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Bolinas Lagoon North End Restoration Project – Site Conditions Report

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°F	degrees Fahrenheit
APN	Assessor's Parcel Number
Cal-IPC	California Invasive Plant Council
Caltrans	California Department of Transportation
CCC	California Coastal Commission
CDFW	California Department of Fish and Wildlife
CFR	Code of Federal Regulations
cfs	cubic feet per second
CNDDB	California Natural Diversity Database
CRHR	California Register of Historic Places
CRLF	California red-legged frog
CRPR	California Rare Plant Rank
EO	element occurrence
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
LiDAR	Light detection and ranging
LOS	Level of Service
MCV2	Manual of California Vegetation, second edition
MHHW	mean higher high water
MHW	mean high water
mi/mi^2	mile(s)/square mile(s)
MLLW	mean lower low water
MLW	mean low water
mm	millimeter(s)
mm/yr	millimeter(s) per year
MSL	mean sea level
MTL	mean tide level
NAVD88	North American Vertical Datum 1988
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRHP	National Register of Historic Places
OHWM	Ordinary high water mark
PG&E	Pacific Gas and Electric Company
ppt	parts per thousand
RI	Recurrence Interval
SLR	sea-level rise
sp.	species (singular)
spp.	species (plural)
SR	state route
ssp.	subspecies
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey

Y	The Bolinas "Y" (or "wye" in some documents)
yr	year

1 Introduction

1.1 Project Purpose and Scope

The Bolinas Lagoon North End Restoration Project (referred to herein as the "the project") is part of a larger and longer-term effort for the restoration of the Bolinas Lagoon. The project was recommended as part of the *Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management,* prepared in August 2008 by a Working Group of the Sanctuary Advisory Council, Gulf of the Farallones National Marine Sanctuary. The project aims to reduce current flooding of roadways and to develop infrastructure adaptations that address future sea-level rise and increased traffic safety. Through this process, the project aims to improve the ecological functions and habitat values of the tidal marshes, streams, riparian corridors, and upland habitats at the north end of the lagoon.

Bolinas Lagoon, located along the California coast north of San Francisco, contains over 1,100 acres of marsh, mudflats, and subtidal and intertidal lagoon habitat that support a variety of special-status plant and animal species. Bolinas Lagoon is one of 37 internationally designated Ramsar[1] sites in the United States (USFWS 2015), and is an important site along the Pacific flyway for migratory and wintering shorebirds and waterfowl; the lagoon also supports a large harbor seal pupping site.

The lagoon and its surroundings are under a mix of private and public ownership. Public land holders include Marin County Parks, the Gulf of the Farallones National Marine Sanctuary (managed by the National Oceanic and Atmospheric Administration [NOAA]), Point Reyes National Seashore, (National Park Service [NPS]), and the Golden Gate National Recreation Area (NPS). The California Department of Transportation (Caltrans) has rights-of-way over State Route 1 (SR 1), which runs along the eastern side of the lagoon. Private properties occur both immediately adjacent to the lagoon and along the hillsides and valleys that surround it.

As the name implies, the project is at the northern end of Bolinas Lagoon, where Olema Bolinas Road splits off from SR 1 (**Figure 1**). There is also a small connector road between these two larger roads (referred to herein as the "connector road"). The triangle formed by these three roads and the areas within and immediately surrounding them is frequently referred to as the Bolinas Y, or simply the Y. The northern end of the lagoon and its fringing marshes border these three roadways, and several streams flow under the roads and into the lagoon itself. This project addresses this complex intersection of natural and built environments.

1.2 Report Purpose

This report presents a summary and analysis of the existing site conditions found at the north end of the Bolinas Lagoon and its surroundings. The first task of the project is to study the current and historical conditions of the north end of the Bolinas Lagoon, Lewis Gulch and Wilkins Gulch Creeks, and the surrounding riparian corridors and uplands. Studies were conducted to address a variety of topics, including biology, hydrology, geomorphology, cultural/archaeological resources, land ownership, infrastructure, and vehicle traffic. These studies and their results and conclusions are fully reported in a series of technical memoranda that are attachments to this report.

The purpose of this report and its constituent memoranda is to provide a foundation for developing restoration and climate change adaptation alternatives in the subsequent tasks of this project. These alternatives will be developed to achieve the project goals of reducing roadway flooding, preparing

[1] "The Convention on Wetlands, signed in Ramsar, Iran, in 1971, [and often referred to as "Ramsar"] is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands. There are presently 162 Contracting Parties to the Convention, with 2,040 wetland sites, totaling 193 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance" (WWF 2015).

for sea-level rise and other potential climate-driven changes, improving habitat function and connectivity, maintaining road capacity and meeting traffic demands, and improving safety.

1.3 Methods

This Site Conditions Report was developed using published historical documents and visual materials combined with the results of focused technical studies that included both desktop and database analysis and field surveys performed at reconnaissance levels. Multiple field surveys, including an initial site walk, were performed in order to gather the data for the technical reports and the technical memoranda listed above. The work itself was performed by AECOM technical staff and several key subcontractors, including Watershed Sciences, Carmen Ecological Consultants, and Peter Baye Consulting.

The technical memoranda were developed by technical discipline, to present the methods and results of these studies. As noted, the general approach to this Site Conditions Report was to draw together and integrate the key contents and insights from the different technical memoranda. This report does not repeat all of the details of the memoranda but instead condenses and distills their contents into this synthesized and integrative document. Further detail or explanation of the data collection and analysis can be found in the attached memoranda.

1.4 Report Organization

This document is organized as follows.

- **Section 1. Project Purpose** lays out the purpose of the project and explains the steps and processes used in developing this report. Section 1 also defines key terms and concepts used in these documents.
- **Section 2. Study Area Overview** presents an overview of the study area and its streams, roads, and other key features to provide a context for the rest of the report.
- **Section 3. Historic Natural Conditions** summarizes the historic natural conditions and development of the study area and the larger region around it. There are subsections on climate; geology, soils, and seismicity; and hydrology and geomorphology presenting an overview of the area. Following those, there are subsections on human settlement and land use and development.
- **Section 4. Current Natural Conditions** presents the current natural conditions in the study area and its surroundings. There are sections on the stream hydrology and geomorphology, biology, and the cultural resources in the study area.
- **Section 5. Current Built Environment** presents the current built environment, which includes landownership, utilities, and roads and traffic.
- **Section 6. Sea Level Rise** presents sea-level rise projections for the lagoon and its implications for restoration projects there.
- **Section 7. Regulatory Environment** summarizes the regulatory environment at the federal, state, and county levels and assesses what permits and other regulatory agreements may be necessary depending on the alternatives selected.
- **Section 8. Additional Studies** notes a few limitations that arose out of the focused scope of the current project and lists recommendations for additional studies or data-collection efforts that should be considered as the project development, planning, and selection proceed.
- **Section 9. References** lists the references specifically noted in this document; and the technical memoranda include longer lists of the references and other resources used within them.
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- **Attachment A** is the Biological and Cultural Resources Technical Memorandum.
- **Attachment B** is the Hydrology and Geomorphology Technical Memorandum.
- **Attachment C** is the Utilities and Parcel Ownership Technical Memorandum.
- **Attachment D** is the Traffic Counts and Analysis Technical Memorandum.

- **Attachment E** is a description of the Regulatory Environment.
- **Attachment F** is the Additional Data Needs Memorandum.

1.5 Definitions

The following is an alphabetical list of definitions of some technical terminology used in this report.

Bankfull depth – Mean depth at bankfull flow.

Bankfull flow – For the purposes of this report, bankfull flow discharge (Qbkf) is defined as the discharge that maintains the channel form and transports the greatest amount of sediment over time without aggrading or degrading its bed (Dunne and Leopold 1978, Rosgen 1996). The height of bankfull discharge is at the insipient level of flooding onto the floodplain. A generally accepted range of recurrence interval (RI) for bankfull discharge in this region is 1.2 to 1.7 years, on average.

Bankfull width – Width (Wbkf) of channel at bankfull flow measured at the insipient level of flooding onto the floodplain bench if one is present.

Entrenchment – A measure of a channel's vertical containment, as determined by the ratio of its bankfull width to its floodprone width, where floodprone width is measured at twice the maximum bankfull depth.

Floodplain – The relatively flat bench located at the insipient level of flooding at bankfull discharge.

Floodprone width – Width (Wfp) of the channel measured at twice its maximum bankfull depth (Rosgen 1996). Floodprone width is not the level of floodplain; it is one bankfull depth higher than the incipient level of flooding. The floodprone width does not have any particular RI of flooding associated with it, but it is considered to be at an elevation that would only experience very large but infrequent flooding.

Graben – A down-dropped block of the earth's crust bordered by parallel faults resulting from extension, or pulling, of the crust.

Invasive non-native species – Invasive non-native species are plant species listed as having a High or Moderate threat by the California Invasive Plant Council (Cal-IPC). Cal-IPC defines "High" threat species as those that have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment, and most are widely distributed ecologically. "Moderate" species have substantial and apparent—but generally not severe—ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal, though establishment is generally dependent upon ecological disturbance, and ecological amplitude and distribution may range from limited to widespread. Low threat species have minor ecological impacts. Their reproductive biology and other invasiveness attributes result in low to moderate rates of invasion. Ecological amplitude and distribution are generally limited (these species may be locally persistent and problematic). (Cal-IPC 2015).

Mean Higher High Water (MHHW) – The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.

Mean High Water (MHW) – The average of all the high water heights observed over the National Tidal Datum Epoch.

Mean Lower Low Water (MLLW) – The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch.

Mean Low Water (MLW) – The average of all the low water heights observed over the National Tidal Datum Epoch.

Mean Sea Level (MSL) – The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch.

Mean Tide Level (MTL) – The arithmetic mean of mean high water and mean low water.

Ordinary High Water Mark (OHWM) – The mark left on the landscape (typically noted by changes in slope, erosion, sediment deposition, presence of leaf or woody debris, or vegetative changes) by a commonly occurring fluctuating high water level (tidal, stream, or lake/reservoir). The OHWM applies to jurisdictional determinations for non-tidal waters under Section 404 of the Clean Water Act and under Sections 9 and 10 of the Rivers and Harbors Act of 1899.

Other Waters of the U.S. (a subset of Waters of the United States) – Other waters of the U.S. are all flowing waters that are traditionally navigable or that flow into a traditionally navigable waterway, plus adjacent waters. They include the portion of all open water located below the (OHWM) of an unvegetated channel, lake, pond, or other body of open water (33 Code of Federal Regulations [CFR] § 328).

Raveling – The gravitational downhill movement of sediment—rolling or bouncing, for example—without the addition of water

Recurrence Interval (RI) – An estimate of the return period of a given event.

Riparian areas – The classification "riparian area" is used to refer to areas above the OHWM of other waters of the U.S. that provide "linkages between water bodies and adjacent uplands and include portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems" (Griggs 2009). For delineation purposes, this area is assumed to extend from the OHWM to the edge of the outer drip line of vegetation that could affect the water quality functions. Typically, riparian areas include all riparian vegetation adjacent to a stream, lake, or other flowing water body. Riparian areas are described in this document alongside wetlands and waters because they are important for the protection of water quality and sensitive biological resources. They are a resource of interest to the U.S. Army Corps of Engineers (USACE), the State Water Resources Control Board, and California Department of Fish and Wildlife (CDFW).

Special-Status Plant Communities – Special-status plant communities are plant communities (also known as natural communities), of limited distribution statewide or within a county or region, and that are often vulnerable to the environmental impacts of projects (CDFW 2009).

Special-Status Species – Special-status species are plants or animals legally protected under the federal Endangered Species Act (ESA), the California ESA, or deemed rare by the California Native Plant Society in its California Rare Plant Rank (CRPR) system or by the NPS.

Study area – The study area includes all area being currently considered for restoration project activities under the North End Project. The extent of the study area is shown as land within the red boundaries on **Figure 2a** and **2b**.

Terrace – An abandoned floodplain.

Waters of the State (California Coastal Commission [CCC]) – Any surface water or groundwater, including saline waters, within the boundaries of the state (California Water Code section 13050(e)). This is defined more broadly than "waters of the United States" and is broadly construed to include all waters within the state's boundaries, whether private or public, including waters in both natural and artificial channels (SWRCB 2008). Waters of the State includes: all "waters of the United States", all surface waters that are not "waters of the United States" including non-jurisdictional wetlands, groundwater, and territorial seas – extending 3 nautical miles beyond the State's outermost islands, reefs, and rocks. The CCC retains jurisdiction over state waters, on land up to the mean high tide line (including submerged and tidelands), lands subject to the public trust, or at the discretion of CCC.

California Coastal Commission wetlands – The CCC Administrative Regulations (Title 14 California Code of Regulations Section 13577 (b)) provides a definition of wetlands: "Wetlands are lands where the water table is at, near, or above the land surface long enough to promote the formation of hydric soils or to support the growth of hydrophytes, and shall also include those types of wetlands where vegetation is lacking and soil is poorly developed or absent as a result of frequent or drastic fluctuations of surface water levels, wave action, water flow, turbidity or high concentrations of salt or other substance in the substrate. Such wetlands can be recognized by the presence of surface water or saturated substrate at some time during each year and their location within, or adjacent to, vegetated wetlands or deepwater habitat." As stated in the Procedural Guidance for the Review of Wetland Projects in California's Coastal Zone (CCC 1994), the CDFW classification system is the delineation methodology generally followed by the CCC. The three environmental parameters (vegetation, soil, and hydrology) used for the delineation of wetlands under USACE jurisdiction are also used in the CDFW delineation methodology; however, CDFW only requires the presence of one parameter for an area to qualify as a wetland. Therefore, wetlands under the jurisdiction of the CCC are identified by the presence of at least one of the following parameters: hydrophytic vegetation, hydric soils, or, wetland hydrology.

Waters of the United States – Jurisdictional waters of the United States include intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, natural ponds, and wetlands or waters adjacent to any water of the United States (33 CFR § 328). During the delineation of wetlands under ACOE jurisdiction, all three environmental parameters (vegetation, soil, and hydrology) must be met. The USACE also regulates navigable waters under Section 10 of the Rivers and Harbors Act as "… those waters of the United States that… are presently used, or have been used in the past, or may be susceptible to use to transport interstate or foreign commerce" (33 CFR § 329).

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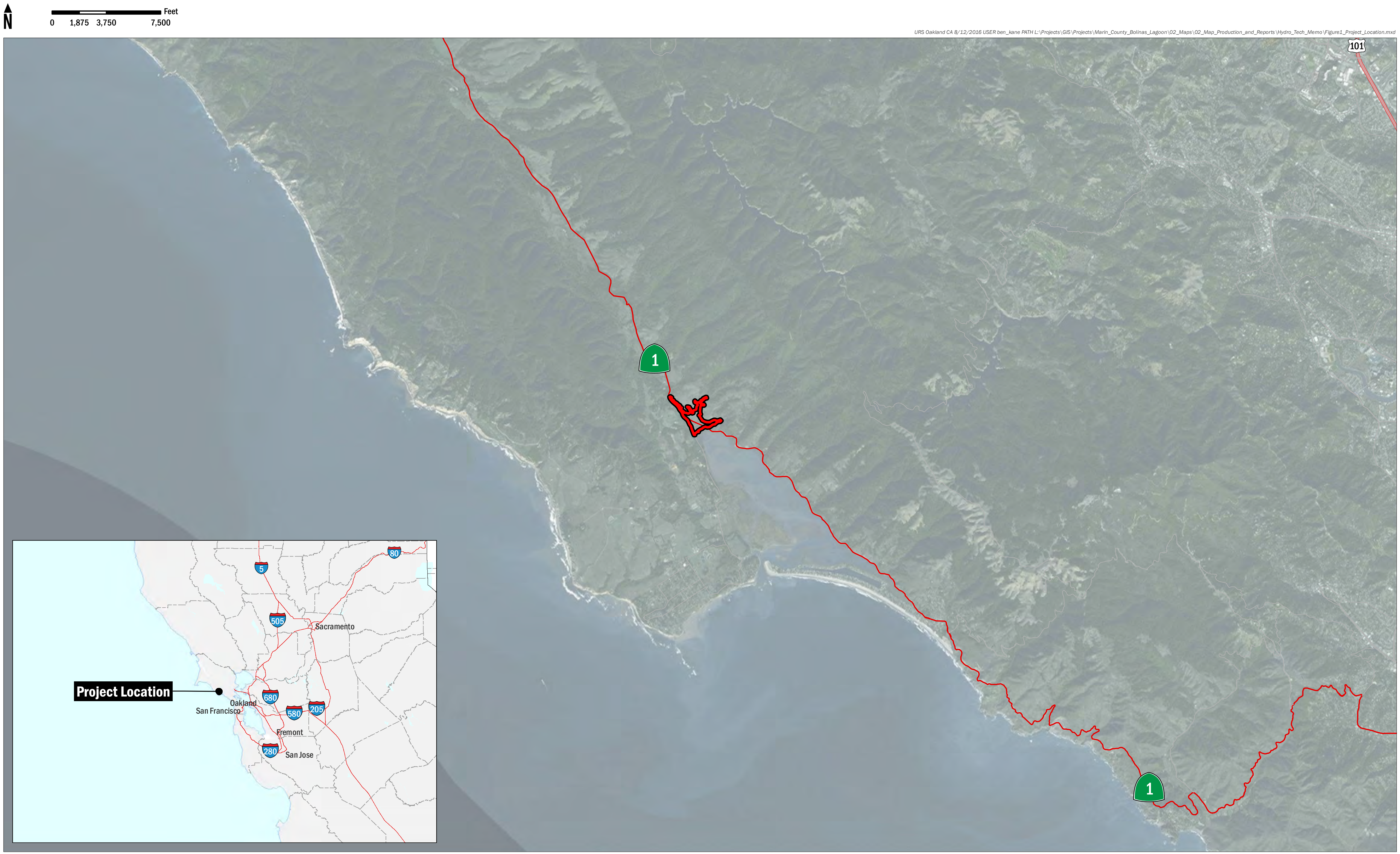

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FIGURE 1
Project Location

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2 Study Area Overview

The project study area includes the triangle of roads that is commonly known as the Bolinas Y (**Figure 2a**). These roads are SR 1, Olema Bolinas Road, and a short connector road, sometimes referred to as the crossover road. The crossover road follows the route of the original SR 1 location, while the northern connection of the current SR 1 was constructed sometime around 1957.

The study area also includes Lewis Gulch Creek, Wilkins Gulch Creek, Salt Creek, and Wharf Creek, that drain through the Y and into the northern tip of the lagoon. The study area extends upstream through these two watersheds for distances sufficient to understand the local hydrology, geomorphology, and biology. There are two study areas defined in this report. The hydrology and geomorphology study area, shown on **Figure 2b**, includes a larger area, and therefore has a narrower focus than the more general study area used for the other technical disciplines (shown on **Figure 2a)**.

Lewis Gulch, Wilkins Gulch, and Salt Creeks drain the steep southwest-facing hillsides of the Bolinas Ridge. The creek that drains into the southwestern side of the study area is unnamed, but since its outlet is near the location of the historical wharf, it is referred to as “Wharf Creek” in this report. Along the east side of the study area, elevations range from mean sea level to 1,653 feet at the headwaters of Wilkins Gulch Creek. The west side ranges up to 321 feet along the Wharf Creek drainage.

These streams and their total watersheds (i.e., beyond just the study area) are shown on **Figure 3**. Each watershed is shown in a different color, and the approximate drainage area of each creek’s watershed is listed in **Table 1**. The downstream boundaries of the watersheds occur at the approximate head of tide near the inlets of the culverts that drain into the Bolinas Lagoon. More detail on the hydrology of the creeks and their watersheds is presented in subsequent sections. Much of the study area is in an upland/tidal transition zone influenced by rising sea level, which is projected to be as much as 170 centimeters (approximately 5.5 feet) higher by 2100 (NRC 2012; CO-CAT 2013).

Table 1. Watershed Names and Drainage Areas

Watershed Name	Drainage Area (mi^2)
Lewis Gulch Creek	0.62
Wilkins Gulch Creek	0.68
Salt Creek	0.15
Wharf Creek	0.08

Note:
Mi^2 = square miles

2.1 Climate

Within the study area, the average annual temperature is approximately 58.4 degrees Fahrenheit (www.USA.com 2015). The mean annual rainfall in Bolinas is approximately 38 inches, most of which falls between October and April. January is the wettest month, typically having an average rainfall of 7.32 inches (www.idcide.com 2015). The Coast Ranges are subject to natural variation that ranges from years of extreme drought to years of extremely high rainfall and streamflow. This has important consequences, because intense and/or prolonged winter rainfall contributes to hillside erosion and landslides, which deliver periodic, large pulses of sediment to the streams. Over thousands of years this has created the large alluvial fans at the base of the steep drainages along the lagoon perimeter. Pre-settlement sedimentation rates have been influenced by the climatic and seasonal variations that supply water and sediment to the creeks. The transport and storage of sediment once it is in the channels is also influenced by stream geometry, vegetation, woody debris, sea level, and local fault block subsidence. Even under natural conditions, the transitional zones of tidal marsh, seasonal wetlands, and upland floodplains in the study area would have been affected by backwater flooding when large rainfall events coincided with high tides in the lagoon.

California is in a fourth year of drought: 2013 and 2014 were two of the three driest years in 119 years of recorded history for the state (U.S. Geological Survey (USGS) 2014), and the Palmer Drought severity Index rates the current drought as the most severe in over 100 years (NOAA 2015b). The 2015 water year had the sixth driest January since 1900 for the North Coast Drainage climate division, which covers the northern half of the San Francisco Bay Area up through the Oregon Border (NOAA 2015b). Average temperatures in January, February and March were also above normal high and normal low average temperatures. These high temperatures exacerbated existing drought conditions (NOAA 2015c).

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FIGURE 2A

Site Location

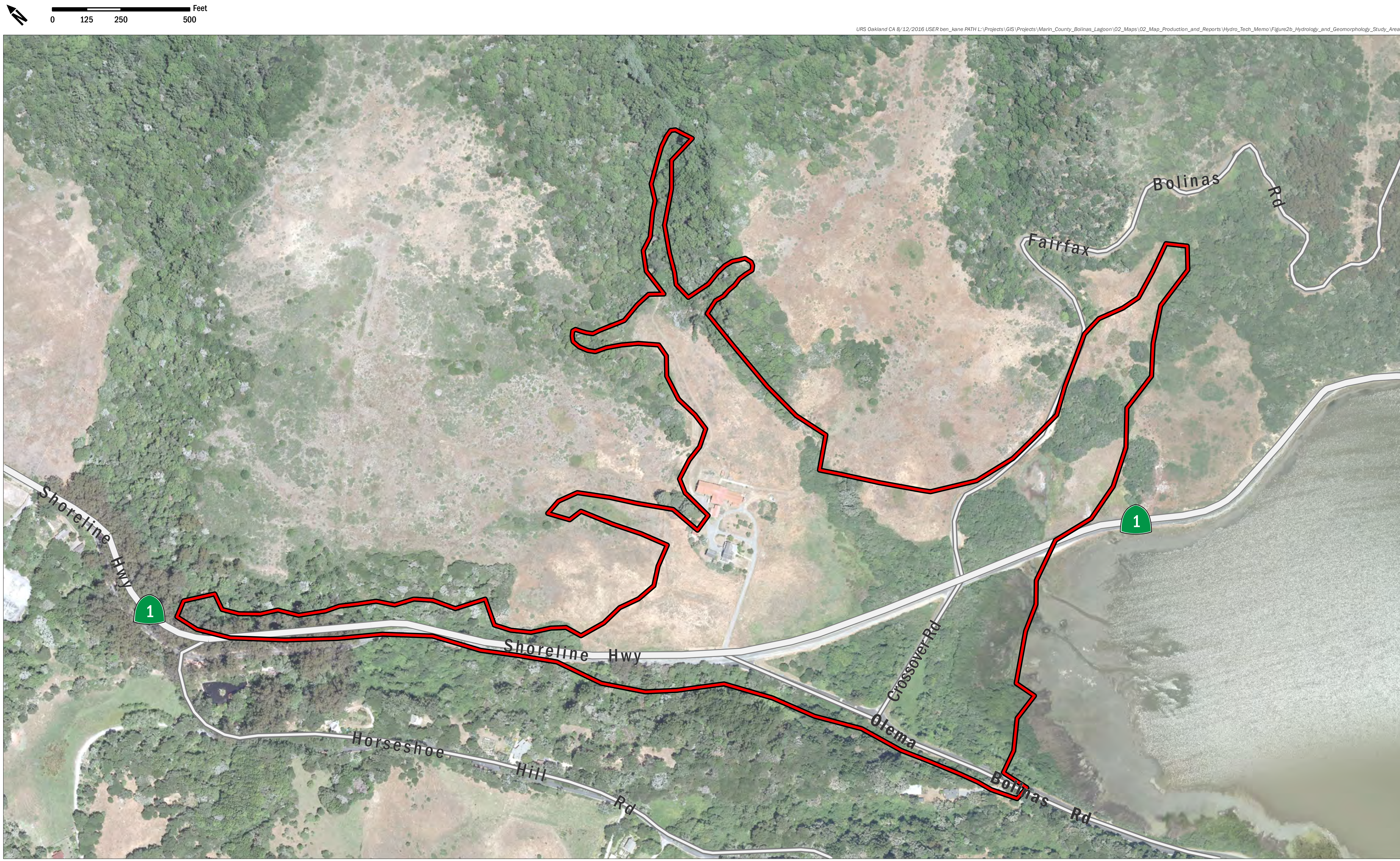

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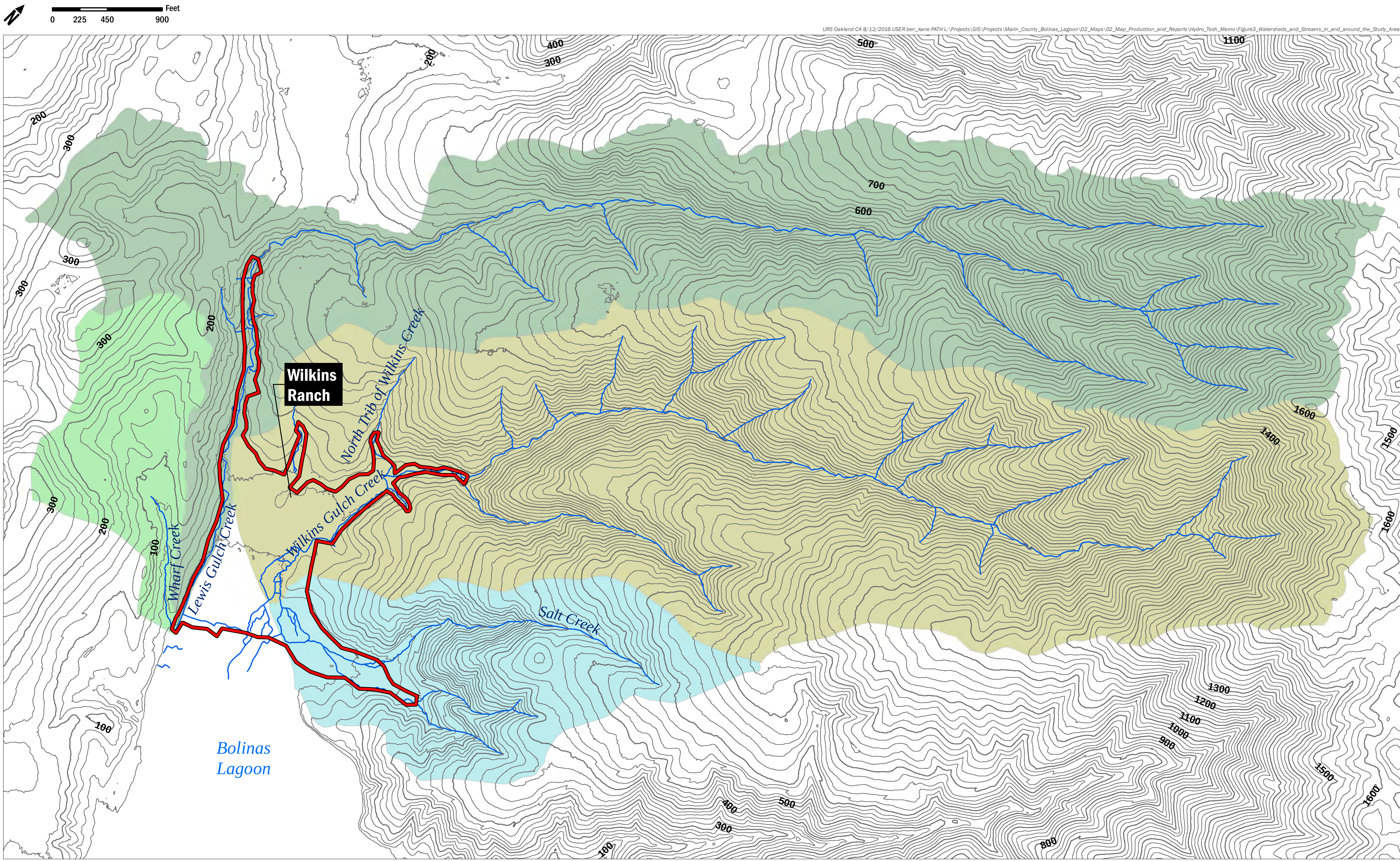
FIGURE 2B
Hydrology and Geomorphology Study Area



Study Area
20ft Contour

Watershed
Lewis Gulch Creek (0.62 sq mi)
Salt Creek (0.16 sq mi)
Wharf Creek (0.08 sq mi)
Wilkins Gulch Creek (0.68 sq mi)

Data Sources:
1. Contours, ARRA Golden Gate LiDAR, USGS, 2010
2. Streams, Watersheds, AECOM, 2015

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FIGURE 3
Watersheds and Streams In and Around the Study Area

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3 Historic Conditions

This section summarizes the historical conditions of streams, riparian corridors, and upland habitats at the north end of Bolinas Lagoon. It discusses the natural environment and the built environment separately. Additional details on these topics are available in the corresponding technical memorandum attachments.

The study area is located in Marin County and encompasses the northernmost corner of the Bolinas Lagoon. The site is part of the hilly to steep mountains of the California Coast Ranges (USDA 1985), with the toe slope of Mount Tamalpais to the east and Horseshoe Hill to the west. Elevations within the study area range from mean sea level at the lagoon up to 321 feet along the Wharf Creek drainage on the west side of the project area and up to 1,653 feet at the headwaters of Wilkins Gulch Creek. Also present within the study area are the mouths of Lewis Gulch Creek and Wilkins Gulch Creek, which flow into the lagoon from the north and east, respectively.

3.1 Geology and Faults

This section discusses the regional geology, seismicity, and faults, as well as ideas about uplift, sedimentation, and the effect of these on the lagoon and several streams. The local geology is complex, and this section is intended to provide context for later discussions and expectations for the site under changing climate conditions.

Bolinas Lagoon is a highly dynamic area influenced by tectonic subsidence and uplift. It is part of the larger San Andreas Fault Zone that extends from the Gulf of California through much of northern California. It is not a single fault, and in many places there are other converging or diverging faults that create complex local geology and seismic activity. The project's study area and its surroundings, including Bolinas Lagoon, Drake's Bay, Tomales Bay, and the entire Point Reyes Peninsula, are an example of such a case. **Figure 4** shows a larger view of the Point Reyes Peninsula, including the San Andreas Fault itself, the Tomales Bay rift valley in the north, and several faults converging on Bolinas Lagoon in the south. It also illustrates the major geologic units on the western side of the fault system.

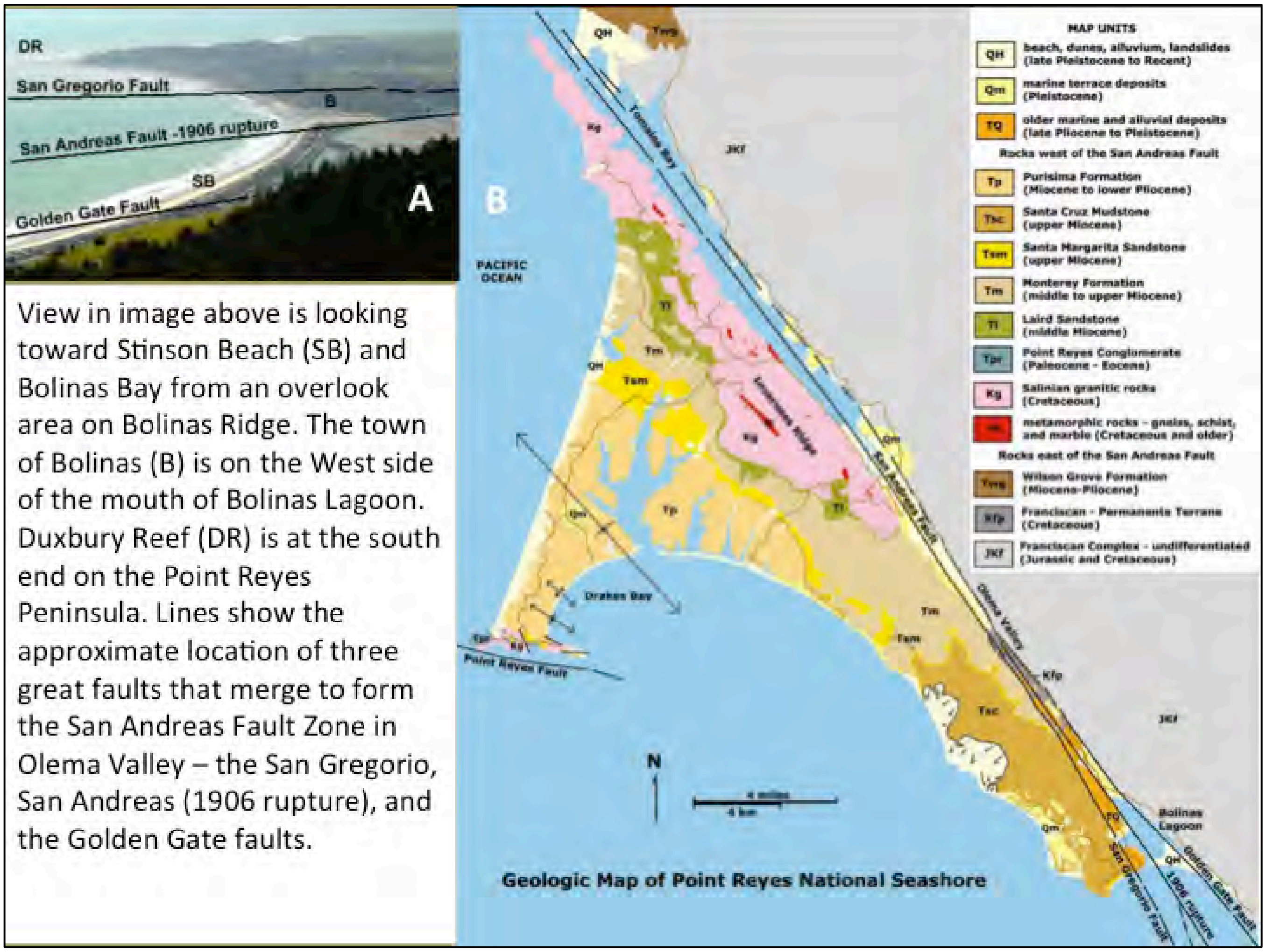

Figure 4. Geologic Map of Point Reyes National Seashore (Division of Mines and Geology 1977)

Figure 5 shows the bedrock unit geology and faulting of the Bolinas Lagoon area in a smaller-scale map. Cretaceous sedimentary Franciscan rocks (Kjf) occur east of the East Boundary (Golden Gate) Fault along Bolinas Ridge and Miocene Monterey shale (Tm) occurs west of the West Boundary (San Gregorio) Fault. Between the faults are a mix Holocene-Pleistocene terrace (Qt) deposits Plio-Pleistocene Merced siltstones (Tmc) and sandstones. A small amount of Holocene-aged alluvium (Qal) is at the northern head of the lagoon near the present-day alluvial fans of the creeks flowing through the study area. A more in-depth discussion of the geology in the study area is provided in **Attachment B**.

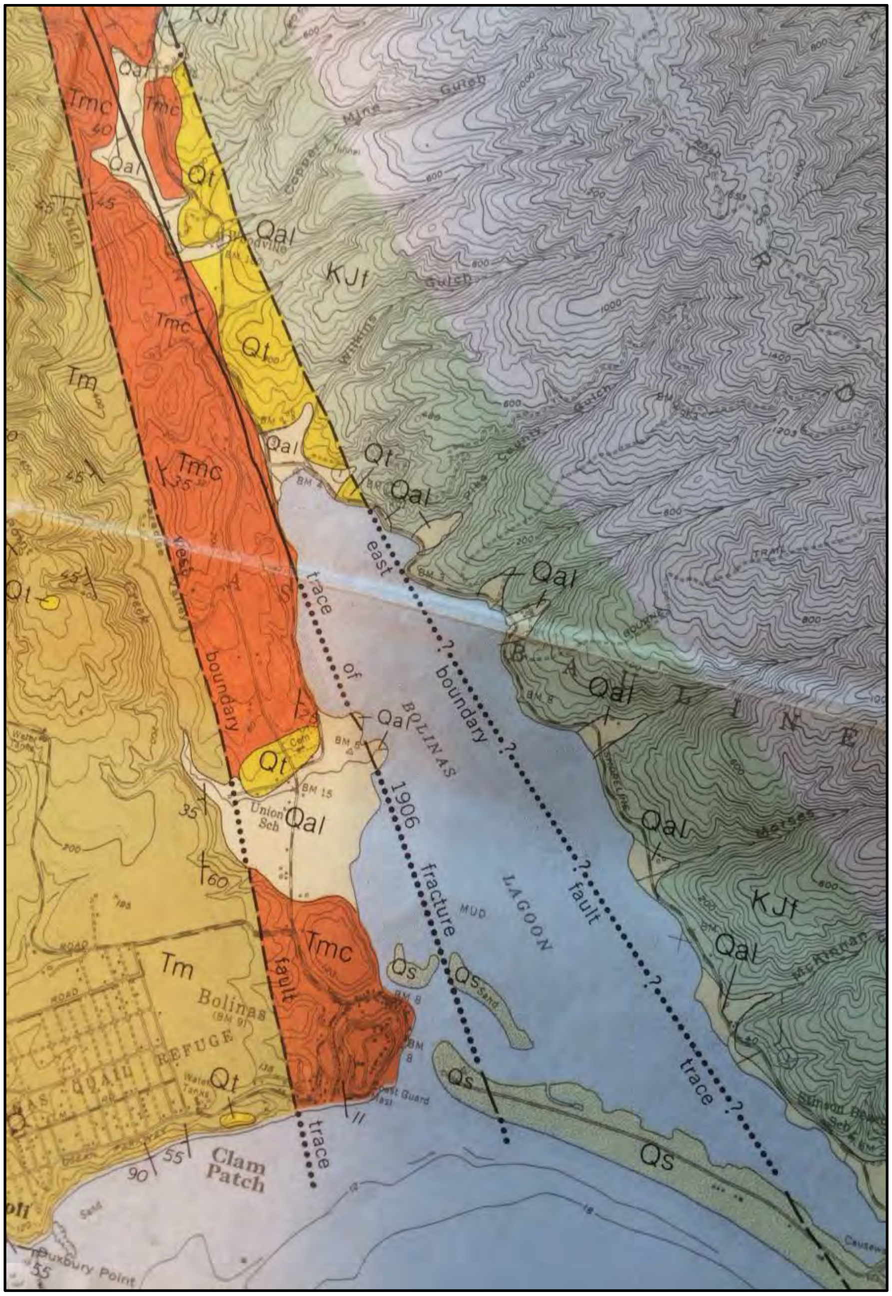

Figure 5. Bolinas Lagoon Bedrock Geology and Faults (Galloway 1977)

The San Andreas is a right lateral strike-slip fault where two or more tectonic plates slide past each other in bursts of movement that can be sudden and dramatic on the human time scale. In the study area, this means that the Point Reyes Peninsula on the west side of the fault appears to be moving north, while the Bolinas Ridge and the rest of Marin County appear to be moving south. The last active fault rupture along the San Andreas was a magnitude 7.8 event in 1906 that formed a rupture 296 miles long. This resulted in up to 12 feet of displacement near Bolinas and about 2 feet of down-dropping along the eastern side of the rupture in the Bolinas Lagoon (Gilbert et al. 1907). The long-term average for right lateral movement on the San Andreas Fault ranges from about 12.7 millimeters per year (mm/yr) to 50 mm/yr. (Niemi and Hall 1992; Noller et al. 1993).

There are two major studies that have been conducted in the region on sedimentation rates and earthquake activity. In 2005, Byrne and Reidy determined that five major earthquakes occurred over the last 1,600 years, on average 300 years apart. Byrne and Reidy's coring analysis indicates that up to 80 percent of the sediment in the lagoon is from natural marine sources and tidal processes. The remainder is from terrestrial sources delivered largely by streams. The northern end of the lagoon is largely affected by accelerated rates of sedimentation from terrestrial sources influenced by land use activities such as logging and dairying. They also found sand lenses in sediment cores, and hypothesized that the lenses could have been deposited from a large tsunami or from frequent winter storms during the Little Ice Age (ca. AD 1400–AD 1800). Based on the literature reviewed, we hypothesize that the sand is a result of rapid over-wash of the Stinson sand spit following a former pre-1800 seismic event that caused sudden down-dropping of the large Holocene graben that forms the lagoon on the east side of the San Andreas Fault. In 2002, Bruns et al. conducted subsurface mapping from the Golden Gate to offshore of Stinson Beach and described the extent of the Holocene graben to have uncertain northern and southern boundaries. They found that the eastern boundary is defined as the Golden Gate Fault and the western boundary is the Potato Patch/San Andreas Fault. Hypothesizing that the graben extends into the the Bolinas Lagoon is consistent with Gilbert et al. (1907) observations of a down dropping along the east side of the San Andreas fault following the 1906 earthquake. Large earthquakes may have resulted in the down dropping of the graben, which would not only deepen the lagoon but also result in differential land subsidence, sediment compaction, increased tidal prism, and realignment of streams in the study area.

Figure 6 shows a simplification (derived from Bruns et al. 2002) of the Holocene graben and associated faults offshore of the Golden Gate. The yellow-green polygon is the area of the graben that has been mapped in detail by subsurface exploration and is known to have net downward block faulting motion (Bruns et al. 2002). The red lines are known fault traces that also have net right lateral offset. Yellow dashed lines are inferred. **Attachment B** contains a more complete description of the graben hypothesis.

Byrne and Reidys (2005) sediment core analysis found that the deepest part of the northern lagoon dropped by as much as 1.5 feet during the 1906 earthquake and was followed by sedimentation rates that were high throughout the early 1900s. However, sedimentation rates were highest preceding the 1906 earthquake, during the logging boom that started in 1849. Sedimentation rates in the northern lagoon declined as sediment was trapped on the delta fans, maintenance dredging in the stream channels increased, and as land disturbing activities declined.

These finding suggest that large local earthquakes induce a "re-set" and deepening of lagoon bottom that increases the depth of the lagoon east of the San Andreas Fault. Byrne and Reidy (2005) report that by year 2050 the combined effects in the north basin of average sedimentation rate (7 mm/yr), auto compaction of sediments (7 centimeters), and sea-level rise (12 centimeters) is not enough to convert the basin to a fresh water marsh.

Figure 6. Holocene Graben and Associated Faults

Looking more closely at the geology of the north end of the Bolinas Lagoon, **Figure 7** shows traces of active faults in red as mapped by USGS (2014) near the alignments of SR 1, Olema Bolinas Road, and the crossover road. The alignment of the 1906 fault rupture indicated by Byrne and Reidy (2005) is shown as a yellow dashed line on this map. It does not coincide with the faults mapped by USGS.

The other fault segments shown on **Figure 7** are not named. The exact location of the 1906 rupture of the San Andreas Fault and the Holocene graben is not evident. The locations of faults on this map differ from the other maps shown in this report (and **Attachment B**), indicating that it is unclear where the exact locations of the active and potentially active faults are in the study area. Lewis Gulch Creek has been sketched in **Figure 7**, to show its relation to SR 1 and the fault traces.

Figure 7. Active Faults near the Study Area

3.2 Historic Hydrology and Geomorphology

The two largest drainages in the study area are Lewis Gulch Creek and Wilkins Gulch Creek. Prior to the large-scale land use changes and development within the study area, geologic and seismic activity, along with the local climate of the time, likely had a larger influence on the high rates of sediment to the Bolinas Lagoon delivered by the streams. It is the stream sediment regime of the early Holocene epoch that formed the vast alluvial fans that cover most of the study area. The streams likely flowed across the surface of the fans, depositing sediment and alternating channel shape and location periodically in response to large flood events. Historical photos, maps, light detection and ranging (LiDAR) imagery, and other methods were studied to determine pre-settlement conditions in the study area. Extensive maps and photos are provided in **Attachment B**, and a selection of these highlighting the most important changes is presented below.

Topographic analysis of the orientation and location of both the Lewis Gulch Creek and upper Pine Gulch Creek suggest that at one point in time, upper Lewis Gulch Creek may have actually been a part of the Pine Gulch Creek watershed. Evaluation of fault locations, along with the location and elevations of Holocene and Pleistocene alluvial deposits in Lewis Gulch, suggest that tectonic down-dropping of the graben may have been the initial and natural cause of a redirection of the ancient Lewis Gulch Creek from its former northward flow into Pine Gulch Creek. A sudden drop in elevation where the creek crosses the fault would cause subsequent headward erosion of (a previously smaller) Lewis Gulch Creek up its drainage. Ruptures along the San Andreas Fault near the head of the Lewis Gulch Creek alluvial fan may also be responsible for redirecting stream flow from the alluvial fan to the present day location against the hillside west of SR 1, where an active fault trace is presumed to be located.

Based on the location of projected active faults, the majority of the Wilkins Gulch Creek fan (with exception of the delta) would be located east of the graben and thus not subject to the down dropping that would have occurred on most of the Lewis Gulch Creek fan. Because the Wilkins Gulch Creek delta is located below the average water level of the lagoon, any down-dropping would not affect the base elevations in the creek. It seems likely that most of the alluvium deposits in the Lewis Gulch Creek fan deposited in the Holocene epoch represent sediment that was reworked Holocene alluvium supplied by channel incision into older early-Pleistocene alluvium. By contrast, the Holocene alluvium of the Wilkins Gulch Creek fan represents mostly sediment generated by steep hillslope erosion and landslides as the major source rather than reworked older alluvial deposits driven by channel incision.

The 1854 T-Sheet map shown in **Figure 8** (Livingston 1995a) provides very early information on what the area was like at that time. The map shows large alluvial fans at Lewis Gulch and Wilkins Gulch Creeks, the two largest drainages in the study area. The alluvial fans are dotted with mature trees (indicated by small circles near the center of the image) no longer present on the Wilkins Ranch. **Figure 8** does not indicate the locations of the streams, however a map made for Bethuel Phelps in1854 (**Attachment B**) shows Lewis Gulch Creek flowing to the northwestern corner of the lagoon. A later map from 1867 (see **Attachment B**) indicates that Lewis Gulch Creek flowed out onto its now-abandoned alluvial fan east of SR 1 (where large trees are drawn in **Figure 8**). The conflicting locations of the creek within a 13 year timespan may indicate that Lewis Gulch Creek flowed along the western edge of the alluvial fan but may have frequently changed channel locations due to watershed disturbances or blocked stream/road crossings. Alternatively, the creek may have been diverted by 1867 towards Wilkins Ranch to provide water for a sawmill or dairy. There is no present-day topographic evidence of a stream diversion on the surface of the alluvial fan (e.g., canal or ditch); only small, braided distributary channels indicative of past use by the stream.

The shoreline of the map in **Figure 8** indicates that the lagoon's wetlands were further inland in the mid 1800's than at present. The main roads at the time are highlighted in yellow. The orange line highlights an older, probably original trail around the seasonally wet areas in Wilkins Gulch Creek and a smaller drainage to the southeast called Salt Creek. The locations of the trails are similar to the ones shown in the 1854 map made for Bethuel Phelps. The roads in **Figure 8** leading to the yellow arrow were used primarily for bringing redwood logs to the wharf/embarcadero (yellow arrow). The white arrow points to a feature that may be the beginning of a constructed berm along the area that is now the alignment of SR 1. Alternatively, it could be a bar that formed from the erosion of the cliffs to the east. The white dashed/dotted lines indicate the approximate present day alignment of SR 1, Olema Bolinas Road, and the connector road. The red arrow points to another feature that may have been a berm or pathway constructed at the edge of upland edge of the tidal marsh. The wharf/embarcadero is shown as a series of concentric circles on the map. It later became known as the "lighter" wharf, because rapid sedimentation associated with the start of logging activities in 1849 prevented deep-draft boats from accessing the area.

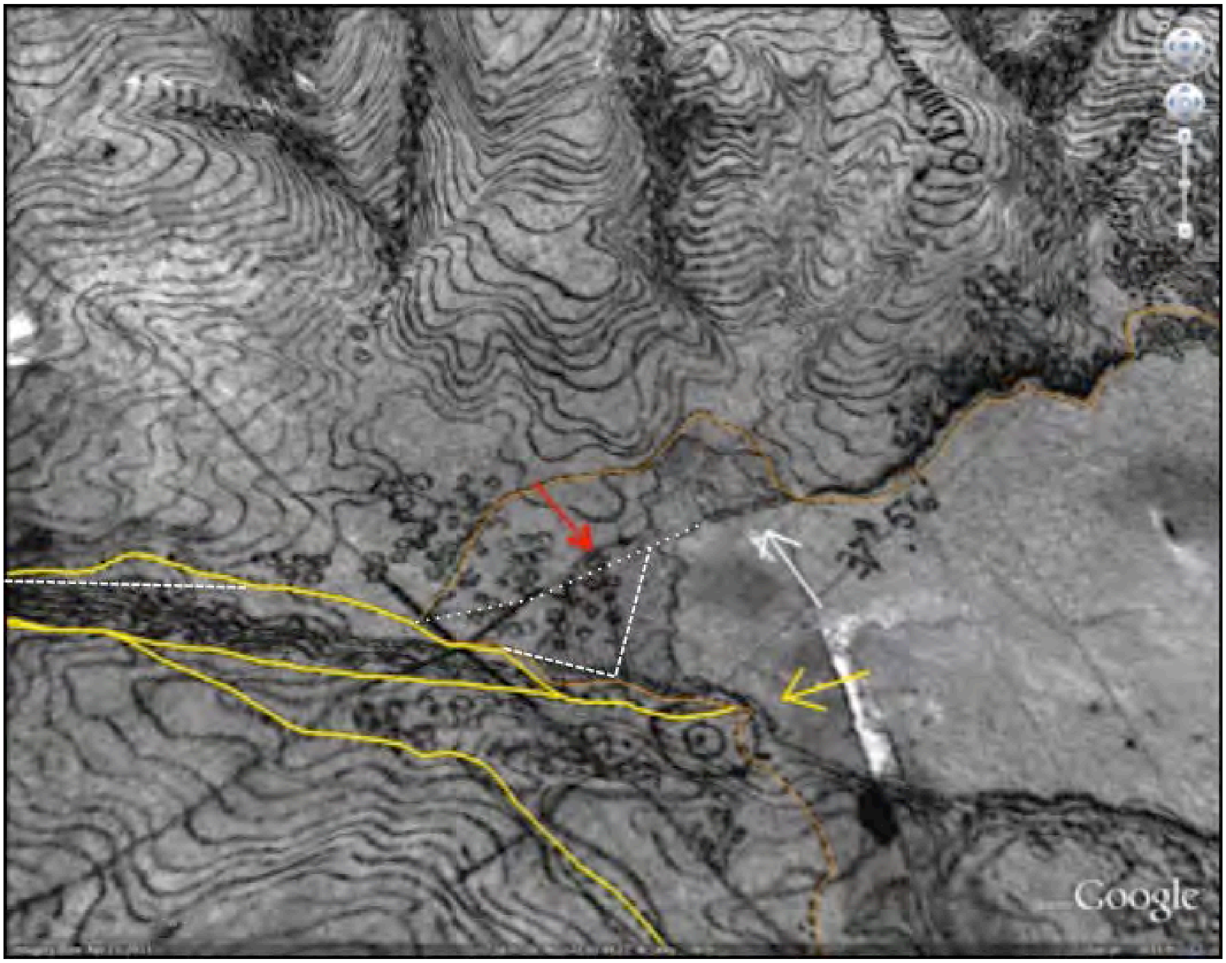

Figure 8. Detail of 1854 U.S. Coast and Geodetic Survey T-Sheet (Livingston 1995a)

Wilkins Gulch Creek and its alluvial fan are shown in **Figure 9**. The LiDAR image projects northward from the base of the Wilkins Gulch Creek alluvial fan, as shown in light orange. The white arrow shows where the "North Tributary" to Wilkins Gulch Creek has been diverted to the upper edges of the alluvial fan. The yellow arrow shows where Wilkins Gulch Creek was likely ditched along the eastern edge of the alluvial fan. In the pre-settlement era, Wilkins Gulch Creek and its tributary would have flowed out of their confined valleys and onto the alluvial fan. Many small discontinuous swales and flow pathways were observed during the field reconnaissance while walking across the body of the fan, indicating the former presence of the streams. The presence of multiple channels indicate the change in stream location across the fan, representing how the fan built upwards through pulses of sediment deposition.

An enlarged view of an 1854 map (**Figure 10**) shows Lewis Gulch Creek (highlighted in blue) relative to the road to Sausalito. The map indicates that the mouth of the creek was at the northwestern corner of the Bolinas Lagoon), and entered at the head of the alluvial plane that makes up the "Y" area. Analysis of maps and LiDAR imagery suggest that tectonic down-dropping of the graben, and subsequent headward erosion of a previous stream draining into the north end of the Bolinas Lagoon, may be the initial and natural cause of a redirection of Lewis Gulch Creek from a northward flow into present day Pine Gulch Creek and into its current channel. Ruptures along the San Andreas Fault near the head of the Lewis Gulch Creek alluvial fan may also be responsible for redirecting stream flow from the alluvial fan to the present day location against the hillside west of SR 1 where an active fault trace is presumed to be located.

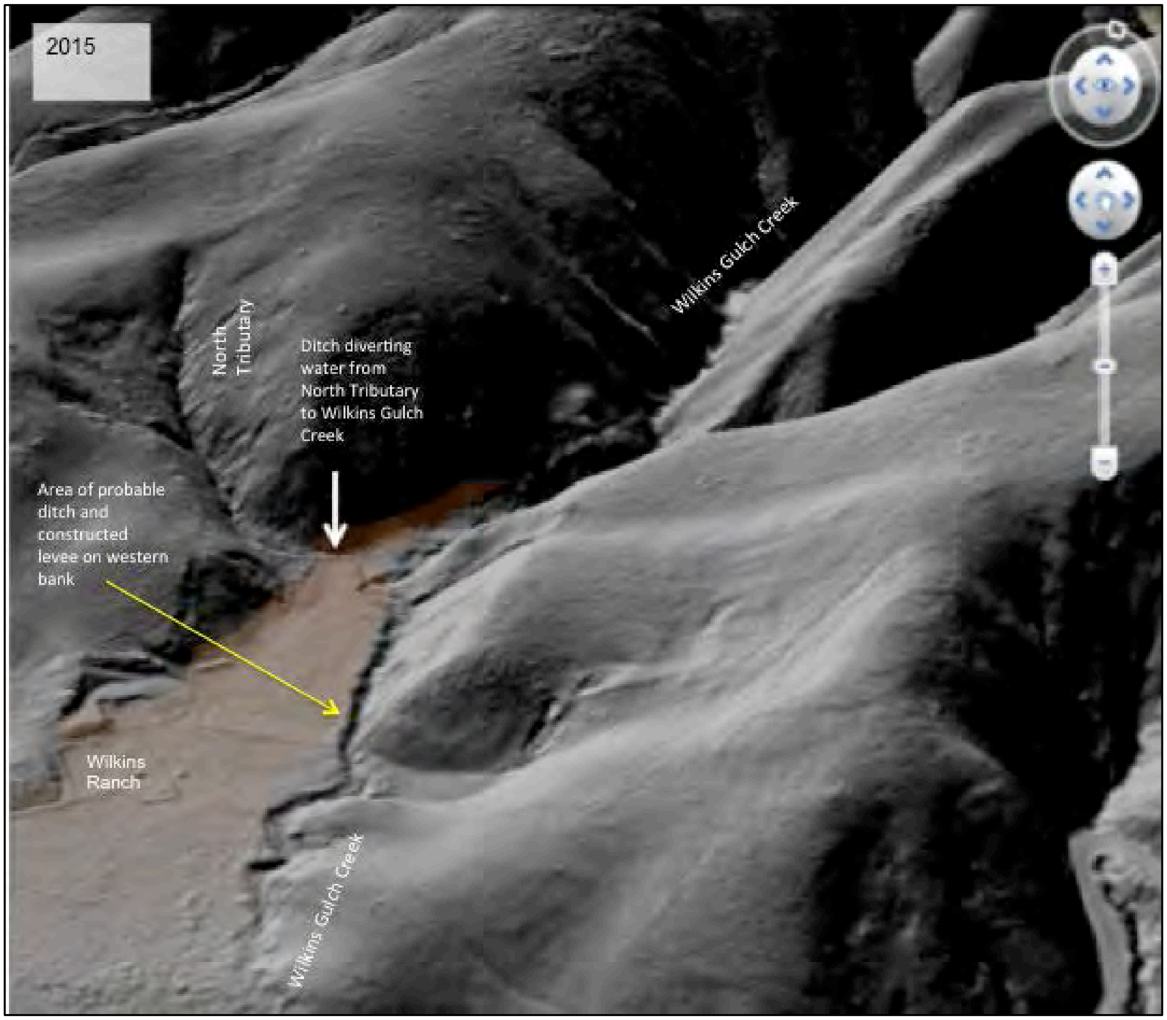

Figure 9. Wilkins Gulch Creek's Alluvial Fan

Water diversions, road construction, logging and woodcutting, dairying, and ranching have had a profound influence on the study area's streams and habitats. As shown in the analysis of historic maps and photo documentation presented in detail in **Attachment B**, active changes to the landscape were taking place prior to 1854. Ranching in the area began as early as 1834, and with it came changes in vegetation and construction of roads and trails. Logging in the watershed occurred between 1849 and 1858. The expansive network of haul roads needed to extract logs from the steep hillsides and deliver them to the wharf in the northwest corner of Bolinas Lagoon is still evident today in LiDAR imagery. Historic maps indicate the construction of a road connecting Horseshoe Hill Road to Olema Bolinas Road near the lighter wharf occurring sometime before 1873 and 1892. As logging tapered off, copper mining began in the watershed to the north of the study area. Goods going to and from the mines were transported on the local roads.

An expanded road network was needed to reach distant trees, get logs to the wharf for loading onto ships, and to accommodate the influx of people traveling to Bolinas from Sausalito. By 1854, road berms were being constructed along the current SR 1 footprint to shorten the route around the head of the lagoon. The toe of the alluvial fan on Salt Creek appears to have been artificially separated from its historical margin with Bolinas Lagoon by the placement of the road berm. The road fill and a small culvert installed to drain the creek effectively cut off the lagoon from Salt Creek. As a result, tidal influence to this area was constricted, and the area was converted from a tidal marsh area to a freshwater-to-brackish pond.

Figure 10. Detail of 1854 Map of the Berry Grant

The practice of draining and reclaiming land, and moving channels to the sides of their valleys was commonplace from the mid-1800s through the early 1900s. A photo of the Wilkins Ranch house and barn in 1880 indicates that Wilkins Gulch Creek had already been altered by removal of vegetation on the banks and/or probable relocation of most of the channel against its eastern hillslope (**Attachment B**, Figure 22). By 1892, it appears that the pre-development shoreline had been pushed further into the lagoon by diking to gain additional farmable land. In a 1906 photo, the mature trees drawn on the 1854 T-Sheet map (**Figure 8**) are no longer present. This further indicates that the land around the ranch was cleared to increase usable dairy land.

Lewis Gulch Creek's stream flow was similarly changed around this time. The downstream extent of Lewis Gulch Creek may have been diverted against the western hillslope between 1910 and 1925. The channel may have previously flowed across its fan as a series of distributaries that emanated near the present day culvert that SR 1 crosses (Figure 11). Downstream of here and following the 1906 quake, Lewis Gulch Creek may have begun flowing along the trace of the rupture. A 1925 map shows Lewis Gulch Creek crossing back across to the eastern side of road near the intersection of Olema-Bolinas Road and the crossover road.

Additional manipulation of lower Wilkins Gulch Creek is evident when comparing changes between maps drawn in 1910 and 1925. Around 1880, the creek was ditched to flow to the east side of Bolinas-Fairfax Road and then beneath SR 1 at the current-day culvert location. It is possible that the culvert or lack of a culvert near the junction of Bolinas-Fairfax Road, SR 1, and the connector road (where the creek flowed previously) had plugged or otherwise flowed over the road during large storm events. The SR 1 culvert at Salt Creek may have been newer or larger at the time and so seemed like a better location to convey the flow of Wilkins Gulch Creek to the lagoon. Another hypothesis is that Wilkins Gulch Creek was ditched to the Salt Creek drainage to deliver freshwater to the pond southeast of Bolinas-Fairfax Road, in order to flush it of salty water for cattle usage. A circa 1949-1958 photograph (**Attachment B**, Figure 31) indicates that fill appears to have been placed around the west edge of the pond on Salt Creek. Fill may have also been placed to provide a staging area for the SR 1 construction, or in an attempt to increase farmable or grazing land.

As ranching and farming activities decreased around Wilkins Ranch, vegetation began to reclaim the land. By 1943, an alder forest was becoming established along the shoreline of the lagoon between Lewis Gulch and Wilkins Gulch Creeks, where fresh groundwater emerges from the alluvial fan. By 1959, willow groves appear to be establishing around the pond on Salt Creek. The extension of SR 1, between the crossover road and Olema Bolinas Road, was believed to have been constructed around 1957. The compacted road fill from the SR 1 extension is thought to inhibit some of the shallow subsurface groundwater flow, thereby promoting wetland vegetation and allowing willow trees to establish in absence of routine land clearing. When comparing more recent aerial photos to those taken in 1943 and 1952 (before construction of SR 1), it seems apparent that the land upslope of where SR 1 was constructed was not a wetland. SR 1 was not present to inhibit flow of shallow subsurface and surface water flow that would provide hydrology necessary for a wetland.

As the community of Bolinas was made more accessible by road network improvements, more people permanently settled in that vicinity. The increased human settlement influenced the local hydrology and runoff by changing groundwater withdrawals from well pumping, vegetation cover, evapotranspiration from agricultural practices, impervious surfaces from roads and structures, and topographic changes from roads, berms, culverts, bridges, and ditches that altered flood and sediment conveyance. In the study area, the population has remained low and has likely decreased during the last 100 years.

Table 2 summarizes the extent of development using data from the SF Estuary Institute's EcoAtlas (SFEI 2015) within the study area. It shows each watershed's drainage area, number of people residing, and the percent of land development. Wharf Creek has the smallest drainage and the greatest percent development, 19.6 percent. Wilkins Gulch Creek has the largest drainage area, the fewest people, and the lowest percent development, 8 percent; Lewis Gulch Creek has 8 percent. Salt Creek has the second highest percent developed land cover, principally due to Bolinas-Fairfax Road. Salt Creek and Wharf Creek are likely to have the flashiest runoff of those in the study area, largely because of the combination of relatively small size and percent developed. This information is important for modeling the influence of urban runoff during the development of conceptual designs.

Table 2. Watershed Development

Watershed	Drainage Area (square miles)	Percent Developed Land Cover[1]	2010 Census Human Population[1]
Wilkins Gulch Creek	0.686	8.0	1
Salt Creek	0.160	17.0	0
Lewis Gulch Creek	0.600	8.4	16
Wharf Creek	0.104	19.6	6

[1]SFEI ECOATLAS: http://www.ecoatlas.org/regions/ecoregion/bay-delta

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4 Current Conditions – Natural Environment

4.1 Stream Hydrology and Geomorphology

Focused field investigations were performed in the study area to characterize current hydrologic and geomorphic conditions. Data were collected on hydraulic geometry of stream reaches, and calculations of bankfull cross sections, bankfull discharge and velocity, and stream capacity were made. These parameters will be critical for designing appropriately sized and shaped channels and water conveyance structures for future restoration alternatives. Channels constructed with appropriate bankfull geometry and capacity for a given location in the study area will be more likely to adequately carry the stream bedload discharge without problems of aggradation or degradation, as currently occurs in stream reaches in the study area. Detailed methods and results of these investigations are explained in detail in **Attachment B** and are summarized below. **Figure 11** presents the study area for the hydrology and geomorphology work as well as the stream reaches and the locations of the cross sections.

The habitat present in the study area is described in more detail in **Attachment A**. In general, the upper watershed consists of mixed conifer forest along the Bolinas Ridge. Oak woodlands occupy the drainage along Wharf Creek, the west side of Lewis Gulch Creek, and portions of the alluvial fans. In some reaches, the streams have a corridor of riparian trees such as red alder, willow, maple, and buckeye, before they reach brackish habitat. In other areas, the trees are lacking. The lower alluvial fan segments, upstream of the road crossings, have a variety of ecotones. Presently, each stream drains through a box culvert to the Bolinas Lagoon. Downstream of the box culverts, the channels flow through a variety of brackish ecotones that transition from freshwater to saltwater where subtidal channels continue through the mudflats of Bolinas Lagoon.

The following sections provide summary descriptions of the geomorphology of Wilkins Gulch Creek, Salt Creek, Lewis Gulch Creek, and Wharf Creek based on observations made during the field surveys and the background research conducted on each of the drainages. These streams and their watersheds are shown on **Figure 12**, **Figure 13**, **Figure 14**, and **Figure 15**, respectively. More detailed descriptions and photographs of the streams and individual reaches of the streams are in **Attachment B**.

