low-value land use such as salt production, grain farming, and duck clubs. Over the past decade, properties in the baylands have been purchased for uses other than agriculture (e.g. gun clubs, biosolids disposal, and habitat restoration), which has driven up the per-acre value of the land. Per-acre values are not given in this report.

Implementation

Feasibility level opinions of probable construction costs were developed for the three restoration alternatives. The quantities used in the cost opinions were determined from generalized ground elevations and assumed embankment dimensions within the planning area, and the breach and channel cross-sectional areas used in the hydrodynamic model (Appendix 1). Channel alignments and lengths were based on the alternative figures presented in Chapter 5. Assumptions pertaining to existing roads, buildings, and other infrastructure were determined through aerial imagery. Levee lowering reduced existing levee heights to MHHW, which was assumed to be 6.3 feet NAVD 88 for the entire planning area. Levee removal reduced levee heights to the generalized ground elevations.

Railroad protection, where called for in the alternatives, is assumed to be provided by earthen embankments constructed parallel to the rail line and flood gates installed at Railroad and Wingo Sloughs. The embankments were assumed to be constructed against the existing railroad embankment with imported material to an elevation of 15 feet NAVD 88 and armored with riprap. SR 37 is assumed to be protected at the Detjen and West End properties through the improvement of the existing berms that parallel the highway along the southern edge of the parcels. Material for this berm improvement is assumed to be imported. PG&E's infrastructure at Detjen and West End consists of transmission towers and maintenance boardwalks; these facilities are assumed to be protected from tidal water by encapsulating the tower legs in concrete and raising the boardwalks above MHHW. Improvements or modifications to the SR 37 Sonoma Creek and Tolay Creek bridges are not included in the cost estimate. The VORTAC at Skaggs Island is assumed to be protected by the construction of a ring levee around the facility and the installation of a dewatering pump. Access to the facility would be from the Hudeman Slough bridge, and the Haire Ranch perimeter levee is assumed to be improved and surfaced as part of this access.

The opinion of probable construction costs was developed using the assumed construction methods outlined earlier in Section 6.3. Unit costs were determined through a combination of resource-based estimating and reference to the cost of similar type and scale projects. The baseline year for this cost estimate is 2020. For planning purposes, an escalation factor of 5% per annum could be assumed to project future funding needs.

Table 6.2 Feasibility level opinion of probable cost for Alternatives 1 - 3 (in $ millions, rounded to the nearest $0.1M).

Alternative 1

Area	Design & Permitting Phase			Construction Phase							
	Engineering Design	Environmental Documentation & Permitting	Design & Permitting Total	Restoration	Railroad Protection	State Route 37 Protection	PG&E Tower Protection	Vortac Protection	Construction Admin. & Management	Construction Total	Alternative Total
Areas 3 & 4	$0.8	$1.1	$1.9	$4.7	$20.9	$0.0	$0.0	$0.0	$3.8	$29.5	$31.3
Camp 2	$1.0	$1.5	$2.5	$7.2	$28.7	$0.0	$0.0	$0.0	$5.4	$41.3	$43.8
Camp 3	$0.8	$1.1	$1.9	$6.9	$16.7	$0.0	$0.0	$0.0	$3.5	$27.1	$29.0
Camp 4	$0.5	$0.8	$1.3	$7.2	$0.0	$0.0	$0.0	$0.0	$1.1	$8.2	$9.5
Skaggs Island	$1.5	$2.3	$3.8	$49.2	$0.0	$0.0	$0.0	$4.0	$8.0	$61.2	$64.9
Camp 1 West & East	$1.0	$1.5	$2.5	$8.0	$18.8	$0.0	$0.0	$0.0	$4.0	$30.9	$33.4
West End & Detjen	$1.0	$1.5	$2.5	$4.7	$0.0	$23.6	$2.2	$0.0	$4.6	$35.0	$37.5
Alluvial Fans/ Riparian Corridors/ Transition Zones	$0.8	$1.1	$1.9	$15.2	$0.0	$0.0	$0.0	$0.0	$2.3	$17.5	$19.3
Subtotal	$7.3	$10.9	$18.1	$103.0	$85.2	$23.6	$2.2	$4.0	$32.7	$250.6	$268.8
Construction Administration & Management				$15.5	$12.8	$3.5	$0.3	$0.6			
Contingency 30%	$2.2	$3.3	$5.4	$35.5	$29.4	$8.1	$0.8	$1.4	$9.8	$75.2	$80.6
Total Costs	$9.4	$14.1	$23.6	$154.0	$127.3	$35.2	$3.3	$6.0	$42.5	$325.8	$349.4

Alternative 2

Area	Design & Permitting Phase			Construction Phase							
	Engineering Design	Environmental Documentation & Permitting	Design & Permitting Total	Restoration	Railroad Protection	State Route 37 Protection	PG&E Tower Protection	Vortac Protection	Construction Admin. & Management	Construction Total	Alternative Total
Areas 3 & 4	$0.2	$0.3	$0.5	$0.3	$0.3	$0.0	$0.0	$0.0	$0.1	$0.6	$1.1
Camp 2	$0.5	$0.8	$1.3	$1.8	$14.0	$0.0	$0.0	$0.0	$2.4	$18.2	$19.4
Camp 3	$0.8	$1.1	$1.9	$6.5	$0.1	$0.0	$0.0	$0.0	$1.0	$7.6	$9.5
Camp 4	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Skaggs Island	$1.5	$2.3	$3.8	$46.9	$0.0	$0.0	$0.0	$4.0	$7.6	$58.5	$62.3
Camp 1 West & East	$1.0	$1.5	$2.5	$8.1	$11.1	$0.0	$0.0	$0.0	$2.9	$22.1	$24.6
West End & Detjen	$1.0	$1.5	$2.5	$4.7	$0.0	$23.6	$2.2	$0.0	$4.6	$35.0	$37.5
Alluvial Fans/ Riparian Corridors/ Transition Zones	$0.8	$1.1	$1.9	$15.2	$0.0	$0.0	$0.0	$0.0	$2.3	$17.5	$19.3
Subtotal	$5.7	$8.5	$14.2	$83.5	$25.5	$23.6	$2.2	$4.0	$20.8	$159.5	$173.8
Construction Administration & Management				$12.5	$3.8	$3.5	$0.3	$0.6			
Contingency 30%	$1.7	$2.6	$4.3	$28.8	$8.8	$8.1	$0.8	$1.4	$6.2	$47.9	$52.1
Total Costs	$7.4	$11.1	$18.5	$124.8	$38.1	$35.2	$3.3	$6.0	$27.1	$207.4	$225.9

Alternative 3

Area	Design & Permitting Phase			Construction Phase							Alternative Total
	Engineering Design	Environmental Documentation & Permitting	Design & Permitting Total	Restoration	Railroad Protection	State Route 37 Protection	PG&E Tower Protection	Vortac Protection	Construction Admin. & Management	Construction Total	
Areas 3 & 4	$0.8	$1.1	$1.9	$4.7	$20.9	$0.0	$0.0	$0.0	$3.8	$29.5	$31.3
Camp 2	$1.0	$1.5	$2.5	$16.2	$28.7	$0.0	$0.0	$0.0	$6.7	$51.6	$54.1
Camp 3	$0.8	$1.1	$1.9	$16.0	$16.7	$0.0	$0.0	$0.0	$4.9	$37.6	$39.5
Camp 4	$0.5	$0.8	$1.3	$6.8	$0.0	$0.0	$0.0	$0.0	$1.0	$7.8	$9.0
Skaggs Island	$1.5	$2.3	$3.8	$48.8	$0.0	$0.0	$0.0	$4.0	$7.9	$60.7	$64.5
Camp 1 West & East	$1.0	$1.5	$2.5	$9.0	$18.8	$0.0	$0.0	$0.0	$4.2	$32.0	$34.5
West End & Detjen	$1.0	$1.5	$2.5	$7.7	$0.0	$23.6	$2.2	$0.0	$5.0	$38.4	$40.9
Alluvial Fans/ Riparian Corridors/ Transition Zones	$0.8	$1.1	$1.9	$15.2	$0.0	$0.0	$0.0	$0.0	$2.3	$17.5	$19.3
Subtotal	$7.3	$10.9	$18.1	$124.2	$85.2	$23.6	$2.2	$4.0	$35.9	$275.1	$293.2
Construction Administration & Management				$18.6	$12.8	$3.5	$0.3	$0.6			
Contingency 30%	$2.2	$3.3	$5.4	$42.9	$29.4	$8.1	$0.8	$1.4	$10.8	$82.5	$88.0
Total Costs	$9.4	$14.1	$23.6	$185.7	$127.3	$35.2	$3.3	$6.0	$46.6	$357.6	$381.1

The cost to carry the project through design, environmental compliance, and permitting was also estimated. Costs of these professional services were developed through reference to the cost of similar projects. Given the size of the planning area, broad assumptions of the necessary services and field investigations were made. Total project cost for the three action alternatives are summarized in Table 6.2. Detailed feasibility level construction cost estimates and quantity breakdowns for each alternative are included in Appendix 4.

The costs presented in Table 6.2 assume a sequential restoration process (i.e. the costs for each parcel are independent of other parcels). The table presents total costs for each planning area by row and total costs for each element by column (construction administration and management costs are shown in row and column to enable the summations but are not double counted). Some cost savings could potentially be realized if professional services and/or construction were bundled together for multiple properties.

Stewardship costs, which include costs associated with ownership, management, monitoring, and property maintenance, would be required post-restoration. These costs will vary depending upon the final design and intensity of maintenance, monitoring, and general management required. For comparison, the South San Francisco Bay Shoreline Study estimates O&M costs of $339/acre/year (Valley Water 2017). Stewardship costs are site-dependent and will be calculated as part of site-specific project budgets.

The total cost per acre of the three alternatives, broken down by project planning area, is presented in Table 6.4. The costs include professional services, restoration, protection of infrastructure, and contingency. Not unexpectedly, the properties with the most infrastructure (railroad associated with Area 4 and Camp 2, and PG&E and SR 37 associated with West End and Detjen) are the highest cost per acre to restore. For comparative purposes, the USACE South San Francisco Bay Shoreline Study Phase 1 estimates the average cost of tidal wetland restoration alone (no protective actions) in the Alviso salt ponds to be in the range of $30,000 per acre (Valley Water 2017).

Table 6.4. Cost per acre by planning area and alternative

Area	Alternative 1		Alternative 2		Alternative 3	
	Acres Restored	Cost per Acre	Acres Restored	Cost per Acre	Acres Restored	Cost per Acre
Areas 3 & 4	556	$56,000			556	$56,000
Camp 2	770	$57,000	280	$69,000	770	$70,000
Camp 3	1,480	$20,000	1,480	$6,000	1,480	$27,000
Camp 4	1,130	$8,000			1,130	$8,000
Skaggs Island	4,224	$15,000	4,224	$15,000	4,224	$15,000
Camp 1 West & East	1,030	$32,000	1,030	$24,000	1,030	$33,000
West End & Detjen	735	$51,000	735	$51,000	735	$56,000
Total*	10,303	$34,000	9,172	$24,626	11,714	$32,536

* includes sloughs and channels in the Project Study Area

The cost opinions provided above do not include the import of material to create habitat features. All created topography is assumed to be constructed from material generated from channel excavations, levee lowering, and levee removal activities. As stated previously, the most likely source of import material for habitat use is hydraulically placed dredged material. Importing dredged material would require a significant investment to establish the necessary infrastructure. San Pablo Bay is extremely shallow, and a facility would need to be located near the Pinole Shoal Channel to ensure adequate water depths. In order to place the material in Skaggs Island, a 45,000-foot pipeline would need to be installed in San Pablo Bay and another 10,000-foot pipeline installed within the restoration site. This distance would require a large dredge pump at the offloader location, and at least two in-line booster pumps. Power could be brought in from the old substation at the south edge of Skaggs Island and distributed to the pumping facilities by a submarine power cable. Setting up this type of infrastructure would require a capital expenditure on the order of $70 million (including 30% contingency). Some of this cost would be salvageable through residual equipment value at the end of the import operation. However, significant sunk costs for onsite improvements (berm construction and water control structure installation) would also be required within Skaggs Island. The infrastructure would also include significant annual operational and maintenance costs, regardless of system usage. Some of these costs could potentially be recovered through fees charged to dredging projects.

6.8 Regulatory Requirements

The following regulatory requirements are to be considered in the Strategy. Included with each is a brief description of the requirements for the alternatives. The list is organized according to the type of regulatory requirements being considered.

Natural Resources

A. California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA)

We have conducted a preliminary review of potential impacts associated with each of the alternatives based on the conceptual designs described herein and have identified the following potentially significant impacts under CEQA and NEPA: hydrology/flood protection; water/sediment quality; biology; land-use changes; transportation; and air quality. The extent of impacts is dependent on phasing, timing, and how and whether the Strategy is handled programmatically. All alternatives would require similar analysis for each of these resource areas where there is the potential to have significant and unavoidable impacts. Depending on ultimate design and phasing, one or more of these impacts may be both significant and unavoidable under one or more alternatives. Determination of impacts as significant and unavoidable is at the discretion of the lead agency during the CEQA and NEPA processes. Any significant and unavoidable impacts would require an Environmental Impact Report under CEQA and an Environmental Impact Statement under NEPA.

Alternatives 1 and 2 rely on utilizing the existing tidal channels to restore tidal action to diked baylands. This could increase erosion along existing channels, causing a loss of adjacent high marsh and eventual replacement with low marsh with less complexity. Marsh erosion could discharge sediment into the channels and the San Francisco Bay affecting water quality. This would also affect existing Ridgeway's Rail and Salt Marsh Harvest Mouse habitat, both state and federally listed species. Alternative 3 will incorporate proposed pilot channels through existing baylands with the anticipation of reducing erosion of existing marsh outboard of levees. Although Alternative 3 has the lowest potential risk of degrading existing marsh habitat it is anticipated that all alternatives would require a similar level of analysis to justify the design.

B. Federal Clean Water Act (Sections 401, 402 and 404)

All three alternatives are assumed to result in a large net gain in acreage as well as functions and services of Section 404 wetlands and waters as large areas of agricultural fields currently in oat hay production would be converted to tidal marsh and subtidal habitats.

Changes in existing marsh habitats: Alternative 1 would have the greatest increase in tidal prism and therefore the highest scour potential, which could lead to a comparatively higher conversion of tidal marsh to open water through erosion at the confluence of the existing tidal sloughs (e.g. Sonoma Creek, Napa Sloughs) and along channel margins in the marshes that developed on the outboard, or channel, side of where levees were constructed to claim lands for agriculture, with only a minor decrease under Alternative 2. With respect to variation in levee breach number and location relative to the existing outboard marsh, impacts associated with these elements would be minimal in comparison. With respect to Detjen and West End parcels, Alternatives 1 and 2 are comparable, with some marsh loss due to excavation of additional channel segments to improve hydrologic connectivity within the parcels, while Alternative 3 includes a greater degree of marsh conversion associated with constructing additional subtidal and intertidal habitat but excludes channel excavation in the far northeast edge of Detjen.

Changes to seasonal wetlands habitats: Seasonal wetlands have formed to varying degrees in baylands that have been claimed for agricultural production depending on intensity of land use, incorporation of field leveling techniques, degree of pumping rainfall off, and other factors. The majority of existing seasonal wetland habitat within the baylands will be converted to tidal marsh and subtidal habitats in all of the alternatives. Acreage of restored tidal marsh and subtidal habitats would greatly exceed seasonal wetland acreage lost due to conversion. All alternatives could be modified to maintain existing seasonal wetlands at Haire Ranch, and Alternative 2 maintains the majority of existing seasonal wetlands within Camp 2.

It is anticipated that all three alternatives will require a Section 404 Permit, a Section 401 Water Quality Certification, and coverage under the Construction General Permit in compliance with Section 402. Permitting efforts would likely be comparable for all three alternatives if the proposed project demonstrates a net increase in functions and services. It is anticipated that all alternatives would result in a net increase in wetland acreage created. Alternative 3 would likely rank the highest in increased functions and services due to maximized wetland creation and reduction of potential loss or degradation of existing wetlands.

C. Federal Rivers and Harbors Act (Section 10)

Due to the activities within Section 10 Waters (i.e., including all waters subject to the ebb and flow of the tides [33 CFR 329.4]), it is anticipated that all three alternatives will require a Section 10 Permit. Permitting efforts would be comparable between alternatives.

D. Federal and California Endangered Species Acts

Due to work within habitat for state and federally listed species, it is anticipated that all three alternatives will require Biological Opinions from USFWS and NMFS and an Incidental Take Permit from CDFW. Permitting efforts would be comparable. Alternatives 1 and 2 could adversely affect Ridgeway's Rail and Salt Marsh Harvest Mouse habitat by eroding existing high marsh habitat along Sonoma Creek. This would potentially degrade the habitat by temporarily reducing habitat acreage and reducing the amount of habitat complexity within the marsh. All three alternatives are expected to provide habitat benefits to listed species and of these, Alternative 3 would likely have the highest benefit for state- and federally-listed species.

E. Magnuson-Stevens Act

It is anticipated that all three alternatives will result in both immediate and long-term improvements to fish habitat. However, all alternatives will likely require consultation with NMFS for potential impacts to Essential Fish Habitat. It is likely that impacts would be similar between alternatives and offset by both near-term and long-term improvements in fish habitat.

F. State Fish and Game Code

Due to work within Sonoma Creek and its tributaries all three alternatives may require a Lake and Stream Alteration Agreement from CDFW. If required, permitting efforts would be similar between alternatives.

G. Porter-Cologne Water Quality Control Act

All three alternatives will result in a net gain of state-regulated wetlands as large amounts of agricultural fields currently in oat hay production would be converted to tidal marsh.

Changes in existing marsh habitats: All alternatives would include conversion of tidal marsh to open water at the confluence of the existing tidal sloughs (e.g. Sonoma Creek, Napa Sloughs) and at levee breach locations that require starter channels through existing outboard marsh. Increased tidal prism associated with Alternative 1 would likely cause erosion of some outboard tidal marsh along Sonoma Creek and the tributary slough network in comparison to Alternative 2 and to Alternative 3 to an even lesser degree. Conversion of muted marsh to open water along proposed channels is comparable within the Detjen and West End parcels for Alternatives 1 and 2. Alternative 3 includes a greater degree of marsh conversion associated with constructing additional subtidal and intertidal habitat but excludes channel excavation in the far northeast edge of Detjen. Alternative 3 would result in the highest acreage of marsh preservation and highest acreage of restored marsh, followed by Alternative 1. Alternative 2 would restore the lowest number of acres of the three, although still far more than the no-action alternative.

Changes to seasonal wetlands habitats: Alternative 1, and Alternative 2 to a lesser degree, would include conversion of existing seasonal wetland habitat to open water and tidal marsh within Skaggs Island and all (Alternative 1) or part (Alternative 2) of Camp 2. Acreage of restored tidal marsh and subtidal habitats would greatly exceed seasonal wetland acreage lost due to conversion, providing an overall net increase to functions and services for all alternatives. Alternatives 1 and 2 will maintain existing seasonal wetlands at Haire Ranch, and Alternative 2 will maintain the majority of existing seasonal wetlands within Camp 2. Due to the activities within waters of the state, it is anticipated that all three alternatives will require Waste Discharge Requirements, which will be aligned with the RWQCB 401 certification. Permitting efforts would likely be comparable for all three alternatives. It is anticipated that all alternatives would result in a net increase in wetland acreage created. Alternative 3 would provide the greatest benefit in increased functions and services due to maximized wetland creation and reduction of potential loss / degradation of existing wetlands.

H. McAteer-Petris Act

BCDC jurisdiction within the planning area includes San Francisco Bay (to mean high tide or the upland edge of wetland vegetation); certain waterways that flow into the Bay, including Tolay Creek to SR 37 and Sonoma Creek to the Second Napa Slough; and the 100-foot shoreline band of San Francisco Bay. It is anticipated that the elements of all three alternatives that occur within BCDC jurisdiction will require a San Francisco Bay Permit from BCDC, and/or a consistency determination, described below. The Bay Plan requires maximum feasible public access consistent with the project, so provisions for public access will be a central feature of BCDC review.

I. Coastal Zone Management Act (Section 307)

In addition to carrying out its regulatory authority under state law, the federal Coastal Zone Management Act (CZMA) allows BCDC to review federal projects (i.e., projects proposed by a federal agency, that require federal approval and / or that receive federal funds) for consistency with the McAteer-Petris Act. The use of federal funding or the issuance of a federal permit in support of the project would trigger a CZMA consistency review, which would address activities in the coastal zone (see above) as well as activities proposed outside the coastal zone that have the potential to impact coastal resources. Accordingly, project elements inland of coastal zone limits that receive federal funding or require federal permits would also be evaluated for their potential to affect coastal zone resources. In the event of a federal lead and/or federal funding, any alternative within or partially within the Coastal Zone will require a Consistency Determination from BCDC, and that the CZMA Consistency Determination will be subsumed with the San Francisco Bay permit process noted above. If required, permitting efforts would be similar between alternatives.

J. Williamson Act

Portions of Camp 1 West, all of Camp 3, all of Camp 4, and all of Area 3 contain parcels that have a Type II contract under the Williamson Act. It is anticipated that all three alternatives would require applications to cancel contracts to change the land use from agriculture to tidal marsh. It is anticipated that application requirements would be similar for all three alternatives. To cancel a contract, the landowner must apply to Sonoma County requesting cancellation for the contracted area.

K. National Historic Preservation Act

All three alternatives will require Compliance with Section 106 of the National Historic Preservation Act and will require a comprehensive assessment of potential prehistoric, historic, archaeological and tribal resources within the restoration area. Until that information is available, it is not possible to compare alternatives. However, it is anticipated that compliance requirements and protection of resources would be similar for all three alternatives.

L. California State Lands Commission

The California State Lands Commission has exclusive jurisdiction over ungranted tidelands and submerged lands. The California Civil Code defines the boundary of tidelands and submerged lands as the ordinary high water mark. A lease is required if any alternative proposes work below the ordinary high water mark, within a waterway under the CSLC's jurisdiction. Due to a lack of parcel data within Sonoma Creek and Tolay Creek it is likely that these parcels are ungranted submerged lands under CSLC's jurisdiction and a lease would be required for work below the ordinary high water mark of these waterways. If required, it is anticipated that application requirements would be similar for all three alternatives.

Infrastructure

A. California Title 23 and U.S. Code Section 408 for flood protection

There are no known Section 408 levees within the planning area.

B. California Streets and Highways Code

Section 660 of the California Streets and Highways Code requires an encroachment permit to enter Caltrans right-of-way to construct, alter, repair, improve facilities, or conduct specified activities. Submitted requests are reviewed to determine impacts of encroachment on: the safety of motorists, pedestrians, and workers; design, construction, operation, maintenance, or integrity of the highway system; future and ongoing highway contracts; aesthetic value of the highway corridor; the environment; existing drainage; water quality; and the risk of tort liability. All alternatives would likely require an encroachment permit from Caltrans for work on state highways (i.e., any needed modification to the Tolay Creek and Sonoma Creek bridges and associated channel crossings along SR 37). Alternatives 1 and 3 would likely include more areas of encroachment as these alternatives would encroach on SR 37 and SR 12/121 for railroad protection work. Alternative 3 would likely require the largest encroachment footprint along SR 37 due to the lengthening of the Tolay Creek Bridge.

C. Federal Aviation Administration: VORTAC and Sonoma Valley Airport

Two facilities could necessitate engagement with the Federal Aviation Administration (FAA): The VHF Omnidirectional Range/Tactical Aircraft Control (VORTAC) device at Skaggs Island, and the Sonoma Valley Airport.

VORTAC. The FAA uses approximately 6.35 acres of land on Skaggs Island as the site for their VHF Omnidirectional Range/Tactical Aircraft Control (VORTAC) device, an ultra-high frequency mileage/distance measuring device which gives air route navigation and course guidance to both military and civilian aircraft traversing the north/south air route from San Francisco to Seattle (NAVFAC Engineering Command, 1984). A use agreement between the FAA and USFWS was formed in 1967 and expired in 2008. The agreement was extended to 2009 but has since expired again. The FAA has continued operation while new agreement negotiations have taken place. As of the date of this report, no agreement had been reached. All alternatives would need to coordinate with the FAA to ensure that the VORTAC tower and access to the tower are protected and not impacted by the project. The USFWS has been communicating to the FAA that they plan to restore tidal action to Skaggs Island and have asked the FAA to plan to move the facility.

Sonoma Valley Airport and Advisory Circular No. 150 / 5200-33B. Sonoma Valley Airport is located west of Camp 2 and southwest of Area 3. FAA policy discourages land use changes, such as wetland restoration, that would attract wildlife near the airport. The FAA recommends a 5,000-foot buffer for airports serving piston-powered aircraft and a 10,000-foot buffer for turbine-powered aircraft. A portion of all alternatives is within 5,000 feet of the runway but alternative 2 provides the largest buffer (approximately 4,000 feet). The consideration of land uses allowed in the vicinity of the airport would be evaluated by the Sonoma County Airport Land Use Commission (ALUC).

Sonoma County ALUC has the authority to coordinate planning at the state, regional and local levels so as to provide for the orderly development of air transportation, while at the same time protecting public health, safety, and welfare; to prepare and adopt airport land use plans; and to review and make recommendations concerning specified plans, regulations and other actions of local agencies and airport operators under Section 21674(b) of the California Public Utilities Code. Projects requiring alteration within the secondary referral area shall be referred to the ALUC for review. All alternatives are within the referral area (**Figure 4.1**) and would require ALUC review of project design before implementation. Projects are reviewed for consistency with the Comprehensive Airport Land Use Plan.

Sonoma Valley Airport is surrounded by various safety zones as identified in the Sonoma County General Plan (2020, Subsection 8.4.1.3). The following uses are prohibited in all airport safety zones:

- Any use which would direct a steady light or flashing light toward aircraft.
- Any use which would cause sunlight to be reflected toward an aircraft.
- Any use which would generate smoke or water vapor, or which would attract large concentrations of birds, or which may affect safe air navigation within the area.
- Any use which would generate electrical interference detrimental to aircraft operation.

Alternative 2 includes work within the fewest safety zones. However, all alternatives would require consultation with the Sonoma County ALUC. Sonoma Creek is located within the Runway Protection Zone (RPZ), Inner Safety Zone (ISZ), Inner Turning Zone (ITZ), Side Safety Zone (SSZ), and Traffic Pattern Zone (TPZ). Camp 2 is located within the ISZ, ITZ, Outer Safety Zone (OSZ), and TPZ. Area 3 is located within ITZ, OSZ, and TPZ. Area 4 is located within TPZ.

Given that all alternatives could lead to open water, including ponded polders in the event that levees are maintained, additional investigations will be needed to fully understand the constraints of this area relative to the ALUC and the Sonoma Valley Airport.

D. Railroad Encroachment Permits

It is anticipated that all alternatives would include work within the railroad right of way. Any work encroaching into railroad right-of-way would require consultation with Northwest Pacific, SMART rail, and possibly the North Coast Rail Authority. This consultation includes submitting an encroachment permit to SMART. If any railroad crossings are added or modified an authorization application must be submitted pursuant to California Code, Public Utilities Code - PUC § 1201 and General Order 88-B.

Alternative 2 would have the least potential to impact the SMART right-of-way. This alternative would require protection of the fewest linear feet of track, and since it only crosses two existing dirt roads, it would be the least likely to require a railroad crossing modification authorization from the California Public Utilities Commission. However, it is likely that this alternative would require an encroachment permit from SMART.

Alternatives 1 and 3 would be comparable in effort needed to secure authorization. It is highly likely that these alternatives would require an encroachment permit from SMART due to the extensive protection needed, and that railroad crossing modification authorization from the California Public Utilities Commission would be required, as the proposed protection footprint crosses four existing dirt roads and two California State Routes (SR 37 and SR 12/121). Submitted requests are reviewed to determine impacts of encroachment on (but not limited to) safety, design and construction of encroachments, and railroad crossing modifications and /or additions.

All alternatives would require coordination with SMART to ensure that modifications to hydrology could not impact the railroad. This coordination is separate from encroachment into SMART right-of-way.

E. Pacific Gas and Electric (PG&E)

PG&E has infrastructure within the footprint of all alternatives including:

- **Electric Transmission Line** - running over Tolay Creek and through the West End and Detjen parcels, and ending at an electrical substation on Skaggs Island (see below)
- **Overhead Electrical Line** – running through Camp 2
- **Natural Gas Pipeline** – running through Area 4

The PG&E substation adjacent to the Skaggs Island Bridge delivering 115 kv power to Skaggs Island was installed just outside the levee boundary in 1959. The substation is constructed on a pad approximately 150 x 150 feet, elevated with fill over the perimeter marsh outside of the tidal range (approximate elevation ± 10 feet). While the substation remains, it no longer feeds the base as all electrical cable was removed in 2010. Its only function is to power the VORTAC facility. Approximately 11,200 linear feet of cable services the facility underneath Rainbow Drive. PG&E has held a 0.024-acre easement for maintenance of its underground electric lines, but the terms of this agreement expired in 2009.

Coordination will be required to ensure that none of the infrastructure listed above is negatively affected by the alternatives. Encroachment permits will be required if PG&E easements are encroached upon. Alternative 2 is the least likely to negatively affect PG&E infrastructure because no project elements are proposed near the natural gas line and the footprint within Camp 2 is reduced, lessening potential impacts on the existing overhead electrical line there. All alternatives are anticipated to have a comparable level of coordination with PG&E.

6.9 Groundwater

Groundwater produced from wells located in the Sonoma Valley Groundwater Subbasin represents the largest source of supply utilized in Sonoma Valley (nearly two-thirds of all water demands are estimated to be met by local groundwater for the Subbasin and contributing watershed areas [Sonoma Water, 2014]). The aquifer system contains both shallow (generally less than 200 feet deep) and deep principal aquifers which are separated in most areas by an aquitard of fine-grained sediments overlying the aquifer (Marcus Trotta, personal communication).

The groundwater aquifer near the Baylands is already impaired with brackish water which has the potential to intrude further northward into the freshwater aquifer system by groundwater well extraction of freshwater for agricultural and urban uses that exceeds groundwater recharge capacity. In addition, sea level rise may exacerbate the intrusion of saltwater into the aquifer. Restoring parcels to tidal action as described in the Strategy is likely to have more impact on the shallow unconfined coastal aquifer than this deeper aquifer. It is uncertain whether and how tidal restorations might impact the saline/freshwater interface in the deeper aquifer.

Monitoring wells could be installed near the project area to track changes in salinity, regardless of how and when restorations are implemented. Installation of monitoring wells prior to beginning restoration work would establish an understanding of baseline conditions and could help Sonoma Water optimize locations of post-restoration monitoring wells. Even if no restorations are implemented, unplanned levee breaches may affect groundwater conditions. Monitoring wells could also be installed to track changes in the depth of the shallow unconfined aquifer, which will become shallower with sea level rise. Rising groundwater in this shallow coastal aquifer may exacerbate levee maintenance challenges as sea level rises.

To gather additional information on potential projects that may help address declining groundwater levels in Sonoma Valley, Sonoma Water and the City of Sonoma conducted a pilot study for aquifer storage and recovery which involved injecting, storing and recovering treated drinking water sourced from the Russian River into the aquifer system.

Sonoma Water will be doing groundwater quantity modeling with USGS' MODFLOW program in June 2020. The model does not include changes in groundwater quality but could potentially project change in head caused by restoration projects. This additional modeling is a follow up activity that will be conducted for the preferred restoration alternative to define areas to be inundated and inundation elevation.

6.10 Feasibility Summary

Feasibility of each of the alternatives is compared with respect to infrastructure, implementation, resource protection and restoration, and environmental outcomes (Table 6.5). Similar to the goals matrix in Table 6.1, the ratings themselves are estimates and are meant to give a relative evaluation of which alternatives are more or less feasible with respect to these parameters. They are not meant to be interpreted as definitive values. For instance, a rating of "2" does not necessarily mean that alternative will be twice as feasible as an alternative with a rating of "1", but rather that it is comparatively more feasible.

Table 6.5. Matrix comparing feasibility of alternatives across a range of parameters

SCORING	
2	Highly Feasible
1	Moderately Feasible
0	Somewhat Feasible
-1	Not Feasible (impediment exists)

				Alternative 0: No Restoration	Alternative 1: Maximum Tidal	Alternative 2: Avoid Railroad	Alternative 3: Enhanced Max. Tidal
INFRASTRUCTURE	F1	Railroad encroachment complexity	1	not applicable	0	1	0
	F2	Highway encroachment complexity (SR121)	1	not applicable	1	1	0
	F3	Highway encroachment complexity (SR 12)	1	not applicable	1	0	2
	F4	Highway encroachment complexity (SR37)	1	not applicable	1	2	0
	F5	Airport adjacent land use constraints	1	not applicable	0	1	0
	SCORE (out of 10 possible points)			0	3	5	2
IMPLEMENTATION	F6	Planning & Implementation Cost	1	not applicable	0	1	0
	F7	Acquisition timeline	1	not applicable	1	2	1
	F8	Planning timeline	1	not applicable	1	2	1
	F9	Construction timeline	1	not applicable	1	2	1
	F10	(Resources)	1	not applicable	2	2	2
	F11	Management Intensity	1	0	2	1	2
	F12	Long term management costs	1	-1	1	0	2
	SCORE (out of 14 possible points)			-1	8	10	9
RESOURCE PROTECTION AND RESTORATION	F13	Cultural resource protection	1	unknown	unknown	unknown	unknown
	F14	Acres protected	1	1	2	1	2
	F15	Acres subtidal habitat restored	1	-1	2	0	1
	F16	Acres intertidal habitat restored	1	-1	1	0	2
	F17	migration space	1	-1	2	1	2
	F18	other sediment source	1	-1	1	1	2
	F19	Mature marsh maintained	1	2	-1	0	1
	F20	Impact of Railroad on marsh	1	not applicable	-1	0	-1
	SCORE (out of 16 possible points)			-1	6	3	9
ENVIRONMENTAL OUTCOMES	F21	Carbon footprint	1	2	0	1	-1
	F22	Carbon sequestration	1	-1	1	0	2
	F23	Sea level rise adaptability 2050	1	-1	1	0	2
	F24	Sea level rise adaptability 2100	1	-1	1	0	2
	F25	Maximize environmental benefits	1	-1	1	0	2
	SCORE (out of 10 possible points)			-2	4	1	7
SCORING			POINTS	PERCENT OF TOTAL POSSIBLE POINTS			
	OVERALL SCORE (%)*			8	48	41	65
	OVERALL RANK		1 = BEST	4	2	3	1

*Derived by SUM:PRODUCT of the respective scoring array to the feasibility array for each alternative

Alternative 3 emerges as the most feasible alternative overall, followed by Alternative 1 then by Alternative 2. Alternatives 1 and 3 are similar in infrastructure impacts, with Alternative 2 emerging as most feasible for navigating infrastructure encroachment complexity (less encroachment on SMART). Alternative 2 also would be most feasible to implement on the shortest timeline in part due to infrastructure avoidance, smaller area, and fewer properties to acquire. Alternative 3 provides the greatest level of resource protection and restoration, with its protection of existing outboard marshes and the species that rely on them, followed by Alternative 1, then Alternative 2. Alternative 3 also provides the most favorable environmental outcomes based on the highest rate of carbon sequestration, greatest sea level rise adaptability, and maximized environmental benefits.