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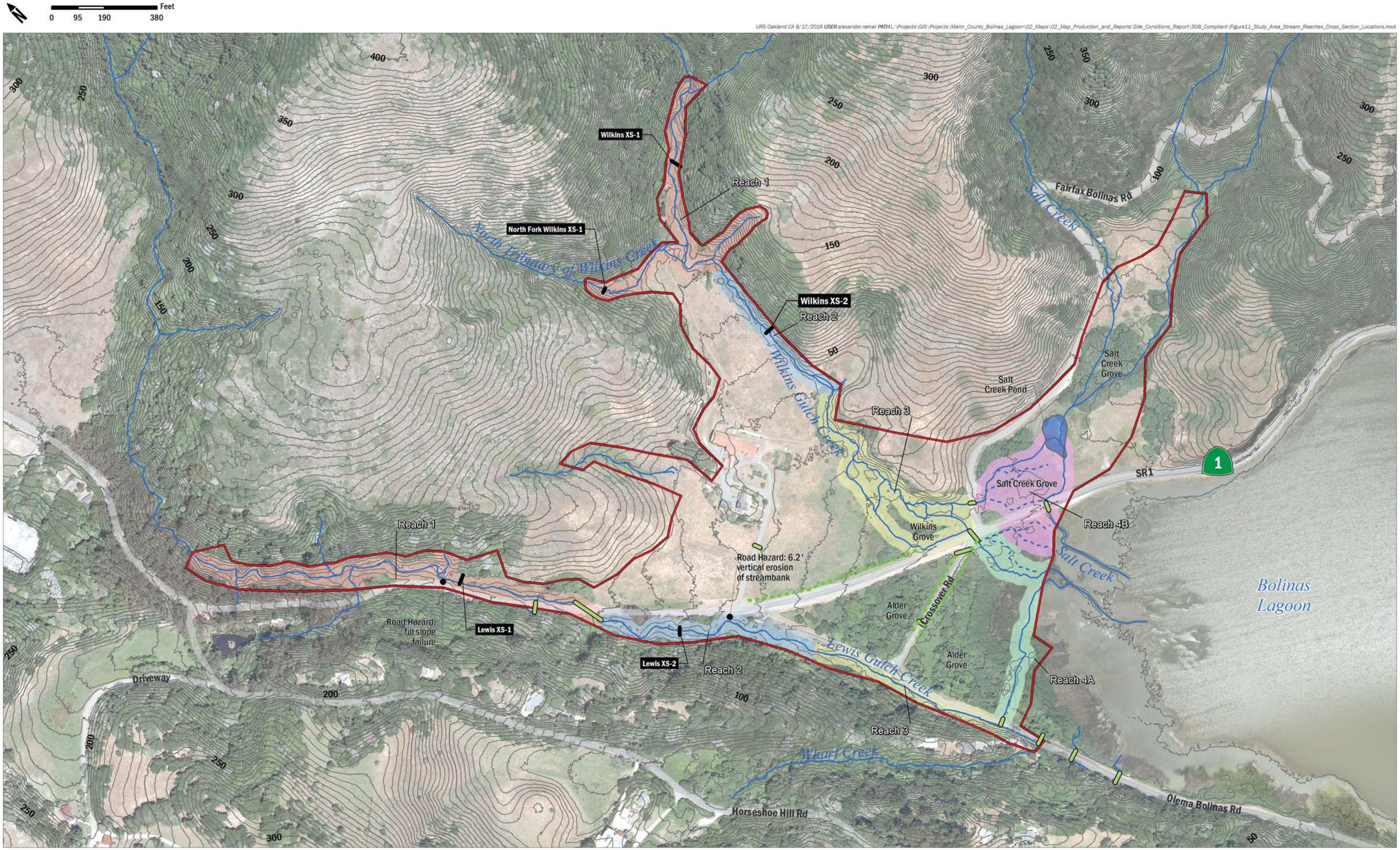


AECOM

Marin County

Bolinas Lagoon Restoration

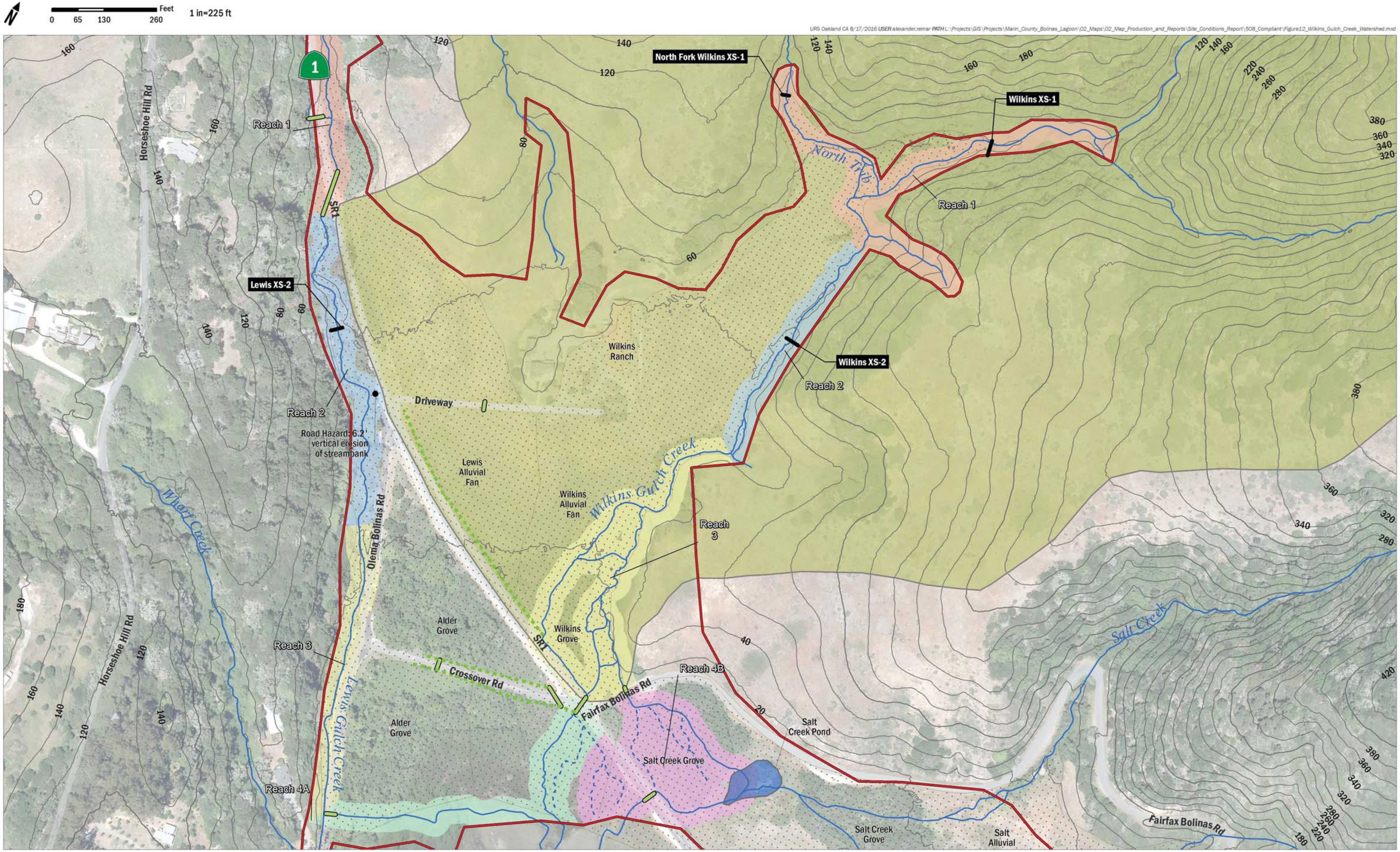
Legend	
Study Area	Cross Section
20ft Contour	Culvert
Stream	
Estimated/Undefined Stream Course	
Roadside Drainage Ditch	

Reach
- Reach 1
- Reach 2
- Reach 3
- Reach 4A
- Reach 4B

Data Sources:
1. Contours, ARRA Golden Gate LiDAR, USGS, 2010
2. Streams, Watersheds, AECOM, 2015

FIGURE 11

Study Area, Stream Reaches, and Cross-Section Locations



AECOM

Marin County

Bolinas Lagoon Restoration

- Study Area
- 20ft Contour
- Roadside Drainage Ditch
- Stream
- Estimated/Undefined Stream Course
- Cross Section
- Culvert
- Alluvial Fan

Watershed

- Wilkins Gulch Creek (0.68 sq mi)

Reach

- Reach 1
- Reach 2
- Reach 3
- Reach 4A
- Reach 4B

Data Sources:

1. Contours, ARRA Golden Gate LiDAR, USGS, 2010

2. Streams, Watersheds, AECOM, 2015

FIGURE 12

Wilkins Gulch Creek Watershed

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Wilkins Gulch Creek

During May of 2015, Wilkins Gulch Creek was essentially dry from a few hundred feet downstream of the head of the fan to the downstream willow grove. Continuous flow was observed from two tributaries flowing into the upper extent of the survey area. Landslides were observed on the eastern slope of Wilkins Gulch Creek along much of the length of the alluvial fan. Earthflows and slumps are the predominant mechanism of adjacent streamside sliding observed in the study area. The slides are triggered naturally by earthquakes, fire, and steep conditions, but accelerated by legacy land use activities (logging, grazing, northern tributary flow diversion, and possible ditching of Wilkins Gulch Creek to the eastern side of its valley). The length of Wilkins Gulch Creek is divided and described as four reaches. **Figure 12** shows the watershed, stream reaches, cross-section locations, and other notable features of this creek.

Reach 1 is characterized by alternating periods of incision and deposition associated with debris flow deposition and large woody debris. The channel indicates that lateral migration is causing areas of bank erosion. Two tributaries enter this reach. The northern tributary's flow was diverted into a ditch that has filled with sediment. A berm at the western downslope edge of the ditch was created to separate the flow in the ditch from the alluvial fan. Diversion of flow from the northern tributary into Wilkins Gulch Creek probably occurred very early in the history of the ranch, perhaps in the 1880s, and certainly before 1943, as indicated by aerial photos. As a result of the diversion, Wilkins Gulch Creek adjusted its channel geometry to accommodate increased flow and sediment load by incising and/or widening its channel. Presently, the diversion ditch is on the verge of abandoning its artificial confluence and flowing down onto the fan where any flow will likely infiltrate into the fan.

A cross section and longitudinal profile were surveyed in Reach 1 on Wilkins Gulch Creek near the head of the alluvial fan and the northern tributary to Wilkins Gulch Creek upstream of the alluvial fan (**Figure 12**). Bankfull hydraulic geometry measurements and discharge calculations based on the survey data are summarized in **Table 3**. The measurements were taken upstream or as close to the head of the alluvial fan as possible, in order to best characterize the stream bankfull flow and hydraulic geometry before streamflow infiltrates into the alluvial fan. The regional curve comparative analysis shows that bankfull discharge for the Wilkins Gulch Creek is predicted to be lower on average (15.9 cubic feet per second [cfs]) than what the field data shows. The physical characteristics of the watershed that affect runoff (e.g., slope, soils, and vegetation) and high average annual rainfall for the watershed, compared to that of the regional datasets, may account for the differences. More detailed analysis of the field data, calculations, and regional curve analysis is provided in **Attachment B**.

Reach 2 extends from the downstream end of Reach 1 to the upper extent of the willow grove that coincides with a very small eastern tributary. Valley width at the lower end is about 425 feet. The channel is incised within its alluvial fan, and there is no evidence of flooding onto the fan since the mid-1950s. There is possible evidence of constructed berms along the lower end of the reach to prevent flooding onto the pastureland upstream of the dairy barn. The upper half of this reach appears to have the capacity to transport most of its sediment load to the middle reach. The lower half appears to be aggrading. This may be due to it losing much of its flow to subsurface recharge of the fan, indicated by the much smaller width and depth of the channel and because during the field survey the entire reach was dry. Throughout Reach 2, channel width and depth varies from bend to bend. There are a number of inactive to active landslides that range in size from small inner gorge slumps to earthflows extending at least 200 feet upslope of the channel banks. The inner gorges of the eastern hillsides along the creek are supplying an abundant amount of sediment to the creek through raindrop impact erosion, surface rill erosion, raveling, and sliding. Sediment supply from stream bank erosion from fluvial processes is relatively minor.

A cross section and longitudinal profile was surveyed in Reach 2 on Wilkins Gulch Creek near the mid-point along the alluvial fan (**Figure 12**). Bankfull hydraulic geometry measurements and discharge calculations based on the survey data are summarized in **Table 3** and further described in

Attachment B. The measurements characterize the stream hydraulic geometry under the influence of the alluvial fan. Loss of streamflow due to infiltration into the porous bed material of the fan results in a smaller cross sectional area and width as well as lower calculated bankfull flow.

Reach 3 extends to the SR 1 culvert. This reach is characterized by emerging groundwater in the upper portion of the reach and aggradation in the middle to lower portions of the reach within the willow grove. Throughout the entire willow thicket, the channel appears to be aggrading, and there are many smaller subsidiary distributaries. The creek divides into three main distributaries off of the main channel along the middle to lower end of the reach. These distributaries likely formed as the channelized portion of the stream (against the toe of the hillslope) filled with bedload. The middle and eastern distributaries currently carry most of the flow. The eastern distributary and ditched channel against the toe of the hillslope appear to transport most of the sediment from Wilkins Gulch Creek, whereas the western distributary seems to carry groundwater from the western side of the valley flat.

The area where the middle and eastern distributaries flow into a 7-foot-wide by 4-foot-high box culvert coincides with the approximate position of the 1854 upland boundary of the tidal marsh. The channel slope into the box culvert appears to be relatively steep compared to the average slope further up the drainages. The outlet of the culvert does not appear to have much, if any, positive drainage towards the lagoon. A well-defined channel leading through the thick wetland vegetation was not found. As a result, the box culvert remains submerged in ponded water and sediment. Periodic attempts to improve drainage by excavating the inlet and outlet of sediment are apparent. It appears that wetland vegetation keeps growing through the deposited sediment blocking flow through the culvert.

The eastern ditched channel may have been channelized to carry sediment and water from Wilkins Gulch Creek to the Salt Creek tidal embayment for one or multiple possible reasons including to fill in the cutoff tidal bay, drain and remove surface water from the Wilkins lower alluvial fan to easily cultivate the land, to provide freshwater to the pond for cattle, and or to drain the creek to the only road culvert located at Salt Creek. The constructed channel was placed at a higher elevation than the valley floor between the base of the hillslope and a fence line that cuts through the willow grove from east to west. The channel appears to be nearly full of sand to gravel sized sediment, thus the future formation of more distributaries and continued deposition within the grove is likely in the future. This segment of the reach ends at Bolinas-Fairfax Road where the channel flows through an 8-foot wide by approximately 2.5-foot tall open grated box culvert that serves as a cattle guard.

Reach 4 comprises two separate stream segments of Wilkins Gulch Creek. The first (western) segment (4A) flows from a concrete box culvert under SR 1 through a thicket of willows toward the lagoon. Reach 4A does not appear to have one defined flow path toward the lagoon. A shallow drainage swale was present alongside SR 1 with standing water, but flow exiting the culvert appears to fan out into the thick wetland vegetation and willows facing the lagoon. Opposite the willow thicket (on the lagoon side), a small tidal channel was mapped leading from the direction of the culvert toward a larger tidal channel that drains Lewis Gulch Creek.

The second (eastern) segment (4B), which flows from the cattle guard/box culvert under Bolinas-Fairfax Road to the Salt Creek Pond, has been ditched to run northwest along a pullout adjacent to a pond before leading into the Salt Creek willow grove. It is uncertain if there are any other distributary channels within the willow grove that may route water around the periphery of the pond to the culvert on SR 1. The distributary drains through a concrete box culvert under SR 1 to the Bolinas Lagoon. The inlet and outlet of the SR 1 culvert on Salt Creek is known to be periodically dredged a short distance from the road because it is prone to filling with sediment.

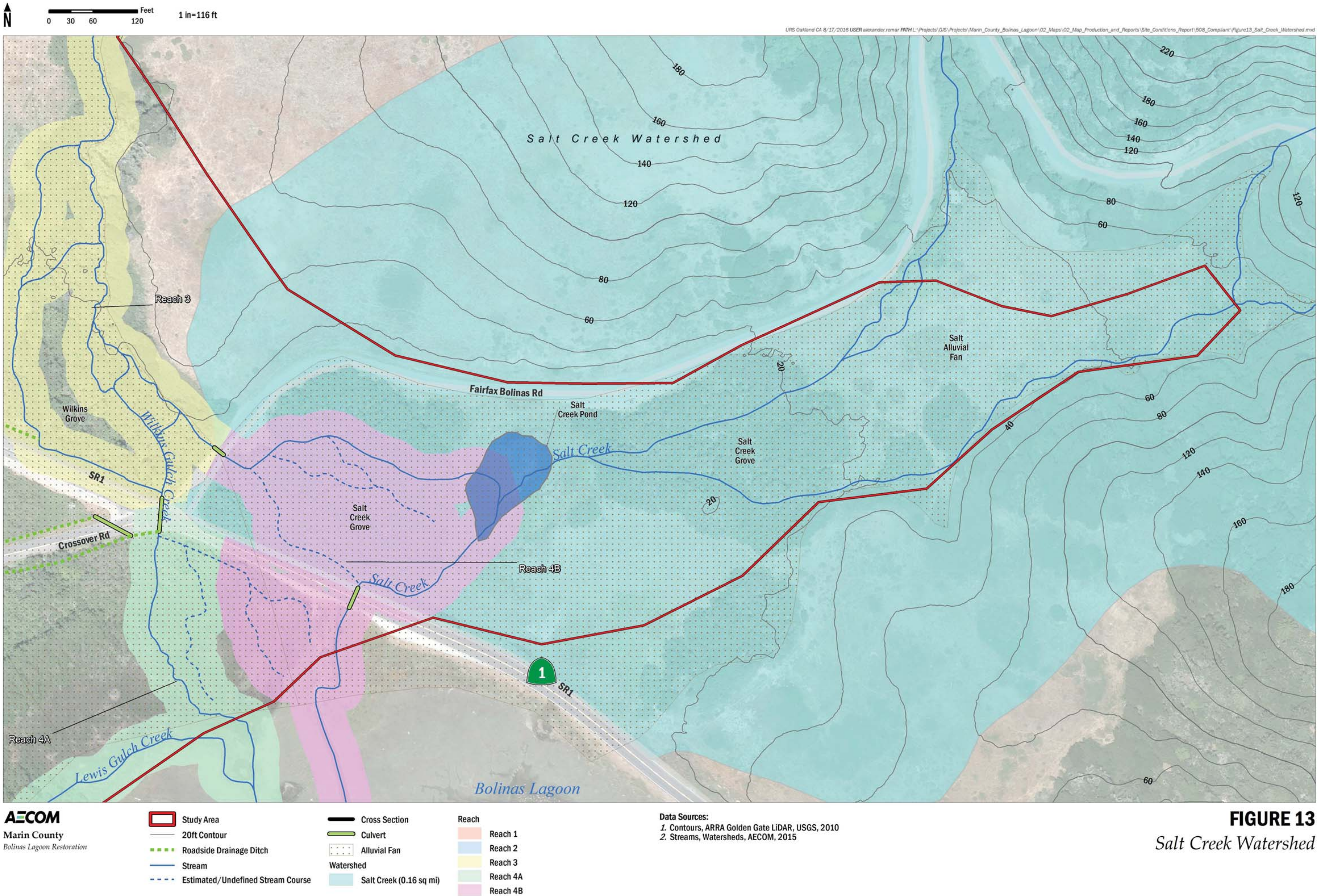
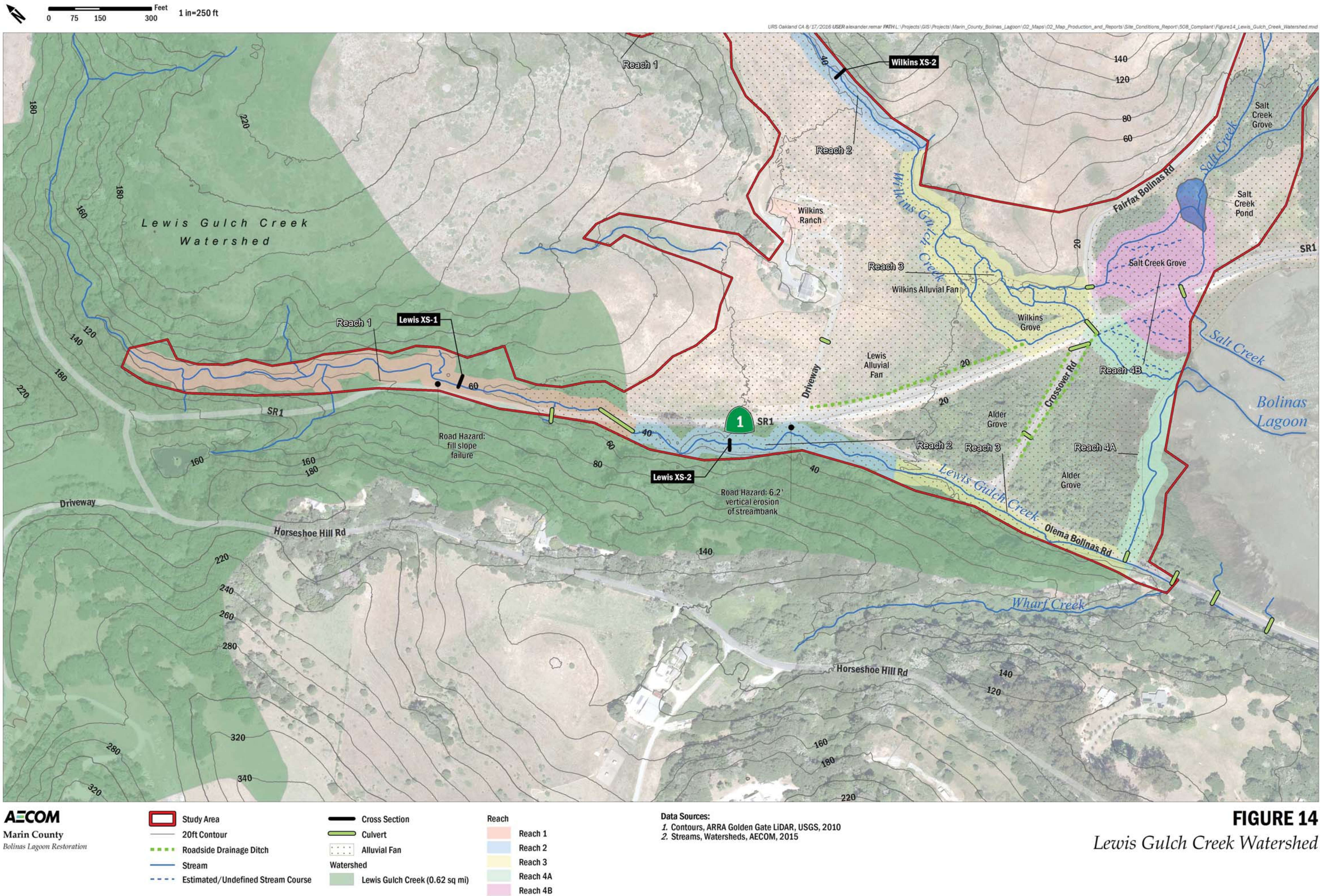


FIGURE 13
Salt Creek Watershed



Data Sources:
1. Contours, ARRA Golden Gate LiDAR, USGS, 2010
2. Streams, Watersheds, AECOM, 2015

FIGURE 14

Lewis Gulch Creek Watershed

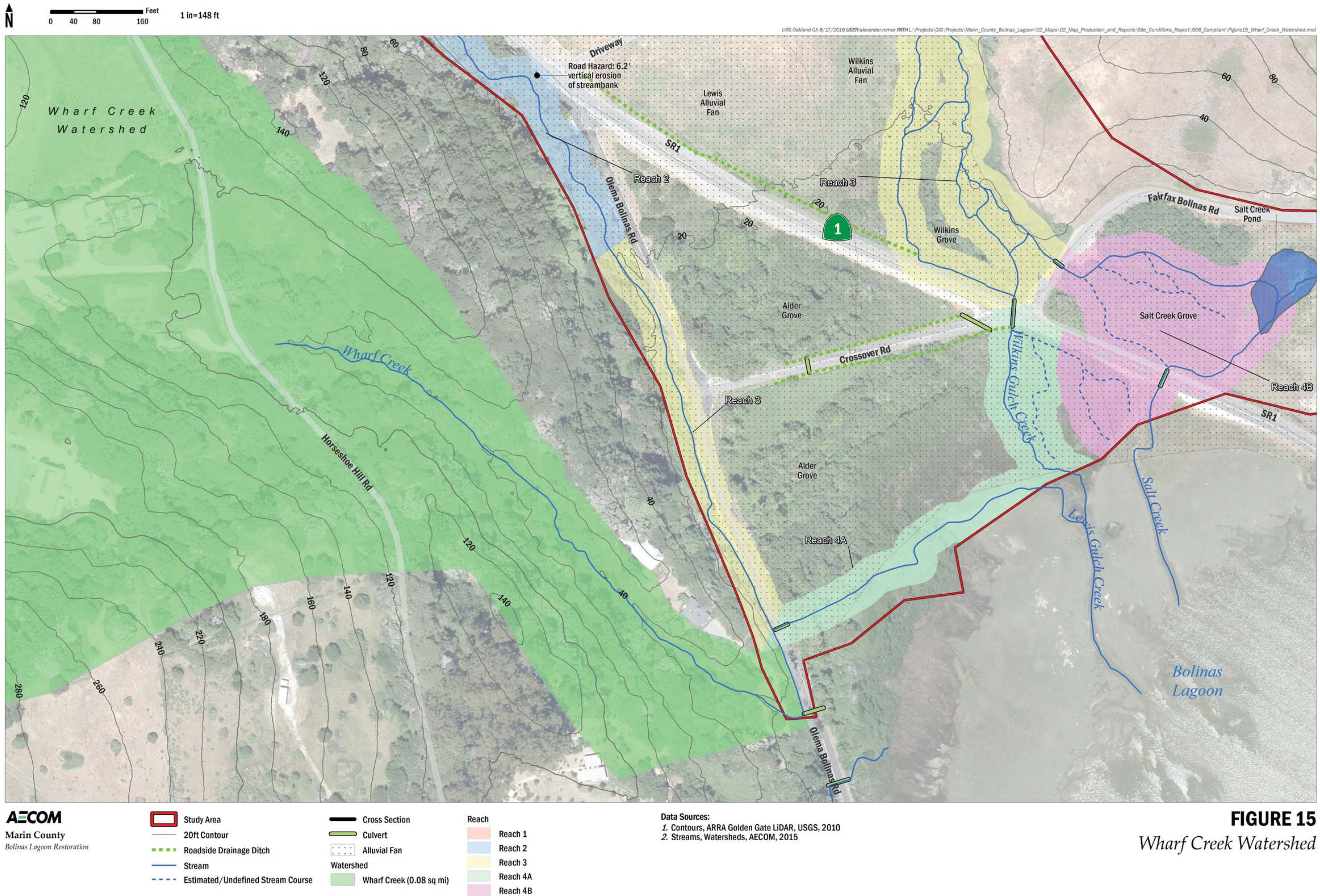


FIGURE 15
Wharf Creek Watershed

Table 3. Wilkins Gulch Creek and North Tributary Hydraulic Geometry

	Drainage Area (mi^2)	Bankfull Discharge (cfs)	Bankfull Cross Section Area (ft^2)	Bankfull Width (feet)	Bankfull Depth (feet)	Velocity (ft/s)	Stream Gradient	Entrench-ment Ratio	W/D Ratio
North Trib. of Wilkins Gulch Cr. Cross section 1 alluvial fan head	0.02	5.1	2.5	3.9	0.6	2.0	0.069	1.7	6.1
Wilkins Gulch Cr. Cross section 1 alluvial fan head	0.56	46.8	11.5	15.1	0.8	4.1	0.043	1.4	19.8
Wilkins Gulch Cr. Cross section 2 middle fan	0.61	28.3	8.7	13.2	0.7	3.2	0.017	1.2	20

Notes:
mi^2 = square miles
cfs = cubic feet per second
ft^2 = square feet

4.1.1 Salt Creek

Salt Creek comprises three main ephemeral drainages that flow onto the active alluvial fan. **Figure 13** shows the watershed, stream reaches and other notable features of this creek. Small channels carry flow across the fan surface, converging at the Salt Creek Pond when the soil is sufficiently saturated or when runoff is great enough to overcome the infiltration capacity of the porous soils of the fan. For the channels at the eastern side of the fan, recent channel flow was evident in 2015. It appears that all the bedload sediment conveyed from the headwaters of Salt Creek is distributed on the fan surface before reaching the pond. The channels form freely on the surface of the alluvial fan. Across the alluvial fan, most surface flow in the upper, steeper portion converts to groundwater and then reemerges near the willows and pond. Water from Salt Creek merges with residual flow from Wilkins Gulch Creek at the pond before flowing through a box culvert under SR 1.

The Salt Creek Pond occurs at an elevation equivalent to the mean higher-high tide (5.6 feet). The pond receives tidal water when tide levels are high enough to overcome the elevation difference that separates the pond from the excavated channel on either side of the SR 1 culvert. Sediment deposition from the incoming higher-high tides accumulates in the excavated channel and box culvert, reducing the flow capacity of the channel and culvert. Lost channel and culvert capacity inhibit the rate of tidal flow muting, thereby reducing the volume and duration of tidal exchange upstream of the SR 1 culvert and in the pond. As a result, pond salinity levels fluctuate with diurnal and seasonal tidal influences. Salinity levels increase in the pond when the box culvert has been cleared out and higher-high tides bring in an influx of saltwater. Salinity levels decrease when seasonal groundwater levels are higher (such as in the winter and spring), when subsurface streamflow moving through the alluvial fan resurfaces near the willow grove, filling the pond with freshwater. Salinity levels likely increase when the water table decreases, lowering the pond level and increasing the concentration of salts. During the biological field assessments conducted in April 2015, the salinity of the pond was 7 parts per thousand (ppt) following a dry winter in an extended drought period (see **Table 4**). No groundwater emergence was observed and tidal inflow did not appear to have occurred in recent months.

Table 4. Water Sample Salinities from Representative Locations in the Study Area[1]

Sample #	Salinity (parts per thousand)	Sample Date (2015)	Sample By
1	5	4/17	Lim
2	0	4/17	Peracca
3	0	4/17	Lim
4	7	4/20	Novak
5	25	4/20	Novak
6	0	4/20	Novak
7	0	4/20	Novak
8	0	5/5	Peracca
9	18	5/5	Peracca
10	0	5/5	Peracca
11	0	5/5	Peracca

[1] Water samples were collected by AECOM Staff (Tammy Lim, Galen Peracca, Jan Novak) from location shown in Figure 21, and measured in the office by Francesca Demgen, 4/28/15 and 5/18/15. Water samples were collected to inform and augment the habitat suitability assessment.

4.1.2 Lewis Gulch Creek

The field survey of Lewis Gulch Creek extended from the Bolinas Lagoon to approximately 1,300 feet upstream of the culvert crossing under SR 1. **Figure 14** shows the stream, the reaches, and other relevant details. The SR 1 culvert crossing is near the head of the inactive alluvial fan. The culvert under SR 1 consists of a 100-foot-long by 58-inch diameter corrugated metal pipe with a paved invert (lined with cement-based slurry). The length of the current creek is divided and described as four reaches.

Reach 1 is the 1,300 feet of stream ending at the upstream SR 1 culvert. Two ephemeral tributaries enter the reach from the west-facing slope. The reach is a confined valley channel, largely by the SR 1 road fill that was placed in the valley bottom. Numerous low terraces are present along the stream and represent prior large flood/depositional events, such as the large storms of 1982-1983 and 1997. Two higher terraces in the upper section of the reach (3 to 7 feet above the channel bed) may have been deposited following a woody debris jam that blocked the channel. There are few locations where small floodplains exist, as indicated by more recent sand deposition on the floodplain. Sediment sources along the reach appear to be predominantly from landslide slumps and bank erosion of older terrace deposits. The stream appears to be actively eroding the toe of the west-facing hillslope on the meander bends, thus leading to small slope failures. At the upper extent of the reach, three gullies run down the hillslope from the highway to the creek; one of them appears to convey runoff from SR 1 and possibly Horseshoe Hill Road. Another has been filled with riprap. There is one location where the creek meanders from the east side of the valley to the west side, where bank erosion is jeopardizing a portion of SR 1 road fill, evident by a scarp in the bank next to the road. Given the confined state of the valley, this reach will likely continue to transport most of its gravel-sized sediment to downstream areas.

A cross section and longitudinal profile was surveyed in Reach 1 on Lewis Gulch Creek upstream of the head of the alluvial fan (**Figure 14**). Bankfull hydraulic geometry measurements and discharge calculations based on the survey data are summarized in **Table 5**. The measurements were taken upstream of the alluvial fan to best characterize the stream bankfull flow and hydraulic geometry before streamflow infiltrates into the alluvial fan. Similar to Wilkins Gulch Creek, without the influence of the alluvial fan, the Lewis Gulch Creek field data can be compared to regional stream data or curves. Based on the drainage area upstream of the cross section location, the regional curve data show that bankfull discharge for the Lewis Gulch Creek is predicted to be lower on average (12.8 - 12.9 cfs) than what the field data shows. The watershed runoff characteristics and higher than average annual rainfall for the area are likely contributing factors to the difference. More detailed analysis of the field data, calculations, and regional curve analysis is provided in **Attachment B**.

Reach 2 extends from the SR 1 crossing from the approximate apex or head of the alluvial fan. This reach has broader alluvial terraces than Reach 1 and valley width is greater in Reach 2. In a couple of locations, relic primary or secondary channels were observed on the terrace surface between SR 1 and the channel. The elevation and orientation of the channels suggest that the channels may have been connected to relic channels on the alluvial fan east of SR 1. Several factors may have caused channel incision into the alluvial fan, including valley flood flow constriction, earthquake down-dropping, and channel manipulation. As a result, the reach seems to largely serve as a sediment transport reach, conveying gravel-sized rock to Reach 3. Historical research suggests that the stream may have been redirected in locations where structures or other infrastructure were built along the northwest bank of the stream. Sediment input in the reach is largely from bank erosion of the terraces at a of couple locations where the channel meanders against the hillslope and roadway. Midway in the reach, the channel has meandered laterally to the point where the 6-foot-high eroded stream bank is within 5 feet of the edge of the SR 1 pavement.

A cross section and longitudinal profile was surveyed in Reach 2 on Lewis Gulch Creek near the mid-point along the alluvial fan (**Figure 14**). Bankfull hydraulic geometry measurements and discharge calculations based on the survey data are summarized in **Table 5** and further described in **Attachment B**. The measurements characterize the stream hydraulic geometry under the influence of the alluvial fan. Loss of streamflow due to infiltration into the porous bed material of the fan results in a smaller cross sectional area and width as well as lower calculated bankfull flow.

Reach 3 runs along Olema Bolinas Road to the culvert leading to the lagoon. The stream has been channelized and straightened to a narrow area between the road and the adjacent hillslope to the west (**Figure 14**). Because the channel lacks the competence and capacity to carry the bedload, the reach is prone to aggradation. Marin County Public Works periodically dredges accumulated sediment in this reach as the channel fills and flooding on the roadway increases. It is believed that much of the larger gravel transported downstream is deposited in this reach. This reach lacks mature riparian vegetation unlike the other reaches, partially due to the frequent stream clearing.

Reach 4 extends from the concrete box culvert under the Olema Bolinas Road to the delta in the Bolinas Lagoon. A portion of the reach has been channelized to convey flow northeastward, across the lower alluvial fan, toward the center of the delta. Marin County Public Works periodically dredges accumulated sediment 250 feet downstream of the Olema Bolinas Road. A gate and access road on the right bank (looking downstream) provides equipment access to clear the channel. Sediment appears to have been excavated out of the channel and placed on the lagoon side of the access road, creating a levee berm. Sediment deposition in this section is likely related to reduction in transport capacity caused by the backwater effect of tides. The actively dredged portion of the channel stops at a sharp jog in the creek where a deep pool exists. Not many deep pools are present along Lewis Gulch Creek. Bed sediment in this reach consists mostly of small gravel and a high percentage of sand and silt. Much of the recent sand deposition appears to be coming from Wharf Creek roadside ditch. Reach 4 runs through a mature alder grove before exiting into a tidal marsh area. The tidal channel is narrow and deep with near vertical banks. Small gravel was present in the lower portion of the reach, indicating that a significant amount of bedload transport to the upper margins of the lagoon is actively occurring. Larger-than-expected gravel in the lower reach and a largely incised and/or entrenched channel seem to indicate the lack of capacity of upstream Reach 3 of Lewis Gulch Creek to process, distribute, or store the current bedload discharge.

Table 5. Lewis Gulch Creek Hydraulic Geometry

	Drainage Area (mi^2)	Bankfull Discharge (cfs)	Bankfull Cross Sectional Area (ft^2)	Bankfull Width (feet)	Bankfull Depth (feet)	Velocity (ft/s)	Stream Gradient	Entrench-ment Ratio	W/D Ratio
Lewis Gulch Cr. Cross section 1 in canyon	0.59	45.3	9.1	8.0	1.1	5.0	0.031	4.4	7.1
Lewis Gulch Cr. Cross section 5 at middle of fan	0.61	25.2	6.7	7.0	1.0	3.7	0.019	1.5	7.2

Notes:
mi^2 = square miles
cfs = cubic feet per second
ft^2 = square feet
ft/s = feet per second

4.1.3 Wharf Creek

Figure 15 shows the watershed, stream reaches, and other notable features of Wharf Creek. Wharf Creek received limited field reconnaissance due to its small size and limited access. The Wharf Creek channel upstream of the Olema Bolinas Road is confined within a relatively narrow and steep valley; however, an abundance of sand was observed in the Lewis Gulch Creek box culvert at the time of the surveys and much of it appeared to be coming from Wharf Creek. USGS mapping indicates that Wharf Creek parallels two ridgeline faults. Unlike the other creeks in the study area, Wharf Creek does not have an extensive alluvial fan. What little alluvial fan the creek may have had has been disturbed by construction of the Olema Bolinas Road. At the time of stream reconnaissance and mapping, a buried culvert (likely a 14-inch corrugated metal pipe similar to other nearby culverts) under Olema Bolinas Road was nonfunctional, which has since been cleared. A small man-made ditch is evident leading from the culvert outlet across the delta. The culvert is undersized and cannot convey the flow and sediment load of the stream. Rather than replace or continually clean the culvert, the creek was redirected to flow northward to Lewis Gulch Creek. During small to large storms, water and sediment have difficulty making the abrupt, 90-degree turn at the roadside ditch. As a result, water and sediment overflow the roadside ditch and flow across and down the road.

4.1.4 Hydrology and Geomorphology Conclusions

In general, alluvial fans build upward by spreading water and sediment on their surfaces through multiple distributary channels. Channels on alluvial fans tend to be inherently unstable features, prone to episodic deposition, erosion, and shifting courses. Loss of surface flow into porous substrate across the upper and middle body of the fan is common, along with resurgence of groundwater and increased streamflow at the toe of the fan. Generally, subsurface flow moving through the fan resurfaces as it meets the underlying water table or a soil contact (e.g., the dissimilar soil buried by the fan) with a lower hydraulic conductivity. These general characteristics apply to the study area channels along the length of their alluvial fans.

The alluvial fan surfaces of Wilkins Gulch and Lewis Gulch Creeks have for the most part been abandoned, except at their toes. The fans are disconnected from flooding because single thread channels are incised and previously ditched in some cases. Subsequently, the single channels are far more efficient at transporting sediment toward and into Bolinas Lagoon than if the flows were distributed on the fans' surfaces. The channels that dissect the fans have highly variable dimensions and degrees of entrenchment along the length of their fans. The more entrenched an alluvial channel is, the more likely that it is unstable and therefore unable to maintain its cross-sectional area without aggrading or degrading under a given climatic regime. Channels that are deeply incised into their valley flats, or alluvial fans, can significantly lower the water table and cause an increase in bank erosion. This occurs through the loss of riparian vegetation, which aids in stabilizing the stream bank.

Occasionally Wilkins Gulch and Lewis Gulch Creeks have high sediment transport from steep upstream canyon reaches and localized high inputs from eroding banks. Sediment loading is punctuated at times by active landslides from the adjacent hillsides to the creeks. Large woody debris inputs are common from both eroding banks and landslides. The channels have diminishing discharge in the middle of their fans (losing reaches) and increasing discharge toward their toes (gaining reaches). Wilkins Gulch, Lewis Gulch, and Salt Creeks become intermittent in the middle segments of their alluvial fans. Some reaches of the Salt Creek tributaries are discontinuous and might be considered ephemeral rather than intermittent. Less can be said about the smaller Wharf Creek because the steep and deeply vegetated slopes were not field-surveyed; however, the same general descriptions are likely to hold there as well.

Much of the sediment load is deposited in the roadside ditches on the upstream side of the culverts and in the culverts under the roads. During flood events, these culverts may become overwhelmed by the high sediment supply, causing a loss in capacity and resulting in roadway flooding. The problem is exacerbated during high tide when channel velocities are reduced or halted at culvert outlets, causing any bedload to be deposited. If a new channel cannot be eroded through the sediment deposits in the channel or culvert following high tide, roadway flooding and sediment deposition will worsen. When the upstream channel is entrenched, downstream flooding is exacerbated because flood peaks arrive more quickly and are higher when they do arrive. At the toes of the alluvial fans on Wilkins Gulch Creek and Salt Creek, notable sediment deposition in the braided channels was observed during field visits within the willow groves. The location of most sediment deposition on or near the fan surface on Wilkins Gulch Creek now occurs near the toe of the alluvial fan upstream of SR 1 and Bolinas Fairfax-Road. Eventually sediment deposited in this area will more frequently affect the functionality of those culverts and may cause roadway flooding.

Streamflow during the 2015 winter-spring drought was observed to go subsurface through the middle reaches of the fan and re-emerge at the toes of the three fans (on Wilkins Gulch, Lewis Gulch, and Salt Creeks). MLLW establishes the base level at the toes of the fans to which freshwater is graded. Fresh groundwater is less dense than saltwater and flows above it into the lagoon. Highest tides probably have a small overall influence on the average elevations of the groundwater table, with seasonal variations in rainfall having the greatest effect on where groundwater re-emerges as surface flow. Willow groves at the alluvial fan toes on both Wilkins Gulch Creek and Salt Creek may represent the more typical extent of perennially wet conditions than what was observed during the extended 2015 drought. Based on the LiDAR topography, the upper extent of these willow groves occurs near elevations of 25 to 30 feet.

Historically, the relocation and straightening of channels away from the alluvial fan and dredging of the streams to maintain channel capacity altered channel hydraulics in such a way that larger quantities of sediment and bedload were transported to the lagoon. The sudden alteration of channels by either human or natural means has made them more susceptible to erosion by changing their cross-sectional area, channel roughness, and stream gradient. Whether the streams were constructed in an incised state or they incised on their own is not clear. What is known is that both Wilkins Gulch and Lewis Gulch Creeks have incised so much that flood flows no longer have access to the fan surface in their upper and middle reaches. The stream modification significantly altered the sediment regime such that where the majority of sediment was once deposited on the upper- to mid-fan surface; it is currently transported further downstream to the channel segments in the lower portions of the alluvial fans. In addition, channel entrenchment has resulted in the loss of floodplain and alluvial fan surface connectivity, both of which spread floods and convert surface flow to subsurface flow through infiltration processes. This in turn reduces the amount of base flow and groundwater available for dry season streamflow that is important for sustaining freshwater and brackish water wildlife habitat.

Gullying and headward extension of channel networks during the period of heavy grazing and logging and conversion of native bunch grasses to non-native annuals resulted in an increased drainage density (channel length per unit area). Road and farm ditches and the connection of formerly disconnected channels on fans such as the Northern Tributary of Wilkins Gulch Creek also contribute to increased drainage density. As landscape-altering activities in the watershed (e.g., logging, road construction, fires, and farming) subsided, vegetation cover increased slowly helping to stabilize formerly disturbed areas. Although the altered contouring of the land in some areas still has a negative effect on channel morphology and sediment supply, the increased vegetation cover in some areas (such as the previously logged areas, the willow groves, and transition zones to tidal marshes) have helped reduce channel erosion and lower the rate of sediment supply.

Previous watershed disturbances within and upstream of the study area still influence road flooding in the study area. Just upstream of the head of tide, the natural topography and brackish transition zone for all four streams has been altered by road berms. Each channel drains to a culvert (box or pipe). A short distance beyond the outlets, their deltas merge together at the northern margin of Bolinas Lagoon. Flooding is the natural process for upland/tidal transition zones, but road berms, ditch diversions, desilting activities, and culverts in the study area have altered the natural flood and sediment conveyance to the Bolinas Lagoon. The placement and design of all of the culverts and orientation, shape, and size of channels leading to and from the roads contribute to road flooding issues. As an example, the Lewis Gulch Creek culvert on Olema Bolinas Road has issues with sediment deposition within and up and downstream of the culvert. The problem is compounded by the 90-degree redirection of streamflow at the entrance to the culvert, which reduces the efficiency of the channel to convey flow and sediment. As a consequence, storm flow will “back up” at the entrance to the culvert increasing the stage of flood flows upstream of the culvert and allowing sediment to be deposited in the channel, thereby exacerbating the road flooding. Flooding occurs during combinations of extreme high tides and intense rainfall runoff. The precise amount of flow required from the various streams to cause flooding in the study area is not presently known. Detailed hydrology and hydraulic modeling of the watersheds and various combinations of tidal and fluvial (in-stream) flows would be required to estimate these volumes.

Cross section and profile surveys of Wilkins Gulch and Lewis Gulch Creeks, conducted as a part of the project, indicate that considerable variability exists in channel hydraulic geometry and discharge within the study area and also when compared to regional data. The variability in the hydraulic geometry is in part due to the influence of human disturbances including channelization, floodplain encroachment, and instream structures combined with natural influences such as landslides and effects of the alluvial fans. Bankfull discharges calculated for the cross sections at the upstream end of the alluvial fans of the North Fork Tributary of Wilkins Gulch Creek, the main stem of Wilkins Gulch Creek, and Lewis Gulch Creek, are all greater than the predicted bankfull discharges estimated using regional data. The likely reason for this is the greater mean annual rainfall that falls in the watersheds of Bolinas Ridge compared to the regions where the regional curve dataset were derived. The measured bankfull discharges of the cross sections measured in the middle of the alluvial fans of Wilkins Gulch and Lewis Gulch Creeks were both less than the predicted amounts because the cross sections were in loosing reaches of alluvial fans.

4.2 Biological Conditions

Biological resources are described in the following subsections:

- Lagoon – Stream Interface;
- Vegetation communities;
- Rare plants;
- Invasive plant species;
- Wetlands, waters, and salinities;
- Wildlife habitats; and
- Special-status wildlife species.

4.2.1 Lagoon – Stream Interface

The northern portions of the lagoon within the study area are at sea level and contain unvegetated tidal mudflats. These mudflats are dissected by defined channels formed by the streams that drain the upper portions of the study area and flow through culverts under SR 1. Moving up through tidal elevations, the mudflats then transition into vegetated salt marshes. The lagoon becomes brackish in upper tidal elevations, as fresh water from groundwater and creek discharges mix in a "subterranean estuary" below the marsh. This is reflected in an abrupt discontinuity in vegetation between low salt marsh and tall, dense brackish alkali-bulrush marsh within a very gentle tidal elevation gradient. Above the brackish lagoon habitat, at supratidal elevations (highest winter storm high tides) stands of alder and willow have developed. The alder/willow forest continues above the crossover road with the isolated triangle of habitat at the Y, which is not tidally influenced.

The study area consists primarily of mudflat, freshwater, brackish and salt marsh, riparian forest (alder and willow), and grasslands. Areas of scrub and eucalyptus forest are also present, but are smaller and scattered. Throughout most of the vegetation communities in the study area, native plants grow intermixed among non-native plant species. Riparian and wetland vegetation, consisting of moisture-dependent trees, shrubs, and forbs, occupy portions of the intermittent and perennial creeks and drainages, as well as the area around the pond. The study area provides habitat for special-status plant and animal species such as steelhead trout (*Oncorhynchus mykiss*) and California red-legged frog (*Rana draytonii*). Within the lagoon and adjacent to the study area there are rookeries for egret and heron nesting, harbor seal (*Phoca vitulina*) pupping areas, and intertidal wetlands.

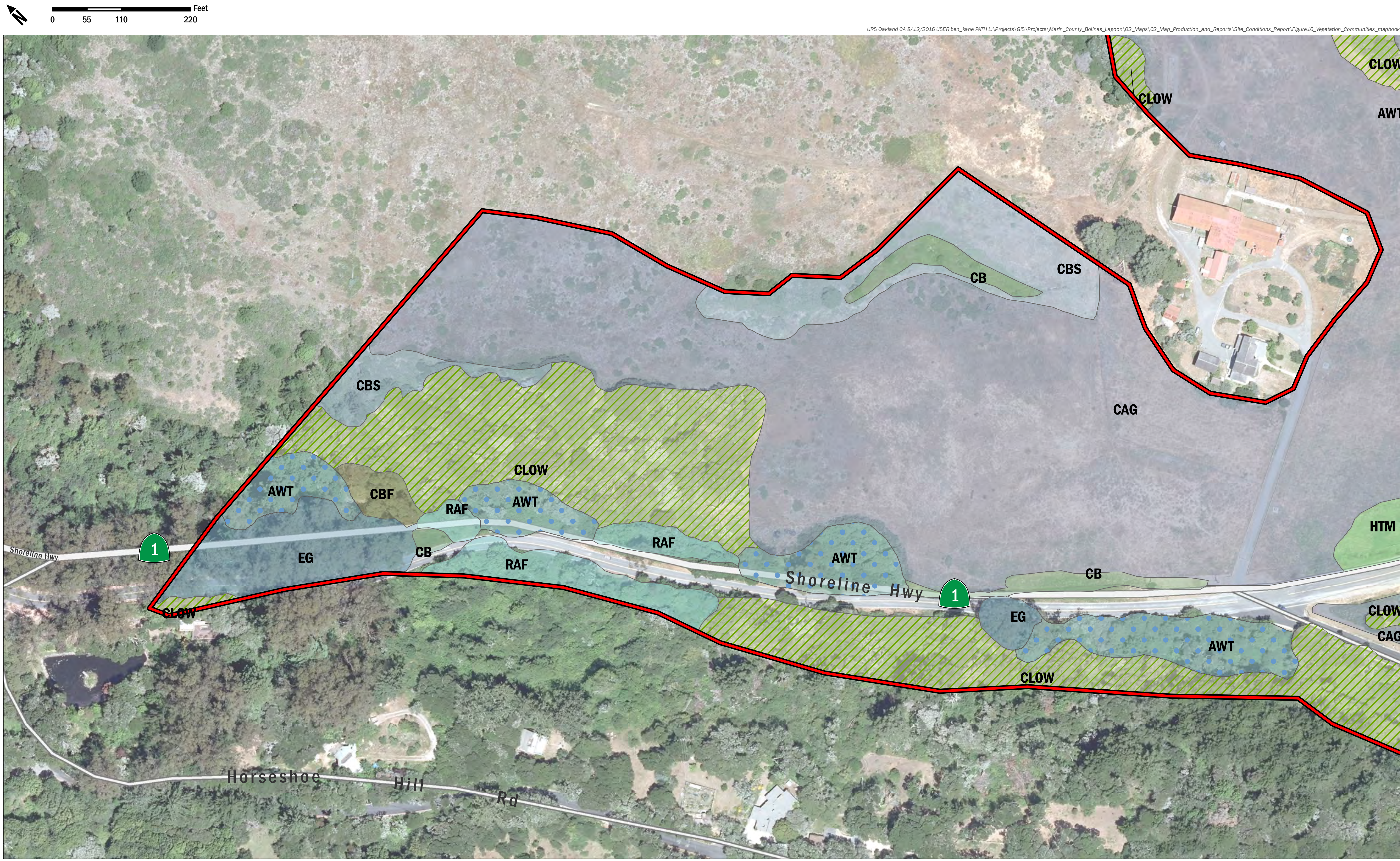
As described in the previous sections, Wilkins Gulch Creek and Salt Creek flow out of the hills in the northern and eastern portions of the study area into the lagoon. Stream flow is contained within the bed and bank of the creeks at the higher elevations. The defined banks give way to drainages that lack distinct stream bank edges at lower elevations; this is seen in the marsh environment near the crossings under SR 1 and a side branch that crosses under Fairfax Bolinas Road to connect with the Salt Creek drainage. This area is heavily vegetated with arroyo willow thickets. Salt Creek Pond is also surrounded by an arroyo willow thicket. Wilkins Gulch Creek discharges into the lagoon via two culvert systems, located north and south of the intersection of SR 1 and Fairfax Bolinas Road. The culvert north of the intersection is small but appears to be the original main stem of the creek. Its flows deposit freshwater into a willow thicket alongside the intersection of SR 1 and the crossover road (**Figure 11**).

Although Bolinas Lagoon buffers the strong tides originating in the Pacific Ocean (west of the study area), the study area experiences a tidal cycle each day that carries salt water into the study area and allows freshwater and groundwater discharge to drain from the creeks. The salinity of the study area, and therefore the species that grow and thrive in the study area, is highly dependent upon the relationship between tidal flooding, freshwater discharges below-ground and above-ground, topography, and hydraulic conductivity of wetland soils. During periods of high freshwater discharge, salinity levels in the study area are lower, and vice-versa. Freshwater discharge is highest when there is a combination of surface and subsurface (groundwater) flows. Surface flows are seasonal and generally come during the rainy season (October to April). The groundwater discharge persists into the dry season when surface flows generally stop. Plant growth, however, is lowest during periods of high surface flows. Groundwater flows dominate during the periods of plant growth, when the plans are most sensitive to salt stress. This means that the vegetation communities are heavily influenced by the groundwater flows and the salinities in them.

Due to the study area having been significantly impacted by roadways, stream diversion, and culverts, the lagoon now has a hardened perimeter that constrains the ability of the lagoon to respond to sea level rise by moving higher up the valley and onto alluvial floodplains. The culverts disconnect the lagoon habitats from the alluvial plains, and riparian and upland habitats. The realignment and berming of the streams separates them from their natural floodplains, altering both ecological and hydrological functions. The roadways and culverts also eliminate continuous transitional habitat between the lagoon, the higher marsh, and uplands. These habitats are important for waterbirds as high tide refugia, and their separation disrupts migration of amphibians and anadromous fish.

4.2.2 Vegetation Communities

The desktop analysis and field surveys identified 18 plant communities and approximately 300 unique plant species. (See **Attachment A** and its appendices for more details on the methods and other details.) **Table 6** lists the plant communities identified in the study area, their total coverage area, and their rarity status as described by the CDFW. Each community is described in the text below. **Attachment A** provides results from plot surveys, area photographs, and detailed descriptions of each of the plant communities. **Figure 16, Sheets 1-5,** display maps of the study area and the vegetation communities.



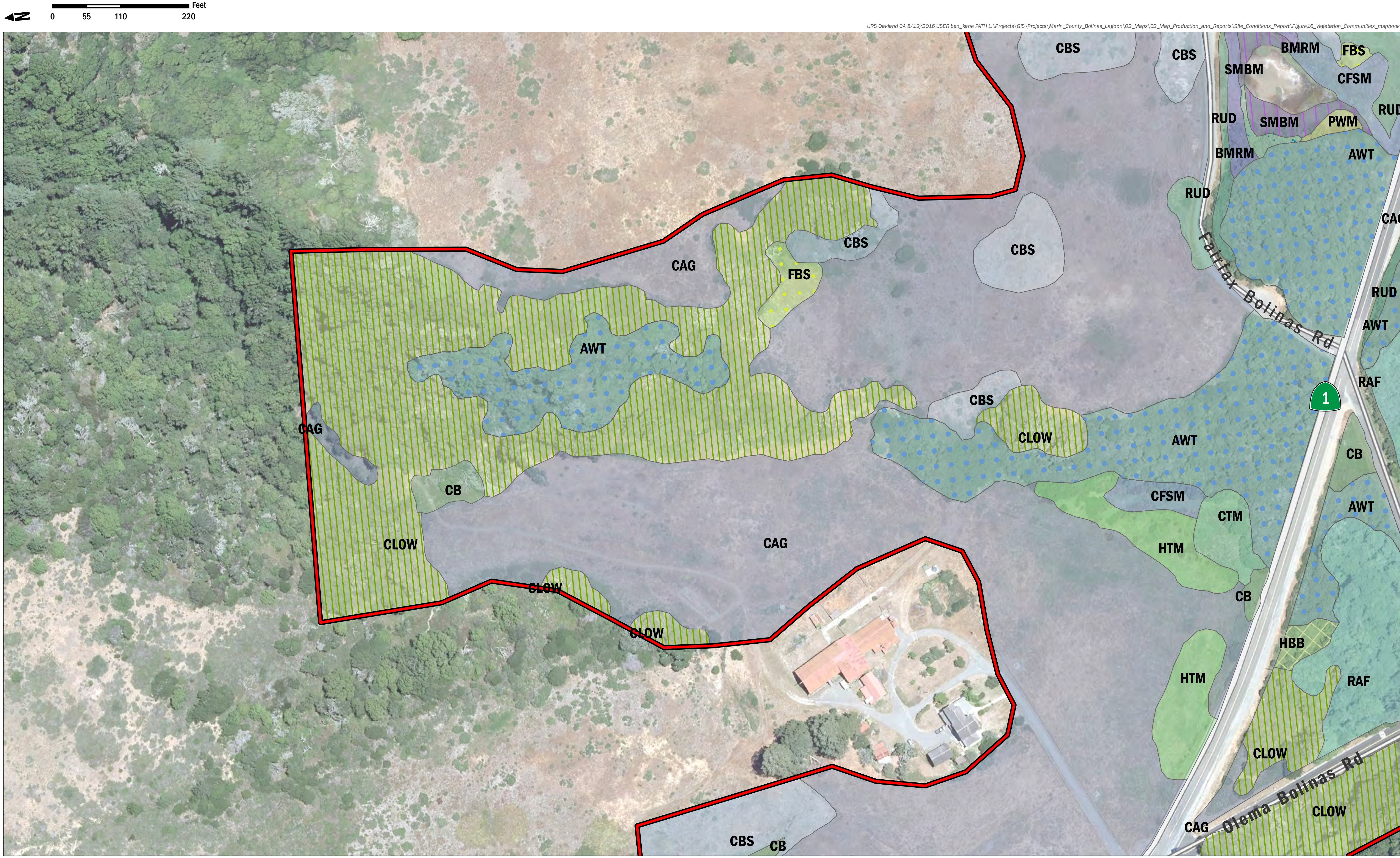
AECOM
MCOSD
Bolinas Lagoon Restoration

Study Area

Vegetation Community

- Arroyo willow thicket (AWT)
- California annual grassland (CAG)
- California bay forest (CBF)
- Coast live oak woodland (CLOW)
- Coastal brambles (CB)
- Coyote brush scrub (CBS)
- Eucalyptus grove (EG)
- Giant horsetail marsh (HTM)
- Red alder forest (RAF)

FIGURE 16.1
Vegetation Communities



AECOM

MCOSD

Bolinas Lagoon Restoration

Study Area

Vegetation Community

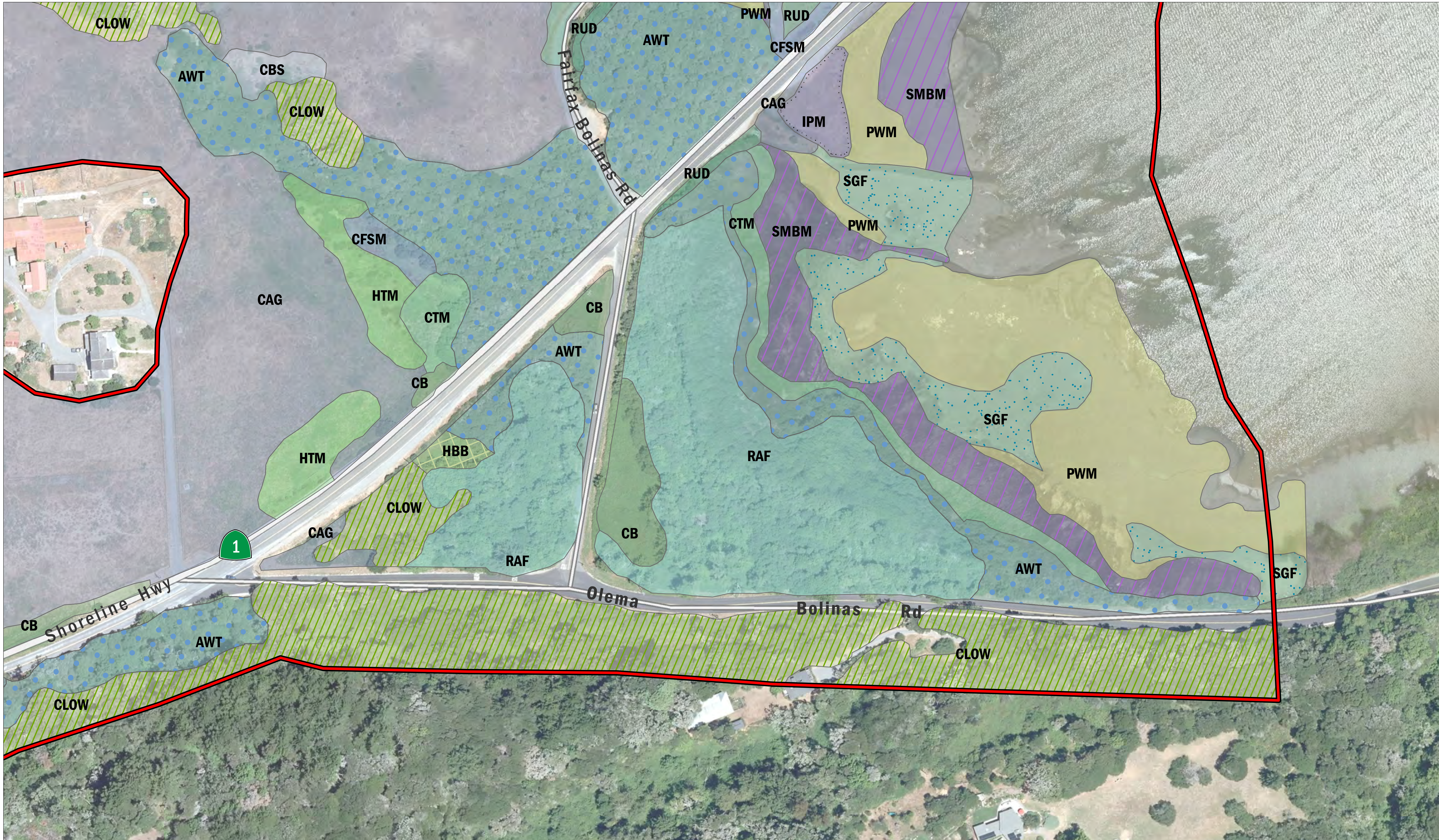
- Arroyo willow thicket (AWT)
- Baltic and Mexican Rush Marsh (BMRM)
- Broom patches (FBS)
- California annual grassland (CAG)
- Cattail marsh (CTM)
- Coast live oak woodland (CLOW)
- Coastal brambles (CB)
- Coyote brush scrub (CBS)
- Giant horsetail marsh (HTM)
- Himalayan blackberry brambles (HBB)
- Pickleweed mats (PWM)
- Ruderal (RUD)
- Salt grass flats (SGF)
- Salt marsh bulrush marsh (SMBM)
- Clustered field sedge marsh (CFSM)
- Red alder forest (RAF)

FIGURE 16.2

Vegetation Communities

Feet
0 55 110 220

URS Oakland CA 8/12/2016 USER ben_kane PATH L:\Projects\GIS\Projects\Marin_County_Bolinas_Lagoon\02_Maps\02_Map_Production_and_Reports\Site_Conditions_Report\Figure16_Vegetation_Communities_mapbook.mxd



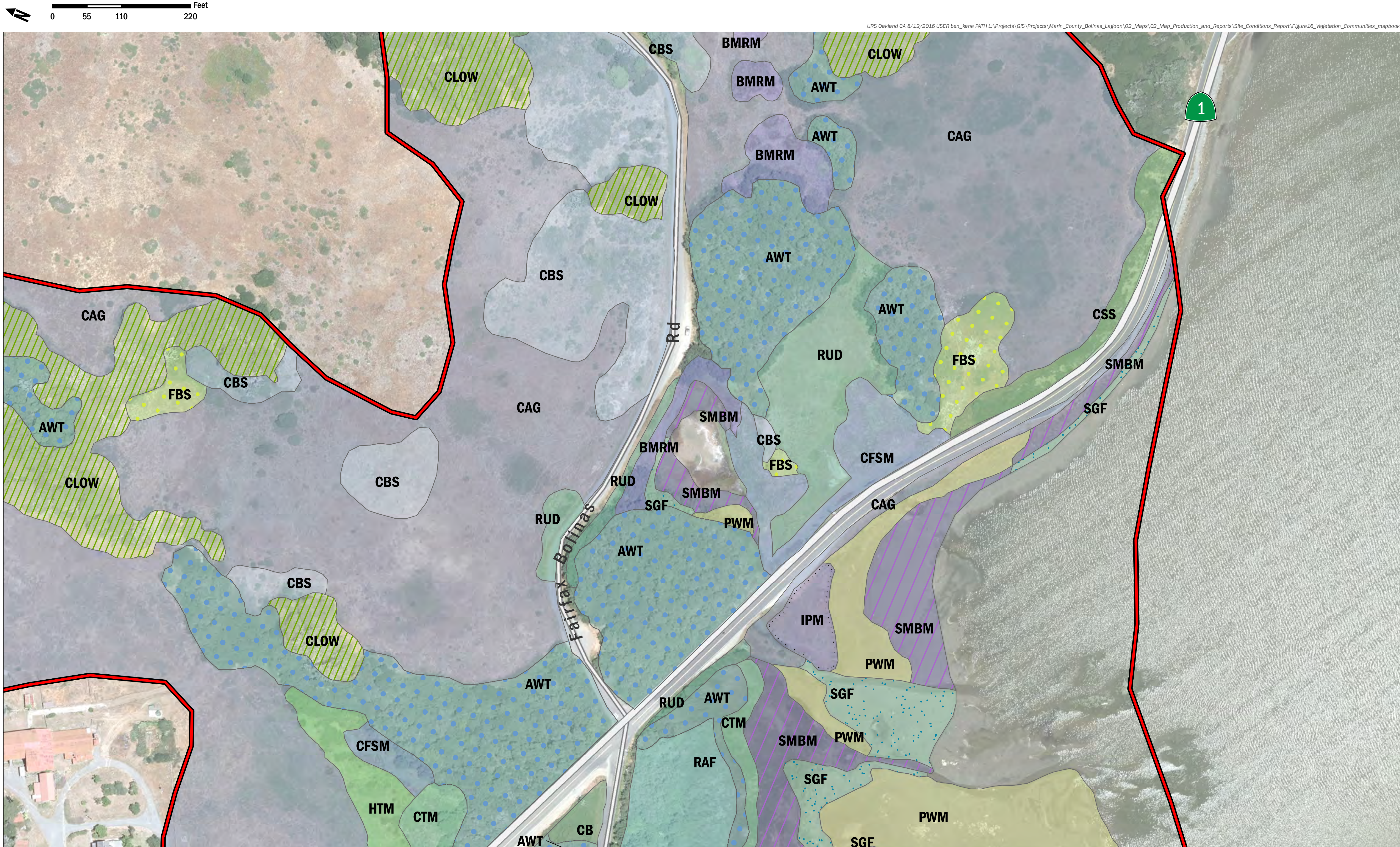
AECOM
MCOSD
Bolinas Lagoon Restoration

Study Area

Vegetation Community

- Arroyo willow thicket (AWT)
- California annual grassland (CAG)
- Cattail marsh (CTM)
- Coast live oak woodland (CLOW)
- Coastal brambles (CB)
- Coyote brush scrub (CBS)
- Eucalyptus grove (EG)
- Giant horsetail marsh (HTM)
- Himalayan blackberry brambles (HBB)
- Ice plant mats (IPM)
- Pickleweed mats (PWM)
- Ruderal (RUD)
- Salt grass flats (SGF)
- Salt marsh bulrush marsh (SMBM)
- Clustered field sedge marsh (CFSM)
- Red alder forest (RAF)

FIGURE 16.3
Vegetation Communities



AECOM

MCOSD

Bolinas Lagoon Restoration

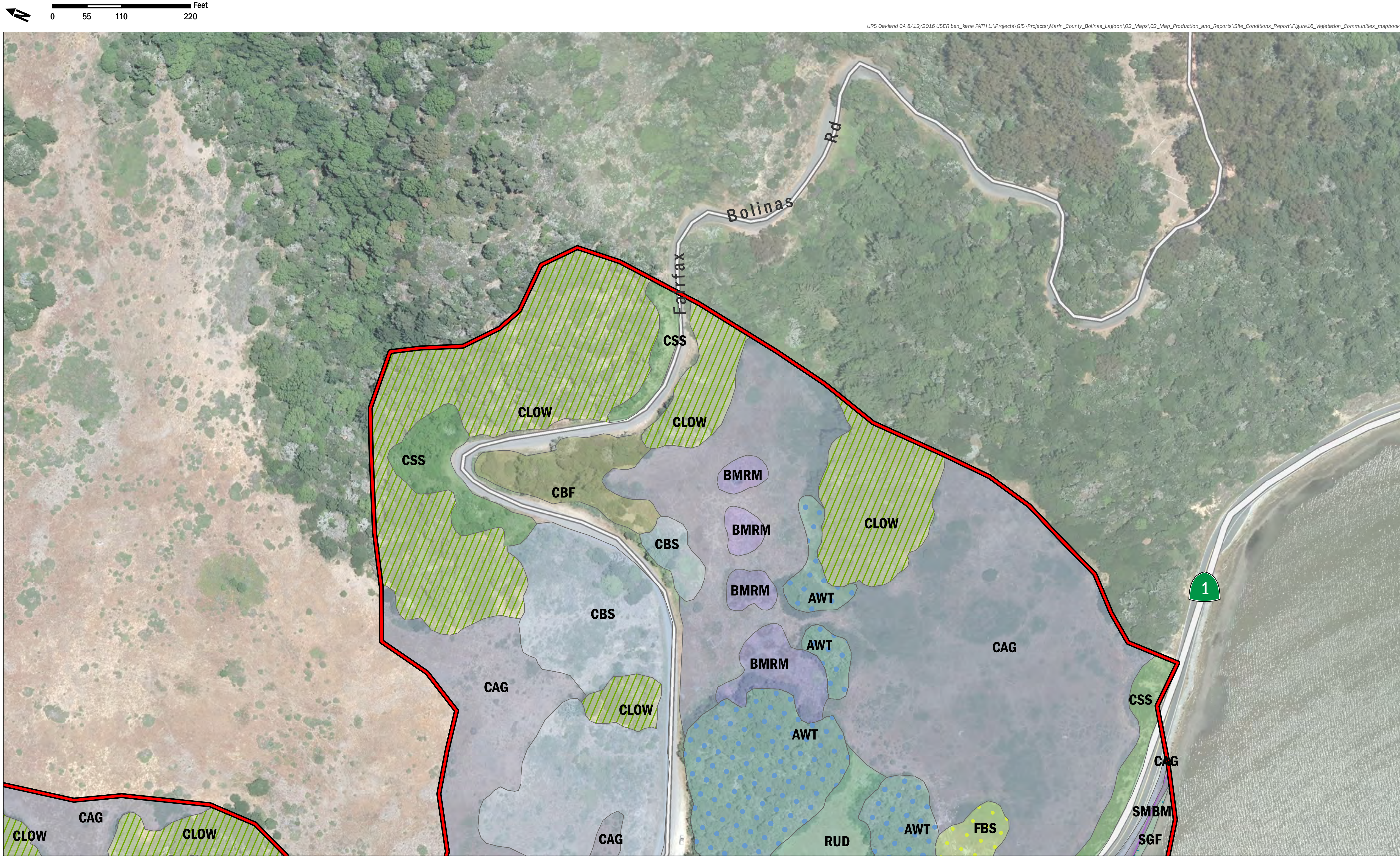
Study Area

Vegetation Community

- Arroyo willow thicket (AWT)
- Baltic and Mexican Rush Marsh (BMRM)
- Broom patches (FBS)
- California annual grassland (CAG)
- California sagebrush scrub (CSS)
- Cattail marsh (CTM)
- Coast live oak woodland (CLOW)
- Coastal brambles (CB)
- Coyote brush scrub (CBS)
- Giant horsetail marsh (HTM)
- Ice plant mats (IPM)
- Pickleweed mats (PWM)
- Ruderal (RUD)
- Salt grass flats (SGF)
- Salt marsh bulrush marsh (SMBM)
- Clustered field sedge marsh (CFSM)
- Red alder forest (RAF)

FIGURE 16.4

Vegetation Communities



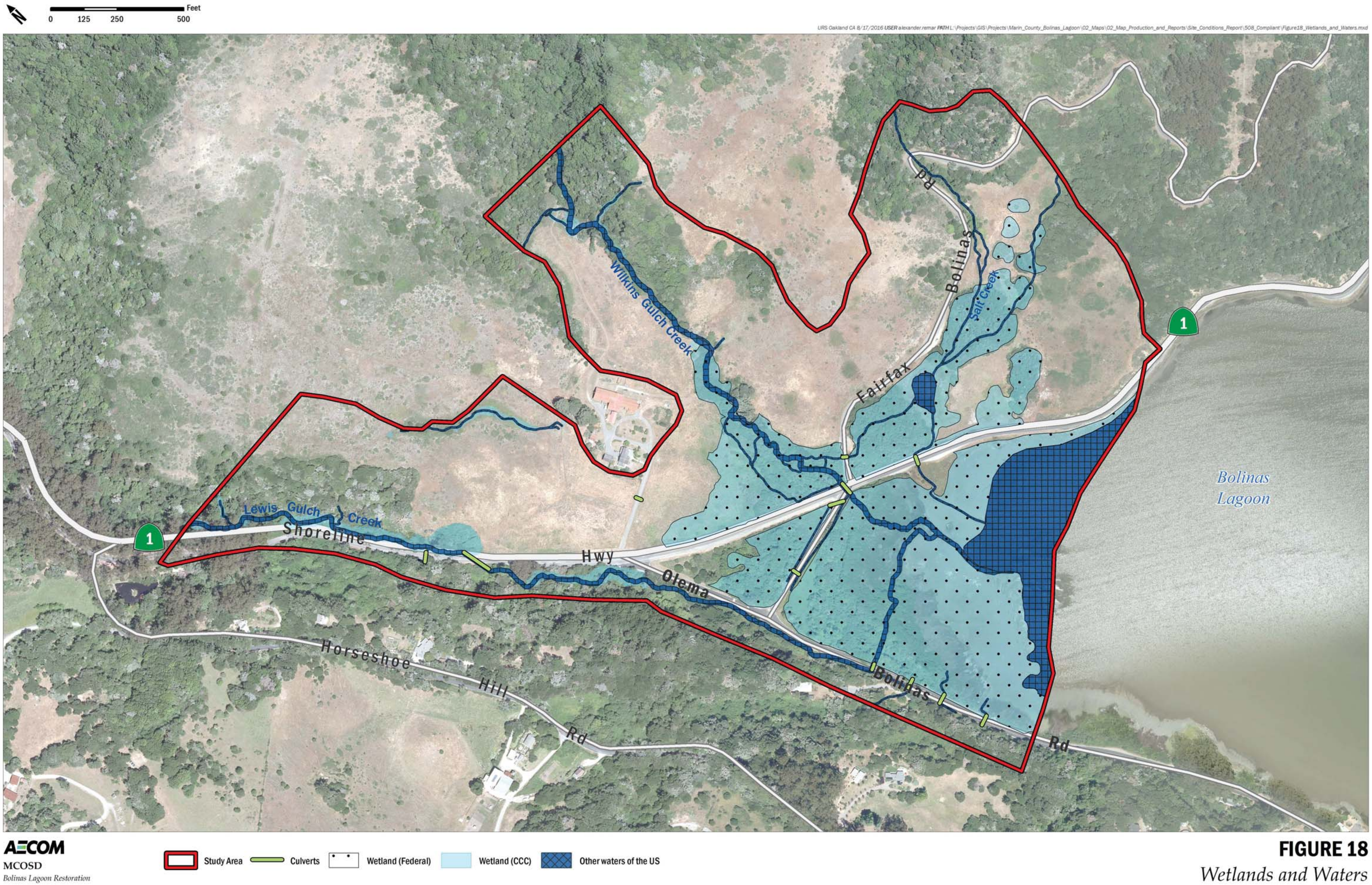
AECOM
MCOSD
Bolinas Lagoon Restoration

Study Area

Vegetation Community

- Arroyo willow thicket (AWT)
- Baltic and Mexican Rush Marsh (BMRM)
- Broom patches (FBS)
- California annual grassland (CAG)
- California bay forest (CBF)
- California sagebrush scrub (CSS)
- Coast live oak woodland (CLOW)
- Coyote brush scrub (CBS)
- Ruderal (RUD)
- Salt grass flats (SGF)
- Salt marsh bulrush marsh (SMBM)

FIGURE 16.5
Vegetation Communities



AECOM
MCOSD
Bolinas Lagoon Restoration

FIGURE 18
Wetlands and Waters

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Table 6. Plant Communities in the Study Area

Plant Community Scientific Name[1]	Plant Community Common Name	Acreage in the study area	Percent of total study area[2]	State Status[3]
Alnus rubra Forest Alliance	Red Alder Forest	5.91	5.76	S4
Artemisia californica Shrubland Alliance	California Sagebrush Scrub	1.06	1.03	S5
Baccharis pilularis Shrubland Alliance	Coyote Brush Scrub	5.16	5.03	S5
Genista monspessulana Broom Semi-Natural Shrubland Stands	French Broom Scrub	0.60	0.58	NA
Bolboschoenus maritimus Herbaceous Alliance	Alkali-Bulrush Marshes	2.54	2.47	S3
Carpobrotus edulis or other Ice Plants Stands	Ice Plant mats	0.26	0.25	NA
Distichlis spicata Herbaceus Alliance	Salt Grass Flats	1.79	1.74	S4
Ecualyptus sp. Semi-Natural Stands	Eucalyptus Groves	1.08	1.05	NA
Juncus arcticus (var. *balticus*, *mexicanus*) Herbaceous Alliance	Baltic and Mexican Rush Marshes	0.83	0.81	S4
Quercus agrifolia Woodland Alliance	Coast Live Oak Woodland	19.83	19.32	S4
Rubus ursinus Shrubland Alliance	Coastal Brambles	1.23	1.20	S3
Salix lasiolepis Shrubland Alliance	Arroyo Willow Thickets	10.30	10.03	S4
Salicornia pacifica Herbaceous Alliance	Pickleweed Mats	3.92	3.82	S3
Typha Herbaceous Alliance	Cattail Marsh	0.78	0.76	S5
*Umbellularia californi*a Forest Alliance	California Bay Forest	0.72	0.70	S3
Other Alliances				
Equisetum telmateia Herbaceous Alliance	Giant Horsetail Marsh	0.87	0.85	NA
Carex praegracilis Herbaceous Stands	Clustered Field Sedge Marsh	0.92	0.90	NA
	California Annual Grassland	32.38	31.54	NA
	Ruderal	1.39	1.35	NA

[1] Plant Community Names (Alliances) based on naming conventions in the Manual of California Vegetation, 2nd ed. (MCV2)
[2.] Total study area equals 102.65 acres.
[3] State Ranking (State of California: The Resources Agency. Department of Fish and Wildlife Biogeographic Data Branch: California Natural Diversity Database, 2007).
S1 = Less than 6 element occurrences (EO)s OR less than 1,000 individuals OR less than 2,000 acres
S2 = 6-20 EOs OR 1,000-3,000 individuals OR 2,000-10,000 acres
S3 = 21-100 EOs or 3,000-10,000 individuals OR 10,000-50,000 acres
S4 - Apparently secure within California
S5 - Demonstrably secure to ineradicable in California

4.2.3 Rare Plant Species

The California Natural Diversity Database (CNDDB) 5-mile radius search identified 32 rare plant species with potential to occur within the study area based upon phenology, documented occurrence location, and appropriate habitat conditions (see **Attachment A** for a complete list). **Table 7** lists those species with moderate to high probability of occurrence within the study area.

Table 7. Rare Plants with Moderate to High Potential to Occur in the Study Area

Species Name	Common Name	Status[1] (federal/ state/ CRPR)	MCV2 Plant Community	Likelihood of Occurrence
Abronia umbellata subspecies *breviflora*	North coast pink sand-verbena	FSC/--/1B	Beach and beach-salt marsh ecotone edge	Moderate. Suitable habitat exists in the study area, and populations were observed in Stinson Beach and Kent Island in recent past.
Alopecurus aequalis var. *sonomensis*	Sonoma alopecurus	FE/--/1B.1	Red Alder Forests, Baltic and Mexican Rush Marshes, Arroyo Willow Thickets, Cattail Marsh, Giant Horsetail Marsh	Moderate. Suitable habitat occurs in the study area, but records are not known at Bolinas Lagoon.
Amorpha californica var. *napensis*	Napa false indigo	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, Eucalyptus Groves, Coast Live Oak Woodland, California Bay Forest	Moderate. Suitable habitat occurs in the study area, but the only plants recorded within a 5-mile radius are east of the Bolinas-Fairfax Ridge.
Amsinckia lunaris	bent-flowered fiddleneck	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, French Broom Scrub, Coast Live Oak Woodland, California Bay Forest, California Annual Grassland, Ruderal	Moderate. Suitable habitat occurs in the study area, but the only plants recorded within a 5-mile radius are east of the Bolinas-Fairfax Ridge.
Arctostaphylos virgata	Marin manzanita	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, Coast Live Oak Woodland, California Bay Forest	High. Suitable habitat occurs in the study area, and numerous records occur within a 5-mile radius. The nearest record is Pablo Point, Pt. Reyes NS.
Astragalus pycnostachyus var. *pycnostachyus*	coastal marsh milk-vetch	--/--/1B.2	Salt Grass Flats, Baltic and Mexican Rush Marshes,	Moderate. Suitable habitat occurs throughout the study area, and numerous records are reported within a 5-mile radius, however, these populations are considered extirpated.
Carex lyngbyei	Lyngbye's sedge	--/--/2B.2	Salt Marsh Bulrush Marshes, Salt Grass Flats, Rush Marshes, Cattail marsh,	Moderate. Suitable habitat occurs throughout the study area, and records are reported within a 5-mile radius. The nearest is at Stinson Beach.

Table 7. Rare Plants with Moderate to High Potential to Occur in the Study Area

Species Name	Common Name	Status[1] (federal/ state/ CRPR)	MCV2 Plant Community	Likelihood of Occurrence
Castilleja ambigua subspecies *ambigua*	salt marsh owl's clover	FSC/--/4.2	Widespread in backbarrier salt marsh ecotone, associated with sparse cover of pickleweed, saltgrass, and others	High. Suitable habitat occurs within the study area, and there are records of this species at several points around Bolinas lagoon.
Ceanothus masonii	Mason's ceanothus	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub	Moderate. Limited suitable habitat is present in the project area, and there are numerous records within a 5-mile radius. The nearest records are, however, along Bolinas-Fairfax Ridge.
Chloropyron maritimum ssp. *palustre*	Northern salt marsh bird's-beak	--/--/1B.2	Salt Grass Flats, Pickleweed Mats	High. Suitable habitat occurs within the study area, and there are records of this species at Bolinas Lagoon, as close as 2 miles from the study area.
Fritillaria lanceolata var. *tristulis*	Marin checker lily	--/--/1B.1	California Sagebrush Scrub, Coyote Brush Scrub, Coastal Brambles, California Annual Grassland	High. Suitable habitat occurs within the study area. Three records occur within 2 miles of the study area.
Gilia capitata ssp. *tomentosa*	woolly-headed gilia	--/--/1B.1	California Sagebrush Scrub, Coyote Brush Scrub, California Annual Grassland	Moderate. Suitable habitat is present in the project area, and there are numerous records within a 5-mile radius. The nearest records are, however, considered extirpated.
Hemizonia congesta ssp. *congesta*	white seaside tarplant	--/--/1B.2	California Annual Grassland, Ruderal	High. Suitable habitat occurs within the study area. Records occur within 2 miles of the study area, adjacent to Bolinas.
Mielichhoferia elongata	elongate copper moss	--/--/2B.2	Coast Live Oak Woodland, California Bay Forest	Moderate. Suitable habitat occurs throughout the study area, and records are reported within a 5-mile radius.
Trifolium amoenum	showy rancheria clover	FE/--/1B.1	California Sagebrush Scrub, Coyote Brush Scrub, California Annual Grassland	High. Suitable habitat occurs within the study area. Records occur within 2 miles of the study area, adjacent to Bolinas Lagoon.

Table 7. Rare Plants with Moderate to High Potential to Occur in the Study Area

Species Name	Common Name	Status[1] (federal/ state/ CRPR)	MCV2 Plant Community	Likelihood of Occurrence

Notes:
This table does not include rare plant species that were determined to have "no potential to occur" within the study area.
[1]Status: Federal Status
- FE: Listed as endangered under the Endangered Species Act
- FT: Listed as threatened under the Endangered Species Act
- FSC: Federal species of concern

State Status
- SE: Listed as endangered under the California Endangered Species Act
- ST: Listed as threatened under the California Endangered Species Act

California Rare Plant Rank (CRPR) Status
- 1B: Rare, threatened, or endangered in California and elsewhere
- 1B.1: Seriously endangered in California
- 1B.2: Fairly endangered in California
- 1B.3: Not very endangered in California
- 2B: Rare, threatened, or endangered in California, but more common elsewhere
- 2B.1: Seriously endangered in California
- 2B.2: Fairly endangered in California
- 4.2: Moderately threatened in California
- -- = no status designation

Likelihood of Occurrence Designations:
High: Suitable habitat and other appropriate conditions are represented onsite and extant records occur within the watershed.
Moderate: Either suitable habitat is represented within the study area or extant records occur within the watershed.
Low: Suitable habitat is limited within the study area and records are outside of the watershed, are extirpated, or have conditions not found onsite.

4.2.4 Invasive Plant Species

Fifty invasive plant species rated as a high or moderate risk by the Cal-IPC were recorded in the study area. The eight species described below pose the greatest threat based upon a combination of their location and extent in the study area, and their overall invasiveness. Three of the species described below were observed to occur in ecologically significant stands, with respect to potential invasions in future conditions of the project area:

- Upright veldtgrass (*Ehrharta erecta*). This perennial South African grass is highly invasive in both shaded and open vegetation gaps of coastal grassland, riparian woodlands, and upland woodlands in many vegetation types. Large discrete roadside stands occur along the edge of Olema Bolinas Road and are spreading. Spread is often rapid and irreversible along roadsides and road cuts. *E. erecta* can strongly interfere with re-establishment of native Marin plant communities in both deep shade and full sun.
- French broom (*Genista monspessulana*) and other broom species, which are establishing on the upland hillslope above SR 1, are increasingly hard to remove due to tenacious root growth and long-lived seed. However, French broom is never invasive in wetlands and seldom occurs in that habitat. French broom is also invading adjacent native communities such as coyote brush scrub and coast live oak woodland.

- Ice plant (*Carpobrotus edulis* x *chilensis*), which is growing as an exclusive mat along SR 1 beside the lagoon and encroaching into saltgrass marsh, is often highly invasive and outcompetes along tidal marsh edges, but does not aggressively invade salt marsh, freshwater marsh, or deep shade or riparian woodland.
- Bluegum (*Eucalyptus globulus*) eucalyptus has formed a dense forest from historical plantings in the northern portion of the study area. There is little evidence of blue gum invasion of adjacent riparian or wetland vegetation within the project area, but shade and leaf litter deposition from blue gum stands may interfere with riparian or wetland enhancement during climate change.
- Yellow flag iris (*Iris pseudacorus*) occurs as a discrete colony (a large wetland roadside stand) on the north side of the connector road. This clonal species can be locally or generally invasive in freshwater to fresh-brackish water wetlands, and is a potential threat to future wetland enhancement. It is expected to expand beyond its present size.
- Fuller's teasel (*Dipsacus sativus)* has extensive coverage in ruderal habitats within the study area, and is an ecological concern because it has long lasting, persistent seeds and often encroaches into disturbed wetland habitats.
- Himalayan blackberry (*Rubus armeniacus*) is present within riparian understories in the study area, particularly within the red alder forests and arroyo willow thicket habitat of the Bolinas Y. This highly competitive and invasive clonal species is a threat to native communities, especially in the early stages of restoration.
- Cape ivy (*Delairea odorata*) is extensive in the understories of arroyo willow, California bay, eucalyptus, and the red alder forests. The species is known for its prolific growth, tolerance of shade and sun in riparian woodlands, resistance to removal, and ability to colonize a variety of coastal habitats.

4.2.5 Wetlands and Other Waters, Tidal Range and Salinity

Both tidal range and freshwater inputs influence the habitat types that occur within the study area. The most significant feature within the study area is the Bolinas Lagoon; **Figure 17** shows tidal range, MLLW, MSL, and MHHW within the study area.

Extensive wetlands and numerous water features were identified and are shown on **Figure 18**. **Figure 19** shows wetland vegetation communities, and **Figure 20** shows waterways and riparian corridors.

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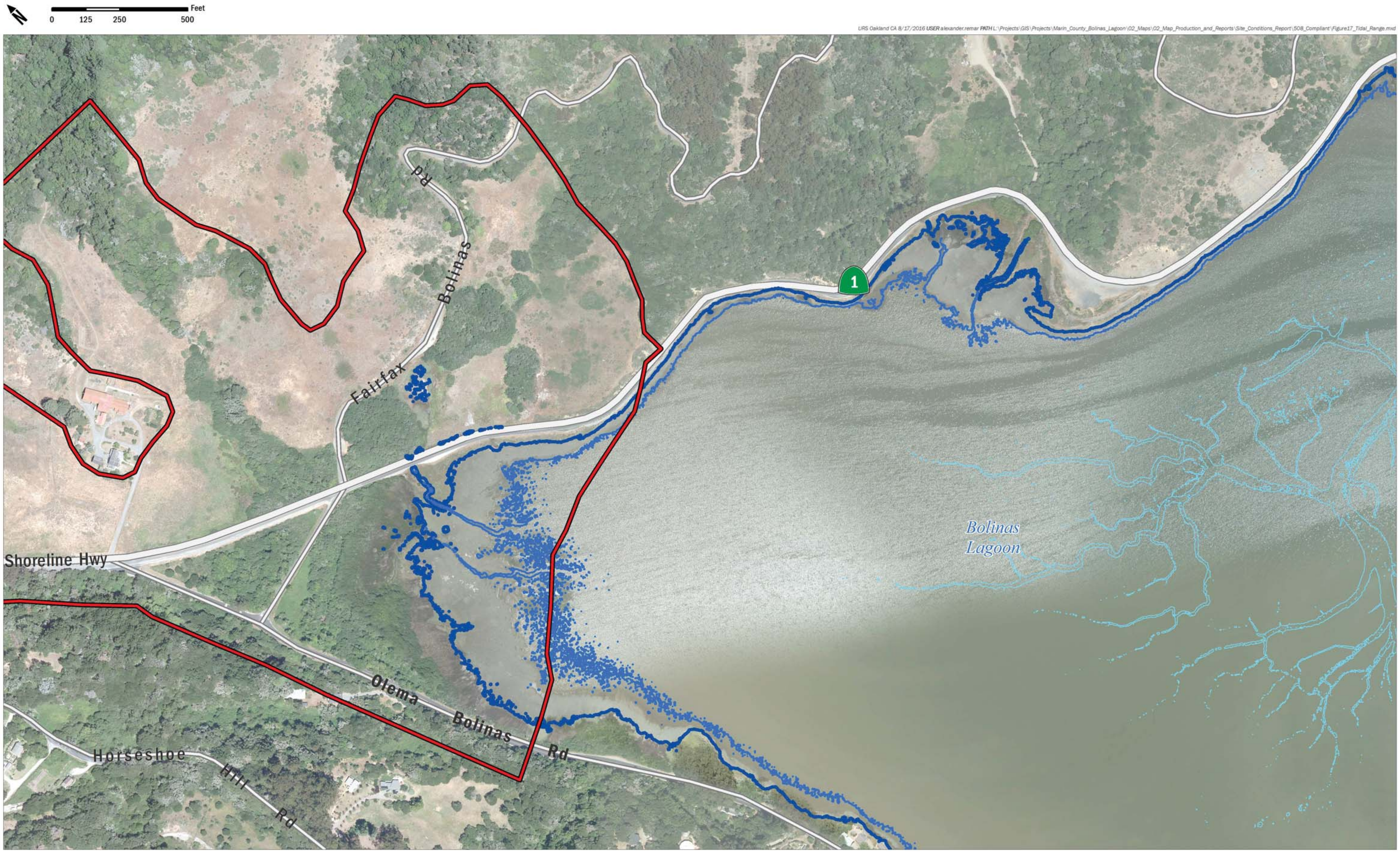

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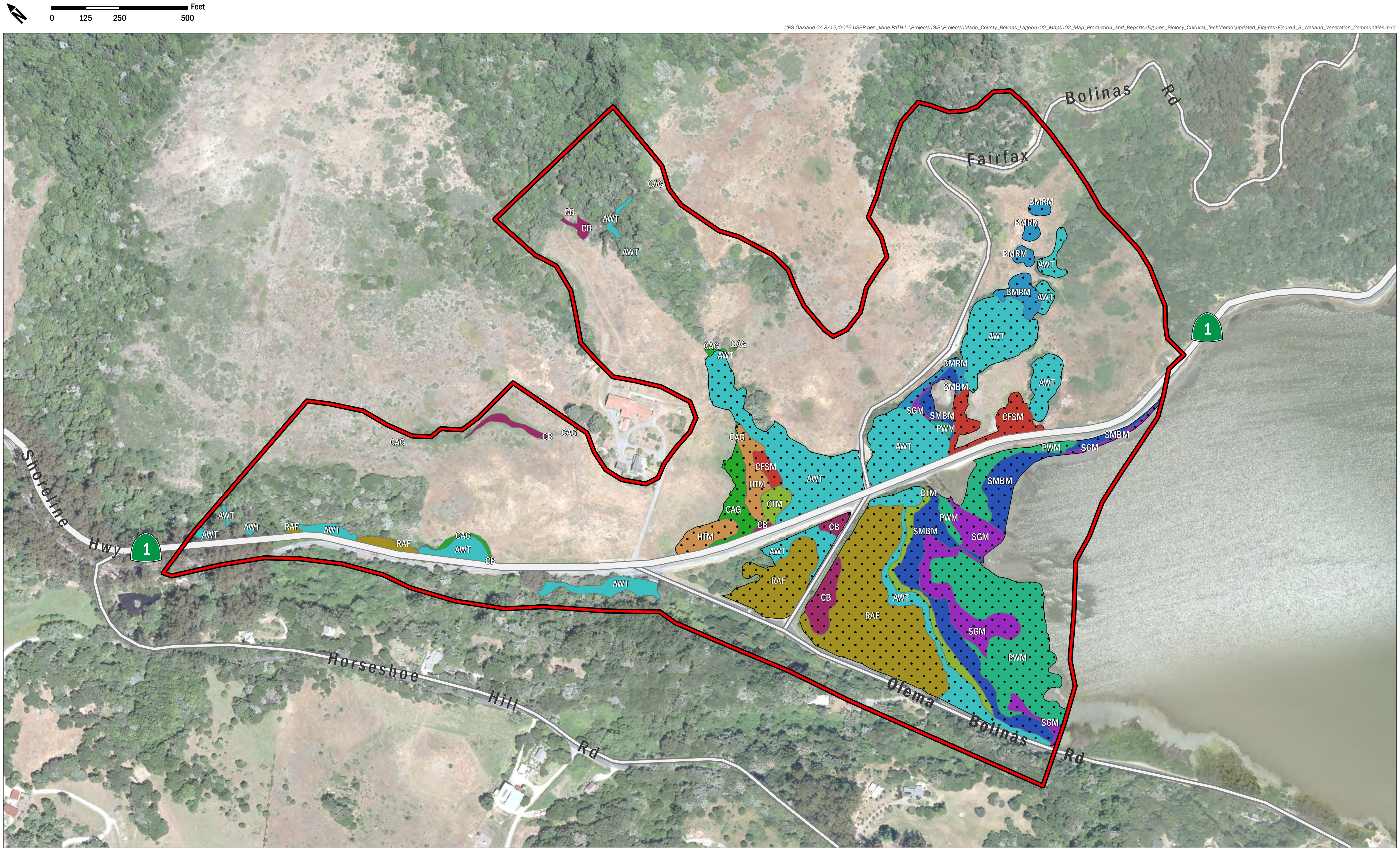
Bolinas Lagoon Restoration

Study Area
Mean Lower-Low Water (MLLW), 1.20 Ft
Mean Sea Level (MSL), 3.52 Ft
Mean Higher-High Water (MHHW), 5.60 Ft

Data Sources:
MHHW, MSL, San Francisco Bay LiDAR, USGS, 2010-2011
MLLW, Golden Gate LiDAR, USGS/SFSU, 2010

FIGURE 17
Tidal Range



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Study Area

Wetland (Federal)

Wetland Types

Arroyo willow thicket (AWT)

Baltic and Mexican rush marsh (BMRM)

California annual grassland (CAG)

Cattail marsh (CTM)

Coastal brambles (CB)

Giant horsetail marsh (HTM)

Pickleweed mats (PWM)

Salt grass flats (SGM)

Salt marsh bulrush marsh (SMBM)

Clustered field sedge marsh (CFSM)

Red alder forest (RAF)

FIGURE 19

Wetland Vegetation Communities

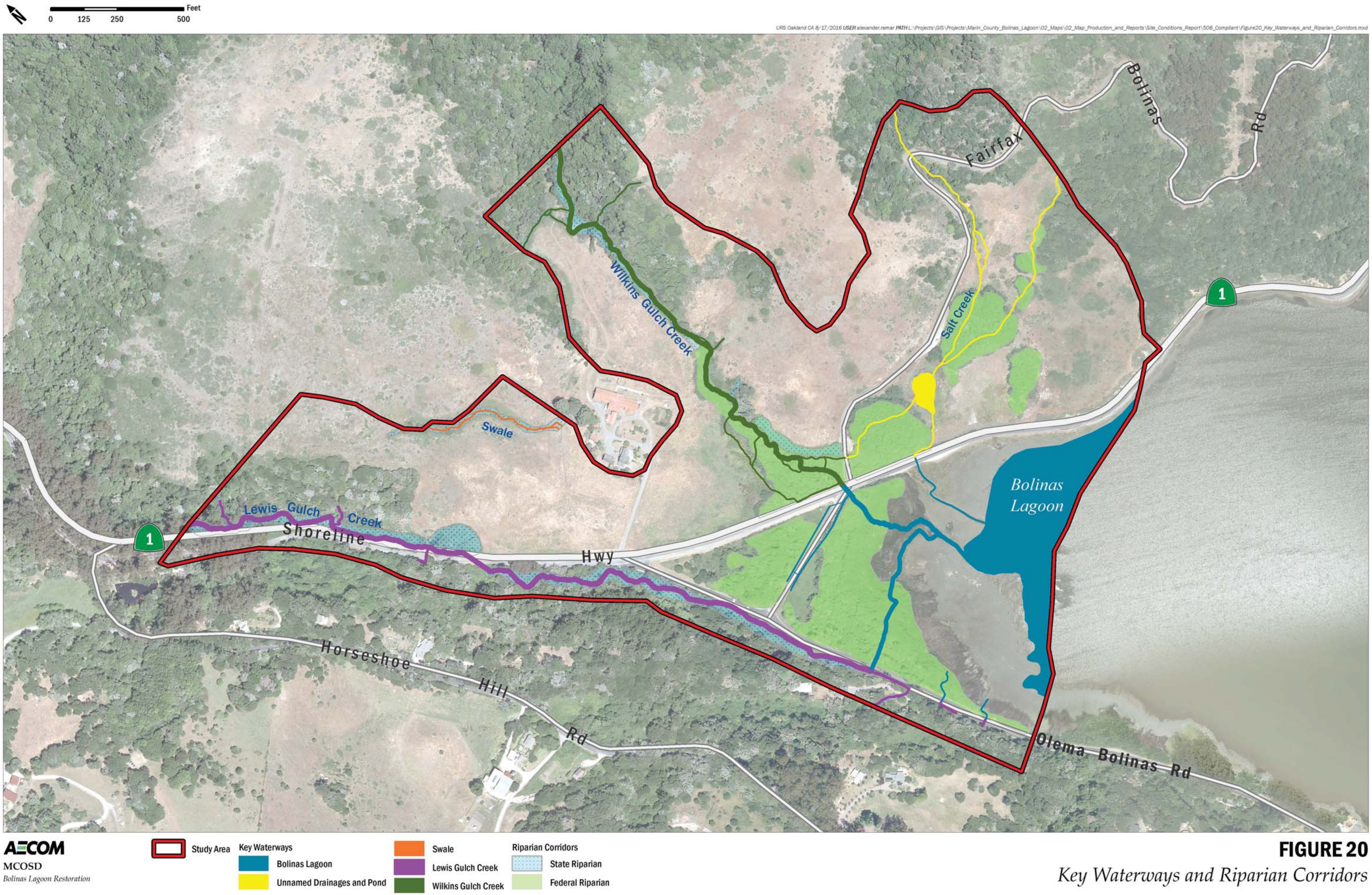

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FIGURE 20
Key Waterways and Riparian Corridors

Eleven distinct wetland types were identified in the study area. The wetlands are named for the vegetation community in which they were found because soil surveys were not conducted. The CCC and the USACE are the two agencies with jurisdictional authority over wetlands in the study area; each has its own definition of a wetland. The acreage of wetlands under each of their definitions, by wetland type, is presented in **Table 8**.

Table 8. Wetland Types and Acreages in the Study Area

Wetland Type (by Vegetation Community)	CCC wetland acreage	USACE wetland acreage
Arroyo willow thicket	8.62	7.38
Baltic and Mexican rush marsh	0.83	0.83
California annual grassland	0.71	0.57
Coastal brambles	0.82	0.59
Cattail marsh	0.78	0.78
Giant horsetail marsh	0.87	0.87
Pickleweed mats	3.92	3.92
Salt grass flats	1.79	1.79
Salt marsh bulrush marsh	2.54	2.54
Sedge marsh	0.92	0.92
Red alder forests	5.32	5.10
Total	**27.13**	**25.29**

Notes:
CCC = California Coastal Commission
USACE = U.S. Army Corps of Engineers

The lagoon and tidal wetlands are vegetated by pickleweed, salt grass, salt marsh bulrush, and clustered field sedge. As a result of tidal influence, these wetlands areas are consistently saturated. Salt grass flats, salt marsh bulrush marsh, and clustered field sedge marsh are also present along Wilkins Gulch Creek, on the east side of SR 1.

Water samples collected in this area (see **Figure 21**) showed relatively high salinities, indicating potential tidal influence from Bolinas Lagoon on both the west and east sides of SR 1. Herbaceous freshwater wetlands were located in the floodplains adjacent to (west of) Lewis Gulch Creek, within the northeastern corner of the Y, and along the alluvial plains between Fairfax-Bolinas Road and SR 1. Vegetation in the freshwater wetlands consisted of cattail (*Typha* spp.), coastal brambles, giant horsetail, and clustered field sedge. Saturated soils were also observed in the floodplains adjacent to Lewis Gulch Creek.

All water features described in the study area, with the possible exception of the swale, are assumed to be potential other waters of the U.S. due to presence of an ordinary high water mark and hydrologic connection to the San Francisco Bay. All water features, including the swale, are assumed to be waters of the State of California (waters of the state).

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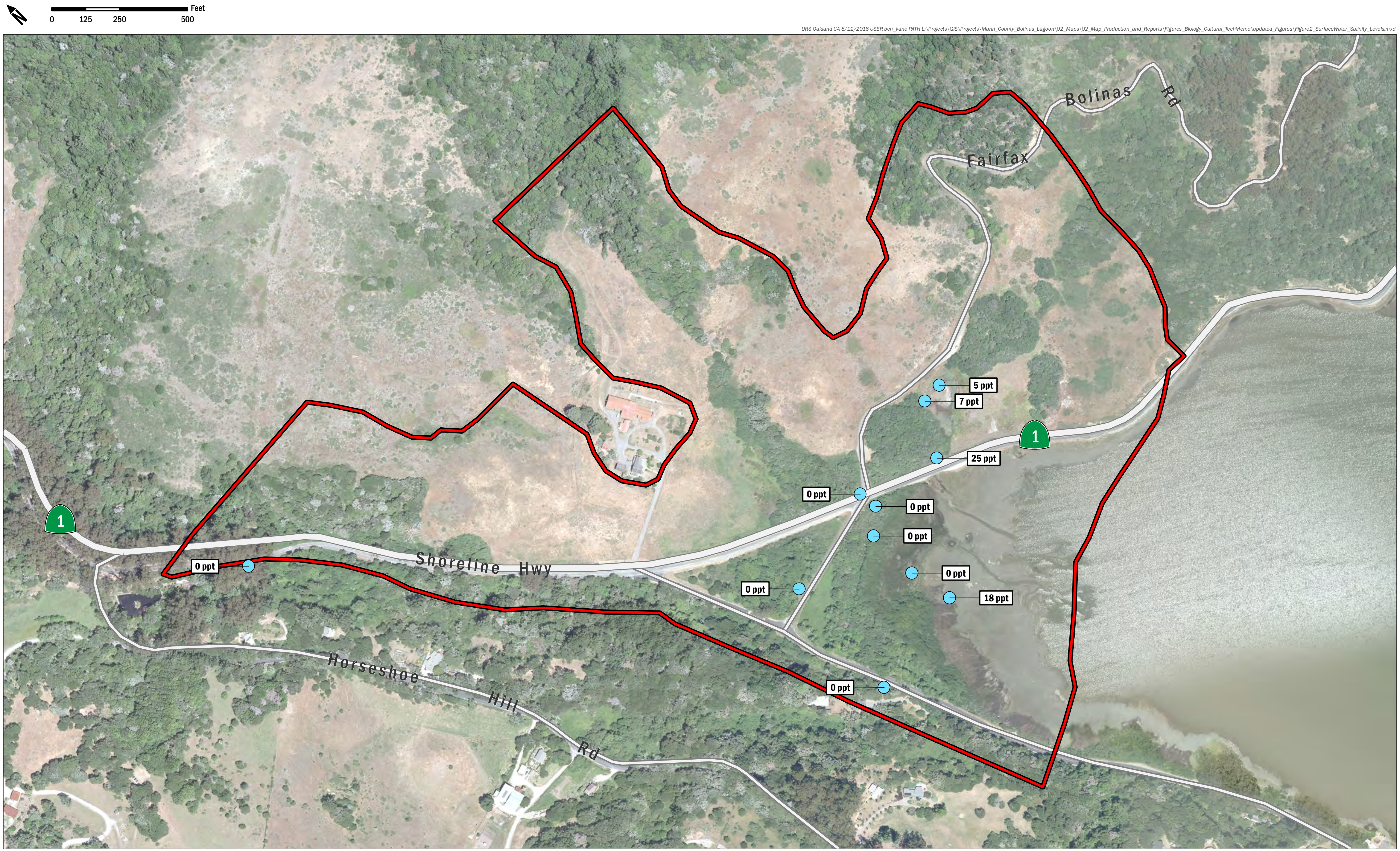

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FIGURE 21
Surface Water Salinity Levels

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Riparian areas were defined by whether they met a definition for wetlands or were upland areas that provided a riparian function due to their vegetation composition and position relative to an adjacent water feature. Riparian areas mapped in the study area are distinguished as Federal riparian if they meet the USACE definition of a wetland and as State riparian if they either meet the CCC definition of wetland or provide upland riparian cover for an adjacent water feature (**Figure 20).**

In the study area, Lewis Gulch Creek is surrounded by a mature riparian corridor that meets the criteria for State riparian jurisdiction. It is primarily shaded by red alder forests and willow alder riparian forest, both of which are considered CCC wetlands. This area also contains stretches of upland eucalyptus grove and coast live oak woodland that provide important riparian functions of shade, bank stabilization, nutrient cycling, and cover. The banks bordering Wilkins Gulch Creek is split into a State riparian portion and a Federal riparian portion based on vegetation and topography. The upper portion of the Wilkins Gulch Creek is shaded by coast live oak riparian overstory, which provides riparian functions. The lower portion of the creek is less steep and is surrounded by a willow alder riparian corridor that is also considered a USACE wetland. The unnamed drainages south of Bolinas-Fairfax Road do not have a riparian corridor near the headwaters, but flow into arroyo willow thickets near the pond. These riparian thickets are also considered USACE wetlands. The swale north of the Wilkins Ranch buildings is surrounded by coastal bramble riparian vegetation that may be a CCC wetland.

4.2.6 Wildlife Habitats

The vegetation communities described in Section 4.2.2 support a diverse assemblage of plant and animal species. The presence of abundant transitional habitat between wetland and upland communities provides ecosystem complexity. The freshwater input into the study area (streams and groundwater) supports fresh and brackish vegetation, providing wildlife habitat that supports an assemblage of species uniquely adapted to these conditions. Shorebirds and waterfowl, including black rail (*Laterallus jamaicensis*), use the high marsh areas at the northern end of the lagoon as high-tide refugia. Black rail may also use the transitional areas for foraging. The brackish pond in the Salt Creek drainage and marsh surrounding it are unique habitat in the study area. The transition from mudflat, to marsh, to upland exists in only a few areas due to fill and the placement of roadways, which block what would otherwise be more gradual gradients.

Based on observations made during field surveys, a number of common wildlife species are anticipated to occur in the vegetation communities in the study area, as summarized below in **Table 9**. A complete list of wildlife species observed during field surveys is provided in **Attachment A** and its appendices.

Table 9. Wildlife Habitats in the Study Area

Vegetation Communities	Common wildlife species
Forests habitats (Red Alder Forests, Eucalyptus Groves, Coast Live Oak Woodland, and California Bay Forest)	Raptors, such as red-tailed hawk (*Buteo jamaicensis*) and great horned owl (*Bubo virginianus*) may nest in large trees, including eucalyptus and large oaks. The latter can also provide habitat for family groups of acorn woodpecker (*Melanerpes formicivorus*). A variety of birds including chestnut-backed chickadee (*Poecile rufescens*), white-breasted nuthatcher (*Sitta carolinensis*), bushtit (*Psaltriparus minimus*), and Nuttall's woodpecker (*Picoides nuttallii*) are often found in woodlands. Black-tailed deer (*Odocoileus hemionus*) often forage along forest edges. Streams in forested areas can provide habitat for newts (*Taricha* sp.) and other amphibians.

Table 9. Wildlife Habitats in the Study Area

Vegetation Communities	Common wildlife species
Shrub habitats, (California Sagebrush Scrub, Coyote Brush Scrub, French Broom Scrub)	Birds commonly found in scrub habitat include wrentit (*Chamaea fasciata*), blue-gray gnatcatcher (*Polioptila caerulea*), Western scrub jay (*Aphelocoma californica*) and California quail (*Callipepla californica*). Reptiles including Western fence lizard (*Sceloporus occidentalis*) and California striped racer (*Coluber lateralis lateralis*) use this habitat.
Grassland and forb-dominated habitats (California Annual Grassland and ruderal)	Common birds of grassland habitats include American pipit (*Anthus rubencens*), Western meadowlark (*Sturnella neglecta*). Snakes such as the western yellow-bellied racer (*Coluber constrictor mormon*) and the gopher snake (*Pituophis catenifer*) are common in grasslands. Coyote (*Canis latrans*), bobcat (*Lynx rufus*), and gray fox (*Urocyon cinereoargenteus*) are regular visitors of the grasslands, preying on small mammals such as Western harvest mouse (*Reithrodonotmys megalotis*).
Riparian habitats, including Arroyo willow thickets and coastal brambles	Arroyo willow thickets and bramble patches support many passerines, including Wilson's warbler (*Cardellina pusilla*) and lesser goldfinch (*Spinus psaltria*).
Marsh habitats, (Salt Marsh Bulrush Marsh, Salt Grass Flats, Baltic and Mexican Rush Marshes, Pickleweed Mats, Cattail Marsh, and Clustered Field Sedge Marsh)	Marshes and wetlands are particularly valuable to birds, supporting, among many other species, snowy egret (*Egretta thula*), Northern harrier (*Circus cyaneus*), song sparrow (*Melospiza melodia*), red-winged blackbird (*Agelaius phoeniceus*), black rail, common yellowthroat (*Geothlypis trichas*), and Canada goose (*Branta Canadensis*). Mammals that use these habitats include river otter (*Lontra canadensis*) and raccoon (*Procyon lotor*). Several species of gartersnake (*Thamnophis* sp.) can be found in marshes with low or no salinity, foraging on breeding amphibians such as Sierran treefrog (*Pseudacris sierra*).

4.2.7 Special-Status Wildlife Species

To generate a list of special-status wildlife species potentially occurring within the study area, multiple sources were queried, including the U.S. Fish and Wildlife Service (USFWS) IPaC (Information for Planning and Conservation, USFWS 2015b), CNDDB (CDFW 2015a), and a review of the animals on the state's fully-protected animals list (CDFW 2015c). **Table 10** provides a list of special-status species likely to occur in the study area; the complete species list is presented in **Attachment A**.

Table 10. Special-Status Species Likely to Occur in the Study Area

Common Name	Scientific Name	Listing Status	Likelihood to be Present
Invertebrates			
California freshwater shrimp	*Syncaris pacifica*	FE, SE	Moderate – habitat potentially present in upper reaches of creeks.
Fish			
steelhead – central California coast DPS	*Oncorhynchus mykiss irideus*	FT	High – steelhead have been observed in Wilkins Creek.
steelhead – central California coast DPS—CRITICAL HABITAT	N/A	Designated	Wilkins Creek is Designated Critical Habitat
Amphibians			
foothill yellow-legged frog	*Rana boylii*	SSC	Moderate – there are historic records from Pike County Gulch and environs.

Table 10. Special-Status Species Likely to Occur in the Study Area

Common Name	Scientific Name	Listing Status	Likelihood to be Present
California red-legged frog	*Rana draytonii*	FT, SSC	High – known occurrences in pond east of SR 1.
Birds			
golden eagle	*Aquila chrysaetos*	FP	Moderate – may forage in the area, but generally breed in more open habitats.
burrowing owl	*Athene cunicularia*	SSC	Moderate – open, grassy habitat present.
white-tailed kite	*Elanus leucurus*	FP	High – may breed and forage within the study area.
American peregrine falcon	*Falco peregrinus anatum*	FP	High – may forage and disperse in the project area, but there is no nesting habitat (rocky cliffs) present.
saltmarsh common yellowthroat	*Geothlypis trichas sinuosa*	SSC	High – marsh habitat for this species occurs in the study area.
bald eagle	*Haliaeetus leucocephalus leucocephalus*	FP	High – may forage and breed within the study area.
California black rail	*Laterallus jamaicensis*	ST, FP	High – potentially suitable habitat present in tidal marsh.
California brown pelican	*Pelecanus occidentalis*	FP	High –known to forage within the lagoon south of the study area but less common in the study area; breeding colonies are not present in the study area.
California least tern	*Sterna albifrons browni*	FP	Moderate – may forage within lagoon but sandy beach habitat not present in study area.
Mammals			
ring-tailed cat	*Bassariscus astutus*	FP	High – wide-ranging species that use a variety of woodland habitats.
Townsend's big-eared bat	*Corynorhinus townsendii*	FC, SSC	High – may use temporary roosts inside buildings and other structures.

Notes:
U.S. Fish and Wildlife Service and Federal Listing Categories:
FC = Candidate for Federal Listing
FE = Federally Listed as Endangered
FT = Federally Listed as Threatened
California Department of Fish and Wildlife State Listing Categories:
FP = Fully Protected

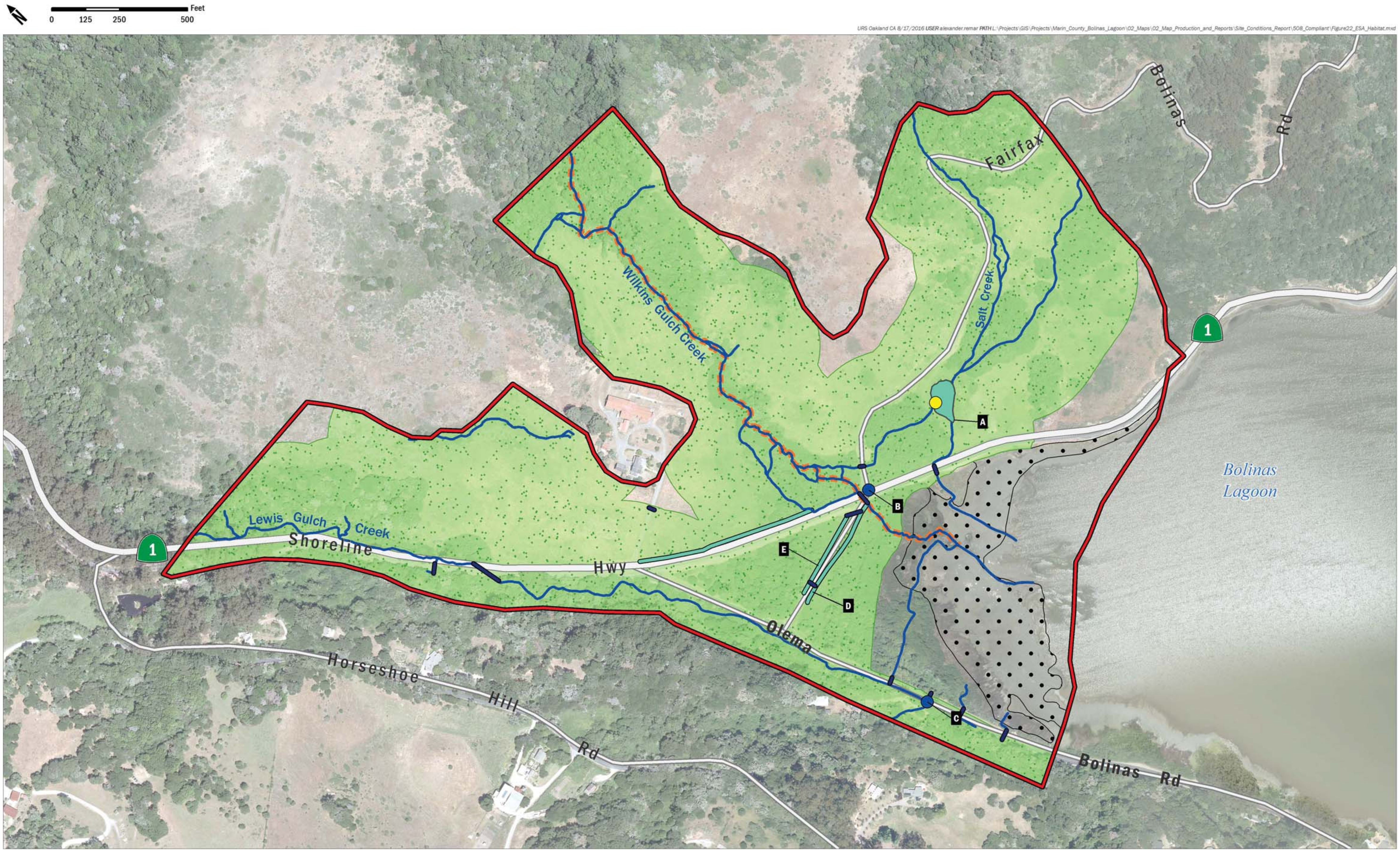
Of the species in the above table, four are protected under the Federal and/or California Endangered Species Acts. A map of the habitats for these species is shown in **Figure 22.** Summary descriptions of those species are below, excerpted from the full list of special-status species in **Attachment A.**

California black rails are found primarily in tidal brackish to saline marshes of the northern San Francisco Bay Area. Habitat for black rails can be found within the project site, at the north end of the lagoon in the vegetation communities that were mapped as pickleweed marsh, salt grass mat, and salt marsh bulrush marsh (**Figures 15** and **16**). Multiple observations of black rails have been documented within the area.

California red-legged frogs (CRLF) inhabit permanent and semi-permanent water sources such as streams, lakes, marshes, natural and artificial ponds, and ephemeral drainages in valley bottoms and foothills. Streams suitable for CRLF breeding typically contain shrubby riparian or emergent vegetation. Aquatic habitat for CRLF within the study area includes the seasonal pond (**Location A, Figure 22**) just north of SR 1, and portions of Lewis Gulch and Wilkins Gulch Creeks which may provide breeding and/or dispersal habitat. While the pond and creeks have the suitable attributes for adult frogs, breeding may be limited in some years, by salinity, hydroperiod, and flow.

Central California coast Steelhead, a federally threatened species, is anadromous and spend their first 1 to 3 years of life in freshwater and then emigrate to the ocean where most of their growth occurs. After spending between one to four growing seasons in the ocean, steelhead return to their native fresh water stream to spawn. Steelhead have been found in Wilkins Gulch Creek (Fong 2002), and Wilkins Gulch Creek is designated as critical habitat for the species (NOAA 2005). There is no data indicating that steelhead use Lewis Gulch Creek, and no fish surveys were conducted.

California freshwater shrimp, is a decapod crustacean of the family Atyidae and is believed to be the only extant species of the genus. They are found in low elevation, low gradient, freshwater, perennial streams in Marin, Napa, and Sonoma Counties, California. Suitable habitat for California freshwater shrimp is present in Lewis Gulch Creek and the species has been found north of the project area in Lagunitas Creek; however, there are no know records of the species within the study site. Due to the cryptic nature of the species, focused surveys for the species in Lewis Gulch Creek and Wilkins Gulch Creek are recommended for a later project phase.



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Study Area
California red-legged frog occurrence California Natural Diversity Database (CNDDB)
X Areas of Interest
California red-legged frog non-breeding habitat
California red-legged frog potential breeding habitat
Steelhead Critical Habitat
Culvert
Black rail habitat
California red-legged frog upland habitat

FIGURE 22
Habitat for ESA-listed Species

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4.3 Cultural Resources

This section discusses the results of a historical records search and a preliminary field survey of the study area, to identify cultural resources that may require protection or mitigation. The Hydrology and Geomorphology Technical Memorandum (**Attachment B** to this report) conducted a separate study to identify physical impacts from historical land use on hydrology and geomorphology.

4.3.1 Native American Period

The study area is part of the territory controlled by the Coast Miwok (Kelly 1978). The Coast Miwok were hunter-gatherers who lived in large, permanent villages and occupied seasonal camps and task-specific sites. Sites were often situated near freshwater sources and in environments where plant and animal life were diverse and abundant. Kelly (1978, p. 415) shows the nearest village, called bauli-n, on the eastern shore of Bolinas Lagoon outside the current study area.

Despite the absence of significant Native American archaeological resources identified by this study, there exists a potential for buried archaeological (geoarchaeological) resources, not evident at the surface, to be present within the study area. Given the setting of the project—within the active floodplain and terraces of the Wilkins Gulch and Lewis Gulch drainages, and associated Holocene alluvial deposition at the head of the lagoon (see Section 3.2)—there appears to be a high potential for recent alluvial deposition that may bury archaeological resources. As such, as project plans develop, and alternatives are considered, a full geoarchaeological analysis is recommended to further assess this potential and determine what portions of the project area have the highest probability of containing buried archaeology, in order to facilitate avoidance of those areas or develop appropriate mitigation measures.

4.3.2 European Settlement Period

At the time of European settlement, historical topographic quadrangles (USGS 1897, 1941) reveal several late 19th and early 20th century buildings and other possible historic features within or proximal to the study area. The farmhouse, barns, and outbuildings on Wilkins Ranch, west of Wilkins Gulch, appear to be of this era (Livingston 1995b:70; USGS 1897, 1941). At least one building on the Wilkins Ranch predates 1897, and the remaining buildings appear to be from the early 20th century (USGS). The Wilkins Ranch is currently outside of the study area, but within the viewshed of the North End project. Another building, possibly the Oyster House restaurant, was depicted on the western bank of the lagoon near the intersection of Olema Bolinas Road and SR 1, within the current study area, however the building is no longer depicted after 1997 (Van Kirk 2000; USGS 1897, 1997). The lighter wharf (Historical Landmark #221) was said to be located on the northern tip of the lagoon on its western bank—the exact location is unknown, but presumably within the current study area—and is no longer evident, nor is there a commemorative plaque (CA OHP 1996).

The Wilkins Ranch and the wharf represent an era when timber and sawmills operated at Dogtown, northwest of the lagoon. William Wallace Wilkins, a “forty-niner” from Massachusetts, leased land from Captain Isaac Morgan, and eventually purchased the tract that became the Wilkins family ranch in 1866 and 1868 (Livingston 1995b:75). During the mid-1800s, lumber from the Dogtown area was shipped via the lighter wharf onto barges (called lighters), which floated out to deeper water where larger boats would bring the much-needed lumber to the rapidly growing San Francisco (Livingston 1995b; Kyle et al. 2002; Van Kirk 2000). It is estimated that 13 million feet of lumber were shipped from Bolinas to San Francisco for building purposes before the supply was exhausted in the 1870s (Kyle et al. 2002: 190). Wilkins Ranch operated as a dairy, and by the 1900s, produced 2,250 pounds of butter per month from 64 cows (Livingston 1995b:80). For further information about the Wilkins Ranch and the lumber industry in Bolinas see Livingston (1995b) and Van Kirk (2000).

4.3.3 Records Searches and Field Surveys

Five previous cultural resources studies have been conducted in the study area. Four studies (Hastings 1975; Leach-Palm et al. 2007; Loyd and Origer 2004; Pape 1993) pertain to SR 1 maintenance or projects adjacent to the highway, and one is a more general regional study (Anthropological Studies Center 2011) assessing the potential effects of climate change on cultural resources within the Point Reyes National Seashore. None of the studies identified extant cultural resources within the current study area.

No previously recorded archaeological sites were identified within the study area as a result of the record search. Two cultural resources (CA-MRN-380 and CA-MRN-642H) were located within a 1-mile radius of the study area: (1) CA-MRN-380 is located 0.5 mile south of the study area, along the west side of the lagoon, and (2) CA-MRN-642H is located in the hills one mile north of the study area along Coppermine Gulch.

CA-MRN-380 is a prehistoric archaeological site recorded as "sporadic shell concentrations along the Olema Bolinas Road cut bordering Bolinas Bay," which has been "largely destroyed" (Barnes 1966). CA-MRN-642H is recorded as the historic-era Coppermine Gulch, a mining complex that includes a cabin, adits, a tailing pile, a boiler, and other features related to mining (Storey et al. 1997).

Examination of historic maps and historic context documents indicated the potential for the presence of several late 19th century and early 20th century buildings and other possible historic features within or proximal to the study area. Of the three historic-era resources noted during the background research—the lighter wharf, the Oyster House, and Wilkins Ranch—only the Wilkins Ranch was positively identified during the field survey. The location of the lighter wharf was identified on historical maps discussed in **Attachment B**.

However, six previously unidentified cultural features were mapped during reconnaissance-level surveys of the study area. Descriptions, photographs, and a map of the locations of these resources are in **Attachment A**. None of these identified resources have been formally evaluated for California Register of Historic Places (CRHR) or National Register of Historic Places (NRHP) eligibility since the project has not been designed and impacts not yet defined, and that the regulatory context is also undefined.

Of these newly recorded resources, all of them appear unlikely to qualify as significant resources under the CRHR and NRHP, with the exception of Wilkins Ranch. Additional background research and analysis is necessary to make formal determinations of eligibility, although it has been suggested that Wilkins Ranch may be architecturally significant for inclusion in the CRHR or NRHP, particularly from a cultural landscape perspective (Livingston 1995b:88). However, it may be possible to avoid impacts to the resources through project design, and thus avoid the necessity for formal eligibility determinations.

5 Current Conditions – Built Environment

The Bolinas Lagoon North End Restoration Project involves developing and considering alternatives that include possible changes to the existing roadways, stream channels, and culverts. These alternatives may involve actions that need to consider the owners of various land parcels in the area and the possibility that certain parts of the existing utility infrastructure may be impacted. To prepare for these considerations, the Parcel Ownership and Utilities Technical Memorandum (**Attachment C**) presents maps and tables of the current parcel ownership and the existing utilities within the study area. The Traffic Count and Analysis Technical Memorandum (**Attachment D**) provides information about existing and projected traffic use of Olema Bolinas Road, the crossover road, and Bolinas-Fairfax Road at the Y.

5.1 Land Ownership

Figure 23 shows the parcels surrounding and within the study area. The area is a mix of parcels under public and private ownership. Assessor's Parcel Number (APN), assigned by the Marin County Assessor office are shown on **Figure 23**.

Publicly owned parcels with the study area are held by Marin County the NPS (managed by Golden Gate National Recreation Area and Point Reyes National Seashore). Marin County owns the portions of the lagoon that are below mean high water, has and has shared jurisdiction over tidal lands with the NOAA's, Greater Farallones National Marine Sanctuary. Caltrans owns SR 1 and also holds easements for up to 25-foot distances on either side of that highway.

The privately owned parcels are largely on the western side of the study area and vary in size and slope. Where possible, the names and contact information of the private property owners were collected and used to obtain rights-of-entry for the field surveys if needed; no field surveys were conducted on private properties without explicit permission of the owner(s).

Table 11 summarizes the following characteristics of each parcel: ownership status, total acreage, acreage within the study area, acreage on land (i.e., above MHHW of Bolinas Lagoon), presence or absence of a stream or other waterway or water body (including areas above MHHW of Bolinas Lagoon). Land owner(s) names and the situs address of the parcels are also included.