6.11 Opportunities to Accelerate Restoration

Beneficial use of dredge sediment and upland import could furnish clean, suitable fill material to accelerate restoration, and to restore wetland habitats in a shorter timeline. The lower Sonoma Creek Baylands and the entirety of the Napa Sonoma Marshes complex represent ideal opportunities for beneficial sediment reuse and should be prioritized for sediment reuse because of their high conservation value, the rural character of the surrounding lands, and the potential for marsh migration and restoration of complete ecosystems, from subtidal to upland habitats. Sediment import may also be an important strategy in areas where subtidal or other aquatic habitats present challenges, such as in the vicinity of Sonoma Valley Airport.

CHAPTER 7

Conclusion

Many of the essential resources required for tidal restoration are already present within the planning area. The existing marshes fringing the historical channels are an opportunity for restoration because they provide a nucleus of mature, complex marsh habitat, including populations of valuable wetland species, from which restorations can be built. Adjacent uplands also provide valuable opportunities. The combination of the space availability in the current diked baylands and the existing water, sediment, and woody debris that can fill this space presents a valuable opportunity for restoration.

Restoration of tidal action in the downstream baylands can reduce backwater effects in fluvial channels and enhance drainage, reducing flood depths, extent, and duration upstream.

Habitat Restoration Alternatives

Alternative 3 emerged as satisfying the most project goals, followed by Alternative 1 and then by Alternative 2. Alternatives 1 and 3 are similar in infrastructure impacts, while Alternative 2 emerges as most feasible in regard to infrastructure impacts because interactions with the railroad are avoided. Alternative 2 could be implemented on the shortest timeline due to infrastructure avoidance, smaller restoration area, and the need to acquire fewer properties. Alternative 2 could be an initial step towards implementing Alternatives 1 or 3.

Alternative 3 represents broad scale tidal restoration, with primary conveyance for tidal and fluvial flows routed through Camp 2, Camp 3, and Skaggs Island. This alternative is configured to protect existing marsh habitat in the channel network by focusing flow and tidal prism in newly graded channels rather than scouring the existing channels. It received the highest ranking for achieving the most project goals. Alternative 3 provides the greatest level of resource protection and restoration, the highest rate of carbon sequestration, greatest sea level rise adaptability, and maximized environmental benefits, mainly due to the protection of existing outboard marshes and the species that rely on them.

Alternative 1 represents broad scale tidal restoration, with the existing channel system serving as the primary conveyance for tidal and fluvial flows. Camps 1-4 and Skaggs Island were assumed to be filled to a mix of habitat elevations—from mudflat to low to high tidal marsh. It was assumed that the channel network would adjust to the additional tidal prism from the restored parcels. Alternative 1 received the second highest ranking toward achievement of project goals; it performs nearly as well as Alternative 3 in reducing flooding and also prioritizes restoring already acquired lands. However, it did not score as highly for the habitat restoration goals because it would cause scour of mature high marsh that would result from routing more tidal prism through existing channels.

Alternative 2 represents less tidal restoration and fill in the restored parcels. The purpose of this alternative was to evaluate a condition that has less impact on existing infrastructure and requires less imported fill to construct. It achieves or partially achieves many of the goals but is less successful than Alternatives 1 and 3 in reducing flooding and improving habitat because less area is restored in this alternative.

Alternative 0 reflects conditions with assumed foreseeable changes (e.g. raising levees) in the absence of new large-scale wetland restoration and did not perform well in the habitat restoration goals nor the flood reduction goals.

Public Access

Implementation of Alternatives 1, 2, or 3 would increase opportunities for public access. Access opportunities should be evaluated based on the guiding principles developed for this Strategy and consistent with the landowner's access goals and mission. Public access can only be provided to the through a variety of means consistent with the project and in a way that accounts for sea level rise.

Implementation

Implementation of the restoration actions will be largely driven by the availability of the various properties within the planning area. West End, Detjen, Skaggs Island, Haire Ranch, and Camp 2 are in public ownership. These properties are situated where they could be tidally restored without further property acquisition and implemented in a manner that would allow future connection to adjacent parcels. Clusters of parcels that could be opportunistically restored have been identified beginning with parcels in public ownership.

An assessment of the constructability of the three action alternatives, which were developed using different configurations of similar design elements, was conducted. All the alternatives are constructible. The primary land use on the properties is active and fallowed agricultural land. Equipment mobilization for all planning areas will be from land and it is anticipated that non-specialized construction equipment and standard methods will be used. The exception to this is the West End and Detjen properties, which are managed wetland systems.

Infrastructure Considerations

The present bridge crossings and embankments disrupt hydrologic and habitat connectivity between the baylands and the Bay. Where possible, the SR 37 design should accommodate reconnecting baylands and tributaries to allow the passage of water, sediment, and species, primarily at the Sonoma Creek and Tolay Creek bridge crossings. Tolay Creek Bridge should be lengthened and elevated sufficiently to accommodate the increased tidal prism that would result from the identified restoration opportunities in Camp 1. Sonoma Creek Bridge tidal prism would be increased by the no-action alternative, where Skaggs Island breaches on its own, or any under any of the restoration alternatives. A more detailed analysis will be required along with close coordination with Caltrans. West End and Detjen are the only properties in the study area directly adjacent to SR 37. Restoring full tidal action will require improvements to SR 37 to maintain existing levels of flood protection.

The segments of SMART rail that were constructed within historical tidal marshes are already vulnerable to flooding and dependent on the aging system of berms and pumps that will be under increasing pressure as sea level rises. Potential protection measures include relocating the railroad outside of tidally-influenced areas, raising the railroad embankment above floodwaters, raising the railroad on a pile-supported causeway, (potentially collocated with the SR 37 causeway), and isolating the existing embankment from floodwaters. A more detailed analysis will be required along with close coordination with SMART.

Near Sonoma Valley Airport, potential bird strike hazards and large water features, including wetlands, may be prohibited. The VORTAC navigational aid on the eastern side of Skaggs Island requires protection and access to be maintained during and after restoration

A fully integrated design for transportation infrastructure maximizing hydrologic and habitat connectivity in the Sonoma Creek baylands would collocate SMART with SR 37 on a piled causeway on the SR 37 alignment to reduce the length of track and minimize ecological disruption with sufficient bridge lengths at Sonoma Creek and Tolay Creek to accommodate increased tidal prism associated with implementation of the Strategy. A partially integrated design to benefit hydrologic and habitat connectivity would lengthen bridges to accommodate increased tidal prism associated with restoration (including SMART bridges at Wingo and Railroad Slough and SR 37 bridges at Tolay Creek and Sonoma Creek) and raise SR 37 and SMART to accommodate sea level rise with costs of infrastructure improvements borne by the respective infrastructure owners, rather than as part of the cost of implementing the Strategy.

Cost Estimates

Feasibility level opinions of probable construction costs were developed for the three restoration alternatives (Table 7.1). The costs of acquisition are not included. Table 7.2 provides the per acre cost of implementing each of the alternatives without the cost of acquisition.

Table 7.1 Total Cost per Alternative without Acquisition Costs

		Construction (includes admin and management)		
Alternative	Design & Permitting	Restoration	Infrastructure Protection	Total
1	$23.6M	$154.0M	$171.8M	**$349.4M**
2	$18.5M	$124.8M	$82.6M	**$225.9M**
3	$23.6M	$185.7M	$171.8M	**$381.1M**

Table 7.2 Cost per Acre per Alternative Excluding Acquisition

Alternative	Acres	Design & Permitting	Restoration	Infrastructure Protection	Total
1	10,303	$2,287/ac	$14,948/ac	$16,677/ac	**$33,912/ac**
2	7,381	$2,504/ac	$16,907/ac	$11,191/ac	**$30,603/ac**
3	10,303	$2,287/ac	$18,028/ac	$16,677/ac	**$36,992/ac**

Next Steps

The Strategy reflects a vision for conservation in this region. Much more detail will be needed as the strategy is more fully planned and implemented. Additional actions include stepping down the Strategy to individual parcels or groups of parcels, developing design plans, conducting additional hydrodynamic modeling, geotechnical and other studies, developing an environmental compliance strategy, identifying willing sellers and willing funders, and a coordinated and collaborative effort. Together, we can conserve and restore the lower Sonoma Creek corridor.

CHAPTER 8

References

AECOM. 2016. San Francisco Bay Tidal Datums and Extreme Tides Study. Prepared for Federal Emergency Management Agency and San Francisco Bay Conservation and Development Commission. https://www.adaptingtorisingtides.org/wp-content/uploads/2016/05/20160429.SFBay_Tidal-Datums_and_Extreme_Tides_Study.FINAL_.pdf.

Atwater, B.F. 1979. Ancient process at the site of southern San Francisco Bay: Movement of the crust and changes in sea level. San Francisco Bay: The urbanized estuary, edited by T.J. Conomos. (34-45). American Association for the Advancement of Science, San Francisco.

Atwater et al. 1979. History, landforms, and vegetation of the estuary's tidal marshes. San Francisco Bay: The urbanized estuary, edited by T.J. Conomos. (347-385). American Association for the Advancement of Science, San Francisco.

Bay Conservation and Development Commission (BCDC). 2008. San Francisco Bay Plan.

BCDC. 2019. Fill for Habitat Amendment Fact Sheet.

Brown, K. 2007. Evidence of spawning by green sturgeon, *Acipenser medirostris*, in the upper Sacramento River, California. Environmental Biology of Fishes. 79 (3-4): 297-303.

California State Coastal Conservancy (SCC) and Ocean Protection Council (OPC), NOAA National Marine Fisheries Service and Restoration Center (NMFS), San Francisco Bay Conservation and Development Commission (BCDC), and San Francisco Estuary Partnership (SFEP). 2010. San Francisco Bay Subtidal Habitat Goals Report - Conservation Planning for the Submerged Areas of the Bay.

California SCC. 2011. Enhanced San Francisco Bay Area Water Trail Plan.

California Department of Fish and Wildlife (CDFW). 2015. California State Wildlife Action Plan, 2015 Update: A Conservation Legacy for Californians. Edited by Armand G. Gonzales and Junko Hoshi, PhD. Prepared with assistance from Ascent Environmental, Inc., Sacramento, CA.

California Native Plant Society (CNPS), Rare Plant Program. 2020. Inventory of Rare and Endangered Plants of California (online edition, v8-03 0.39); http://www.rareplants.cnps.org.

California Natural Resources Agency (CNRA) and California Ocean Protection Council (OPC). 2018. "State of California Sea-Level Rise Guidance: 2018 Update." http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf.

California Regional Water Quality Control Board (RWQCB). 2006. Amending the Water Quality Control Plan for the San Francisco Bay Region to Establish a Total Maximum Daily Load and Implementation Plan for Pathogens in the Sonoma Creek Watershed. Resolution R2-2006-0042.

California RWQCB. 2008. Amending the Water Quality Control Plan for the San Francisco Bay Region to Establish a Total Maximum Daily Load for Sediment in Sonoma Creek, and an Implementation Plan to Achieve the TMDL and Related Habitat Enhancement Goals. Resolution R2-2008-0103.

California Wetlands Monitoring Workgroup (CWMW). EcoAtlas. Accessed January 7, 2020. https://www.ecoatlas.org.

CEMAR, 2013. Sonoma Creek Watershed Outmigrant Study – Project Report. Prepared in association with Hagar Environmental Science, Sonoma Ecology Center, and Sonoma Resource Conservation District. Spring 2013.

Cloern JE, Knowles N, Brown LR, Cayan D, Dettinger MD, Morgan TL, et al. 2011. Projected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change. PLoS ONE 6(9): e24465. https://doi.org/10.1371/journal.pone.0024465.

Collins, L. and K. Leising. 2004. Geomorphic analyses of processes associated with flooding and historic channel changes in lower Sonoma watershed: Synopsis of first year findings. Watershed Sciences. Prepared for Southern Sonoma Resource Conservation District. April 2004.

Cornwall, C., S. Moore, D. DiPietro, S. Veloz, L. Micheli, L.Casey, M. Mersich. 2014. Climate Ready Sonoma County: Climate Hazards and Vulnerabilities. Prepared as part of Climate Action 2020 by North Bay Climate Adaptation Initiative for Sonoma County Regional Climate Protection Authority. Santa Rosa, CA.

Dawson, A. 2016. Sonoma Baylands Oral History Project. Prepared for Sonoma Land Trust and Sonoma Resource Conservation District.

Dawson, A., M. Salomon, A. Whipple, and R. Grossinger. 2008. An Introduction to the Historical Ecology of the Sonoma Creek Watershed: A Tool for Developing an Action Plan for the Critical Coastal Area Program. San Francisco Estuary Institute and Sonoma Ecology Center.

Ducks Unlimited, Inc. 2017. Skaggs Island Haire Ranch Subsidence Reversal Project. Bid Set 6/15/2017.

Ducks Unlimited, Inc. 2018. Skaggs Island Draft Existing Conditions Report. Prepared for USFWS.

Eddleman, W. R. and C. J. Conway (2018). Ridgway's Rail (*Rallus obsoletus*), version 2.1. In The Birds of North America (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY. https://doi.org/10.2173/bna.ridrai1.02.1.

Environmental Science Associates (ESA). 2018. Southern Sonoma County Stormwater Resources Plan. Prepared for Sonoma County Water Agency.

ESA. 2012. Lower Sonoma Creek Flood Management and Ecosystem Enhancement Plan. Prepared for California SCC and Sonoma County Water Agency.

Evens, J. G., G. W. Page, S. A. Laymon, and R. W. Stallcup. 1991. Distribution, Relative Abundance and Status of the California Black Rail in Western North America. The Condor, 93(4): 952-966.

Evens, J. and N. Nur. 2002. California Black Rails in the San Francisco Bay Region: Spatial and Temporal Variation in Distribution and Abundance. Bird Populations 6: 1-12.

Goals Project. 2015. The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California SCC, Oakland, CA.

Goals Project. 2000. Baylands Ecosystem Species and Community Profiles: Life histories and environmental requirements of key plants, fish, and wildlife. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. P.R. Olofson, Editor. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

Goals Project. 1999. Baylands Ecosystem Habitat Goals. A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. U.S. Environmental Protection Agency, San Francisco, CA/S.F. Bay RWQCB, Oakland, CA.

Grinnell, J., and A. H. Miller. 1944. The Distribution of the Birds of California. Cooper Ornithological Club. Pacific Coast Avifauna 27: 617pp.

Jones and Stokes Associates. 1979. Protection and Restoration of San Francisco Bay Fish and Wildlife Habitat. U.S. Fish and Wildlife Service and California Department of Fish and Game.

Kelly J. P., K. Etienne, C. Strong, M. McCaustland, and M. L. Parkes. 2006. Annotated Atlas and Implications for the Conservation of Heron and Egret Nesting Colonies in the San Francisco Bay Area. Audubon Canyon Ranch Technical Report 90-3-17.

Krone, R.B. 1979. Sedimentation in the San Francisco Bay System. San Francisco Bay: The urbanized estuary, edited by T.J. Conomos. (85-96). American Association for the Advancement of Science, San Francisco.

Leidy, R.A., G.S. Becker, and B.N. Harvey. 2005. Historical distribution and current status of steelhead/rainbow trout (*Oncorhynchus mykiss*) in streams of the San Francisco Estuary, California. Center for Ecosystem Management and Restoration, Oakland, CA.

Ganju, N. K., Schoellhamer, D. H., Warner, J. C., Barad, M. F., & Schladow, S. G. 2004. Tidal oscillation of sediment between a river and a bay: a conceptual model. Estuarine, Coastal and Shelf Science, 60(1), 81–90.

McKee, L. J., Ganju, N. K., and Schoellhamer, D. H. 2006. Estimates of suspended sediment entering San Francisco Bay from the Sacramento and San Joaquin Delta, San Francisco Bay, California. Journal of Hydrology, 323(1-4): 335-352.

Moyle, P.B. 2002. Inland fishes of California – Revised and Expanded. University of California Press, 2002.

National Marine Fisheries Service (NMFS). 2014. Recovery Plan of the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of the California Central Valley Steelhead. California Central Valley Area Office. July 2014.

North Bay Water Reuse Authority (NBWRA). 2018. North Bay Water Reuse Program. http://www.nbwra.org/. Accessed January 29, 2019.

Olofson Environmental, Inc. 2014. San Francisco Estuary Invasive Spartina Project, 2012 Progress Report. Prepared for California SCC.

Olofson Environmental, Inc. 2018. San Francisco Estuary Invasive Spartina Project, 2015-16 ISP Monitoring and Treatment Report. Prepared for California SCC.

Pierce, David., 2014. Statistical Downscaling Using Localized Constructed Analogs (LOCA). https://doi.org/10.1175/JHM-D-14-0082.1.

Raabe, A., R. Wadsworth, J. Scammell-Tinling, L. Cholodenko, C. Battistone, M. Nobriga, C. Enos. 2010. Suisun Marsh Tidal Marsh and Aquatic Habitats Conceptual Model, Chapter 4: Species.

Robinson, A., Fulfrost, B., Lowe, J., Nutters, H., Bradt, J. 2017. Transition Zone Mapping Methodology: Integrating the Bay Margin and Upper Boundary Methods. San Francisco Estuary Partnership, San Francisco Estuary Institute. September 2017.

San Francisco Estuary Institute (SFEI). 2009. Salt marsh harvest mouse database and maps. San Francisco Estuary Institute, Richmond, CA. https://www.sfei.org/content/salt-marsh-harvest-mouse-database-and-maps#sthash.pdof3vNI.dpbs.

SFEI-ASC. 2020 (in preparation). Marsh shoreline change, estuarine beach evolution, and lessons learned from San Francisco Bay beach habitat assessment (Part 1). A Report of SFEI-ASC's Resilient Landscapes Program, SFEI, Richmond, CA.

Shellhammer, H. and L. Barthman-Thompson. 2015. Science Foundation Chapter 5, Appendix 5.1 – Case Study, Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*). Bayland Ecosystem Habitat Goals Science Update. https://www.baylandsgoals.org.

Schoellhamer, D. H. 2011. Sudden Clearing of Estuarine Waters upon Crossing the Threshold from Transport to Supply Regulation of Sediment Transport as an Erodible Sediment Pool is Depleted: San Francisco Bay, 1999. Estuaries and Coasts, 34(5), 885–899.

Schoellhamer, D., L. McKee, S. Pearce, P. Kauhanen, M. Salomon, S. Dusterhoff, L. Grenier, M. Marineau, and P. Trowbridge. 2018. Sediment Supply to San Francisco Bay, Water Years 1995 through 2016: Data, trends, and monitoring recommendations to support decisions about water quality, tidal wetlands, and resilience to sea level rise. SFEI, Richmond, CA. SFEI Contribution Number 842.

Sommer, T.R., R.D. Baxter, and F. Feyrer. 2007. Splittail "delisting": a review of recent population trends and restoration activities. American Fisheries Society Symposium 53:25-38.

Sonoma Ecology Center. 2006. Understanding Sonoma Valley Watersheds: Steelhead and Salmon. Fact Sheet.

Sonoma Ecology Center, 2013. Understanding Sonoma Valley Watersheds – Steelhead and Salmon.

Sonoma Valley Groundwater Sustainability Agency. *In Progress.* Draft Groundwater Sustainability Plan for Sonoma Valley Groundwater Subbasin.

Sonoma Veg Map. 2017. Sonoma County Fine Scale Vegetation and Habitat Map. http://sonomavegmap.org/data-downloads/.

Sonoma Water. 2014. Sonoma Valley Groundwater Management Program Five Year Review and Update, March. http://sonomavalleygroundwater.org/wp-content/uploads/5-year-Review-and-Update-2014.pdf.

Southern Sonoma Resource Conservation District. 1997. Sonoma Creek Watershed Enhancement Plan.

Spautz, H. and N. Nur. 2002. Distribution and Abundance in Relation to Habitat and Landscape Features and Nest Site Characteristics of California Black Rail (*Laterallus jamaicensis coturniculus*) in the San Francisco Bay Estuary. Final Report to USFWS. Point Reyes Bird Observatory.

Spautz, H., N. Nur, and D. Stralberg. 2005. California Black Rail (*Laterallus jamaicensis coturniculus*) Distribution and Abundance in Relation to Habitat and Landscape Features in the San Francisco Bay Estuary. USDA Forest Service Gen. Tech. Rep. PWS-GTR-191.

State Route 37 – Baylands Group. 2017. San Pablo Baylands: Ensuring a Resilient Shoreline.

Swanson, K., Shellenbarger, G.G., Schoellhamer, D.H., Ganju, N.K., Athearn, N., and Buchanan, P.A., 2003, Desalinization, erosion, and tidal changes following the breaching of Napa salt pond 3: Proceedings of the 6th biennial State-of-the-Estuary Conference, Oakland, California, October 21–23, 2003, p. 156.

Takekawa, J. Y., Thorne, K. M., Buffington, K. J., Spragens, K. A., Swanson, K. M., Drexler, J. Z., Schoellhamer, D. H., Overton, C. T., & Casazza, M. L. (2013). Final report for sea-level rise response modeling for San Francisco Bay estuary tidal marshes. US Geological Survey.

Tsao, D. C., R. E. Melcer, Jr., and M. Bradbury. 2015. Distribution and Habitat Associations of California Black Rail (*Laterallus jamaicensis cortuniculus*) in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 13(4). https://escholarship.org/uc/item/6cn2h9tt.

URS Corporation. 2011. Final Napa-Sonoma Marshes Wildlife Area Land Management Plan. Prepared for CDFW.

USFWS. 2009. Biological Opinion: Formal Endangered Species Consultation on the Proposed Demolition of Structures at the Navy Installation on Skaggs Island, Sonoma County, California. USFWS reference no: 81420-2009-F-0309. 31 pp.

USFWS. 2011. San Pablo Bay National Wildlife Refuge Final Comprehensive Conservation Plan. Prepared by USFWS San Francisco Bay National Wildlife Refuge Complex.

USFWS. 2013a. San Pablo Bay National Wildlife Refuge. Accessed January 29, 2019. https://www.fws.gov/refuge/San_Pablo_Bay/resource_management.html.

USFWS. 2013b. Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California. Sacramento, California.

USFWS. 2019. Natural Resource Management Plan for the San Francisco Bay National Wildlife Refuge Complex. National Wildlife Refuge System, Pacific Southwest Region, Sacramento, CA.

USFWS. 2020. 2019 Activities Involving the California Ridgway's Rail at San Pablo Bay National Wildlife Refuge.

Valley Water, 2017. Preliminary Feasibility Study for South San Francisco Bay Shoreline Economic Impact Areas 1 - 10 Final Evaluation Report. Prepared for Department of Water Resource, Division of Flood Management, State of California.

Veloz, S., Wood, J., Jongsomjit, D., Block, G., and Robinson, K. F. 2016. San Pablo Bay National Wildlife Refuge Climate Adaptation Plan. USFWS.

Warner, J.C., Schoellhamer, D. and Schladow, G., 2003. Tidal truncation and barotropic convergence in a channel network tidally driven from opposing entrances. Estuarine, Coastal and Shelf Science, 56(3-4): pp.629-639.

WRA, Inc. 2015. Biological Resources Assessment, Skaggs Island Wetland Restoration. Prepared for Ducks Unlimited, Inc.

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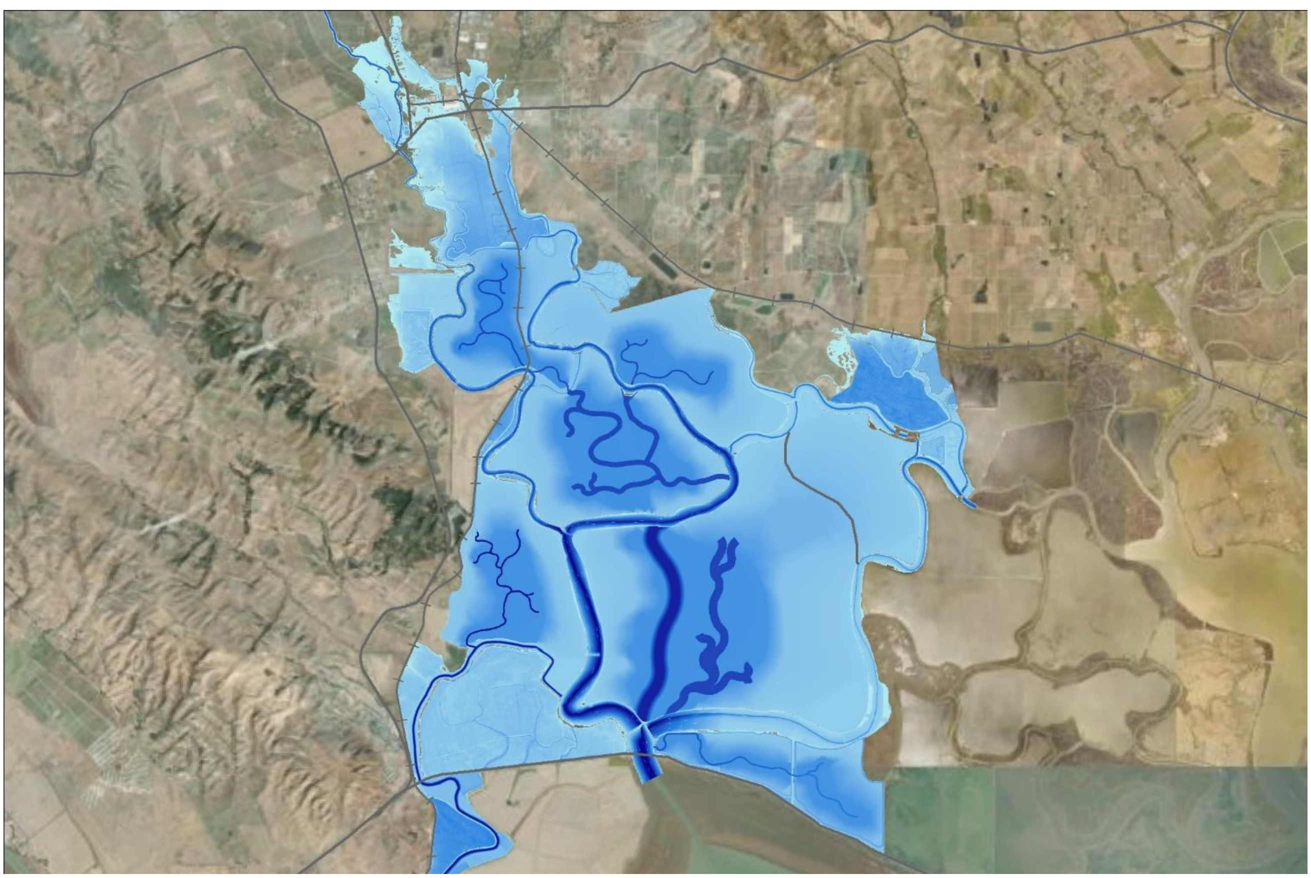
SONOMA CREEK BAYLANDS STRATEGY

Hydrodynamic modeling appendix

Prepared for
Sonoma Land Trust

January, 2020



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1 INTRODUCTION

The Sonoma Land Trust is developing the Sonoma Creek Baylands Strategy, a multi-benefit land management strategy that combines landscape-scale restoration, flood protection, and public access within the former tidal wetlands at the freshwater-saltwater interface between Sonoma Creek and San Pablo Bay. The strategy is focused downstream of Highway 121, where several large parcels which formerly supported tidal wetland habitat were historically leveed off and converted to agricultural use. A map of the project site and parcels under consideration for tidal restoration is shown in Figure 1. The site is also constrained by significant transportation infrastructure including Highway 37 which runs along the southern end of the Sonoma Creek Baylands, the Sonoma Marin Area Rail Transit (SMART) rail line which runs through several of the parcels, and Highway 121 which runs east-west along the north end of the Sonoma Creek Baylands and is near the fluvial-tidal interface. In recent years, the U.S. Fish and Wildlife, and California Department of Fish and Wildlife have acquired parts of the Baylands complex. This has presented the opportunity for restoring tidal inundation to the system, restoring thousands of acres of tidal marsh and wetland habitat, and improving flood conditions for local and upstream communities. The Strategy is being developed to assess long term potential restoration scenarios while accounting for constraints that are expected to persist into the future.

Three restoration scenarios were developed and analyzed for this project (Alternative 1) a maximum tidal restoration scenario, (Alternative 2) a restoration scenario constrained by existing landuse, infrastructure, and ownership, and (Alternative 3) a scenario reflecting significant tidal restoration with measures to minimize impacts to existing tidal marsh. These were compared to a No Action scenario without additional restoration. To support analysis of potential restoration scenarios, understand tradeoffs between scenarios, and inform restoration project components, ESA developed a hydrodynamic model of the Sonoma Creek Baylands system. The hydrodynamic model—a coupled one-dimensional/two-dimensional model—a was adapted from prior modeling conducted by ESA (formerly PWA, and ESA PWA). Hydrologic scenarios were identified to bracket key conditions for regular tidal inundation as well as extreme flood conditions. ESA calibrated the model to the New Year's Eve 2005 flood event— an approximately 1% annual chance event and the largest flood event on record for the system. The model was used to simulate the physical hydrologic processes of the site under current and proposed restored conditions, as well as current and future hydrology under climate change, to estimate key hydraulic parameters including depth, duration, and extent of flooding on- and off-site, channel velocities, residence time, and tidal circulation in the restored areas and existing channel network.

2 KEY FINDINGS AND CONCLUSIONS

ESA analyzed Baseline, No-action, and three restoration alternatives under a range of hydrologic scenarios. The results indicate that the larger-scale restoration scenarios have the potential to reduce peak flood stage as well as flood depth, extent, and duration in some areas. The key findings of the analysis include:

- For present day and future climate conditions hydrology, Alternatives 1, 2, and 3 result in decreased water level from Camp 2 downstream on Sonoma Creek and Schell Creek. Only Alternative 3 results in decreased stage on both Creeks upstream of Highway 121. Under No-action future conditions, peak stage is increased on both Sonoma Creek and Schell Creek.

- On Sonoma Creek at the north end of Camp 2, model results show a reduction in stage of 2.9, 3.3, and 4.4 ft for Alternatives 1, 2, and 3 respectively for a 1% chance flow with a typical tide. Immediately upstream of Highway 121, peak stage is reduced by 1.2’ for Alternative 3 for this event.

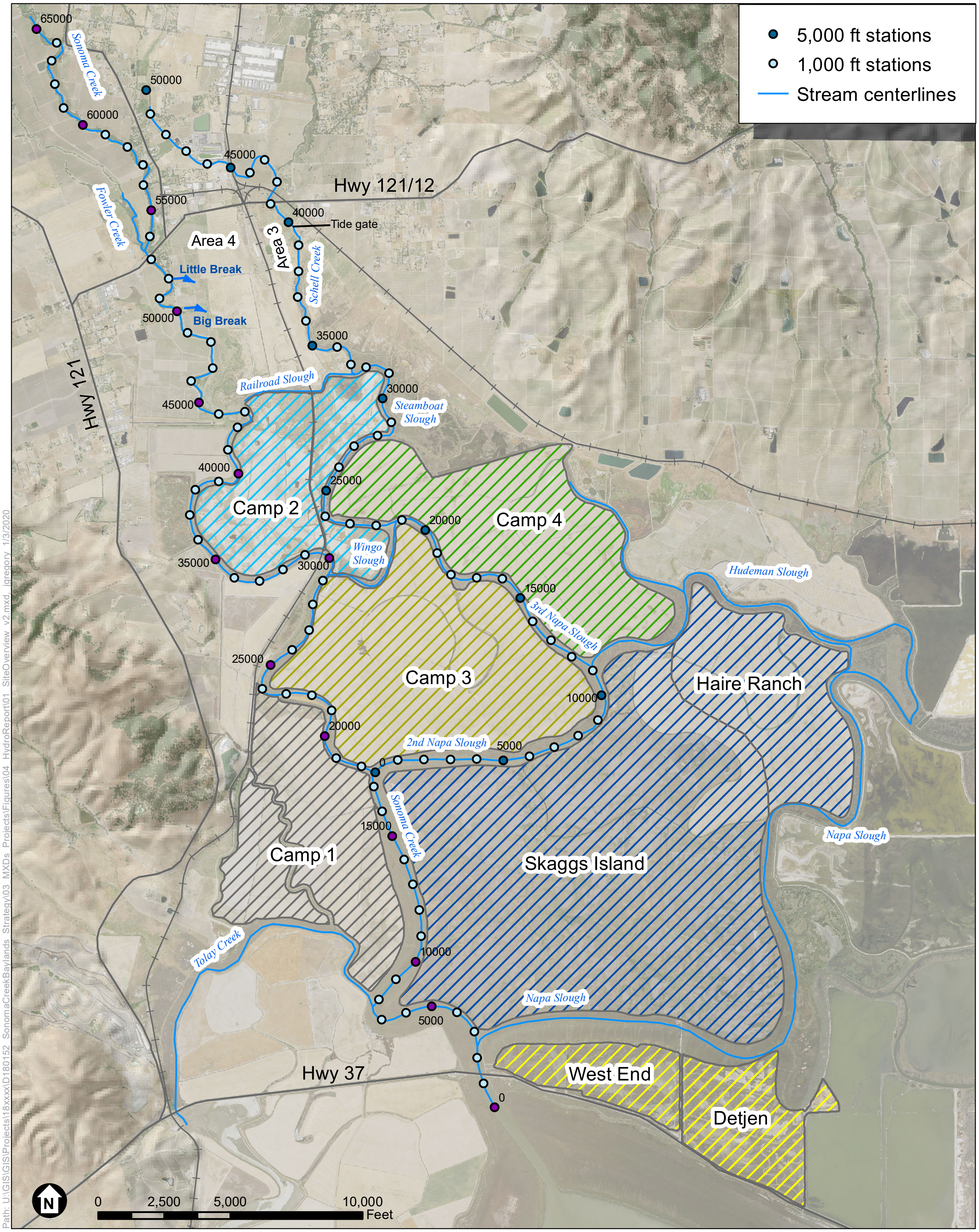
- Modeling of the No-action scenario suggests that for 2050 conditions, peak stage on Sonoma Creek increases by 0.9 ft at the north end of Camp 2 for a 1% chance flow with an elevated tide. Peak stage on Schell Creek increases by 1.0 ft at the tide gate and by 0.6 ft immediately upstream of Highway 121.