Table 11. Parcel Information

APN	Owner-ship Status	Owner Entity or Name	Address	Size (acres)	Acres in Study Area	Acres below MHHW in Study Area	Streams or Other Water Feature
18814035	Private	WHALEY SUZANNE C	630 HORSESHOE HILL RD, BOLINAS, CA, 94924	5.34	1.26	0.00	x
18814050	Private	BIRD-OTAKA FAMILY REVOC TRUST 2012	430 HORSESHOE HILL RD, BOLINAS, CA, 94924	2.78	0.00	0.00	
18814049	Private	THACKREY SEAN	660 HORSESHOE HILL RD, BOLINAS, CA, 94924	3.90	0.56	0.00	x
18816028	Public	MARIN, COUNTY OF	n/a	17.56	0.00	0.00	
18809006	Private	HORSESHOE HILL LLC	605 HORSESHOE HILL RD, BOLINAS, CA, 94924	68.01	0.00	0.00	
18814007	Public	MARIN COUNTY OF	n/a	4.91	1.34	0.92	x
18814056	Private	ROSENMAN JOHN E & ROSENMAN ANDREA M	n/a	2.65	0.00	0.00	
18814029	Private	MORNELL 2005 TRUST MORNELL SASCHA /TR/	480 HORSESHOE HILL RD, BOLINAS, CA, 94924	15.81	1.27	0.00	x
18814008	Public	SANITARY DISTRICT NO 3	n/a	0.61	0.00	0.00	
18811009	Public	UNITED STATES OF AMERICA	n/a	1376.41	67.78	0.03	x
18814019	Private	WYETH LANCE & WYETH BARBARA	1015 OLEMA BOLINAS RD, BOLINAS, CA, 94924	1.67	0.00	0.00	
18814034	Public	MARIN, COUNTY OF	830 OLEMA BOLINAS RD, BOLINAS, CA, 94924	6.27	0.00	0.00	
18814061	Private	MARQUIS ELLEN TR	530 HORSESHOE HILL RD, BOLINAS, CA, 94924	4.84	0.00	0.00	
18814062	Private	HILL LUTHER B & VOETS-HILL CANDY P	855 OLEMA BOLINAS RD, BOLINAS, CA, 94924	2.09	0.00	0.00	
18814032	Private	YOUNG FAMILY HOUSE LLC	945 OLEMA BOLINAS RD, BOLINAS, CA, 94924	4.62	0.00	0.00	
18814004	Private	SILVANI HELEN H ETAL SILVANI STEPHEN H TR ETAL	1299 OLEMA BOLINAS RD, BOLINAS, CA, 94924	5.59	2.00	0.00	x
18811010	Public	MARIN, COUNTY OF	n/a	22.01	22.01	7.88	x
18814060	Private	L MARQUIS LLC MARQUIS TESSA ETAL	1125 OLEMA BOLINAS RD, BOLINAS, CA, 94924	3.37	0.88	0.00	x
18814074	Private	SPENCER ROBERT B TR	730 HORSESHOE HILL RD, BOLINAS, CA, 94924	3.16	0.00	0.00	

Table 11. Parcel Information

APN	Owner-ship Status	Owner Entity or Name	Address	Size (acres)	Acres in Study Area	Acres below MHHW in Study Area	Streams or Other Water Feature
18809013	Private	MINOR 2004 TRUST ETAL SOLOMON LAWRENCE R /TR/ ETAL	875 HORSESHOE HILL RD, BOLINAS, CA, 94924	99.59	0.00	0.00	
18809015	Private	MARTINELLI RODERICK P TR ETAL FBO ISSUE OF JORDON MARTINELLI GENEVIEVE TR ETAL	615 PARADISE VALLEY RD A, BOLINAS, CA, 94924	153.28	0.00	0.00	
18814071	Private	SAMUELS MICHAEL /TR/ SAMUELS MICHAEL /TR/	710 HORSESHOE HILL RD, BOLINAS, CA, 94924	1.05	0.00	0.00	
18816015	Private	AUDUBON CANYON RANCH INC	4990 STATE ROUTE 1, BOLINAS, CA, 94924	195.80	0.00	0.00	

Notes:

APN = Assessor's Parcel Number

MHHW = mean higher high water

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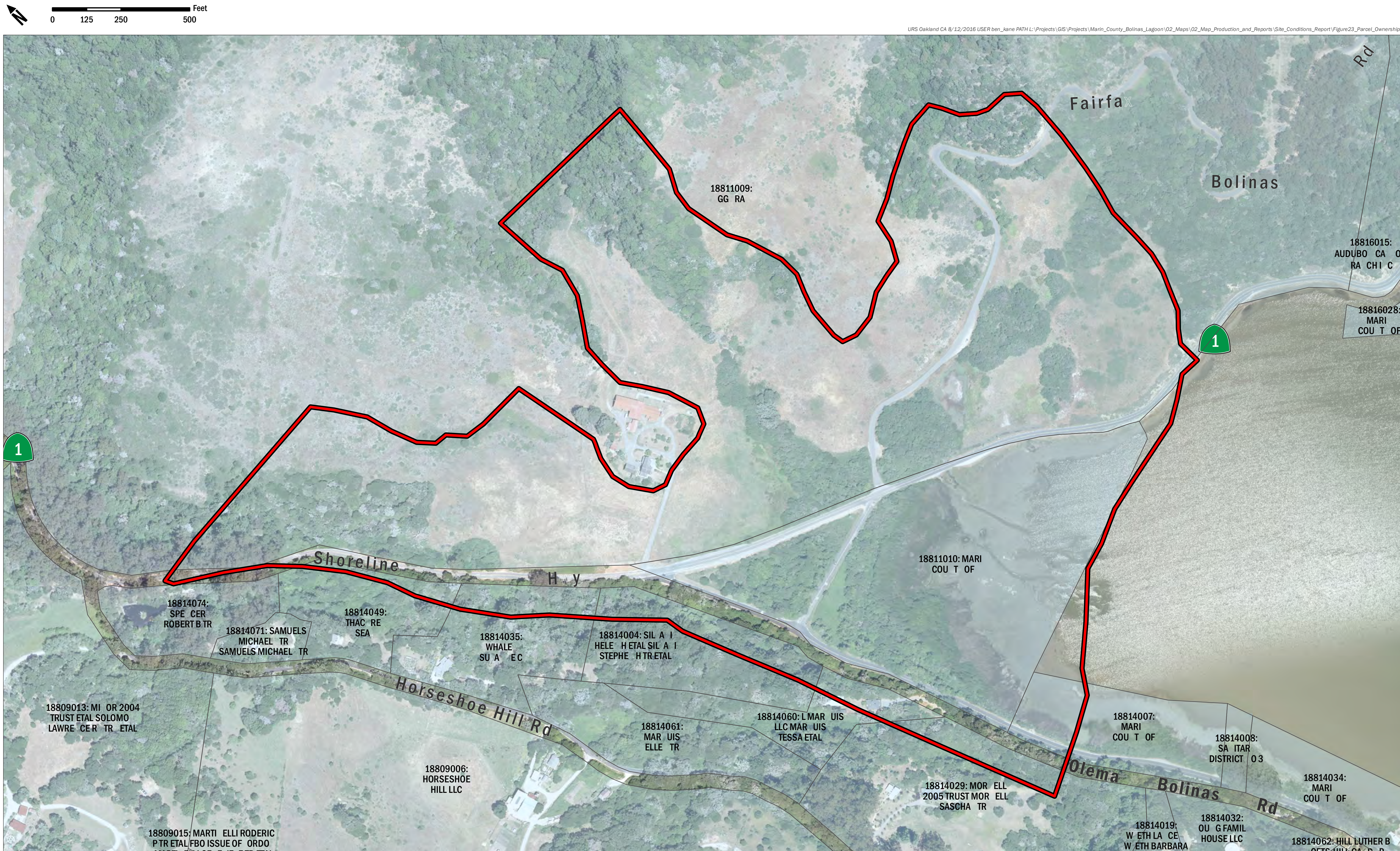

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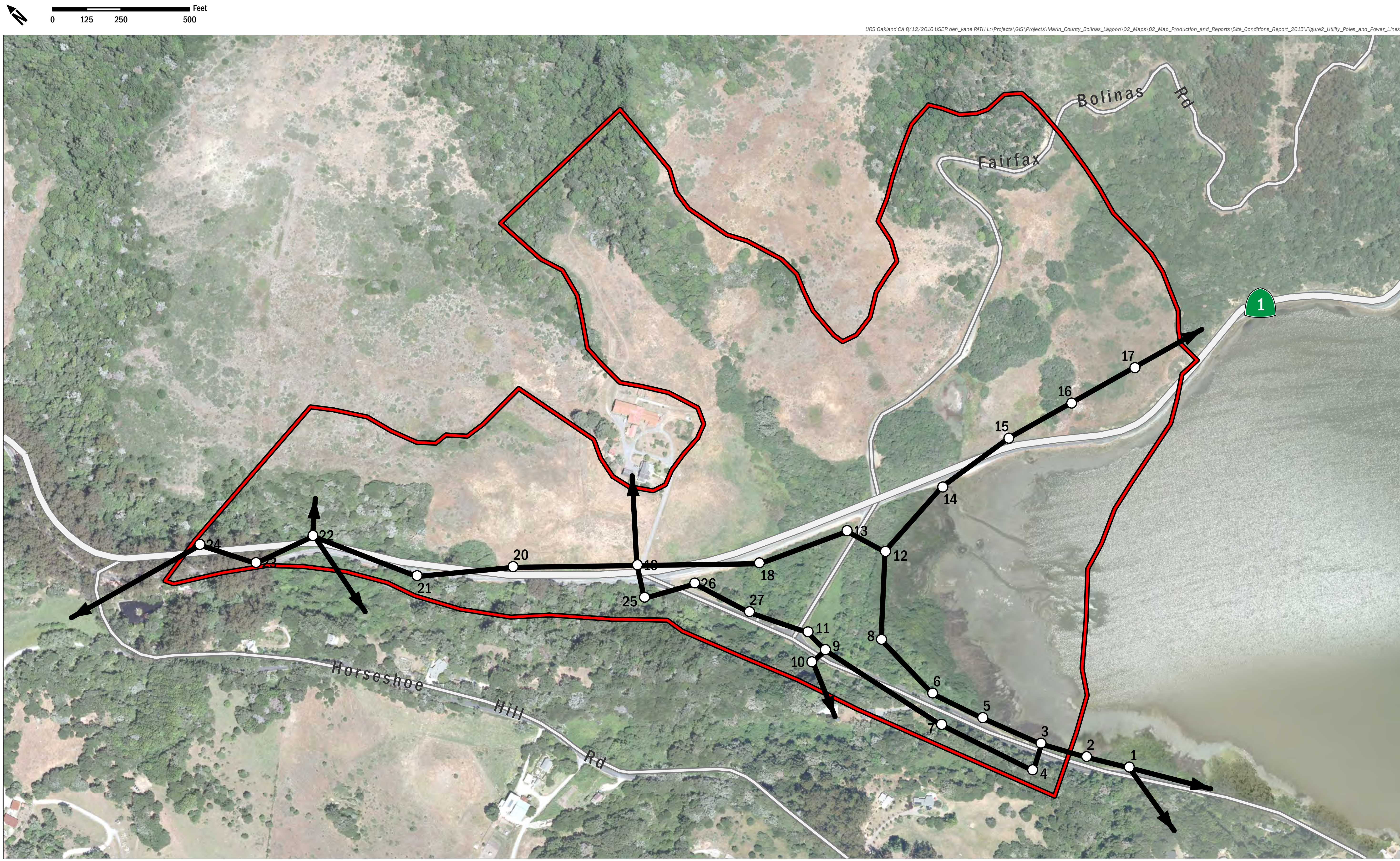
Bolinas Lagoon North End Restoration Project

Study Area
Parcel Boundary

FIGURE 23
Parcel Ownership



AECOM
MCOSD
Bolinas Lagoon North End Restoration Project

Study Area
Utility Pole
Power Line

FIGURE 24
Utility Poles and Lines

5.3 Utility Infrastructure

Utility-related infrastructure may be above or below ground. In many developed areas, underground utilities often include gas, sewer, and water supply lines, telecommunications (e.g., internet and/or television cables). In some places, power lines are placed underground to protect scenic values or to protect the lines from extreme weather conditions. However, there does not appear to be any underground utility infrastructure in the study area. The project team evaluated the Marin County assessor's parcel maps, and there are no underground utility easements shown around the Bolinas Y. Similarly, there are no major gas pipelines on Pacific Gas and Electric Company's (PG&E's) publicly available maps of the area (http://www.energy.ca.gov/maps/infrastructure/natural_gas.html). The Marin County Geographic Information System (GIS) Department's on-line map viewer includes the typical underground utilities for much of the county, but none appear in the general vicinity of the project study area. The water supply and water treatment for the community of Bolinas appear to be locally self-contained and do not connect with any larger municipal systems at the Bolinas Y.

The above-ground utilities include utility poles and power or telephone/telecommunications lines. According to PG&E's public website, there are no major electric transmission lines along SR 1 or along Olema Bolinas Road. The power lines that are present are therefore electricity distribution lines that carry lower loads to smaller end users.

To evaluate above-ground utilities, the project team conducted visual surveys, took photographs and videos, and made sketches of the utility lines and poles along SR 1, Olema Bolinas Road, and the crossover road. Then, a desktop analysis of aerial imagery was used as an independent check on the poles and lines. The results of these reconnaissance-level surveys are illustrated in **Figure 24**. There appear to be approximately 27 utility poles in and immediately adjacent to the study area. The approximate locations of the poles are shown, and these generally match with what is visible on the imagery. As the figure shows, two poles outside of the study area (on Olema Bolinas Road) were counted and mapped to provide a greater context for future planning. As **Figure 24** shows, near the southern end of the study area on SR 1, the utility lines do not run immediately adjacent to the road, but instead extend up and over a bluff inland from the road alignment.

5.4 Roads, Traffic, and Safety

Roads, traffic counts, and safety are important to consider. Because part of the project involves considering a number of changes to the existing roadways, the traffic counts and level of service analysis are summarized here (and presented in full in **Attachment D**) to help inform future decisions about outcomes of these possible changes to the roads and intersections. To get a baseline understanding of existing traffic conditions, the project team conducted continuous tube counts of traffic in both directions that were summed in 15-minute intervals at 3 locations at the Bolinas Y for 7 days during June of 2015. These locations were as follows:

- On the crossover road
- On SR 1 south of the crossover road
- On Olema Bolinas Road south of the crossover road.

Traffic counts were calculated for road segments that were not directly measured, including Olema Bolinas Road north of the crossover road, on SR 1 north of the crossover road, and on SR 1 north of Olema Bolinas Road. Traffic counts for these roads were calculated using traffic counts described above , with a few simplifying assumptions. (e.g., that the number of left turns from the eastbound crossover road were negligible). The peak and non-peak traffic volumes were derived for weekdays and weekends, as was the vehicle turning movements through each of the three intersections.

The results of these calculations were used in a traffic simulation software program to generate Level of Service (LOS) results for three different scenarios:

- Present conditions
- Future (2040) conditions with the crossover road in place
- Future conditions (2040) with the crossover road removed

All of the intersections operate at LOS A or B in the existing conditions, the 2040 no-build conditions, and the 2040 build conditions. LOS A and B are the highest levels of service and represent the lowest amounts of delay due to traffic congestion. Importantly, the model showed that no change in LOS is expected in the "greatest impact scenario"—the one which has the crossover road removed and a 1 percent per year increase in local traffic. Therefore, no road volume or capacity improvements, such as pocket lanes, turn-only lanes or signals would be needed at the SR 1 Olema Bolinas Road intersection if the crossover road were removed.

There are other potential roadway changes that may be necessary to achieve the project goals. Portions of the roads may require elevation changes or new alignments, and removing the crossover road may be part of future conceptual designs. These design components may involve changes in intersection geometry, road bed construction, drainage, and so on. These questions and developments are part of the next project phase, but the results of the current analysis show that there is no need to include an increases road capacity.

Safety is an important consideration when considering potential modifications to existing roadways and associated traffic. A formal safety assessment was not conducted as part of this preliminary review; however, the public has communicated that safety is an issue in the study area. Any roadway modification would involve designs that take safety into consideration.

6 Sea-Level Rise

6.1 Sea-Level Rise Projections in the Lagoon

Bolinas Lagoon has a complex tidal hydrology that was well described in other reports (e.g., PWA 2008). The lagoon is connected to the Pacific Ocean by a tidal inlet that dampens the lagoon's response to tides. **Table 12** shows an example of high and low tide values and phase shifts for two dates, providing insight into difference between tides on the open coast and within the Bolinas Lagoon. These are not observed tide heights, but rather predicted tide heights obtained from the NOAA Tides and Currents website. These dates can be considered representative of typical spring tide elevations where the tide range is generally larger than average (the highs are higher and the lows are lower).

Table 12 illustrates when comparing high tides in January and July, and low tides in January and July, there is a dampening in high and low tide depths and a delay in high and low tide timing inside of the lagoon (Bolinas Lagoon Tide Gage) when compared to outside of the lagoon (Pt. Reyes Tide Gage). Bolinas Lagoon experiences a muted tide range compared to the open coast. High tides are lower in the lagoon than on the open coast (by up to 0.5 foot). Low tides are higher in the lagoon than on the open coast (by up to 2.0 feet). The timing of Bolinas Lagoon tides lags the open coast by approximately 45 minutes at high tide and 90 minutes at low tide. The narrow lagoon mouth and extensive shallow mudflats within the lagoon impede tidal flow into and out of the lagoon and are responsible for the muted tide range.

Table 12. Predicted Spring (2015) Tidal Elevations

Bolinas Lagoon Tide Gage #9414958				Pt. Reyes Tide Gage #9415020						
feet MLLW	feet NAVD88	Date (2015)	Time	feet MLLW	feet NAVD88	Date (2015)	Time	High or Low Tide	Difference b/w Gages (feet NAVD88)	Difference (mins)
5.18	6.38	20-Jan	10:36 AM	6.93	6.91	20-Jan	9:49 AM	High	0.53	47
5.00	6.20	30-Jul	11:17 PM	6.76	6.74	30-Jul	10:31 PM	High	0.54	46
-0.51	0.69	20-Jan	6:31 PM	-1.32	-1.34	20-Jan	4:57 PM	Low	-2.03	94
-0.33	0.87	31-Jul	7:10 AM	-0.93	-0.95	31-Jul	5:37 AM	Low	-1.82	93

Notes:

MLLW = mean lower low water

NAVD88 = North American Vertical Datum of 1988

Table 13 shows a summary of tidal data for the NOAA tide gages inside and outside the lagoon relative to the North American Vertical Datum of 1988 (i.e., the NAVD88 datum). The NAVD88 datum is the standard for absolute tidal elevations in each region of shoreline. Other tidal data, such as the MLLW data, are only for local relative tidal elevations. The table shows that MLLW and NAVD88 at the Point Reyes station are very close, but at the Bolinas station, the tide range is compressed, leading to a shift and muting of the system. This is reflective of the tidal lag time in the lagoon when compared to the open ocean. The MHHW in the lagoon is similar to that of the open ocean; however, the MLLW of the lagoon is higher than the open ocean. This is because not all of the tide water has drained out from the lagoon back into the ocean at low tide, before the tide starts coming in again.

Table 13. Tidal Data for Bolinas Lagoon Tide Gage and Point Reyes Tide Gage

Epoch – 1983-2001	Relative to Station Datum (feet station datum)	Relative to MLLW	Estimated Relative to NAVD88 based on PWA Report* (feet NAVD88)
Bolinas Lagoon Gage 9414958 (from NOAA website)(07/01/2009 – 06/30/2011, 11/01/2012 – 10/31/2013)			
MHHW	6.63	4.40	**5.60**
MHW	6.02	3.79	**4.99**
MTL	4.52	2.29	**3.49**
MSL	4.55	2.32	**3.52**
MLW	3.02	0.79	**1.99**
MLLW	2.23	0.00	**1.20**
Point Reyes, CA Gage 9415020 (from NOAA website)(01/01/1983 – 12/31/2001)			
MHHW	9.72	5.76	**5.74**
MHW	9.06	5.10	**5.08**
MTL	7.10	3.14	**3.12**
MSL	7.06	3.10	**3.08**
MLW	5.14	1.18	**1.16**
MLLW	3.96	0.00	**-0.02**
NAVD88	3.98	0.02	**0.00**

Notes:
MHW = mean high water
MHHW = mean higher high water
MLW = mean low water
MLLW = mean lower low water
MSL = mean sea level
MTL = mean tide level
NAVD88 = North American Vertical Datum of 1988
NOAA = National Oceanic and Atmospheric Administration

The lagoon is also vulnerable to sea-level rise, which is predicted to raise the tidal elevations in the lagoon by up to 5.5 feet (170 centimeters) by 2100 (CO-CAT 2013[2]; NRC 2012). **Table 14** lists the range of projected sea-level rise between 2000 and 2100. Projections indicate anticipated sea-level rise upward of 2.0 feet by 2050 and 5.5 feet by 2100 (CO-CAT 2013). Given the unknown magnitude of sea-level rise over the next century, these numbers could be greater. For example, more recent 2015 predictions from National Atmospheric and Space Administration scientists suggest that these rates might be conservative and sea-level rise could be as much as 18 feet or higher (National Geographic, 2015.) However, the Marin County-selected 2013 projections shown in this table are used as the basis of this discussion (CO-CAT 2013; NRC 2012).

Table 14. Projected Sea-Level Rise South of Cape Mendocino Using 2000 as a Baseline (CO-CAT 2013)

Time Period	Projected Sea-Level Rise
2000–2030	4 to 30 centimeters (0.13 to 0.98 foot)
2000–2050	12 to 61 centimeters (0.39 to 2.0 foot)
2000–2100	42 to 167 centimeters (1.38 to 5.48 feet)

[2] The CO-CAT projections are among the modeled projections used by the Our Coast Our Future Project, which was recommended by Marin County for use in the current project's assessment of sea-level rise.

This anticipated 2100 sea-level rise of 5.5 feet would regularly inundate up to an elevation of 11.1 feet NAVD88. **Figure 25** illustrates an example of these tidal changes by showing the MHHW elevation as it is now, as projected by 2050, and by 2100. This would flood portions of the crossover road, Olema Bolinas Road and SR 1, and would greatly affect drainage along the roadways. **Figure 26** is similar, showing the projected elevations of the highest regular high tides that would likely cause increased flooding.

Portions of the mid- and end-of-century sea-level rise projections along the margin of the lagoon bounded by paved roads do not look radically different than the Federal Emergency Management Agency (FEMA) existing Flood Hazard Zone boundary that presently is reported to have a 1 percent chance of flooding from stream flows (**Figure 27**). The main difference is that FEMA (2015) does not show flooding upstream of the Salt Creek culvert in the Salt Creek watershed. The implication is that stream flooding coinciding with projected sea-level rise is very likely to push the flood boundary well upstream of the projected tidal elevations in **Figure 25** and **Figure 26**.

The extent of sea-level rise and flooding will depend on the tidal-freshwater transition zones, on how both water and sediment is delivered and stored, the shape of the channel and surrounding topographic morphology, and whether in-stream structures (if used) can convey water and sediment unhampered in either direction. Such a transition zone is likely to become a deposition zone with braided channels and distributary channels regressing landward as sea level rises. King tides, storm surges (especially those associated with El Niño conditions), and wind-wave run-up would also flood greater areas than those shown in **Figure 25** and **Figure 26**. What are currently extreme events are a preview of what would become regular occurrences under projected sea-level rise.

As sea-level rise increases, the backwater effect of the lagoon on streamflow (i.e., water in the lagoon slowing outflows from the streams, especially at high tides) would move up into the stream drainages. During storm events, the bedload is transported downstream, and depending on the channel morphology, some portion of it would be deposited where the streamflow meets the sea level of the lagoon. Finer sediment may be carried out further into the lagoon with the outgoing tide via subtidal channels. With 2100 sea-level rise projected to be immediately adjacent to SR 1 and to the county roads, any bedload carried downstream to that point under existing conditions would be deposited within culverts or other drainage structures under the road. The tidal delta would also expand from the current location and elevation to normalize with the projected elevation. If the road drainage structures do not have adequate capacity to accommodate the sediment, road flooding will dramatically increase. As a result, maintenance needs, frequency, and costs of any drainage structures to clear sediment and reestablish drainage would increase.

Upstream of the 2100 mean higher high tide elevation, the existing configuration of the stream channels would change as aggradation occurs in the lower reaches. This change would be due to the same backwater flooding and sedimentation effect discussed above. Ongoing sedimentation in some of the presently incised reaches may once again expand the floodprone width and reconnect abandoned terraces. In some cases, flooding may be such that the channel would alter its flow path and establish a new pathway. Vegetation changes may also affect the channel morphology, as alder and willow species that grow on the stream banks in a freshwater environment die because of higher salinities and are replaced by saltmarsh species. As the trees die and contribute woody organic debris, more sediment would likely become trapped and culvert clogging would increase.

6.2 Sea-Level Rise Complications and Implications

The sea-level-rise–driven impacts to roadways and infrastructure due to changes in tidal elevations, discussed in Section 6.1, are those expected to occur in the Bolinas Lagoon with no project, based on MHHW, and roughly half of the daily higher high tides are above those mean elevations. Therefore, some roadway flooding is expected even in the locations where the MHHW elevation is not above the roads, for example at king tide events. In addition, the roads at the Y already flood at extreme high tides, and when heavy rainfall runoff coincides with a moderate high tide in the lagoon.

The undersized culverts, and narrow shallow roadside ditches that carry runoff are part of the cause of overland flooding, but they are not the sole cause. Currently, at the highest tides, even adequately sized culverts and straightened stream channels do not allow efficient drainage into the lagoon because there is nowhere for the runoff to go. Even though adequately sized channels at a high tide are present, the water cannot discharge into the lagoon and instead creates a backwater effect, flooding onto the land. SLR would make this even worse. Sea-level rise would exacerbate these effects.

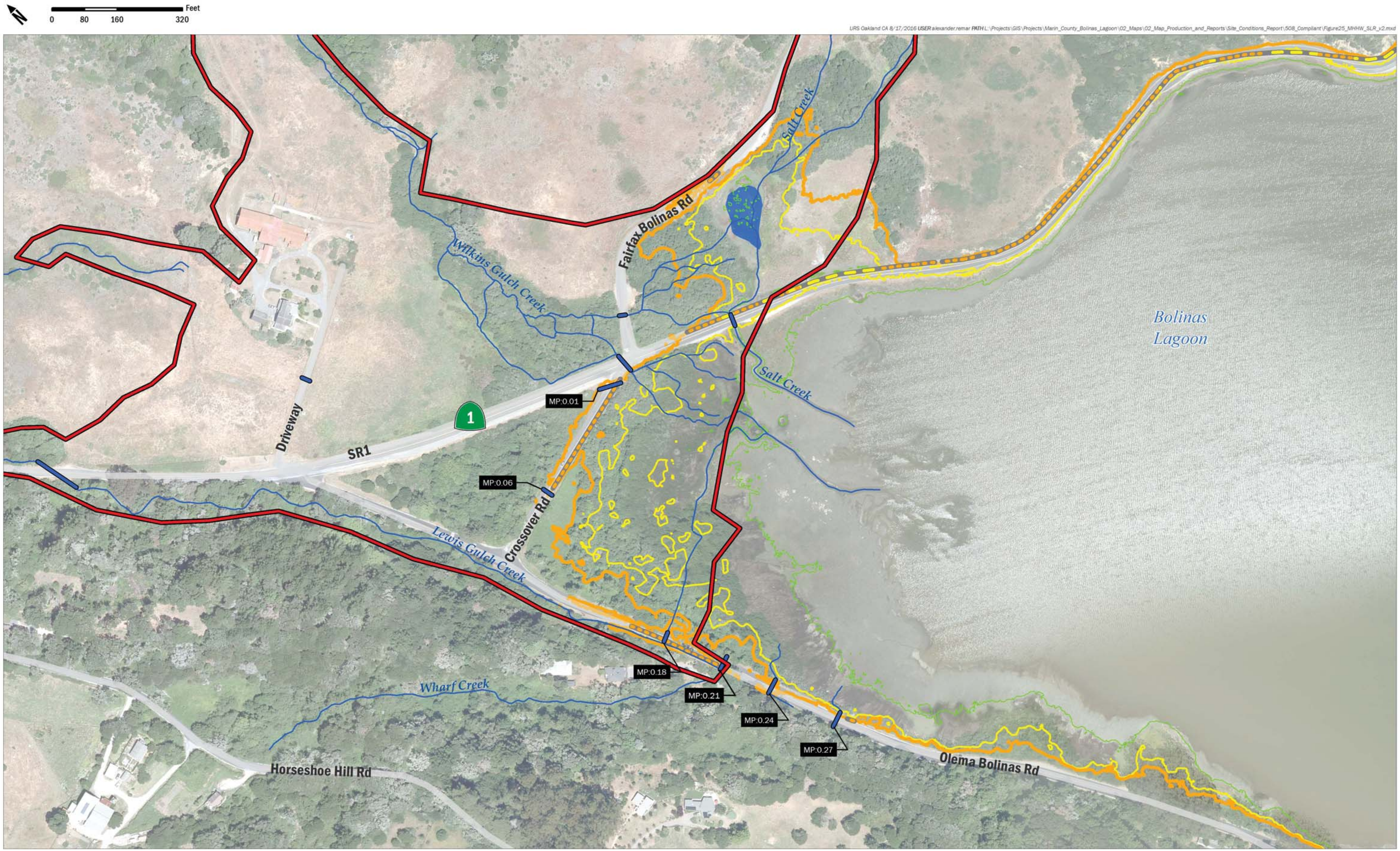
The rate of increase in sea-level rise over time is still in dispute, with most recent projections showing the increase as being linear and until 2050. After that time, most projections show the rate of sea-level rise increasing more rapidly and becoming exponential until 2100. However, recent studies indicate that global sea-level rise may be even more rapid, more severe, and non-linear. For example, some studies show that large land-based glaciers (e.g., in Greenland) and Antarctic ice shelves appear to be melting and/or calving off into the oceans more rapidly than predicted even a few years ago. (See for example, Haring and Simon 2015.) If that is correct, sea-level rise is likely to be more rapid than earlier projections. This means that more typical conditions in the next 30 to 50 years are expected to look a lot like today's extremes, and that they will happen more frequently as sea-level rise increases. King tides, simultaneous high spring tides, and overland flow are likely to affect a much larger area and have greater impacts.

In addition to roadway flooding, the increased tidal elevations are expected to change the local groundwater salinity and the vegetation that is supported by local soils. The existing interface between streams, the fringing tidal marsh, and the lagoon itself would migrate up-valley within each watershed. The area of each watershed and the stream channels and alluvial fans within them would change. Because the watersheds are generally steeper and narrower than the lagoon interface is now, the result would be a migration of vegetation up-valley. The location and area of habitat for fish and wildlife would change in response to these shifts.

Utilities could also be affected by future higher sea levels. Above-ground utilities in the study area would not be directly affected by higher tides, but access and maintenance may be made more difficult in areas more frequently or severely affected by tidal flows or flooding.

The alternatives development phase of this project is still to come, and it will include identifying possible ways to accommodate the expected changes in tidal elevations. Some likely points of consideration for those alternatives and for understanding the implications of sea-level rise are noted in the bullets below.

- Sea-level rise would not happen all at once, so modular implementation of design solutions may be appropriate.
- It may be beneficial to develop solutions that can be implemented in phases over the coming decades, and/or design and build only those components that are immediately necessary and to expand the project over time.
- Construct only the components that would not require a large amounts of ongoing maintenance. Possible components include: re-connecting streams to their alluvial fans, deltas, and the marsh and lagoon; and raising roads.
- Prepare "No-Regrets" designs, which bring improvements even if sea-level rise is lesser or slower than these projections indicate. This might include benefits from flooding avoided, reduced maintenance costs, and habitat restoration gains.



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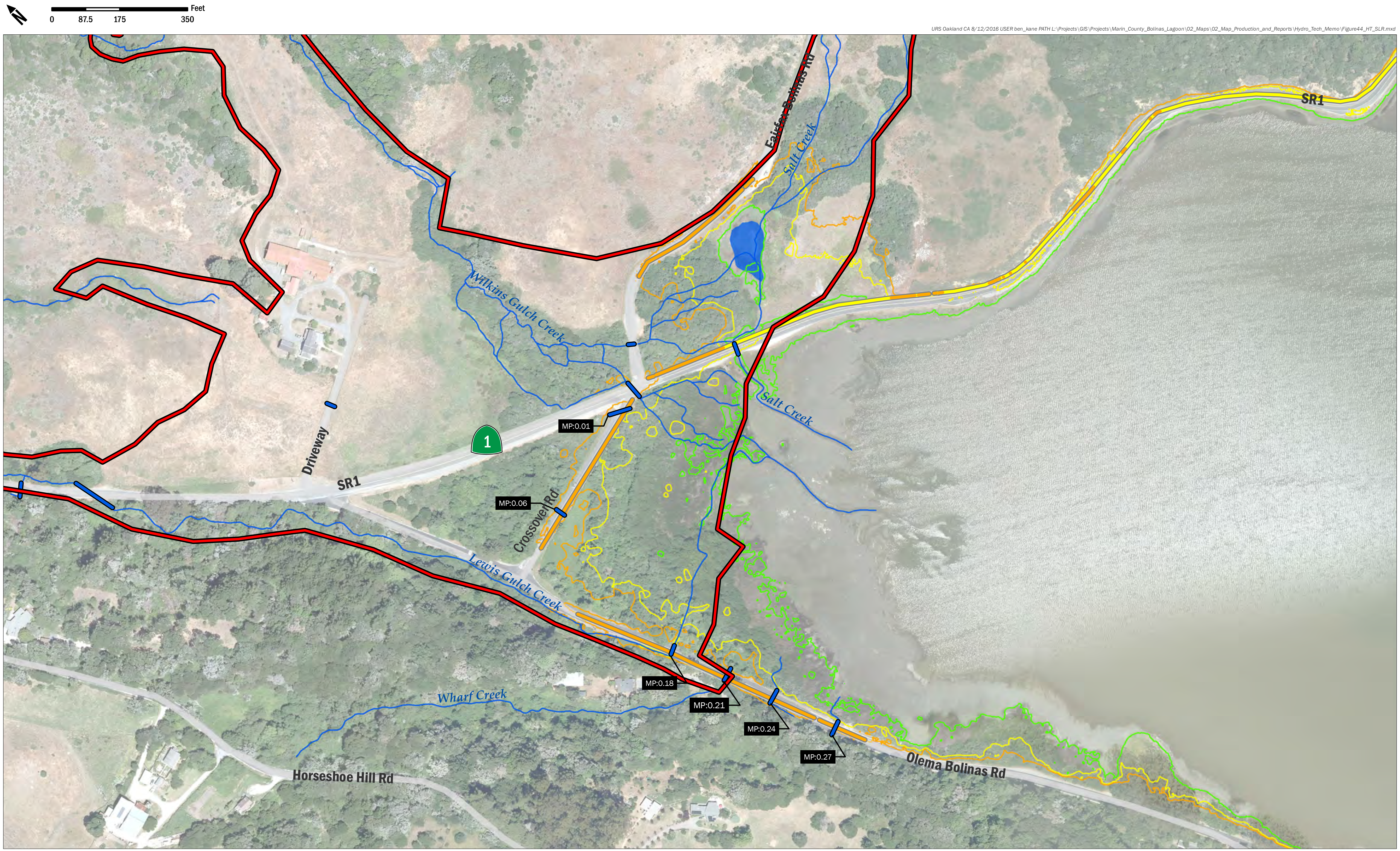
Study Area	Mean Higher-High Water (MHHW), 5.60 Ft
Water Feature	Mid-Century Sea Level Rise (MHHW + 3 Ft), 8.60 Ft
Culvert	End-of-Century Sea level Rise (MHHW + 5.5 Ft), 11.1 Ft

Roads Impacted by Sea Level Rise
- Mid-Century Scenario
- End-of-Century Scenario

Data Sources:
Elevation, San Francisco Bay LiDAR, USGS, 2010-2011
Sea Level Rise Data: Projections from Our Coast; Our Future (2015)

FIGURE 25
Sea Level Rise Projections for Mean Higher-High Water



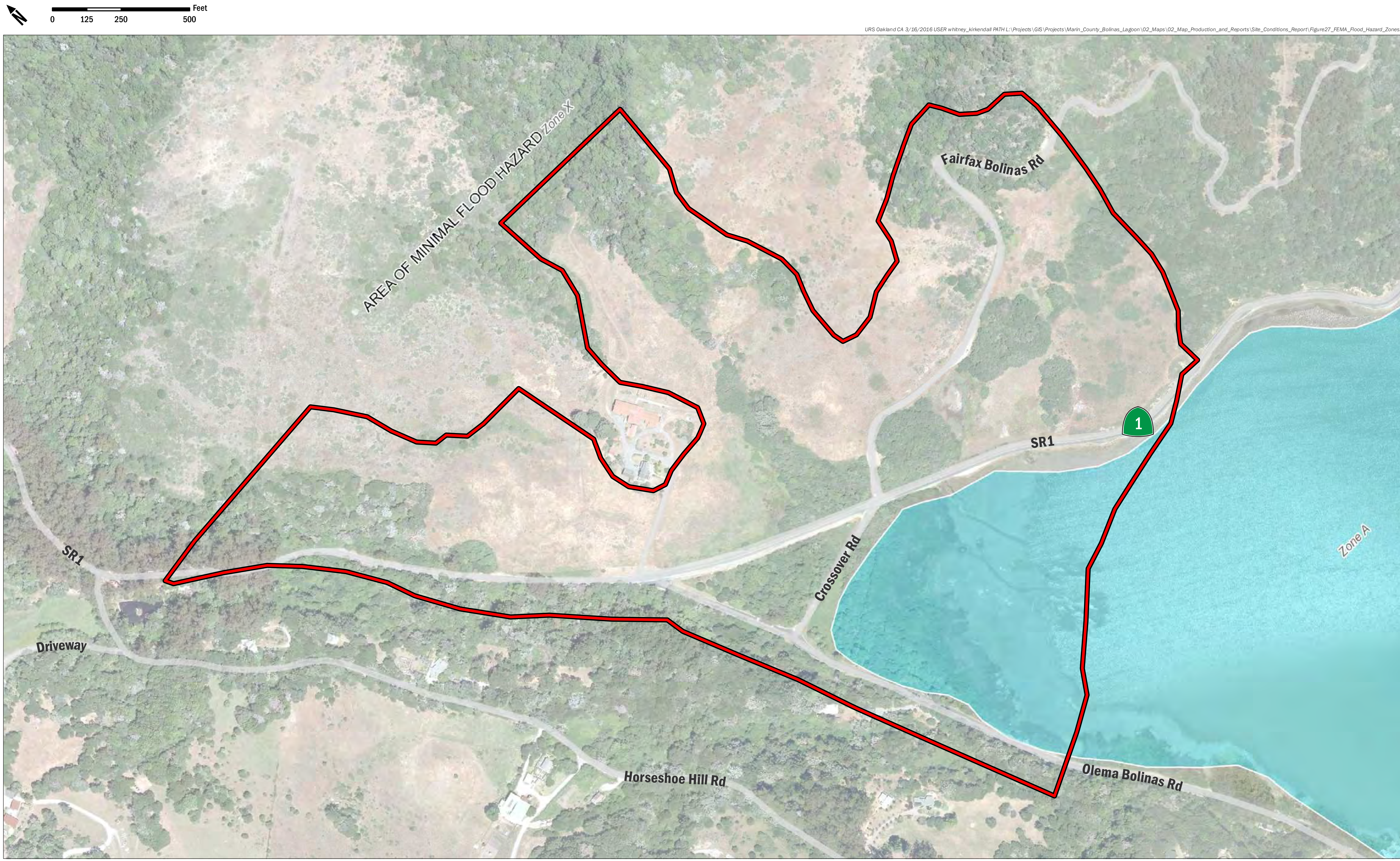
AECOM
MCOSD
Bolinas Lagoon Restoration

Study Area
Water Feature
Culvert
High Tide (HT), 5.60 Ft
Mid-Century Sea Level Rise (HT + 3 Ft), 9.40 Ft
End-of-Century Sea level Rise (HT + 5.5 Ft), 11.9 Ft

Roads Impacted by Sea Level Rise
Mid-Century Scenario
End-of-Century Scenario

Data Sources:
Elevation, San Francisco Bay LiDAR, USGS, 2010-2011
Sea Level Rise Data: Projections from Our Coast; Our Future (2015)

FIGURE 26
Sea Level Rise Projections for Highest Tides



AECOM
MCOSD
Bolinas Lagoon Restoration

Data Sources:
National Flood Hazard Layer (NFHL), FEMA, 2015.

FIGURE 27
FEMA Flood Hazard Zones

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7 Regulatory Environment

Any project in the study area at the north end of the Bolinas Lagoon would require a range of permits and other regulatory agreements because of the plentiful protected habitats and special-status species, the complex mixture of land under public agency ownership, and the relatively narrow corridors for transportation and utilities.

The regulatory agencies involved would be at the federal, state, regional, and local level. The following agencies (listed alphabetically) are likely to have regulatory jurisdiction for the project:

- Bay Area Air Quality Management District
- California Coastal Commission
- California Department of Fish and Wildlife
- California Department of Transportation
- San Francisco Bay Regional Water Quality Control Board
- County of Marin
- National Oceanic and Atmospheric Administration – Marine Sanctuaries
- National Marine Fisheries Service – Endangered Species
- National Park Service
- State Historic Preservation Office
- State Lands Commission
- U.S. Fish and Wildlife Service – Endangered Species
- U.S. Army Corps of Engineers, San Francisco District

Table 15 below presents a matrix of the regulatory agencies likely to have jurisdiction over the project and the permits or consultations that would fall under their jurisdiction. For a complete discussion of the various levels of permitting and regulatory requirements, as well as the regulatory authority of each respective agency, see **Attachment E**.

Table 15. Agencies with Jurisdiction or Regulatory Authority in the Study Area

Agency/Permit or Consultation	BAAQMD	CCC	CDFW	Caltrans	SFBRWQCB	County of Marin	GFNMS	NMFS	NPS	SHPO	USFWS	USACE
NEPA							X	X	X	X	X	X
CEQA	X		X	X	X	X				X		
Coastal Development Permit		X				X						
CWA Section 404								X		X	X	X
CWA Section 401					X							X
CWA Section 402					X							
CZMA		X										
ESA Section 7								X			X	X
EFH								X				
NHPA Section 106										X		X
LSAA (1602)			X									
CESA Section 2080 or 2081			X									
Encroachment Permit				X								
HREP 2014			X									
NPS Director's Order #77-1									X			
Tree Preservation						X						
Sanctuary Permit							X					

BAAQMD = Bay Area Air Quality Management District
CCC = California Coastal Commission
CDFW = California Department of Fish and Wildlife
CEQA = California Environmental Quality Act
CESA = California Endangered Species Act
CWA = Clean Water Act
CZMA = Coastal Zone Management Act
EFH = essential fish habitat
ESA = Endangered Species Act
GFNMS = Greater Farallones National Marine Sanctuary
HREP = Habitat Restoration and Enhancement Act of 2014
LSAA = Lake and Streambed Alteration Agreement
NEPA = National Environmental Policy Act

NHPA = National Historic Preservation Act
NMFS = National Marine Fisheries Service
NPS = National Park Service
NWP = Nationwide Permit
SFBRWQCB = San Francisco Bay Regional Water Quality Control Board
SHPO = State Historic Preservation Officer
SWPPP – storm water pollution prevention plan
SWRCB = State Water Resources Control Board
USACE = U.S. Army Corps of Engineers
USFWS = U.S. Fish and Wildlife Service

8 Limitations and Additional Data Needs

The contents of this Site Conditions Report are drawn from other technical memorandums and studies conducted as part of this project. Those individual memoranda explain their own limitations, which are presented here.

The focused field surveys conducted to inform this Report were generally limited to the areas shown on **Figure 1**, though the hydrology and geomorphology field surveys was narrowly focused on waterways and their immediate surroundings. The intertidal and subtidal areas of Bolinas Lagoon that fell within this boundary were visually surveyed, as were areas of steep slopes. Other parts of the study that were visually assessed were in areas of dense vegetation, including poison oak.

The cultural and biological resources field work was conducted at a reconnaissance level to map and characterize the various habitats and vegetation communities, and to list the species observed. It did not include delineations of jurisdictional wetlands and other waters of the United States, protocol-level rare plant surveys, or USFWS protocol-level surveys for ESA-listed or ESA candidate species. A thorough investigation of the lighter wharf, the embarcadero, and its history in serving the ranching, logging, and mining communities at the time has not been conducted. Many Bolinas community members have expressed an interest in the history of the lighter wharf.

The hydrology and geomorphology surveys and analyses were more extensive efforts, but are a result of field efforts limited to two days. Field surveys and data analysis identified significant variability in the bankfull hydraulic geometry of each stream, indicating a need for more thorough field surveys to accurately describe channel morphology. In addition, the severe drought of 2015 and the years immediately preceding have had a negative effect upon presence and growth of rare plant species, the composition of vegetation communities, and the extent of freshwater wetlands and water resources. Therefore, survey results should be interpreted with drought conditions in mind.

The automated traffic counts were only conducted for one week during the summer of 2015. Though appropriate for estimating the types of large-scale traffic levels and demands intended for this project, the week may not be a complete representative of traffic demands throughout the year. A safety assessment was not conducted as part of this site condition report. A review of auto vehicle collisions and other safety records would further inform roadway design modifications, as described in **Attachment F**.

Attachment F is a technical memorandum about the types of additional information and data needs, surveys, etc., that may be needed to inform the next stages of design, permitting, and eventual implementation of a project. **Table 16**, below presents a summary table of those additional studies that may be needed to develop, design, and permit the restoration alternatives. However, depending on what the actual alternatives are, the details presented in the memorandum will likely to need to be reconsidered and modified.

Table 16. Additional Data Needs

Item	Data Collection Effort or Study	Justification	Approximate Cost Range & Notes
1	Geotechnical investigations (borings and cone penetrometer testing); piezometer installation along roadway for structural design[1]	Assess subsurface conditions and the ability of existing roadbeds and areas adjacent to them to support additional fill (e.g., concrete box culverts, piles for a causeway).	$123,000 for borings and/or Cone Penetrometer Testing (CPT) at 10 locations plus lab analysis, county permits, and geotechnical report
2*	Groundwater monitoring for salinity and determining groundwater profile and annual fluctuations; piezometer installation along alluvial fans in anticipated flow direction, plus equipment and monitoring	Preliminary ecological assessments indicate that existing roadbeds and culverts interfere with groundwater flow and have created barriers to natural gradients, which affect vegetation. It would be important to verify and refine these conclusions prior to restoration actions being implemented. Monitoring budget includes two years' time.	$66,000 for 10 hand-augured test wells; or $92,000 for drilled piezometers including permits, installation, monitoring equipment, data download and analyses, and reporting
3	More detailed hydrologic and geomorphic surveys, instream flow monitoring*, and reference reach assessment/surveys	Preliminary stream geometry surveys and simplified hydrologic analysis provide an understanding of existing conditions, but more detailed information would refine alternatives development (i.e., evaluating bankfull geometry, etc.). In-stream flow monitoring would help determine the flow losses to the alluvial fan at various discharges and times of the year to further determine any necessary design considerations for appropriate channel sizing along the length of the alluvial fan. A reference reach assessment could be necessary. This would involve identifying and surveying a stream reach outside of the project study area, to be used as a reference reach for sizing aspects of a newly designed channel within the study area.	$139,000 - $160,000 for additional stream cross-sections[2] and other analyses of local hydrology, stream gage installation and monitoring, and reference reach surveys

Item	Data Collection Effort or Study	Justification	Approximate Cost Range & Notes
4*	Upstream sediment source surveys	Upstream sediment source surveys would involve the assessment of general upper stream/watershed geomorphic conditions, in order to determine whether there are any potential large sediment sources currently not visible on the aerial or LiDAR imagery. Potential sediment sources, if present, could dramatically alter the amount of sediment supplied to the project site in the future.	$16,000 for field work, desktop surveys, analysis, mapping and reporting
5	Hydrology & hydraulic (H&H) modeling of watershed(s) included in the project; sediment transport modeling	Preliminary stream geometry surveys provided estimates of bankfull flood elevations; however, a comprehensive H&H modeling analysis could be necessary for determination of various design discharges (e.g. 2, 50, 100 year recurrence interval), and for the assessment of existing and proposed flood extent for each recurrence event. Modeling results would be used at a later point to design stream channels, floodplains, and stream-road crossing structures.	$25,000 for model set up, parameterization, initial runs and alternatives, and report on results; data collected from cross section surveying and profile data (Item 6) and sediment data collected in the more detailed field stream assessments (item 3) would feed into this analysis
6	Detailed topographic land surveys	Existing LiDAR data accuracy is limited to portions of the study area that are not in steep or complex terrain or covered with dense vegetation; however, much of the study area along the streams contains dense vegetation and complex topography, not accurately represented in the LiDAR datasets. Initial hydrology and geomorphology surveys were coarse and not tied into established benchmarks. More detailed land surveys would establish current, detailed elevations for use in design and planning of any restoration alternatives.	$67,000 total for a detailed topo survey for Lewis Gulch and Wilkins Gulch Creeks and blending of LiDAR data with traditional survey data to produce a comprehensive topographic surface
7	Full cultural resource surveys and records searches/ geoarchaeological studies for selected project footprint; California Dep't of Recreation 523 form (site records)	These records will eventually be required for the California Environmental Quality Act (CEQA) and Section 106 consultation with the State Historic Preservation Office.	$20,000 for surveys, record searches, geoarcheological studies

Item	Data Collection Effort or Study	Justification	Approximate Cost Range & Notes
8	Delineation of Jurisdictional Wetlands; riparian corridor surveys	Determine the extent and location of jurisdictional wetlands and non-wetland waters of the U.S. for Clean Water Act Section 404 and 401, as well as the California Coastal Commission. This could also include determination of whether the area qualifies as an Environmentally Sensitive Habitat Area under the Coastal Act.	$25,000 for all desktop and field surveys as well as necessary reports (e.g., Approved Jurisdictional Determination)
9	Rare plant surveys	Will be required for CEQA, the Federal Endangered Species Act (ESA), the California ESA, and permitting	$19,000 for all desktop and field surveys as well as necessary reports
10	Targeted wildlife surveys	Initial surveys classified wildlife habitats and noted species observed, they also noted special-status species that would be expected to occur in the area, but CEQA, the Federal ESA, and the California ESA would require targeted wildlife surveys of the area of a particular footprint to generate enough information to rule out or rule in a number of special-status wildlife species	$40,000-$50,000 for all desktop and field surveys as well as necessary reports
11	USFWS protocol-level surveys for California red-legged frog	Not recommended; there are recent records nearby and suitable habitat present; recommend inferring presence	$0
12	USFWS protocol-level surveys for other Federal ESA listed species	Protocol-level surveys could demonstrate presence or absence of ESA-listed species, which could shape their consideration under federal and state permitting. Alternatively, infer presence and obtain CEQA and ESA clearance for them.	Up to $60,000 depending on the species selected; protocol-level surveys require multiple long (including overnight) visits during multiple seasons as well as reporting
13	Maintenance records (culvert clearing; road repairs) and as-builts for roads and culverts in the selected project area	Efforts to obtain these as part of this scope have met with partial and limited success; these will be important for determining how much and what types of improvements in drainage might be required to address current flooding issues	Very low; Marin County Open Space District staff could perform tasks

Item	Data Collection Effort or Study	Justification	Approximate Cost Range & Notes
14	Traffic accident study	A review of State and County vehicle accident reports and accident history, along with any related traffic studies would provide insightful information to further assess the means to improve safety in the project design.	Estimated at $5,000
15	Noise study	A noise consultant would conduct a brief noise assessment to determine what the increase in noise would be for the design alternatives. While the project would not lead to a net increase in the amount of noise, raising the roadway onto bridges or a causeway would likely increase the noise transmission to the human and animal receptors in the area.	Up to $10,000
16	Underground utility searches and records queries	Preliminary searches had limited success in obtaining this information from publicly available information and from various sources; more formal coordination between utility providers (e.g., the Underground Service Alert (USA) system) is necessary to verify locations or demonstrate absence of underground utilities once a project footprint is known.	Up to $3,000 for coordination time

*Data collection may not be necessary, but could further inform project design.

1 = Note that the geotechnical investigation borings and groundwater wells may in some cases could be combined to significantly lower the listed costs here; these estimates assume separate implementation.

2 = Cross sections used for additional bankfull analysis and flow monitoring would be conducted at the same cross sections surveyed for the H&H analysis to reduce costs.

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Attachment A. Biological and Cultural Resources Technical Memorandum

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AECOM

Submitted to
Marin County Open Space District
3501 Civic Center Drive
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Submitted by
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December 2015

Bolinas Lagoon North End Project Technical Memorandum for Biological and Cultural Resources

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List of Acronyms

°F	degrees Fahrenheit
Cal-IPC	California Invasive Plant Council
Caltrans	California Department of Transportation
CCC	California Coastal Commission
CDFW	California Department of Fish and Wildlife
CFR	Code of Federal Regulations
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CRHR	California Register of Historic Places
CRLF	California red-legged frog
CRPR	California Rare Plant Rank
DBH	diameter at breast height
EO	element occurrence
ESA	Endangered Species Act
GIS	Geographic Information System
GPS	global positioning system
MCV2	Manual of California Vegetation, second edition
NHD	National Hydrography Data set
NPS	National Park Service
NRCS	Natural Resource Conservation Service
NRHP	National Register of Historic Places
OHWM	Ordinary high water mark
ppt	parts per thousand
PRNS	Point Reyes National Seashore
sp.	species (singular)
spp.	species (plural)
SR	state route
ssp.	sub species
TJM2	The Jepson Manual of Higher Plants, second edition
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey

1 Introduction

This document is a technical memorandum on the conditions of the biological and cultural resources found at the north end of the Bolinas Lagoon and its surroundings. The Bolinas Lagoon, along the California coast north of San Francisco, contains over 1,100 acres of marsh, mudflats, and subtidal and intertidal lagoon habitat. Bolinas Lagoon is one of 37 internationally designated Ramsar[1] sites within the United States (USFWS 2015a). It is an important site along the Pacific flyway, used as a stopover or wintering area by migrating waterfowl. This predominantly subtidal and intertidal habitat supports a variety of special-status species, including steelhead trout, coho salmon, and a variety of rare plants. It also contains egret and heron nesting areas, and harbor seal pupping areas. The uplands surrounding the lagoon contain a mix of grasslands, chaparral, and forest habitats that contain permanent and seasonal streams as well as wetlands and a pond (Figure 1).

The lagoon and its surroundings are under a mix of private and public ownership. Public land holders include Marin County Parks, the Greater Farallones National Marine Sanctuary), Point Reyes National Seashore, (National Park Service, [NPS]), and the Golden Gate National Recreation Area (NPS). The California Department of Transportation (Caltrans) also has rights-of-way over State Route 1 (SR 1), which runs along the eastern side of the lagoon. There are also private properties, both immediately adjacent to the lagoon and along the hillsides and valleys that surround it.

The Bolinas Lagoon North End Project (often referred to herein as the North End Project) is a part of a larger and longer-term effort for the restoration of the Bolinas Lagoon. The project was recommended as part of the *Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management* prepared in August 2008 by a Working Group of the Sanctuary Advisory Council,. The North End Project aims to improve the ecological functions and habitat values of the tidal marshes, streams, riparian corridors, and upland habitats at the north end of the lagoon. The project also seeks to reduce current flooding of roadways and plan adaptations for future sea-level rise.

The project's study area (study area) includes the triangle of roads that is commonly known as the Bolinas "Y". These roads are SR 1, Olema Bolinas Road, and a short connector road, sometimes referred to as the crossover road. The study area also includes Lewis Gulch Creek and Wilkins Gulch Creek that drain through the "Y" and into the northern tip of the lagoon. The study area extends upstream through these two watersheds for distances sufficient to understand the local hydrology, geomorphology, and biology.

The first task of the North End Project is to study the current and historical conditions of the north end of the Bolinas Lagoon, Lewis Gulch and Wilkins Gulch Creeks, and the surrounding riparian corridors and uplands. Studies are planned to address a variety of topics, including biology, hydrology, geomorphology, cultural/archaeological resources, infrastructure, and vehicle traffic. Subsequent tasks will include developing and analyzing alternatives for achieving the project goals of improving habitat function and connectivity, maintaining road capacity and meeting traffic demands, reducing roadway flooding, and preparing for sea-level rise and other climate changes. Separate technical memoranda will be provided for (1) the biological and cultural/archaeological conditions, and (2) the hydrologic and the geomorphologic status and history of the study area. A larger, Site Conditions Report will then integrate information from these two technical memoranda and also include information on the traffic counts on local roads, the existing infrastructure, ownership, and the regulatory climate affecting the project.

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[1] "The Convention on Wetlands, signed in Ramsar, Iran, in 1971, [and often referred to as "Ramsar"] is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands. There are presently 162 Contracting Parties to the Convention, with 2,040 wetland sites, totaling 193 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance" (WWF 2015)

This document is organized as follows. Section 1 is this introduction. Section 2 describes the methods for the background research, desktop analysis, data collection, and field surveys of the study area. Section 3 presents the environmental setting of the project's study area. Section 4 describes the biological conditions in the project's study area, including the vegetation communities, wildlife habitats, wetlands, and streams. The biological conditions were developed from background research, desktop analysis, and field surveys. The cultural and archaeological resources in the study area are also presented in Section 4. Section 5 discusses limitations of the current studies. Section 6 lists the references, databases, and background documents that were used to develop and perform the studies. Section 7 presents the field survey teams and scientists who conducted research and prepared this memorandum.

AECOM
Marin County
Bolinas Lagoon Restoration

FIGURE 1
Site Location

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2 Methods

The methods section describes key definitions used throughout the document, material reviewed by each technical specialty, and field survey techniques implemented during surveys.

2.1 Definitions

Study area – The study area includes all areas currently considered for restoration activities under the North End Project. The extent of the study area is shown as land within the red boundary on Figure 1.

Special-Status Species – Special-status species are plants or animals legally protected under the federal Endangered Species Act (ESA), the California ESA, or deemed rare by the California Native Plant Society (CNPS) in its California Rare Plant Rank (CRPR) system or by the NPS.

Special-Status Plant Communities – Special-status plant communities are plant communities (also known as natural communities), of limited distribution statewide or within a county or region, and that are often vulnerable to the environmental impacts of projects (CDFW 2009).

Invasive non-native species – Invasive non-native species are plant species listed as having a High or Moderate threat by the California Invasive Plant Council (Cal-IPC). CAL-IPC defines “High” threat species as those that have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment, and most are widely distributed ecologically. “Moderate” species have substantial and apparent—but generally not severe—ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal, though establishment is generally dependent upon ecological disturbance and ecological amplitude, and distribution may range from limited to widespread. Low threat species have minor ecological impacts. Their reproductive biology and other invasiveness attributes result in low to moderate rates of invasion. Ecological amplitude and distribution are generally limited (these species may be locally persistent and problematic). (Cal-IPC 2015).

Vegetative cover – Vegetative (plant) cover is the percentage of ground surface covered by vegetation. It can be measured as absolute cover or relative cover (see below).

Absolute cover – Absolute cover is a method of describing the percentage of vegetation covering a specified area. Unlike relative cover, it adds overlapping layers of vegetation such as an understory, mid-story, and canopy (each with the potential to cover up to 100 percent), and therefore can exceed 100 percent in total.

Relative cover – Relative cover is a method of describing the percentage of vegetation covering an area that, unlike absolute cover, does not count overlapping layers of vegetation. Relative cover stipulates that the percent of bare ground and vegetation must add up to, and cannot exceed, 100 percent.

Waters of the United States – Jurisdictional waters of the United States include intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, natural ponds, and wetlands or waters adjacent to any water of the United States (33 Code of Federal Regulations [CFR] § 328). The United States Army Corps of Engineers (USACE) also regulates navigable waters under Section 10 of the Rivers and Harbors Act as “… those waters of the United States that… are presently used, or have been used in the past, or may be susceptible to use to transport interstate or foreign commerce” (33 CFR § 329).

Jurisdictional Wetlands (a subset of Waters of the United States) – Jurisdictional wetlands are all areas that meet, or are presumed to meet, the USACE definition of wetlands, as established using the three-parameter approach (Environmental Laboratory, 1987) and that meet the significant nexus or connectivity criteria (33 CFR § 329). The three parameters are the presence of wetland hydrology, dominance of hydrophytes, and presence of hydric soil) (Environmental Laboratory, 1987; USACE 2008).

Other Waters of the U.S. (a subset of Waters of the United States) – Other waters of the U.S. are all flowing waters that are traditionally navigable or that flow into a traditionally navigable waterway, plus adjacent waters. They include the portion of all open water located below the ordinary high water mark (OHWM) of an unvegetated channel, lake, pond, or other body of open water (33 CFR § 328).

California Coastal Commission (CCC) wetlands – These are wetlands that are regulated by the CCC. The guidelines for delineation of a CCC wetland differ from USACE guidelines in that they rely on a single-parameter approach, rather than a three-parameter approach, to establish the presence of wetlands and the extent of their jurisdiction. The CCC's published wetland delineation guidelines define boundaries for vegetated wetlands either as the line between areas with hydrophytic land cover and predominantly mesophytic or xerophytic cover, or as the line between hydric soil and predominantly non-hydric soil (14 CCR 13577(b)).

National Park Service (NPS) Wetlands – Under NPS Director's Order #77-1, the NPS classifies wetlands according to the U.S. Fish and Wildlife Services "Classification of Wetlands and Deepwater Habitats of the United States" (Report FWS/OBS-79/31; Cowardin et al. 1979). Under this definition, a wetland must have one or more of the following three attributes:

1. At least periodically, the land supports predominantly hydrophytes (wetland vegetation);
2. The substrate is predominantly undrained hydric soil; or
3. The substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Because of the similarity of the NPS wetland definition and the CCC wetland definition, NPS wetlands are assumed herein to have the same extent in the project area as CCC wetlands and are not discussed independently. Note that this document discusses both jurisdictional wetlands and CCC/NPS wetlands, as appropriate, and illustrates them both on the maps.

Riparian areas – The classification "riparian area" is used to refer to areas above the OHWM of other waters of the U.S. that provide "linkages between water bodies and adjacent uplands and include portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems" (Griggs 2009). For delineation purposes, this area is assumed to extend from the OHWM to the edge of the outer drip line of vegetation that could affect the water quality functions. Typically, riparian areas include all riparian vegetation adjacent to a stream, lake, or other flowing water body. Riparian areas are described in this document alongside wetlands and waters because they are important for the protection of water quality and sensitive biological resources. They are a resource of interest to the USACE, the State Water Resources Control Board, and California Department of Fish and Wildlife (CDFW).

2.2 Background Review of Documents, Data, Imagery, Records, Etc.

In addition to site-specific background documents for the natural environment in the vicinity of the study area, statewide data sources provide important overview information such as aerial imagery, hydrology, and special-status species information. Available sources of information on the study area were reviewed by technical specialists prior to field surveys to prepare for focused survey efforts, as described below.

2.2.1 Wetlands and Waters

In advance of field surveys, AECOM wetland scientists reviewed aerial imagery of the study area, as well as United States Fish and Wildlife Service (USFWS) National Wetland Inventory data (USFWS, 2009) and the national hydrography data set (NHD) (USGS 2015a). Additional documents such as the Bolinas Lagoon Ecosystem Restoration Feasibility Project: Final Public Reports (MCOSD 2006) and the Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management (GFNMS 2008) were reviewed to provide background on previously conducted wetland and water surveys in the vicinity of the project.

2.2.2 Vegetation

An AECOM botanist reviewed aerial imagery of the study area, U.S. Geological Survey (USGS) topography maps (USGS 2015b), as well as a relevant habitat information compiled by Peter Baye (Baye, personal communication, 2015) in advance of field surveys to develop a potential list of sensitive natural communities in the study area.

2.2.3 Special-Status Plant and Animal Species

An AECOM GIS specialist ran a California Natural Diversity Database (CNDDB) query of all reported special-status plant and animal species within a 5-mile radius of the project center point (CDFW 2015a). The output list was examined by qualified wildlife and plant ecologists to select species with potential to occur in habitats found in the study area. This species list was used to plan habitat assessments for the special-status species with a potential for occurrence.

2.2.4 Cultural and Archaeological Resources

AECOM conducted a records search at the Northwest Information Center (NWIC) of the California Historical Resources Information System, Sonoma State University, Rohnert Park, California, on April 6 2015 (File No. 14-1359). The NWIC, an affiliate of the State of California Office of Historic Preservation (OHP), is the official state repository of cultural resource records and studies for Marin County. Site records and previous studies were accessed for the study area and a 0.5-mile radius on the Bolinas, California. USGS 7.5-minute topographic quadrangle. The purpose of the records search was to: (1) determine whether known cultural resources have been recorded within the study area; (2) assess the likelihood for unrecorded cultural resources to be present based on historical references and the distribution of nearby resources; and (3) develop a historical context for the study area.

The following references were also reviewed during the NWIC records search:

- National Register of Historic Places (NRHP) (2008)
- California Register of Historical Resources (CRHR) (2008)
- Historic Property Data File for Bolinas, Marin County (OHP, April 2012)
- California State Historical Landmarks (OHP 1996)
- California Inventory of Historic Resources (California Department of Parks and Recreation 1976)
- California Points of Historical Interest (OHP 1992)
- Caltrans Historic Bridge Inventory (Caltrans 2010)
- Bolinas, California 7.5- and 15-minute topographic quadrangle (USGS 1897, 1910, 1941, 1955, 1966, 1971, 1997)
- Hiram Austin Map of Marin County (1873)
- Five Views: An Ethnic Historic Sites Survey for California (OHP 1988)
- California Place Names (Gudde 1998)
- Historic Spots in California (Kyle et al. 2002)

- Historical Atlas of California (Beck and Haase 1974)
- Handbook of the North American Indians: Coast Miwok (Kelly 1978)

2.3 Field Surveys

Multiple field surveys were performed in order to gather the data presented in this memo. In addition to an initial site walk, technical field surveys were conducted to map wetlands and other waters (waters of the United States and waters of the State), identify plant species and map plant communities, and identify the presence of special-status species and their habitat (Table 1).

Table 1. Field Survey Dates, Type, and Staff

Survey Date (2015)	Survey Type/Data Collected	Survey Staff
April 3	Initial Site Walk and Field Survey Planning Meeting	David Halsing, Rosemary Laird, Jason Pearson, Peter Baye, Bill Carmen, John Takekawa, Laurel Collins, Francesca Demgen
April 17	Botany, Special-Status Species, Water Sampling	Ivan Parr, Tammy Lim
April 20	Wetlands and Waters; Water Sampling	Galen Peracca, Jan Novak
May 5	Botany, Wetlands and Waters; Water Sampling	Galen Peracca, Ivan Parr
June 17	Cultural & Archaeological Resources	Karin Beck, Karen Gardner

2.3.1 Initial Site Walk and Planning Coordination Meeting

On April 3, 2015, an initial site visit and meeting were held to plan and coordinate the field surveys. This meeting provided an opportunity for the AECOM project manager and several task leads to discuss the project scope and goals with the various subcontractors and for the subcontractors to share their local knowledge and subject matter expertise. These subcontractors have all worked in and around the Bolinas Lagoon and surrounding areas, and their roles on the project team included participation in the project through working meetings such as the site walk and planning meeting. The indoors portion of the meeting consisted of over 2 hours of facilitated discussion on topics relevant to the studies. These topics included areas of particular concern for field crews to be aware of, as well as various ideas about local hydrology, the importance of salinity, the true routes of Lewis Gulch Creek and Wilkins Gulch Creek (as opposed to those shown on several pre-existing maps), and the types of species habitat that might be relevant.

The meeting was followed by a site walk and tour of the developed and safely accessible portions of the study area. During the walk, attendees discussed more specifics of wildlife and plants observed, areas of focus for the surveys, and ideas for future consideration in restoration alternatives. Notes from both portions of the meeting and site walk were compiled and shared with the field teams prior to their field survey efforts.

2.3.2 Water Sampling

To measure salinity, single water samples were taken from the first few inches of surface waters at 11 random locations (Figure 2). The samples were taken on different days and were not correlated to tides and thus do not a full analysis of surface or groundwater salinities or their flow patterns. Salinity sampling reflects 2015 conditions. A refractometer was used to measure the salinity. Salinity was used as a parameter for determining the suitability of water features in the study area for special-status wildlife species and vegetation communities. The extreme drought year, and low runoff and groundwater recharge, likely have resulted in elevated salinities higher than in typical or average rain years.

2.3.3 Vegetation

AECOM botanists and ecologists conducted focused field surveys of the study area to identify plant species observed and map the extent of all vegetation communities. All observed plant species in the study area were identified to species using the Jepson Manual of Vascular Plants (TJM2) (Baldwin et al. 2012) and Marin Flora (Howell et al. 2007) and named according to conventions presented in the updated TMJ2. The limits and composition of vegetation communities in the study area were also examined. Plant community boundaries were mapped using a combination of handheld Trimble global positioning system (GPS) units with sub-meter accuracy and hand-markings on aerial imagery (field sheets). All plant communities within the study area that covered an area equal to or greater than a half-acre were classified based on the system developed by Sawyer et al. (2009) in the Manual of California Vegetation, second edition (MCV2).

The sizes (diameter at breast height [DBH][2]) of representative trees were measured in select areas dominated by tree cover. Representative trees were chosen as those appearing to be the median size within a forest or woodland.

Additionally, ocular (visual) assessments of density (absolute percent cover) were collected in each vegetation alliance using representative plots. Representative plots were placed in the center of an alliance, never coming within 1 meter of its boundary. If the alliance was comprised of multiple acres or disjunctive segments, plots were placed where topography and vegetation cover appeared to be most characteristic. Characteristic topography and vegetation was assessed after the communities had been identified and mapped, and were determined using ocular observation, aerial map signatures, field notes, and alliance descriptions in the MCV2. For the largest and most prevalent communities (California annual grassland, *Quercus agrifolia* woodland alliance, *Salix lasiolepis* Shrubland alliance), two plots were sampled. Plot size was 10 meters by 10 meters for communities dominated by trees, shrubs, or large herbaceous species (such as cattails), and 2 meters by 2 meters for herb-dominated communities.

2.3.4 Wetlands, Other Waters of the U.S., and Riparian Surveys

The survey for wetlands and waters (which included wetlands and other waters of the United States, waters of the State, riparian habitat, and CCC wetlands) entailed identifying areas with a dominance of hydrophytic plant species. The surveys did not include an analysis of hydric soil indicators or subsurface hydrology and therefore was not a formal delineation of wetlands under the jurisdiction of the USACE. Instead, indicators of wetland surface hydrology (saturated soils, ponding, sediment deposits, etc.), as defined by the USACE, were used to distinguish the boundary between one-parameter CCC wetlands and three-parameter USACE wetlands. Wetland areas were defined based upon their dominant plant composition and delineated based on the extent of these plant community boundaries. Similarly, riparian areas were delineated based upon the extent of riparian vegetation extending outward from the OHWM of each water feature. The extent of other waters was determined based upon field indicators of the OHWM impressed upon the banks of each channel (or pond edge) in the study area. The extreme drought year, and low runoff and groundwater recharge, likely have resulted in a reduced areal extent of hydrophytic vegetation and surface hydrology than would be evident in typical or average rain years. Wetland community mapping reflects current year conditions.

The boundaries of all wetlands, other waters, and riparian areas were mapped using GPS units and hand-drawn on aerial imagery (field sheets). After riparian habitat was delineated, the federal and state jurisdictional riparian areas were determined by the field biologists for the purposes of

[2] Diameter at breast height (DBH) is equal to the diameter of a tree trunk measured 4.5 feet above grade on the upslope side of a tree.

characterizing habitats and their general boundaries. Federal riparian habitat was identified as all areas within bankfull[3] and all areas beyond bankfull where hydrology was observed beneath riparian vegetation. State riparian habitat was identified as areas beyond bankfull that featured riparian vegetation but no indicators of long-term saturation (as evidenced by surface hydrology indicators).

Separate hydrology and geomorphology investigations took place after the field surveys described in this memorandum. Those investigations conducted more detailed assessments of the stream channels and their surroundings to inform future decisions about possible stream modifications or other aspects of restoration alternatives. A separate technical memorandum describes how bankfull was determined using field indicators (e.g. a defined break in cross sectional shape, flow lines, silt deposition, height of gravel bars, and the root/trunk transition of riparian vegetation). The different intended uses of information from these two surveys (habitat assessment and hydrology/geomorphology) explain the different level of detail and specificity in these assessments of streams and riparian areas.

2.3.5 General Wildlife Habitat Assessment

AECOM biologists conducted reconnaissance-level wildlife surveys of the study area. Because these were reconnaissance-level surveys, there was no formal sampling of survey plots. Data were collected in the field during two daytime site visits; two biologists qualified to identify vertebrates walked several roughly parallel transects through the accessible portions of the site making wildlife observations of habitats several feet on either side. Areas where special-status species had highest potential (creeks, ponds, marshes, and riparian habitats) were targeted. The biologists recorded all wildlife observed to species or genus. More focused habitat assessments were conducted for special-status species identified during the desktop review. Water samples were taken at various locations to determine salinity levels and suitability of aquatic features to support special-status amphibians.