- Under existing conditions, out of bank flooding upstream of Highway 121 inundates approximately 500 acres. This area is reduced by 12 acres under Alternative 1, 10 acres under Alternative 2, and 50 acres under Alternative 3. Under the No-action scenario with future conditions hydrology, inundation increases by 9 acres.

- Average flooded depth is decreased upstream of Highway 121 for all Alternatives. Alternatives 1 and 2 reduce flood depth by 0.1 ft or more in 40% (~200 acres) of the flooded area upstream of the highway. Alternative 3 reduces flood depth in 90% (~400 acres) of this area.

- Flooding duration is significantly reduced under restored conditions in the floodplain area between Sonoma Creek and Schell Creek upstream of Camp 2. Ponded area which drains down from peak stage by 3ft in 50 hours under existing conditions, drains down by 7 ft in 33 hours under Alternative 3. At the intersection of Highway 121 and Highway 12, flooded depth is lower by a maximum of 0.7 ft and an average of 0.3 ft over the full 30-hour period of inundation.

- Channel velocities at the mouth of Sonoma Creek are increased by the increased tidal prism added for the restoration scenarios. Velocity is increased to a similar degree under the No-action scenario for which Skaggs is the only parcel breached. The breaching on Skaggs appears to drive much of this increase suggesting that modifying the location and size of the Skaggs breach, grading or filling Skaggs could help mitigate increased velocities at the mouth.



SOURCE: NAIP (2014 aerial imagery)

Sonoma Creek Baylands Strategy

Figure 1
Project site overview

ESA

3 PROJECT BACKGROUND

3.1 Hydrologic Setting

The Sonoma Creek watershed drains an area of approximately 170 square miles, originating from the northeast in the Mayacamas Mountains. The watershed drains the eastern slopes of the Sonoma Mountains and the western slopes of the Mayacamas Range. Major tributaries include Fowler Creek, Champlin Creek, Rodgers Creek, Felder Creek, Lewis Creek, Carriger Creek, Dowdall Creek, Asbury Creek, Yulupa Creek, Bear Creek, Calabazas Creek, Nathanson Creek, Schell Creek, and Arroyo Seco. The main stem of Sonoma Creek begins in steep mountainous terrain in the Mayacamas Range and flows westerly before reaching the valley floor, flattening out and passing through vineyards and into Kenwood. The creek then turns southerly, flowing through Glen Ellen and Eldridge and, eventually, the City of Sonoma where the creek is relatively urbanized. Downstream of the City of Sonoma, the Creek passes through large vineyard parcels before passing under Highway 121 where it joins the Napa-Sonoma Marsh complex. Here the channel substantially flattens out and becomes increasingly uniform in shape and meandering as conditions change from being fluvially to tidally dominant. The Creek flows along the western perimeter of Camp 2 before flowing under a railroad crossing near the inlet to Wingo Slough. Downstream of Wingo Slough, the Creek runs along the western perimeter of Camp 3 before joining Napa Slough where the channel substantially enlarges (from approximately 30-feet to 150-feet top width) and continues along the western perimeter of Skaggs Island. The channel continues to increase in size and eventually passes under Highway 37 as it flows into the northern edge of San Pablo Bay—a northern portion of the San Francisco Bay.

The project site and contributing watershed has cool, wet winters and very dry summers with most precipitation falling between the months of December and March each year. Average annual rainfall is 39.5 inches and ranges from 47.9 inches in the headwaters to 25.8 inches near the mouth of the Creek (PRISM, 2012).

In 2008, ESA (as PWA) conducted a hydrologic modeling analysis to characterize flow statistics for Sonoma Creek and its tributaries (PWA, 2008). A summary of peak flow statistics from this analysis for Sonoma Creek at Agua Caliente is provided in Table 1. From this analysis, it was estimated that the design 1% annual chance flow on Sonoma Creek at Agua Caliente is 20,663 cfs. Further downstream at Highway 121, the upstream boundary of the project site, the peak 1% annual chance flow on Sonoma Creek and Schell Creek is 24,360 and 3,100 cfs respectively.

Table 1. Peak flow statistics on Sonoma Creek based on modeled and observed data

Return Period (years)	Existing Peak Discharge (cfs)	Future Peak Discharge (cfs)	Updated Bulletin 17B Peak Discharge (cfs)
2	2,654	2,913	4,697
10	10,055	10,643	10,460
25	13,905	14,607	13,000
100	19,821	20,663	16,170

During flood events, flows passing under Highway 121 on Sonoma Creek break out in two low points along the left bank. The upstream and downstream breakout locations are referred to as Little Break (STA 520+00) and Big Break (STA 500+00) respectively. Little Break is a low point in the bank which is regularly repaired after large flood events. The breakout from Big Break is more formalized and discharge is conveyed in a channelized section to the east of Sonoma Creek. The overflows from Sonoma Creek upstream of Camp 2 flow easterly into adjacent vineyard and are impounded north of the berms along Railroad Slough. Schell Creek also breaks out in several locations on both the east and west sides. Flow from the western side of Schell Creek is similarly impounded by the Railroad Slough berms. An existing rail line runs north-south through this area separating overbank flows from Sonoma Creek and Schell Creek. During large flood events, such as the New Year's Eve flood of 2005, this railroad washes out in several places and is later repaired. Flow to the east of Schell Creek floods a significant area of existing agricultural land.

The levees along Camp 2 have failed in large flood events including the NYE 2005 event as well as a large flood which occurred in late February, 2019. The levees along Camp 4 are low enough such that this parcel also flooded during those events. Camp 1 experienced a moderate degree of flooding during the NYE 2005 event. Some degree of flooding is observed on Skaggs Island during these types of large floods which is likely a combination of inflooding and, potentially, minor overtopping. No significant tidal breaches have formed on this parcel. Camp 3 has not flooded during these events.

3.2 Project scenarios

ESA used the model to evaluate a range of landscape conditions (restoration scenarios) and hydrologic conditions. Landscape and hydrologic conditions were evaluated for present day and year 2050 conditions.

3.2.1 Alternative Conditions Scenarios

Five alternative conditions scenarios were evaluated.

1. Baseline conditions – Baseline conditions reflects site conditions under current management of the project site. For this condition, it was assumed that all levees around existing parcels are intact at elevations reflected in the 2014 Sonoma County LiDAR topographic dataset (Sonoma County, 2014). Baseline conditions provide a point of reference for existing conditions and for comparison with known historic flood events.
2. No Action conditions - The No Action scenario reflects conditions with assumed foreseeable changes in the absence of new large-scale wetland restoration. For this scenario, it was assumed that, due either to intentional intervention or levee degradation, Skaggs Island is fully tidal. Levees included in the restoration alternatives (below) to protect private land on the east side of Schell Creek and west side of Sonoma Creek were assumed in place. All other locations were expected to be maintained at present conditions as reflected in the 2014 LiDAR. The Sonoma Creek channel downstream of

Skaggs Island was assumed to be scoured to accommodate the additional tidal prism from Skaggs.

3. Alternative 1 – This alternative represents a broad scale tidal restoration condition for the project site. The alternative assumes that Skaggs Island and Camps 1-4 are fully tidal. Levees along Railroad Slough were removed to allow conveyance from Sonoma Creek into Camp 2 and downstream areas. Additionally, levees along the right bank of Schell Creek north of Camp 2 were removed to allow floodwater to escape this channel earlier than current conditions and reduce water levels in Schell Creek. Levees along Wingo Slough were removed to increase flow exchange from Camp 2 to Camp 3 for fluvial and tidal conditions. The Camps 1-4 and Skaggs Island parcels were assumed to be filled to a mix of habitat elevations from mudflat to low to high tidal marsh. It was assumed that the channel network had adjusted to the additional tidal prism from the restored parcels.
4. Alternative 2 – This alternative represents less tidal restoration and less fill in the restored parcels. The purpose of this alternative was to evaluate a condition that has less impact on existing infrastructure and would require less imported fill to construct. Under this alternative, the Railroad Slough berms are left intact, as is the right (west) levee on Schell Creek upstream of Camp 2. The portion of Camp 2 west of the Railroad is not restored to tidal action while the portion to the east is. Camp 4 is left at current conditions and is not restored to tidal action. It was assumed that the channel network had adjusted to the additional tidal prism from the restored parcels.
5. Alternative 3 – This alternative represents a modification of Alternative 1 with the primary conveyance in the system for tidal and fluvial flows routed through Camp 2, Camp 3, and Skaggs Island. The Railroad Slough berms are removed for this alternative. Levee breaches and tidal channels in Camps 1-4 and Skaggs Island allow tidal action in those parcels. This alternative is configured to protect existing marsh habitat in the channel network by focusing flow and tidal prism in newly graded channels rather than scouring the existing channels. It was assumed that the mouth of Sonoma Creek had scoured to accommodate the increase in tidal prism under this alternative. All other channels were assumed to match baseline conditions.

3.2.2 Hydrologic Scenarios

Three hydrologic scenarios were selected to bracket the range of conditions relevant to assessing the hydraulic impact of restoration scenarios. The hydrologic scenarios reflect various combinations of tidal conditions and streamflow in the primary channels. The hydrologic scenarios include:

1. 1% annual chance flow, typical tides – This scenario reflects a large flood from the Sonoma Creek watershed and a tide signal ranging between typical mean higher-high water (MHHW) and mean lower-low water (MLLW). This scenario reflects was included to bracket the effect of the alternatives on a large flood in the absence of an elevated tide.
2. 1% annual chance flow, storm surge tide – This scenario reflects a large flood condition coincident with an elevated tide level in San Pablo Bay. This captures extreme flow and tide conditions at the site.

3. 1% annual chance flow at 2050, storm surge tide with 2050 sea-level rise – This scenario reflects extreme fluvial and coastal flooding including future climate change impacts on precipitation and sea-level.

The peak flows on Sonoma Creek and Schell Creek and the peak tide level for each of these scenarios is summarized in Table 2.

Table 2. Peak flows and tide levels for hydrologic scenarios

Time period	Hydrologic scenario	Peak flow (cfs)		Peak tide (ft NAVD)	Short ID
		Sonoma Creek	Schell Creek		
Present day	1% annual chance flow, typical tides	24,360	3,100	6.7	1% flow, typical tide
	1% annual chance flow, storm surge tide			9.2	1% flow, elevated tide
2050	2050 1% annual chance flow, storm surge tide + 2050 sea-level rise	27,100	3,400	11.1	2050 1% flow, elevated tide w/SLR

In addition to these 1% flood scenarios, a typical tide condition with base flow was modeled for existing and w/SLR conditions to assess parcel inundation extents and tidal muting under typical tidal cycles with background watershed flow contribution.

The 2050 hydrologic scenarios reflect assumptions for the influence of climate change on coastal water levels and future rainfall intensity. The approach and assumptions made in characterizing climate change impacts to these variables are summarized in the following section.

3.2.2.1 Climate change analysis

Climate change impacts to sea-level rise and watershed hydrology were characterized for mid-century (2050) conditions. Sea-level rise increases were based on California statewide guidance (OPC, 2018). This guidance provides sea-level rise estimates for various risk scenarios. The highest risk scenario is appropriate for critical infrastructure, however, given that the landuse at the current site is primarily agricultural it was assumed that a medium-high risk scenario was appropriate. For this category, the estimated increase in sea-level by 2050 is 1.9 ft.

For future conditions, discharge, downscaled rainfall data was used as input to the hydrologic model developed by PWA for estimating design discharges. Climate model data developed as part of the International Governmental Panel on Climate Change's fifth Assessment Report has been downscaled to more regional scale information by various research agencies. The latest California statewide Climate Assessment report utilized datasets created by researchers at Scripps which has been downscaled to 6km x 6km grid cells of daily climate data from 1950 to 2100 (Pierce, 2014) covering the conterminous United States. ESA used extreme value analysis with the daily rainfall totals from this dataset to estimate rainfall depths for the 1% annual chance event at 2050. The 2050 1% annual chance rainfall was estimated in this way for a medium-high emissions scenario (RCP 8.5). The climate grids overlaid with the watershed model subbasins is shown in Figure 2.

Statewide guidance on scenario selection for climate change by the CA Department of Water Resources (DWR, 2015) recommends using this emissions scenario at mid-century when most of the scenarios are undifferentiated. Data from 29 climate models was processed to generate an estimate of future design rainfall. Using this methodology, an average increase of 7% over the Sonoma Creek Watershed was estimated for 2050. This value reflects an average over all climate models and the standard deviation among models was 16%.

The rainfall depth for the 2050 1% annual chance event was increased by 7% and run through the hydrologic model for the Sonoma Creek watershed. The peak flow increased by 11% from 24,360 to 27,100 cfs.

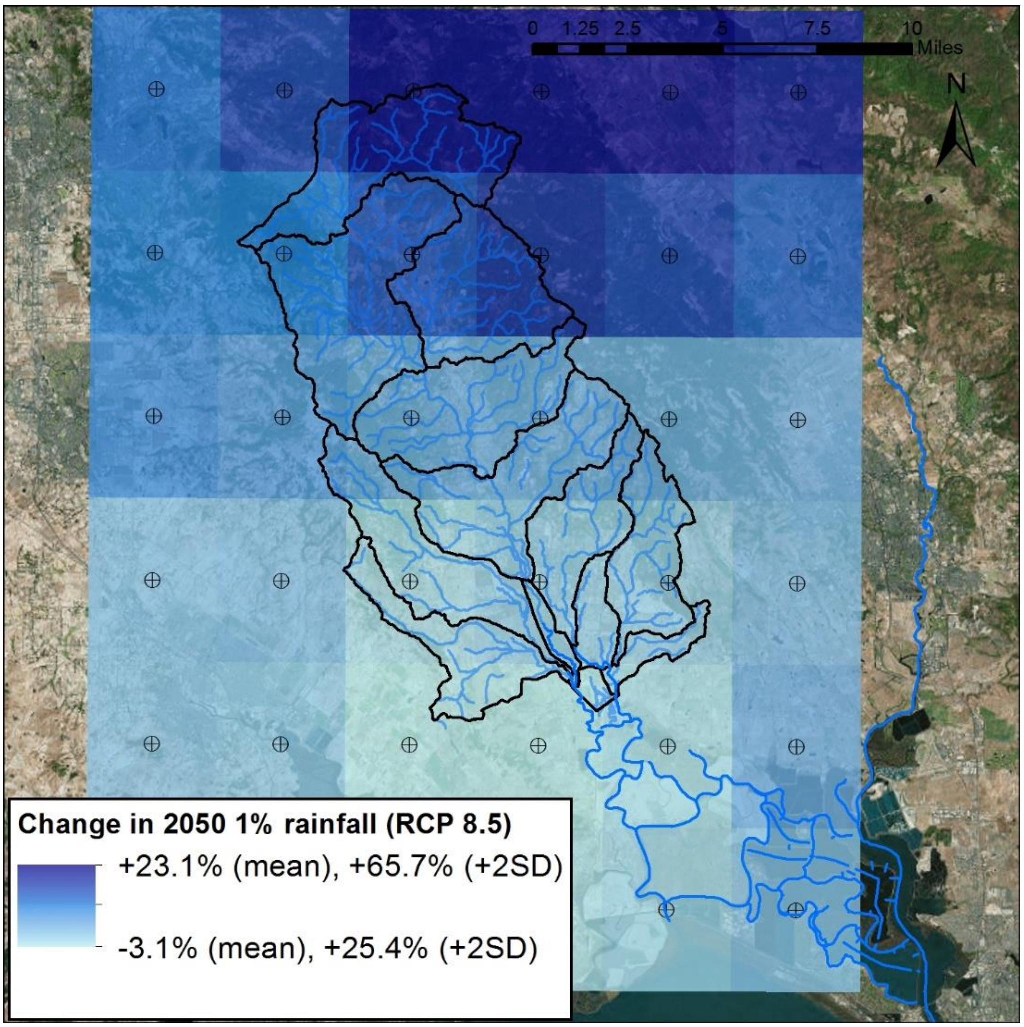


Figure 2. Map of climate change grid cells and hydrologic model subbasins

4 HYDRODYNAMIC MODEL DEVELOPMENT

A coupled one-dimensional/two-dimensional (1D/2D) hydrodynamic model was developed to analyze the range of landscape and hydrologic scenarios for this project. The model was adapted from a prior model developed by ESA (as PWA) in 2008, and updated in 2012 (ES PWA, 2012). Several refinements were applied to the original model as described in the following sections.

4.1 Software package

The original ESA PWA model was constructed using the MIKE-FLOOD modeling software by DHI. The MIKE-FLOOD model was converted to TUFLOW (Two-dimensional Unsteady FLOW), a depth-averaged, one and two-dimensional surface flow model by the model developers. ESA selected TUFLOW for its ability to model both flood and tidal flows, its computational speed, and its simple file structure that allows the modeler to easily iterate between model scenarios.

The TUFLOW HPC (Heavily Parallelized Compute) solver allows for high speed execution of model runs, significantly reducing run times. The HPC solver uses full one-dimensional (1D) free surface St Venant flow equations.

4.2 Elevation data

All elevations are vertically referenced to the North American Vertical Datum of 1988 (NAVD88) and are stated in feet unless otherwise specified. A recent high-resolution LiDAR dataset covering Sonoma County was surveyed in 2014. ESA replaced the topography in all overbank areas in the 2D model domain with this dataset to reflect the latest ground conditions and improve the accuracy of the floodplain data. Cross-section data for all areas above the tidal channel in the 1D model domain was also replaced with 2014 LiDAR data.

Additionally, ESA conducted one day of field reconnaissance and topographic survey (March, 2019) to validate the LiDAR and existing cross sectional survey data in key locations where breakouts are known to occur and where the LiDAR survey may have been obscured by vegetation. ESA surveyed the breakout locations known as 'little break' and 'big break' and incorporated the surveyed data into the model to ensure the elevations here were captured correctly.

4.3 Two-dimensional domain

ESA expanded the downstream extent of the 2D model domain from Camp 3 to the Bay in order to capture floodplain hydraulics for Skaggs Island, Camp 1, West End, Detjens, Tolay Creek and other adjacent areas. Topographic data was updated with the 1-meter grid resolution Sonoma County LiDAR dataset (2014) sampled to 5-meters for the entire model domain. The Sonoma

County LiDAR did not cover a few areas of the 2D model domain including the mouth of Tolay Creek. The topography for these areas were updated using a 5-meter grid resolution corrected LiDAR dataset for vegetation published by NOAA (Buffington, *et. al.*, 2019).

In addition, elevations of areas with known overbank breakouts and levees were updated. Elevation data for Little Break and Big Break were added to the two-dimensional domain as breaklines.

In addition to updating the topography, ESA updated the computation mesh settings, including decreasing the mesh cell size from a 15-meter to 5-meter grid. This increase reflects an increase in the model resolution by nine times.

Surface roughness was updated using data from uniform to varied using land use data from the Sonoma County Vegetation Map (citation). Values for manning's n roughness values are summarized in Table 3.

Table 3. Manning's roughness values

Land Use	Manning's n
No Data	0.03
Annual Cropland	0.06
Barren	0.04
Deciduous Forest	0.1
Developed, low intensity	0.06
Forest and Woodland	0.1
Herbaceous	0.08
Herbaceous Wetland	0.1
Intensively Managed Hayfield	0.045
Orchard	0.08
Pasture	0.06
Roads	0.022
Shrub/shrub	0.08
Sparsely vegetated salt marsh	0.06
Sparsely vegetated wetland	0.08
Vineyard	0.08
Water	0.035

4.4 One-dimensional domain

All existing conditions cross sections within the 1D/2D domain were modified to include the overbank terrain from LiDAR from levee to levee. The low flow channel from the MIKE model was preserved and spliced into cross sections derived from the LiDAR terrain. The channel roughness was maintained at 0.03. Alternative conditions channel dimensions were represented based on hydraulic geometry equations after Williams *et al* (2002) relating tidal prism (i.e. storage volume between mean lower-low water and mean higher-high water) and cross-sectional area, top width, and average depth below ground surface. This was implemented in the channel network for Alternatives 1 and 2 for all channels, and just at the mouth of Sonoma Creek for Alternative 3 and the No-action scenario.

4.5 Boundary conditions

The flow and tide time series' applied for the three hydrologic scenarios are shown in Figure 3. Discharge data for the Sonoma Creek watershed was derived from modeling conducted previously by ESA (as PWA) (PWA, 2004). Inflow locations on Sonoma Creek include Sonoma Creek at Watmaugh Road, Fowler Creek at Highway 121, and Schell Creek at Highway 121. Inflow locations on the Napa River include Oak Knoll Avenue, downstream of Milliken Creek, downstream of Napa Creek, downstream of Tulucay Creek, and downstream of Carneros Creek. Typical tidal conditions were derived from tide gage data for previous modeling by ESA (ESA PWA, 2012).

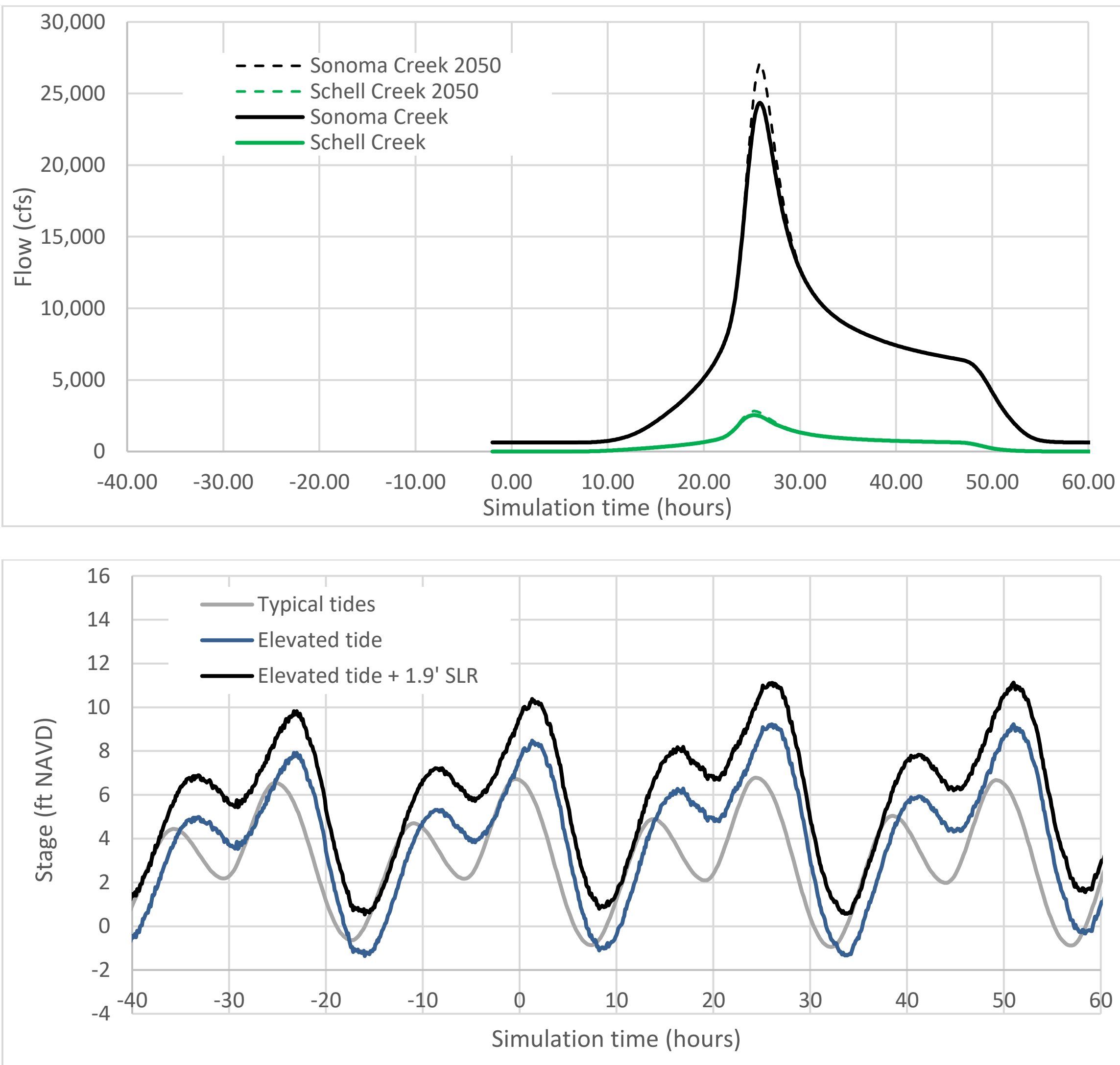


Figure 3. Discharge and tide boundary conditions for present and future hydrologic scenarios

5 MODEL RESULTS AND DISCUSSION

The model was used to evaluate the range of site conditions including no-action and each of the project alternatives, under typical tides, joint fluvial-tidal flooding, and both these conditions with climate change impacts on sea-level and extreme streamflow. Key hydraulic variables including peak flood stage, maximum inundation, flood duration, channel velocities, and discharge were extracted from the model for each of these scenarios. This section summarizes the results of the modeling.

5.1 Flood impacts

5.1.1 Peak stage

Maximum water surface elevation profiles for each alternative for the 1% flow, typical tides scenario are shown in Figure 4 and Figure 5 for Sonoma Creek and Schell Creek respectively. For the 1% flow, elevated tide scenario, profiles are shown in Figure 6 and Figure 7, and for the 2050 1% flow, elevated tide with SLR scenario, in Figure 8 and Figure 9 for Sonoma Creek and Schell Creek respectively. The change in water surface elevation at key locations for both creeks under these flow scenarios is summarized in Table 4.

Table 4. Change in peak water surface elevation for alternatives relative to existing conditions

Location	1% flow, typical tide			1% flow, elevated tide			2050 1% flow, elevated tide w/SLR[1]			
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3	No-action
Sonoma Creek										
Immediately U/S of Hwy 121	0.0	0.0	-1.2	0.0	0.0	-1.2	0.0	0.0	-1.2	0.0
Big Break	-0.1	-0.1	-1.6	-0.1	-0.1	-1.6	-0.1	-0.1	-1.6	0.0
Northwest Corner of Camp 2	-2.9	-3.3	-4.1	-2.2	-2.0	-2.7	-1.1	-1.0	-1.3	0.9
Wingo Slough	-1.5	-2.1	-2.0	-0.6	-0.5	-0.5	0.7	0.8	1.0	0.3
2nd Napa Slough	-0.9	-0.6	-0.7	-0.2	-0.1	-0.2	0.9	1.0	1.2	0.2
Mouth of Channel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Schell Creek										
Immediately U/S of Hwy 121	-0.4	-0.2	-0.3	-0.4	-0.2	-0.3	-0.3	-0.1	-0.2	0.6
Tide gate	-2.7	-0.9	-2.9	-2.3	-0.8	-2.2	-1.4	-0.6	-1.2	1.0
Junction with Steamboat Slough	-3.8	-1.3	-3.1	-2.9	-1.1	-2.2	-1.7	-1.0	-1.1	0.7
Junction with 3rd Napa Slough	-2.6	-1.9	-2.2	-0.8	-0.5	-0.5	0.6	0.7	1.0	0.3
Junction with 2nd Napa Slough	-1.5	-1.2	-1.3	-0.3	-0.2	-0.1	1.0	1.1	1.5	0.4
Junction with Sonoma Creek	-0.8	-0.6	-0.7	-0.2	-0.1	-0.2	0.9	1.0	1.2	0.2

[1] For the 2050 scenario, Existing and No-actions model results do not behave as anticipated. Affected results are shown in grey text. Specifically, peak stage does not persist upstream from the mouth of

Sonoma Creek at the max tide level of 11.1 ft NAVD. However, results are included for these runs for the purposes of completeness and transparency.

For Alternative 1, the water surface elevation on Sonoma Creek is lowered downstream of Big Break. Upstream of here, the peak water surface merges with existing conditions. However, inundation in the Sonoma Creek overbanks is reduced moderately. On Schell Creek, water surface is reduced downstream of Highway 121 but peak water levels remain unchanged upstream of the road crossing.

For Alternative 2, the water surface elevation on Sonoma Creek is lowered downstream of Camp 2 but increases slightly between Camp 2 and Big Break. This is a result of constraining flow on both Schell Creek and Sonoma Creek between raised levees without compensating by increasing conveyance across Railroad Slough as included in the other alternatives. Upstream of Big Break, the peak water surface merges with existing conditions. However, inundation in the Sonoma Creek overbanks is reduced moderately. On Schell Creek, water surface is reduced downstream of Highway 121 but peak water levels remain unchanged upstream of the road crossing.

For Alternative 3, the water surface elevation is lowered on Sonoma Creek from the mouth to approximately 1 mile upstream of Highway 121 under typical tides. Under higher tide levels, water surface for this alternative merges with existing conditions upstream of the mouth, however, the reductions upstream of Highway 121 persist. On Schell Creek, water surface is reduced downstream of Highway 121 and peak water levels are slightly lower than existing conditions upstream of the road crossing.

For the No-action alternative, water levels on Sonoma Creek are increased from Big Break to midway through Camp 2 for the 2050 1% flood. Upstream of Big Break, water levels are not changed. On Schell Creek, water levels are increased from Camp 2 to the upstream end of the model. This increases flood extent and depths upstream of Highway 121. This suggests that future flooding would worsen for large floods under the No-action scenario considered for this analysis.

5.1.2 Inundation depth

The result of change in peak stage is reflected in inundation depths in flooded areas outside of the main channels. Change in maximum depth relative to Existing Conditions for the three hydrologic scenarios and three restoration scenarios for areas upstream of Camp 2 in Figure 10 to Figure 18. Results for the No-action scenario are shown in Figure 19. Decreases in inundation depth are shown in green color bands and increases in yellow to red. Change between -0.1 and 0.1 ft is shown in grey to screen out the effect of minor perturbations in the model results. All alternatives result in some reduction in inundation depth upstream of Highway 121, however, Alternative 3 generates the most widespread reductions with over 400 of the 500 acres flooded reduced by 0.1ft or more. The No-action alternative raises water levels along Sonoma Creek and Schell Creek resulting in increases north of Camp 2 as well as upstream of Highway 121 around Schell Creek. A summary of the area for which depth is increased or decreased by 0.1ft upstream of Highway 121 for each of the alternatives and No-action is included in Table 5.

Table 5. Area (ac) upstream of Highway 121 changed by >0.1 ft relative to existing conditions

	Hydrologic scenario	No-action	Alt 1	Alt 2	Alt 3
Area with depth reduction	1% flow, typical tide	-	196	193	410
	1% flow, elevated tide	-	196	193	409
	2050 1% flow, elevated tide w/SLR	0	196	190	410
Area with depth increase	1% flow, typical tide	0	0	17	1
	1% flow, elevated tide	0	0	36	2
	2050 1% flow, elevated tide w/SLR	86	9	56	1

As this table indicates, the depth reduction for Alternatives 1 and 2 reduce is comparable—covering around 40% of the flooded area. For Alternative 3, the depth reduction covers approximately 90% of the total flooded area. Under the No-action scenario, flood depth is increased for approximately 20% of the flooded area. Depth increases are observed for significant areas under Alternative 2 and some minor increases are observed under Alternative 3. This suggests that minor landscape modifications may be required to eliminate any increase in flooding while achieving the significant flood reductions accomplished under Alternative 3.

5.1.3 Inundation extent

The maximum flood extents for Existing Conditions, No-action, Alternative 1, Alternative 2, and Alternative 3 are shown for the three flow scenarios in Figure 20 to Figure 23. The inundation plots show that significant areas are removed from flooding to the east and west of the restored parcels for all alternatives. The area west of Sonoma Creek near the Sonoma Valley Airport is removed from flooding until 2050. Additionally, the area east of Schell Creek and north of Camp 2 along several vineyards is excluded from flooding in all alternatives and all hydrologic scenarios. The area north of Camp 1 and west of the railroad is removed from flooding for all alternatives and all hydrologic scenarios. The total flooded area upstream and downstream of Highway 121 is summarized in Table 6.

Table 6. Peak flooded area (ac) for all alternatives

	Upstream of State Highway 121			Downstream of State Highway 121		
Scenario	1% flow, typical tide	1% flow, elevated tide	2050 1% flow, elevated tide	1% flow, typical tide	1% flow elevated tie	2050 1% flow, elevated tide
Existing conditions	502	502	502	5,402	8,875	13,640
No-action	N/A	N/A	511	N/A	N/A	13,526
Alt 1	490	490	491	9,984	11,426	14,387
Alt 2	492	492	492	9,926	11,498	14,024
Alt 3	452	452	452	10,562	12,593	14,532

The table shows that upstream of Highway 121, the peak flooded area is reduced under Alternative 1 by 12 acres, by 10 acres under Alternative 2, and by 50 acres under Alternative 3. Under the No Action alternative for future conditions hydrology, inundation increases by 9 acres.

Downstream of Highway 121, peak inundation is increased significantly relative to existing conditions as a result of restoring currently leveed parcels to tidal action. Thus, though some areas are fully removed from flooding under the restoration alternatives, peak inundation increases by 2,510 acres, 2,570 acres, and 3,700 acres downstream of Highway 121 for Alternatives 1, 2, and 3 respectively.

5.1.4 Inundation duration

In addition to peak inundation benefits accorded by the restored scenarios, inundation duration is significantly reduced in areas both upstream and downstream of Highway 121. Water level time series at an overbank location in Area 4 just north of Railroad Slough and on Highway 12 at Highway 121 are shown in Figure 24 and Figure 25 respectively.