2.3.6 Cultural & Archaeological Resource Surveys

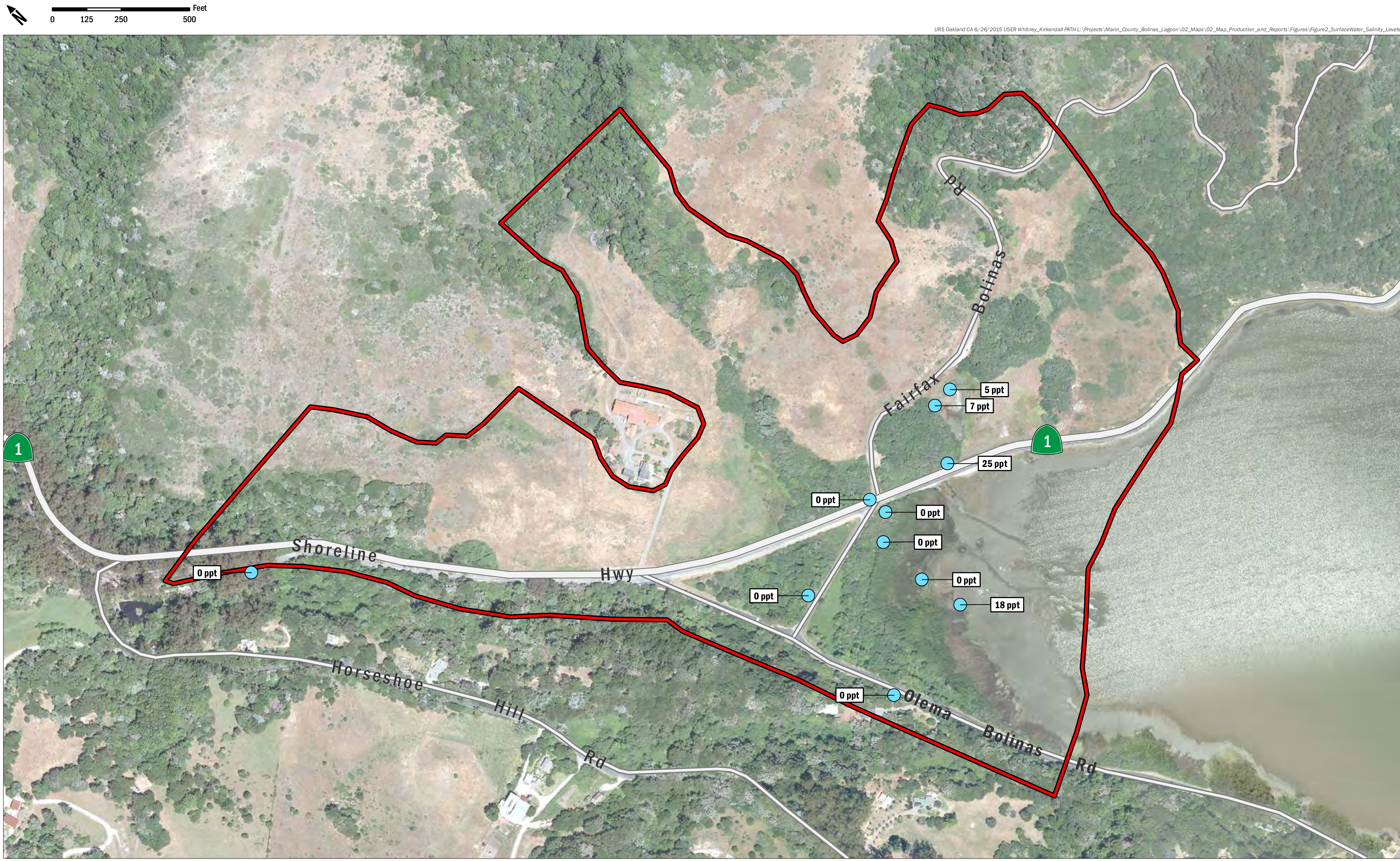
AECOM applied for a permit with the U.S. Department of the Interior to conduct archaeological investigations on the property of PRNS and GGNRA, under the authority of the Archaeological Resources Protection Act of 1979 (ARPA Permit PWR-1979-15-CA-08 [GOGA/PORE]).

A cultural resources survey of the study area was conducted by AECOM on June 17, 2015 in order to identify any previously unrecorded cultural resources that may be present in the study area. Survey transects were spaced approximately 10 meters apart, and covered all areas of the study area except the lagoon. Surface visibility was limited to less than 10 percent throughout the study area, except in areas of prior ground disturbance (road pullouts and driveways, etc.) and where vegetation had been cleared in the southeast portion of the study area, on a marine terrace east of SR 1. Ground visibility was increased by making intermittent boot scrapes along the transect lines in order to move aside the vegetation and expose the ground surface.

2.4 Post-Field Data Processing and Analysis

GPS data collected in the field was post-processed in the office. The spatial extent of vegetation communities were refined based on aerial imagery and synchronized with wetland community data and with the wildlife habitat assessment information collected in the field. A GIS was used to estimate areas of various cover types and habitats.

[3] Bankfull is defined as the amount of flow that maintains the channel and reaches the height of the surrounding floodplain, which is the relatively flat bench at the incipient level of flooding.



AECOM
MCOSD
Bolinas Lagoon Restoration

FIGURE 2
Surface Water Salinity Levels

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3 Environmental Setting

The study area is located in Marin County (NRCS 1985) and encompasses the northernmost corner of the Bolinas Lagoon with the toe slope of Mount Tamalpais to the east and Horseshoe Hill to the west. Elevations range from near 100 feet along the slope of Mount Tamalpais to sea level in the lagoon. Also present within the study area are the mouths of Lewis Gulch Creek and Wilkins Gulch Creek, which flow into the lagoon from the north and east, respectively. The lagoon is bordered on both sides by roadways; SR 1 parallels the eastern edge of the lagoon and Olema Bolinas Road follows the western edge. The roadways meet northwest of the lagoon. There is also a crossover road that provides a shortcut for travelers driving between Stinson Beach and Bolinas that creates an isolated triangle of habitat. This area is locally referred to as the Bolinas "Y". This section below describes the climate, topography, soils, basic hydrology, and surface water conditions in the study Area.

3.1 Climate and Hydrology

The climate in the study area is characterized by cool, moderate temperatures and fog, typical of coastal Northern California. Average 30-year temperatures recorded at Bodega Bay (the most ecologically relevant proximate weather station) average 53.6 degrees Fahrenheit (°F), with an average seasonal low of 50.2 °F and an average seasonal high temperature of 57.1 °F (NOAA 2015). Most precipitation falls within six months of the year, as is typical of xeric climates. Average annual precipitation in Point Reyes Station is 30 inches. Relative humidity along the coast is about 80 percent throughout the year due to coastal fog.

The dominant hydrologic features in the study area are Lewis Gulch Creek, Wilkins Gulch Creek, and the Bolinas Lagoon (Figure 1). More detailed information on all of these features and on the hydrology of the study area is presented in a separate technical memorandum that focuses on the hydrology and geomorphology of the area, but some information is presented here for context.

Lewis Gulch Creek (Figure 4.4) enters the study area in the northwest corner, crosses underneath SR 1 through a corrugated metal culvert, parallels the western edge of SR 1 for about 700 feet and then is conveyed via a ditch alongside Olema Bolinas Road. When the creek approaches the northernmost tip of the Lagoon it is routed into a culvert and makes a 90 degree turn east under Olema Bolinas Road and released into the marsh at the head of the lagoon.

Wilkins Gulch Creek flows out of the hills in the northern portion of the study area into the lagoon. The stream channel is contained within bed and bank at the higher elevations, and then loses its banks in a marsh environment near the crossing under SR 1 and a side branch that crosses under Fairfax Bolinas Road. This area is heavily vegetated with arroyo willow thickets (see section 3.2.1 for a more thorough description of the vegetation communities). The arroyo willow thicket is also present south of Fairfax Bolinas Road where a shallow pond, surrounded by arroyo willow thicket and sedge communities, is located. Wilkins Gulch Creek discharges into the lagoon via two culvert systems, located north and south of the intersection of SR 1 and Fairfax Bolinas Road. The culvert north of the intersection is small but appears to be the main stem of the creek. Its flows deposit freshwater into a willow thicket alongside the intersection of SR 1 and the crossover road (Figure 6, B). A side channel off Wilkins Gulch Creek runs through a culvert under Fairfax Bolinas Road and flows into and through the pond (Figure 6, A), then turns southwest, and passes through a concrete box culvert that routes water under SR 1 directly into the saltmarsh community at the fringes of Bolinas Lagoon.

A third, apparently unnamed stream drains a smaller area south of Fairfax Bolinas Road and meets Wilkins Gulch Creek's side channel near the pond east of SR 1. The box culvert under SR 1 south of Fairfax Bolinas Road carries the combined flows of this unnamed stream and Wilkins Gulch Creek.

While the Bolinas Lagoon buffers the strong tides originating in the Pacific Ocean (west of the study area), the study area experiences a tidal cycle each day that both carries salt water into the study area and allows freshwater and groundwater discharge to drain from the creeks. The salinity of the study area, and therefore the species that grow and thrive in the study area, is highly dependent upon the relationship between tidal flooding, freshwater discharges below-ground and above-ground, topography, and hydraulic conductivity of wetland soils. During periods of high freshwater discharge, salinity levels in the study area will be lower, and vice versa. Freshwater discharge is highest when there is a combination of surface and subsurface (groundwater) flows. Surface flows are seasonal and generally come in the winter rainy months. The groundwater discharge persists into the dry season when surface flows generally stop. Plant growth, however, is lowest during periods of high surface flows. Groundwater flows dominate during the periods of plant growth, when the plans are most sensitive to salt stress. This means that the vegetation communities are heavily influenced by the groundwater flows and the salinities in them.

The southern portions of the lagoon within the study area are at sea level and contain unvegetated tidal mudflats. There are several defined channels within this area, the largest of which forms at the mouth of the culvert draining Wilkins Gulch Creek under SR 1. The second channel forms where Lewis Gulch Creek is released into the lagoon from a culvert under the Olema Bolinas Road.

Moving up the tideline, the mudflats transition into vegetated salt marsh. The lagoon becomes brackish in upper tidal elevations, as freshwater from groundwater and creek discharges mix in a “subterranean estuary” below the marsh. This is reflected in an abrupt discontinuity in vegetation between low salt marsh and tall, dense brackish alkali-bulrush marsh within a very gentle tidal elevation gradient. Above the brackish lagoon habitat, at supratidal elevations above the reach of all but the highest winter storm high tides, stands of alder and willow have developed. These forests continue above the crossover road into the “Y”, which is an isolated triangle of habitat that is physically separated from tidal influence. Willow alder groves are prominent in the triangle area between the three roadways (Baye, personal communication, 2015).

3.2 Geology and Soils

Bolinas Lagoon and its surroundings, including the study area, are located above the San Andreas Fault Zone. The submerged valleys flooded by Bolinas Lagoon and Tomales Bay, and the Olema Valley, are part of the larger San Andreas Rift Valley. Three major earthquake faults (the Golden Gate, San Andreas, and San Gregorio faults) merge together as the San Andreas Fault Zone in the Bolinas area. These faults are submerged under water in the lagoon or covered by sediments beneath the beach. The Golden Gate Fault runs along the eastern shore of Bolinas Lagoon. The San Andreas Fault comes onshore near the east end of Stinson Beach. The San Gregorio Fault extends onshore between the town of Bolinas and Duxbury Point. These three faults merge into a narrow (kilometer-wide) fault zone that extends northward through Olema Valley and under Tomales Bay. The three faults converge to a narrow point in the Olema Valley near Five Brooks. (USGS 2015c)

The east side of the Golden Gate Fault consists of Franciscan Complex, a mix of oceanic crustal rocks formed in the late Mesozoic Era (Jurassic and Cretaceous Periods) that gradually and more recently accreted onto the North American tectonic plate margin. Bolinas Ridge consists mostly of sandstone and metasandstone from the Cretaceous Period. Basalt formed on ancient submarine volcanoes, was metamorphosed to become greenstone, and now forms outcrops along SR 1 south of the Bolinas Y. Serpentinite occurs in scattered outcrops along SR 1and throughout the Mount Tamalpais area. The San Andreas Fault roughly parallels the western shore of Bolinas Lagoon. Unsorted and poorly consolidated terrace gravels are offset along this part of the fault and Pliocene- to Pleistocene-aged marine and marine-terrace deposits occur as the Merced Formation on the hillsides on the west side of the 1906 San Andreas Fault rupture. The San Gregorio Fault comes onshore on the east side of downtown Bolinas. The fault follows Paradise Valley west of Horseshoe Hill Road, crossing into Olema Valley. The fault scarp is visible as a steep slope east of the intersection of Olema Bolinas Road and Mesa Road. The east side of the fault is mapped as the Merced Formation and the west side of the fault is mapped as Santa Cruz Mudstone. (USGS 2015c)

South of the intersection of Bolinas Olema Road and SR 1, older Quaternary alluvial gravels (about 55,000 years) of the Olema Formation overlie weathered Franciscan bedrock along SR 1. The age of the gravels is based on correlation of volcanic ash found in this unit (USGS 2015c). The three distinct geologic units in the study area are represented by the six soil map units (Table 2, Figure 3).

Table 2. Soil Maps Units within the Study Area

Soil Map Unit	Location
Blucher-Cole complex 2 to 5 percent slopes	Floodplain
Cronkhite-Barnabe complex 9 to 15 percent slopes	Toeslope of Mount Tamalpais
Cronkhite-Barnabe complex 15 to 30 percent slopes	Toeslope of Mount Tamalpais
Hydraquents saline	Bolinas Lagoon
Palomarin-Wittenberg complex 50 to 75 percent slopes	Hillside south of State Route 1
Tocaloma-McMullin complex 30 to 50 percent slopes	Toeslope of Mount Tamalpais

Soils in the Bolinas Lagoon consist of saline hydraquents, which are salt-affected fine-textured marine sediments. These soils have very little profile development as they are formed from sediment deposition under water. The floodplain is mapped as the Blucher-Cole soil map unit, which consists of deep soils formed from alluvium in a gently sloped floodplain. Both the Blucher and Cole soil series are fine-textured somewhat poorly drained soils. (USDA 1985)

The toeslope of Mount Tamalpais is mapped as a combination of Cronkite-Barnabe and Tocaloma-McMullin soil map units, with slopes ranging from 9-50 percent. These units represent moderately deep soils formed from weathered sandstone and shale derived from the Franciscan Complex sedimentary rocks. Their depth, composition, and plant cover vary with aspect. (USDA 1985)

Horseshoe Hill to the west of SR 1 is mapped as the Palomarin-Wittenberg soil map unit, which consists of deep well-drained soils formed from siliceous shale. These soils vary greatly in terms of gravel content. (USDA 1985)

3.3 Cultural and Historical Setting

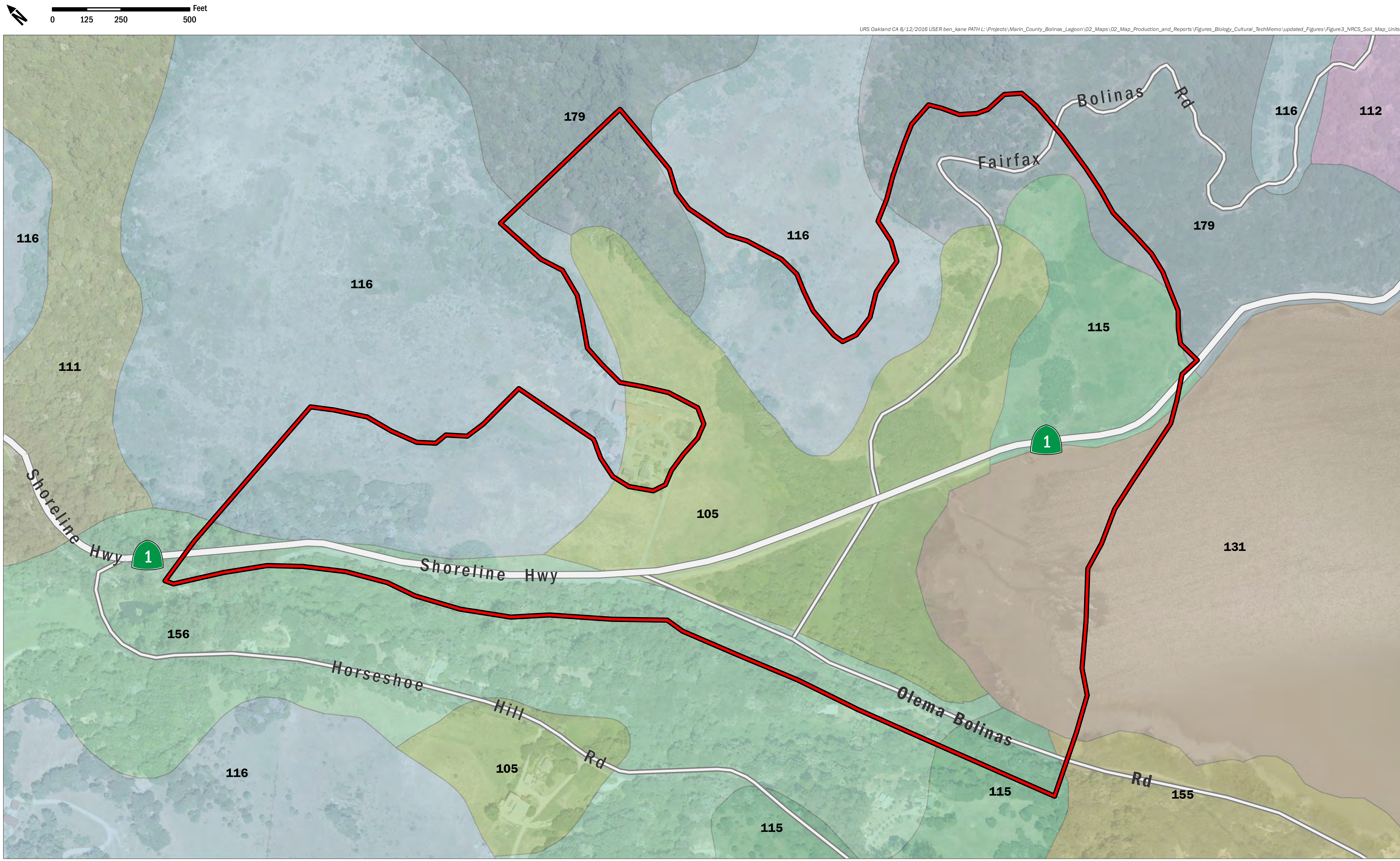
The study area is located within the Rancho Las Baulines (sometimes Baulenes) granted to Gregorio Briones in 1846 (Beck and Haase 1974:29; Calisphere 184-?; Gudde 1998:29; Livingston 1995:11). The 8,911-acre land grant extended around Bolinas Lagoon and encompassed present day Stinson Beach and the town of Bolinas (Beck and Haase 1974). The Briones adobe was said to be in the northeast boundary of the rancho, outside the current study area (Kyle et al. 2010:190).

At the time of European settlement, the study area was included in the territory controlled by the Coast Miwok (Kelly 1978). The Coast Miwok were hunter-gatherers who lived in large, permanent villages and occupied seasonal camps and task-specific sites. Sites were often situated near freshwater sources and in environments where plant and animal life were diverse and abundant. Kelly (1978:415) shows the nearest village, called bauli-n, on the eastern shore of Bolinas Lagoon outside the current study area.

Historical topographic quadrangles (USGS 1897, 1941) reveal several late 19th and early 20th century buildings and other possible historic features within or proximal to the study area. The farmhouse, barns, and outbuildings on Wilkins Ranch, west of Wilkins Gulch, appear to be of this era (Livingston 1995:70; USGS 1897, 1941). At least one building on the Wilkins Ranch predates 1897, and the remaining buildings appear to be from the early 20th century (USGS). The Wilkins Ranch is currently outside the study area, but within the viewshed of the North End project. Another building, possibly the Oyster House restaurant, was depicted on the western bank of the lagoon near the intersection of Olema-Bolinas Road and SR-1, within the current study area, however the building is no longer depicted after 1997 (Van Kirk 2000; USGS 1897, 1997). The lighter wharf (Historical Landmark #221) was said to be located on the northern tip of the lagoon on its western bank—the exact location is unknown, but presumably within the current study area—and is no longer evident, nor is there a commemorative plaque (CA OHP 1996).

The Wilkins Ranch and the wharf represent an era when timber and sawmills operated at Dogtown, northwest of the lagoon. William Wallace Wilkins, a “forty-niner” from Massachusetts, leased land from Captain Isaac Morgan, and eventually purchased the tract that became the Wilkins family ranch in 1866 and 1868 (Livingston 1995:75). During the mid-1800s, lumber from the Dogtown area was shipped via the lighter wharf onto barges (called lighters), which floated out to deeper water where larger boats would bring the much-needed lumber to the rapidly growing San Francisco (Livingston 1995; Kyle et al. 2002; Van Kirk 2000). It is estimated that 13 million feet of lumber were shipped from Bolinas to San Francisco for building purposes before the supply was exhausted in the 1870s (Kyle et al. 2002: 190). Wilkins Ranch operated as a dairy, and by the 1900s, produced 2,250 pounds of butter per month from 64 cows (Livingston 1995:80). For further information about the Wilkins Ranch and the lumber industry in Bolinas see Livingston (1995) and Van Kirk (2000).

URS Oakland CA 8/12/2016 USER ben_kane PATH L:\Projects\Marin_County_Bolinas_Lagoon\02_Maps\02_Map_Production_and_Reports\Figures_Biology_Cultural_TechMemo\updated_Figures\Figure3_NRCS_Soil_Map_Units.mxd



Study Area

NRCS Soil Map Units

- 105 Blucher-Cole complex, 2 to 5 percent slopes
- 111 Centissima-Barnabe complex, 30 to 50 percent slopes
- 112 Centissima-Barnabe complex, 50 to 75 percent slopes
- 115 Cronkhite-Barnabe complex, 9 to 15 percent slopes
- 116 Cronkhite-Barnabe complex, 15 to 30 percent slopes
- 131 Hydraquents, saline
- 155 Palomarin-Wittenberg complex, 30 to 50 percent slopes
- 156 Palomarin-Wittenberg complex, 50 to 75 percent slopes
- 179 Tocaloma-McMullin complex, 30 to 50 percent slopes

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FIGURE 3

NRCS Soil Map Units

Data Source: 2003 USDA NRCS, STATSGO2 1:250,000.

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4 Survey Results

The following sections describe the surface water salinity, the biological conditions (including plant communities, potential special-status species, wetlands and other waters), and the cultural resources in the study area. Several figures illustrate these results. Figures 4.1 through 4.4 present the waters and wetlands. Figures 5.1 through 5.5 show the locations of the vegetation communities, and Figure 6 illustrates the wildlife habitats. Figure 7 shows the cultural and archaeological resources identified in the study area.

4.1 Surface Water Salinity Levels

Surface water salinity measurements were taken throughout the study area to augment the habitat suitability assessment, under current climate conditions, for special status species (Table 3, Figure 2).

Table 3. Water Sample Salinities from Representative Locations in the Study Area[1]

Sample #	Salinity (ppt)	Sample Date (2015)	Sample By
1	5	4/17	Lim
2	0	4/17	Peracca
3	0	4/17	Lim
4	7	4/20	Novak
5	25	4/20	Novak
6	0	4/20	Novak
7	0	4/20	Novak
8	0	5/5	Peracca
9	18	5/5	Peracca
10	0	5/5	Peracca
11	0	5/5	Peracca

[1] Water samples were collected by AECOM Staff (Tammy Lim, Galen Peracca, Jan Novak) and measured in the office by Francesca Demgen, 4/28/15 and 5/18/15. Water samples were collected to inform and augment the habitat suitability assessment.

Salinity values vary with the location based upon different factors including surface and groundwater input, drought conditions, topography, and tidal level. While salinity values at some locations may fluctuate through the tidal cycle, the presence or absence of salinity is a significant factor influencing vegetation communities and wildlife habitat suitability. The presence of salinity was noted in the pond east of Fairfax Bolinas Road, in the ditch north of SR 1 (draining Wilkins Gulch Creek) and in the Bolinas Lagoon. No salinity was measured in Wilkins Gulch Creek, west of Fairfax Bolinas Road, within the northern portion of the Bolinas "Y", or in the southwest portion of the study area (Figure 2). Salinity values in current drought conditions likely do not reflect values under more typical climate conditions.

4.2 Biological Conditions

The study area consists primarily of mudflat, freshwater, brackish and salt marsh, riparian forest (alder and willow), and grasslands. Areas of scrub and eucalyptus forest are also present, but are smaller and scattered. Throughout most of the vegetation communities in the study area, native plants grow intermixed among non-native plant species. Riparian and wetland vegetation, consisting of moisture-dependent trees, shrubs, and forbs, occupy portions of the intermittent and perennial creeks and drainages, as well as the area around the pond. The study area provides habitat for special-status plant and animal species such as steelhead trout (*Oncorhynchus mykiss*) and red-legged frogs (*Rana draytonii*). Within the lagoon and adjacent to the study area there are rookeries for egret and heron nesting, harbor seal (*Phoca vitulina*) pupping areas and intertidal wetlands, and habitat for rare plants.

4.2.1 Vegetation Communities

Fourteen natural and semi-natural plant communities defined in the MCV2 were identified within the study area boundary. An additional four communities not listed within the MCV2 were also identified within the study area. These communities were deemed important enough to designate and define independently. Within the 18 communities, approximately 300 unique plant species were identified during surveys; these are presented in Appendix B, along with their native status, invasive rating, and wetland indicator status. Table 4 lists the plant communities identified in the study area, the acreage and the percentage of the study area they cover, and their state rarity status as described by CDFW (see footnote 2 in Table 4 for rarity definitions). The text below provides descriptions of each community and species[4] noted within them. Detailed vegetation cover and composition results from plots taken in each vegetation community are provided in Appendix A.

Table 4. Natural Plant Communities within the Study Area

Plant Community Scientific Name[1]	Plant Community Common Name	Acreage in the study area	Percent of total study area[2]	State Status[3]
Alnus rubra Forest Alliance	Red Alder Forest	5.91	5.76	S4
Artemisia californica Shrubland Alliance	California Sagebrush Scrub	1.06	1.03	S5
Baccharis pilularis Shrubland Alliance	Coyote Brush Scrub	5.16	5.03	S5
Broom (*Genista monspessulana*) Semi-Natural Shrubland Stands	French Broom Scrub	0.60	0.58	NA
Bolboschoenus maritimus Herbaceous Alliance	Alkali-Bulrush Marshes	2.54	2.47	S3
Carpobrotus edulis or other Ice Plants Stands	Ice Plant mats	0.26	0.25	NA
Distichlis spicata Herbaceus Alliance	Salt Grass Flats	1.79	1.74	S4
Ecualyptus sp.Semi-Natural Stands	Eucalyptus Groves	1.08	1.05	NA
Juncus arcticus (var. *balticus*, *mexicanus*) Herbaceous Alliance	Baltic and Mexican Rush Marshes	0.83	0.81	S4
Quercus agrifolia Woodland Alliance	Coast Live Oak Woodland	19.83	19.32	S4
Rubus ursinus Shrubland Alliance	Coastal Brambles	1.23	1.20	S3
Salix lasiolepis Shrubland Alliance	Arroyo Willow Thickets	10.30	10.03	S4

[4] The common name and scientific name of each species are generally listed only at the first use in the text below; common names are used thereafter.

Table 4. Natural Plant Communities within the Study Area

Plant Community Scientific Name[1]	Plant Community Common Name	Acreage in the study area	Percent of total study area[2]	State Status[3]
Salicornia pacifica Herbaceous Alliance	Pickleweed Mats	3.92	3.82	S3
Typha Herbaceous Alliance	Cattail Marsh	0.78	0.76	S5
Umbellularia californica Forest Alliance	California Bay Forest	0.72	0.70	S3
Other Alliances				
Equisetum telmateia Herbaceous Alliance	Giant Horsetail Marsh	0.87	0.85	NA
Carex praegracilis Herbaceous Stands	Clustered Field Sedge Marsh	0.92	0.90	NA
	California Annual Grassland	32.38	31.54	NA
	Ruderal	1.39	1.35	NA

[1] Plant Community Names (Alliances) based on naming conventions in the Manual of California Vegetation, 2nd ed (MCV2)
[2.] Total study area equals 102.65 acres.
[3] State Ranking (State of California: The Resources Agency. Department of Fish and Wildlife Biogeographic Data Branch: California Natural Diversity Database, 2007)
S1 = Less than 6 element occurrences (EO)s OR less than 1,000 individuals OR less than 2,000 acres
S2 = 6-20 EOs OR 1,000-3,000 individuals OR 2,000-10,000 acres
S3 = 21-100 EOs or 3,000-10,000 individuals OR 10,000-50,000 acres
S4 - Apparently secure within California
S5 - Demonstrably secure to ineradicable in California

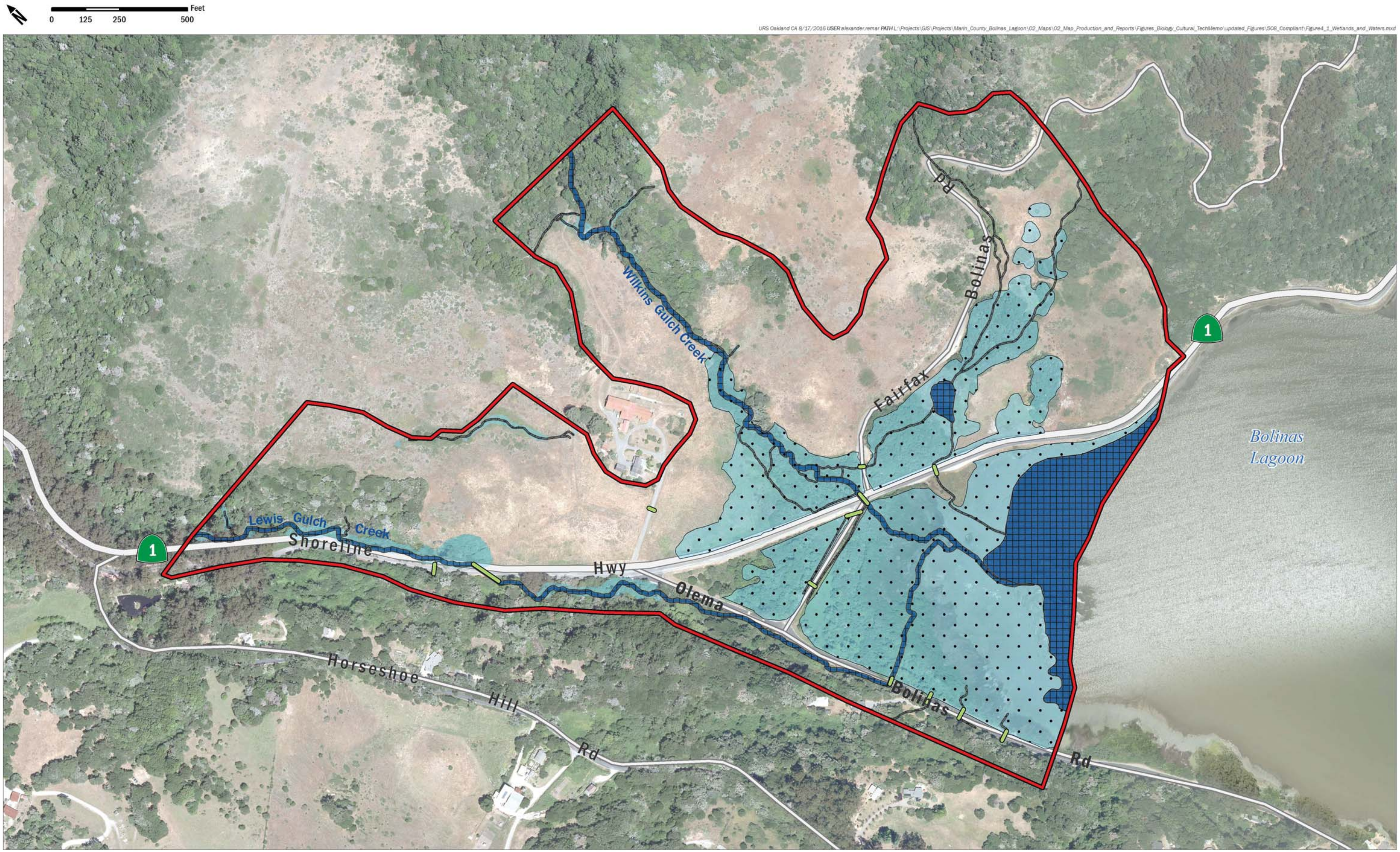

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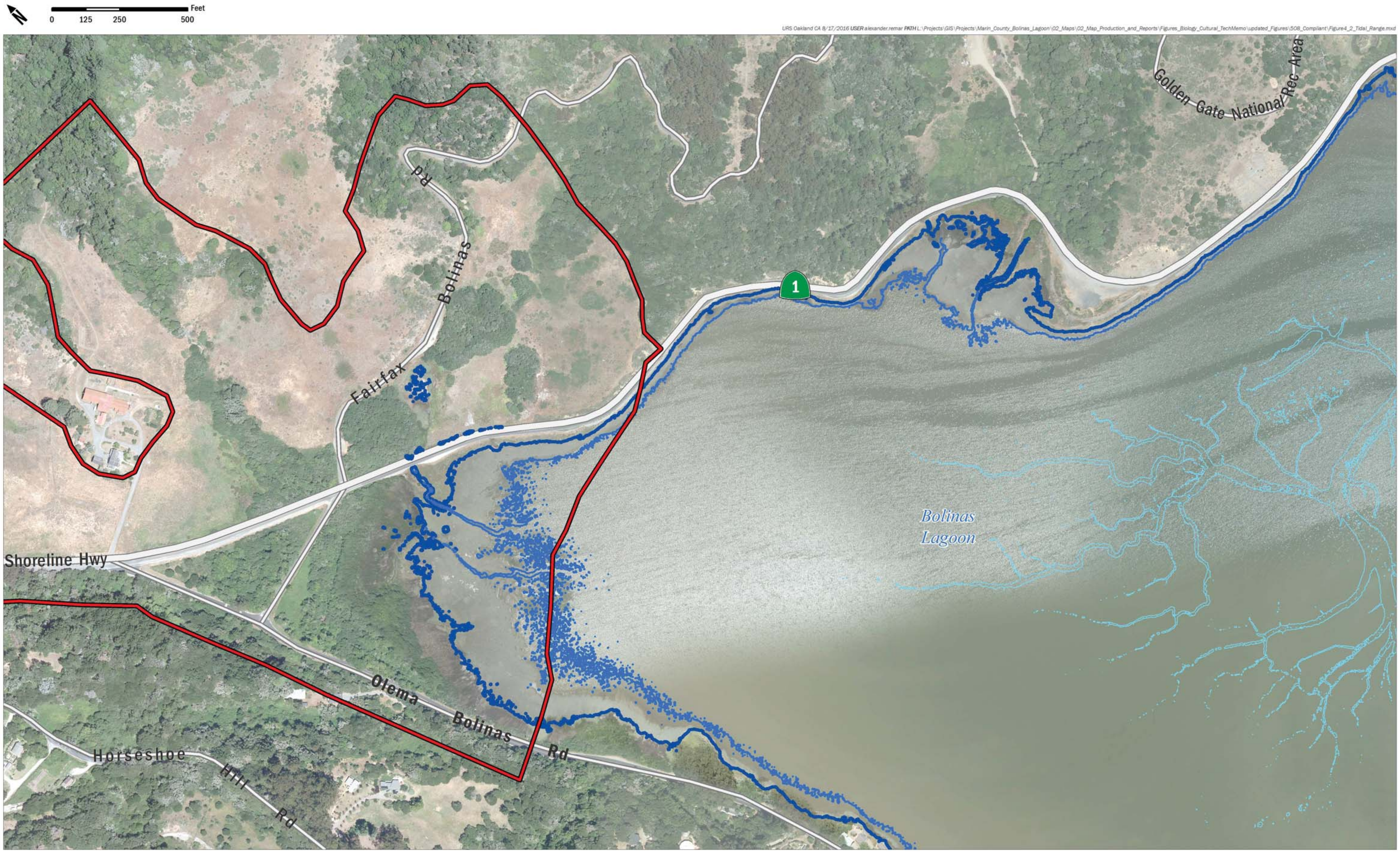
FIGURE 4.1
Wetlands and Waters



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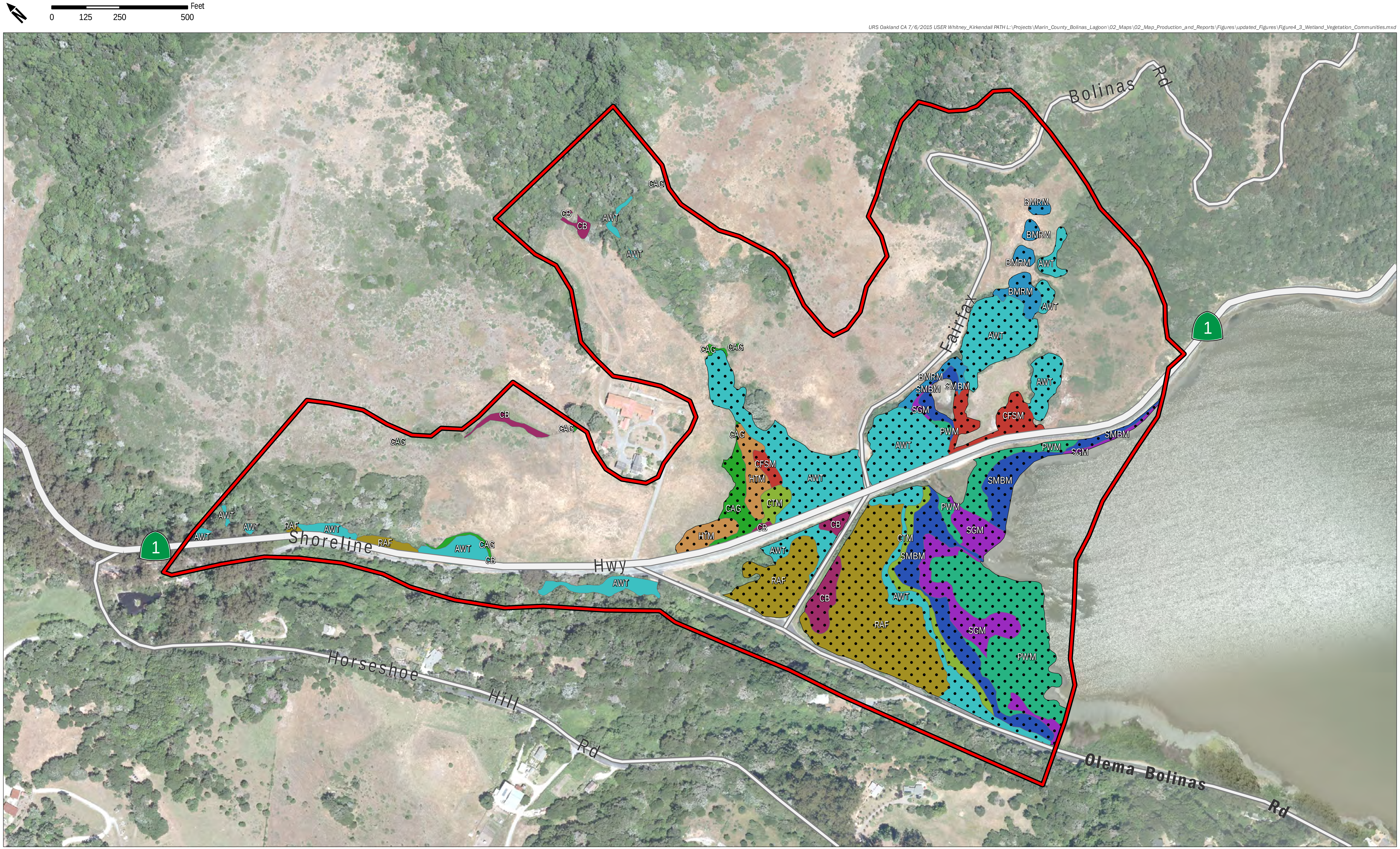
Bolinas Lagoon Restoration

Study Area
Mean Lower-Low Water (MLLW), 1.20 Ft
Mean Sea Level (MSL), 3.52 Ft
Mean Higher-High Water (MHHW), 5.60 Ft

Data Sources:
MHHW, MSL, San Francisco Bay LiDAR, USGS, 2010-2011
MLLW, Golden Gate LiDAR, USGS/SFSU, 2010

FIGURE 4.2
Tidal Range



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Bolinas Lagoon Restoration

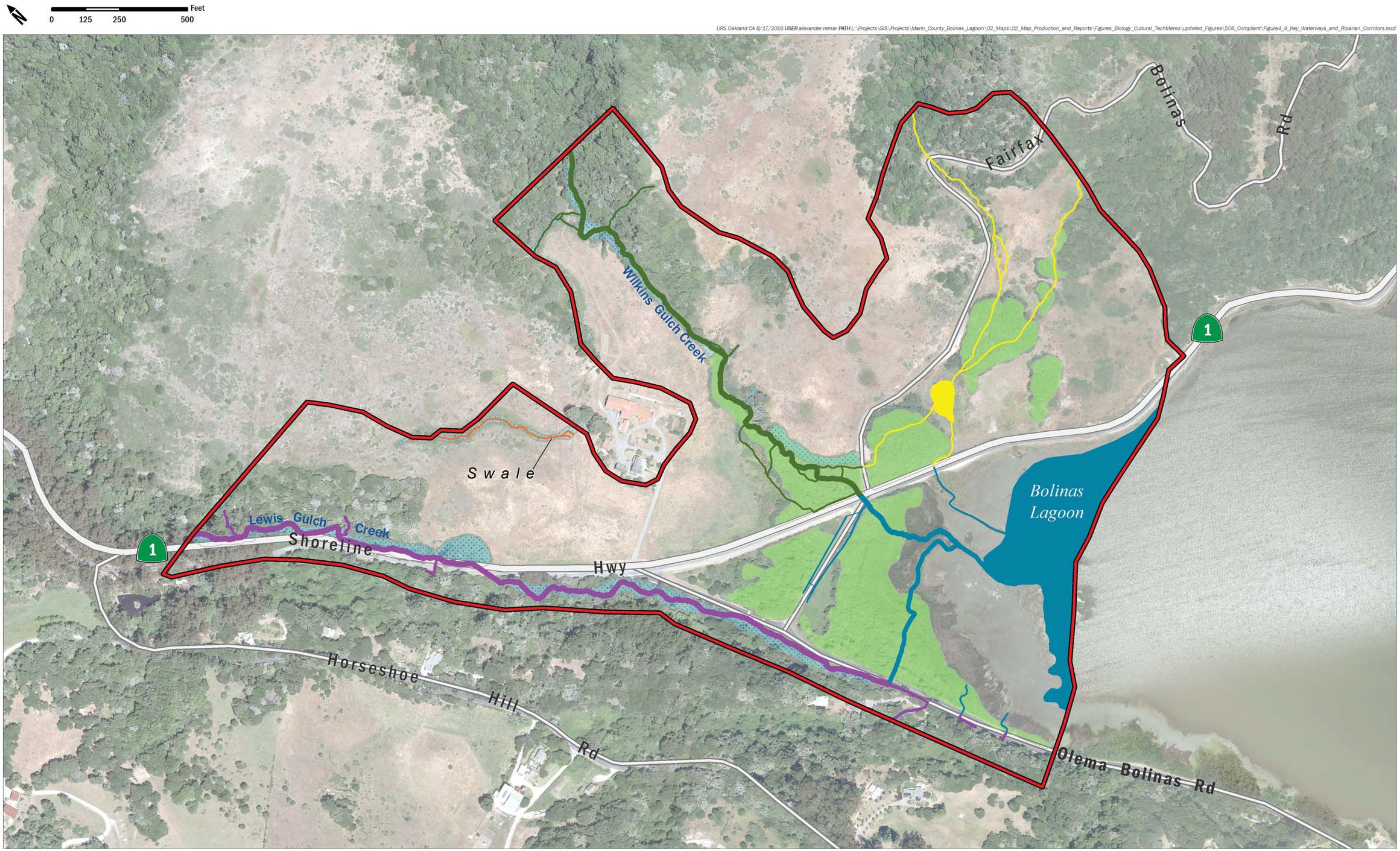
- Study Area
- Wetland (Federal)

Wetland Types

- Arroyo willow thicket (AWT)
- Baltic and Mexican rush marsh (BMRM)
- California annual grassland (CAG)
- Cattail marsh (CTM)
- Coastal brambles (CB)
- Giant horsetail marsh (HTM)
- Pickleweed mats (PWM)
- Salt grass flats (SGM)
- Salt marsh bulrush marsh (SMBM)
- Clustered field sedge marsh (CFSM)
- Red alder forest (RAF)

FIGURE 4.3

Wetland Vegetation Communities



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Bolinas Lagoon Restoration

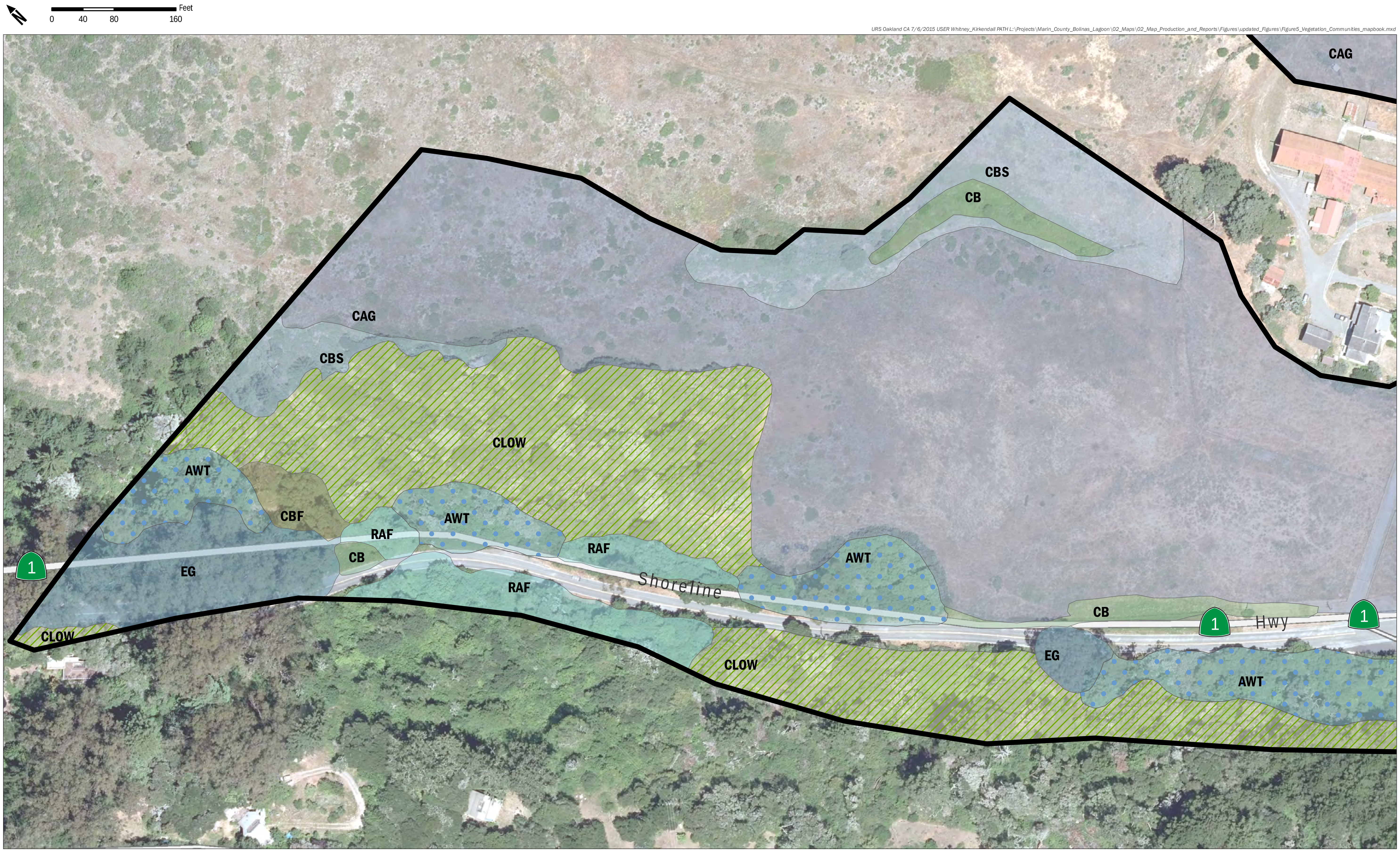
Study Area

Key Waterways
- Bolinas Lagoon
- Unnamed Drainages and Pond
- Swale
- Lewis Gulch Creek
- Wilkins Gulch Creek

Riparian Corridors
- State Riparian
- Federal Riparian

FIGURE 4.4

Key Waterways and Riparian Corridors



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Bolinas Lagoon Restoration

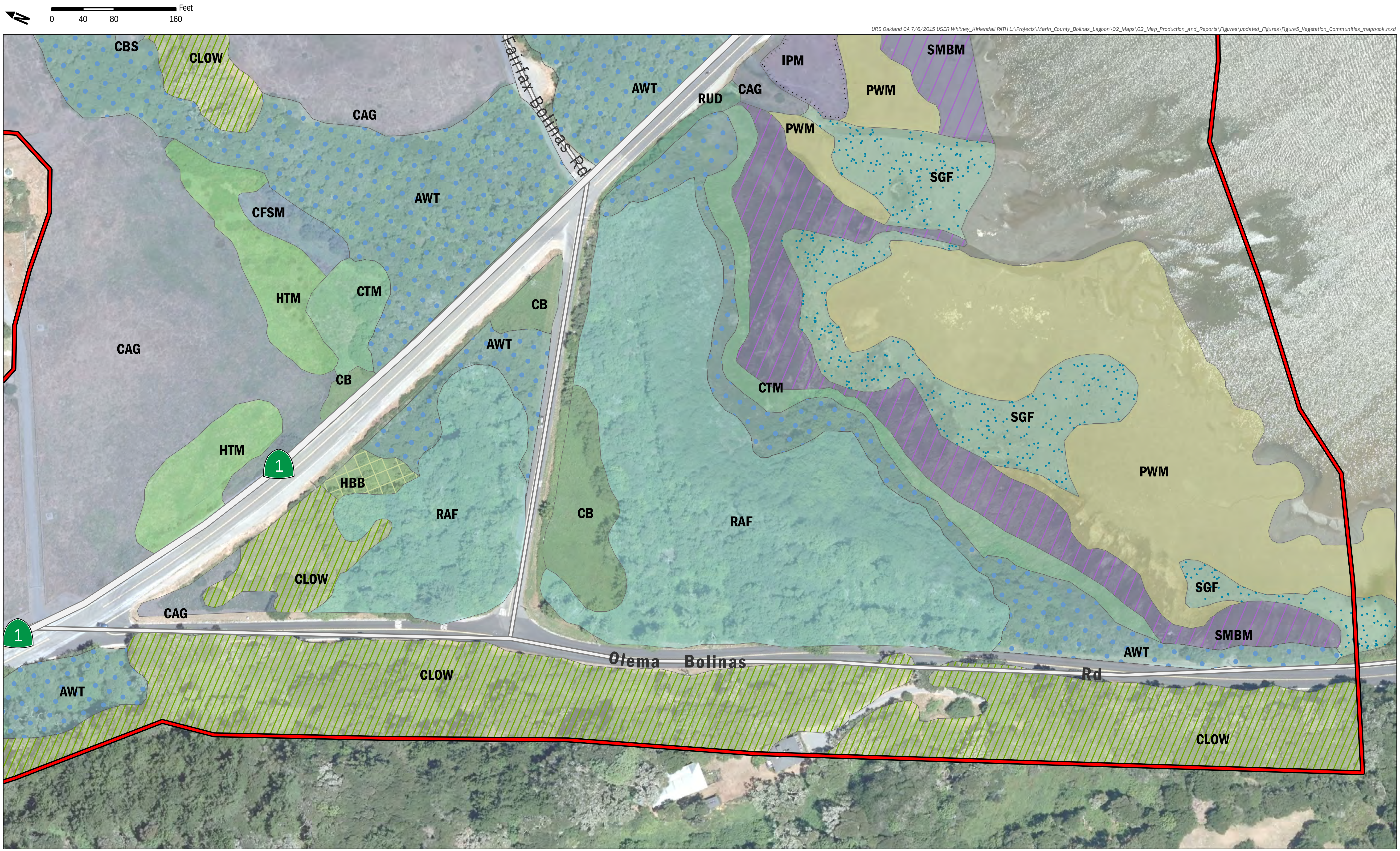
Study Area

Vegetation Community

- Arroyo willow thicket (AWT)
- California annual grassland (CAG)
- California bay forest (CBF)
- Coast live oak woodland (CLOW)
- Coastal brambles (CB)
- Coyote brush scrub (CBS)
- Eucalyptus grove (EG)
- Red alder forest (RAF)

FIGURE 5.1

Vegetation Communities



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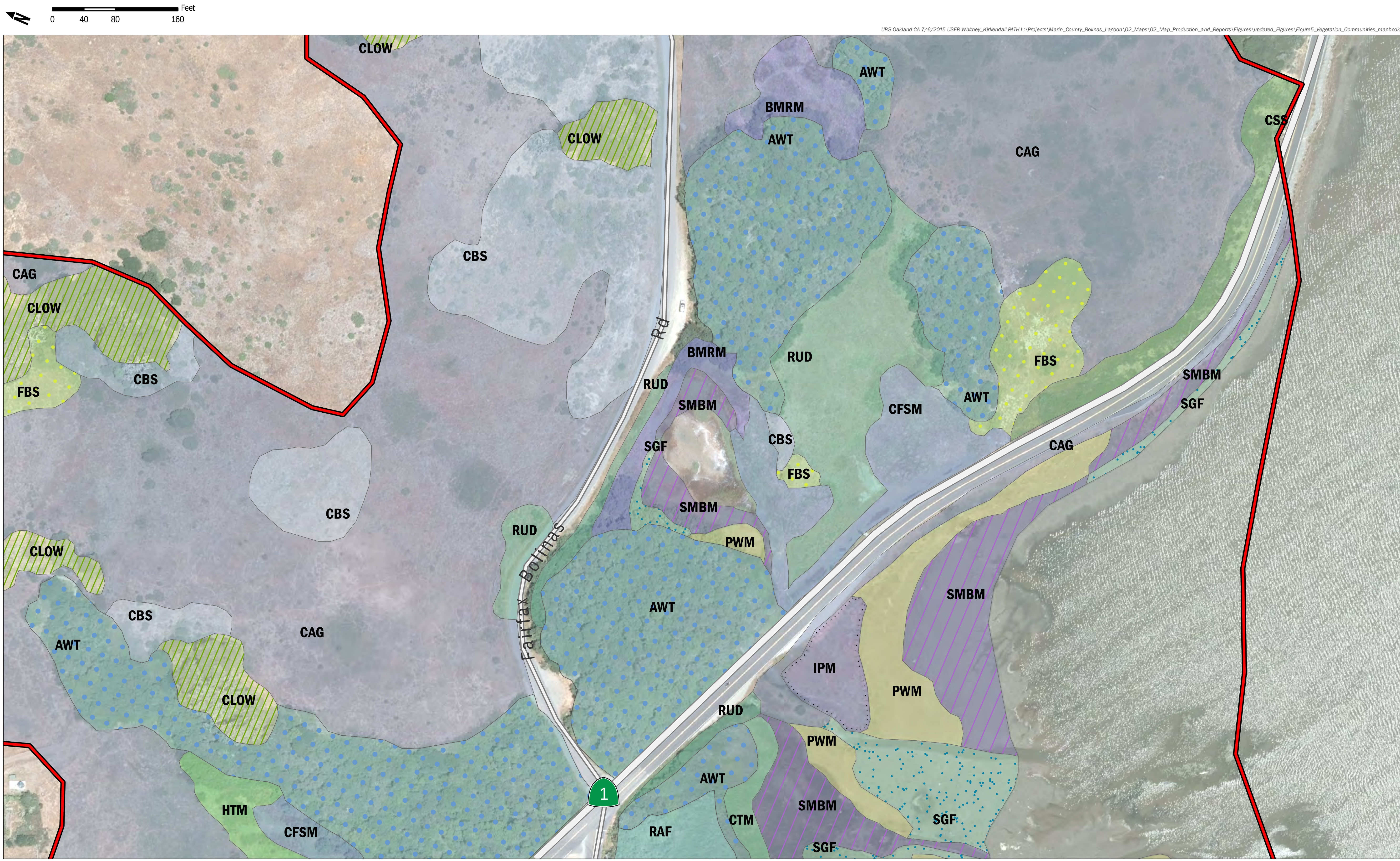
Study Area

Vegetation Community

- Arroyo willow thicket (AWT)
- California annual grassland (CAG)
- Cattail marsh (CTM)
- Coast live oak woodland (CLOW)
- Coastal brambles (CB)
- Coyote brush scrub (CBS)
- Giant horsetail marsh (HTM)
- Himalayan blackberry brambles (HBB)
- Ice plant mats (IPM)
- Pickleweed mats (PWM)
- Ruderal (RUD)
- Salt grass flats (SGF)
- Salt marsh bulrush marsh (SMBM)
- Clustered field sedge marsh (CFSM)
- Red alder forest (RAF)

FIGURE 5.3
Vegetation Communities



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Study Area

Vegetation Community

- Arroyo willow thicket (AWT)
- Baltic and Mexican Rush Marsh (BMRM)
- Broom patches (FBS)
- California annual grassland (CAG)
- California sagebrush scrub (CSS)
- Cattail marsh (CTM)
- Coast live oak woodland (CLOW)
- Coyote brush scrub (CBS)
- Giant horsetail marsh (HTM)
- Ice plant mats (IPM)
- Pickleweed mats (PWM)
- Ruderal (RUD)
- Salt grass flats (SGF)
- Salt marsh bulrush marsh (SMBM)
- Clustered field sedge marsh (CFSM)
- Red alder forest (RAF)

FIGURE 5.4

Vegetation Communities

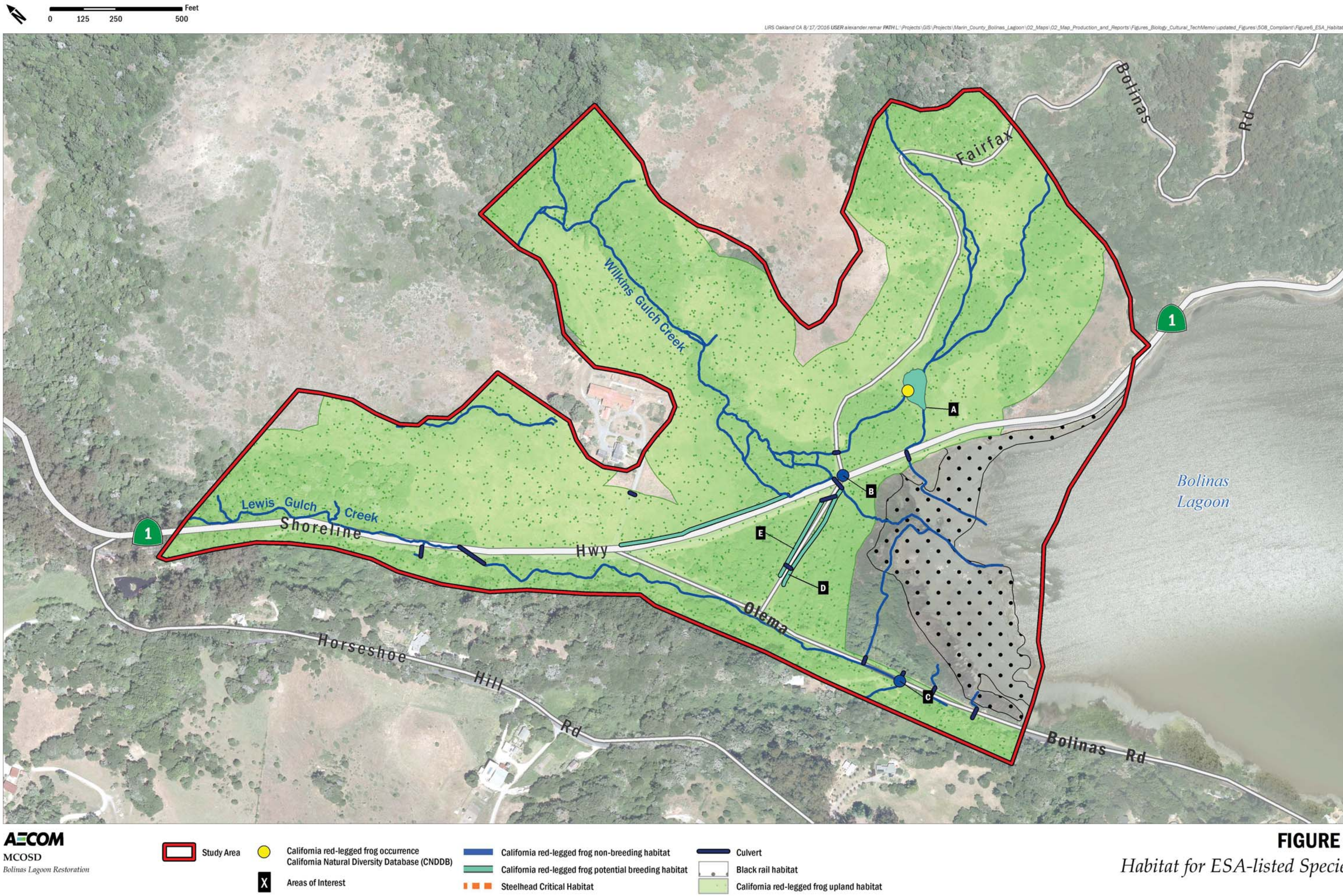

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FIGURE 6
Habitat for ESA-listed Species

Alnus rubra Forest Alliance (Red Alder Forest)

Within the study area, red alder forest is abundant along streams and riparian floodplains northwest of Bolinas Lagoon. It contributes a total of 5.91 acres within the study area (5.76% of the study area) and is the predominant alliance within the Lewis Gulch Creek floodplain. Red alder forest in the study area appears to be moist for most of the year, having saturated soils in summer and containing areas of flowing water into late spring. Red alder forest within the study area often share boundaries with arroyo willow thickets and coast live oak woodland, and are separated as a community wherever alder is the most abundant tree in the highest canopy, generally forming about 35% absolute cover within the community, and 50-100% of the canopy. The red alder forest is ranked as S4, and is not considered a special-status community within the state of California. It is considered a riparian community and protected under Sections 1600-1603 of the State Fish and Game code. It may also be considered a jurisdictional wetland depending upon soil and hydrology conditions.

In this alliance in the study area, red alder (*Alnus rubra*) trees are typically between 8 and 12 inches DBH and co-dominant with arroyo willow (*Salix lasiolepis*), which form the shrub layer. Throughout the study area, the understory of red alder forest is very dense, reaching up to 100% cover, not including the shrub and tree canopy. In addition to smaller willows, the ground layer supports shade-tolerant freshwater marsh species in perennial wetland depressions (small-fruited bulrush, *Scirpus microcarpus*; water pennywort, *Hydrocotyle ranunculoides*; smartweed, *Persicaria punctata*; water-parsley *Oenanthe sarmentosa*) and relatively mesic. Seasonal wetlands under alder canopy support dense stands of stinging nettle (*Urtica doica*), California bee plant (*Scrophularia californica*), California blackberry (*Rubus ursinus*), and rushes (*Juncus* spp.). Open gaps along alder grove margins support white alder (*Alnus rhombifolia*), redroot umbrella sedge (*Cyperus eragrostis*), fringed willowherb (*Epilobium ciliatum*), horsetail (*Equisetum* spp.); and non-native poison hemlock (*Conium maculatum*), wild radish (*Raphanus sativus*), Fuller's teasel (*Dipsacus fullonum*), docks (*Rumex* spp.), and cattail (*Typha latifolia*).

Artemisia californica Herbaceous Alliance (California sagebrush scrub)

In the study area, California sagebrush scrub is found in patches between grasslands and oak woodland, where it intersperses with the *Baccharis pilularis* shrubland alliance and *Quercus agrifolia* forest alliance. It comprises a total of 1.06 acres within the study area (1.03% of the study area). It is visible on steep cliff sides, including above SR 1, on the eastern side of the study area. The community occurs exclusively within the Coast Ranges of the California Floristic Province. California sagebrush scrub is ranked as S5, and therefore is not a special-status vegetation community in California.

In the study area, vegetation in this alliance is often dense, with as much as 80% absolute cover of all vegetation. Shrubs form about 70% of this vegetation, and 60% of these are California sagebrush (*Artemisia californica*). Other shrub species within the community include non-native French broom (*Genista monspessulana*), toyon (*Heteromeles arbutifolia*), and poison oak (*Toxicodendron diversilobum*). In spite of the presence of French broom, this alliance contains a high diversity of native species within the study area, including California blackberry, woodland strawberry (*Fragaria vesca*), morning glory (*Calystegia* sp.), soap plant (*Chlorogalum pomeridianum*), blue dicks (*Dichelostemma capitatum*), Douglas iris (*Iris douglasiana*), and Galiums (*Galium* spp.). Where it occurs on roadcuts or adjacent to disturbances, the alliance is often surrounded by non-native annual grasses.

Baccharis pilularis Shrubland Alliance (Coyote Brush Scrub)

Within the study area, coyote brush scrub is found on ridges, rocky outcrops, and areas between forest and grasslands. In some areas, it may even grow adjacent to wetlands and moist ravines. Coyote brush scrub is ranked S5, and therefore is considered a common plant community within the State of California. It comprises of 5.16 acres of the study area (5.03% of the study area).

In the study area, cover in this community is often dense, forming 90% absolute vegetative cover, of which 75% consists of woody shrubs. Coyote brush (*Baccharis pilularis*) has about 45% absolute cover and covers about 60% of the woody layer. Minor shrubs and forbs found in the community include poison oak, purple needlegrass (*Stipa pulchra*), California blackberry, emergent coast live oak (*Quercus agrifolia*), and non-native French broom, and other coastal scrub species.

Salix lasiolepis Shrubland Alliance (Arroyo Willow Thicket)

Within the study area, arroyo willow thickets are abundant on riparian floodplains, on the edges of creeks and swales, and fringing the forests west of Bolinas Lagoon. It accounts for a total of 10.30 acres of the study area (10.03% of the study area). Willow thickets also dominate the upper edges of the tidal marsh, behind alkali-bulrush (*Bolboschoenus maritimus*) marsh, within the study area. The alliance often occurs in association with the *Alnus rhombifolia* forest alliance and the *Quercus agrifolia* forest alliance, and intergrades with both. In spite of overlap between the dominant species, the areas of overlap tend to be narrow and arroyo willow groves stand out. This alliance is the most abundant woody community within the study area. *Salix lasiolepis* shrubland is ranked S4, and is not considered a special-status plant community in California.

The arroyo willow thickets in the study area are dense, reaching over 150% absolute cover. Approximately 80% of this cover is in the canopy layer and is almost exclusively composed of arroyo willow ($\leq$ 75%). The canopy layer may contain emergent red or white alder (*Alnus* spp.) (at around 5%); however, these alders are typically immature. By contrast, mature arroyo willows are abundant in the red alder forest alliance understory. Additional species found in the understory in the study area include California blackberry, which forms dense brambles below the willows; or an assortment of hardstem bulrush, sedges (*Carex* spp.), rushes (*Juncus* spp.), redroot umbrella sedge, fringed willow herb, horsetail, sword fern (*Polystichum munitum*), and giant chain fern (*Woodwardia fimbriata*). Non-native poison hemlock, wild radish (*Raphanus sativus*), Fuller's teasel, docks (*Rumex* spp.), and broadleaf cattails (*Typha latifolia*) are common along the margins of the community, where it is adjacent to grassland.

Broom (Genista monspessulana) Semi-Natural Shrubland Stands [French Broom Scrub]

Broom semi-natural shrubland stands within the study area are exclusively dominated by shrubby French broom, and therefore referred to as "French Broom Scrub" (and shown on Figure 5 as "Broom Patches (FBS)". French broom scrub occurs in disturbed or semi-disturbed areas within the study area, such as above SR 1 on the northern shore of Bolinas Lagoon, and adjacent to ruderal and grassy areas throughout the study area. In total, it accumulates to 0.60 acres of the study area (0.58% of the study area). It has also invaded more interior areas, including hillsides above Wilkins Gulch Creek. French broom is a Cal-IPC High-listed invasive weed, considered to have high potential for negative impact on native ecosystems.

In the study area, French broom forms 65% absolute cover, and 65% relative cover within the French Broom Scrub community. It intergrades with California annual grassland, ruderal habitat, and sometimes coyote brush scrub and coast live oak woodland. The stands contain 95% vegetative cover, mostly consisting of understory species. It is often the sole woody plant within the alliance, composing 65% absolute cover of the canopy and 100% relative cover of weedy broom species. In some cases, Spanish broom (*Spartium junceum*), Scotch broom (*Cytisus scoparius*), coyote brush, and other woody shrubs may occur on the fringes of this alliance. Much of the French broom scrub within the study footprint appears young, not reaching over 100% absolute cover, as it may when the shrubs are mature and overlapping. The understory of the community includes fennel (*Foeniculum vulgare*), and various weedy, non-native species including teasel, biennial flax (*Linum bienne*), soft brome (*Bromus hordeaceus*), big rattlesnake grass (*Briza maxima*), little rattlesnake grass (*Briza minor*), rough cat's ear (*Hypochaeris radicata*), soft cat's ear (*Hypochaeris glabra*), and false broom (*Brachypodium distachyon*). Native salt grass (*Distichlis spicata*), particularly in areas along SR 1, immediately adjacent to the lagoon, where salt grass is dominant, and California ponysfoot (*Dichondra donelliana*) may be found in densities up to 5% within French broom scrub.

Bolboschoenus maritimus Herbaceous Alliance (Alkali-Bulrush Marshes)

In the study area, salt marsh bulrush marshes are among the most abundant alliances, forming a continuous strip between the more freshwater cattail marsh or arroyo willow thickets to the west and

the more littoral pickleweed mats and salt grass flats. Alkali-bulrush marshes are also found around the pond. A total of 2.54 acres of the study area is considered alkali-bulrush marshes (2.47% of the study area). The alliance is ranked S3 by the State of California and is considered to be a threatened special-status plant community.

Within the study area, the alliance forms comparatively productive, dense, and tall single-species stands, which typically indicate low salinity stress (oligohaline to mesohaline marsh soil porewater salinity). Alkali-bulrush stands elsewhere in Bolinas Lagoon tidal marshes are associated with brackish transition zones of groundwater seepage discharge zones or stream mouths. Vegetative cover within the community, within the study area, is approximately 70%; the remaining 30% is composed of mud or water. The stands are be formed almost exclusively of native species, pickleweed (*Salicornia pacifica*), salt grass, dune rush (*Juncus lescurii*), common spikerush (*Eleocharis macrostachya*), and saltbrush (*Atriplex patula*). Salt marsh bulrush is visually dominant (standing anywhere from 1 decimeter to 2 meters tall) and overshadows the vegetation below. An observed minor species and non-native species identified with this alliance is jaumea (*Jaumea carnosa), and* creeping bent-grass (*Agrostis stolonifera*), respectively.

Distichlis spicata Herbaceous Alliance (Salt Grass Flats)

Within the study area, salt grass flats are abundant on the tidal flats of Bolinas lagoon, and the adjacent muddy shores. The community forms discontinuous patches between pickleweed mats and salt marsh bulrush marshes. A small patch of the community is also present at the pond. The extent of salt grass flats within the study area adds up to 1.79 acres (1.74% of the study area). The alliance is ranked S4 by the State of California, and therefore is not a special-status plant community.

Where it was examined in the study area, salt grass flat contained 100% vegetative cover, 90% of which was salt grass (both absolutely and relatively). Salt marsh bulrush, jaumea, pickleweed, silverweed cinquefoil (*Potentilla anserina;* syn*. Argentina egedii*), and fathen were also present in Salt Grass Flats. The density of salt grass flats is variable, as it intergrades freely with pickleweed marshes. Along the fringes, where it is closest to the tidal lagoon, it often occurs in mixed stands with multiple salt marsh or brackish marsh plants.

Eucalyptus (globulus, camaldulensis) Semi-Natural Stands (Eucalyptus Groves)

Within the study area, Eucalyptus groves are the dominant community type along SR 1, from the intersection of Horseshoe Hill Road and SR 1 north. The eucalyptus trees in these groves are the largest trees within the study area, both in terms of diameter and height. Trees immediately beside the road averaged in size from 18-30 inches DBH. Larger individuals, measuring more than 40 inches DBH were visible on steep slopes east of Hwy 1 in inaccessible portions of the study area. A total of 1.08 acres of the study area are Eucalyptus groves (1.05% of the study area). Eucalyptus groves are dominated by blue gum (*Eucalyptus globulus*) which is considered to be a moderate threat by Cal-IPC (2006), and therefore is not a special-status plant community.

Eucalyptus groves in the study area contain as much as 120% absolute cover, with blue gum supporting 60% or more of this cover. Although eucalyptus groves typically have a high buildup of litter in the understory (leaves, seeds, and twigs that can suppress growth of understory plants) litter does not appear to persist on the ground in the study area as extensively as in nearby areas. Eucalyptus groves in the study area support an understory that includes some natives, such as California coffeeberry (*Frangula californica*), Pacific water parsley (*Oenanthe sarmentosa*), horsetail, and California man-root (*Marah fabacea*). In areas along the road, the understory contains weedier species such as Himalayan blackberry (*Rubus armeniacus*), cape ivy (*Delairea odorata*), and poison oak.

***Juncus* spp.(*J. lescurii*, *J. balticus*, *J. mexicanus*) Herbaceous Alliance (Salt, Baltic and Mexican rush stands)**

Within the study area, salt rush, Baltic rush, and Mexican rush stands are common in dense patches in brackish tidal marsh edges (*J. lescurii* and *J. balticus*) and seasonal wetlands of adjacent lowland meadows (*J. mexicanus* and *J. balticus*), totaling 0.83 acres of the study area (0.81% of the study area). They tend to have a high vegetative cover (90%), of which the rush comprises 60% absolute cover, and over 50% relative cover. A fair amount of persistent standing leaf litter is present and covers up to 10% of the community. Many rush stands are nearly single-species or single-dominant vegetation. Associated species include water parsley, silverweed cinquefoil, docks (*Rumex* spp.), water smartweed (*Persicaria* sp.), and (in upland areas), annual and perennial grasses and sedges. Baltic and Mexican rush marshes is ranked as S4, and is therefore not considered a special-status plant community.

***Quercus agrifolia* Woodland Alliance (Coast Live Oak Woodland)**

Within the study area, coast live oak woodland is the most abundant woody upland alliance, forming dense woodlands around the perimeter of the study area and the steeper portions of the Lewis Gulch Creek and Wilkins Gulch Creek drainages. One of the most prevalent alliances within the study area, coast live oak woodland covers 19.83 acres of it (19.32% of the study area). The alliance is comprised of mature trees measuring between 12 and 24 inches DBH. Coast live oak woodland is ranked by the state as an S4 community, and is therefore not considered a special-status plant community in California.

Within the study area, the community contains a great diversity of trees, including alders, Douglas fir (*Pseudotsuga menziesii*), California bay (*Umbellularia californica*), madrone (*Arbutus menziesii*), among others, and the community intergrades with the California Bay Forest, red alder forests, and arroyo willow thickets. On south-facing slopes in the study area, coast live oak woodland provides almost 100% vegetative cover, including both canopy and understory. Coast live oak is present at 50% relative and absolute cover, with California bay as a co-dominant providing as much as 20% relative cover. Douglas fir may be present at up to 10% relative cover, and California buckeye

(*Aesculus californica*) up to 5% relative cover. This community has a high diversity of native and non-native understory species, including a shrub layer with toyon, poison oak, California sagebrush, hairy honeysuckle (*Lonicera hispidula*), French broom, blueblossom ceanothus (*Ceanothus thyrsiflorus*), and coyote brush. California bee plant, soap plant, California man-root, woodland strawberry, and morning glories (*Calystegia* spp.) are present in the understory. On north-facing slopes, coast live oak woodland contains even higher absolute cover (155%) providing three diverse, robust canopy layers of plants. Coast live oak is present at 60% relative cover in the canopy, with California bay at 45% in both the highest canopy and the shrub layer. Hazelnut (*Corylus cornuta* var. *californica*) creates a dense shrub layer with 40% relative cover. The understory contains bracken fern (*Pteridium aquilinum*), California blackberry, poison hemlock, miner's lettuce, and a host of other herbs. Oso berry (*Oemleria cerasiformis*) and French broom are also common as emergent vegetation.

***Rubus [parviflorus, spectabilis, ursinus]* Shrubland Alliance (Coastal Brambles)**

In the study area, coastal brambles (native blackberry, salmonberry, and thimbleberry) specifically refer to areas dominated by California blackberry. This is not a common community type within the study area, totaling only 1.23 acres (1.20% of the study area), but it is found along SR 1, adjacent to the Point Reyes National Seashore (PRNS) property, and at the western end of the Bolinas "Y". It is also found along a drainage north of the PRNS property. Coastal brambles are ranked S3 and are considered a threatened plant community in California. . Native bramble stands occur primarily at the borders of wetlands, in contrast with invasive non-native Himalayan blackberry (*R. armeniacus*), which occurs in disturbed uplands as well as bordering wetland or mesic riparian areas.

Coastal brambles within the study area are typically dense, with 100% cover of vegetation. Nearly all of this vegetation (≤ 95 percent) is California blackberry; with emergent arroyo willow, horsetail, seep monkeyflower (*Mimulus guttatus*), sedges and rushes, spring vetch (*Vicia sativa*), cow parsnip (*Heracleum maximum*), coast manroot (*Marah oreganus*), and California wax myrtle (*Morella californica*) as minor components, with the exact composition depending on location.

***Salicornia pacifica* Herbaceous Alliance (Pickleweed Mats)**

Within the study area, pickleweed mats dominate or co-dominate the tidal marsh shoreline surrounding Bolinas lagoon above mean high water. Pickleweed forms contiguous mats, with salt grass flats, above and within the intertidal zone; it is also common at the pond east of SR 1. It is the most abundant herbaceous community type dominated by a native species, and contributes to 3.92 acres of the study area (3.82% of the study area). Although pickleweed as a species has a complex taxonomical history and the species at Bolinas lagoon is not necessarily clear, taxonomy adopted by the MCV2 is used here. Pickleweed mats are ranked S3, and are therefore considered a special-status plant community in California. In late summer, salt marsh dodder (*Cuscuta pacifica*) can co-dominate, and salt grass can co-dominate in wet years. Thus, composition during this year's extreme drought may overstate the relative dominance of pickleweed.

In pickleweed mats in the study area, vegetation cover averages 80%, with open water or mud being 20%. Pickleweed (*Salicornia pacifica* (formerly referred to as *Sarcocornia pacifica*)) occupies 75% absolute cover within the study area, with salt grass occurring along the fringes or patchily within the community, averaging 5%. Low-growing fathen, brass buttons (*Cotula coronopifolia*), salt marsh dodder, sea lavender (*Limonium californicum*), narrow-leaf gumplant (*Grindelia stricta* var. *angustifolia*), jaumea, alkali heath (*Frankenia salina*) and other species including creeping sea arrow-grass (*Triglochin concinna*) may be present along the edges, or in small numbers within the alliance.

***Carpobrotus edulis* or other Ice Plants Stands (Ice plant mats)**

In the study area, this community consists of 95% hybrid ice plant (*Carpobrotus edulis* x *chilensis*), the remaining 5% being leaf litter accumulating between the branches. Ice plant mats occur only in a small strip along SR 1 where the road enters the study area at the northern shore of Bolinas Lagoon, totaling only 0.26 acres (0.25% of the study area). Ice plants are ranked by Cal-IPC as High, and therefore this community is considered as having severe ecological impacts.

This "semi-natural" coastal vegetation (composed of invasive non-native single-species or single-dominant stands) is easily identified since ice plant mats often carpet large areas, smothering native vegetation and preventing other communities from establishing (Vivrette and Muller 1977).

***Cattail marshes* (*Typha latifolia*] Herbaceous Alliance)**

Cattail marshes are composed of species that are adapted to transitional areas between fresh and

brackish water. They are found throughout the study area, and more specifically at the margin between arroyo willow thicket and alkali-bulrush marsh, at the edge of Bolinas lagoon. Cattail marshes also occur between the riparian forest and grasslands along Wilkins Gulch Creek near PRNS property. In total, cattail marshes cover 0.78 acres of the study area (0.76% of the study area). Cattail marshes are S5 communities, a rank reserved for the most common plant communities in California.

In the study area, cattail marshes were usually well vegetated (80-100%), and dominated by native broadleaf cattail (*Typha latifolia*). Broadleaf cattail formed 30%-100% absolute cover and relative cover, and were occasionally co-dominant with giant chain fern, which was present at up to 60%. Rushes and sedges were also present where cattails appeared to have died back. Throughout the study area, it was noted that the cattails were almost always dead or dormant, and therefore, positive identification to species during surveys was difficult.

Umbellularia californica Forest Alliance (California bay forest)

The alliance contains some of the most characteristic flora of cismontane California. California bay (*Umbellularia californica*) is usually greater than 50% of the relative cover, and is co-dominant with bigleaf maple (*Acer macrophyllum*), alder, madrone, hazelnut, Douglas fir, and various oaks. It is found on 0.72 acres of the study area (0.70% of the study area). California bay forest is an S3 community type, and therefore is considered a special-status plant community in California.

Within the study area, the community is found mixed with coast live oak woodland, and it is difficult to divide. It is only common in the upland, interior portions of the study area. In the study area, California bay forest has 100% vegetated cover, across three strata. California bay was present at 70% relative cover. Blue elderberry (*Sambucus nigra*), hazelnut, and California blackberry were in the shrub layer at low densities (5-10%). Bracken fern and hedge-nettle (*Stachys* spp.) were present in the herb layer. Non-native herbs, including cape ivy, poison hemlock, milk thistle (*Silybum marianum*), bur clover (*Medicago polymorpha*), and common plantain (*Plantago lanceolata*) were present in low numbers.

California Annual Grassland

California annual grassland is defined as being dominated by one or more annual grasses and having no or very little shrub or tree layer. This is among the most abundant community types within the state of California and within the study area, where it accounts for a total of 32.38 acres (31.54% of the study area). In the study area, California annual grassland is a combination of a variety of alliances, including the wild oats grassland (*Avena* [*barbata*, *fatua*] Semi-Natural Herbaceous Stands), annual brome grasslands (*Bromus* [*diandrus, hordeaceus*]-*Brachypodium distachyon* Semi-Natural Herbaceous Stands), red brome or Mediterranean grass grasslands (*Bromus rubens-Schismus* [*arabicus, barbatus*] Semi-Natural Stands), cheatgrass grassland (*Bromus tectorum* Semi-Natural Herbaceous Stands), and common velvet grass—sweet vernal grass meadows (*Holcus lanatus-Anthoxanthum odoratum* Semi-Natural Herbaceous Stands). Because these alliances co-mingle, and dominants may differ depending on the season, it is accurate to combine them under the general category of California annual grassland.

Within the study area, California annual grassland is the most abundant upland community. It occurs in variable density, but averages around 85%. In addition to the species named above, California annual grasslands in the study area contain native creeping wildrye (*Elymus triticoides*), clustered field sedge (*Carex praegracilis*), California poppy (*Eschscholzia californica*), sky lupine (*Lupinus nanus*), dove lupine (*Lupinus bicolor*), miner's lettuce (*Claytonia perfoliata*), whitetop yarrow (*Achillea millefolium*), California ponysfoot, and emergent coyote brush. Non-native species identified in this community include tall fescue (*Festuca arundinacea*), mustards (*Brassica* spp.), wild radish, pygmy weed (*Crassula tillaea*), storksbill (*Erodium* spp), windmill pink (*Petrorhagia dubia*), common plantain, rough cat's ear, soft cat's ear, and dovesfoot (*Geranium molle*). Dense areas of cutleaf geranium (*Geranium dissectum*), Italian thistle (*Carduus pycnocephalus* ssp. *pycnocephalus*), sheep sorrel (*Rumex acetosella*), and fennel were also common throughout this community.

Ruderal

Ruderal refers to mainly herbaceous habitats that are invading highly disturbed areasand contain a mix of weedy volunteer species growing in urban or disturbed settings. Ruderal habitats have low native species diversity . Within the study area, ruderal habitat is roughly 60% vegetated, and appears to be dominated by teasel (*Dipsacus sativus*), occurring in as much as 30% of the vegetation along the margins of roadways and east of SR 1. A total of 1.39 acres of ruderal habitats occur within the study area (1.35% of the study area).

Other characteristic species included bromes (*Bromus* spp.), fescue (*Festuca* spp.), Italian wildrye (*Festuca perennis*), mustards, radish, thistles, star-thistles (*Centaurea* spp.), ice plant, foxtail (*Hordeum* spp.), emergent brooms, ornamental shrubs, and poison hemlock. Rattlesnake grass, fennel, spring vetch, California ponysfoot, French broom, dovesfoot, biennial flax, and asters (*Symphyotrichum* spp.) were present at low densities in this community. This community is dominated by non-native species and is not protected in California.

Equisetum telmateia **Herbaceous Alliance (Giant Horsetail Marsh)**

Giant horsetail marsh is not described in the MCV2, however it was a distinct community within the study area that could not be otherwise classified, and it is therefore presented as a provisional alliance. Giant horsetail marsh is found north of SR 1 on the PRNS property. It occurs adjacent to California annual grassland and adds up to 0.87 acres (0.85% of the study area).

Areas designated as "Giant horsetail marsh" in the study area contained 100% vegetative cover within the herbaceous layer. Giant horsetail (*Equisetum telmateia*) contributed to approximately 40% of this cover, while non-native creeping buttercup (*Ranunculus repens*) was common in the lowest layers at 10%. Invasive tall fescue (*Festuca arundinacea*), blue rush (*Juncus patens*), common rush (*Juncus effusus*), velvet grass (*Holcus lanatus*), bristly ox-tongue (*Helminthotheca echioides*), and redroot umbrella sedge were present as well.

Carex praegracilis **stands (Clustered Field Sedge Marsh)**

Areas dominated by clustered field sedge were locally common in two wetlands within the study area: the terrestrial wet meadow east of Highway 1, and the high brackish marsh surrounding a pond with intermittent extreme high tide flooding. The total area of these stands within the study area was 0.92 acres (0.90% of the study area). These stands were almost entirely composed of clustered field sedge but contained minor components of other grasses and forbs. Unlike freshwater wetlands in adjacent valleys south of the study area, which are dominated by slough sedge (*Carex obnupta*), freshwater and brackish marshes in the study area contained clustered field sedge stands.

Areas designated as clustered field sedge marsh contained 99% vegetative cover, of which clustered field sedge was nearly the exclusive contributor. Trace amounts of jaumea, silverweed cinquefoil, grasses, and other small forbs were occasionally present.

4.2.2 Rare Plants and Invasive Plant Species

The CNDDB 5-mile radius search identified 32 rare plant species with potential to occur within the study area. A determination of the potential of each species to occur was based upon documented occurrence locations near the study area and appropriate habitats within it (Table 5). Further studies providing information on soil type (particularly for species which are serpentine-dependent) may refine the assessment of the number of species with potential to occur. Although no rare plants were observed during 2015 field surveys, protocol-level rare plant surveys were not conducted because they were beyond the scope of the current project. Thus, there is still a potential for undetected rare plant populations to be found within the study area.

Table 5. Rare Plants with Potential to Occur in the Study Area

Species Name	Common Name	Status[1] (federal/ state/ CRPR)	MCV2 Plant Community	Likelihood of Occurrence
Abronia umbellata subspecies *breviflora*	North coast pink sand-verbena	FSC/--/1B	Beach and beach-salt marsh ecotone edge	Moderate. Suitable habitat exists in the study area, and populations were observed in Stinson Beach and Kent Island in recent past.
Alopecurus aequalis var. *sonomensis*	Sonoma alopecurus	FE/--/1B.1	Red Alder Forests, Baltic and Mexican Rush Marshes, Arroyo Willow Thickets, Cattail Marsh, Giant Horsetail Marsh	Moderate. Suitable habitat occurs in the study area, but records are not known at Bolinas Lagoon.
Amorpha californica var. *napensis*	Napa false indigo	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, Eucalyptus Groves, Coast Live Oak Woodland, California Bay Forest	Moderate. Suitable habitat occurs in the study area, but the only plants recorded within a 5-mile radius are east of the Bolinas-Fairfax Ridge.
Amsinckia lunaris	bent-flowered fiddleneck	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, French Broom Scrub, Coast Live Oak Woodland, California Bay Forest, California Annual Grassland, Ruderal	Moderate. Suitable habitat occurs in the study area, but the only plants recorded within a 5-mile radius are east of the Bolinas-Fairfax Ridge.
Arctostaphylos montana ssp. *montana*	Mount Tamalpais manzanita	--/--/1B.3	California Sagebrush Scrub, Coyote Brush Scrub	Low. Marginal habitat is present in the study area. All recorded within a 5-mile radius are east of the Bolinas-Fairfax Ridge.
Arctostaphylos virgata	Marin manzanita	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, Coast Live Oak Woodland, California Bay Forest	High. Suitable habitat occurs in the study area, and numerous records occur within a 5-mile radius. The nearest record is Pablo Point, Pt. Reyes NS.

Table 5. Rare Plants with Potential to Occur in the Study Area

Species Name	Common Name	Status[1] (federal/ state/ CRPR)	MCV2 Plant Community	Likelihood of Occurrence
Astragalus pycnostachyus var. *pycnostachyus*	coastal marsh milk-vetch	--/--/1B.2	Salt Grass Flats, Baltic and Mexican Rush Marshes,	Moderate. Suitable habitat occurs throughout the study area, and numerous records are reported within a 5-mile radius, however, these populations are considered extirpated.
Cardamine angulata	seaside bittercress	--/--/2B.1	Red Alder Forests, Baltic and Mexican Rush Marshes, Coast Live Oak Woodland, Coastal Brambles, Arroyo Willow Thickets, Cattail Marsh, Giant Horsetail Marsh, Clustered Field Sedge Marsh	Low. Suitable habitat is present in the study area, but no recent (within 20 years) records are reported within a 5-mile radius.
Carex lyngbyei	Lyngbye's sedge	--/--/2B.2	Salt Marsh Bulrush Marshes, Salt Grass Flats, Rush Marshes, Cattail marsh,	Moderate. Suitable habitat occurs throughout the study area, and records are reported within a 5-mile radius. The nearest is at Stinson Beach.
Castilleja ambigua subspecies *ambigua*	salt marsh owl's clover	FSC/--/4.2	Widespread in backbarrier salt marsh ecotone, associated with sparse cover of pickleweed, saltgrass, and others	High. Suitable habitat occurs within the study area, and there are records of this species at several points around Bolinas lagoon.
Castilleja affinis var. *neglecta*	Tiburon paintbrush	FE/ST/1B.2	California sagebrush scrub (rock outcrops)	Low. Although some habitat occurs within the study area, this species is a strict endemic to serpentine, which is not reported from the study area. No records are known within a 5-mile radius.
Ceanothus masonii	Mason's ceanothus	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub	Moderate. Limited suitable habitat is present in the project area, and there are numerous records within a 5-mile radius. The nearest records are, however, along Bolinas-Fairfax Ridge.
Chloropyron maritimum ssp. *palustre*	Northern salt marsh bird's-beak	--/--/1B.2	Salt Grass Flats, Pickleweed Mats	High. Suitable habitat occurs within the study area, and there are records of this species at Bolinas Lagoon, as close as 2 miles from the study area.

Table 5. Rare Plants with Potential to Occur in the Study Area

Species Name	Common Name	Status[1] (federal/ state/ CRPR)	MCV2 Plant Community	Likelihood of Occurrence
Cirsium hydrophilum var. *vaseyi*	Mount Tamalpais thistle	--/--/1B.2	California annual grassland	Low. Marginal habitat may be present within the study area. The species is known only from serpentine soils on Mount Tamalpais and adjacent areas.
Dirca occidentalis	western leatherwood	--/--/1B.2	Red Alder Forests, California Sagebrush Scrub, Coyote Brush Scrub, Eucalyptus Groves, Coast Live Oak Woodland, Coastal Brambles, Arroyo Willow Thickets, California Bay Forest	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are northeast of the Bolinas-Fairfax Ridge, in Lagunitas.
Eriogonum luteolum var. *caninum*	Tiburon buckwheat	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, Coast Live Oak Woodland, Coastal Brambles, California Bay Forest, California Annual Grassland	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are east of the Bolinas-Fairfax Ridge. The species is a strict serpentine soil endemic.
Fritillaria lanceolata var. *tristulis*	Marin checker lily	--/--/1B.1	California Sagebrush Scrub, Coyote Brush Scrub, Coastal Brambles, California Annual Grassland	High. Suitable habitat occurs within the study area. Three records occur within 2 miles of the study area.
Gilia capitata ssp. *chamissonis*	blue coast gilia	--/--/1B.1	None	Low. Dune habitat does not occur within the study area. Records occur within 2 miles of the study area, adjacent to Bolinas Lagoon.
Gilia capitata ssp. *tomentosa*	woolly-headed gilia	--/--/1B.1	California Sagebrush Scrub, Coyote Brush Scrub, California Annual Grassland	Moderate. Suitable habitat is present in the project area, and there are numerous records within a 5-mile radius. The nearest records are, however, considered extirpated.
Hemizonia congesta ssp. *congesta*	white seaside tarplant	--/--/1B.2	California Annual Grassland, Ruderal	High. Suitable habitat occurs within the study area. Records occur within 2 miles of the study area, adjacent to Bolinas.

Table 5. Rare Plants with Potential to Occur in the Study Area

Species Name	Common Name	Status[1] (federal/ state/ CRPR)	MCV2 Plant Community	Likelihood of Occurrence
Hesperolinon congestum	Marin western flax	FT/ST/1B.1	California Sagebrush Scrub, Coyote Brush Scrub, California Annual Grassland	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are well east of the Bolinas-Fairfax Ridge. The species is a strict serpentine soil endemic.
Holocarpha macradenia	Santa Cruz tarplant	FT/SE/1B.1	California Sagebrush Scrub, Coyote Brush Scrub, California Annual Grassland	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are well east of the Bolinas-Fairfax Ridge and considered extirpated.
Horkelia tenuiloba	thin-lobed horkelia	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, California Annual Grassland	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are well east of the Bolinas-Fairfax Ridge.
Leptosiphon croceus	coast yellow leptosiphon	--/--/1B.1	California Sagebrush Scrub, Coyote Brush Scrub, California Annual Grassland	Low. Suitable habitat occurs within the study area, but the only extant records within a 5-mile radius are on the Northwestern Pt. Reyes Peninsula.
Lessingia micradenia var. *micradenia*	Tamalpais lessingia	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, California Annual Grassland, Ruderal	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are well east of the Bolinas-Fairfax Ridge. This species typically grows on serpentine.
Mielichhoferia elongata	elongate copper moss	--/--/2B.2	Coast Live Oak Woodland, California Bay Forest	Moderate. Suitable habitat occurs throughout the study area, and records are reported within a 5-mile radius.
Navarretia rosulata	Marin County navarretia	--/--/1B.2	California Sagebrush Scrub, Coyote Brush Scrub, Coast Live Oak Woodland, California Bay Forest	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are well east of the Bolinas-Fairfax Ridge

Table 5. Rare Plants with Potential to Occur in the Study Area

Species Name	Common Name	Status[1] (federal/ state/ CRPR)	MCV2 Plant Community	Likelihood of Occurrence
Pleuropogon hooverianus	North Coast semaphore grass	--/ST/1B.1	Red Alder Forests, Baltic and Mexican Rush Marshes, Coast Live Oak Woodland, Arroyo Willow Thickets, Cattail Marsh, California Bay Forest, Giant Horsetail Marsh, Clustered Field Sedge Marsh, California Annual Grassland	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are well east of the Bolinas-Fairfax Ridge
Quercus parvula var. *tamalpaisensis*	Tamalpais oak	--/--/1B.3	Coast Live Oak Woodland, California Bay Forest	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are concentrated around Mount Tamalpais.
Sidalcea calycosa ssp. *rhizomata*	Point Reyes checkerbloom	--/--/1B.2	Red Alder Forests, Baltic and Mexican Rush Marshes, Arroyo Willow Thickets, Cattail Marsh, Giant Horsetail Marsh, Clustered Field Sedge Marsh	Low. Suitable habitat occurs within the study area, but the only records within a 5-mile radius are east of the Bolinas-Fairfax Ridge, or on the western Pt. Reyes Peninsula.
Sidalcea hickmanii ssp. *viridis*	Marin checkerbloom	--/--/1B.3	California Sagebrush Scrub, Coyote Brush Scrub	Low. No suitable habitat occurs very sparsely within the study area. The only records within a 5-mile radius are concentrated near Pine Mountain.
Streptanthus batrachopus	Tamalpais jewelflower	--/--/1B.3	None	Low. Suitable habitat occurs very sparsely within the study area, if at all. The only records within a 5-mile radius are east of the Bolinas-Fairfax Road. This species is a serpentine endemic.
Streptanthus glandulosus ssp. *pulchellus*	Mount Tamalpais bristly jewelflower	--/--/1B.2	None	Low. Suitable habitat occurs sparsely within the study area, if at all. The only records within a 5-mile radius are east of the Bolinas-Fairfax Road. This species is a serpentine endemic.
Trifolium amoenum	showy rancheria clover	FE/--/1B.1	California Sagebrush Scrub, Coyote Brush Scrub, California Annual Grassland	High. Suitable habitat occurs within the study area. Records occur within 2 miles of the study area, adjacent to Bolinas Lagoon.

Table 5. Rare Plants with Potential to Occur in the Study Area

Species Name	Common Name	Status[1] (federal/ state/ CRPR)	MCV2 Plant Community	Likelihood of Occurrence

Notes:
This table does not include rare plant species that were determined to have "no potential to occur" within the study area.
[1]Status:Federal Status
FE: Listed as endangered under the Endangered Species Act
FT: Listed as threatened under the Endangered Species Act
FSC: Federal species of concern
State Status
SE: Listed as endangered under the California Endangered Species Act
ST: Listed as threatened under the California Endangered Species Act
California Rare Plant Rank (CRPR) Status
1B: Rare, threatened, or endangered in California and elsewhere
1B.1: Seriously endangered in California
1B.2: Fairly endangered in California
1B.3: Not very endangered in California
2B: Rare, threatened, or endangered in California, but more common elsewhere
2B.1: Seriously endangered in California
2B.2: Fairly endangered in California
4.2: Moderately threatened in California
-- = no status designation

Likelihood of Occurrence Designations:
High: Suitable habitat and other appropriate conditions are represented onsite and extant records occur within the watershed.
Moderate: Either suitable habitat is represented within the study area or extant records occur within the watershed.
Low: Suitable habitat is limited within the study area and records are outside of the watershed, are extirpated, or have conditions not found onsite.

Fifty invasive plant species rated as a high or moderate risk by the Cal-IPC were recorded in the study area. The species described below pose the greatest threat based upon a combination of their location and extent in the study area, and their overall invasiveness. Three of the species described below were observed to occur in ecologically significant stands, with respect to potential invasions in future conditions of the project area:

- Upright veldtgrass (*Ehrharta erecta*). This perennial South African grass is highly invasive in both shaded and open vegetation gaps of coastal grassland, riparian woodlands, and upland woodlands in many vegetation types. Large roadside stands occur along Olema Bolinas Road edges in discrete stands that are apparently spreading. Spread is often rapid and effectively irreversible along roadsides and road cuts. *E. erecta* can strongly interfere with re-establishment of native Marin plant communities in both deep shade and full sun.
- French broom (*Genista monspessulana*) and other broom species, which are establishing on the upland hillslope above SR 1, are increasingly hard to remove due to tenacious root growth and long-lived seed. French broom seldom occurs in wetlands, however, and is never invasive in wetlands. It is worth noting that French broom is also invading adjacent native communities such as coyote brush scrub and coast live oak woodland.

- Ice plant (*Carpobrotus edulis* x *chilensis*), which is growing as an exclusive mat along SR 1 beside the lagoon and encroaching into saltgrass marsh, is often highly invasive and outcompetes along tidal marsh edges, but does not aggressively invade salt marsh, freshwater marsh, or deep shade of riparian woodland
- Bluegum (*Eucalyptus globulus*) form a dense forest from historical plantings in the northern portion of the study area. There is little evidence of blue gum invasion of adjacent riparian or wetland vegetation within the project area, but shade and leaf litter deposition from blue gum stands may interfere with riparian or wetland enhancement during climate change.
- Yellow flag iris (*Iris pseudacorus*) occurs as a discrete colony (a large wetland roadside stand) on the north side of the cross-road. This clonal species can be locally or generally invasive in freshwater to fresh-brackish wetlands, and is a potential threat to future wetland enhancement. It is expected to expand beyond its present size.
- Fuller's teasel (*Dipsacus sativus)* has extensive coverage in ruderal habitats within the study area and is an ecological concern because it has long lasting, persistent seeds and often encroaches into disturbed wetland habitats.
- Himalayan blackberry (*Rubus armeniacus*) is present within riparian understories in the study area, particularly within the red alder forests and Arroyo Willow Thickets habitats of the Bolinas "Y". The highly competitive and invasive clonal species is a threat to native communities, especially in early stages of succession during restoration of riparian habitats.
- Cape ivy (*Delairea odorata*) is extensive in the understories of arroyo willow thickets, California bay forests, eucalyptus groves, and red alder forests in the study area. The species is known for its prolific growth, tolerance of shade and sun in riparian woodland, resistance to removal, and ability to colonize a variety of coastal habitats.

4.2.3 Wetlands and Waters

Extensive wetlands and numerous water features were identified in the study area, as shown on Figures 4.1, 4.3, and 4.4. A total of eleven distinct wetland types were identified in the study area; and since a subsurface exploration of soils and hydrology was not performed as part of this study, the wetlands are named for the vegetation community in which they were found. The acreage of CCC wetlands and USACE wetlands, by wetland type, is presented in Table 6.

Table 6. Wetland Types and Acreages in the Study Area

Wetland Type (by Vegetation Community)	CCC wetland acreage	USACE wetland acreage
Arroyo willow thicket	8.62	7.38
Baltic and Mexican rush marsh	0.83	0.83
California annual grassland	0.71	0.57
Coastal brambles	0.82	0.59
Cattail marsh	0.78	0.78
Giant horsetail marsh	0.87	0.87
Pickleweed mats	3.92	3.92
Salt grass flats	1.79	1.79
Salt marsh bulrush marsh	2.54	2.54
Sedge sedge marsh	0.92	0.92
Red alder forests	5.32	5.10
Total	**27.13**	**25.29**

The most significant feature within the study area is the Bolinas Lagoon itself. The lagoon and tidal wetlands were vegetated by pickleweed mats, salt grass flats, salt marsh bulrush marsh, and clustered field sedge marsh. As a result of tidal influence, these wetlands areas are consistently saturated. Additional areas along Wilkins Gulch Creek, on the east side of SR 1, also presented areas of salt grass flats, salt marsh bulrush marsh, and clustered field sedge marsh. Water samples collected in this area (Figure 2) showed relatively high salinities, indicating potential tidal influence from Bolinas Lagoon on both the west and east sides of SR1. Herbaceous freshwater wetlands were located in the floodplains adjacent to (west of) Lewis Gulch Creek, within the northeastern corner of the "Y" and in the sloped floodplains between Fairfax Bolinas Road and SR 1. Vegetation in the freshwater wetlands consisted of cattail (*Typha* spp.) marsh, coastal brambles, giant horsetail marsh, and clustered field sedge marsh. Saturation was observed in the floodplains adjacent to Lewis Gulch Creek.

Two named creeks, Lewis Gulch Creek and Wilkins Gulch Creek, flow into Bolinas Lagoon and provide freshwater inputs. There are also two unnamed, and apparently intermittent, drainages that flow through a sloped field south of Fairfax Bolinas Road. These unnamed drainages flow down from Mount Tamalpais and are partially fed by springs. The unnamed drainages do not have a definite bed or bank throughout the study area; they discharge downslope onto the field near the pond via overland flow. One additional feature located east of SR 1 and north of the National Park Service farm house was identified as a vegetated swale. It exhibits a discontinuous bed and bank and appears to carry ephemeral flows. The channel within the swale ends where the study area boundary meets the farm house. It is unclear if this channel is hydrologically connected to any other features. The details of the connection and interactions between these key water features are described more fully in the technical memorandum on the hydrology and geomorphology of the study area. The acreage of each key waterway in the study area, including the open water portion of Bolinas Lagoon, is presented in Table 7 and Figure 4.5.

Table 7. Key Waterways in the Study Area

Key Waterway name	Acreage
Bolinas Lagoon	5.50
Lewis Gulch Creek	1.07
Wilkins Gulch Creek	1.04
Unnamed Drainages and Pond	0.56
Swale	0.08
Total	**8.25**

All water features described in the study area, with the possible exception of the swale, are assumed to be potential other waters of the U.S. due to presence of an ordinary high water mark and hydrologic connection to the San Francisco Bay. All water features, including the swale, are assumed to be waters of the State of California (waters of the state).

Riparian areas in the study area were defined depending upon whether they met a definition for wetlands or were upland areas that provided a riparian function due to their vegetation composition and position on the landscape relative to an adjacent water feature. Riparian areas mapped in the study area are distinguished as Federal riparian if they meet the USACE definition of a wetland and as State riparian if they either meet the CCC definition of wetland or provide upland riparian cover for an adjacent water feature (Figure 4.4).

In the study area Lewis Gulch Creek is surrounded by a mature riparian corridor that meets the criteria for State riparian. It is primarily shaded by red alder forests and willow alder riparian forest, both of which are considered CCC wetlands. This area also contains stretches of upland eucalyptus grove and coast live oak woodland that provide important riparian functions. The area bordering Wilkins Gulch Creek is split into a State riparian portion and a Federal riparian portion due to a dramatic vegetation and topographic transition. The upper portion of the Wilkins Gulch Creek in the study area is shaded by a coast live oak riparian overstory, which provides riparian functions. The lower portion of the creek is much less steep and is surrounded by a willow alder riparian corridor that is also considered a USACE wetland. The unnamed drainages south of Bolinas Fairfax Road do not have riparian corridor surrounding their upper portions but flow into arroyo willow thickets as they approach the pond. These riparian thickets are also considered USACE wetlands. The swale north of the farm house is surrounded by coastal bramble riparian vegetation that may be considered a CCC wetland.

4.2.4 Wildlife Habitat

The vegetation communities described above include forests, marshes, grasslands, and scrub habitat that support a diverse assemblage of plant and animal species. The presence of abundant transitional habitat between wetland and upland communities provides ecosystem complexity. The freshwater input into the study area through streams and groundwater produces fresh and brackish vegetation, providing wildlife habitat that supports an assemblage of species uniquely adapted to these conditions. For instance, shorebirds and waterfowl, including black rails, use the high marsh areas at the north end of the lagoon a high-tide refugia. Black rails may also use the transitional areas for foraging. The brackish pond and surrounding marsh are unique habitat in the study area and the transition from mudflat to marsh to upland exists in only a few areas due to fill and the placement of roadways.

Based on observations made during surveys, a number of common wildlife species are anticipated to occur in the vegetation communities in the study area, as detailed below in Table 8.

Table 8. Common Wildlife Habitats within the Study Area

Vegetation Communities	Common wildlife species
Forests habitats (Red Alder Forests, Eucalyptus Groves, Coast Live Oak Woodland, and California Bay Forest)	Raptors, such as red-tailed hawks (*Buteo jamaicensis*) and great horned owls (*Bubo virginianus*) may nest in large trees, including eucalyptus and large oaks. The latter can also provide habitat for family groups of acorn woodpeckers (*Melanerpes formicivorus*). A variety of birds including chestnut-backed chickadees (*Poecile rufescens*), white-breasted nuthatches (*Sitta carolinensis*), bushtits (*Psaltriparus minimus*), and Nuttall's woodpeckers (*Picoides nuttallii*) are often found in woodlands. Black-tailed deer (*Odocoileus hemionus*) often forage along forest edges. Streams in forested areas can provide habitat for newts (*Taricha* sp.) and other amphibians.
Shrub habitats, (California Sagebrush Scrub, Coyote Brush Scrub, French Broom Scrub)	Birds commonly found in scrub habitat include wrentits (*Chamaea fasciata*), California thrashers (*Toxostoma redivivum*), blue-gray gnatcatchers (*Polioptila caerulea*), Western scrub jays (*Aphelocoma californica*) and California quail (*Callipepla californica*). Reptiles including Western fence lizards (*Sceloporus occidentalis*) and California striped racers (*Coluber lateralis lateralis*) use this habitat.
Grassland and forb-dominated habitats (California Annual Grassland and ruderal)	California ground squirrels (*Otospermophilus beecheyi*) are a keystone species in many grassland habitats. Common birds of grassland habitats include American pipits (*Anthus rubencens*), Western meadowlarks (*Sturnella neglecta*). Snakes such as the western yellow-bellied racer (*Coluber constrictor mormon*) and the gopher snake (*Pituophis catenifer*) are common in grasslands. Coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and gray fox (*Urocyon cinereoargenteus*) are regular visitors of the grasslands, preying on small mammals such as Western harvest mice (*Reithrodonotmys megalotis*).
Riparian habitats, including Arroyo willow thickets and coastal brambles	Arroyo willow thickets and bramble patches support many passerines, including Wilson's warblers (*Cardellina pusilla*) and lesser goldfinches (*Spinus psaltria*).

Table 8. Common Wildlife Habitats within the Study Area

Vegetation Communities	Common wildlife species
Marsh habitats, (Salt Marsh Bulrush Marsh, Salt Grass Flats, Baltic and Mexican Rush Marshes, Pickleweed Mats, Cattail Marsh, and Clustered Field Sedge Marsh)	Marshes and wetlands are particularly valuable to birds, supporting, among many other species, snowy egrets (*Egretta thula*), Northern harriers (*Circus cyaneus*), song sparrows (*Melospiza melodia*), red- winged blackbirds (*Agelaius phoeniceus*), and common yellowthroats (*Geothlypis trichas*). Mammals that use these habitats include river otters (*Lontra canadensis*) and raccoons (*Procyon lotor*). Several species of gartersnakes (*Thamnophis* sp.) can be found in marshes with low or no salinity, foraging on breeding amphibians such as Sierran treefrogs (*Pseudacris sierra*).

A complete list of wildlife species observed during field surveys is provided in Appendix D.

4.2.5 Special-Status Wildlife

Special-status wildlife includes those that are:

- Species listed or proposed for listing as threatened or endangered under the federal ESA (50 Code of Federal Regulations [CFR] 17.12 [listed plants]; 50 CFR 17.11 [listed animals]).
- Species that are candidates for possible future listing as threatened or endangered under the federal ESA (73 FR 75176, December 10, 2008).
- Species listed or proposed for listing by the State of California as threatened or endangered under the California ESA (14 California Code of Regulations [CCR] 670.5).
- Bird species listed under the Migratory Bird Treaty Act (MBTA) (U.S. Code Sections 703 to 712).
- Bald and golden eagles protected under the Bald and Golden Eagle Protection Act (16 U.S. Code Sections 668 to 668d, 54 Statute 250).
- Species that meet the definitions of "rare" or "endangered" under the California Environmental Quality Act (CEQA Guidelines Sections 15380 and 15125).
- Animal species of special concern to the CDFW (CDFW 2015b).
- Bird species of conservation concern as identified by USFWS in Birds of Conservation Concern 2008 (USFWS 2008).
- Animals that are fully protected in California (California Fish and Game Code Sections 3511 [birds], 4700 [mammals], 5050 [amphibians and reptiles], and 5515 [fish]) (CDFW 2015c).

To generate a list of special-status wildlife species potentially occurring within the study area, multiple sources were queried, including a USFWS IPaC (Information for Planning and Conservation, USFWS 2015b) search, a CNDDB query (CDFW 2015a), and a review of the animals on the state’s fully-protected animals list (CDFW 2015c). These species and their listing status are presented in Table 9.

Table 9. CNDDB Occurrences of Listed Species and Critical Habitat in and around the Study Area

Common Name	Scientific Name	Listing Status	Likelihood to be Present
Invertebrates			
San Bruno elfin butterfly	*Callophrys mossii bayensis*	FE	Low – habitat for host plant not present in study area.
Myrtle's silverspot butterfly	*Speyeria zerene myrtleae*	FE	Low – known only from four locations north of Bolinas Lagoon.
California freshwater shrimp	*Syncaris pacifica*	FE, SE	Moderate – habitat potentially present in upper reaches of creeks.
Fish			
tidewater goby – CRITICAL HABITAT	*Eucyclogobius newberryi*	FE	Low – Bolinas Lagoon is designated as critical habitat; habitat not present in creeks or pond.
Tomales roach	*Lavinia symmetricus*	SSC	Low – occur in Lagunitas and Walker Creek, though roach of "uncertain taxonomic affinity" occur in Pine Gulch Creek.
Coho salmon - central California coast ESU	*Oncorhynchus kisutch*	FE, SE	Low – sufficient deep, cold, freshwater habitat not present in study area.
steelhead - central California coast DPS	*Oncorhynchus mykiss irideus*	FT	High – steelhead have been observed in Wilkins Creek.
steelhead - central California coast DPS -- CRITICAL HABITAT	N/A	Designated	Wilkins Creek is Designated Critical Habitat
Amphibians			
foothill yellow-legged frog	*Rana boylii*	SSC	Moderate – there are historic records from Pike County Gulch and environs.
California red-legged frog	*Rana draytonii*	FT, SSC	High – known occurrences in pond east of SR 1.
Birds			
golden eagle	*Aquila chrysaetos*	FP	Moderate – may forage in the area, but generally breed in more open habitats.
burrowing owl	*Athene cunicularia*	SSC	Moderate – open, grassy habitat present.
marbled murrelet	*Brachyramphu smarmoratus*	FT	Low – Critical habitat designated to the south of the study area; requires very large, old trees for nesting.
western snowy plover	*Charadrius alexandrinus nivosus*	FT	Low – sandy beach habitat not present in study area.
black swift	*Cypseloides niger*	SSC	Low - no nesting habitat, though birds may forage in the area.
white-tailed kite	*Elanus leucurus*	FP	High – may breed and forage within the study area.

Table 9. CNDDB Occurrences of Listed Species and Critical Habitat in and around the Study Area

Common Name	Scientific Name	Listing Status	Likelihood to be Present
American peregrine falcon	*Falco peregrinus anatum*	FP	High – may forage and disperse in the project area, but there is no nesting habitat (rocky cliffs) present.
saltmarsh common yellowthroat	*Geothlypis trichas sinuosa*	SSC	High – marsh habitat for this species occurs in the study area.
bald eagle	*Haliaeetus leucocephalus leucocephalus*	FP	High – may forage and breed within the study area.
California black rail	*Laterallus jamaicensis*	ST, FP	High – potentially suitable habitat present in tidal marsh.
San Pablo song sparrow	*Melospiza melodia samuelis*	SSC	Low – the subspecies range is limited to the San Pablo Bay and does not extend to the coast.
California brown pelican	*Pelecanus occidentalis*	FP	High – may forage within the lagoon, but breeding colonies are not present in the study area.
short-tailed albatross	*Phoebastria albatrus*	FE	Low – seen on the Farallones; no eBird records from the coast; breeds on isolated islands.
Ridgway's rail (formerly California clapper rail)	*Rallus obsoletus*	FE, SE, FP	Low – marginal habitat only along shoreline. No known occurrences in study area.
California least tem	*Sterna albifrons browni*	FP	Moderate – may forage within lagoon but sandy beach habitat not present in study area.
northern spotted owl	*Strix occidentalis caurina*	FT	Low – occurs at Muir Woods and may forage in the study area but suitable nesting habitat not observed. Requires large, contiguous stands of old-growth forest for nesting,
Mammals			
pallid bat	*Antrozous pallidus*	SSC	Low – prefers open, dry areas with rocky crevices for rooting.
Point Reyes mountain beaver	*Aplodontia rufa phaea*	SSC	Low – all extant observations are north of the project site, within Point Reyes National Seashore.
ring-tailed cat	*Bassariscus astutus*	FP	High – wide-ranging species that use a variety of woodland habitats.
Townsend's big-eared bat	*Corynorhinus townsendii*	FC, SSC	High – may use temporary roosts inside buildings and other structures.
American badger	*Taxidea taxus*	SSC	Low – prefers large, open, grassland habitat that is limited within the project area.

Notes:

U.S. Fish and Wildlife Service and Federal Listing Categories:
FC = Candidate for Federal Listing
FE = Federally Listed as Endangered
FT = Federally Listed as Threatened
California Department of Fish and Wildlife State Listing Categories:
FP = Fully Protected

The results of the surveys for special-status species' habitat and discussions of the potential for presence of each species in the study area are described below.

San Bruno elfin butterfly (*Callophrys mossii bayensis*) is a federally listed endangered butterfly found in coastal mountains near San Francisco Bay, generally in the fog-belt of steep north-facing slopes that receive little direct sunlight. It lives near prolific growths of the larval food plant, stonecrop (*Sedum spathulifolium*), which is a low growing succulent. The adult butterflies are observed to be quite sedentary during their short life span, which is about one week (USFWS 2007b). Stonecrop is associated with rocky outcrops that occur at 900-1075 feet (274-328 meters) elevation, and therefore presence of the host plant, and thus the species, is highly unlikely in the study area. However, due to proximity of historic occurrences, east of the study area near Alpine Lake, the species was retained for discussion. No San Bruno elfin butterflies were observed during surveys.

Myrtle's silverspot butterfly *(Speyeria zerene myrtleae)* is federally and state-listed as endangered. This butterfly uses patches of the western dog violet (*Viola adunca*) as the host plant on which to reproduce. These butterflies occur in coastal dune, prairie, and scrub habitats with protection from onshore winds (Launer et al. 1992). The species is currently only known from four locations north of the study are in Point Reyes National Seashore and on private land to the north in Bodega Bay (Launer et al. 1992). There are no known records from within the study area.

California freshwater shrimp (*Syncaris pacifica*) is federally and state-listed as endangered. This is a decapod crustacean of the family Atyidae and is believed to be the only extant species of the genus. They are generally less than 50 millimeters (2.17 inches) in length. They are found in low elevation, low gradient, freshwater, perennial streams in Marin, Napa, and Sonoma Counties, California. During the winter, habitat includes shallow margins of stream pools containing undercut banks and exposed living fine-root material that provide shelter and refuge from high water velocities associated with winter storm events. During the summer months, California freshwater shrimp are often associated with submerged leafy branches. It is believed both winter and summer habitat components need to be found in close proximity in order for this species to persist for prolonged periods (USFWS 2011b).

Although suitable habitat for California freshwater shrimp is present in Lewis Gulch Creek and the species has been found north of the project area in Lagunitas Creek, the species was not identified during surveys. Due to the cryptic nature of the species, focused surveys for the species in Lewis Gulch Creek and Wilkins Gulch Creek are recommended for a later project phase.

Tidewater goby (*Eucyclogobius newberryi*) is federally listed as endangered. These fish are endemic to California and inhabit coastal lagoons, estuaries, and marshes. Their historic range spans these habitat types along the coast from near the Oregon border to San Diego. There are no historic records for this species within the study area, although Bolinas Lagoon is considered a potential reintroduction site and is designated critical habitat (USFWS 2005).

Central California coast Steelhead (*Oncorhynchus mykiss irideus*) are federally listed as threatened species that belongs to the family Salmonidae which includes all salmon, trout, and chars. Steelhead require both freshwater streams and the ocean to complete their life cycle: they are born in freshwater streams, where they spend their first 1-3 years of life, and then emigrate to the ocean where most of their growth occurs. After spending between one to four growing seasons in the ocean, steelhead return to their natal stream to spawn. Unlike Pacific salmon, steelhead do not necessarily die after spawning and are able to spawn more than once (USFWS 2015c). Steelhead have been found in Wilkins Gulch Creek (Fong 2002), which is designated as critical habitat for the species (NOAA 2005). There are no data indicating that steelhead currently use Lewis Gulch Creek, but no surveys have been done.

Central California coast ESU[5] Coho salmon (*Oncorhynchus kisutch*) are federally and state-listed as endangered. They belong to the family Salmonidae which includes all salmon, trout, and chars. Coho are born in freshwater streams and spend approximately the first half of their life cycle rearing and feeding in streams and small freshwater tributaries. Coho require sufficient cold, clean water, for over-summering in their in-stream habitat. They then migrate to the ocean where most of their growth occurs. After spending between 1 to 2 years in the ocean, coho return to their natal stream to spawn in small streams with stable gravel substrates. Coho, like other Pacific salmon, die after spawning once. Designated Critical Habitat for the Central California Coast ESU encompasses accessible reaches of all rivers (including estuarine areas and tributaries) between Punta Gorda and the San Lorenzo River (inclusive) in California, including two streams entering San Francisco Bay: Arroyo Corte Madera Del Presidio and Corte Madera Creek, therefore the study area includes designated critical habitat for the species (NOAA 2005). There is no data indicating coho use either Wilkins Gulch Creek or Lewis Gulch Creek. Coho generally require deep, cold pools and highly structured habitat that do not occur in the study area.

California red-legged frogs (*Rana draytonii*) are federally listed as threatened and are a state species of special concern. They typically inhabit permanent and semi-permanent water sources such as streams, lakes, marshes, natural and artificial ponds, and ephemeral drainages in valley bottoms and foothills. They breed between November and April in standing or slow-moving water. Streams suitable for California red-legged frogs (CRLF) breeding typically contain shrubby riparian or emergent vegetation. Egg masses are attached to vegetation below the surface of the water. The larvae require up to 8-9 months for development through metamorphosis. Once metamorphosed, frogs require appropriate upland refugia for aestivation during dry periods; suitable refugia include small mammal burrows, downed logs or vegetation, and dense vegetation/litter layer (USFWS 2002).

The locations of suitable habitats for CRLF are illustrated in Figure 6 and summarized in Table 10, below. Aquatic habitat for CRLF occurs within the study area: the seasonal pond (Location A, Figure 6) just north of SR 1 and portions of Lewis Gulch and Wilkins Gulch Creeks may provide breeding and/or dispersal habitat. While the pond and creeks have the suitable attributes for adult frogs, breeding may be limited, at least in some years, by salinity, hydroperiod, and flow. The short-term (drought) salinity readings from two locations in the pond were 5 and 7 parts per thousand (ppt). CRLF embryos are killed by salinity greater than 6 ppt and adults avoid salinities greater than 6.5 ppt (Jennings and Hayes 1990). Current extreme drought conditions in the pond would not be suitable for CRLF breeding due to salinity; the hydroperiod may also be too short. However, for much of the last 20 years, this pond has not drawn down or become overly saline and thus has provided suitable, though intermittent, CRLF habitat.

During field surveys in April and May of 2015, there were only a few inches of water left in the pond, and it will likely become increasingly brackish and dry up before CRLF larvae are able to metamorphose. Significantly, Sierra treefrog (*Pseudacris sierrae*) metamorphs were present in the pond, indicating that they were able to successfully reproduce; their larval salt tolerance is lower than CRLF. These conditions may be due to successive drought years; CRLF have successfully bred in this pond as recently as 2008 (Figure 6).

The surveys identified a location at Wilkins Gulch Creek as it flowed under SR 1 (Location B, Figure 6) and a location at Lewis Gulch Creek (Location C, Figure 6) with salinities low enough for CRLF reproduction at the time of the survey. The water at these locations was fresh (salinity = 0 ppt) and the creeks were edged by riparian vegetation. Both creeks are suitable for adult frogs and

[5] This evolutionarily significant unit, or ESU, includes naturally spawned coho salmon originating from rivers south of Punta Gorda, California, to and including Aptos Creek, as well as such coho salmon originating from tributaries to San Francisco Bay. Also, coho salmon from three artificial propagation programs:
- Don Clausen Fish Hatchery Captive Broodstock Program
- Scott Creek/King Fisher Flats Conservation Program
- Scott Creek Captive Broodstock Program

metamorphs, but breeding would most likely be precluded by streamflow. In a study of CRLF populations in the East Bay Regional Park District, biologists recorded CRLF adults and metamorphs using stream gradients up to 21%, but breeding did not occur in streams with gradients greater than 4%. Eggs and tadpoles generally will not be able to persist in high flows (Bobzein and Didonato 2007). Typical stream-breeding habitat for these frogs includes slower-moving water or pooled water in low-gradient streams with riparian vegetation. During the winter and early spring, when egg masses are laid, Wilkins Gulch Creek would probably generate flows significant enough to detach and wash away egg masses. Despite this, Wilkins Gulch Creek and Lewis Gulch Creek may serve as an important salinity refugia during much of the year for adult and juvenile frogs.

Table 10. Summary of Suitable CRLF Habitat in the Study Area

Location[1]	Description	Suitable Use by CRLF
A	Seasonal Pond	Potential breeding habitat, but limited by high salinities.
B	Culvert from Wilkins Gulch Creek	Breeding likely limited by high flows during the breeding season. Suitable adult refugia/dispersal habitat.
C	Ponded area behind culvert at Lewis Gulch Creek	Breeding likely limited by high flows during the breeding season. Suitable adult refugia/dispersal habitat.
D and E	Roadside Ditches at the “Y”	Potential breeding habitat.

[1] See Figure 6 for locations.

The roadside ditches at the “Y” may be potential breeding habitat for CRLF (Locations D and E, Figure 6). They are not connected to a linear waterway (which would cause high flows) and are instead supplied by surface flows or groundwater. Therefore, high winter flows that would likely preclude breeding in the streams would not do so in these ditches. Also, salinity levels are appropriate – the water in these ditches is fresh (0 ppt). AECOM hydrologist Jason Pearson observed large frogs (4-5” in body length) jumping into the water during surveys on May 8, 2015. Based on the size of the frogs he observed, they could only be bullfrogs or CRLF. Bullfrogs, especially young ones, will often – though not always – emit a squeak as they jump into the water; no squeaks were heard during this event. Based on this observation and description, it is possible though not certain that CRLF are currently present in these roadside ditches.

CRLF will disperse up stream corridors 2 miles from known breeding sites (Rathbun et al. 1993), and they will disperse over three hundred feet from aquatic habitats (Bulger et al. 2003). The USFWS (2002) notes that associated uplands for the species should include up to 91 meters (300 feet) from the edge of aquatic features. Based on these estimates, Figure 6 also delineates the distribution of upland habitats for CRLF as a 300-foot buffer around suitable aquatic features.

California black rails (*Laterallus jamaicensis coturniculus*) are state-listed as threatened and are fully-

protected species under the California Fish and Game Code. They are found primarily in tidal brackish to saline marshes of the northern San Francisco Bay Area. They are positively associated with large marshes isolated from urbanization, with saline to brackish water and vegetation dominated by pickleweed, gumplant (*Grindelia* sp.), bulrush, rushes and cattails (Spautz et al. 2005). Habitat for black rails can be found within the project site, at the north end of the lagoon in the vegetation communities that were mapped as pickleweed marsh, salt grass mat, and salt marsh bulrush marsh (Figures 4 and 5). There is a small amount of potentially suitable vegetation for black rails along the north side of SR 1, but this area is less likely to be suitable habitat as it is a small, more isolated patch of habitat. Multiple observations of black rails have been documented from the area. The CNDDB query (Appendix C) shows three observations between 1986 and 2001. The eBIRD web-enabled database (eBIRD 2015) also lists observations of black rails in the fringing marshes around the lagoon, but none of these cryptic birds were observed during the surveys for this project. The high tidal marsh and transitional habitat around the north end of the lagoon is very important for providing refugia for black rails and other shorebirds and waterfowl. The transition from mudflat or vegetated low marsh to high marsh and upland in the North End occurs elsewhere only near Pine Gulch Creek and Gospel Flats.

Ridgway's rails (*Rallus obsoletus;* formerly California clapper rail) are federally and state-listed as endangered and are fully-protected species under the California Fish and Game Code. They are restricted to dense tidal marshes that provide nesting and foraging habitats relatively free of predators. Foraging habitat for Ridgway's rail is typically the edge of tidal mudflats and slough channels, where prey items such as mussels, clams, crabs, worms, and other invertebrates are found. Ridgway's rail may also opportunistically prey on fish, carrion, and small rodents. Nesting habitat consists of dense stands of tidal vegetation adjacent to preferred foraging areas (Overton 2007).

Habitat for this rail in the study area is only marginally suitable for the species. While there are tidally influenced marshes and a suitable prey base, the significant stands of emergent wetland vegetation or a well-developed channel network typical of good Ridgway's rail habitat is not present. There is a single CNDDB record of this species for the lagoon, from 1975, but no eBIRD records.

Western snowy plover (*Charadrius alexandrinus nivosus*) are federally listed as threatened. Pacific coast populations breed primarily on coastal beaches from southern Washington to southern Baja California, Mexico. The population breeds above the high tide line on coastal beaches, sand spits, dune-backed beaches, sparsely-vegetated dunes, beaches at creek and river mouths, and salt pans at lagoons and estuaries (USFWS 2007a). These types of habitats suitable for western snowy plover are not present in the study area. There is a single CNDDB record of this species for the lagoon, from 1978 (Appendix C), but no eBIRD records.

The **marbled murrelet** (*Brachyramphus marmoratus*) is federally listed as threatened. It is a seabird that nests in mature, old-growth forests along the Pacific Coast. They breed by laying a single egg on a platform provided by a large horizontal branch or tree deformities. Suitable nest locations and murrelet breeding habitat is correlated with large, contiguous areas of old-growth forest (USFWS 2009). There is critical habitat for this species designated to the southeast of the study area, at Mount Tamalpais and Muir Woods, but habitat does not occur within the study area for these birds.

Northern spotted owls (*Strix occidentalis caurina*) are federally listed as threatened. They occur along the Pacific Northwest into northern California. They are primarily associated with forest, especially old-growth forests with high canopy closure, large trees, snags, and woody debris. Northern spotted owls are known to occur nearby in Muir Woods, but habitat does not occur within the study area for this species (USFWS 2011a).

Short-tailed albatross (*Phoebastria albatrus*) is federally listed as endangered. It is a seabird that nests primarily in Japan but forages widely across the northern Pacific Ocean. During the non-breeding season, individuals may forage off the coast of northern California, primarily along continental shelf margins (USFWS 2008). Habitat for these pelagic seabirds does not occur within the study area.

In addition to federally and state-listed species, native birds are protected by the Migratory Bird Treaty Act (MBTA). This act was first enacted in 1918 and implements a series of treaties between the United States and Great Britain (on behalf of Canada), Mexico, Japan, and the former Soviet Union that provide for international migratory bird protection. The MBTA authorizes the Secretary of the Interior to regulate the taking of migratory birds; the act provides that it shall be unlawful, except as permitted by regulations, "to pursue, take, or kill any migratory bird, or any part, nest or egg of any such bird…" (USC Title 16, Section 703). This prohibition includes both direct and indirect acts, although harassment and habitat modification are not included unless they result in direct loss of birds, nests, or eggs. The current list of species protected by MBTA includes several hundred species and essentially includes all native birds (see Appendix D for a representative list of birds that may be protected under this act). The act offers no statutory or regulatory mechanism for obtaining an incidental take permit for the loss of non-game migratory birds.

The Bald and Golden Eagle Protection Act (16 USC 668-668d, 54 Stat. 250) as amended, provides protection for the bald eagle and golden eagle by prohibiting the taking, possession, and commerce of such birds, their nests, eggs, or feathers unless expressly authorized by permit pursuant to Federal regulations. Both species may use the study area for foraging; bald eagles may nest within the study area.

4.3 Cultural and Archaeological Resources

4.3.1 Background Research Results

Five previous cultural resources studies have been conducted in the study area. Four studies (Hastings 1975; Leach-Palm et al. 2007; Loyd and Origer 2004; Pape 1993) pertain to SR-1 maintenance or projects adjacent to the highway, and one is a more general regional study (Anthropological Studies Center 2011) assessing the potential effects of climate change on cultural resources within the Point Reyes National Seashore. None of the studies identified cultural resources within the current study area.

No previously recorded archaeological sites were identified within the study area as a result of the record search. Two cultural resources (CA-MRN-380 and CA-MRN-642H) were located within a mile radius of the study area: (1) CA-MRN-380 is located 0.5-miles south of the study area, along the west side of the lagoon, and (2) CA-MRN-642H is located in the hills one mile north of the study area along Coppermine Gulch.

CA-MRN-380 is a prehistoric archaeological site recorded as “sporadic shell concentrations along the Olema-Bolinas Road cut bordering Bolinas Bay,” which has been “largely destroyed” (Barnes 1966). CA-MRN-642H is recorded as the historic-era Coppermine Gulch, a mining complex that includes a cabin, adits, a tailing pile, a boiler, and other features related to mining (Storey et al. 1997).

Examination of historic maps and historic context documents indicated the potential for the presence of several late 19th century and early 20th century buildings and other possible historic features within or proximal to the study area.

4.3.2 Field Survey Results

Of the three historic-era resources noted during the background research – the lighter wharf, the Oyster House, and Wilkins Ranch – only the Wilkins Ranch was positively identified during the field survey.

However, six previously unidentified cultural features were mapped during reconnaissance-level surveys of the study area. None of the newly identified resources have been formally evaluated for CRHR or NRHP eligibility, given that the project has not been designed and impacts not yet defined, and that the regulatory context is also undefined. Photographs of these features are on the following pages, and their locations are shown on Figure 7. The features are as follows:

- **A corral (NorthEnd#1, Photo 1):** NorthEnd#1 is a corral measuring approximately 24 feet (north/south) by 13.5 feet (east/west) situated in a meadow to the south and west of Fairfax-Bolinas Road (Photo 1). The corral consists of approximately 4 to 8 inch-diameter wooden posts, held together with larger, round nails. The two horizontal rails of the corral are approximately 12 inches and 28 inches above the ground.
- **A well and associated pump house (NorthEnd#2, Photos 2 & 3):** NorthEnd#2 is a well and pump house situated in Lewis Creek, west of SR-1 north of the Bolinas “Y”. The pump house is dilapidated and overgrown the dense vegetation (Photo 2). The front of the house, which faces

the creek and runs roughly north/south, is approximately 3 feet wide by 3 feet tall, and shingled in large wooden shingles that appear to have been painted or stained at one point. The pump sits exposed behind the front of the house in a tangle of vines and branches. The face plate of the pump is labeled “Wagner Electric Corporation” out of St. Louis, MO (Photo 3). The Company was founded in 1891, and was purchased in 1966 by Tung-Sol Electric, Inc., of Newark, New Jersey but retained the name Wagner Electric. Wagner Electric merged with Studebaker and Worthington Corporation to create Studebaker-Worthington, a diversified manufacturer, in 1967 (Harvard Business School 2015). As such, the well and pump house are likely over 50 years old.