In Area 4, flows leaving Sonoma Creek to the east and Schell Creek to the west pile up in Areas 3 and 4 north of the berms along Railroad Slough. Under existing conditions, this area is not tidal, and is only inundated periodically by high streamflows. With the railroad slough berms removed (Alternative 1 and 3), the area becomes fully tidal and would be inundated during high tide; however, during a large flood event, the area would also drain much more quickly and peak water levels would be significantly reduced. Under Alternative 3, water level peaks at 11.1 ft NAVD and drops to 3.9 ft after 33 hours while under Existing Conditions, water level peaks at 13.3 ft and only drops to 10.3 ft after 51 hours. The simulation does not continue past this point; however, water levels are known to persist for several weeks in these areas after a flood event. Alternatives 1 and 3 substantially lower the peak water level in Area 4 by 2.6 and 2.0 ft respectively for the 1%, elevated tide scenario. Due to increased conveyance capacity for tidal flows, Alternative 3 has a slightly higher peak than Alternative 1 but also drains more rapidly and more completely. Alternative 2 increases water levels in this scenario by 0.6 ft in this area as the raised railroad constrains overflows from Sonoma Creek.

Upstream of the Highway 121 crossing with Sonoma Creek, at the Hwy 12 and Hwy 121 intersection, Alternatives 1 and 2 closely match Existing Conditions with a slightly lower peak and similar drawdown timing while Alternative 3 has a significantly lower peak and drains down more rapidly. At peak stage, Alternative 3 is 0.7 ft lower than Existing Conditions and is lower by an average of 0.3 ft for the full 30-hour period during which this location is inundated. Alternatives 1 and 2 decrease peak water levels by 0.2 ft with an average decrease of 0.05 over the 30-hour inundation period.

5.2 Channel Velocities

By opening tidal action to the currently leveed parcels and adding new tidal prism, the restoration alternatives have the potential to influence channel velocities. Plots of velocity at the mouth of Sonoma Creek over the simulation for the three hydrologic scenarios are shown in Figure 26 to Figure 28. Positive velocity represents flow downstream towards the bay, and negative velocity represents flow from the Bay upstream. These plots show that typical and maximum velocities are increased relative to Existing Conditions for all alternatives and the No-action scenario.

Alternative 3 reflects the largest increase in velocities. Peak velocity for the 2050 1% flow, elevated tide w/SLR scenario increases by 3.4 ft/s for the No-action scenario, 4.0 ft/s for Alternative 1, 3.8 ft/s for Alternative 2, and 5.2 ft/s for Alternative 3 respectively.

The No-action velocity time series matches fairly closely with Alternatives 1 and 2. Given that the only area breached under No-action is Skaggs Island, this suggests that the additional prism in Skaggs accounts for much of the velocity increases for the alternatives. This suggests that the size and location of breaches on Skaggs Island should be further analyzed to evaluate options for mitigating velocity impacts. Other options for mitigation may involve reconfiguring the Highway 37 crossing over Sonoma Creek. The hydrodynamic model would provide a valuable tool for designing a modified Highway crossing to accommodate future site conditions.

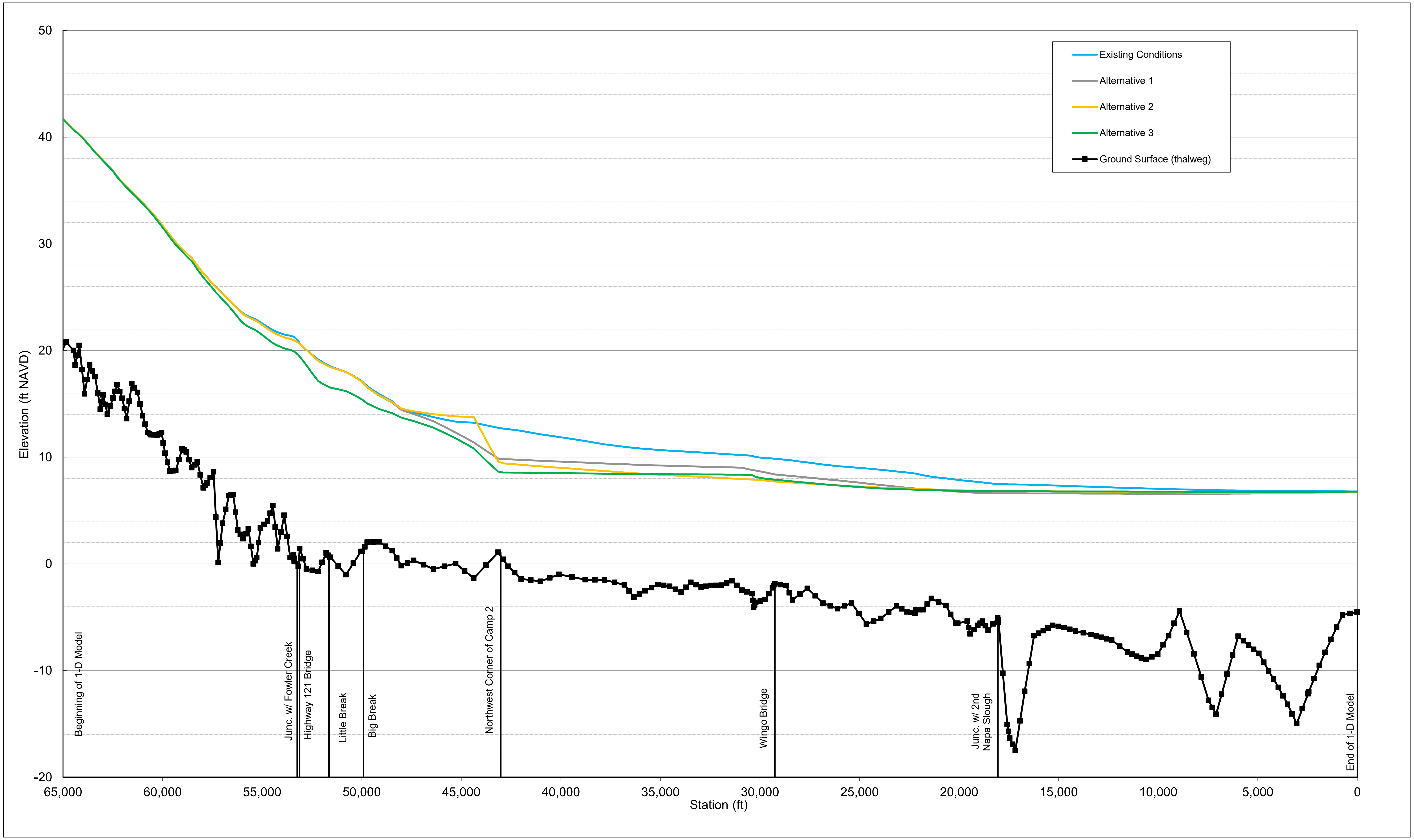
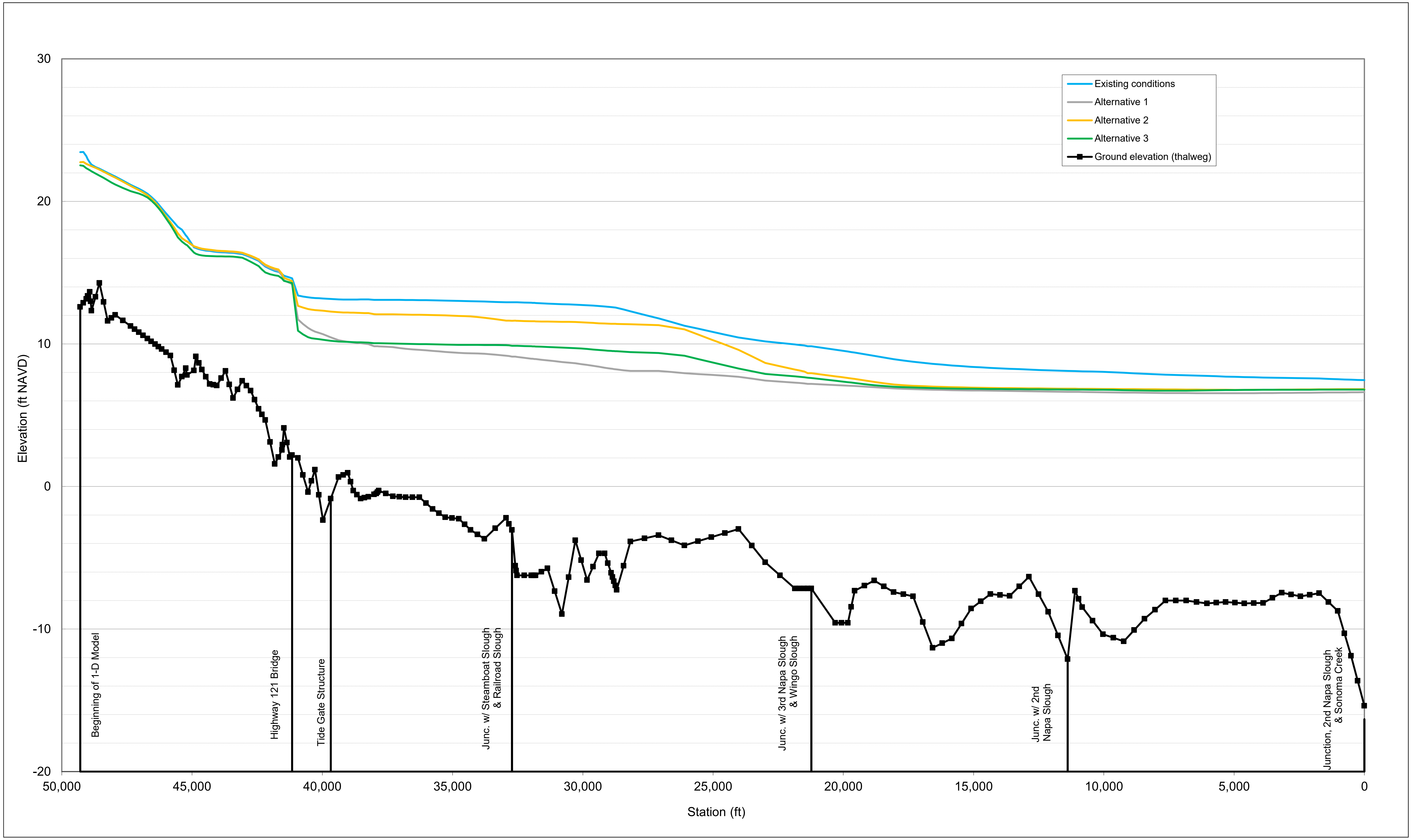


Figure 4

Sonoma Creek water surface profiles
1% flow, typical tide

ESA



Lower Sonoma Creek Strategy. D180152.01

Figure 5

Schell Creek water surface profiles
1% flow, typical tide

ESA

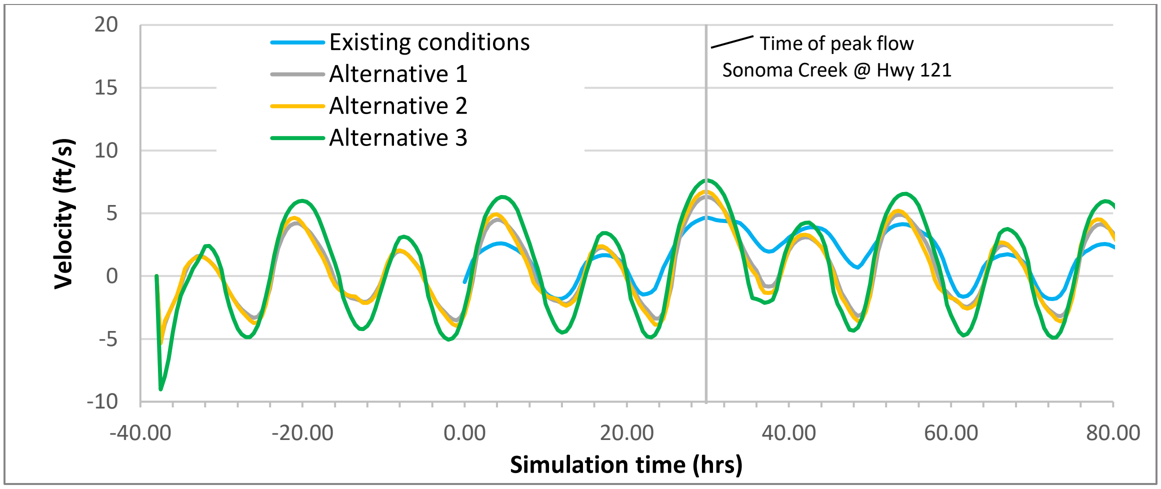


Figure 26. Velocity time series comparisons for all alternatives. 1% flow, typical tide.

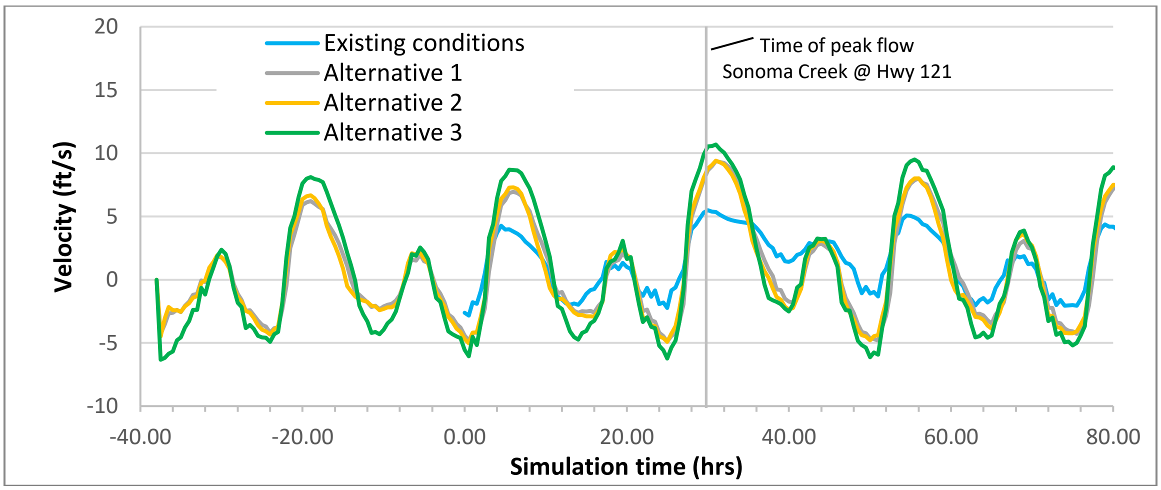


Figure 27. Velocity time series comparisons for all alternatives. 1% flow, elevated tide.

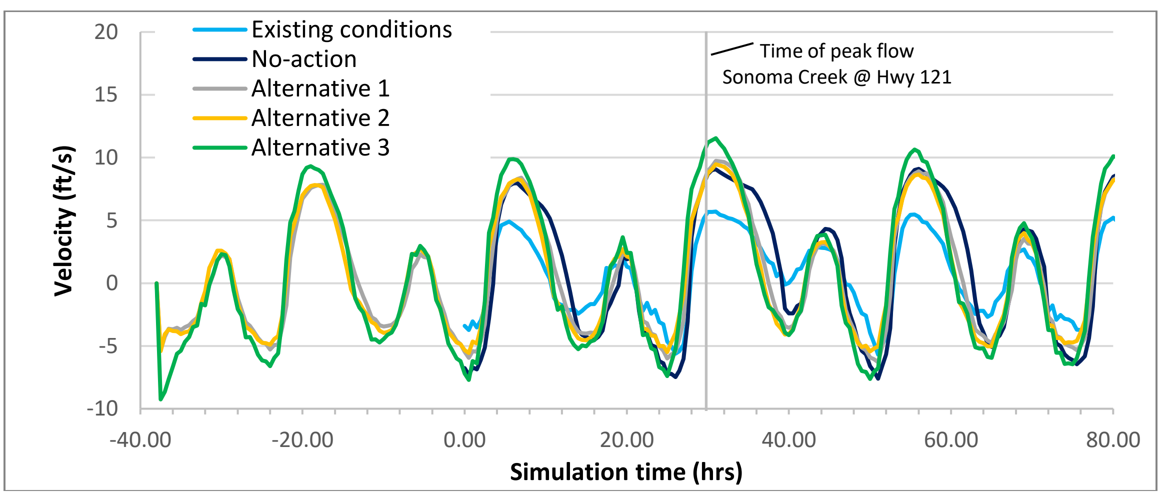


Figure 28. Velocity time series comparisons for all alternatives. 2050 1% flow, elevated tide w/SLR.

6 REFERENCES

Buffington, K.J., and Thorne, K.M., 2019, LEAN-corrected San Francisco Bay digital elevation model, 2018: U.S. Geological Survey data release, https://doi.org/10.5066/P97J9GU8.

DWR, 2015. Perspectives and Guidance for Climate Change Analysis.

ESA PWA, 2012. Lower Sonoma Creek Flood Management and Ecosystem Enhancement.

OPC, 2018. State of California, Sea-level Rise Guidance.

Pierce, David., 2014. Statistical Downscaling Using Localized Constructed Analogs (LOCA).

PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu. 1981-2010 precipitation normals. Created July, 2012.

PWA, 2004. Sonoma Creek & Tributaries Basin Hydrologic Investigation. PWA Ref. #1411.21.

PWA, 2008. Sonoma Creek Flood Management and Enhancement Project. Hydraulic Model Development.

Williams, Philip B., Orr, Michelle K., Garrity, Nicholas J., 2002. Hydraulic Geometry: A Geomorphic Design Tool for Tidal Marsh Channel Evolution in Wetland Restoration Projects

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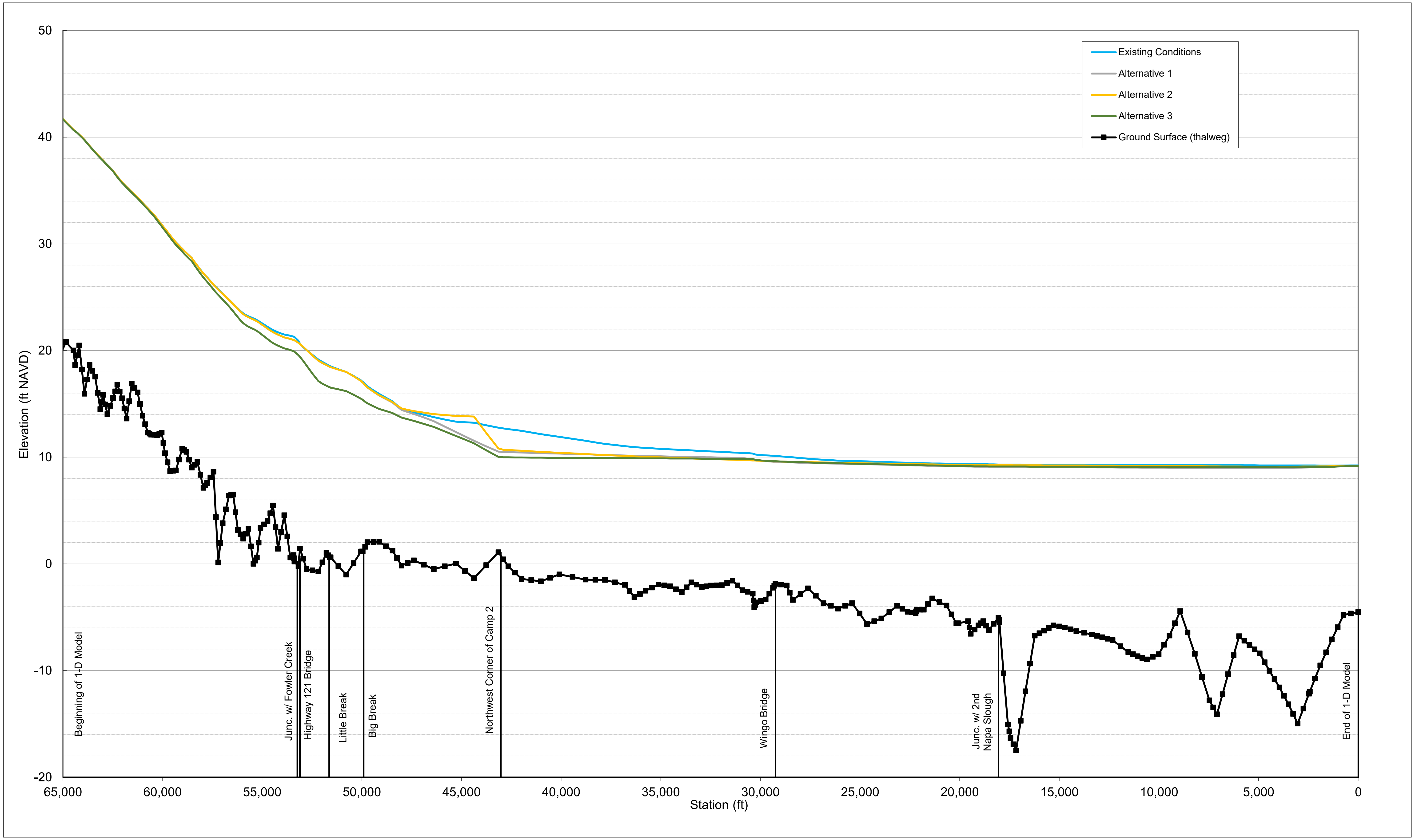


Figure 6
Sonoma Creek water surface profiles
1% flow, elevated tide

ESA

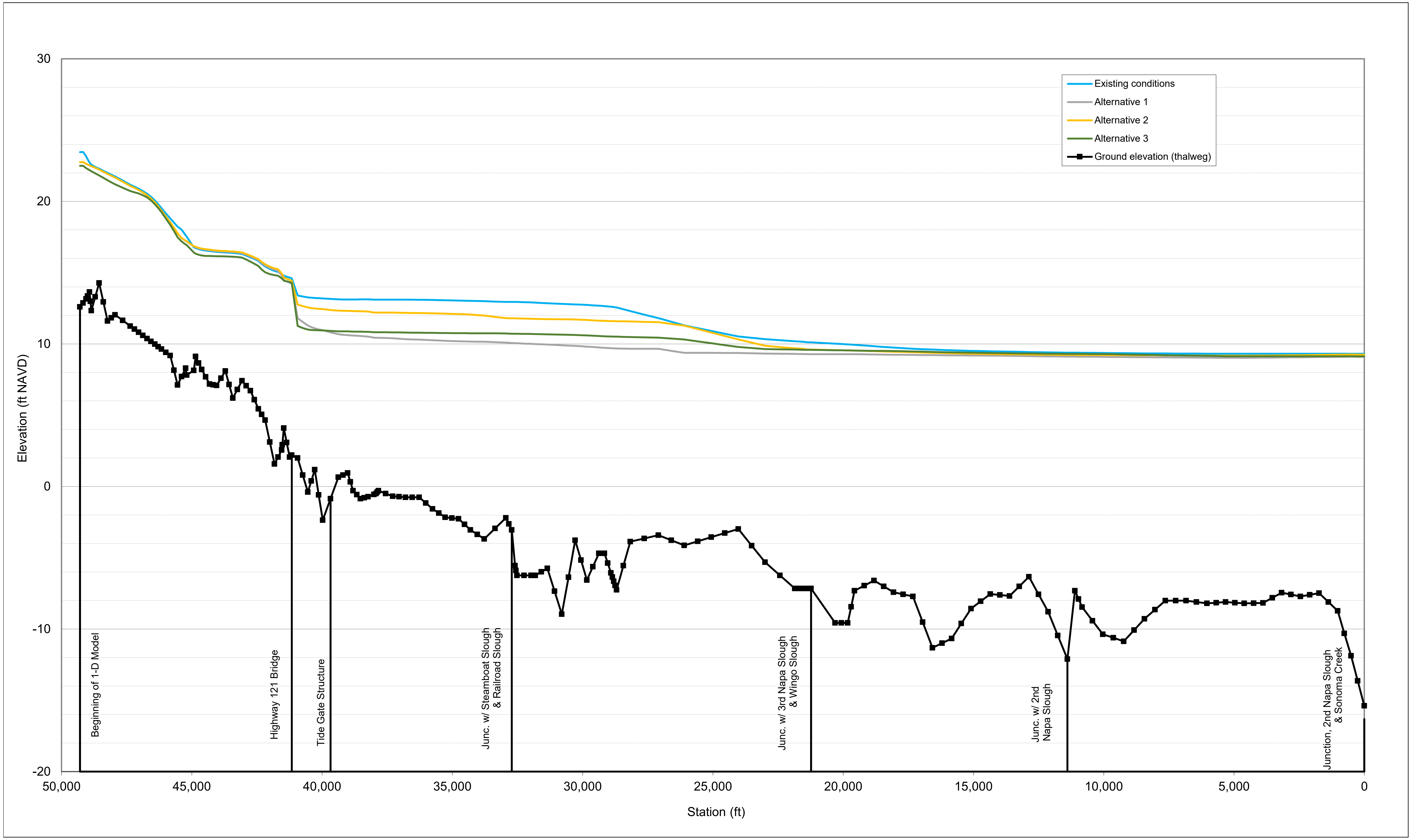


Figure 7

Schell Creek water surface profiles
1% flow, elevated tide

ESA

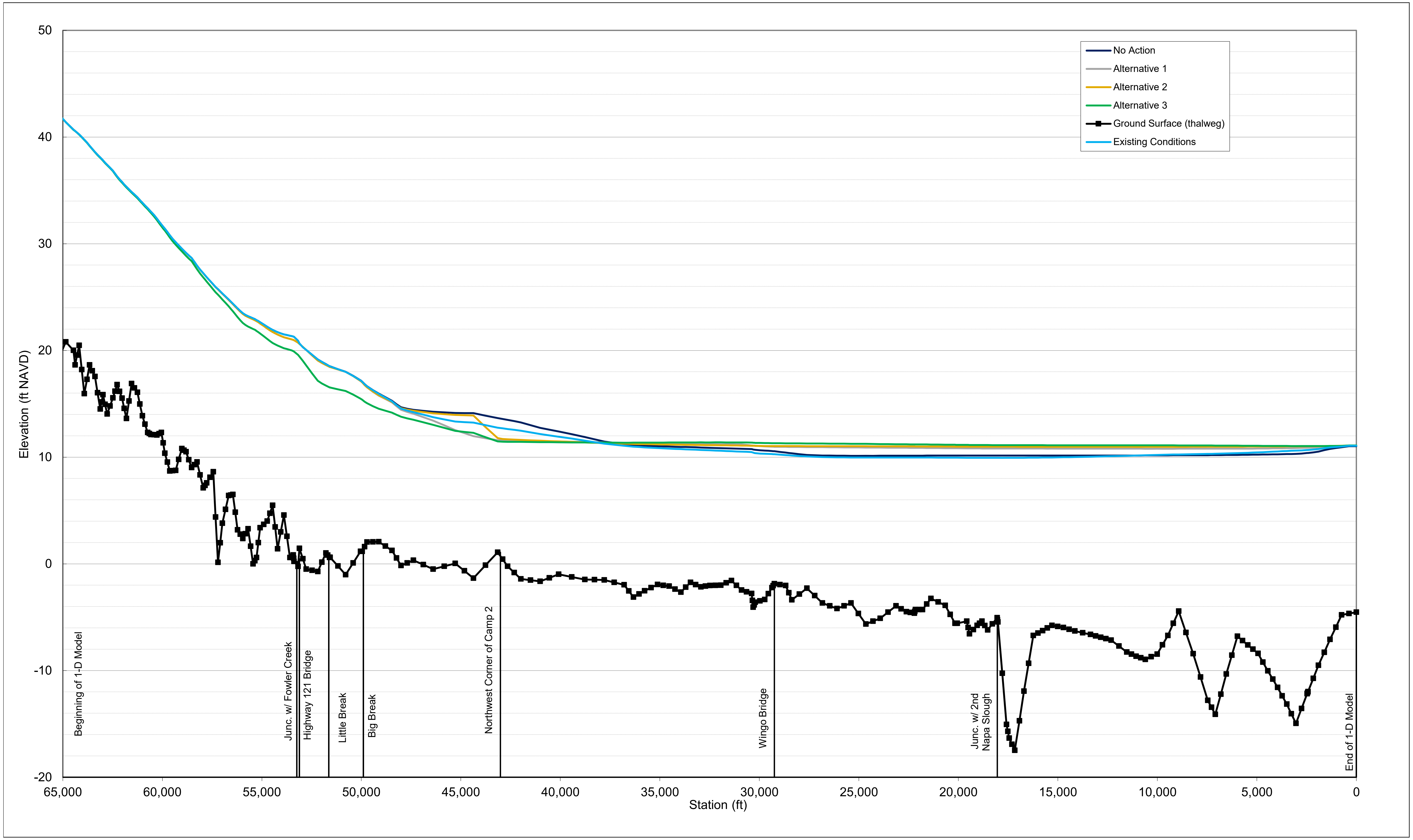


Figure 8

Sonoma Creek water surface profiles
2050 1% flow, elevated tide w/SLR

ESA

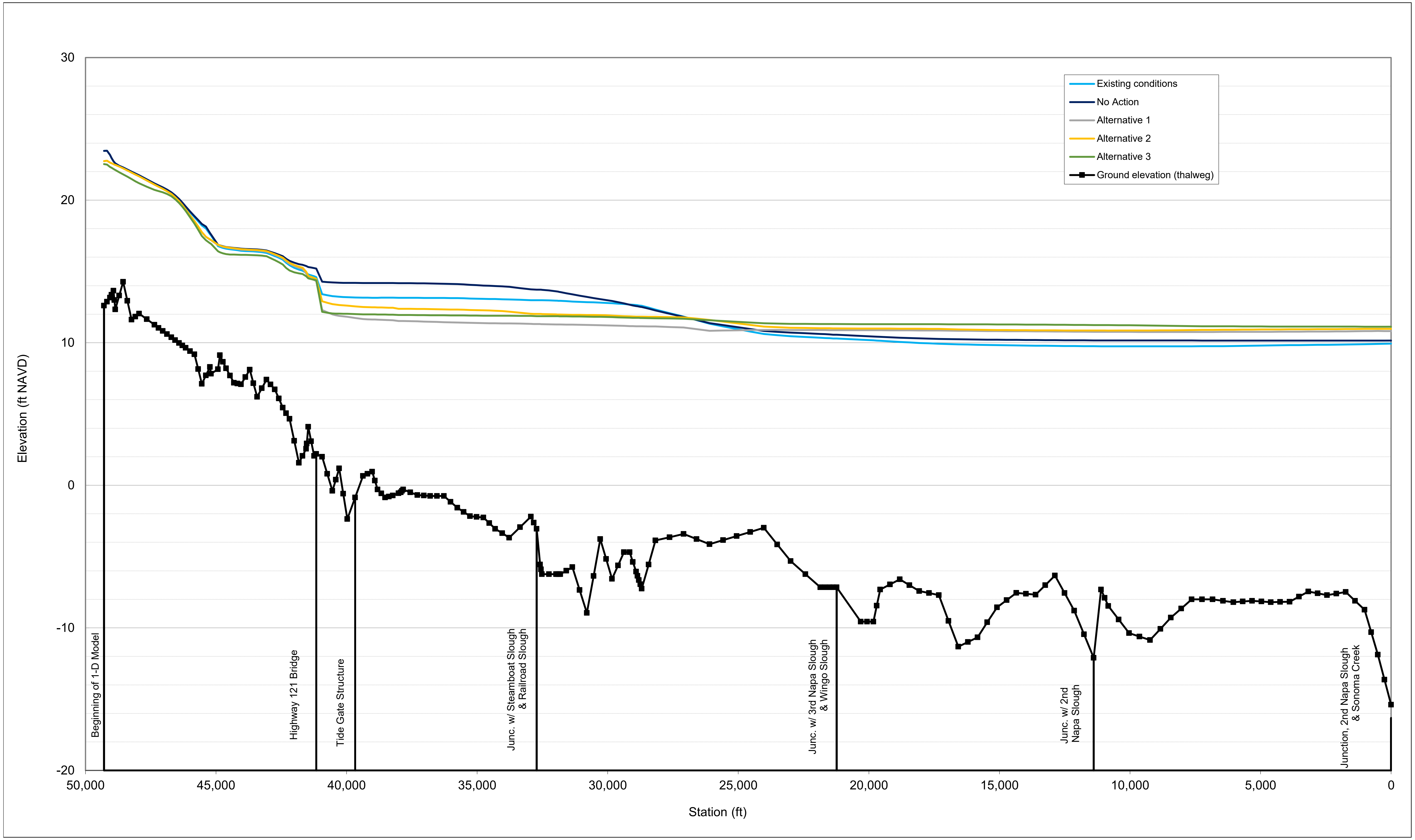
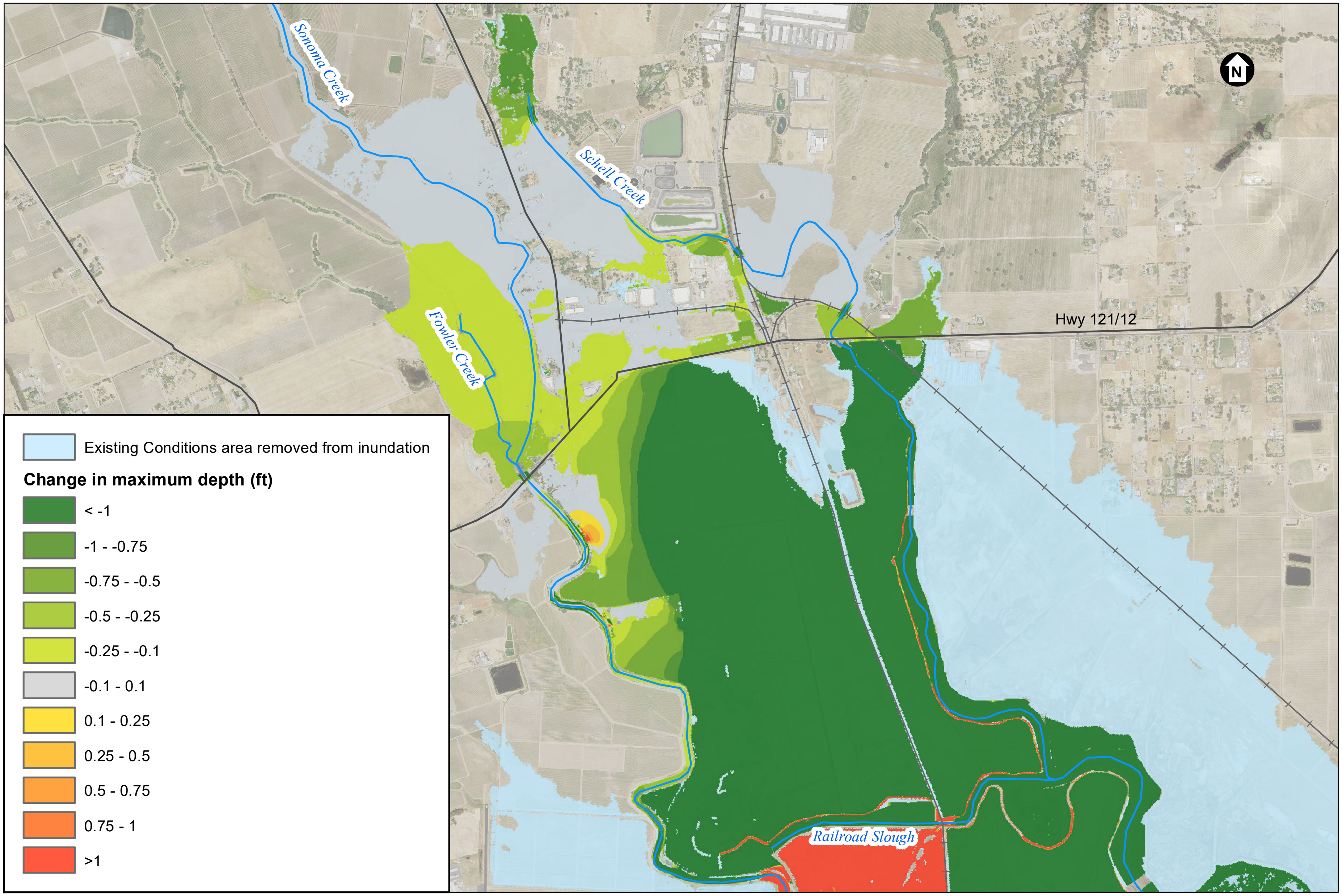


Figure 9

Schell Creek water surface profiles
2050 1% flow, elevated tide w/SLR

ESA

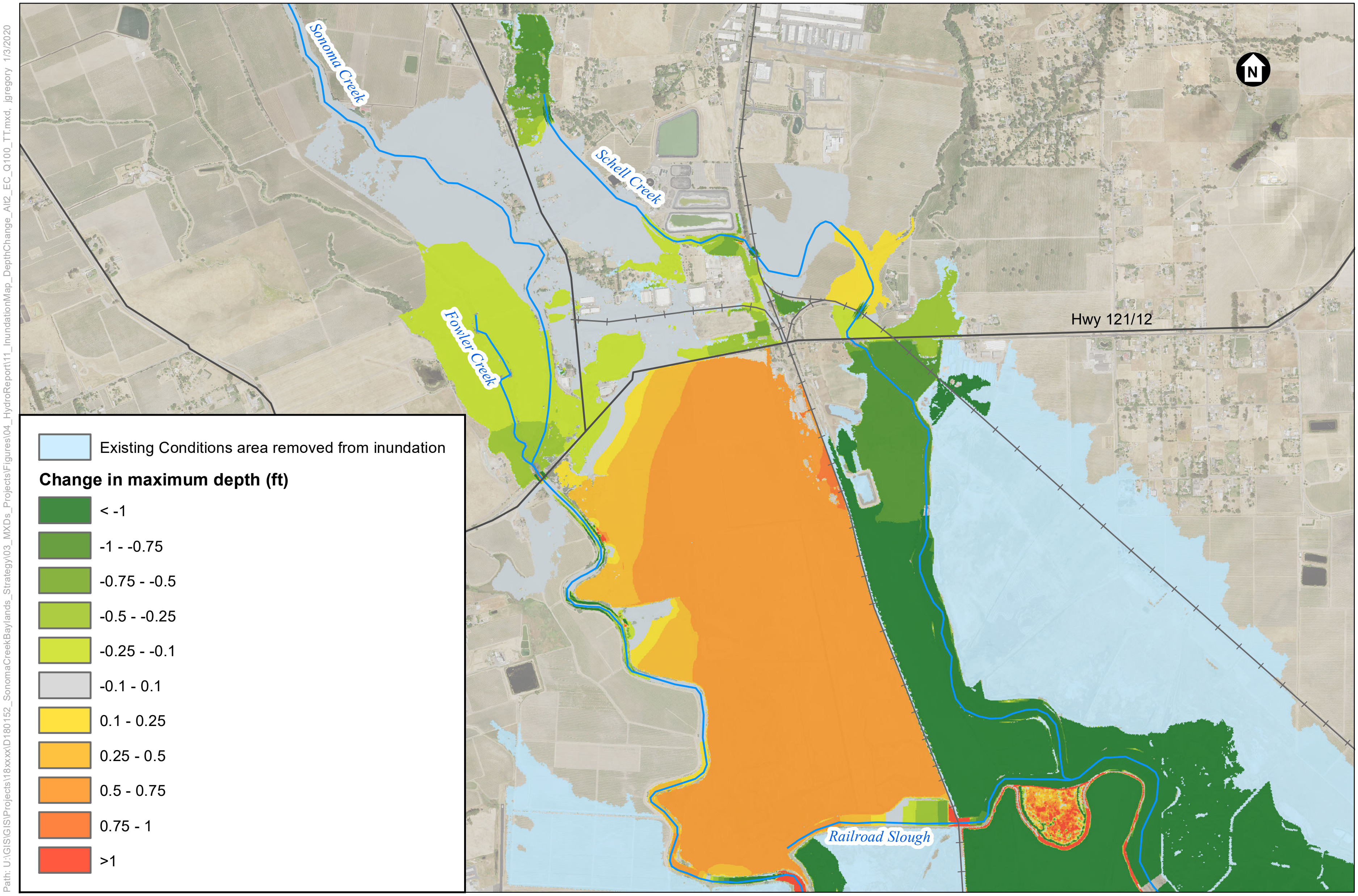


SOURCE: NAIP (2014 aerial)

Lower Sonoma Creek Strategy

Figure 10
Change in maximum depth, 1% flow, typical tide
Alternative 1 minus Existing Conditions

ESA

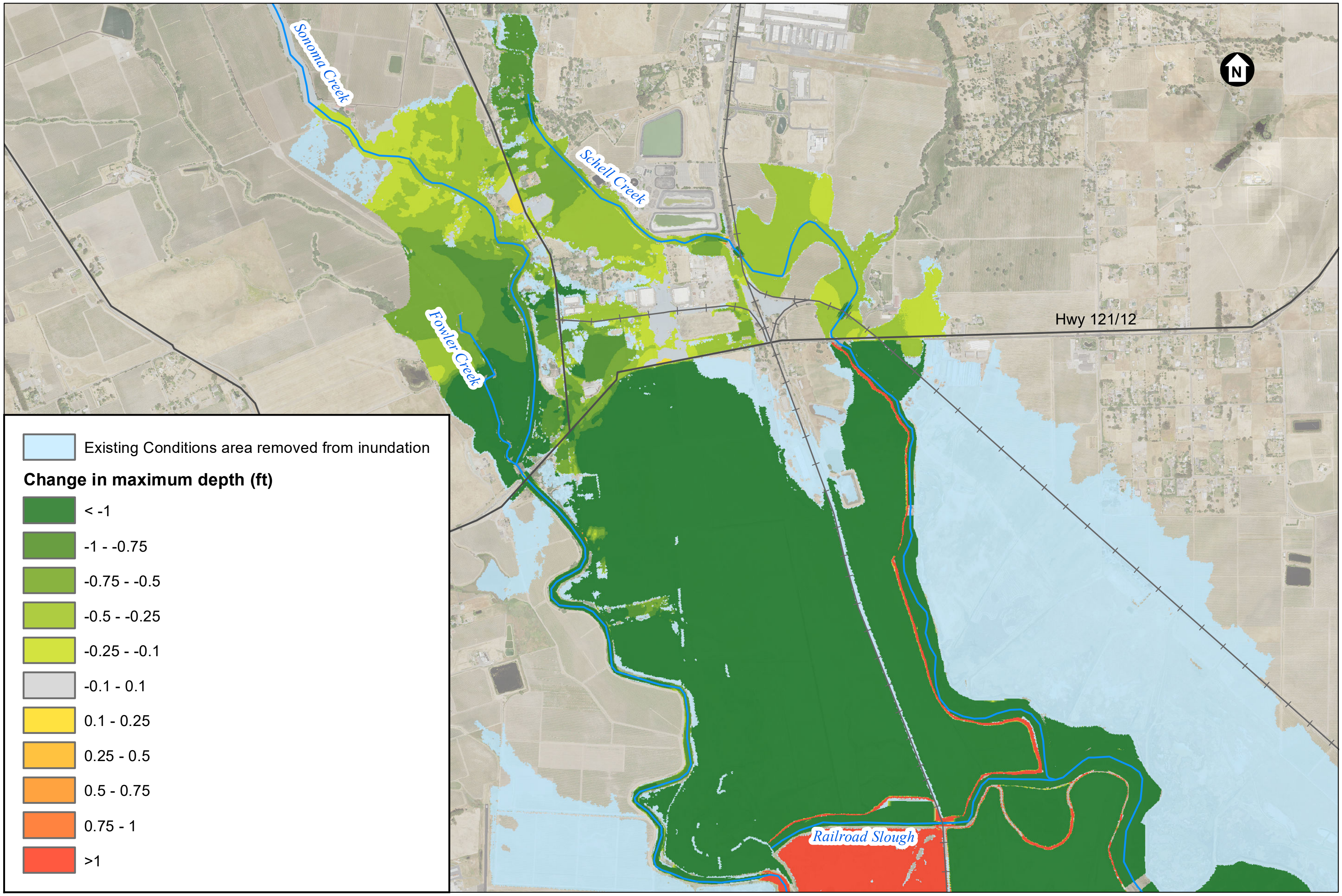


SOURCE: NAIP (2014 aerial)

Lower Sonoma Creek Strategy

Figure 11
Change in maximum depth, 1% flow, typical tide
Alternative 2 minus Existing Conditions

ESA



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SOURCE: NAIP (2014 aerial)

Lower Sonoma Creek Strategy

ESA

Figure 12
Change in maximum depth, 1% flow, typical tide
Alternative 3 minus Existing Conditions

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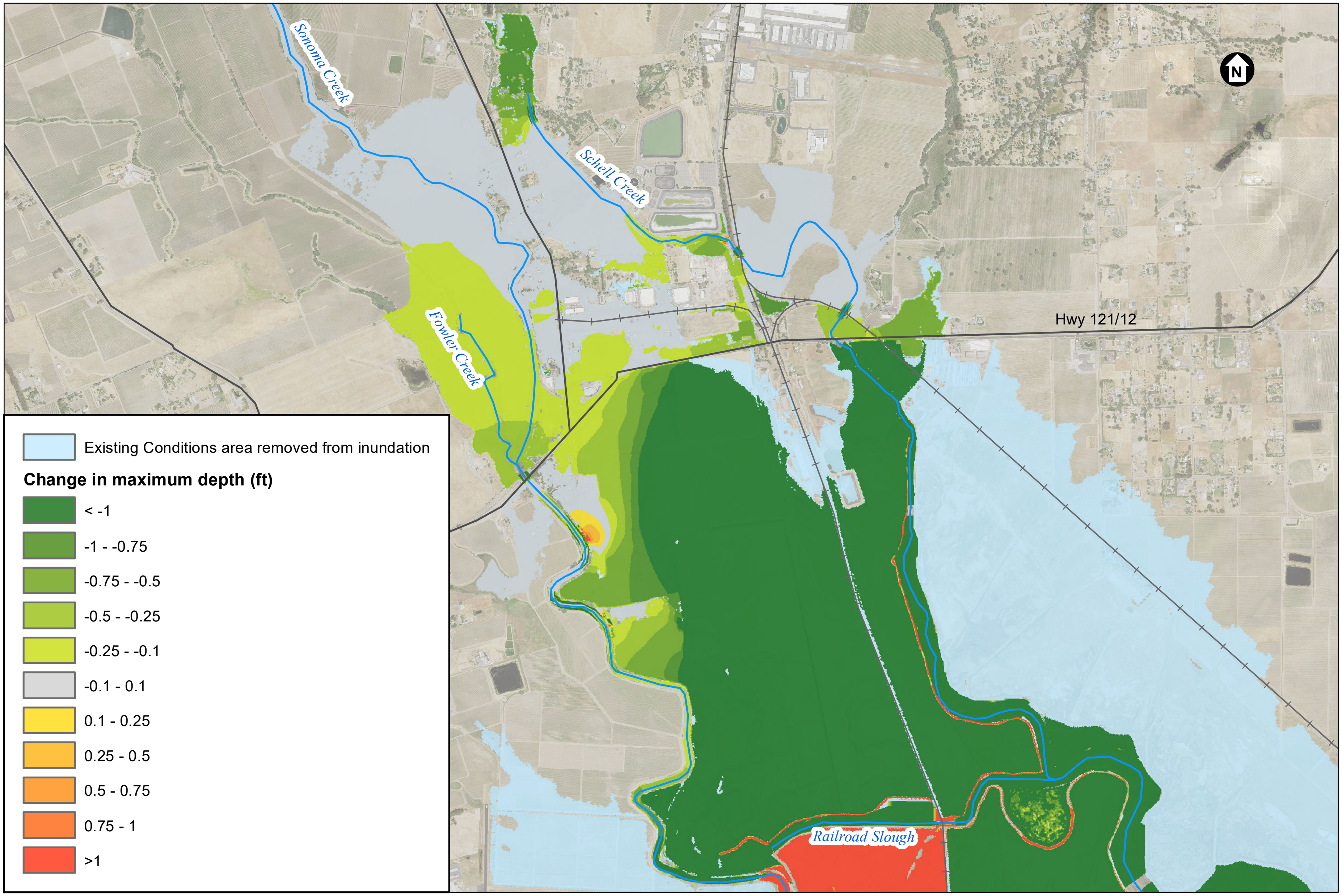
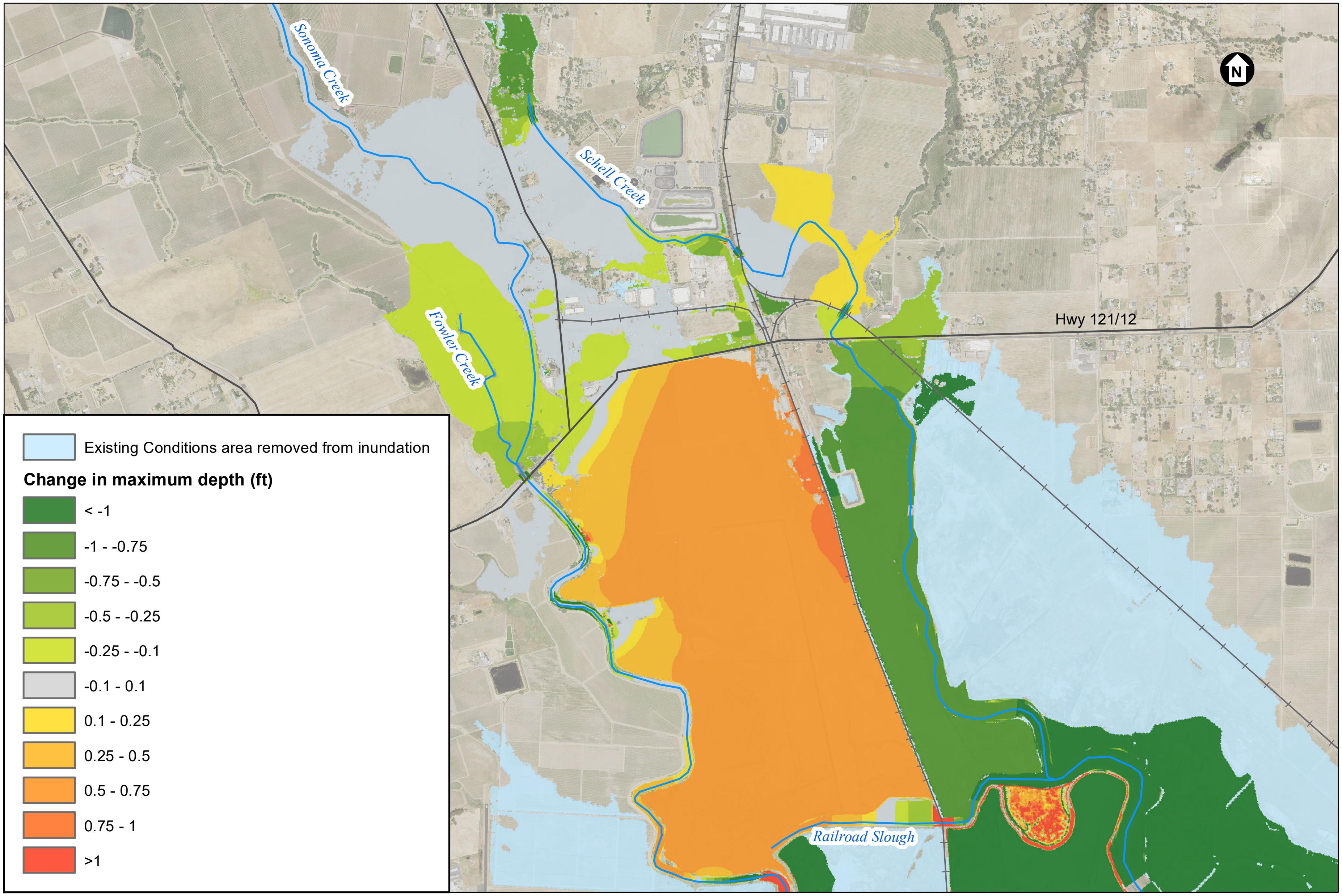


SOURCE: NAIP (2014 aerial)

Lower Sonoma Creek Strategy

Figure 13
Change in maximum depth, 1% flow, elevated tide
Alternative 1 minus Existing Conditions

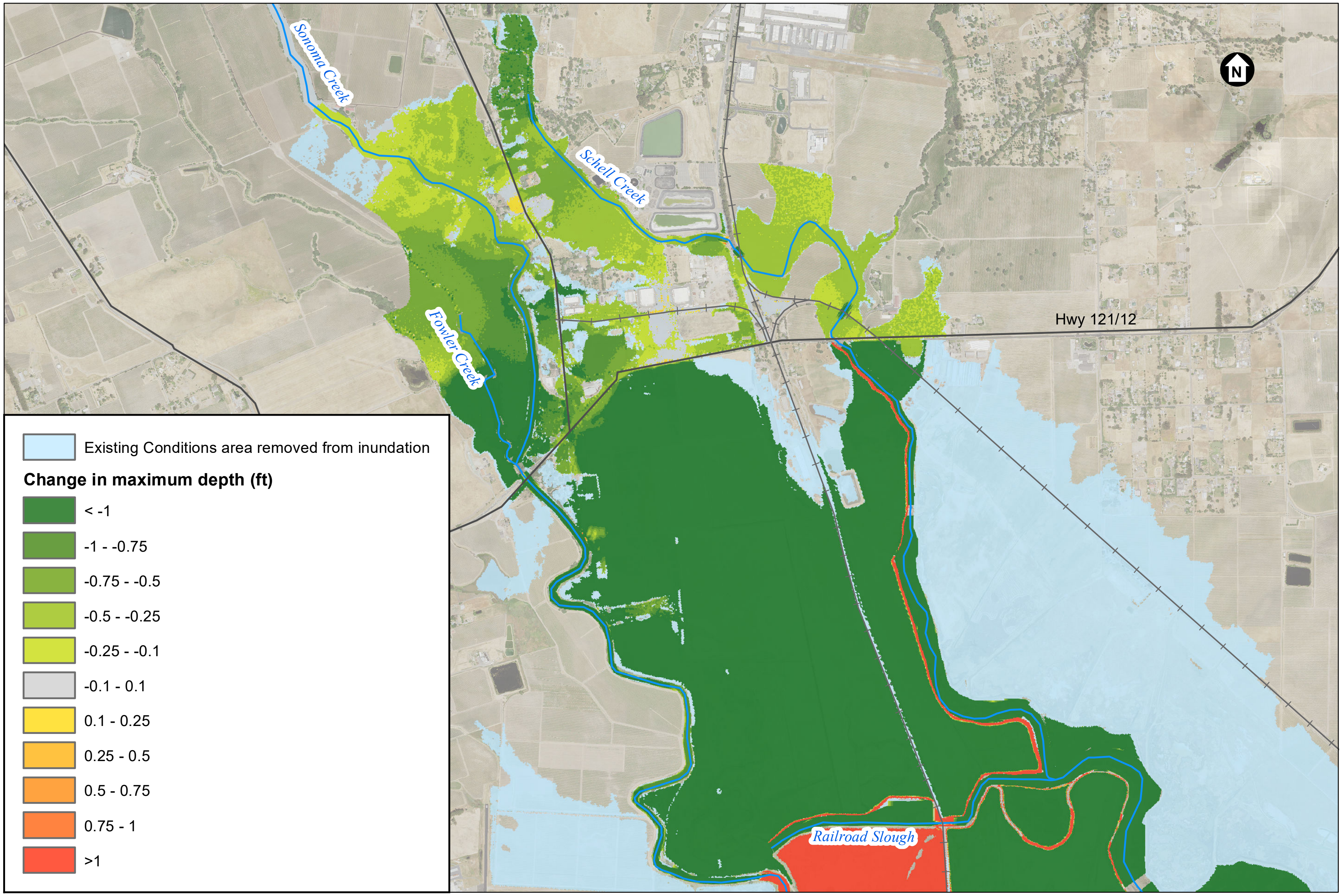
ESA



SOURCE: NAIP (2014 aerial)

Figure 14
Change in maximum depth, 1% flow, elevated tide
Alternative 2 minus Existing Conditions

ESA



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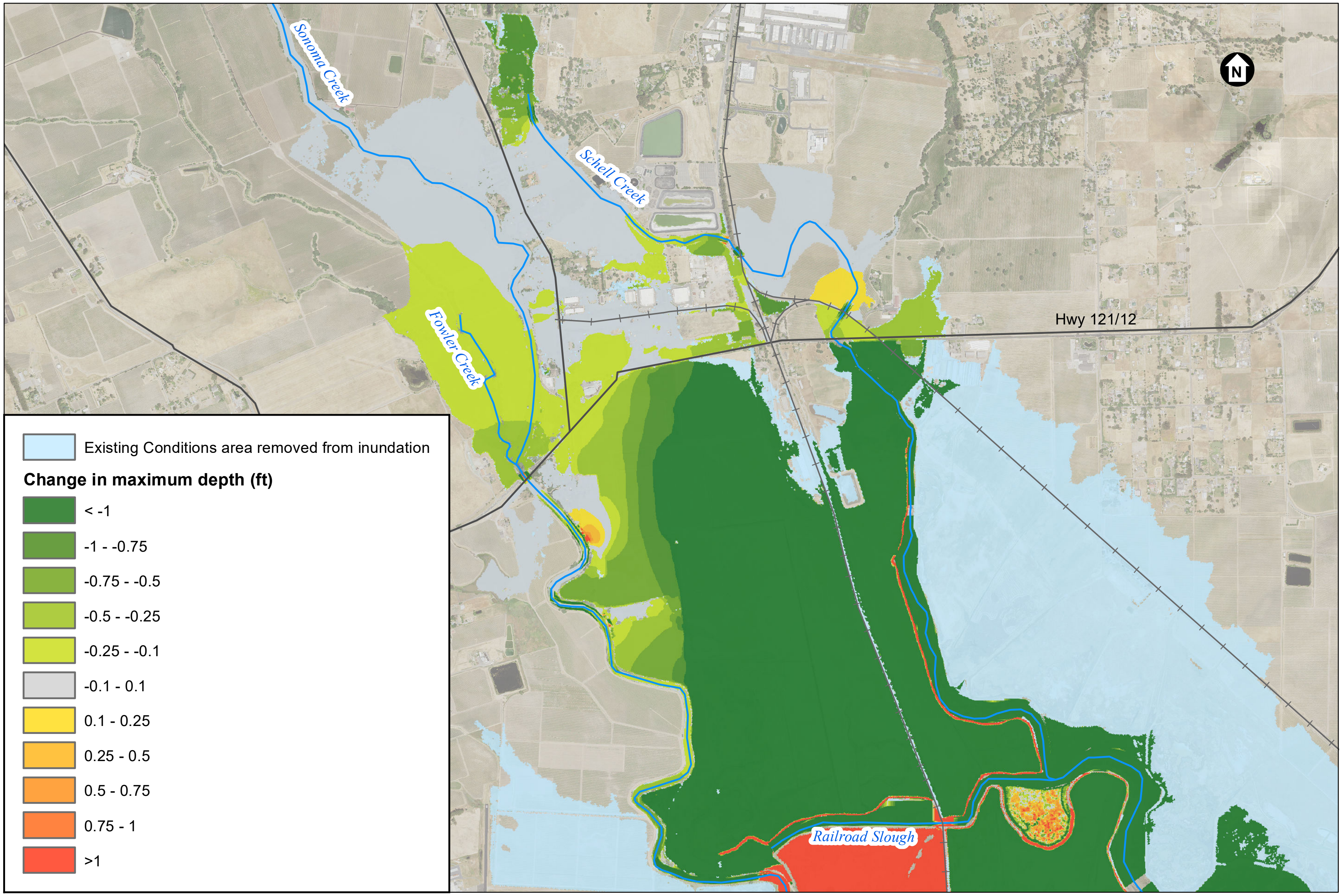
SOURCE: NAIP (2014 aerial)

Lower Sonoma Creek Strategy

ESA

Figure 15
Change in maximum depth, 1% flow, elevated tide
Alternative 3 minus Existing Conditions



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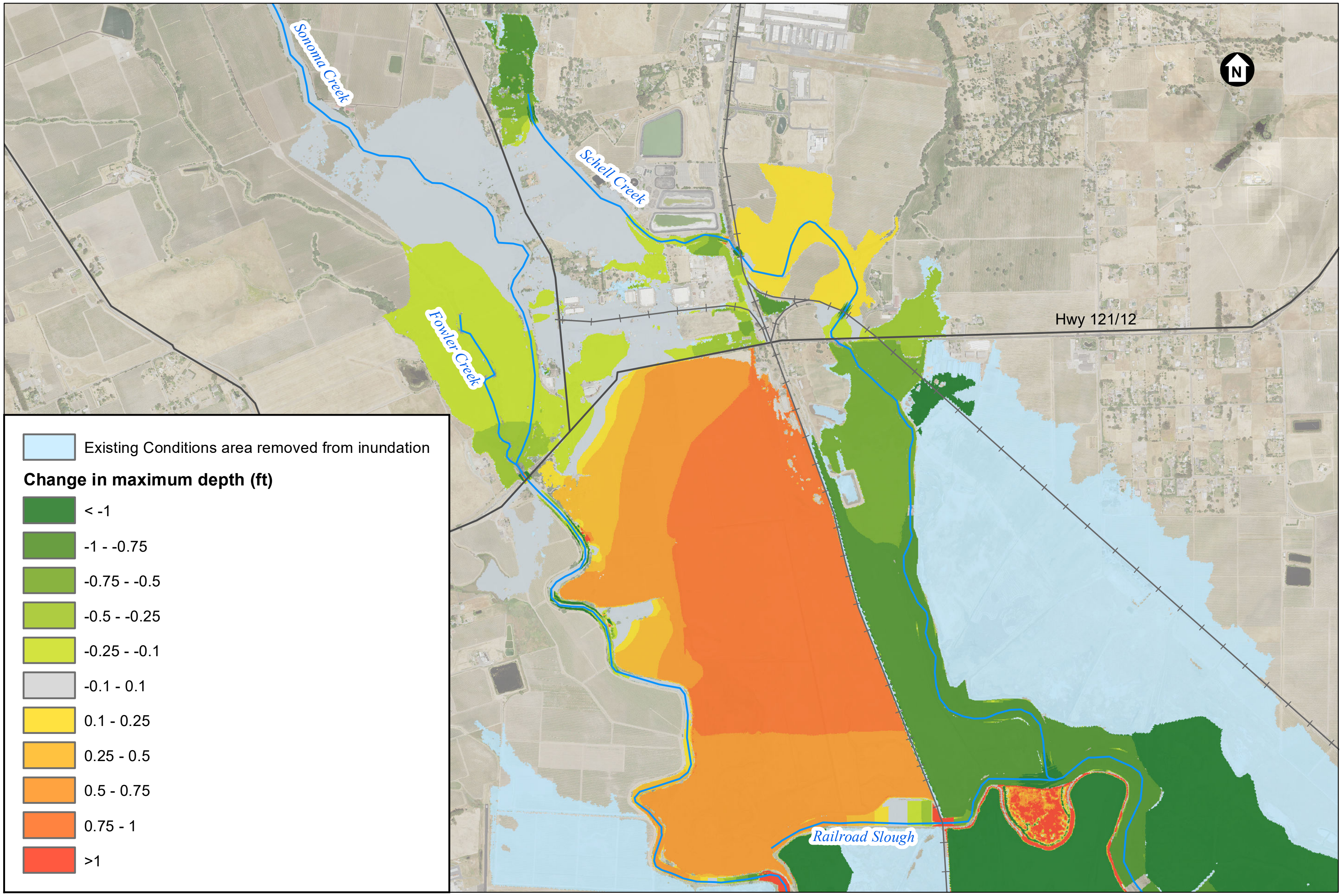
SOURCE: NAIP (2014 aerial)

Lower Sonoma Creek Strategy

Figure 16
Change in maximum depth, 2050 1% flow, elevated tide w/SLR
Alternative 1 minus Existing Conditions

ESA



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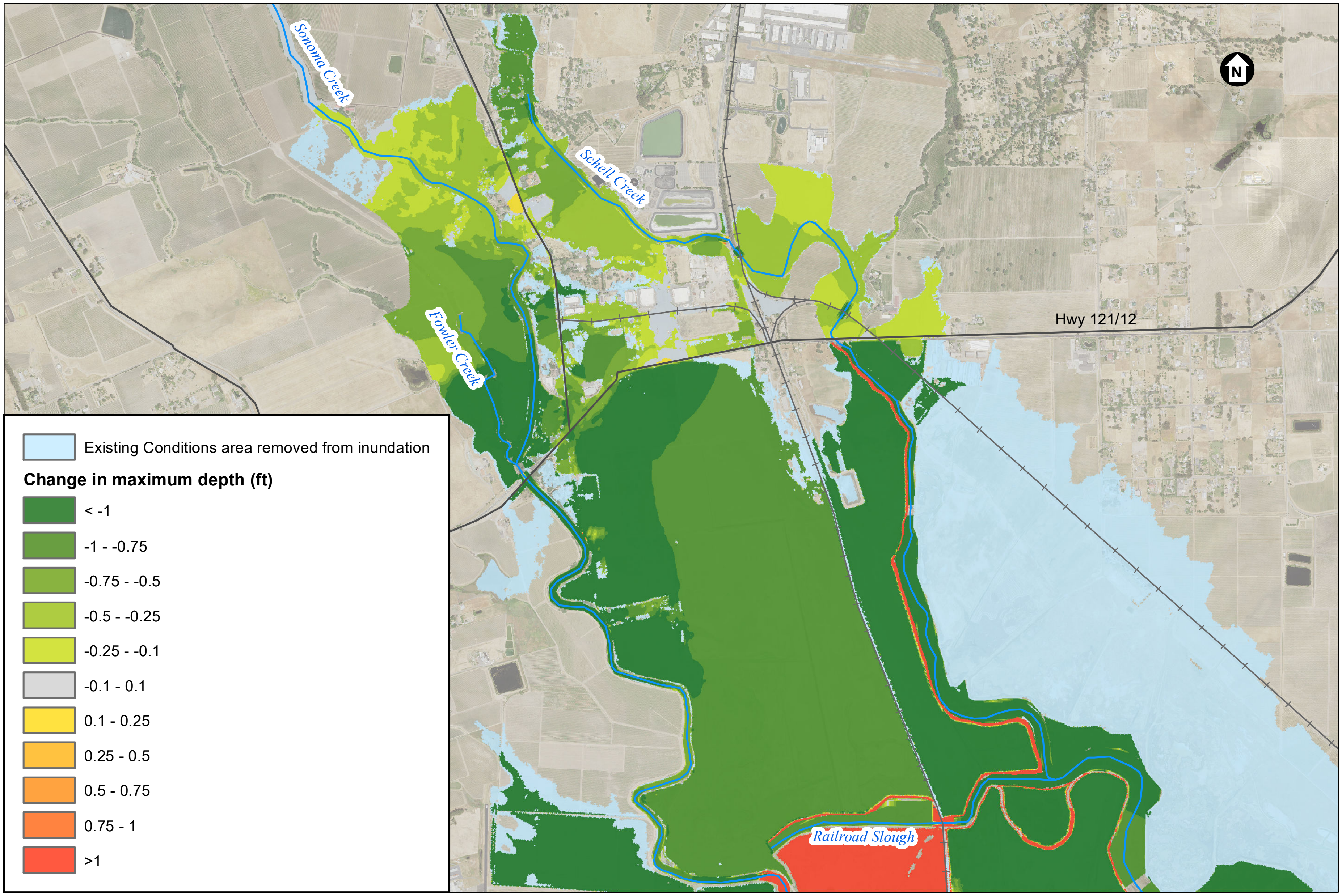
SOURCE: NAIP (2014 aerial)

Lower Sonoma Creek Strategy

Figure 17
Change in maximum depth, 2050 1% flow, elevated tide w/SLR
Alternative 2 minus Existing Conditions