- **A pile of lumber that appears to be a small dismantled building and associated bricks and decorative tile (NorthEnd#3, Photo 4):** NorthEnd#3 is a pile of approximately 100 pieces of lumber with round nails, some galvanized that have been disassembled and stacked under the tree line of the Wilkins Creek (Photo 4). The boards of lumber vary in length and thickness; however, some planks are 11.5 inches wide by 8 feet long. The boards of lumber are not painted. The pile of lumber is approximately 6 feet west of the creek bed, and within the creek bank, there are numerous bricks (both fire and common red, with no diagnostic features) and a board with white and blue decorative tiles still adhered.
- **An older trailer in a picnic area that appears to have been turned into a bar-b-que (NorthEnd#5, Photo 5):** NorthEnd#5 is an old rusted trailer, overgrown with vegetation, located in the southwest corner of a grassy clearing within a picnic area west of Wilkins Creek (Photo 6). The small utility trailer measures approximately 4 by 7 feet and is 24 inches deep. It has two, 36 inch diameter tires, one of which has “Pacific El Capitan” embossed on the sidewall, with a V-shaped tow hitch. The top of the open trailer is covered in a make-shift grate, while red common brick is stacked on the inside.
- **An outhouse (NorthEnd#4, Photo 6):** NorthEnd#4 is an outhouse, constructed approximately 6 feet west of Wilkins Creek. The single-seat outhouse measures approximately 35.5 by 39 by 90 inches and has a shed-type roof made from a clear, corrugated fiberglass panel. The walls are comprised of 8 to 12 inch-wide boards, with the side walls having 2 inch slats covering the seams of the larger boards. The exterior of the outhouse has been electrified with a light, with a switch and an outlet in a box (labeled “Bell”) on the west side of the structure. The interior has been painted white and there are portions of the exterior, such as the slats on the north wall, are also painted white.
- **Wilkins Ranch, which is outside the current study area, but within the viewshed of the study area (NorthEnd#6, Photo 7):** NorthEnd#6 is the Wilkins Ranch, located between Wilkins Creek and SR-1, north of the Bolinas “Y” (Photo 7). The ranch complex, which includes a farmhouse, several barns, and other outbuildings was constructed in the late 1800s (Livingston 1995:79).

Of these newly recorded resources, NorthEnd#1 through NorthEnd#5 appear unlikely to qualify as significant resources under the CRHR and NRHP, due to a lack of age or historical associations. However, additional background research and analysis is necessary to make formal determinations of eligibility. Although the resources identified are unlikely to qualify for inclusion in the CRHR or NRHP, it may be possible to avoid impacts to the resources through project design, and thus avoid the necessity for formal eligibility determinations.

Photo 1. Wooden corral (NorthEnd#1)

Photo 2. Pump house (NorthEnd#2)

Photo 3. Face plate on pump motor (NorthEnd#2)

Photo 4. Lumber from dismantled building near west bank of Wilkins Creek (NorthEnd#3)

Photo 5. Trailer converted to a bar-b-que, located in a picnic area (NorthEnd#5)

Photo 6. Outhouse near west bank of Wilkins Creek (NorthEnd#4)

Photo 7. Wilkins Ranch (NorthEnd#6)

The Wilkins Ranch (NorthEnd#6), which is outside the current study area and was not formally surveyed or documented, is within the viewshed of the future project. The ranch complex—with the original barn built in 1866 and the main ranch house built in 1875 (Livingston 1995)—is one of the oldest extant ranch complexes in the area, and is directly associated with the early lumber and farming history of the Bolinas/Dogtown area. As such, it may qualify for inclusion in the CRHR or NRHP. Development of the future project design and alternatives should carefully consider the potential for indirect (visual, vibration, etc.) effects to the Wilkins Ranch complex. Although the primary goal of the project is to return the head of Bolinas Lagoon to a more natural hydrologic regime—and, thus, likely in keeping with the original natural setting of the Wilkins Ranch— project design should take into account the potential for direct and indirect effects to the ranch. If any potential impacts are identified, the ranch complex should be formally surveyed and evaluated against the CRHR and NRHP eligibility criteria, to determine if the future project will impact those qualities that make the ranch potentially eligible.

Despite the absence of significant archaeological resources identified by this study, there exists a potential for buried archaeological (geoarchaeological) resources, not evident at the surface, to be present within the study area. Given the setting of the project—within the active floodplain and terraces of the Wilkins Gulch and Lewis Gulch drainages, and associated Holocene alluvial deposition at the head of the lagoon (see Geomorphology section of conditions memorandum)—there appears to be a high potential for recent alluvial deposition that may bury archaeological resources. As such, as project plans develop, and alternatives are considered, a full geoarchaeological analysis is recommended to further assess this potential and determine what portions of the project area have the highest probability of containing buried archaeology, in order to facilitate avoidance of those areas or develop appropriate mitigation measures.

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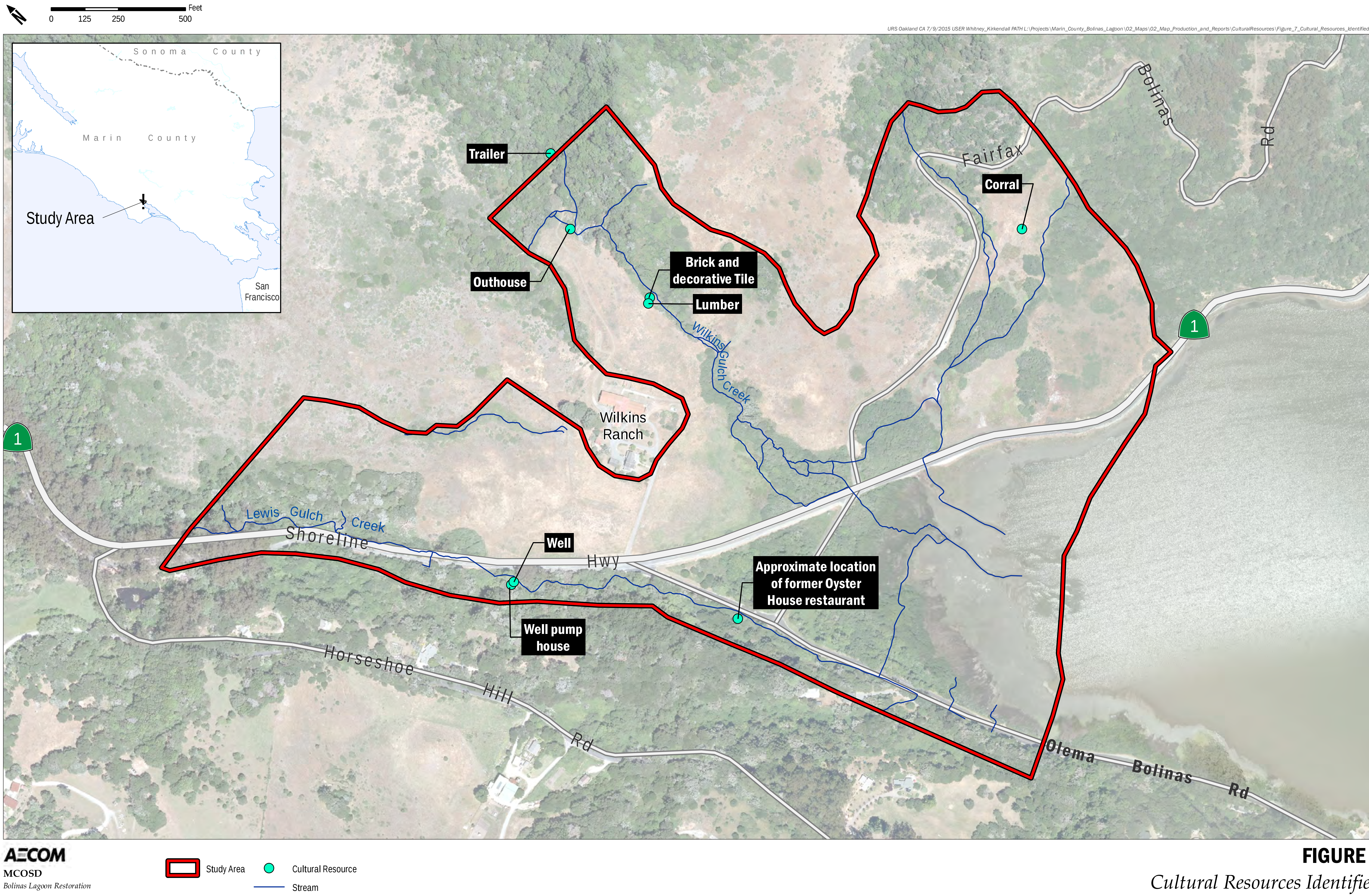

AECOM
MCOSD
Bolinas Lagoon Restoration

FIGURE 7
Cultural Resources Identified

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5 Limitations That May Influence Results

The biological and cultural resource surveys conducted for this project were limited to the areas shown on Figure 1. The intertidal and subtidal areas of Bolinas Lagoon that fell within this boundary were primarily surveyed visually. Further, several areas of steep slopes were only visually surveyed. Other parts of the study area were too densely vegetated and/or covered with poison oak to be safely accessed by the survey teams. The field work funded by this contract was done at a reconnaissance level to map and characterize the various habitats and vegetation communities and to list the species directly observed. It did not include delineations of jurisdictional wetlands and other waters of the United States, protocol-level rare plant surveys, or USFWS protocol-level surveys for ESA-listed or -candidate species.

In addition, the 2014/ 2015 winter left Marin County, California in a severe drought, making it the third consecutive year of drought (NOAA NCIE 2015). This condition is believed to have had a negative effect upon presence and growth of rare plant species, the composition of vegetation communities, and the extent of freshwater wetlands and water resources.

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7 Report Preparers and Field Survey Crews

Table 11 presents the project team members who conducted the background research and field surveys and who prepared portions of this memorandum. Reviewers are listed below.

Table 11. Field Survey Crews and Report Preparers

Name	Education/Degree	Years of Experience	Knowledge Areas
Ivan Parr	B.S. Biology, St. Mary's College	9	Botanical identification, natural community classification and identification, wildlife biology
Tammy Lim	M.A., Ecology, San Francisco State University; B.S., Wildlife Biology, U.C. Davis	15	Wildlife biology with a focus on reptiles and amphibians.
Galen Peracca	Master of Forestry, University of California, Berkeley; B.S., Resource Management, University of California, Berkeley.	11	Forest and wetland ecology, and environmental permitting
Jan Novak	B.S., Soil Science, California Polytechnic State University, San Luis Obispo	14	Soil science and wetland ecology, and environmental permitting. Professional Wetland Scientist.
Jason Pearson	M.S. Forestry Sciences: Watershed Hydrology, California Polytechnic University; B.S., Forestry and Natural Resources Management. California Polytechnic University	13	Hydrology, geomorphology, and forest ecology
Karin Beck	M.A. Cultural Resources Management, Sonoma State University; B.A. Anthropology, University of California, Los Angeles	19	Prehistoric and historical archaeology; cultural resources management
Karen Gardner	M.A. Anthropology, California State University, Chico; B.A. Anthropology, University of California, Santa Cruz	5	Osteology, archaeology, forensic anthropology

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Appendix A.
Vegetation Species Composition Results

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Appendix A

Vegetation Community Composition and Cover

Distichlis Spicata Herbaceaus **Alliance**	
Salt Grass Flats	
Vegetation Cover:	100
Bare Ground:	0
Nativity:	100
Phenology:	Vegetative/Flowering
Quadrat Size	2m X 2m
Species Composition	
Species	**Percentage of Quadrat**
Distichlis spicata	90
Bolboschoenus maritimus	>1
Jaumea carnosa	>1
Salicornia pacifica	5
Potentilla anserina	>1
Atriplex prostrata	<1

Bolboschoenus maritimus **Herbaceous Alliance**	
salt marsh bulrush marshes	
Vegetation Cover:	70
Bare Ground:	0
Open Water:	30
Nativity:	70
Phenology:	Flowering
Quadrat Size	2m x 2m
Species Composition	
Species	**Percentage of Quadrat**
Bolboschoenus maritimus	60
Distichlis spicata	5
Salicornia pacifica	5
Jaumea carnosa	<1

Salicornia pacifica (_Salicornia depressa_) Herbaceous Alliance

Pickleweed Mats

Vegetation Cover:	80
Bare Ground:	0
Open Water:	20
Nativity:	100
Phenology:	Vegetative
Quadrat Size	2m x 2m

Species Composition

Species	**Percentage of Quadrat**
Salicornia pacifica	75
Distichlis spicata	5
Bolboschoenus maritimus	<1

Juncus arcticus (var. _balticus_, _mexicanus_) Herbaceous Alliance

Mexican rush marshes

Vegetation Cover:	90
Bare Ground:	<1
Thatch	10
Nativity:	100
Phenology:	Vegetative
Quadrat Size	2m x 2m

Species Composition

Species	**Percentage of Quadrat**
Juncus balticus	60
Potentilla anserina	30
Persicaria punctata	>1
Oenanthe sarmentosa	>1

***Carex praegracilis* Stands**

Clustered field sedge Marsh

Vegetation Cover:	99
Bare Ground:	<1
Thatch	<1
Nativity:	100
Phenology:	Flowering
Quadrat Size	2m x 2m

Species Composition

Species	Percentage of Quadrat
Carex praegracilis	99
Potentilla anserina	>1
Jaumea carnosa	>1

***Genista monspessulana* Semi-Natural Shrubland**

French Broom Scrub

Vegetation Cover:	95
Bare Ground:	<1
Thatch	5
Nativity:	5
Phenology:	Flowering
Quadrat Size	2m x 2m

Species Composition

Species	Percentage of Quadrat
Genista monspessulana	65
Foeniculum vulgare	10
Distichlis spicata	5
Dichondra sp.	>1
Linum bienne	>1
Bromus hordeaceus	>1
Briza major	>1
Hypochaeris radicata	>1
Brachypodium distachyon	>1

Ruderal

Vegetation Cover:	60
Bare Ground:	5
Thatch	35
Nativity:	Low
Phenology:	Vegetative
Quadrat Size	2m x 2m

Species Composition

Species	**Percentage of Quadrat**
Dipsacus sativus	30
Briza major	10
Foeniculum vulgare	5
Plantago lanceolata	5
Vicia sativa	<1
Dichondra sp.	5
Genista monspessulana	>1
Symphyotrichum sp.	>1
Linum bienne	<1
Geranium molle	<1

Baccharis Pilularis Shrubland Alliance

Coyote Brush Scrub

Vegetation Cover:	90
Bare Ground:	5
Thatch	5
Nativity:	Moderate
Phenology:	Vegetative
Quadrat Size	10 x 10 m

Species Composition

Species	Percentage of Quadrat
Baccharis pilularis	45
Artemisia californica	20
Toxicodendron diversilobum	5
Mimulus aurantiacus	5
Stipa pulchra	>1
Rubus ursinus	5
Genista monspessulana	>1
Dryopteris arguata	>1
Bromus carinatus	5
Briza maxima	>1
Plantago lanceolata	>1
Frangula californica	>1
Lonicera hispidula	>1
Sanicula crassicaulis	>1

California Annual Grassland

Vegetation Cover:	85
Bare Ground:	<1
Thatch	15
Nativity:	Low
Phenology:	Flowering
Quadrat Size	2m x 2m

Species Composition

Species	**Percentage of Quadrat**
Bromus diandrus	30
Raphanus sativus	10
Avena fatua	10
Conium maculatum	10
Carduus pycnocephalus var. *pycnocephalus*	5
Briza maxima	5
Eschscholzia californica	>1
Brassica nigra	>1
Plantago lanceolata	>1
Rumex acetosella	>1
Hypochaeris radicata	>!
Geranium molle	>1
Foeniculum vulgare	5
Holcus lanatus	>1
Taraxacum officinale	>1
Dichondra sp.	>1
Cirsium vulgare	>1

Umbellularia californica Forest Alliance

California Bay Forest

Vegetation Cover:	100
Bare Ground:	0
Thatch	0
Nativity:	high
Phenology:	vegetative
Quadrat Size	10m x 10m

Species Composition

Species	Percentage of Quadrat
Umbellularia californica	70
Sambucus nigra	10
Rubus ursinus	10
Corylus cornuta	5
Pteridium aquilinum	5
Briza maxima	<1
Stachys ajugoides	<1
Delairea odorata	<1
Conium maculatum	<1
Silybum marianum	<1
Medicago polymorpha	<1
Plantago lanceolata	<1

Quercus agrifolia Woodland Alliance (south-facing)

Coast Live Oak Woodland

Vegetation Cover:	100
Bare Ground:	<1
Thatch	<1
Nativity:	high
Phenology:	vegetative
Quadrat Size	10m x 10m

Species Composition

Species	Percentage of Quadrat
Quercus agrifolia	50
Umbellularia californica	20
Pseudotsuga menziesii	10
Genista monspessulana	1
Heteromeles arbutifolia	5
Aesculus calfiornica	5
Toxicodendron diversilobum	5
Artemisia californica	1
Calystegia subacaulis	1
Lonicera hispidula	1
Scrophularia californica	<1
Fragaria vesca	<1
Chlorogalum pomeridianum	<1
Marah oregana	<1

***Quercus agrifolia* Woodland Alliance (north-facing)**

Coast Live Oak Woodland

Vegetation Cover:	155
Bare Ground:	0
Thatch	5
Nativity:	high
Phenology:	vegetative
Quadrat Size	10m x 10m

Species Composition

Species	**Percentage of Quadrat**
Quercus agrifolia	60
Umbellularia californica	45
Corylus cornuta	40
Pteridium aquilinum	>1
Oemleria cerasiformis	>1
Montia perfoliata	>1
Rubus ursinus	5
Conium maculatum	>1
Genista monspessulana	5

***Artemisia californica* shrubland alliance**

California sagebrush Scrub

Vegetation Cover:	80
Bare Ground:	5
Thatch	15
Nativity:	high
Phenology:	vegetative
Quadrat Size	10m x 10m

Species Composition

Species	**Percentage of Quadrat**
Artemisia californica	45
Genista monspessulana	15
Toxicodendron diversilobum	10
Heteromeles arbutifolia	5
Chlorogalum pomeridianum	1
Calystegia sp.	1
Galium aparine	1
Rubus ursinus	>1
Quercus agrifolia	>1
Foeniculum vulgare	>1
Fragaria vesca	>1

***Alnus rubra* Forest Alliance**

Red alder groves

Vegetation Cover:	135
Thatch	5
Nativity:	high
Phenology:	vegetative
Quadrat Size	10m x 10m

Species Composition

Species	**Percentage of Quadrat**
Alnus rubra	35
Salix lasiolepis	30
Scrophularia californica	30
Delairea odorata	10
Fumaria parviflora	<1
Bromus carinatus	5
Bromus diandrus	<1
Urtica dioica	20
Sambucus racemosa	5
Vinca major	<1
Equisetum telmateia	<1
Woodwardia fimbriata	<1

***Salix lasiolepis* Shrubland Alliance**

Arroyo willow thickets

Vegetation Cover:	155
Thatch	15
Nativity:	high
Phenology:	vegetative
Quadrat Size	10m x 10m

Species Composition

Species	**Percentage of Quadrat**
Salix lasiolepis	75
Alnus rubra	5
Rubus ursinus	40
Woodwardia fimbriatum	10
Carduus pycnocephalus var. *pycnocephalus*	5
Equisetum sp.	10
Scirpus microcarpus	5
Conium maculatum	5
Rumex crispus	>1

***Eucalyptus globulus* Woodland Semi-Natural Alliance**

Eucalyptus groves

Vegetation Cover:	120
Bare ground	0
Thatch	1
Nativity:	Low
Phenology:	vegetative
Quadrat Size	10m x 10m

Species Composition

Species	**Percentage of Quadrat**
Eucalyptus globulus	60
Frangula californica	10
Oenanthe sarmentosa	1
Equisetum telmateia	5
Rubus ursinus	40
Vinca major	>1
Vicia sativa	>1
Marah fabacea	5

Equisetum telmateia Herbaceous Alliance (not in MCV2)

Horsetail Marsh

Vegetation Cover:	100
Bare ground	0
Thatch	0
Nativity:	Moderate
Phenology:	vegetative
Quadrat Size	2m x 2m

Species Composition

Species	**Percentage of Quadrat**
Equisetum telmateia	40
Ranunculus repens	10
Festuca arundinacea	10
Juncus effusus	10
Holcus lanatus	15
Rumex crispus	5
Helminthotheca echioides	5
Cyperus eragrostis	5

Rubus ursinus Shrubland Alliance

Coastal brambles

Vegetation Cover:	100
Bare ground	0
Thatch	>1
Nativity:	99
Phenology:	Flowering
Quadrat Size	10m x 10m

Species Composition

Species	**Percentage of Quadrat**
Rubus ursinus	95
Salix lasiolepis	1
Equisetum telmateia	1
Mimulus guttatus	1
Juncus lescurii	1
Vicia sativa	1

***Typha* (*angustifolia*, *domingensis*, *latifolia*) Herbaceous Alliance**

Cattail Marsh

Vegetation Cover:	100
Bare ground	0
Thatch	>1
Nativity:	99
Phenology:	Flowering
Quadrat Size	10m x 10m

Species Composition

Species	Percentage of Quadrat
Typha latifolia	30
Woodwardia fimbriata	60
Rubus armeniacus	5
Alnus rubra	5

Appendix B.
Plant Species Observed

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Appendix B. Plant species Observed in the Study Area

Scientific Name[3]	Common Name	Nativity	Cal-IPC Rating[1]	Wetland Indicator Status[2]
Acer macrophyllum	bigleaf maple	Native	NA	FAC
Acer negundo	boxelder	Native	NA	FACW
Achillea millefolium	whitetop yarrow	Native	NA	FACU
Adiantum jordanii	maidenhair fern	Native	NA	FAC
Aesculus californica	California buckeye	Native	NA	NL
Agrostis stolonifera	creeping bent-grass	Native	Limited	FAC
Aira caryophyllea	silvery hairgrass	Non-Native	NA	FACU
Allium triquetrum	Three cornered leek	Non-Native	NA	NL
Alnus rhombifolia	white alder	Native	NA	FACW
Alopecurus sp.	foxtail	Native	NA	OBL/FACW
Ambrosia chamissonis	beach bur weed	Native	NA	NL
Anagallis arvensis	scarlet pimpernel	Non-Native	NA	NL
Anredera cordifolia	mignonette vine	Non-Native	NA	NL
Anthoxanthum occidentale	California sweetgrass	Native	NA	NL
Anthoxanthum odoratum	sweet vernal grass	Non-Native	Moderate	FAC
Anthriscus caucalis	bur chervil	Non-Native	NA	NL
Aphanes occidentalis	lady's mantle	Native	NA	NL
Arbutus menziesii	madrone	Native	NA	NL
Arctotheca calendula	Cape weed	non-native	Moderate - Alert	NL
Armeria maritima	thrift seapink	Native	NA	FACU
Artemisia californica	California sagebrush	Native	NA	NL
Atriplex patula	fathen	Native	NA	FACW
Atriplex prostrata	fathen	Non-Native	NA	FACW
Avena barbata	slender wild oats	Non-Native	Moderate	NL
Avena fatua	fat wild oats	Non-Native	Moderate	NL
Avena sativa	sweet wild oats	Non-Native	NA	UPL
Baccharis pilularis	coyote brush	Native	NA	NL
Barbarea orthoceras	American wintercress	Native	NA	FACW
Bellis perennis	English daisy	Non-Native	NA	NL
Bolboschoenus maritimus subsp. *paludosus*	salt marsh bulrush	Native	NA	OBL
Bolboschoenus robustus	sturdy bulrush	Native	NA	OBL
Brachypodium distachyon	false brome	Non-Native	Moderate	NL
Brassica nigra	black mustard	Non-Native	Moderate	NL
Brassica rapa	rape mustard	Non-Native	Limited	FACU
Briza maxima	big rattlesnake grass	Non-Native	Limited	NL
Briza minor	little rattlesnake grass	Non-Native	NA	NL
Bromus carinatus	California brome	Native	NA	NL
Bromus diandrus	ripgut brome	Non-Native	Moderate	NL
Bromus hordeaceus	soft brome	Non-Native	Limited	NL
Bromus madritensis ssp. *rubens*	Red brome	Non-Native	High	NL
Cakile edentula	American searocket	Non-Native	NA	FACU
Cakile maritima	European searocket	Non-Native	Limited	FAC
Calendula arvensis	field marigold	Non-Native	NA	NL

Scientific Name[3]	Common Name	Nativity	Cal-IPC Rating[1]	Wetland Indicator Status[2]
Calochortus albus	white globe lily	Native	NA	NL
Calystegia purpurata ssp. *purpurata*	purple morning glory	Native	NA	NL
Calystegia subacaulis	stemless morning glory	Native	NA	NL
Capsella bursa-pastoris	shepherd's purse	Non-Native	NA	FACU
Cardamine californica	California toothwort	Native	NA	NL
Cardamine oligosperma	bitter cress	Native	NA	FAC
Carduus pycnocephalus ssp. *pycnocephalus*	Italian thistle	Non-Native	Moderate	NL
Carex praegracilis	clustered field sedge	Native	NA	NL
Carpobrotus edulis x *chilensis*	hybrid iceplant	Non-Native	Moderate	FACU
Castilleja sp.	Indian paintbrush	Native	NA	NL
Ceanothus thyrsiflorus	blueblossom ceanothus	Native	NA	NL
Centaurea melitensis	tocalote	Non-Native	Moderate	NL
Cerastium glomeratum	mousear chickweed	Non-Native	NA	UPL
Chasmanthe bicolor	Chasmanthe	Non-Native	NA	NL
Chasmanthe x crocosmiiflora	Montbretia	Non-Native	Limited	NL
Chlorogalum pomeridianum	soap plant	Native	NA	NL
Cirsium vulgare	bull thistle	Non-Native	Moderate	FACU
Claytonia perfoliata	miner's lettuce	Native	NA	FAC
Claytonia sibirica	spring beauty	Native	NA	NL
Clinopodium douglasii	yerba buena	Native	NA	FACU
Conium maculatum	poison hemlock	Non-Native	Moderate	FACW
Convolvulus arvensis	field bindweed	Non-Native	NA	NL
Cortaderia sp.	Pampas grass	Non-Native	High	NL
Corylus cornuta ssp. *californica*	hazelnut	Native	NA	NL
Cotoneaster franchetii	orange cotoneaster	Non-Native	Moderate	NL
Cotoneaster pannosus	silverleaf cotoneaster	Non-Native	Moderate	NL
Cotula coronopifolia	brass buttons	Non-Native	Limited	OBL
Crassula tillaea	pygmy weed	Non-Native	NA	FACU
Cuscuta pacifica	Pacific dodder	Native	NA	NL
Cynodon dactylon	bermudagrass	Non-Native	Moderate	FACU
Cynoglossum grande	western houndstongue	Native	NA	NL
Cynosurus echinatus	dogsfoot grass	Non-Native	Moderate	NL
Cyperus eragrostis	redroot umbrella sedge	Native	NA	FACW
Cyperus involucratus	umbrella plant	Non-Native	NA	FACW
Cystopteris fragilis	brittle bladder fern	Native	NA	FACU
Cytisus scoparius	Scotch broom	Non-Native	High	NL
Dactylis glomerata	Orchard grass	Non-Native	Limited	FACU
Delairea odorata	cape ivy	Non-Native	High	NL
Dichelostemma capitatum	blue dicks	Native	NA	FACU
Dichondra donelliana	California ponysfoot	Native	NA	NL
Digitaria sanguinalis	hairy crabgrass	Non-Native	NA	FACU
Dipsacus fullonum	Fuller's teasel	Non-Native	Moderate	FAC
Dipsacus sativus	teasel	Non-Native	Moderate	NL
Distichlis spicata	salt grass	Native	NA	FAC
Dittrichia graveolens	stinkwort	Non-Native	Moderate - Alert	NL

Scientific Name[3]	Common Name	Nativity	Cal-IPC Rating[1]	Wetland Indicator Status[2]
Drymocallis glandulosa	sticky cinquefoil	Native	NA	FAC
Dryopteris arguta	wood fern	Native	NA	NL
Echinochloa crus-galli	barnyard grass	Non-Native	NA	FACW
Echium candicans	pride of Madeira	Non-Native	Limited	NL
Ehrharta erecta	pacific veldt grass	Non-Native	Moderate	NL
Eleocharis macrostachya	common spikerush	Native	NA	OBL
Epilobium brachycarpum	annual fireweed	Native	NA	NL
Epilobium ciliatum	fringed willowherb	Native	NA	FACW
Epipactis helleborine	broadleaf helleborine	Non-Native	NA	FACU
Equisetum arvense	Common horsetail	Native	NA	FAC
Equisetum telmateia	Giant horsetail	Native	NA	FACW
Erigeron canadensis	Canada horseweed	Native	NA	FACU
Erigeron glaucus	seaside daisy	Native	NA	FACU
Erodium botrys	heron's bill	Non-Native	NA	FACU
Erodium brachycarpum	white-stemmed filaree	Non-Native	NA	NL
Erodium cicutarium	red-stemmed storksbill	Non-Native	Limted	NL
Erodium moschatum	musky stork's bill	Non-Native	NA	NL
Eruca vesicaria	rocketsalad	Non-Native	NA	NL
Eschscholzia californica	California poppy	Native	NA	NL
Eucalyptus camaldulensis	red river gum	Non-Native	Limited	FAC
Eucalyptus globulus	blue gum	Non-Native	Moderate	NL
Eucalyptus sp.	Eucalyptus	Non-Native	NA	NL
Festuca arundinacea	tall fescue	Non-Native	Moderate	FACU
Festuca bromoides	coastal fescue	Non-Native	NA	FAC
Festuca myuros	ratstail fescue	Non-Native	Moderate	FACU
Festuca perennis	Italian wildrye	Non-Native	Moderate	FAC
Ficus carica	common fig	Non-Native	Moderate	FACU
Foeniculum vulgare	fennel	Non-Native	High	NL
Fragaria vesca	woodland strawberry	Native	NA	UPL
Frangula californica	California coffeeberry	Native	NA	NL
Frankenia salina	alkali heath	Native	NA	FACW
Galium aparine	stickywilly	Native	NA	FACU
Galium spp.	bedstraw	Native	NA	NL
Gamochaeta ustulata	featherweed	Native	NA	NL
Garrya elliptica	coast silk-tassle	Native	NA	NL
Gazania linearis	treasureflower	Non-Native	Moderate - Alert	NL
Genista monspessulana	French broom	Non-Native	High	NL
Geranium dissectum	cutleaf geranium	Non-Native	Limited	NL
Geranium molle	dovesfoot	Non-Native	NA	NL
Geranium robertianum	Robert geranium	Non-Native	NA	NL
Grindelia stricta var. *angustifolia*	narrow-leaf gum plant	Native	NA	FACW
Hedera helix	English ivy	Non-Native	High	FACU
Helminthotheca echioides	bristly ox-tongue	Non-Native	Limited	FACU
Heracleum maximum	cow parsnip	Native	NA	NL
Hesperocnide tenella	western nettle	Native	NA	NL
Hesperocyparis macrocarpa	Monterey cypress	Non-Native	NA	NL

Scientific Name[3]	Common Name	Nativity	Cal-IPC Rating[1]	Wetland Indicator Status[2]
Heteromeles arbutifolia	toyon	Native	NA	NL
Hirschfeldia incana	short-podded mustard	Non-Native	Moderate	NL
Holcus lanatus	velvet grass	Non-Native	Moderate	FAC
Holodiscus discolor	ocean spray	Native	NA	FACU
Hordeum brachyantherum	meadow barley	Native	NA	FACW
Hordeum marinum	seaside barley	Non-Native	Moderate	FAC
Hordeum murinum	foxtail barley	Non-Native	Moderate	FACU
Horkelia cuneata	wedgeleaf horkelia	Native	NA	NL
Hydrocotyle verticillata	Whorled pennywort	Native	NA	OBL
Hypochaeris glabra	soft cat's ear	Non-Native	Limited	NL
Hypochaeris radicata	rough cat's ear	Non-Native	Moderate	FACU
Iris douglasiana	Douglas iris	Native	NA	NL
Iris pseudacorus	yellow iris	Non-Native	Limited	OBL
Jaumea carnosa	jaumea	Native	NA	OBL
Juncus balticus	Baltic rush	Native	NA	FACW
Juncus lescurii	dune rush	Native	NA	FACW
Juncus effusus	common rush	Native	NA	FACW
Juncus mexicanus	Mexican rush	Native	NA	FACW
Juncus patens	blue rush	Native	NA	FACW
Kickxia elatine	sharpleaf cancerwort	Non-Native	NA	UPL
Lactuca serriola	prickly lettuce	Non-Native	NA	FACU
Lathyrus latifolius	perennial sweetpea	Non-Native	NA	NL
Lathyrus vestitus	Pacific pea	Native	NA	NL
Limonium californicum	sea lavender	Native	NA	FACW
Linum bienne	biennial flax	Non-Native	NA	NL
Lonicera hispidula	hairy honeysuckle	Native	NA	FACU
Lonicera involucrata	twinberry	Native	NA	FAC
Lupinus albifrons	silver bush lupine	Native	NA	NL
Lupinus bicolor	dove lupine	Native	NA	NL
Lupinus nanus	sky lupine	Native	NA	NL
Lupinus variicolor	manycolored lupine	Native	NA	NL
Lythrum hyssopifolia	hyssop loosetrife	Non-Native	NA	OBL
Madia sativa	coast tarweed	Native	NA	NL
Maianthemum stellatum	starry false lily of the valley	Native	NA	FACU
Malva arborea	tree mallow	Non-Native	NA	NL
Malva parviflora	cheeseweed	Non-Native	NA	NL
Marah fabacea	California man-root	Native	NA	NL
Marah oreganus	coast man-root	Native	NA	NL
Matricaria discoidea	pineapple weed	Non-Native	NA	FACU
Medicago arabica	spotted medick	Non-Native	NA	NL
Medicago polymorpha	bur clover	Non-Native	Limited	FACU
Melilotus indicus	annual yellow sweetclover	Non-Native	NA	FACU
Mentha pulegium	pennyroyal	Non-Native	Moderate	OBL
Mentha spicata	spearmint	Non-Native	NA	OBL
Mimulus aurantiacus	bush monkeyflower	Native	NA	NL
Mimulus cardinalis	scarlet monkeyflower	Native	NA	FACW
Mimulus guttatus	seep monkeyflower	Native	NA	OBL

Scientific Name[3]	Common Name	Nativity	Cal-IPC Rating[1]	Wetland Indicator Status[2]
Morella californica	California wax-myrtle	Native	NA	FACW
Myoporum laetum	nago	Non-Native	Moderate	FACU
Myosotis latifolia	forget me not	Non-Native	Limited	NL
Nasturtium officinale	water parsley	Native	NA	OBL
Navarretia squarrosa	skunkweed	Native	NA	FACU
Oemleria cerasiformis	oso berry	Native	NA	FACU
Oenanthe sarmentosa	Pacific water parsley	Native	NA	OBL
Osmorhiza berteroi	Sweet cicely	Native	NA	FACU
Oxalis articulata ssp. rubra	windowbox sorrel	Non-Native	NA	NL
Oxalis pes-caprae	Bermuda buttercup	Native	Moderate	NL
Paspalum dilatatum	dallisgrass	Non-Native	NA	FAC
Pedicularis densiflora	Indian warrior	Native	NA	NL
Pentagramma triangularis	goldenback fern	Native	NA	NL
Persicaria punctata	Dotted smartweed	native	NA	OBL
Persicaria sp.	smartweed	native	NA	FAC/OBL
Petrorhagia dubia	windmill pink	Non-Native	NA	NL
Phacelia sp.	caterpillar flower	Native	NA	NL
Phalaris aquatica	harding grass	Non-Native	Moderate	FACU
Plantago coronopus	buckhorn plantain	Non-Native	NA	FACW
Plantago lanceolata	common plantain	Non-Native	Limited	FAC
Plantago major	big plantain	Non-Native	NA	FAC
Plantago maritima	goose tongue	Native	NA	FACW
Plantago subnuda	coastal plantain	Native	NA	FACW
Polypodium calirhiza	licorice fern	Native	NA	NL
Polypodium scouleri	leather fern	Native	NA	NL
Polypogon australis	Chilean rabbitsfoot grass	Non-Native	NA	FACW
Polypogon monspeliensis	rabbitsfoot grass	Non-Native	Limited	FACW
Polystichum munitum	sword fern	Native	NA	FACU
Potentilla anserina	silverweed cinquefoil	Native	NA	OBL
Prunus cerasifera	cherry plum	Non-Native	Limited	NL
Prunus emarginata	bitter cherry	Native	NA	FACU
Pseudotsuga menziesii	Douglas fir	Native	NA	FACU
Pteridium aquilinum	bracken fern	Native	NA	FACU
Quercus agrifolia	coast live oak	Native	NA	NL
Quercus lobata	valley oak	Native	NA	FACU
Ranunculus aquatilis	aquatic buttercup	Native	NA	OBL
Ranunculus californicus	California buttercup	Native	NA	FACU
Ranunculus repens	creeping buttercup	Non-native	Limited	FAC
Raphanus raphanistrum	charlock	Non-Native	NA	NL
Raphanus sativus	wild raddish	Non-Native	Limited	NL
Ribes menziesii	canyon gooseberry	Native	NA	NL
Robinia pseudoacacia	black locust	Non-Native	Limited	FACU
Romulea rosea var. australis	rosy sandcrocus	Non-Native	NA	NL
Rorippa curvisiliqua	water yellowcress	Native	NA	OBL
Rosa californica	California rose	Native	NA	FAC
Rubus armeniacus	Himalayan blackberry	Non-Native	High	FACU

Scientific Name[3]	Common Name	Nativity	Cal-IPC Rating[1]	Wetland Indicator Status[2]
Rubus parviflorus	thimbleberry	Native	NA	FAC
Rubus spectabilis	salmonberry	Native	NA	FAC
Rubus ursinus	California blackberry	Native	NA	FAC
Rumex acetosella	sheep sorrel	Non-Native	Moderate	FACU
Rumex conglomeratus	clustered dock	Non-Native	NA	FACW
Rumex crispus	curly dock	Non-Native	Limited	FAC
Rumex pulcher	fiddle dock	Non-Native	NA	FAC
Salix lasiolepis	arroyo willow	Native	NA	FACW
Sambucus nigra	Blue elderberry	Native	NA	FAC
Sambucus racemosa	red elderberry	Native	NA	FACU
Sanicula crassicaulis	cutleaf sanicle	Native	NA	NL
Salicornia pacifica	pickleweed	Native	NA	OBL
Schoenoplectus acutus	hardstem bulrush	Native	NA	OBL
Scirpus microcarpus	panicled bulrush	Native	NA	OBL
Scrophularia californica	California bee plant	Native	NA	FAC
Senecio minimus	coastal burnweed	Non-Native	Moderate	FACU
Senecio vulgaris	Old man of the spring	Non-Native	NA	FACU
Sequoia sempervirens	coast redwood	Native	NA	NL
Sherardia arvensis	field madder	Non-native	NA	NL
Sidalcea malviflora	checkerbloom	Native	NA	FACW
Silybum marianum	milk thistle	Non-Native	Limited	NL
Sisymbrium officinale	hedgemustard	Non-Native	NA	NL
Sisyrinchium bellum	blue-eyed grass	Native	NA	FACW
Solanum americanum	American black nightshade	Native	NA	FACU
Solanum umbelliferum	blue witch	Native	NA	NL
Sonchus asper	prickly sowthistle	Non-Native	NA	FAC
Sonchus oleraceus	common sowthistle	Non-Native	NA	NL
Sparaxis tricolor	wandflower	Non-Native	NA	NL
Spartium junceum	Spanish broom	Non-Native	High	NL
Spergularia sp.	sand spurry	Non-Native	NA	FAC/OBL
Stachys ajugoides	bugle hedge-nettle	Native	NA	OBL
Stachys chamissonis	coast hedge-nettle	Native	NA	OBL
Stachys bullata	California hedge-nettle	Native	NA	NL
Stipa pulchra	purple needlegrass	Native	NA	NL
Symphyotrichum spp.	aster	Native	NA	NL
Taraxacum officinale	dandelion	Non-Native	NA	FACU
Torilis arvensis	hedge parsley	Non-Native	Moderate	NL
Toxicodendron diversilobum	poison oak	Native	NA	FACU
Trifolium hirtum	rose clover	Non-Native	Moderate	NL
Trifolium repens	white clover	Non-Native	NA	FACU
Trifolium wormskioldii	cow clover	Native	NA	FACW
Triglochin concinna	Utah arrowgrass	Native	NA	OBL
Triglochin maritima	arrowgrass	Native	NA	OBL
Typha angustifolia	narrowleaf cattail	Non-Native	NA	OBL
Typha latifolia	broadleaf cattail	Native	NA	OBL
Ulmus pumila	Siberian elm	Non-Native	NA	UPL

Scientific Name[3]	Common Name	Nativity	Cal-IPC Rating[1]	Wetland Indicator Status[2]
Umbellularia californica	California bay	Native	Moderate - Alert	FAC
Urtica dioica	stinging nettle	Native	NA	FAC
Vicia benghalensis	purple vetch	Non-Native	NA	NL
Vicia gigantea	giant vetch	Native	NA	NL
Vicia sativa	spring vetch	Non-Native	NA	FACU
Vinca major	bigleaf periwinkle	Non-Native	Moderate	NL
Woodwardia fimbriata	giant chain fern	Native	NA	FACW
Zantedeschia aethiopica	common calla lily	Non-Native	Limited	OBL

[1] Cal-IPC ratings are defined as follows:

- **High –** These species have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically.
- **Moderate** – These species have substantial and apparent—but generally not severe—ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal, though establishment is generally dependent upon ecological disturbance. Ecological amplitude and distribution may range from limited to widespread.
- **Limited** – These species are invasive but their ecological impacts are minor on a statewide level or there was not enough information to justify a higher score. Their reproductive biology and other attributes result in low to moderate rates of invasiveness. Ecological amplitude and distribution are generally limited, but these species may be locally persistent and problematic.

[2] Wetland indicator status is based upon published ratings found in the U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory National Wetland Plant Draft Ratings for the Arid West Region (2012). Ratings are defined as follows:

- **OBL**= obligate
- **FACW**=facultative wet
- **FAC**=facultative
- **FACU**=facultative upland
- **NL**=not listed

[3] Scientific names were determined in accordance with the latest version of the Jepson Flora Project (eds.) 2015 Jepson eFlora, http://ucjeps.berkeley.edu/IJM.html. Accessed on July, 2, 2015

Appendix C.
CNDDB Occurrences of Federally and State-Listed Species within a 5-mile Radius of the Study Area

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APPENDIX C. CNDDB Occurrences of Federally and State-Listed Species within a 5-mile Radius of the Study Area

OBJECT ID	Scientific Name	Common Name	Date	Federal Listing	State Listing	Location	General
85	*Oncorhynchus kisutch*	coho salmon - central California coast ESU	20031022	Endangered	Endangered	LAGUNITAS CREEK DRAINAGE, POINT REYES STATION, POINT REYES NATIONAL SEASHORE, SAMUEL P. TAYLOR STATE PARK.	FISH TOTALS (LIVE & DEAD) FOR LAGUNITAS CR WATERSHED: 1995-6, 290; 1996-7, 525; 1997-8, 241. MARIN MWD SURVEYS, FISH/ YEAR: 216/1993; 578/1994; 210/1995; 246/1996; 541/1997; 124/1998; 168/1999. 2000; 2084/2000-01 OBS ALL 4 CRKS. 608/2003.
105	*Rallus longirostris obsoletus*	California clapper rail	1975XXXX	Endangered	Endangered	BOLINAS LAGOON.	ONE RAIL OBSERVED IN 1970; ONE RAIL OBSERVED IN 1973.
88	*Syncaris pacifica*	California freshwater shrimp	1999XXXX	Endangered	Endangered	PORTION OF LAGUNITAS CREEK, 1.0 MI UPSTREAM FROM PT REYES STATION TO SOUTHEAST BORDER OF SAMUEL P. TAYLOR STATE PARK.	IN 1981, 1,947 NETTED, 80% FOUND DOWNSTREAM FROM BIG BEND. IN 1988/89 SURVEY, LARGEST NUMBERS FOUND FROM BELOW PETERS DAM TO PT REYES STATION. MARIN MWD SURVEY OBSERVED TOTAL 12282 SHRIMP, 3355 ADULTS, 8927 JUVENILES IN YEARS 1997 TO 1999.
2	*Callophrys mossii bayensis*	San Bruno elfin butterfly	XXXXXXXX	Endangered	None	NEAR ALPINE LAKE.	
112	*Laterallus jamaicensis coturniculus*	California black rail	200105XX	None	Threatened	MARSH IN SW BOLINAS LAGOON, IN VICINITIY OF BOLINAS COUNTY PARK & KENT ISLAND.	DETECTIONS IN 1986, 1988, 1996, 2000 & 2001. LOW ABUNDANCE (<0.6 RAILS/HA) IN 2001.
121	*Laterallus jamaicensis coturniculus*	California black rail	19860612	None	Threatened	COVE IN BOLINAS LAGOON AT MOUTH OF PIKE COUNTY GULCH.	ONE RAIL RESPONDED TO A TAPED CALL DURING 1986 SURVEY.
122	*Laterallus jamaicensis coturniculus*	California black rail	19860612	None	Threatened	COVE IN BOLINAS LAGOON AT MOUTH OF AUDUBON CANYON.	ONE RAIL RESPONDED TO A TAPED CALL DURING 1986 STUDY.
113	*Charadrius alexandrinus nivosus*	western snowy plover	1978XXXX	Threatened	None	BOLINAS LAGOON SPIT, WEST OF STINSON BEACH.	1-2 NESTS OBSERVED DURING THE 1970'S; ONE PAIR OBSERVED DURING THE 1978 STUDY.
87	*Oncorhynchus mykiss irideus*	steelhead - central California coast DPS	20031022	Threatened	None	LAGUNITAS CREEK, 1.2 MILES NE OF POINT REYES STATION TO CONFLUENCE GERONIMO CREEK UP TO WOODACRE, & 3/4 OF DEVILS GULCH.	TOTAL STEELHEAD COUNTS/YEAR: 809/1993; 968/1994; 1176/1995; 1041/1996; 1309/1997; 2078/1998; 1761/1999. 1582 JUVENILES OBS AT 12 SITES BETWEEN 23 SEP & 22 OCT 2003.
60	*Rana draytonii*	California red-legged frog	20060517	Threatened	None	OUTFLOW FROM KENT LAKE, JUST UPSTREAM FROM THE CONFLUENCE	1 ADULT OBSERVED ON 17 MAY 2006.

APPENDIX C. CNDDB Occurrences of Federally and State-Listed Species within a 5-mile Radius of the Study Area

OBJECT ID	Scientific Name	Common Name	Date	Federal Listing	State Listing	Location	General
						WITH LAGUNITAS CREEK, WEST OF LAGUNITAS.	
141	*Rana draytonii*	California red-legged frog	20040304	Threatened	None	4 SMALL PONDS SE OF BASS LAKE, POINT REYES NATIONAL SEASHORE.	TOTAL OF 14 ADULTS OBSERVED AT P103, 104 & 106 ON 23 AUG 1993, 1 ADULT OBSERVED AT P106 ON 3 MAR 2004 AND 2 ADULTS OBSERVED AT P600 ON 4 MAR 2004.
146	*Rana draytonii*	California red-legged frog	20080514	Threatened	None	WEST SIDE OF HWY 1, 2.33 AIR MI NNW OF WOODVILLE, POINT REYES NATIONAL SEASHORE.	OC: '97; 3 ADULTS & 1SUBADULT. MP: EGGS OBS IN '95-'97 & '00- '02. LARVAE OBS IN '93, '95, '05, '06 & '08. ADULTS OBS IN '97, '99, & '07. OVTP: EGGS OBS IN '96-98 & '00-'02. LARVAE OBS IN '93, '95, '99, '03, & '05-'07. 1 ADULT OBS IN '98.
152	*Rana draytonii*	California red-legged frog	20020401	Threatened	None	EAST & WEST SIDE OF HWY 1, 0.49 AIR MI SSE OF FIVE BROOKS, GOLDEN GATE NATIONAL RECREATION AREA.	1 ADULT OBSERVED ON 1 AUG 1994. 1 ADULT OBSERVED ON 1 APR 2002.
153	*Rana draytonii*	California red-legged frog	20060712	Threatened	None	WEBER POND & MIDDLE PINE GULCH CREEK, JUST SOUTH OF LAUFF RANCH RD, BOLINAS.	MIDDLE PINE GULCH CREEK: 1 ADULT OBS ON 25 MAY & 1 AD, 1 SUBADULT ON 28 JUN 2006. WEBER POND: 4 AD, 1 SUBADULT OBS ON 15 MAR, 10 AD ON 31 MAY, 8 AD ON 6 JUL, & 1 AD ON 12 JUL 2006. DIURNAL & NOCTURNAL SURVEYS. BULLFROGS PRESENT.
154	*Rana draytonii*	California red-legged frog	20040311	Threatened	None	NW AND NE ENDS OF CRYSTAL LAKE, POINT REYES NATIONAL SEASHORE.	1 ADULT OBSERVED AT EACH SITE ON 7 JUL 2004.
157	*Rana draytonii*	California red-legged frog	20040709	Threatened	None	OCEAN LAKE, POINT REYES NATIONAL SEASHORE.	1 LARVA OBSERVED ON 29 JUN 2004 AT P-628B. 6 ADULTS, 1 SUBADULT & 10 LARVAE OBSERVED ON 8 JUL 2004 AT P-628A. 3 ADULTS OBSERVED ON 9 JUL 2004 AT P-628C.
169	*Rana draytonii*	California red-legged frog	20060706	Threatened	None	GREEN POND, 0.45 AIR MI WEST OF THE TIP OF BOLINAS LAGOON, GOLDEN GATE NATIONAL RECREATION AREA.	1 ADULT OBSERVED ON 15 MAR, 2 ADULTS OBSERVED ON 31 MAY, AND 3 ADULTS OBSERVED ON 6 JUL 2006 DURING NOCTURNAL SURVEYS. NO SIGNS OF SUCCESSFUL CRLF REPRODUCTION OBSERVED. A SUBSTANTIAL # OF BULLFORGS OBSERVED DURING EACH NOCTURNAL SURVEY.
172	*Rana draytonii*	California red-legged frog	20070402	Threatened	None	ADJACENT TO OLEMA-BOLINAS ROAD, 0.25 MILE NORTH OF THE INTERSECTION WITH MESA ROAD, BOLINAS.	2+ OBSERVED ON 30 MAR; 1 OBSERVED AND PHOTOGRAPHED ON 2 APR 2007.

APPENDIX C. CNDDB Occurrences of Federally and State-Listed Species within a 5-mile Radius of the Study Area

OBJECT ID	**Scientific Name**	**Common Name**	Date	**Federal Listing**	**State Listing**	**Location**	**General**
173	*Rana draytonii*	California red-legged frog	20080307	Threatened	None	POND ON THE NORTH SIDE OF HWY 1 AT THE NORTH TIP OF BOLINAS LAGOON, GOLDEN GATE NATIONAL RECREATION AREA.	3 JUN 1996: 1 ADULT & 1 LARVA. 6 JAN 1997: "48,203" EGGS. 2 FEB 2000:"9,400" EGGS. 11 JAN 2001: 3 ADULTS. 16 JAN 2002: 67 LARVAE & "3" EGGS. 17 MAY 2005: 1 LARVA. 19 APR 2006: 7 LARVAE. 7 MAR 2008: 8 LARVAE.
174	*Rana draytonii*	California red-legged frog	20011026	Threatened	None	ARROYO HONDO CREEK, 0.12MI FROM THE PACIFIC OCEAN, POINT REYES NATIONAL SEASHORE.	1 ADULT OBSERVED ON 26 OCT 2001.
175	*Rana draytonii*	California red-legged frog	20040316	Threatened	None	WILDCAT LAKE, POINT REYES NATIONAL SEASHORE.	5 ADULTS OBSERVED ON 16 MAR 2004.
176	*Rana draytonii*	California red-legged frog	20040311	Threatened	None	NW SIDE OF BASS LAKE, POINT REYES NATIONAL SEASHORE.	4 ADULTS OBSERVED ON 11 MAR 2004.
177	*Rana draytonii*	California red-legged frog	20040909	Threatened	None	SMALL POND 0.31 MI NE OF OCEAN LAKE, POINT REYES NATIONAL SEASHORE.	6 ADULTS & 2 SUBADULTS OBSERVED ON 9 SEP 2004.
178	*Rana draytonii*	California red-legged frog	20060209	Threatened	None	MUD LAKE, POINT REYES NATIONAL SEASHORE.	1 ADULT, 100 LARVAE & 1,200 EGGS OBSERVED ON 25 FEB 2005. 25 ADULTS OBSERVED ON 9 FEB 2006.
179	*Rana draytonii*	California red-legged frog	19950524	Threatened	None	EAST SIDE OF HWY 1, 2.30 AIR MI NNW OF WOODVILLE, GOLDEN GATE NATIONAL RECREATION AREA.	1 ADULT OBSERVED ON 24 MAY 1995.
180	*Rana draytonii*	California red-legged frog	19970212	Threatened	None	POND ON THE EAST SIDE OF HWY 1, 1.66 MI NNW OF WOODVILLE, GOLDEN GATE NATIONAL RECREATION AREA.	5 EGGS OBSERVED ON 14 FEB 1995. 7 EGGS OBSERVED ON 29 JAN 1996. 33,285 EGGS OBSERVED ON 12 FEB 1997.
181	*Rana draytonii*	California red-legged frog	20000201	Threatened	None	POND ON THE EAST SIDE OF HWY 1, 2.42 AIR MI NNW OF WOODVILLE, GOLDEN GATE NATIONAL RECREATION AREA.	2 SUBADULTS & 2 LARVAE OBSERVED ON 12 AUG 1994. 1 LARVA OBSERVED ON 29 MAY 1996. 2,245 EGGS OBSERVED ON 12 FEB 1997. 1,500 EGGS OBSERVED ON 1 FEB 2000.

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Appendix D.
Wildlife Species Observed in the Study Area

Appendix D. Wildlife Species Observed

	Common Name	Scientific Name
Amphibians	Anaxyrus boreaus	Western toad
	Sierra Treefrog	Pseudacris sierra
	Rough-skinned Newt	Taricha granulosa
Reptiles	Western Fence Lizard	*Sceloporus occidentalis*
	Aquatic Gartersnake	*Thamnophis atratus*
	California Red-sided Gartersnake	*Thamnophis sirtalis infernalis*
	Coast Gartersnake	*Thamnophis elegans terrestris*
Birds	Greater Scaup	*Aythya marila*
	Common Goldeneye	*Bucephala clangula*
	Double-crested Cormorant	*Phalacrocorax auritus*
	Great Egret	*Ardea alba*
	Snowy Egret	*Egretta thula*
	Turkey Vulture	*Cathartes aura*
	Osprey	*Pandion haliaetus*
	Cooper's Hawk	*Accipiter cooperii*
	Red-shouldered Hawk	*Buteo lineatus*
	Unidentified Larus Gull	*Larus* sp.
	Forster's Tern	*Sterna forsteri*
	Band-tailed Pigeon	*Patagioenas fasciata*
	Anna's Hummingbird	*Calypte anna*
	Rufous or Allen's Hummingbird	*Selasphorus* sp.
	Acorn Woodpecker	*Melanerpes formicivorus*
	Red-breasted Sapsucker	*Sphyrapicus ruber*
	Northern Flicker	*Colaptes auratus*
	Olive-sided Flycatcher	*Contopus cooperi*
	Pacific-slope Flycatcher	*Empidonax difficilis*
	Black Phoebe	*Sayornis nigricans*
	Western Scrub-Jay	*Aphelocoma californica*
	Common Raven	*Corvus corax*
	Tree Swallow	*Tachycineta bicolor*
	Cliff Swallow	*Petrochelidon pyrrhonota*
	Chestnut-backed Chickadee	*Poecile rufescens*
	Wrentit	*Chamaea fasciata*
	Swainson's Thrush	*Catharus ustulatus*
	Orange-crowned Warbler	*Oreothlypis celata*
	Common Yellowthroat	*Geothlypis trichas*
	Yellow-rumped Warbler	*Setophaga coronata*
	Wilson's Warbler	*Cardellina pusilla*
	Spotted Towhee	*Pipilo maculatus*

Appendix D. Wildlife Species Observed

	Common Name	Scientific Name
Birds (continued)	California Towhee	*Melozone crissalis*
	Lark Sparrow	*Chondestes grammacus*
	Song Sparrow	*Melospiza melodia*
	White-crowned Sparrow	*Zonotrichia leucophrys*
	Golden-crowned Sparrow	*Zonotrichia atricapilla*
	Dark-eyed Junco	*Junco hyemalis*
	Red-winged Blackbird	*Agelaius phoeniceus*
	Lesser Goldfinch	*Spinus psaltria*
Mammals	Raccoon (prints)	*Procyon lotor*
	River otter (prints and scat)	*Lontra canadensis*
	Mule Deer (prints)	*Odocoileus hemionus*
	Shrew	*Sorex* sp.
	California Meadow Vole	*Microtus californicus*
	Dusky-footed Woodrat (nest)	*Neotoma fuscipes*

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Attachment B. Hydrology and Geomorphology Technical Memorandum

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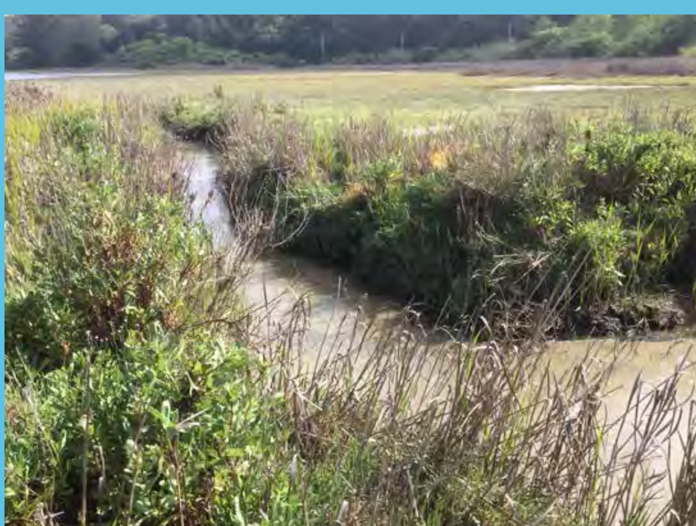
Submitted to
Marin County Open Space District

Submitted by
AECOM
Oakland, CA
and
Watershed Sciences
Berkeley, CA

January 2016

Bolinas Lagoon North End Restoration Project Technical Memorandum Current and Historic Geomorphology and Hydrology



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+/-	plus or minus
˚F	Degrees Fahrenheit
A	Area of cross section for bankfull flow
A/P	Bankfull cross sectional area divided by wetted perimeter
AD	anno Domini
CA	California
ca.	circa
Caltrans	California Department of Transportation
cfs	cubic foot/feet per second
Cr.	Creek
District	Marin County Open Space District
et al.	et alia, et aliae, et alii
ft	feet
ft^2	square feet
ft/s	feet per second
GIS	Geographic Information System
GPS	Global Positioning System
Kjf/Kfs	Cretaceous sedimentary Franciscan rocks
LiDAR	Light Detection And Ranging
mi	mile(s)
mi^2	square mile(s)
MHHW	mean higher-high water
MLLW	mean lower low water
mm	millimeters
mm/yr	millimeters per year
Mt.	Mount
NA	not applicable
ND	not determined
NOAA	National Oceanic and Atmospheric Administration
P	Wetted perimeter of bankfull flow
Project	North End Bolinas Lagoon Project
Qha	Holocene-aged alluvium deposits
Qoa/Qt	Holocene-Pleistocene alluvial terrace deposits
R	hydraulic radius
R^2	coefficient of determination
RI	recurrence interval
Rosgen System	Rosgen Stream Classification System
SFEI	San Francisco Estuary Institute
SLR	sea-level rise
SR	State Route
Tm	Miocene Monterey shale
Tmc	Plio-Pleistocene Merced siltstones and sandstones
U.S.	United States
USGS	United States Geological Survey
W/D	width to depth ratio
Xsec	Cross Section
Y	intersection of State Route (SR) 1 and Olema Bolinas Road at the north end of the Bolinas Lagoon
yr	year

Definitions

The following is a list of definitions of technical terminology used in this memorandum. Some of these terms and naming conventions are defined and used somewhere differently by specialists with different backgrounds and training. However, the definitions below are what are used in this memorandum.

Bankfull depth	Mean depth at bankfull flow.
Bankfull flow	For the purposes of this report, bankfull discharge (Q_{bkf}) is defined as the discharge that maintains the channel form and transports the greatest amount of sediment over time without aggrading or degrading its bed (Dunne and Leopold 1978, Rosgen 1996). The height of bankfull discharge is at the insipient level of flooding onto the floodplain. A generally accepted range of recurrence interval (RI) for bankfull discharge in this region is 1.2 to 1.7 years, on average.
Bankfull width	Width (W_{bkf}) of channel at bankfull flow measured at the insipient level of flooding onto the floodplain bench if one is present.
Entrenchment Ratio	Floodprone width divided by bankfull width (W_{fp}/W_{bkf}).
Floodplain	The relatively flat bench located at the insipient level of flooding at bankfull discharge.
Floodprone width	Width (W_{fp}) of the channel measured at twice its maximum bankfull depth (Rosgen 1996). Floodprone width is not the level of floodplain; it is one bankfull depth higher. The floodprone width does not have any particular recurrence interval of flooding associated with it, but it is considered to be at an elevation that would only experience very large but infrequent flooding.
Max bankfull depth	Depth (D_{mx}) measured from the channel thalweg to the isipient level of the floodplain
Terrace	An abandoned floodplain.
Thalweg	Deepest part of the channel at any given cross section.
Recurrence Interval	An estimate of the return period of a given event.
Width /Depth Ratio	Bankfull width divided by bankfull depth (W_{bk}/D).

1 Introduction

This technical memorandum provides the Marin County Open Space District (MCOSD) hydrologic and geomorphic information for the upland streams and watersheds of the North End Bolinas Lagoon Project (project). The project is located near the intersection of State Route (SR) 1 and Olema Bolinas Road at the north end of the Bolinas Lagoon (**Figure 1**). This area is frequently referred to as the Bolinas Wye or "Y" (this document uses the latter designation).

The District's goals for the project are to alleviate roadway flooding, restore and enhance stream and riparian habitat, and adapt to future sea-level rise (SLR). The project is broken up into a number of phases. This is Phase 1, which is made up of a number of tasks. This technical memorandum on the hydrology and geomorphology is part of Task 1.The project's other main work products include existing conditions memoranda that will be integrated into a larger Site Conditions Report, which is the main Task 1 deliverable. Task 2 entails development of three conceptual alternatives for the project.

This memo discusses the historical and current landscape conditions, based on archival research, field surveys, and data analysis and modeling. A discussion of the geology and the geomorphic and fluvial processes in the area is also provided to add context and understanding of the historical and modern influence of land use on current landscape conditions. The intent of this memo is to assist in developing conceptual designs that improve natural ecological functions and geomorphic processes. The memo includes discussion on bankfull flows, sediment supplies, and man-made alterations, which influence the form of the channel, surrounding environment, and hydrologic functions. It also includes assessments of projected sea-level rise within the lagoon and the sorts of effects on streams, roads, and water conveyance infrastructure that would be important to consider in future project phases.

This was a reconnaissance-level study, and additional cross section surveys could refine estimates of local bankfull discharge, hydraulic geometry, and improve the statistical analysis. No reconnaissance or remote investigations were performed outside the study area on geomorphic conditions or sediment sources from landslides. Therefore, it is possible that there are physical conditions that could dramatically alter existing channel or alluvial fan morphology in the study area.

The remainder of this document is organized as follows:

- Section 2 – STUDY AREA OVERVIEW establishes a context for the background research, surveys, and analyses.
- Section 3 – METHODS: Describes methods used to conduct the research, surveys, and analysis.
- Section 4 – RESULTS: Presents findings of each major component of the work.
- Section 5 – DISCUSSION: Describes the implications of the results and presents findings and recommendations for developing restoration alternatives.
- Section 6 – REFERENCES: Lists the scientific literature, data sources, and tools that were used.

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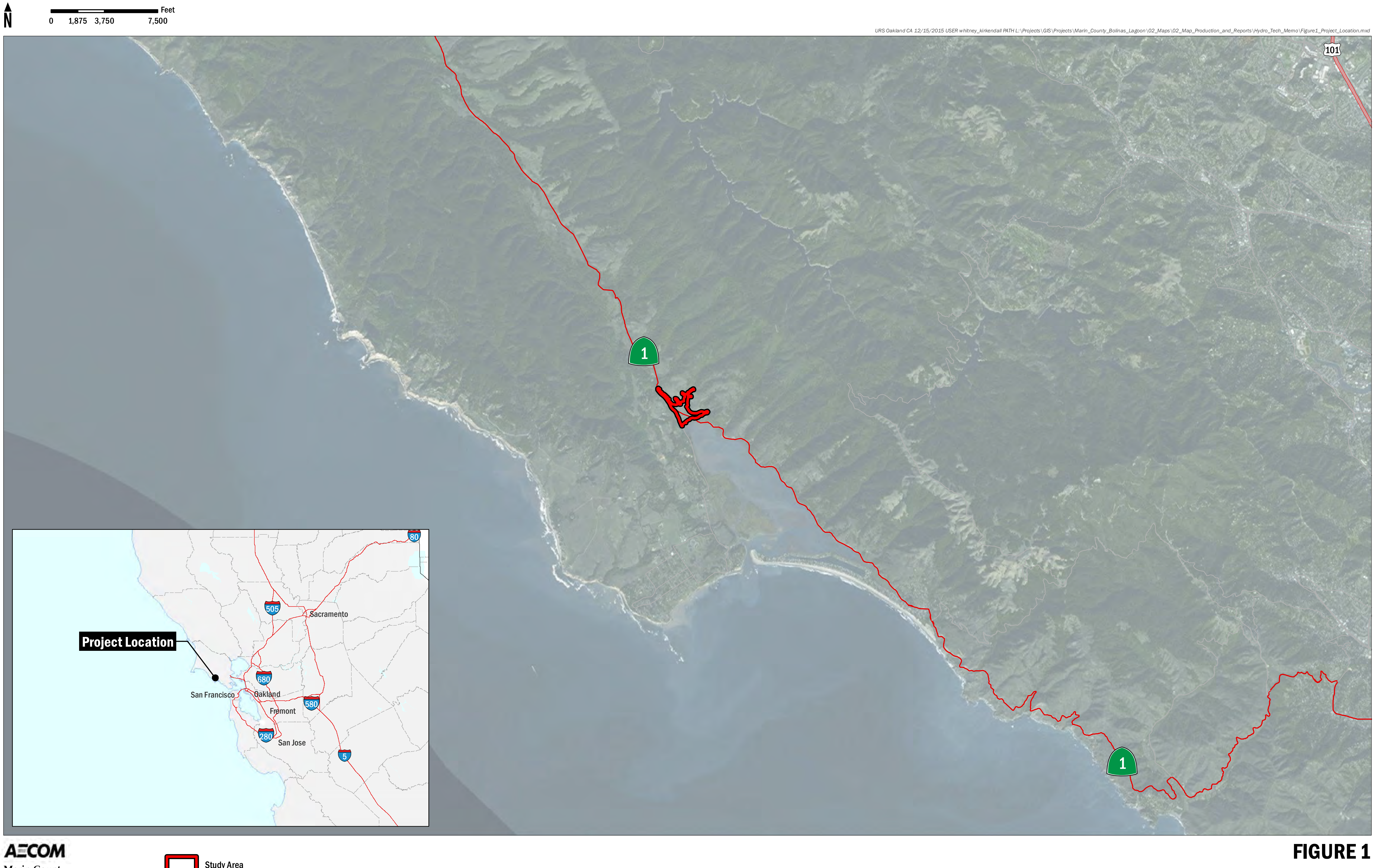

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Bolinas Lagoon Restoration

FIGURE 1
Project Location

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2 Study Area Overview

The study area around the Bolinas Y is in an upland/tidal transition zone influenced by rising sea level, which is projected to be as much as 170 centimeters (approximately 5.5 feet) by 2100 (MCP 2014). The study area is centered at the triangular road intersections of SR 1, Olema Bolinas Road, and a short connector road, referred to herein as the crossover road (**Figure 2**). The crossover road follows the route of the original SR 1 location, while the northern connection of the current SR 1 was constructed sometime around 1957, as deduced by the historical photos and maps shown in Figures 13-33.