ESA

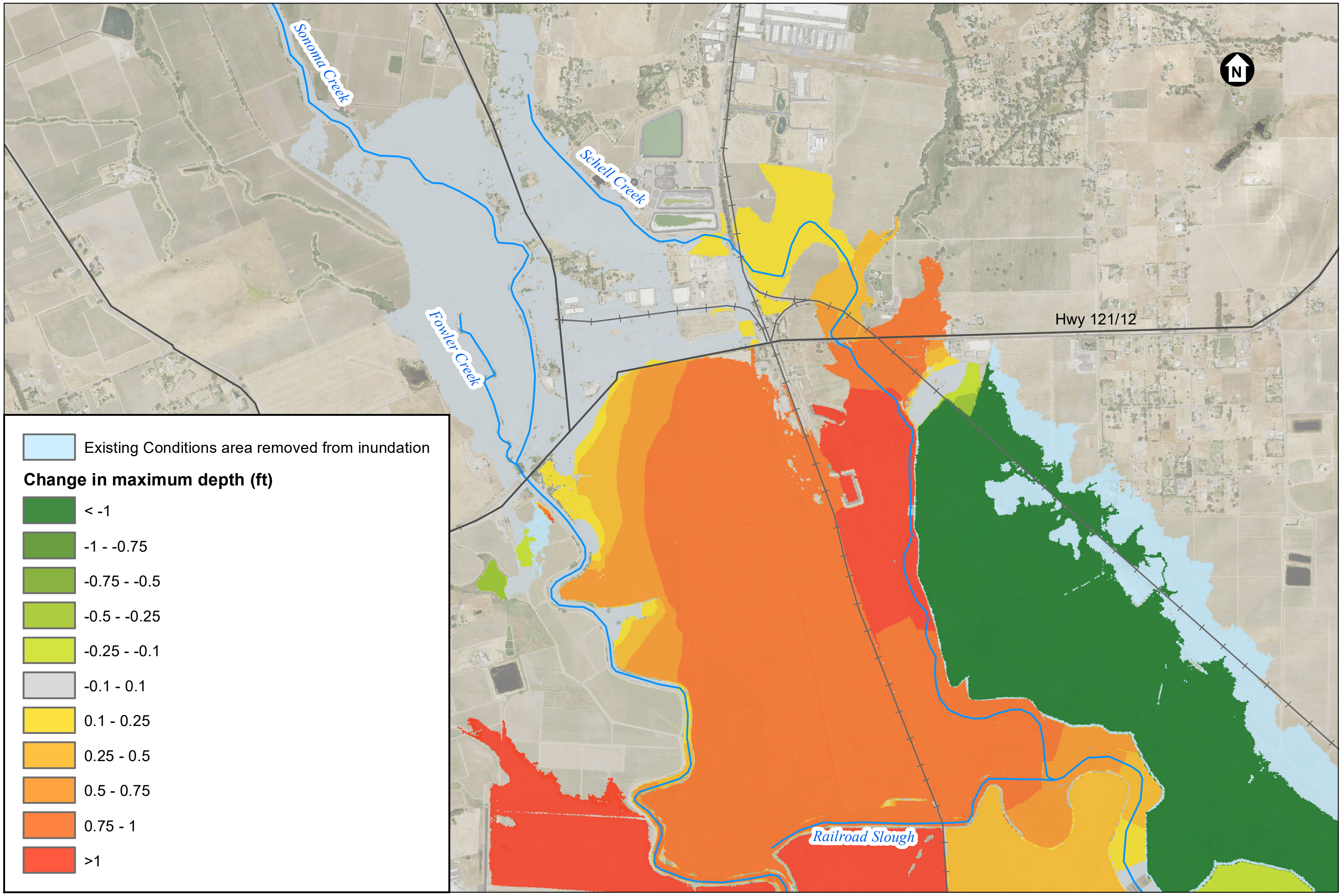


SOURCE: NAIP (2014 aerial)

Lower Sonoma Creek Strategy

Figure 18
Change in maximum depth, 2050 1% flow, elevated tide wSLR
Alternative 3 minus Existing Conditions

ESA

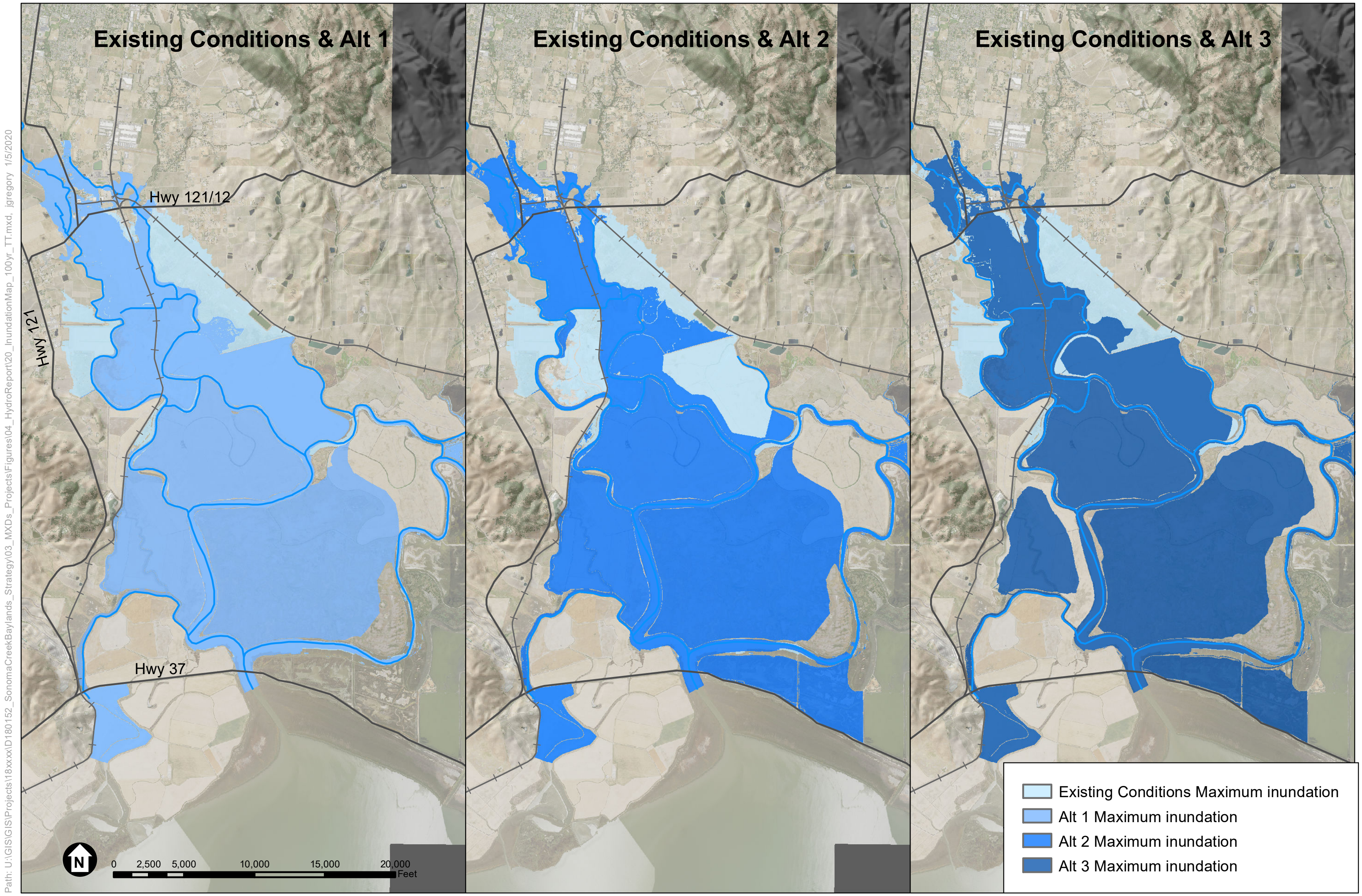


SOURCE: NAIP (2014 aerial)

Lower Sonoma Creek Strategy

Figure 19
Change in maximum depth, 2050 1% flow, elevated tide wSLR
No-action minus Existing Conditions

ESA

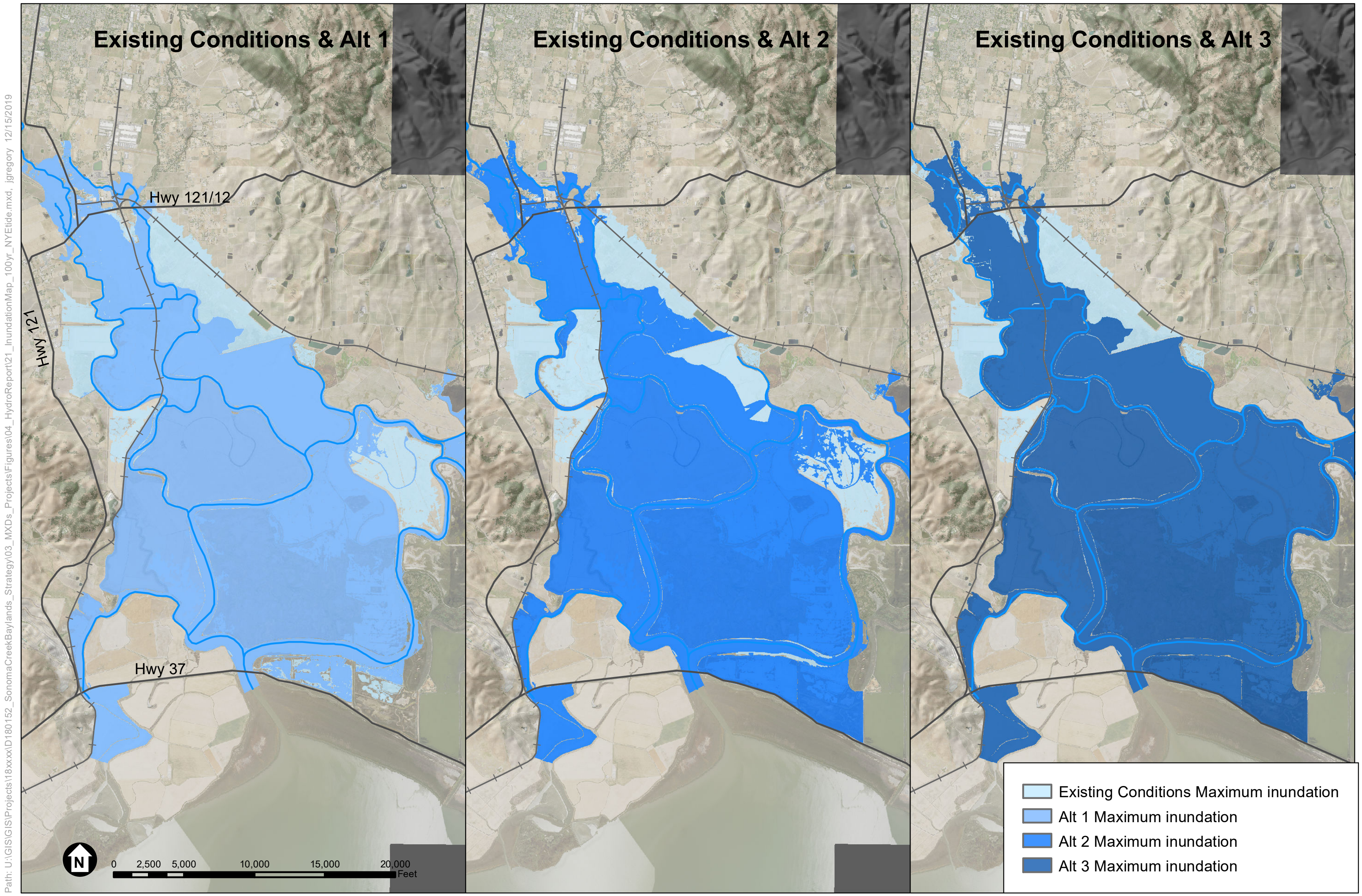


SOURCE: NAIP (2014 aerial)

Sonoma Creek Baylands Strategy

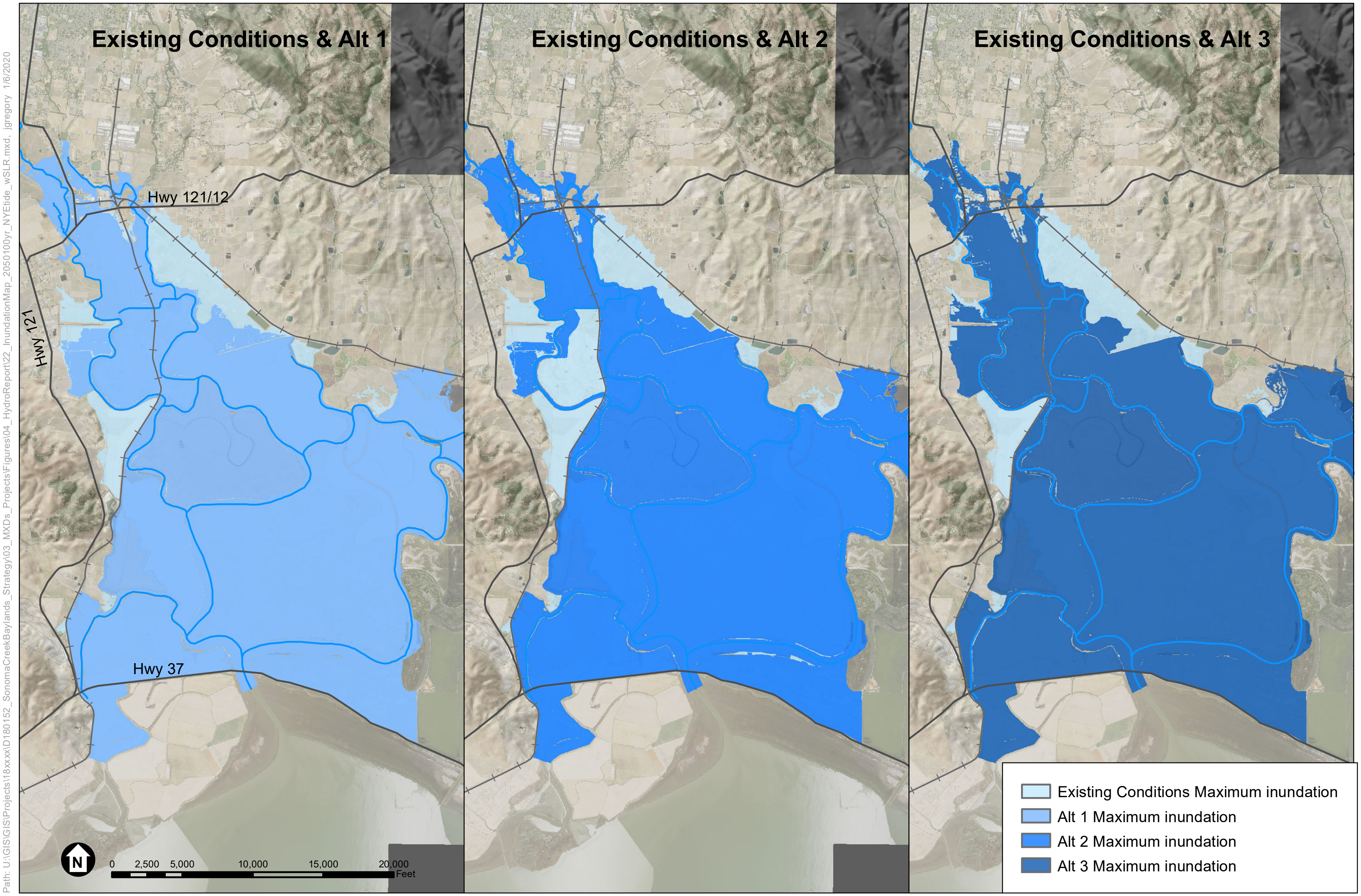
Figure 20
Maximum inundation extent for 1% flow, typical tide
Existing Conditions, Alternative 1, Alternative 2, and Alternative 3

ESA



SOURCE: NAIP (2014 aerial)

Figure 21
Maximum inundation extent for 1% flow, elevated tide
Existing Conditions, Alternative 1, Alternative 2, and Alternative 3

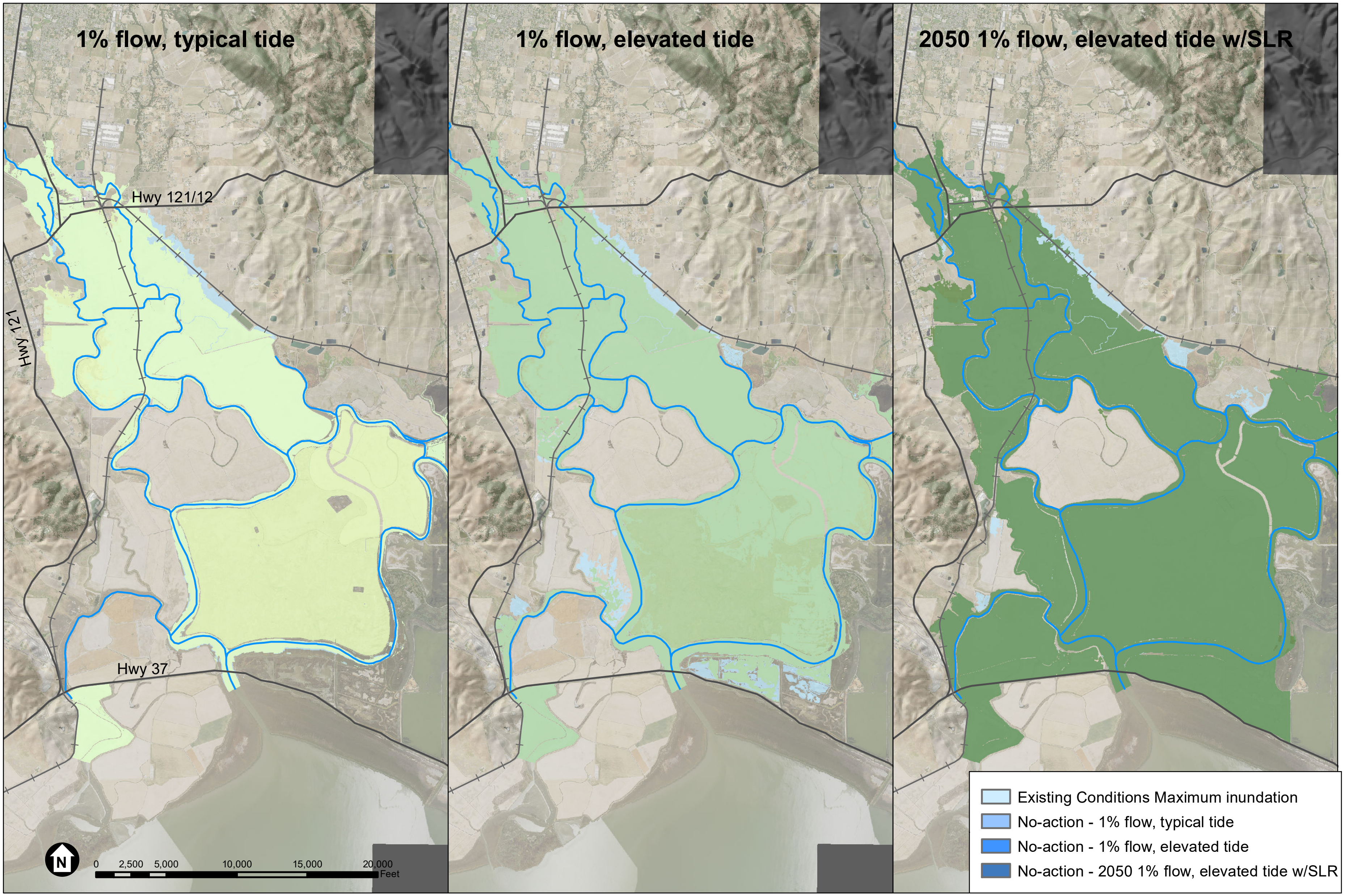


SOURCE: NAIP (2014 aerial)

Sonoma Creek Baylands Strategy

Figure 22
Maximum inundation extent for 2050 1% flow, elevated tide w/SLR
Existing Conditions, Alternative 1, Alternative 2, and Alternative 3

ESA



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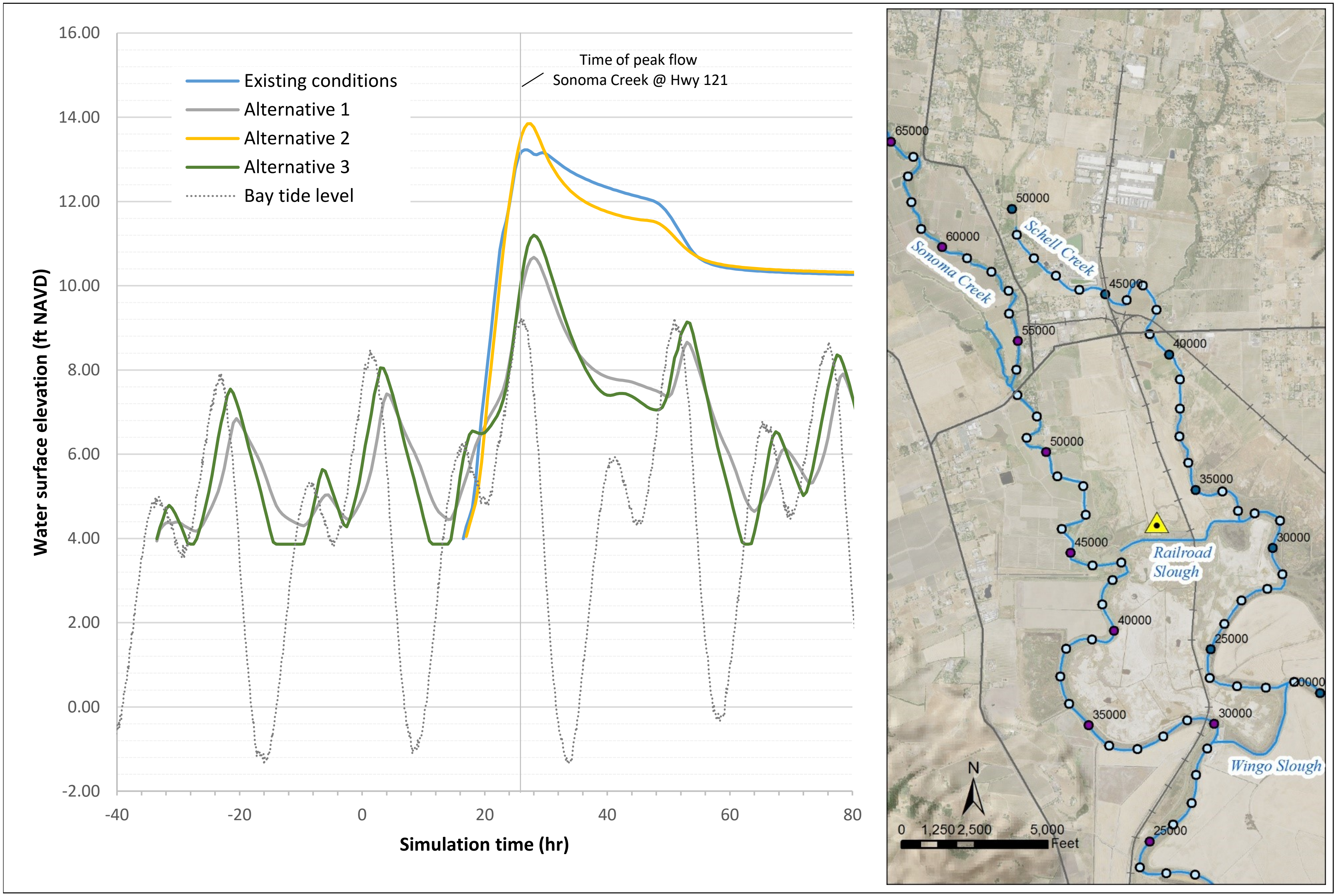
SOURCE: NAIP (2014 aerial)

Sonoma Creek Baylands Strategy

Figure 23
Maximum inundation extent for three hydrologic scenarios
Existing Conditions and No Action

ESA

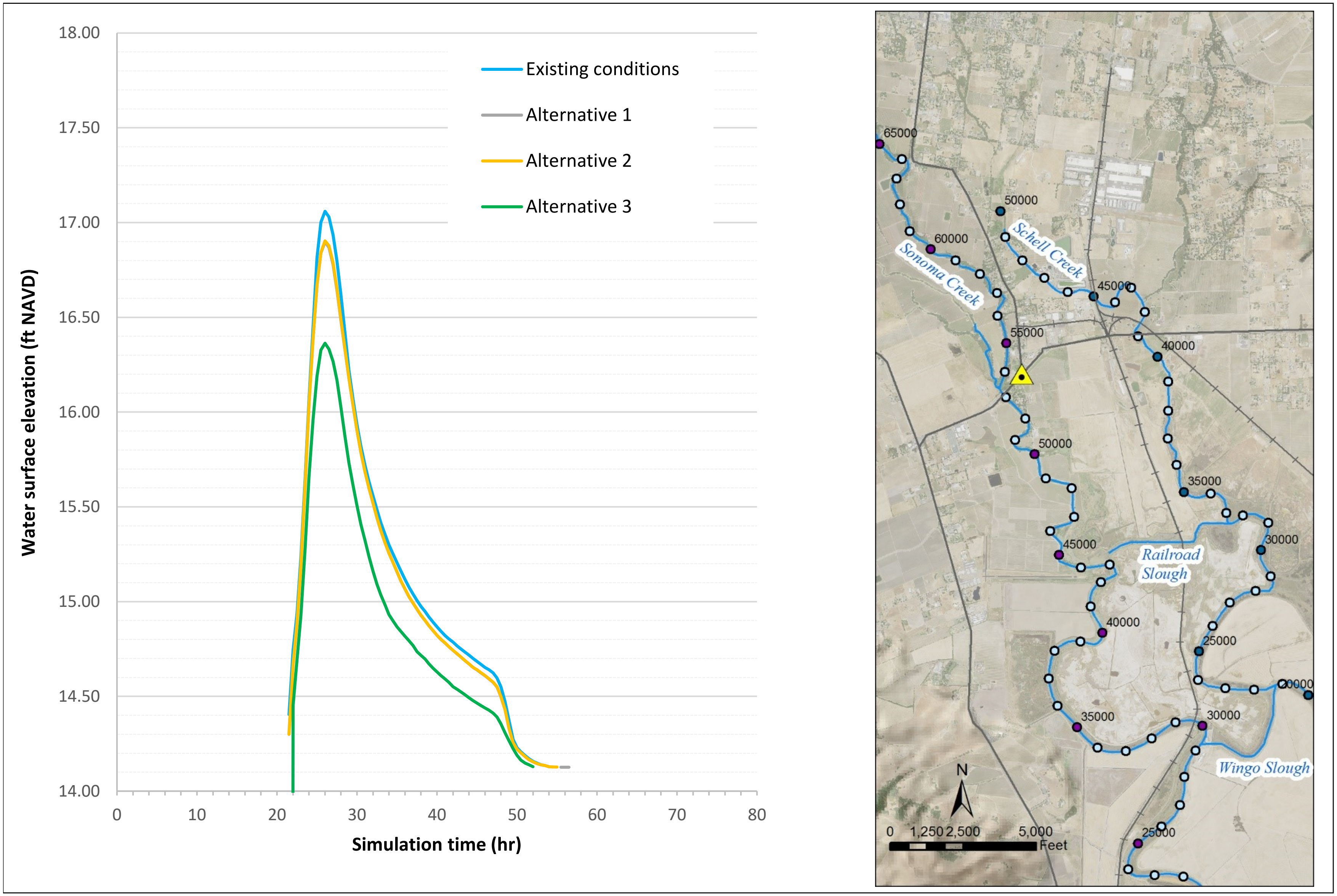


NOTE: Time series shown at yellow marker on righthand map panel

Sonoma Creek Baylands Strategy. D180152.01

Figure 24

Water surface elevation time series in Area 4 for all alternatives. 1% flow, elevated tides.



NOTE: Time series shown at yellow marker on righthand map panel

Sonoma Creek Baylands Strategy. D180152.01

Figure 25

Water surface elevation time series, Highway 12 at Highway 121 for all alternatives. 1% flow, elevated tides.

Appendix 2: Geomorphic Analysis

Jeremy Lowe, San Francisco Estuary Institute

Introduction

The restoration strategy and alternatives are designed to provide a mosaic of functional and resilient habitats in the Lower Sonoma and Tolay Creek watersheds. This section of the plan evaluates how well each of the alternatives succeeds at achieving this goal up to 2100 based on the designs of the alternatives and habitat evolution in response to sea level rise.

Of particular concern is the potential increase in flow rates along the tidal channels of Sonoma Creek as tidal action is restored to diked areas either by design through restoration projects, or by accident due to erosion and breaching of dikes. The presently diked parcels are very large areas of subsided land which, since they lie within the tidal range, will fill and empty on each tide. The volume of water that enters on the flood and leaves on the ebb is called the tidal prism and is conveyed to and from the marsh by the remaining tidal channels. The present tidal prism is relatively small, since most areas are protected by dikes, and many of the channels have been filling in with marshes. If the tidal prism increases, then these channels will erode to a size that allows them to convey the increased volume of water. Erosion of the channels to convey water may result in erosion of the existing fringing infill wetlands and dikes, and scouring around bridge piles. It is therefore essential to estimate the future widths of the main channels if tidal prism is increased.

Methods

The relationship between channel size at a particular cross-section of a channel and some measure of flow discharge (such as tidal prism) upstream of that cross-section is known as hydraulic geometry. The hydraulic geometry relationships for marshes in San Francisco Bay have been investigated by Williams et al. (2002) for marshes in San Francisco Bay. In that study, empirical correlations between channel cross-section morphology (width, depth, area) and tidal prism for a San Francisco Bay data set were used to predict equilibrium cross-section morphology for a given tidal prism. For each cross-section were characterized:

- Depth, *D* (m) - depth relative to MHHW at the deepest part of the cross-section, the thalweg;
- Width, *W* (m) - distance between the two banks at MHHW, or projected to MHHW if the banks were lower;
- Cross-sectional area, *A* (m^2) - area below MHHW for the part of the channel within the channel width;
- Diurnal Tidal prism, TP (m^3) - volume of water between MLLW and MHHW within the contributing tidal watershed area landward (upstream) of the cross-section, extending to the drainage divide between channel networks.

The dataset included the historical pre-diked Sonoma Creek, Petaluma River and Napa River, as well as modern channels within ancient marshes such as China Camp, Heerdt Marsh, Petaluma Marsh and Wildcat Marsh (**Figure 1**).

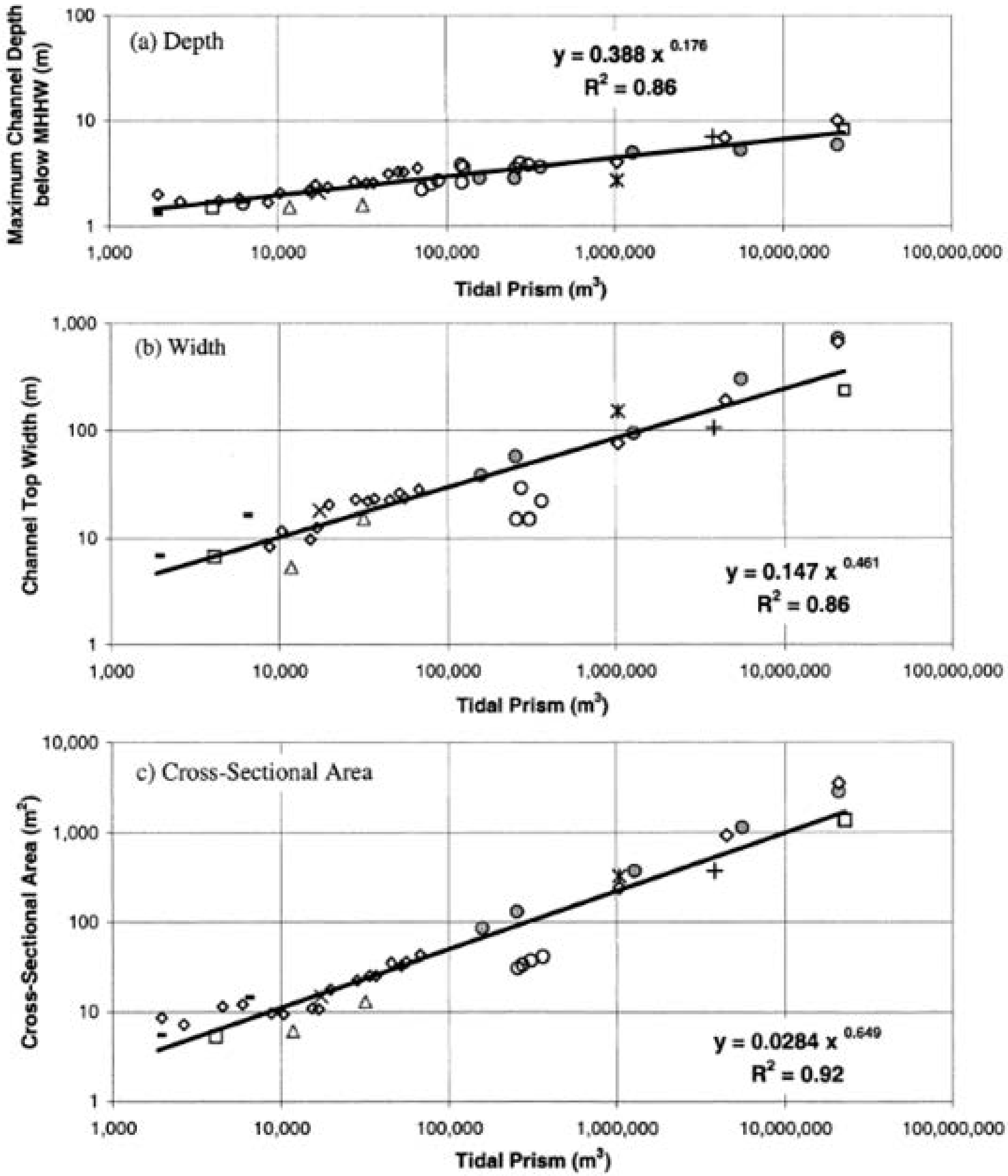


Figure 1. Depth, width, and cross-sectional area versus diurnal tidal prism for ancient marshes in San Francisco Bay (Figure 6 from Williams et al. 2002).

From the analysis of the historical and present-day marsh channels, Willams et al. determined the following hydraulic geometry relationships:

$$D = 0.388\,TP^{0.176};\; W = 0.147\,TP^{0.461};\; A = 0.0284\,TP^{0.649} \quad \text{Eq. 1-3}$$

Tidal prism was calculated. **Table 1** shows the tidal datum and extreme total water levels for Sonoma Creek calculated as part of their recent FEMA remapping of the Bay (AECOM 2016):

Table 1: Present (2000) tidal datum and extreme water surface elevations for Sonoma Creek.

		Elevation ft (m) NAVD88	
Extreme water levels	100-year total water level	9.74 (2.97)	100-year storm surge is 3.5ft (1.07m)
	10-year total water level	8.53 (2.60)	
	1-year total water level	7.48 (2.28)	
Daily Tides	Highest Astronomical Tide (HAT)	7.71 (2.35)	Tide range is 5.8ft (1.76m)
	Mean Higher High Water (MHHW)	6.23 (1.90)	
	Mean Sea Level (MSL)	3.48 (1.06)	
	Mean Lower Low Water (MLLW)	0.46 (0.14)	

The net effect of diking and draining was a dramatic loss of tidal marsh habitat, the creation of discrete diked bayland parcels, a significant reduction in tidal prism, and the creation of a significant sediment trap in the historical channels. The former marshes have subsided by several feet below MHHW , and the whole area is dependent upon levees and pumping to prevent flooding.

Elevations for all parcels except West End and Detjen were derived from Sonoma County Veg Map's 3ft bare earth LiDAR-derived DEM (2013). West End and Detjen elevations were derived from CA Ocean Protection Council's 3.3 feet (1 meter) LiDAR-derived DEM (2010). **Figure 2** shows that most of the diked baylands have subsided to an elevation at about MLLW (0.43 ft/0.13 m NAVD88). Camps 1-4 and Skaggs Island are all clustered around this elevation, with Camp 3 the lowest-lying parcel at a mean ground elevation of -0.05 ft /-0.01m NAVD88. The Ringstrom Bay, West End, and Detjen units have average elevations equivalent to low marsh (between 4.22 ft/1.29m and 5.04 ft/1.54m, according to Takekawa et al. 2013). On the alluvial fan, south of SR 121, Area 4 is at high marsh elevation, and Area 3 has an average elevation above the tidal range.

Average elevations for each parcel of interest are shown in **Figure 3** and reveal a north-south gradient from the alluvial fan south of SR 121 to the diked marshes further south.

Potential tidal prisms for each parcel are shown in **Figure 4**. These volumes were calculated for void space between the present ground surface and MHHW. The volumes were approximated based on hypsometric curves generated for each parcel using Sonoma County Veg Map's 3ft bare earth LiDAR-derived DEM (2013) (and OPC's 1m LiDAR-derived DEM (2010) for West End and Detjen) and are estimates only. Skaggs Island has the largest potential tidal prism, as a large area at relatively low existing elevation (an average of 0.99 ft/0.30m NAVD88). Camps 3 and 4, other large and low-lying parcels, also have large potential tidal prisms. In comparison, smaller and higher parcels like Camps 1-2, Detjen, and West End, have smaller potential tidal prisms. Tubbs Island is shown for comparison.

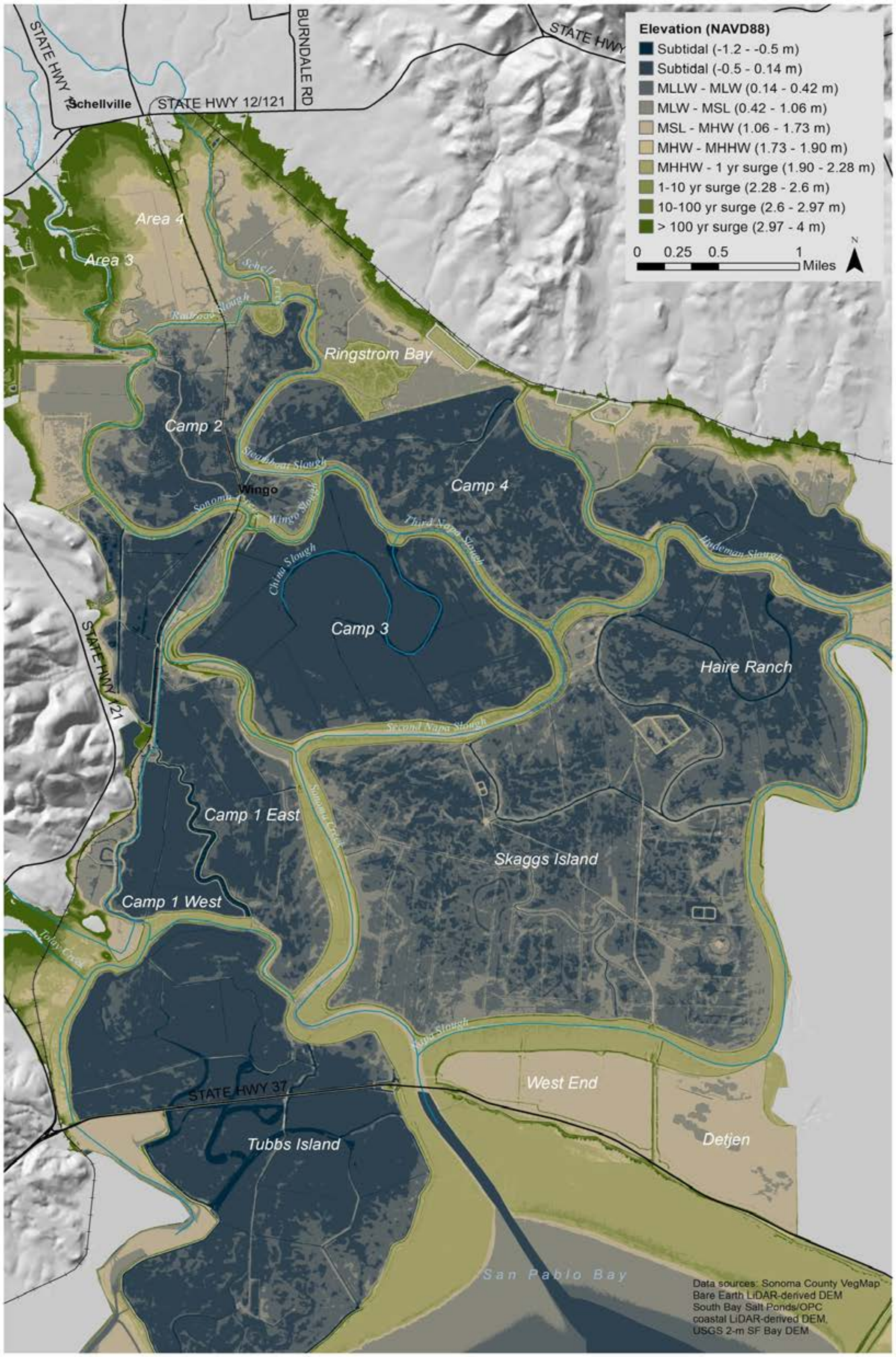


Figure 2. Present day topography of the broader Sonoma Creek area following diking. Digital elevation model sources: South Bay Salt Pond/OPC coastal Lidar-derived DEM, USGS 2-m SF Bay DEM.

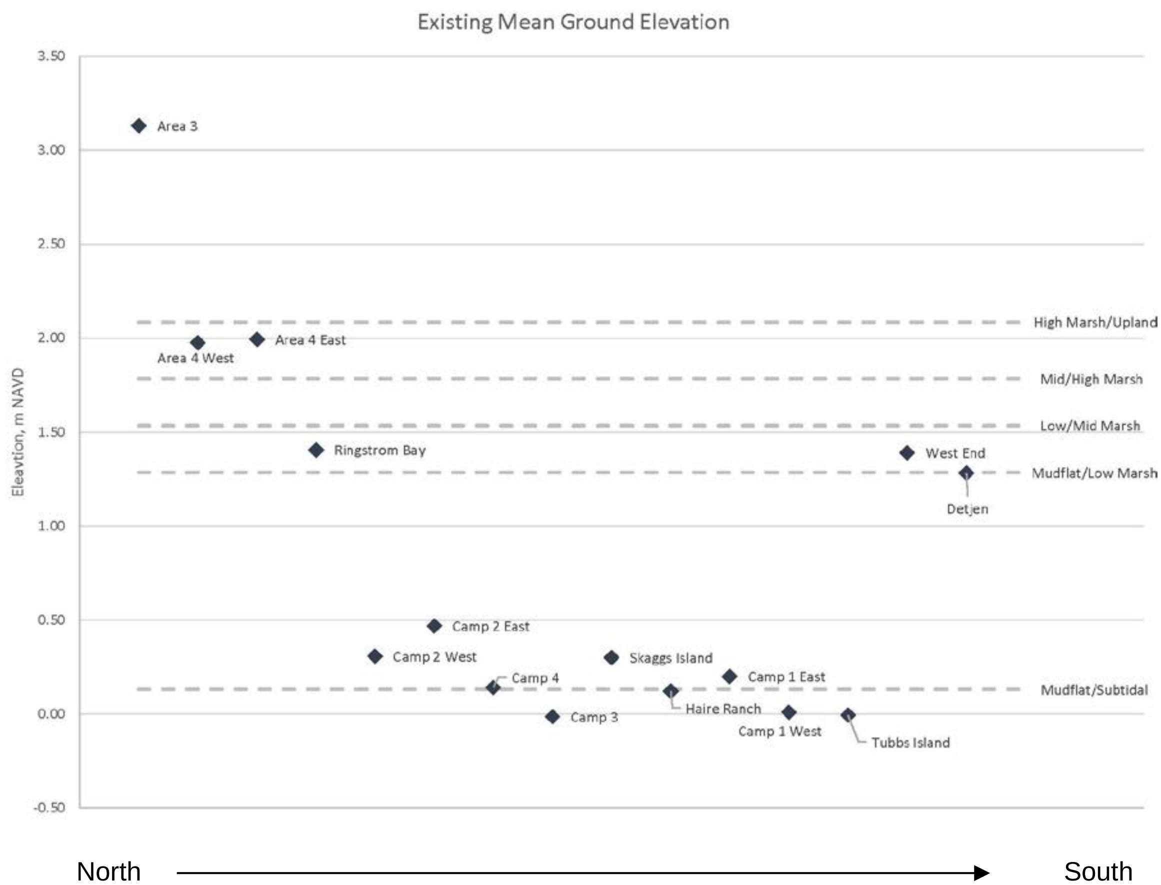


Figure 3. Existing mean ground elevations (data from Sonoma County Veg Map and CA OPC LiDAR-derived DEM).

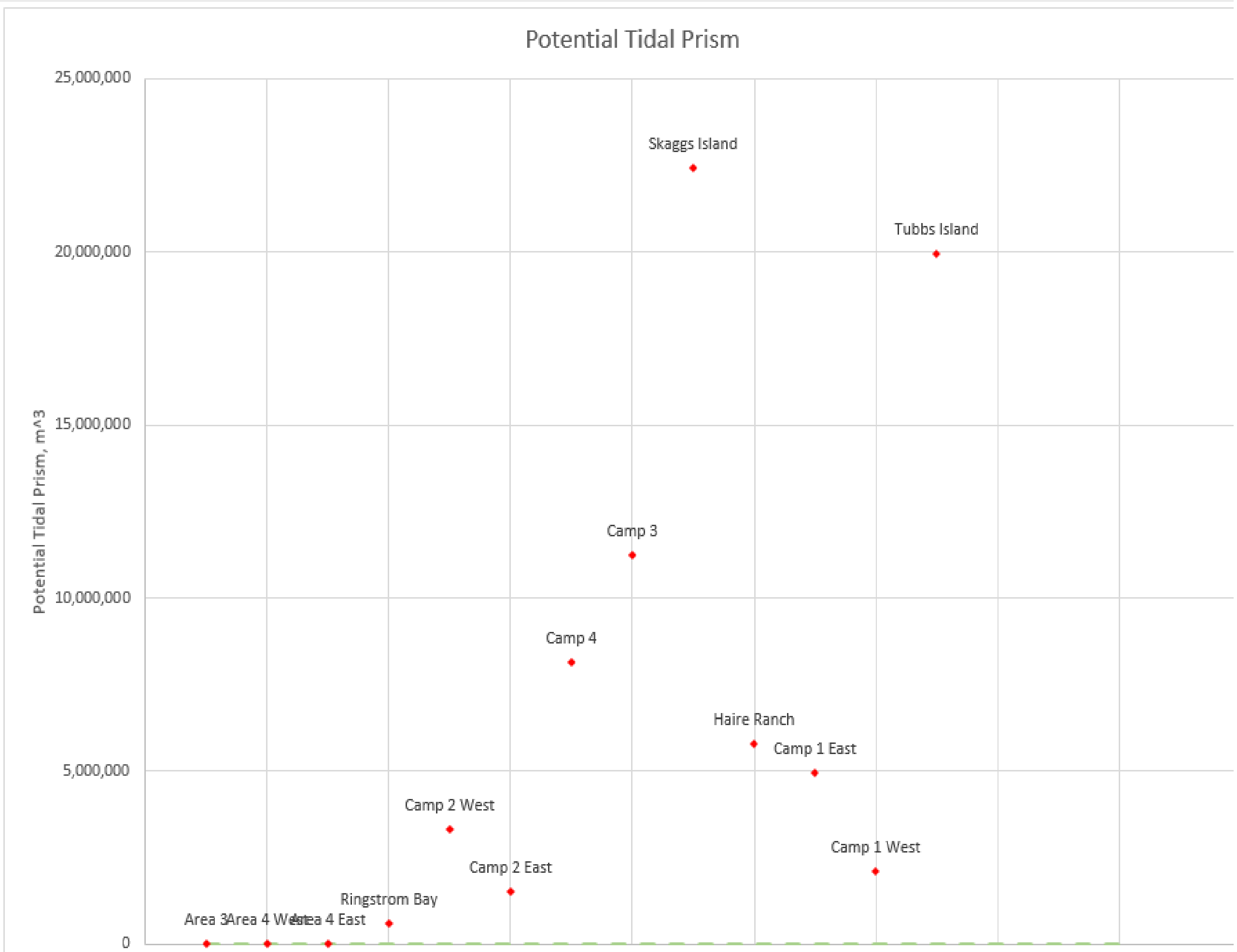


Figure 4. Potential tidal prisms of diked bayland, based on elevations from Sonoma County Veg Map and CA OPC LiDAR-derived DEM.

Historical Sonoma Creek

The historical width of Sonoma Creek prior to diking, measured from the earliest accurate surveys of these marshes taken in 1856 by the U.S. Coast and Geodetic Survey, was about 354m at the SR 37 bridge which corresponds to a tidal prism of approximately 25.2 million m^3 (Table 2). Subsequent diking and draining has reduced the channel at the bridge to its present width of about 118m for a tidal prism of about 2.0 million m^3.

Table 2. Historical, present, and potential Sonoma Creek width, depth, and cross-sectional area based on hydraulic geometry described in Williams et al. (2002).

	Historical	Present	Potential
Tidal Prism (Mm^3)	25.2	2.0	58.0
Width (m)	364	118	557
Depth (m)	7.9	4.9	9.1
Area (m^2)	1486	305	2694

In the future, an accidental breach on the east bank of the Sonoma Creek could inundate the whole of Skaggs Island including the former subtidal and mudflat areas. Such a breach at Skaggs Island could increase the tidal prism passing under the SR 37 bridge to as much as 21 million m^3 (more than it was historically due to the subsidence of former marshes) and increase the present width of 118m to about 357m. In the past, such breaches have been repaired relatively quickly, and the Sonoma Creek channel has not been significantly eroded. But in the future with rising sea levels, it may not be cost-effective to maintain these dikes, and the inundation could become permanent. In the extreme case, tidal action could be restored to all the former marshes either as planned marsh restoration projects or by accidental breaching. In this case, the maximum tidal prism of the Sonoma Creek is about 58 million m^3 giving a potential maximum width of about 557m. In addition to the channel to accommodate normal tidal flows, allowance would have to be made to maintain the adjacent creek marsh which at present is about 152m wide.

References

Williams, P. B., Orr, M. K., and Garrity, N. J. (2002). Hydraulic geometry: A geomorphic design tool for tidal marsh channel evolution in wetland restoration projects. *Restoration Ecology*, 10(3), 577–590.

Appendix 3: Landscape (Ecological) Analysis

Sam Veloz, Point Blue Conservation Science

Introduction

The restoration strategy and alternatives are designed to provide a mosaic of functional and resilient habitats in the Lower Sonoma and Tolay Creek watersheds. This section of the plan evaluates how well each of the alternatives succeeds at achieving this goal up to 2100 based on the designs of the alternatives and habitat evolution in response to sea level rise.

Methods

We are taking advantage of existing models of habitat and wildlife response to sea level rise to assess the performance of each of the alternatives. Stralberg et al. (2011) used a hybrid approach to marsh accretion modeling in which projections from a point-based accretion model were spatially interpolated across the San Francisco Estuary. Hayden et al. (2019) modified these models to incorporate more extreme sea level rise projections and to allow variation of timing of restoration within an evolving landscape. Here we applied these models to each of the alternatives developed for the project.

The Marsh98 accretion model applied in the study is briefly described here, although Stralberg et al. (2011) provides additional detail. Marsh98 models accretion (the vertical accumulation of organic material and inorganic sediment) as a function of the availability of suspended sediment, depth and periods of inundation by tides and the addition of organic material. For this analysis we used constant values of 150 mg/L of suspended sediment and 2 mm/year of contribution from organic material. The model does not include the effects of erosion that are likely to occur due to changes in tidal prism or from wind wave forces. We applied a "medium-high risk" sea level rise curve from the 2018 State of California sea level rise guidance which projects an increase of sea levels of 1.9 feet by 2050 and 6.9 feet by 2100 (California Ocean Protection Council 2018). The starting elevation of each model run was based on the SonomaVegMap 3-ft bare earth LiDAR-derived digital elevation model(DEM) (2013, http://sonomavegmap.org/data-downloads/) and the 3.3-ft OPC LiDAR-derived DEM for the Detjen and West End properties.

In all cases, the model begins accretion in 2010 for all areas that are currently open to tides and continues until 2100. To assess how the timing of restoration would affect results, we ran seven different runs of the accretion model in which potential restoration areas are restored in 2022, then in 5-year intervals from 2025 – 2050. For each model run, accretion begins at the specified restoration year and continues until 2100 in areas that are not currently open to full tidal exchange.

We used habitat classes from Takekawa et al. (2013) to categorize the marsh surface by habitat class and summed the acreage of each habitat class within each potential restoration area.

We used existing models of tidal marsh bird abundance (Veloz et al. 2013) to assess whether the habitat provided in each alternative could provide functional habitat for wildlife species. Observations of four species of tidal marsh birds were made from the entire San Francisco Estuary between 2000 and 2009: California black rail (*Laterallus jamaicensis,* CA state threatened), California Ridgway's rail (*Rallus obsoletus obsoletus*, federally endangered), saltmarsh common yellowthroat (*Geothlypis trichas*, state species of special concern) and marsh wren (*Cistothorus palustris*). These species were selected as they represent a range of conservation concern from endangered to common and each species utilizes different aspects of marsh habitat thus serving as indicators for a range of marsh species. We used a statistical machine learning approach to correlate the abundance of individuals of each species to a suite of environmental variables such as elevation-based habitat metrics, salinity, channel density and distance to the bay and levees. Additional details on modeling are provided in Veloz et al. (2013). We used these existing models to project the abundance of individuals of each species to the evolved landscape at 20-year intervals (2020-2100) from the Marsh98 model results. We summarized the number of each species within each property in the study area to assess the response to the management alternatives.

We used observations of the relative abundance of fish at mature marshes and restoring marshes in the North Bay to estimate how the fish community will respond to habitat evolution and the management alternatives. We acquired data only from monitoring studies in which sampling was conducted within mature or restored marshes, thus excluding data from channels and sloughs. We evaluated data collected within the Green Island Unit of the Napa Sonoma Marshes Wildlife Area and Fagan Slough Ecological Reserve (Fagan SER) from 2009 - 2011 (URS 2012). Fish were sampled at three restoration sites and one mature marsh. We also included fish monitoring data from the Sears Point restoration project (Keegan and Lee, 2018). In all cases, marsh sites were attributed with the maximum observed relative abundance of each species at a site. We were not able to include all observations over years or months as the environmental variables (marsh elevation) of interest do not vary substantially on such a short time scale.

As sampling locations within the reports we investigated only provided the location at the resolution of the site, we summarized the mean elevation of each site where sampling occurred. We visually inspected scatter plots of the relative abundance of each species vs the mean elevation of the sites. We characterized species into groups that preferred relatively deeper water habitats (sub-tidal and mudflat habitats) and those that preferred higher elevations (mudflat to mid-marsh habitats). We included only native California species in our assessment. We were able to estimate a correlation between relative abundance and elevation for: Bay Goby (*Lepidogobius lepidus*), California halibut (*Paralichthys californicus*), Central California Coast steelhead (*Oncorhynchus mykiss*), Pacific herring (*Clupea pallasii*), staghorn sculpin (*Leptocottus armatus*) and Threespine stickleback (*Gasterosteus aculeatus*). We could not detect any clear correlation between relative abundance and elevation for any other species.

Results

Marsh accretion models

There is a general pattern of accretion across all alternative and restoration starting year scenarios. While mid and low marsh habitats can increase in acreage between 2030 and 2070, as rates of sea level rise increase towards the end of the century, the models consistently predict that marshes will drown with the landscape dominated by mudflat habitat (**Figure 1**). Additionally, starting restoration later results in a greater proportion of high marsh habitat but less mid marsh habitat at 2050 than starting restoration early, because elevations are raised to high marsh elevation prior to breaching in the restoration design and are thus at a higher elevation than when restoration begins earlier.

There tends to be more low marsh habitat remaining in the landscape at 2090 when restoration is initiated in 2022 vs 2050. By 2100, almost all models project very little marsh habitat remaining in the landscape with the exception of close to 2500 acres of low marsh persisting at 2100 in Alternative 3 when restoration starts at 2050. However, the potential benefits of delaying restoration must be contrasted with the loss of any habitat prior to 2050 in which species could be building populations.

For the remainder of the results we focus on model runs where restoration is initiated in 2022. Alternative 3 results in the greatest range of habitats persisting consistently throughout the study period with substantially more subtidal habitat than the other two alternatives. In addition to starting with substantially more subtidal habitat than the other alternatives, Alternative 3 also begins with more high marsh and upland habitat than the other two (**Figure 2**).

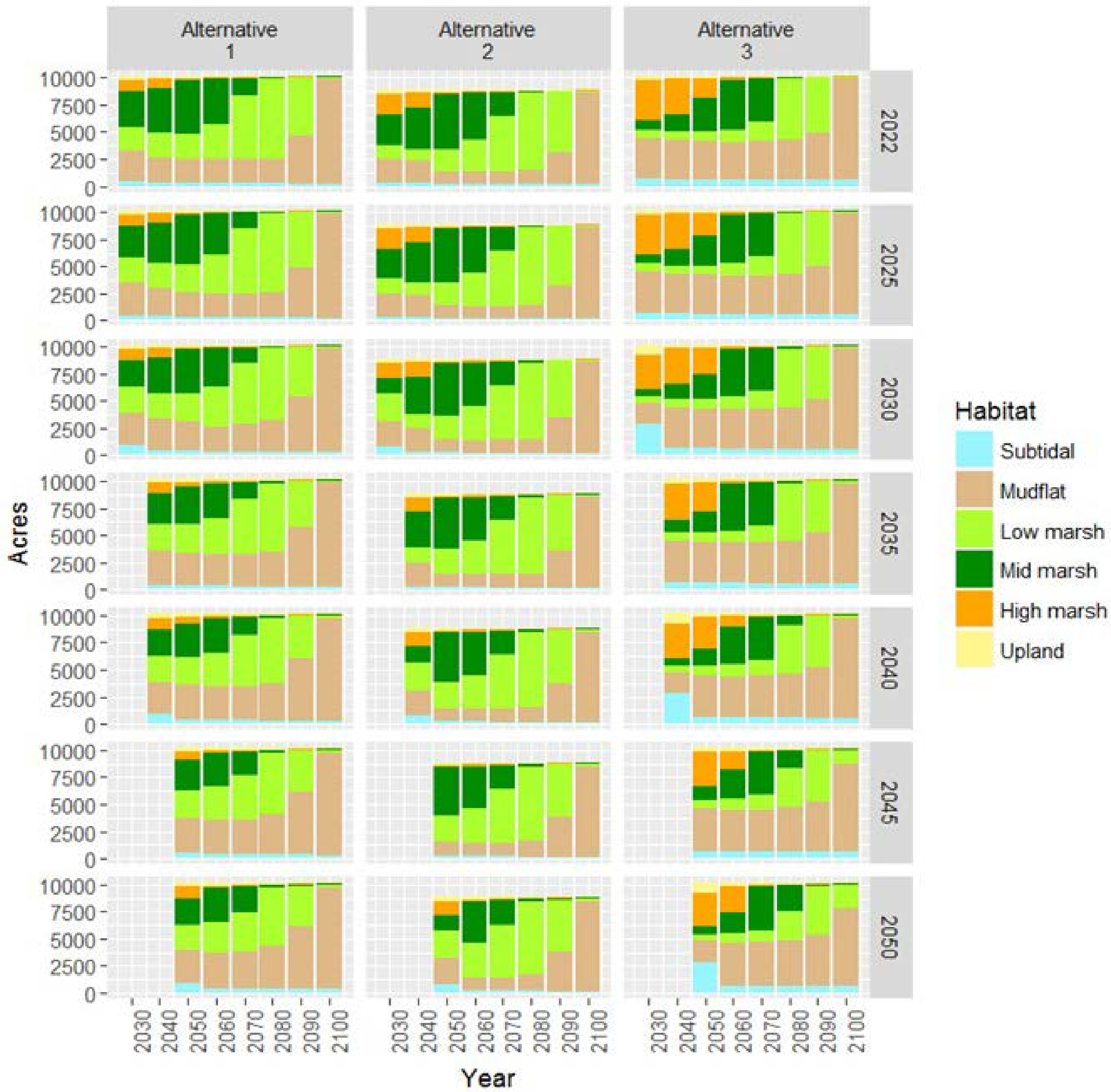


Figure 1. The acres of bayland habitats projected by the Marsh98 model in response to sea-level rise. The bars in each graph are colored by habitat type. The years along the x axis indicate the model year from the Marsh98 model. Each vertical panel represents the results from the management alternatives. Each horizontal panel indicates the year in which restoration was initiated in the model. Columns are left blank where the model year precedes the restoration year.

The high marsh habitat persists through 2050 in Alternative 3, whereas the high marsh habitat in Alternatives 1 & 2 is largely converted to mid-marsh by 2050 (**Figure 2**). Alternatives 1 & 2 achieve relatively more mid-marsh habitat than alternative 3 through 2050 but by 2060, Alternative 3 has more mid-marsh habitat than Alternatives 1 & 2. By 2080, very little mid-marsh habitat remains in any of the alternatives (**Figures 2 & 3**). Marsh98 projects that the amount of low marsh habitat substantially increases in 2070 in Alternatives 1 & 2 and by 2080 in Alternative 3, corresponding to decreases in the projections of mid-marsh habitat (Figure 2 & 3). Although there is less overall area restored in Alternative 2, Marsh98 projects similar acreage of low, mid, and high marsh habitat between Alternatives 1 & 2 (**Figure 2**).

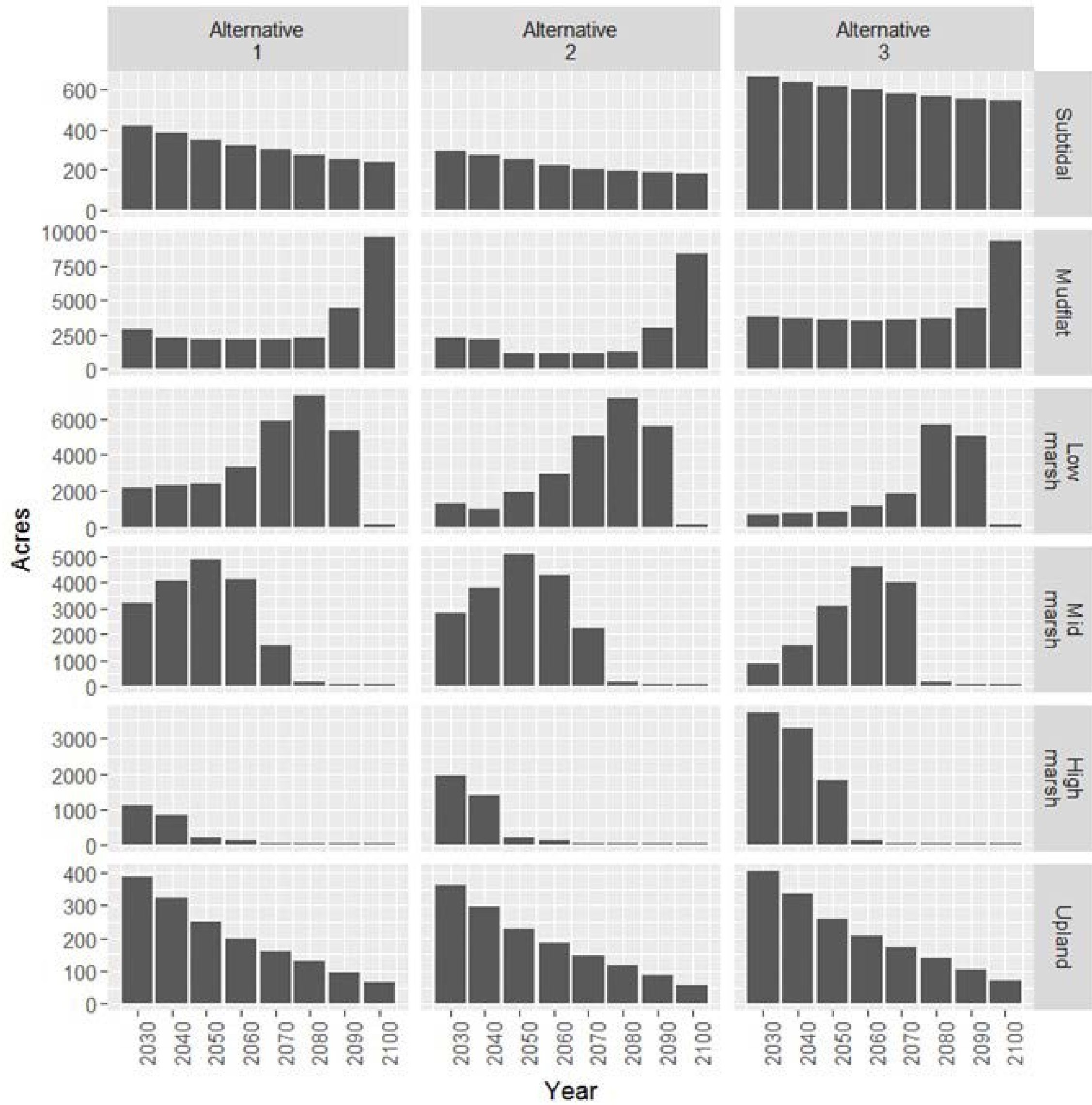


Figure 2. Acres of bayland habitat projected for each model year. Each vertical panel displays the results from each management alternative. Horizontal panels provide results by habitat classes. Restoration was initiated in 2022.

The design of each of the alternatives leads to varying spatial patterns in habitat availability across the alternatives. By 2080, Alternatives 1 & 2 result in large areas of low marsh habitat distributed fairly homogeneously across the landscape. In contrast, there is a mixture of habitats in many of the restored properties in Alternative 3, primarily mudflat and low marsh habitat by 2080 but also narrow patches of mid-marsh along the edges of properties (**Figure 3**). Detailed summaries of habitat present in each property for each alternative are available in Appendix 3A.

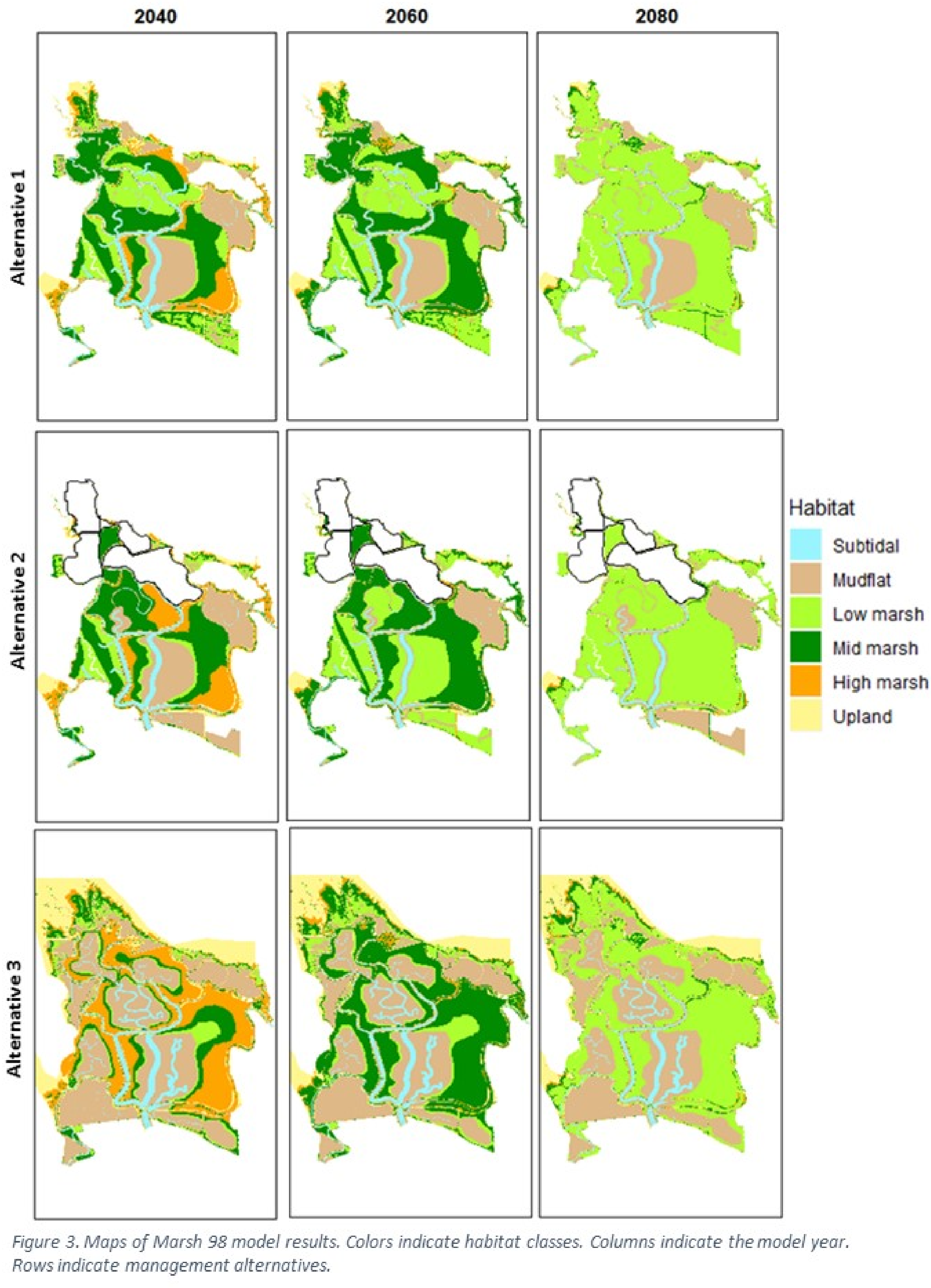


Figure 3. Maps of Marsh 98 model results. Colors indicate habitat classes. Columns indicate the model year. Rows indicate management alternatives.

Bird models
We found substantial differences in the projected abundance of each species within the study area across the three management alternatives. Which alternative resulted in the highest abundance of each species varied by when restoration was initiated and the species of interest. Across all species and models we found that birds respond fairly quickly to restoration as we project large increases in each species immediately following restoration (**Figure 4**). A peak in abundance for each species is projected around 2060 then declines in abundance as habitats begin to drown in the last half of the century. We also found a consistent pattern that starting restoration sooner results in greater numbers of each species, although this difference declines by 2080 as little marsh habitat remains irrespective of when restoration was initiated (**Figure 4**).

In general, we project decreased abundance of the four bird species in Alternative 3 versus Alternatives 1 & 2. The differences are likely due to the greater areas of non-tidal marsh habitat within Alternative 3. By 2080, where the landscapes become similar across the alternatives in terms of the amount of marsh habitat remaining (primarily low marsh, **Figure 1**), we project similar abundance of each species in each of the scenarios (Figure 4). The projected decline in abundance in each of the species between 2060 and 2080 is less pronounced in Alternative 3 versus Alternatives 1 & 2. As marshes drown by 2100, we project that all species will decline to near zero within the study properties within each of the alternatives (**Figure 4**).

The timing of restoration seems to have varying effects on the four tidal marsh species studied across management alternatives. When restoration is initiated in 2022, we almost always project greater numbers of each species in Alternative 1 versus Alternatives 2 & 3 (**Figure 4**). In contrast, when restoration is initiated in 2040, we project similar or higher abundance of each species in Alternative 2 versus Alternatives 1 & 3, with the greatest difference occurring at model year 2060.

Focusing on models in which restoration was initiated in 2022, we can see the upper limits of the abundance of each species across the alternatives. Restoration will result in dramatic increases in the numbers of each species within San Pablo Bay between 2040 and 2080 as compared to current populations. For example, we estimated approximately 300 Ridgway's rail occurred in San Pablo Bay in 2010 (Veloz et al. 2012), so restoration will result in a doubling or tripling of the 2010 population between 2040 and 2080, depending on which alternative is selected. We project similar population increases following restoration for the other three species as well (**Figure 5**). Although we project these population gains are essentially lost by 2100, the restoration can create habitat from which species can migrate to newly available habitats beyond the study region.

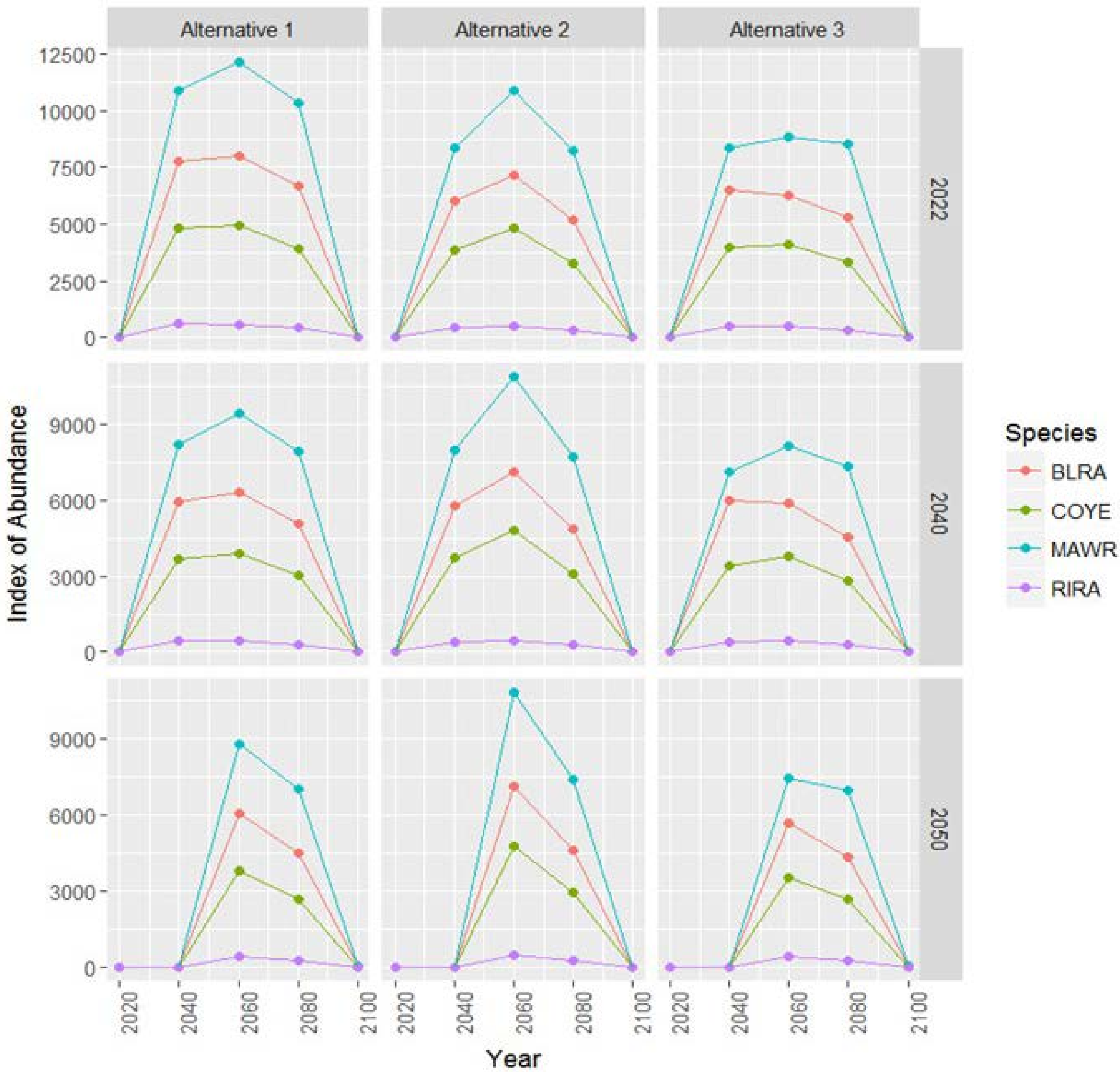


Figure 4. Index of the projected number of individuals of four species of tidal marsh birds; black rail (BLRA), common yellowthroat (COYE), marsh wren (MAWR) and Ridgway's rail (RIRA). The horizontal axis indicates the year of the model results. Each vertical panel represents a management alternative. Each horizontal row represents the year restoration was initiated in the model.

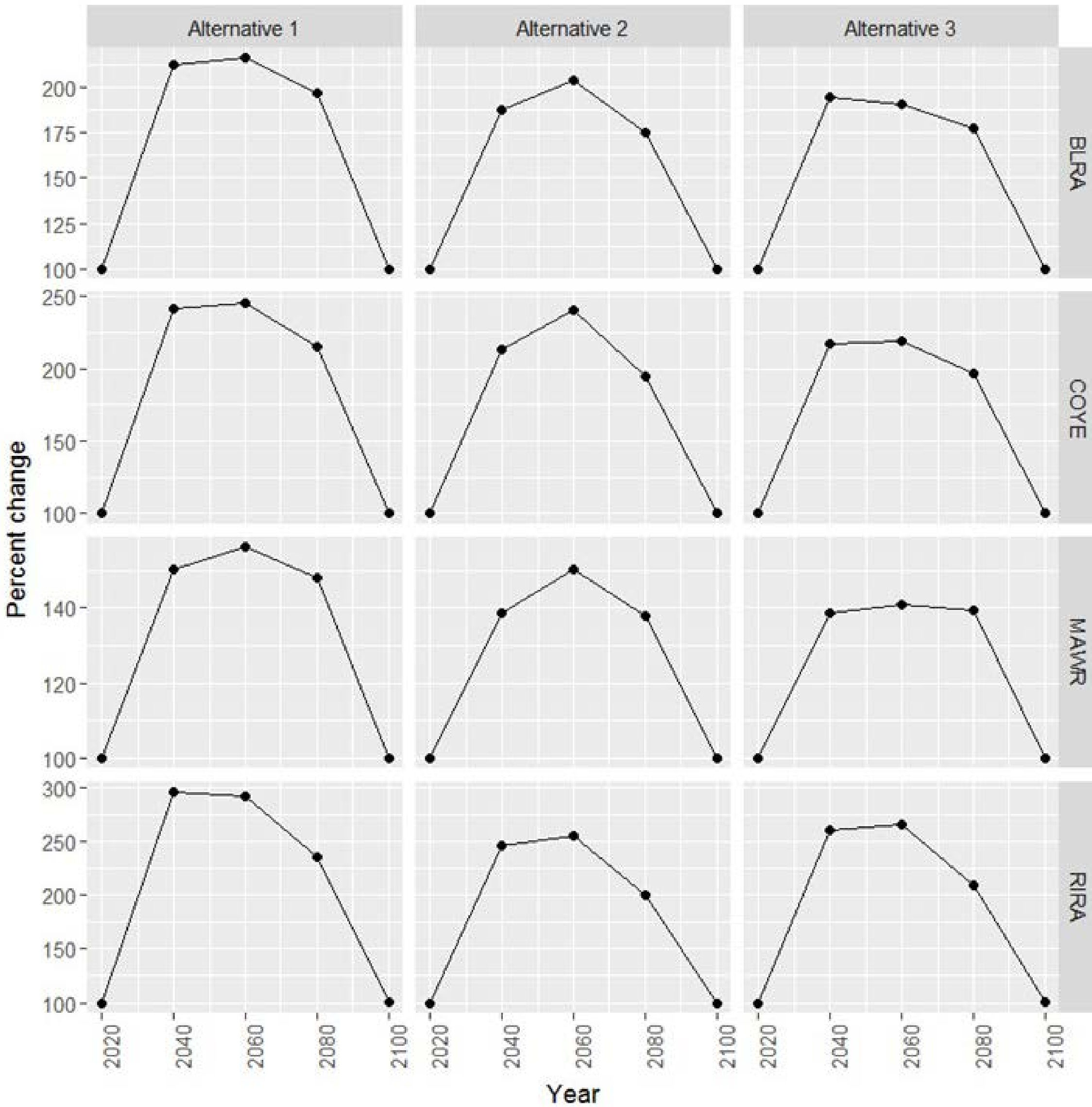


Figure 5. Percent change in the 2010 San Pablo Bay population for each of four species of tidal marsh birds; black rail (BLRA, 6,900), common yellowthroat (COYE, 3,400), marsh wren (MAWR, 21,700) and Ridgway's rail (RIRA, 300). Values following the acronym here are the 2010 population estimate in San Pablo Bay for each species from Veloz et al. (2012). Restoration was initiated in 2022 for these results.

Fish observations

With the limited observation data available for this assessment we were only able to coarsely characterize fish habitat into those that prefer deeper waters (subtidal - mudflat habitat) and those that prefer shallower habitats (mudflat - mid-marsh). Our assessment classified bay goby, California halibut and staghorn sculpin as species that prefer the deeper habitats within baylands with the highest relative abundance of these species found at sites with mean elevation < -0.6 m MHHW. Central California Coast steelhead, Pacific herring and threespine stickleback were all found at higher relative abundance at sites with mean elevation > -0.3 m MHHW.

Using these coarse classifications we can qualitatively ranking of the three management alternatives by how they affect fish species. Alternative 3 that results in the highest proportion of mudflat and subtidal habitat would provide the somewhat more preferred habitat. Similarly, as marshes lose elevation with increasing sea level rise, the increase of low elevation habitat should benefit the deeper habitat associated species. In contrast, the species more closely associated with lower marsh elevations will likely experience a decline in the quality of their habitats as the marshes drown with increasing sea level rise.
The assessment of fish habitat we provide here should be considered extremely preliminary as we had very limited data with which to estimate habitat preferences. Conducting surveys across more sites that better sample the range of marsh elevations would help enhance our assessment and allow quantitative predictions of fish response to restoration and marsh evolution.

Discussion

Our survey shows that restoration will substantially increase habitat that will result in increases in the populations of tidal marsh dependent species within the study area between 2020 and 2080. With high rates of sea level rise, we do project that by 2100 this habitat will largely be lost as marshes drown. However, with lower rates of sea level rise, previous surveys have shown that these habitat gains and subsequent population gains may be resilient beyond 2100 (Veloz et al. 2013). If rates of sea level rise are as high as assumed for this analysis, maintaining the population gains that follow restoration will require additional habitat restoration and space for marsh migration in currently upland areas.
The benefits of each of the alternatives relative to one another are assessed by focusing on the abundance of four representative tidal marsh species. However, there is no clear preferred alternative based on that metric alone as the results vary by when restoration is initiated and which species is used. Additionally, the other habitats not included in our assessment, subtidal and mudflat, will likely provide habitat for fish and wildlife such as shorebirds and waterfowl. It is possible that including a wider range of taxa in the assessment of benefits across alternatives would result in a different perspective of which alternative could provide the greatest benefits to biodiversity.

Creating higher habitat within restoration sites that provides migration space as sea levels rise seems to be the most resilient strategy for maintaining marsh habitat for the longest period of time. Starting elevations within alternative 3 are higher within some of the properties considered and these areas provide the most resilient habitat within the restoration areas. Additionally, we project that areas of fringing infill wetlands will develop in areas that are currently at upland elevations outside the planning area. If these areas were protected as open space, the habitat created through restoration in each of the alternatives could provide source populations in the future from which individuals could colonize newly evolving habitat outside the planning area.

References

California Ocean Protection Council 2018. State of California Sea-Level Rise Guidance 2018 Update. Sacramento, CA.

Hayden, M., L. Salas, N. Eliott, D. Jongsomjit, S. Veloz, N. Nur, J. Wood, H. Papendick, and K. Malinowski. 2019. Informing sea level rise adaptation planning through quantitative assessment of the risks and broader consequences of tidal wetland loss: A case study in San Mateo County. Petaluma, CA.

Keegan, T. and D. Lee. 2018. Sears Point restoration project fisheries monitoring: results of ARIS camera and traditional sampling surveys. Prepared for Ducks Unlimited.

Stralberg, D., M. Brennan, J. C. Callaway, J. K. Wood, L. M. Schile, M. Kelly, V. T. Parker, and S. Crooks. 2011. Evaluating Tidal Marsh Sustainability in the Face of Sea- Level Rise : A Hybrid Modeling Approach Applied to San Francisco Bay. PLoS ONE 6.

Veloz, S. D., N. Nur, L. Salas, D. Jongsomjit, J. Wood, D. Stralberg, and G. Ballard. 2013. Modeling climate change impacts on tidal marsh birds: Restoration and conservation planning in the face of uncertainty. Ecosphere 4.

Veloz, S., N. Nur, L. Salas, D. Stralberg, D. Jongsomjit, J. Wood, L. Liu, and G. Ballard. 2012. San Francisco Bay Sea-Level Rise Website. A PRBO online decision support tool for managers, planners, conservation practitioners and scientists. Phase II report to the California State Coastal Conservancy. Petaluma, CA.

Appendix 4: Feasibility Level Opinion of Probable Cost

Steve Carroll, Ducks Unlimited and Jeremy Lowe, San Francisco Estuary Institute

Units Abbreviation Legend:

AC	acre
CY	cubic yard
EA	each
LF	linear foot
LS	lump sum
MI	mile
TN	ton

The Extended Price numbers have been rounded to the nearest $1,000.

Alternative 3

Line	Site	Line Item	Quantity	Units	Unit Price	Extended Price	Description of Actions
1	**Areas 3 & 4**	Mobilization & Demobilization	1	LS	$3,343,000	$3,343,000	Mobilizing & demobilizing forces, equipment, and facilities to needed to perform the work.
2		Site Preparation & Env. Compliance	1	LS	$2,026,000	$2,026,000	General site preparations, environmental compliance measures and BMP's
3	Levee Lowering	Remove Railroad Slough Levee	20,000	CY	$8.00	$160,000	Excavate and haul for onsite use as habitat fill.
4		Remove Schell Creek Levee	12,000	CY	$8.00	$96,000	Excavate and haul for onsite use as habitat fill.
5		Remove Stock Pond Levees	10,000	CY	$5.00	$50,000	Excavate and haul for onsite

							use as habitat fill.
6	Channel Excavation	Big Break Channel Expansion	19,000	CY	$7.50	$143,000	Expand Big Break channel to Area 4. Reuse material as habitat fill.
7	Levee Improvement	Area 4 West Levee	44,000	CY	$10.00	$440,000	Construct ~4,400 LF levee along west edge of Area 4 using onsite fill.
8	Railroad Infrastructure	Railroad Embankment	149,000	CY	$70.00	$10,430,000	Construct ~7,500 LF embankment along both sides of railroad using imported material.
9		Rock Slope Protection	60,000	TN	$100.00	$6,000,000	Armor new embankments on both sides of railroad.
10		Railroad Slough Bridge Flood Gate	1	EA	$100,000	$100,000	Construct flood gate at north side of Railroad slough bridge.
11	Other Infrastructure	Millerick Road Low Water Crossing	1,000	TN	$100.00	$100,000	Install a rocked low water crossing on Millerick Road at Big Break.
12		Power Line Installation	7,500	LF	$20.00	$150,000	Construct new powerline along railroad from SR121 to Camp 2.

13	Demolition	Millerick Road Demolition	3,000	LF	$10.00	$30,000	Demolish Millerick Road south of Vineyard to Camp 2.
14		Railroad Slough Tide Gate Demolition	1	EA	$25,000	$25,000	Demolish the existing concrete tide gate structure.
15		Power Line Demolition	3,000	LF	$10.00	$30,000	Remove the powerline along Millerick Road from the vineyard south to Camp 2.
16		House Demolition	3	EA	$200,000	$600,000	Demolish homes in the northern part of Area 4.
17		Septic System Demolition	3	EA	$10,000	$30,000	Demolish septic systems per county standards
18		Barn Demolition	12	EA	$100,000	$1,200,000	Demolish barns in the northern part of Area 4.
19		Fence demolition	2	MI	$5,000	$10,000	Remove fencing in Area 4.
20		Miscellaneous Demolition	40	AC	$10,000	$400,000	General debris, equipment, & structure removal and clean up.
21		General Ripping & Discing	40	AC	$1,000	$40,000	Rip and disc hardened lands in northern Area 4.

22		Road Demolition	11,000	LF	$132.80	$141,000	Demolish existing asphalt and rock surfaced areas (estimated equivalent of 3 acres).
23		Well Demolition	3	EA	$15,000	$45,000	Demolish wells per county standards.
24		Pump Demolition	2	EA	$20,000	$40,000	Remove existing pumps and appurtenances.
25	**Areas 3 & 4 Subtotal**					**$25,629,000**	
26	**Camp 2**	Mobilization & Demobilization	1	LS	$5,854,000	$5,854,000	Mobilizing & demobilizing forces, equipment, and facilities to needed to perform the work.
27		Site Preparation & Env. Compliance	1	LS	$3,548,000	$3,548,000	General site preparations, environmental compliance measures and BMP's
28	Levee lowering	Lower Sonoma Creek Levee	57,000	CY	$5.00	$285,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
29		Remove Railroad Slough Levee	111,000	CY	$8.00	$888,000	Excavate and haul for onsite use as habitat fill.

30		Remove Wingo Slough Levee	53,000	CY	$8.00	$424,000	Excavate and haul for onsite use as habitat fill.
31		Lower Steamboat Slough Levee	30,000	CY	$5.00	$150,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
32	Levee Breaching	SW Sonoma Creek Breach	14,000	CY	$12.00	$168,000	Excavate breach and sidecast material nearby.
33		SE Wingo Slough Breach	15,000	CY	$12.00	$180,000	Excavate breach and sidecast material nearby.
34	Channels Excavation	SW Sonoma Creek Channel	1,214,000	CY	$7.50	$9,105,000	Excavate channel and haul material for use as habitat fill onsite.
35		Wingo Slough Channel	161,000	CY	$7.50	$1,208,000	Excavate channel and haul material for use as habitat fill onsite.
36	Railroad Infrastructure	Railroad Embankment	253,000	CY	$70.00	$17,710,000	Construct ~6,000 LF embankment along both sides of railroad using imported material.

37		Rock Slope Protection	48,000	TN	$100.00	$4,800,000	Armor new embankments on both sides of railroad.
38		Railroad Slough Bridge Flood Gate	1	EA	$100,000	$100,000	Construct flood gate at south side of Railroad Slough bridge.
39		Wingo Slough Bridge Flood Gate	1	EA	$100,000	$100,000	Construct flood gate at north side of Wingo Slough bridge .
40	Other Infrastructure	Power Line Installation	6,000	LF	$20.00	$120,000	Install powerline along railroad alignment from railroad slough to wing slough.
41	Demolition	Millerick Road Demolition	7,800	LF	$10.00	$78,000	Demolish Millerick Road from Area 3 to Wingo Slough.
42		Power Line Demolition	7,800	LF	$10.00	$78,000	Remove powerline within west side of Camp 2.
43		Pump Station Demolition	11	EA	$40,000	$40,000	Demolish NW Pump station
44		Well Demolition	3	EA	$15,000	$45,000	Demolish wells per county standards.
45	**Camp 2 Subtotal**					**$44,881,000**	
46	**Camp 3**	Mobilization & Demobilization	1	LS	$4,264,000	$4,264,000	Mobilizing & demobilizing forces, equipment, and facilities to needed to

							perform the work.
47		Site Preparation & Env. Compliance	1	LS	$2,584,000	$2,584,000	General site preparations, environmental compliance measures and BMP's
48	Levee Lowering	Lower Sonoma Creek Levee	4,000	CY	$5.00	$20,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
49		Remove Wingo Slough Levee	43,000	CY	$8.00	$344,000	Excavate and haul for onsite use as habitat fill.
50		Lower Third Napa Slough Levee	11,000	CY	$5.00	$55,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
51		Lower Second Napa Slough Levee	1,000	CY	$5.00	$5,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
52		Remove Residential Levees	8,000	CY	$5.00	$40,000	Remove ~ 1,200 LF of levees around residence.

53	Levee Breaching	Second Napa Slough Breach	14,000	CY	$12.00	$168,000	Excavate breach and sidecast material nearby.
54		Wingo Slough Breach	14,000	CY	$20.00	$280,000	Excavate breach and sidecast material nearby.
55		Third Napa Slough Breach	15,000	CY	$12.00	$180,000	Excavate breach and sidecast material nearby.
56	Channel Excavation	Sonoma Creek Channel	819,000	CY	$7.50	$6,143,000	Excavate channel and haul material for use as habitat fill onsite.
57		China Slough Channel	409,000	CY	$7.50	$3,068,000	Excavate channel and haul material for use as habitat fill onsite.
58	Railroad Infrastructure	Railroad Embankment	157,000	CY	$70.00	$10,990,000	Construct ~5,300 LF embankment on east side of railroad from Wingo Slough to Camp 1 using import fill.
59		Rock Slope Protection	21,000	TN	$100.00	$2,100,000	Armor new embankment.
60		Wingo Slough Bridge Flood Gate	1	EA	$100,000	$100,000	Construct flood gate at south side of Wingo Slough bridge.

61	Demolition	Power Line Demolition	200	LF	$10.00	$2,000	Remove 2 poles at residence
62		House Demolition	7	EA	$200,000	$1,400,000	Remove homes around Camp 3
63		Septic System Demolition	7	EA	$10,000	$70,000	Demolish septic systems per county standards.
64		Barn Demolition	6	EA	$100,000	$600,000	Demolish barns.
65		General ripping/discing	6	AC	$1,000	$6,000	Loosen soil around barns and residences.
66		Road Demolition	2,500	LF	$1312.80	$32,000	Demolish ~2,500 LF of paved/heavily surfaced road.
67		Road Demolition	5,400	LF	$10.00	$54,000	Demolished ~5,400 LF of graveled road east of the railroad.
68		Well Demolition	3	EA	$15,000	$45,000	Demolish wells per county standards.
69		Pump Demolition	1	EA	$20,000	$20,000	Remove pump station
70		Miscellaneous Demolition	2	AC	$10,000	$20,000	General debris, equipment, & structure removal and clean up.
71		Miscellaneous Demolition	1	EA	$100,000	$100,000	Demolish bridge, ~50 ft length

72	**Camp 3 Subtotal**					**$32,690,000**	
73	**Camp 4**	Mobilization & Demobilization	1	LS	$881,000	$881,000	Mobilizing & demobilizing forces, equipment, and facilities to needed to perform the work.
74		Site Preparation & Env. Compliance	1	LS	$534,000	$534,000	General site preparations, environmental compliance measures and BMP's
75	Levee lowering	Lower Steamboat Slough Levee	149,000	CY	$6.50	$969,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
76		Lower Third Napa Slough Levee	12,000	CY	$6.50	$78,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
77		Lower Hudeman Slough Levee	7,000	CY	$6.50	$46,000	Selectively lower to MHHW levees south and east of property, sidecast material.
78		Lower Internal Berms	10,000	CY	$5.00	$50,000	Selectively lower ~3,600 LF of internal berms.

79	Levee Breaching	Third Napa Slough Breach	13,000	CY	$12.00	$156,000	Excavate breach and sidecast material nearby.
80	Channel Excavation	Third Napa Slough Channel	488,000	CY	$7.50	$3,660,000	Excavate and haul for onsite use as habitat fill.
81	Demolition	Power Line Demolition	900	LF	$10.00	$9,000	Remove powerlines.
82		Barn Demolition	3	EA	$100,000	$300,000	Remove barns.
83		General ripping/discing	7	AC	$1,000	$7,000	Loosen ~7 acres around barn areas
84		Road Demolition	4,400	LF	$10.00	$44,000	Demolish ~4,400 LF of internal rocked road
85		Pump Demolition	1	EA	$20,000	$20,000	Demolish pump stations and appurtenances
86	**Camp 4 Subtotal**					**$6,754,000**	
87	**Skaggs Island**	Mobilization & Demobilization	1	LS	$6,890,000	$6,890,000	Mobilizing & demobilizing forces, equipment, and facilities to needed to perform the work.
88		Site Preparation & Env. Compliance	1	LS	$4,176,000	$4,176,000	General site preparations, environmental compliance

							measures and BMP's
89	Levee Lowering	Lower Sonoma Creek Levee	35,000	CY	$5.00	$175,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
90		Lower Second Napa Slough Levee	12,000	CY	$5.00	$60,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
91		Lower Napa Slough Levee	69,000	CY	$5.00	$345,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
92		Remove Hair Ranch Internal Levee	112,000	CY	$6.50	$728,000	Excavate and haul for onsite use as habitat fill.
93	Levee Breaching	Breach at Napa Slough confluence	58,000	CY	$20.00	$1,160,000	Excavate breach and sidecast material nearby.
94		Second Napa Slough Beach	14,000	CY	$12.00	$168,000	Excavate breach and sidecast material nearby.

95	Channel Excavation	Napa Sl. - Second Napa Sl. Channel	2,997,000	CY	$7.50	$22,478,000	Excavate channel and haul material for use as habitat fill onsite.
96		Napa Slough - Haire Channel	1,605,000	CY	$7.50	$12,038,000	Excavate channel and haul material for use as habitat fill onsite.
97	VortacORTAC	Vortac Levee	267,000	CY	$10.00	$2,670,000	Construct a ring levee inside Skaggs around Vortac.
98		Grade Levee for Vortac Access	16,000	LF	$10.00	$160,000	Improve levee from Hudeman Slough bridge to Vortac for access.
99		Surface Levee for Vortac Access	2,000	CY	$150.00	$300,000	Surface levee from Hudeman Slough bridge to Vortac for access.
100		Vortac Pump Station	1	EA	$40,000	$40,000	Install a pump to keep Vortac dewatered, connect to existing electrical supply.
101	Demolition	Power Line Demolition	6,400	LF	$10.00	$64,000	Remove powerlines within the Haire Unit.
102		House Demolition	2	EA	$200,000	$400,000	Remove homes

103		Septic System Demolition	2	EA	$10,000	$20,000	Demolish septic systems per county standards
104		Barn Demolition	3	EA	$100,000	$300,000	Remove barns.
105		Misc. demolition	4	AC	$10,000	$40,000	Clearing debris, leveling land
106		General ripping/discing	8	AC	$1,000	$8,000	Loosen soil on ~8 acres at Haire Ranch
107		Road Demolition	29,000	LF	$132.80	$371,000	Demolish ~29,000 LF of asphalt roads (excludes road from 37 to vortex)
108		Well Demolition	1	EA	$15,000	$15,000	Demolish well per county standards.
109		Pump Demolition	3	EA	$20,000	$60,000	Demolish pump stations and appurtenances
110		Miscellaneous Demolition	1,000	LF	$10.00	$10,000	Demolish HDPE discharge to deep water unit
111		Miscellaneous Demolition	10,000	LF	$15.00	$150,000	Cut to grade steel sheet pile along Second Napa & Hudeman Sloughs
112	**Skaggs Island Subtotal**					**$52,826,000**	

113	**Camp 1 West & East**	Mobilization & Demobilization	1	LS	$3,627,000	$3,627,000	Mobilizing & demobilizing forces, equipment, and facilities to needed to perform the work.
114		Site Preparation & Env. Compliance	1	LS	$2,198,000	$2,198,000	General site preparations, environmental compliance measures and BMP's
115	Levee lowering	Sonoma Creek Levee	4,000	CY	$5.00	$20,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
116		Lower West Camp 1 Levee	4,000	CY	$5.00	$20,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
117		Lower Bush Slough Levees	26,000	CY	$6.50	$169,000	Excavate and haul for onsite use as habitat fill.
118		Lower Tolay Creek Levee	11,000	CY	$5.00	$55,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
119	Levee Breaching	Tolay Creek SW Breach	9,000	CY	$12.00	$108,000	Excavate breach and sidecast

							material nearby.
120		Tolay Creek - Bush Slough Breach	9,000	CY	$12.00	$108,000	Excavate breach and sidecast material nearby.
121	Channel Excavation	Tolay Creek SW Channel	256,000	CY	$87.50	$1,920,000	Excavate and haul for onsite use as habitat fill.
122		Tolay Creek - Sonoma Creek Channel	252,000	CY	$15.00	$3,780,000	Excavate from Bush Slough to Sonoma Creek and haul for onsite use as habitat fill.
123		Tolay Creek Pickleweed Clearing	28	AC	$25,0400	$712,000	Hand clear Tolay Creek channel footprint, place material in site.
124	Railroad Infrastructure	Railroad Embankment	160,000	CY	$70.00	$11,200,000	Construct ~9,400 LF embankment along east side of railroad using imported material. From Camp 3 to where ground elevation = 15 ft.
125		Rock Slope Protection	37,000	TN	$100.00	$3,700,000	Armor new embankment.
126	Demolition	Barn Demolition	1	EA	$100,000	$100,000	1Demolish barn

127		Miscellaneous Demolition	5	AC	$10,000	$50,000	General debris, equipment, & structure removal and clean up.
128		General ripping/discing	6	AC	$1,000	$6,000	Loosen soils on ~6 acres around the farm epicenter
129		Road Demolition	3,500	LF	$10.00	$35,000	Demolish ~3,500 LF gravel road along west side
130	**Camp 1 West & East Subtotal**					**$27,808,000**	
131	**West End & Detjen**	Mobilization & Demobilization	1	LS	$4,357,000	$4,357,000	Mobilizing & demobilizing forces, equipment, and facilities to needed to perform the work.
132		Site Preparation & Env. Compliance	1	LS	$2,641,000	$2,641,000	General site preparations, environmental compliance measures and BMP's
133	Levee Lowering	Lower Napa/South Slough Levee	18,000	CY	$5.00	$90,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
134		Lower Napa Slough Levee	28,000	CY	$5.00	$140,000	Selectively lower to MHHW. Sidecast material to

							flatten interior side slope.
135		Lower Detjen internal berms	28,889	CY	$5.00	$144,000	Selectively lower to MHHW. Sidecast material to flatten interior side slope.
136	Levee Breaching	West End Breach	8,000	CY	$20.00	$160,000	Excavate breach and sidecast material nearby.
137		Skaggs Island Road Culvert	1	EA	$150,000	$150,000	Install box culverts in Skaggs Is. Road to connect parcels
138	Channel Excavation	West End Channel	529,000	CY	$87.50	$3,968,000	Excavate and haul for onsite use as habitat fill.
139	Levee Improvement	Detjen East Levee	11,000	CY	$70.00	$770,000	Build up Detjen East Levee - imported materials
140		Detjen Hwy 37 Levee	117,000	CY	$70.00	$8,190,000	Build up existing south berm - imported materials
141		West End Hwy 37 Levee	149,000	CY	$70.00	$10,430,000	Build up south existing berm - imported materials

142	PG&E Infrastructure	Transmission Tower Improvement	25	EA	$60,000	$1,500,000	Raise concrete around tower footings
143		Boardwalk Improvement	6,200	LF	$38.00	$236,000	Raise existing boardwalks
144	Demolition	House Demolition	2	EA	$200,000	$400,000	Demolish houses
145		Septic System Demolition	1	EA	$10,000	$10,000	Demolish septic systems per county standards
146		Barn Demolition	2	EA	$100,000	$200,000	Demolish barns
147		Miscellaneous Demolition	2	AC	$10,000	$20,000	Demolish water tower, ditch boardwalks, etc.
148	**West End & Detjen Subtotal**					**$33,406,000**	
149	**Alluvial Fans, Riparian Corridors, Transition Zones**	Mobilization & Demobilization	1	LS	$1,980,000	$1,980,000	Mobilizing & demobilizing forces, equipment, and facilities to needed to perform the work.
150		Site Preparation & Env. Compliance	1	LS	$1,200,000	$1,200,000	General site preparations, environmental compliance measures and BMP's
151		Alluvial Fans	1	LS	$5,000,000	$5,000,000	Restoration (plug number)

152		Riparian Corridors	1	LS	$3,000,000	$3,000,000	Restoration (plug number)
153		Transition Zones	1	LS	$4,000,000	$4,000,000	Restoration (plug number)
154	**Alluvial Fans Subtotal**					**$15,180,000**	
155	**Alternative Subtotal**					**$239,174,000**	
158	**Construction Cost Contingency**					**$71,752,000**	**30%**
159	**Total Construction Costs**					**$310,926,000**	