The study area, shown on **Figure 2**, is 47.3 acres. As discussed in Section 3, field surveys of the streams and watersheds within this area were conducted during May 2015. Literature, imagery, and historical and current parcel, topographic, planform sketches, and roadway maps of these watersheds were reviewed. The regional geology, seismic activity, evolution of Bolinas Lagoon, and historical land use and development were researched and are described the following sections.

Streams and Watersheds

Lewis Gulch Creek, Wilkins Gulch Creek, Salt Creek,[1] and Wharf Creek are located in the study area. These streams and their total watersheds (i.e., beyond just the study area) are shown on **Figure 3**. Each watershed is shown in a different color, and the approximate drainage area of each creek's watershed is listed in **Table 1**. More detail on the hydrology of the creeks and their watersheds is presented in subsequent sections.

Table 1. Watershed Areas

Watershed Name	Drainage Area (mi^2)
Lewis Gulch Creek	0.62
Wilkins Gulch Creek	0.68
Salt Creek	0.15
Wharf Creek	0.08

Lewis Gulch, Wilkins Gulch, and Salt Creeks drain the steep southwest-facing hillsides of the Bolinas Ridge. The creek that drains into the southwestern side of the study area is unnamed, but since it is outlet was near the location of the historical wharf, it is herein referred to as "Wharf Creek" for this memo . Along the east side of the study area, elevations range from mean sea level to 1,653 feet at the headwaters of Wilkins Gulch Creek The west side ranges up to 321 feet along the Wharf Creek drainage.

[1] Salt Creek appears to be the name of the stream drainage to the southeast of Wilkins Gulch Creek based on the 1854 U.S. Coast and Geodetic Survey (NOAA 2015), though it is not always named on maps of the area. The Biological & Cultural Resource Technical Memorandum, for example, referred to it as an unnamed stream. In the Site Conditions Report that will be produced as the final Task 1 deliverable, this inconsistency will be resolved.

Ownership

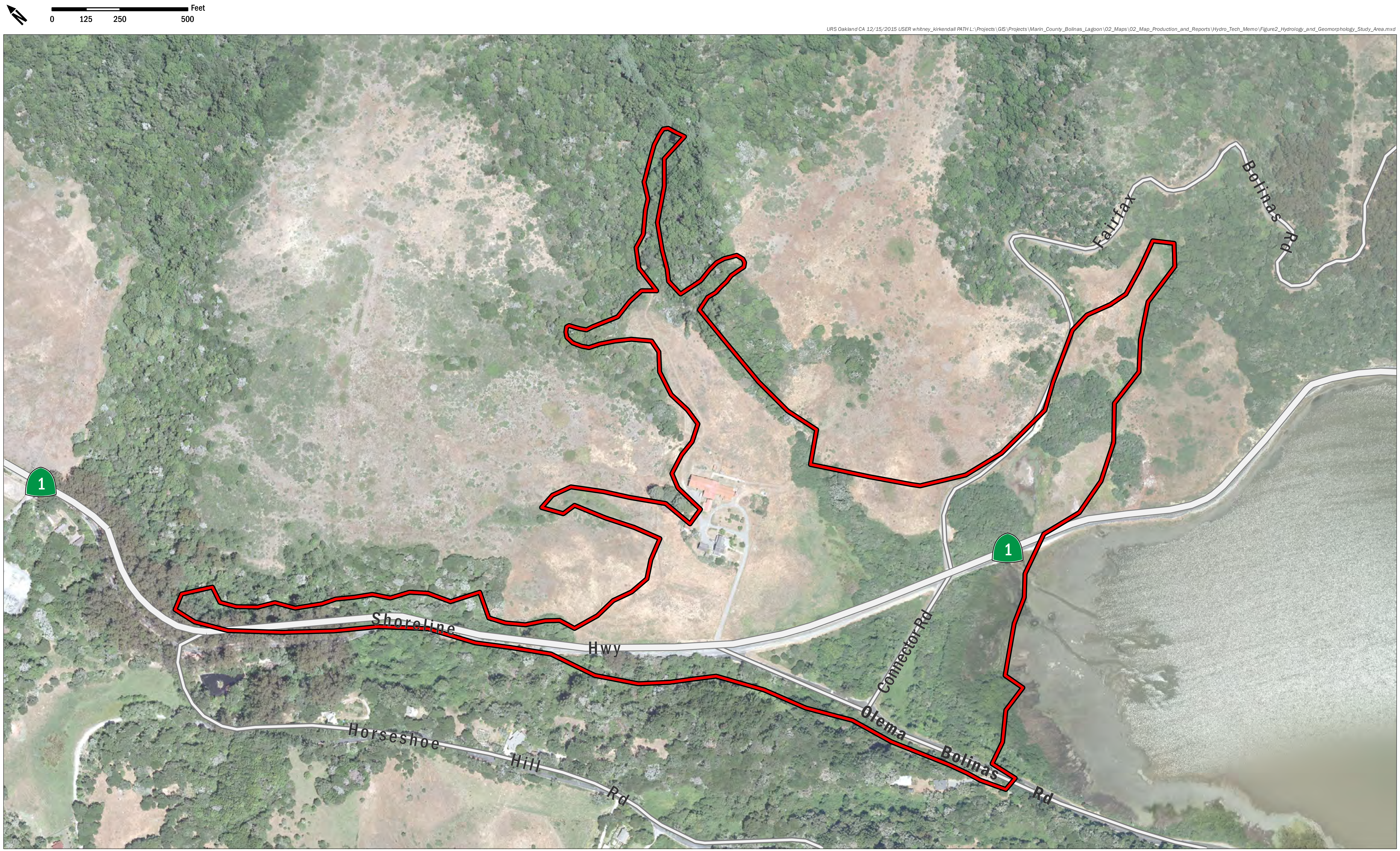
Property within the study area is owned by Point Reyes National Seashore (PRNS), Golden Gate National Recreation Area (GGNRA), MCOSD, and private parties. PRNS manages Wilkins Ranch, a former dairy and cattle ranch. GGNRA manages lands along the Salt Creek drainage. The property within the "Y" and along the northwestern shoreline is owned and managed MCOSD. There a number of parcels in private ownership along the western portion of the study area. The Site Conditions Report will contain a separate section about parcel ownership, parcel size, and other relevant characteristics.

Climate

The study area is in California's Coast Ranges, which have a Mediterranean climate characterized by warm, dry summers and cooler, wet winters. The average annual temperature is approximately 58.4˚F (www.USA.com 2015). The mean annual rainfall in Bolinas is approximately 38 inches, most of which falls between October and April, yet January is the wettest month typically having an average rainfall of 7.32 inches (www.idcide.com 2015). **Table 2** lists mean annual rainfall for other local areas relatively near the study area. Orographic influences probably cause rainfall totals to be much greater at the headwaters of Lewis Gulch and Wilkins Gulch Creeks than at their outlets along the Bolinas Lagoon.

Table 2. Average Annual Precipitation near Study Area

Mean Annual Rainfall (inches)	Location	Source
38.3	"Bolinas, CA" - specific location not given	http://rainfall.weatherdb.com/l/2845/Bolinas-California
37.6	Muir Woods Weather station, CA - 6.61 miles from Bolinas	http://www.idcide.com/weather/ca/bolinas.htm
37.2	Olema Valley, CA	http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?caCOLV
58.5	Middle Peak, Mt. Tam, CA	http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?caCMPK
35.2	Barnaby, CA	http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?caCBAR
45.9	Redwood Creek at Tam Valley, CA	Northern Hydrology Engineering (2015)
44.9	Redwood Creek at SR 1 Bridge, CA	Northern Hydrology Engineering (2015)



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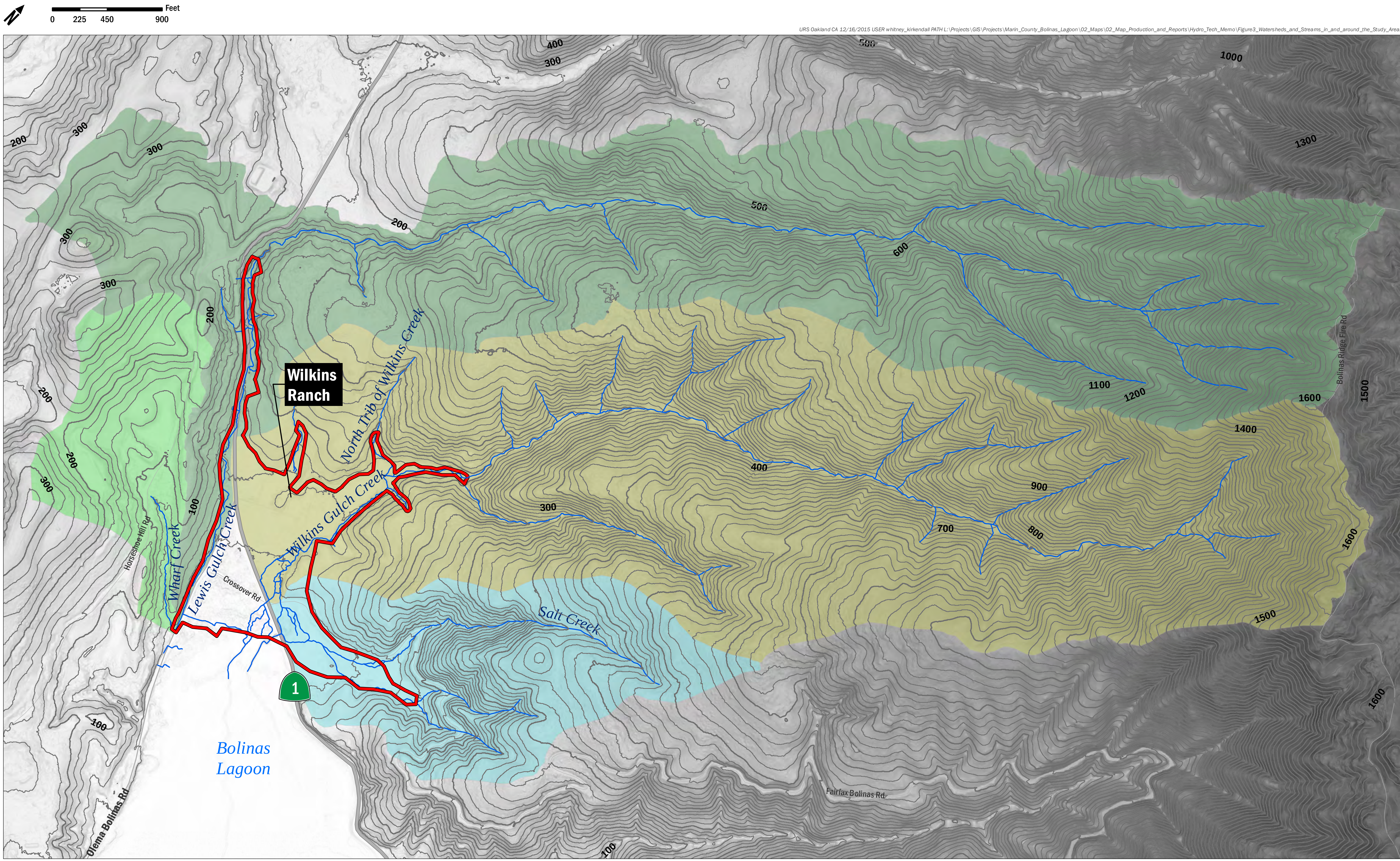
Study Area

FIGURE 2
Hydrology and Geomorphology Study Area



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Bolinas Lagoon Restoration

Study Area
20ft Contour

Watershed
Lewis Gulch Creek (0.62 sq mi)
Salt Creek (0.16 sq mi)
Wharf Creek (0.08 sq mi)
Wilkins Gulch Creek (0.68 sq mi)

Data Sources:
1. Contours, ARRA Golden Gate LiDAR, USGS, 2010
2. Streams, Watersheds, AECOM, 2015

FIGURE 3
Watersheds and Streams In and Around the Study Area

3 Methods

3.1 Background Research

The topics covered in the background research included:.

- Geology, seismicity, and faulting;
- Historical and modern land use, and landscape impacts;
- Historical and modern geomorphology; and
- Hydrology.

The results for each of these topics are covered in Section 4.

A review of existing literature and historical documents was conducted to establish the historical and current landscape conditions that influence the hydrology, flooding, and geomorphic processes in the study area. Historical maps, stereo aerial photography, photographic and aerial imagery, academic research publications, government reports, newspaper articles, and other sources were reviewed and are referenced accordingly.

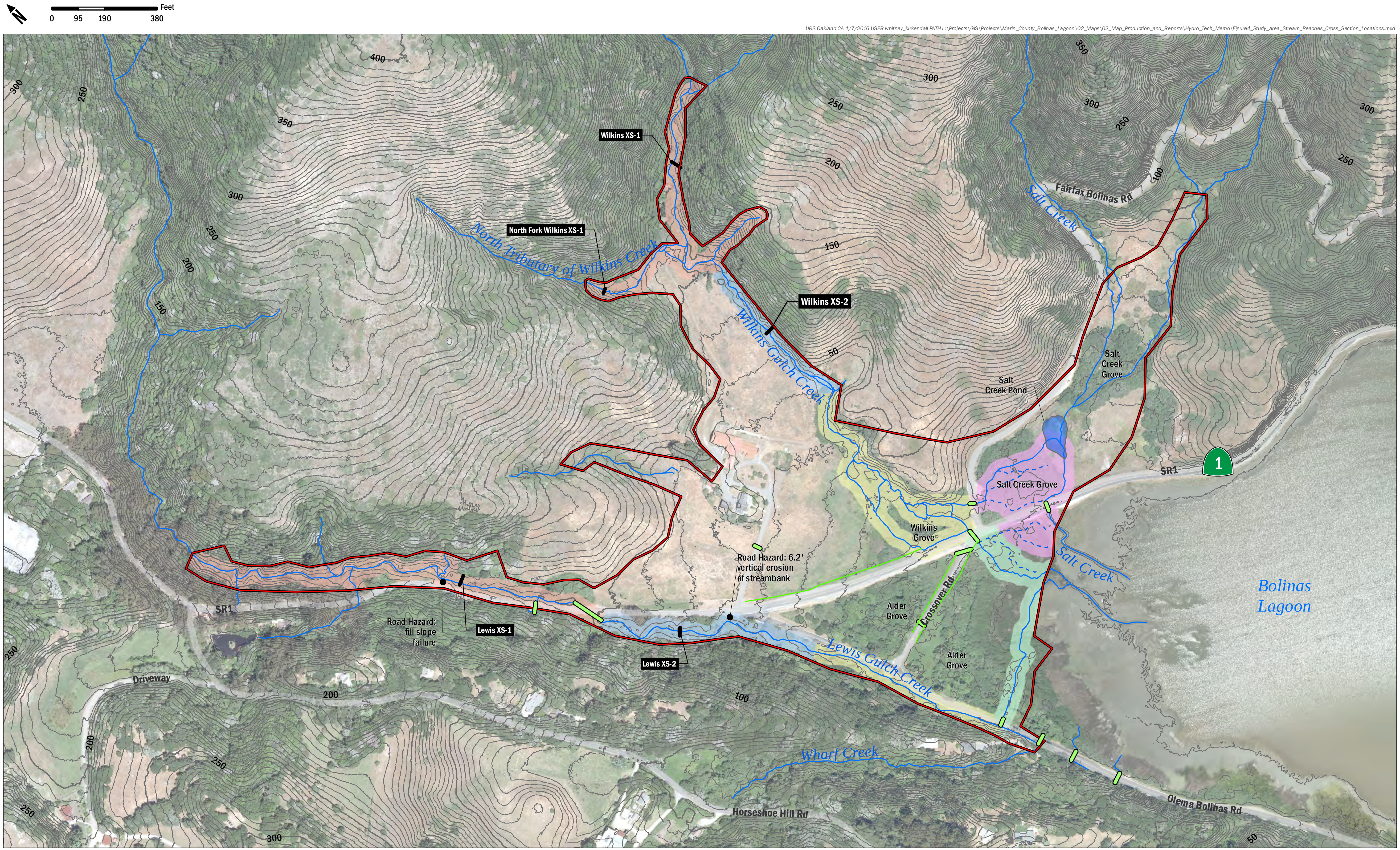
Documents from the Bolinas Lagoon Ecosystem Restoration Feasibility Project (including studies by Philip Williams and Associates and Wetland Research Associates (PWA 2005), Roger Byrne and other UC Berkeley researchers, the Technical Review Group, and others) were drawn upon for background information on the lagoon as a whole and as a starting point for a focused study of the dynamics of the interface of the north end of the lagoon with the inflowing streams.

Historical information was essential to examining how land use activities have influenced the location, channel geometry, sediment load, and flow within the channels of Lewis Gulch, Wilkins Gulch, Salt, and Wharf Creeks. Statements found in the literature pertaining to landscape change, land use activities, or observations of natural processes (e.g., large storms, flooding, earthquakes) are provided as a table in **Appendix A.** The project team developed a timeline of important events and perturbations that have likely influenced the hydrologic, geomorphic, and biological processes within the study area.

A review was conducted of a series of 1943, 1953, 1973, 1976, 1978, and 1989 stereo aerial photos provided by the County of Marin. Historical maps, photos, and documents were provided by the County of Marin and local historical museums. Photos and maps acquired during the literature search that were relevant to the Bolinas Lagoon, but not explicitly mentioned in this report are provided in **Appendix B** with their pertinent information. The historical maps and photos were compared with the current conditions by overlaying Google Earth's imagery with topographic data. Changes in the landscape were noted and examined to understand why the landscape changed and how those changes might affect flooding and ecological functions.

3.2 Field Surveys

Laurel Collins of Watershed Sciences and Jason Pearson of AECOM conducted reconnaissance field surveys on May 8th and 11th of 2015. **Figure 4** shows the coverage of the field surveys. The reconnaissance surveys were performed along 0.75 mile of Lewis Gulch Creek, 0.45 mile of Wilkins Gulch Creek, and 0.25 mile of Salt Creek. A reconnaissance survey of Wharf Creek upstream from its confluence with the Olema Bolinas Road was not conducted because of site access to private property and because its small drainage area is expected to have minimal influence on the study area, although the latter has not been verified.



AECOM

Marin County

Bolinas Lagoon Restoration

- Study Area
- 20ft Contour
- Stream
- Estimated/Undefined Stream Course
- Roadside Drainage Ditch
- Cross Section
- Culvert

Reach
- Reach 1
- Reach 2
- Reach 3
- Reach 4A
- Reach 4B

Data Sources:
1. Contours, ARRA Golden Gate LiDAR, USGS, 2010
2. Streams, Watersheds, AECOM, 2015

FIGURE 4

Study Area, Stream Reaches, and Cross-Section Locations

The primary purpose of the reconnaissance surveys was to survey channel cross sections and establish bankfull flow to make some reasonable estimates of the discharges responsible for maintaining channel form within the study area. Bankfull flow and its associated hydraulic geometry are critical elements in stream channel design and hydraulic structure (e.g. culvert) selection and dimensions. This information is an important component of developing scenarios and conceptual alternatives for flood reduction and stream restoration.

After conducting the initial reconnaissance, cross sections and longitudinal profiles were surveyed in the most stable reaches that could be found that had bankfull field indicators (e.g. a defined break in cross sectional shape, flow lines, silt deposition, height of gravel bars, and the root/trunk transition of riparian vegetation). These field measurements of channel conditions are needed to calculate bankfull hydraulic geometry and discharge under current climatic and landscape conditions; yet, there is uncertainty around how changes in future climatic conditions might alter the hydrology, bankfull flow, and groundwater storage in the study area watersheds. The floodplain bench was used to identify bankfull elevation, as well as additional bankfull field indicators (described above). In highly unstable channels where all these features can be absent or confounding, additional cross sections were surveyed and regional conditions of other similar streams were used to predict bankfull discharge.

Section 4 – Results draws comparisons between bankfull values determined from surveyed results and nearby regional predictions that generally have a 1.3-year return interval (RI) (Collins and Levanthal 2013). The numbered stream reaches, locations of the surveyed cross sections, and other relevant features are noted in **Figure 4**. Stream reaches were defined and identified from maps and imagery before beginning the field surveys. The divisions of streams into reaches was based on the sediment size, evidence of scouring versus deposition, degree of stream confinement, vegetation present, and evidence of gaining versus losing bankfull discharge. A gaining reach is one in which the adjacent water table is higher than the stream's surface water, which causes ground water to seep into the stream and increase its flow. In a losing reach flows seep into the groundwater.

To measure natural channel geometry and estimate bankfull flow, five cross sections were surveyed in total. The cross section locations are shown on **Figure 4**. Ideally, the most downstream cross sections surveyed would be at the toe of the fans, where total drainage area is at its largest and where groundwater from the fans would create gaining reaches. Yet, channels and their various stages of flow in the study area have been artificially modified along Olema Bolinas Road, along portions of SR 1, and at the stream crossings of both these roads. Modifications include box culverts, road berms (that impede flood flows), ditches that diverted the flow from their natural courses, and maintenance dredging. These alterations are explained in detail for each creek in Section 4.3. These altered conditions hindered the establishment of what the natural channel geometry would be near the Y, and estimates of bankfull discharge made from those locations would be problematic.

As a result, two different reach locations with relatively stable riffles were selected for cross sections in Wilkins and Lewis Gulch Creeks. Upstream reaches for each creek were selected as close as possible to the apex of each alluvial fan to represent minimal surface flow loss to the fan.These were named Cross Section 1 of Wilkins Gulch Creek and Cross Section 1 of Lewis Gulch Creek. The downstream reaches at each creek were surveyed as near to the Y as possible, where a single-thread, mainstream channel existed near the toes of the alluvial fans, regardless of gaining or losing conditions. These were named Cross Section 2 of Wilkins Gulch Creek and Cross Section 2 of Lewis Gulch Creek. A fifth cross section was surveyed at the fan apex of North Tributary of Wilkins Gulch because flow from the North Tributary is artificially diverted across the main valley head of the Wilkins Gulch fan to a point roughly 150 yards downstream of Cross Section 1 of Wilkins Gulch Creek.

Stable channel geometry was uncommon within the alluvial fan reaches of the study area. This is because fans are inherently unstable features, and channel dimensions can be highly inconsistent in reaches that lose and gain surface flow over the span of the fan features. In addition, complexities caused by land use, landsliding, channel braiding, and inputs of large woody debris minimized the number of suitable sites to survey stable channel dimensions.

Pebble counts using a modified Wolman method (Wolman 1954) were conducted at each cross section to estimate roughness for calculating discharge using methods from the U.S. Forest Service manual (Harrelson, Rawlins, and Potyondy 1994). Bulk sampling of channel or depositional feature pavement and sub-pavement was not conducted because sediment discharge modeling was beyond the scope.

In addition to the cross sections, the following items were recorded where they were relevant to interpretation of field surveys or land use impacts:

- Observations of stream stability and indications of man-made alterations such as culverts, ditches, berms, and channel diversion;
- The possible age of adjacent riparian trees and their elevations relative to the floodplain or stream terraces (abandoned floodplains);
- The location and activity status of adjacent landslides;
- The continuity of channel width and depth, channel sediment size and sources, and any occurrence of perennial flow;
- The flow paths of historical and existing channels; and
- Road hazards associated with stream bank erosion.

Photo base maps from a Geographic Information System (GIS) were annotated, and coordinates of significant features were tracked using a Trimble GeoXT Global Positioning System (GPS) unit. The data were then post-processed and differentially corrected as discussed below.

3.3 Data Processing and Analysis

Following data collection, stream types were assigned for the given reach measurements, and hydraulic geometry and flow estimates were determined. The cross section and pebble count data were analyzed with the Reference Reach Spreadsheet program, Version 4.3L, developed by Mecklenberg (2006). Calculation of hydraulic parameters, bankfull cross sections, and pebble count plots were determined. The longitudinal profiles were plotted in Microsoft Excel to derive the bankfull channel gradient. Full results of this analysis are presented in **Appendix C**.

A modified Rosgen Stream Classification System (Rosgen System) (Rosgen 1996) was used to classify the stream type based on the bankfull width to depth ratio, entrenchment ratio and floodprone area. The Rosgen Stream Classification System (Rosgen System; Rosgen 1996) can be a useful guide in stream restoration design and to assess stream stability. It uses a letter designation to classify stream form and relative stability. A detailed graphical representation of the Rosgen System is shown in **Appendix D** while a modified Rosgen System, shown in **Figure 5**, uses a more appropriate width/depth ratio threshold for Bay Area/Coast Range channels (Dave Rosgen, personal communication June 15, 2002).[2] Since

[2] The classification is based upon Rosgen (1996), however, the modification changes the W/D ratio threshold to 10, rather than 12, and allows it to vary by +/-3 rather than +/-2. The threshold for entrenchment is not modified and varies by +/-0.2 units. Its threshold is less than 1.4 for entrenched streams (A, G, and F stream types), 1.4 to 2.2 for moderately entrenched streams (B stream type), and greater than 2.2 for slightly entrenched streams, which are considered to have the most stable form (C and E stream types). G channels are incising their streambed, while F channels are eroding their

the parameters needed for classifying streams can be derived from the hydraulic geometry surveys, the Rosgen Classification is useful for visualizing and describing stream types based on the bankfull width/depth and entrenchment ratios.

Due to the limited number of cross sections surveyed on Wilkins and Lewis Gulch Creeks, the calculated bankfull discharge were compared to predicted bankfull discharge values from the regional curve for Marin and Sonoma County streams (Collins and Leventhal (2013), and the San Francisco Bay Area (Dunne and Leopold, 1978).

A third regional curve was constructed from this study's data combined with data from Bear Valley Creek, East Fork Olema Creek, and West Fork Olema Creek (Collins and Leventhal 2013) and Redwood Creek (Northern Hydrology and Engineering 2015). Additional data points are needed to make this curve statistically robust. If design concepts eventually require better estimates of discharge, an additional flood frequency analysis based upon regional flood frequency analyses (as described by Rantz, 1971 or Waananen and Crippen, 1977) could be performed.

Form Example							
Stream Type	A	B	C	D_A	E	F	G
Entrenchment Ratio	<4	1.4-2.2	>2.2	>4.0	> 2.2	<1.4	<1.4
Width/Depth Ratio	<10	>10	>10	<40	<10	>10	<10

Figure 5. Modified Rosgen Stream Classes

3.4 Interpretive and Analytical Processes

Interpretation of landscape features and their morphological development was conducted in the field and in the office using topographical maps and LiDAR data. The location, size, and orientation of terraces and inactive, remnant ,primary or secondary channels in the current channel corridor or on the alluvial fans were observed and mapped to assist in determining how channel alignment has changed over time.

The location and elevation of mature trees were noted in the field and on maps and historical photographs to develop a hypothesis on historical channel location and morphology. The elevation and approximate age of mature trees (based on physical characteristics including branch/bole diameter, height, presence/extent of furrowed bark, number of branch whorls, etc.) can indicate when a channel incised and abandoned its floodplain or lost its connection to the surface of its alluvial fan.

banks and have minimal floodprone width. D-type channels have multiple threads, such as braided channels found on alluvial fans or unstable channels with high sediment supply.

4 Results

This section presents the results of the four major components of this analysis.

4.1 Geology, Seismicity, and Faults

This section discusses the regional geology, seismicity, and faults, as well as ideas about uplift and down-dropping, sedimentation, and the effect of these on the lagoon and several streams. Throughout the section, maps are used to illustrate and explain different interpretations of the evolution of Bolinas Lagoon and offshore region. The local geology and associated faulting is extremely complex, and a detailed survey, analysis, and synthesis of all geologic aspects of the study area, Bolinas Lagoon and the Point Reyes peninsula was beyond the scope of this effort. All efforts were made to use a consistent naming convention for faults and other features, but the maps and information from which the research is drawn are not in their use of terminology and nomenclature.

The Bolinas Lagoon is part of the larger San Andreas Fault Zone. The San Andreas Fault is a major right-lateral strike-slip fault extending from the Gulf of California through much of northern California. It is not a single fault, and in many places, such as the region surrounding the study area, there are other converging or diverging faults that create complex local geology and seismic activity. **Figure 6A** shows an oblique view of the Bolinas Lagoon and the juxtaposition of three faults and **Figure 6b** shows a geologic map of the Point Reyes Peninsula along the western side of the San Andreas Fault zone and the Tomales Bay (USGS, 2005). The major geologic units are detailed in the map legend.

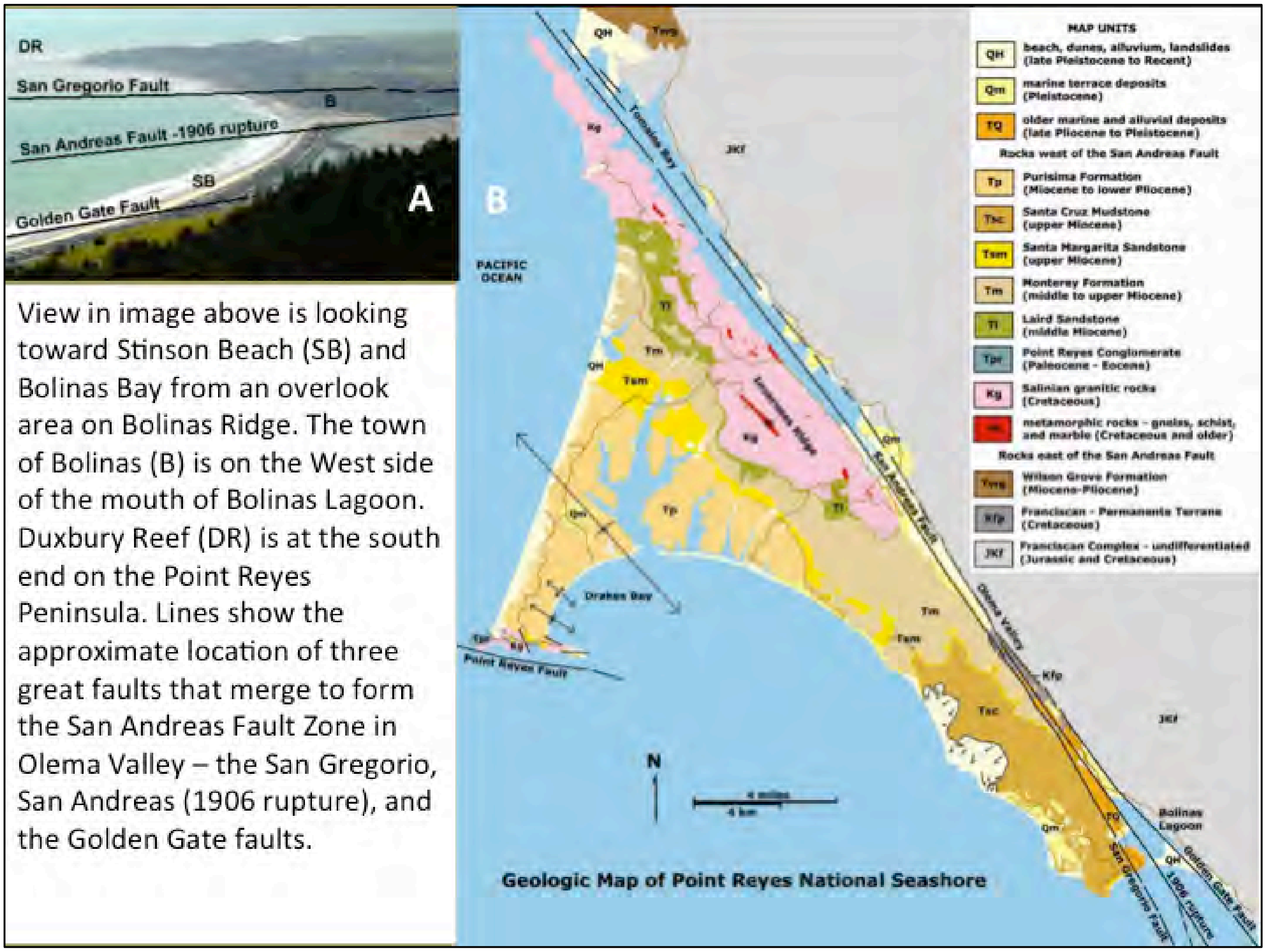


Figure 6. Geologic Map of Point Reyes National Seashore

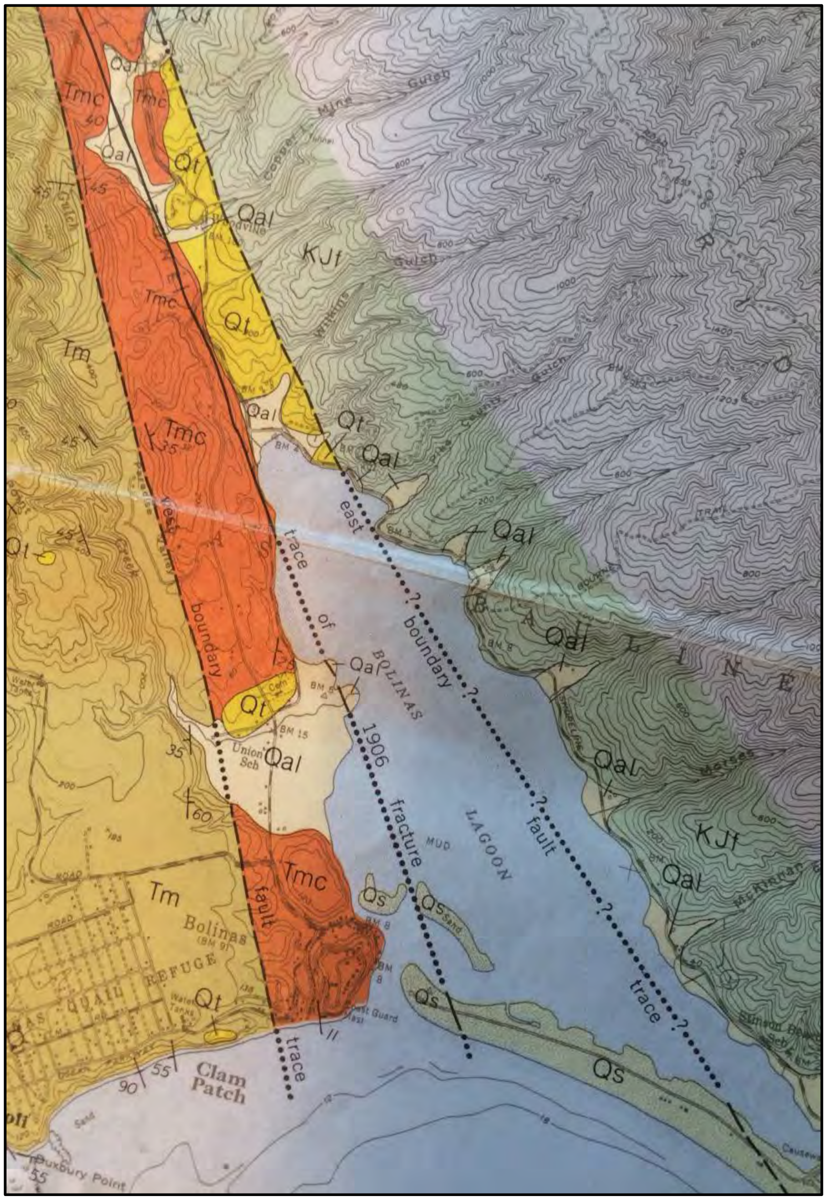


Figure 7. Bolinas Lagoon Bedrock Geology and Faults

Figure 7 shows the bedrock unit geology and faulting of the Bolinas Lagoon area in a larger-scale map, produced by Galloway (1977). In it, the three faults are shown, though with different names than on the U.S. Geological Survey (USGS) map. The three faults passing through the study area are active traces of the San Andreas Fault Zone, and they appear to converge northward toward each other in the lagoon and then parallel each other northward in the Olema Valley. Galloway found that the East Boundary Fault was a large fault distinguished by strong topographic evidence, with many sag ponds east of SR 1 near Five Brooks (about 5.5 miles northwest of the study area). Galloway suggests that the East Boundary Fault determines the position of the east side of the Bolinas Lagoon and that its topographic expression near Five Brooks is greater than that of the 1906 fault trace. He suggests that movements along it have been large and frequent in the not too distant past.

Cretaceous sedimentary Franciscan rocks (KJf) occur east of the East Boundary Fault along Bolinas Ridge. At the head of the Bolinas Lagoon, Holocene-Pleistocene terrace deposits (Qt) define much of the west side of the East Boundary Fault between the 1906 earthquake fracture of the San Andreas Fault. The Plio-Pleistocene Merced siltstones (Tmc) and sandstones occur between the East and West Boundary Faults where the 1906 fracture of the San Andreas Fault bisects the two boundary faults. Miocene Monterey shale (Tm) occurs west of the West Boundary Fault (west of the study area). Galloway states that the striking features of the West Boundary Fault has a more pronounced effect upon the geology of the area since it separates Monterey shale and granitic basement in the north from the Franciscan of the fault zone. The granitic rocks are shown in pink and labeled Kp in **Figure 6B**. A small amount of Holocene-aged alluvium (Qal) is at the northern head of the lagoon near the present-day alluvial fans of the creeks in the study area.

Strike-slip faults are where two or more tectonic plates horizontally slide past each other over geologic time, in either bursts of movement that can be sudden and dramatic on the human time scale or by slow imperceptible creep movement. A right-lateral fault is one in which an observer on either side of the fault line sees the other side moving to the right. In the study area, this means that the Point Reyes Peninsula on the west side of the fault appears to be moving north, while the Bolinas Ridge and the rest of Marin County appears to be moving south. The last active fault rupture along the San Andreas was a magnitude 7.8 forming a 296 mile-long rupture in 1906. Galloway reported that observations made by G.K. Gilbert in 1906 (Gilbert et al. 1907) included 12 feet of fence displacement near Bolinas and about 1 foot of down-dropping along the east side of the rupture in the Bolinas Lagoon (Lawson 1908). The long-term average for right lateral movement on the San Andreas Fault ranges from about 12.7 mm/yr to 50 mm/yr, though the slip rate increases north of Bolinas because of added slip from the merging San Gregorio Fault system (Dickinson and Grantz, 1968; Niemi and Hall 1992; Noller et al. 1993). Grove and Niemi (2005) indicate that general slip rates just to the North in the Olema Valley range from 17 mm/yr to 35 mm/yr.

The Working Group on California Earthquake Probabilities (1999) reported a 12 percent probability for a magnitude 6.7 quake in the next 30 years along the North Coast South segment of the San Andreas Fault (the segment that crosses Bolinas Lagoon),. Byrne and Reidy (2005) determined from their subsurface study of long cores taken in the upper Bolinas Lagoon that five major earthquakes have influenced the lagoon depth in the last 1,600 years. The prior ones occurred in about 450 AD, 1080 AD, 1220 AD, and 1520 AD. The mean recurrence interval of major quakes is reported to be about 300 years, although the time between the second and third quakes was only 130 years. Byrne et al. also suggested that sand lenses found at depth in the cores could have been deposited from a large tsunami, or they were rapidly deposited from frequent winter storms during the Little Ice Age (ca. AD 1400–AD 1800). An alternative hypothesis presented here to Byrne’s suggestions about causes of sand lenses found in sediment cores sampled in the Bolinas Lagoon is that the sand is associated with down-dropping of a Holocene graben that caused the Stinson Beach sand spit to be overwashed by tides until it was rapidly rebuilt. A graben is a down-dropped section of land between parallel faults.

Some researchers, including Bruns et al. (2002), have postulated that the complex convergence of faults in Drake’s Bay and faults projecting into Bolinas Lagoon (and the study area itself) moving at different rates and with some directionally different compression has created a graben in relatively recent geologic history (the Holocene epoch, the last 11,700 years). **Figure 8** shows a simplification (derived from Bruns et al. 2002) of the Holocene graben and associated faults offshore of the Golden Gate. The yellow-green polygon (as labeled) is the area of the graben that has been mapped by subsurface exploration and is known to be down dropping (Bruns et al. 2002). The red lines are known fault traces, whereas yellow dashed lines are inferred. The northern and southern extents of the Holocene graben are indicated as uncertain. Up and down motions are shown in black text labels on the figure; directions of horizontal motion of the faults are indicated by black arrows. The idea is that subsidence between the major faults is creating a surface and near-surface graben from the Golden Gate to Bolinas Lagoon. Bruns et al. suggest that several different faults (including the Potato Patch, San Pedro, and San Andreas Faults) could be transfer faults that enable a strike-slip motion from the San Gregorio to the Golden Gate Fault, creating the graben. It is unknown whether the eastern extent of the downward-dropping block in the northern part of Bolinas Lagoon or through Stinson Beach has ever been defined. Although 1 to 2 feet of down-dropping on the east side of the San Andreas Fault has been well documented, the literature reviewed did not provide information on the northern extent of the down-dropped block along the eastern side of the lagoon. Therefore, the hypotheses presented here is that the northern Bolinas Lagoon is within the Holocene graben that pinches out northward in the Lewis Gulch Creek drainage.

Figure 8. Holocene Graben and Associated Faults

The Holocene graben exists within the larger San Gregorio Basin that is also indicated by **Figure 9** (modified from Bruns at al. 2002), which shows the approximate actual extent of the San Gregorio Basin extending northward beyond the open waters of the Bolinas Lagoon. We present additional geomorphic evidence that indicates that the actively down dropping Holocene graben extends north of the subsurface exploration boundary (green polygon in Figure 8) to about the large eastward bend in Lewis Gulch Creek, as will be discussed following discussion of additional research by others.

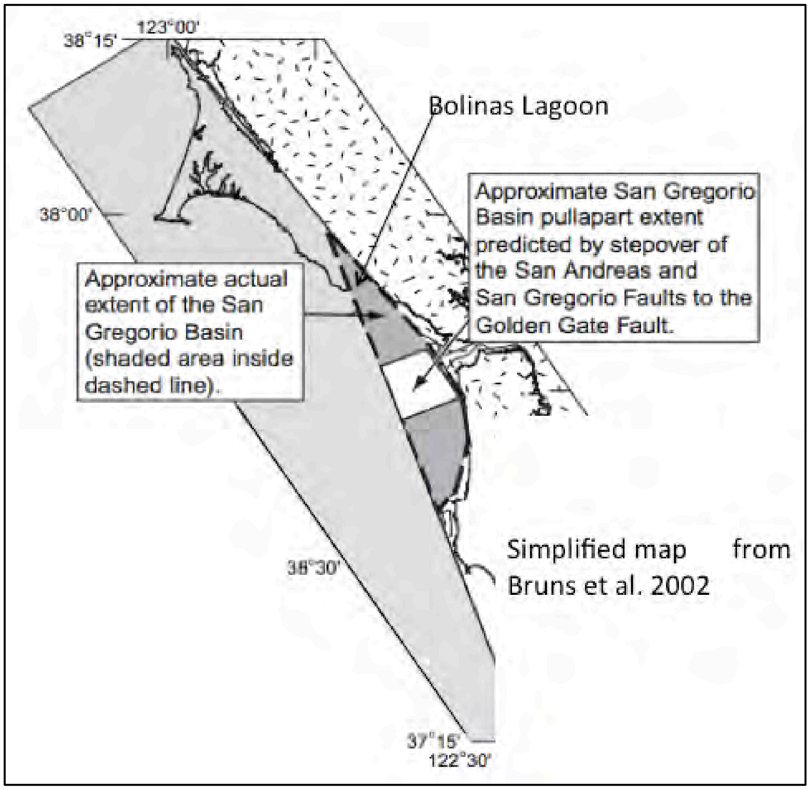


Figure 9. Extent of San Gregorio Basin

In a study referenced in and used by the Bolinas Lagoon Restoration Project Design Review Group, a University of California (UC) Berkeley study (Byrne and Reidy 2005) reanalyzed the deep sediment history of Bolinas Lagoon. That research showed that most of the sedimentation in the lagoon (up to 80% of the total) was from natural marine sources and tidal processes; the remainder is from terrestrial sources delivered largely by streams. Further, the main physical driver of sedimentation in the lagoon in the 20th century came in the aftermath of the 1906 earthquake. Sediment cores indicated that the lagoon deepened by as much as four feet during that event. Following that rapid subsidence, sedimentation rates were very high throughout the 1900's and kept ahead of the rate of sea level rise (about 20 cm/century). This cycle of rapid subsidence or down-dropping of Bolinas Lagoon has occurred several times following major earthquakes, with an average recurrence interval of about 300 years, though there is much variability around this average. Each earthquake induced a "re-set" of the deepened lagoon bottom.

There are other ideas and published academic papers and government reports on the geology of this area, but a detailed review of them is beyond the scope of this project. Among those reviewed, there was some disagreement about the details of the faulting and seismic activity in the project study area. What can be said with confidence is that the interrelationships and magnitude of vertical and horizontal displacement among the faults at the north end of Bolinas Lagoon is unclear, but down-dropping and subsidence – followed by increased sediment accumulation rates –is occurring and will likely continue.

Just south of the study area, Byrne and Reidy (2005) took sediment cores in Bolinas Lagoon. These cores allowed Byrne and Reidy to estimate sedimentation rates after and before the 1906 earthquake (between 1906 and 2005 [part A of **Figure 10**] and between 1850 and 1906 [part B of **Figure 10]**). The contour lines indicate sedimentation rates in mm/yr, and the dashed line indicates the trace of the San Andreas Fault. Byrne and Reidy interpret that average sediment deposition rates in the north end of the lagoon were higher (10 mm/yr) before the 1906 earthquake and decreased to an average of 8 mm/yr in the years following the 1906 earthquake. They documented an average of 1.5 feet of down-dropping in the deepest area of the north basin. Sediment cores were not taken in the vegetated alluvial fan toe/delta features at the upper extent of the tides where sediment trapping and potential deposition rates might be increasing.

Byrne and Reidy (2005) concluded that sediment supply in the extreme northern end of the Lagoon was largely associated with Lewis Gulch and Wilkins Gulch Creeks and that dairying and logging activities were probably the main cause. We assert that Byrne and Reidy are correct but add that these channels always naturally supplied sediment – that is why the alluvial fans and deltas are there; they are depositional features from the streams.

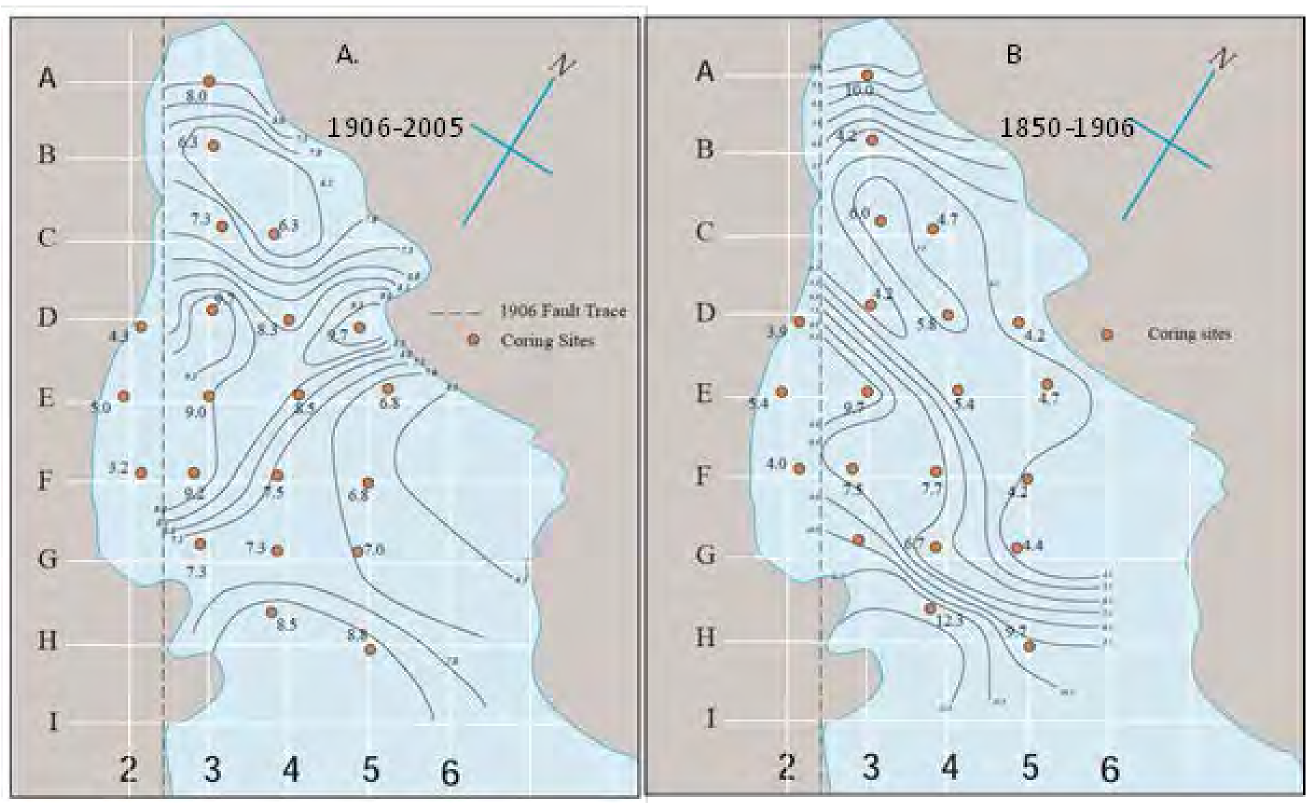


Figure 10. Sedimentation Rates in Bolinas Lagoon in Different Time Periods

We hypothesize that the source of much of the sediment from Lewis Gulch Creek has been associated with stream incision (probably associated with stream capture and down-dropping of the Holocene graben – explained later in the report), while sediment sources in Wilkins Creek have been predominantly from the landslides in the steep hillslopes above the fan. We suggest that although Byrne and Reidy (2005) indicate that the rate of deposition in the Bolinas Lagoon is decreasing, the flux in the rate of sediment supply within the creeks upstream of the lagoon margin has not been established. Burn and Reidy (2005) also contend that repeated tectonic subsidence is the fundamental reason for the lagoon's continued existence. Clearly, the potential influences of both right lateral offset (down-dropping), significant seismic shaking, and subsequent subsidence must be considered when planning road improvements in the study area, as will be discussed in subsequent sections and in future project deliverables.

Figure 11 shows traces of active faults in red as mapped by USGS (2014) near the alignments of Highway 1, Olema Bolinas Road, and the crossover road. The Golden Gate and East Boundary Faults are not depicted; however, other maps show one or the other of them as active (Bruns et al. 2002; Galloway 1977; Gartner et al. 2007). The alignment of the 1906 fault rupture indicated by Byrne and Reidy (2005) on **Figure 10** is shown in yellow dashed line on this map. It does not coincide with the faults mapped by USGS.

Figure 11. Active Faults near the Study Area

Lewis Gulch Creek was not shown on the original active fault map shown in **Figure 11**, but it has been approximately sketched in to show its relation to SR1 and the fault traces. The locations of faults on this map differ from the other maps shown in this report, indicating that it is unclear where the exact locations of the active and potentially active faults are in the study area. Also, the other fault segments shown are not named on the original map. All maps indicate that Lewis Gulch Creek parallels the west side of a splay of the San Andreas fault along SR 1, and then crosses it toward the fault before it takes a large eastward bend toward the Bolinas Ridge. The exact location of the 1906 rupture of the San Andreas Fault and the Holocene graben is not evident.

In an effort to interpret the northern extent of the Holocene graben and determine whether it might influence the study area, it is useful to look at the Holocene alluvium at the north and south banks near the major southward bend of Lewis Gulch Creek. **Figure 12** shows a conceptual synthesis of a number of different elements discussed in this section. It is a view looking north from the Lewis Gulch Creek drainage, using 2015 Geo Space LiDAR, overlaid with the USGS geology map (USGS 2006). Shown in the figure are the following bedrock units listed below from youngest to oldest:

- Qha – Holocene Alluvium/alluvial fan deposits.
- Qts – Early Pleistocene or Pliocene Sediments.
- Qoa - early Pleistocene Alluvium. Tms – Miocene Sedimentary rocks.
- Kfs – Cretaceous Franciscan Complex rocks.

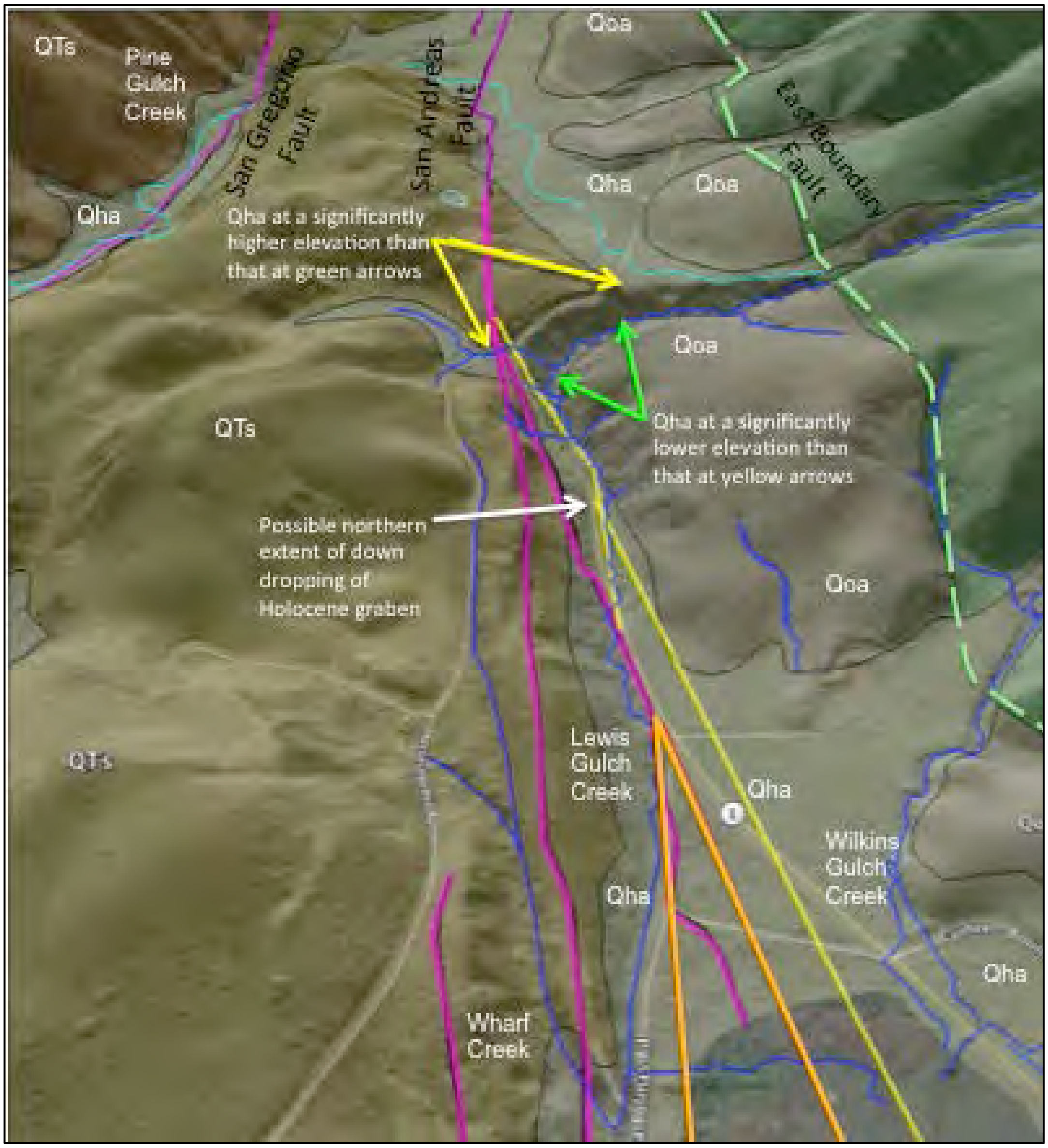


Figure 12. Synthesis of Geology, Faults, Plate Motion, and Streams

In **Figure 12**, the active faults as indicated in the USGS 2006 map are highlighted here in pink. Galloway's inferred East Boundary Fault has been added and is shown as a dashed green line. Modern stream courses are shown in navy blue and were mapped by interpretation of LiDAR imagery (Earth Scope, 2015). The light blue stream line represents a paleo channel course of Lewis Gulch Creek, which is further discussed below. The orange lines indicate our interpretation of the possible active fault boundaries of the Holocene graben in the study area. The yellow lines represent possible fault locations as interpreted from lineations seen in the LiDAR imagery and from the information associated with the graben presented in this report. The eastern trace of the yellow line that is south of the white arrow might coincide with the Golden Gate Fault as shown in **Figure 8**. Although there are no apparent indications that this fault has been active since or during the 1906 quake, Bruns (2006) considered it active within the Holocene epoch. The actual status of seismic activity and exact location of all the faults depicted in the study area in **Figure 12**, is presently unclear; however, it is evident that there are several locations where SR1, the crossover road and Olema Bolinas Road could be influenced by future fault offsets.

The San Andreas Fault and the inferred inactive East Boundary Fault bound the older alluvial deposits (Qoa), whereas the younger Holocene alluvial fan deposits (Qha) are incised within the early Pleistocene alluvium (Qoa). The Qha extends well east and north of the projected Golden Gate Fault and suddenly gains out 30 feet in elevation just north of the large eastward bend of Lewis Gulch Creek. The Qha on Lewis Gulch Creek to the south of the eastward bend has its alluvial fan merge with that of Wilkins Creek Gulch, together forming a delta and tidal marsh at the northward margin of the Bolinas Lagoon.

The left-most orange line near the bottom of **Figure 12** indicates the possible 1906 fault rupture where 1 foot of down-dropping was recorded to the east, while the orange line on the right indicates the possible eastern edge of the down-dropped wedge. The southern projection of the eastern-most orange line (beyond what is shown) in **Figure 12** seems to follow the deepest parts of Bolinas Lagoon. Horizontal and vertical motion along the faults is indicated.

The yellow arrows point to two “hanging” valleys that consist of younger Holocene alluvium (Qha) that remains at a higher elevation and disjointed or cut off from the main-stem Lewis Gulch Creek following severe headward erosion and stream capture that was may have been initiated by the down-dropping of the northern extent of the Holocene graben where the faults (orange and yellow lines on **Figure 12**) converge. The white arrow points to the possible northern extent of the Holocene graben. The two yellow arrows point to the north and western terrace banks, where Qha is higher (about 30 feet) than the opposite banks (indicated by the two green arrows). To the south and east of Lewis Gulch Creek, the Qha (including the alluvial fan of Wilkins Gulch Creek) is graded much lower and closer in elevation to the present-day Lewis Gulch Creek. To the west, Pine Gulch Creek and Wharf Creek flow within their Qha at elevations that indicate they are not being influenced by Holocene down-dropping.

The USGS geologic mapping Qha is interpreted to indicate that during the Holocene, a “paleo” Lewis Gulch Creek once flowed northward on its fan and connected as a tributary to Pine Gulch Creek. It is likely that the down-dropping of the Holocene graben caused a smaller channel at the head of Bolinas Lagoon to deeply incise, erode headward north of the white arrow and capture the “paleo” Lewis Gulch Creek that used to flow into Pine Gulch Creek, permanently causing Lewis Gulch Creek to flow southward along the down-dropped graben and directly into the Bolinas Lagoon. A notional pathway for the “paleo” Lewis Creek that existed prior to stream capture is shown as the light-blue line.

4.2 Historical Geomorphic Landscape and Land Use

This section builds on the previous discussion of the geology and faults by examining more recent changes to the geomorphic landscape and its associated hydrology and vegetation communities, most of which have been caused by land use and other anthropogenic changes. Section 4.2.1 demonstrates and explains these changes in chronological order through the use of historical maps, photographs, and other documents. Section 4.2.2 provides a summary of the important insights and details.

4.2.1 Historical Maps and Photographs

Figures 13 through 32 provide evidence of historical vegetation and landscape changes in the greater watershed areas in and around the study area. These changes have influenced the current channel morphology and riparian ecosystem. Evidence of and support for the conditions described and assertions on the effects of land practices are provided in captions under each figure. **Appendix A** contains additional details about the historical research. **Appendix B** contains unclipped or unmodified versions of these figures and others that were not included in the main text.

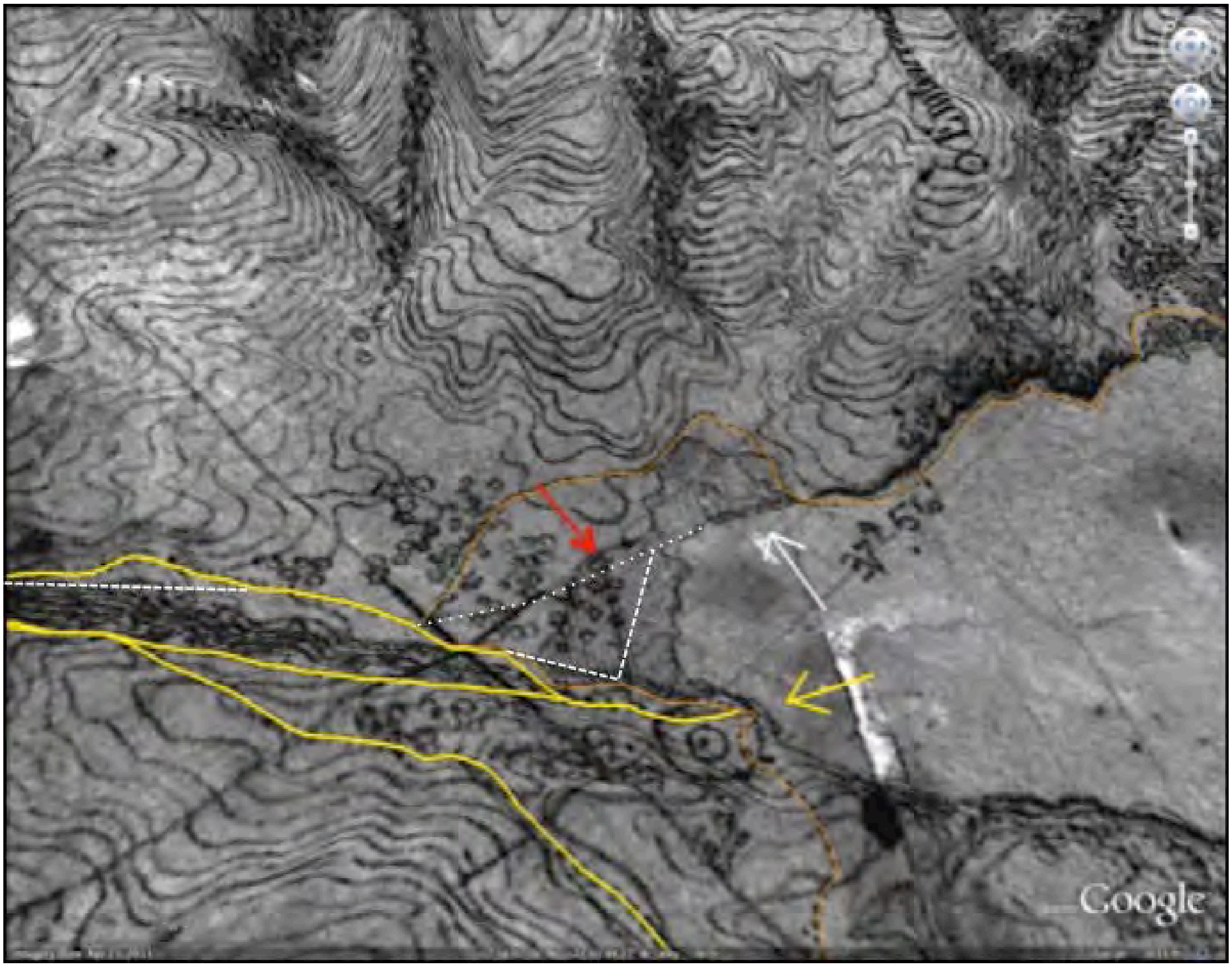


Figure 13. Detail of 1854 U.S. Coast and Geodetic Survey T-Sheet

The 1854 T-Sheet from the U.S. Coast and Geodetic Survey map (Livingston 1995) in **Figure 13** has been overlaid onto Google Earth to enhance the visibility of its features. The hachured (cross-hatched) area at the north end of the lagoon was mapped to represent marsh that is now part of the Y. The main roads at the time of 1854 are highlighted in yellow. The roads leading to the yellow arrow were used primarily for bringing redwood logs to the wharf. The embarcadero is shown as a series of concentric circles on the map. The embarcadero later became known as the lighter wharf because rapid sedimentation associated with the start of logging activities in 1849 prevented deep draft boats from accessing the area. The orange line highlights an older, probably original trail around the seasonally wet areas in Wilkins Gulch and Salt Creeks. To the south (right) of the white arrow, much of it follows a similar course to what is now SR1. The white arrow points to what appears to be the start of construction of a road berm to cross the Salt Creek embayment. The white dashed line indicates the original alignment of what became SR1 after it was completed some time after the 1850s, and the dotted line indicates the present day alignment of SR1 in the area of the Y. The alluvial fans of Wilkins Gulch and Lewis Gulch Creeks are shown to have large trees growing in areas that were subsequently converted to pasturelands. It seems likely that many of the trees were oaks and a few live ones today correspond to the map. Creek lines are not mapped for Lewis Gulch and Wilkins Gulch Creeks. Along the northern marsh area of the lagoon, near the downstream extent of trees, heavier dark lines in the marsh might indicate the placement of another berm (shown at the red arrow) for a trail crossing. A larger area and unmarked version of the map can be viewed in **Appendix B**.

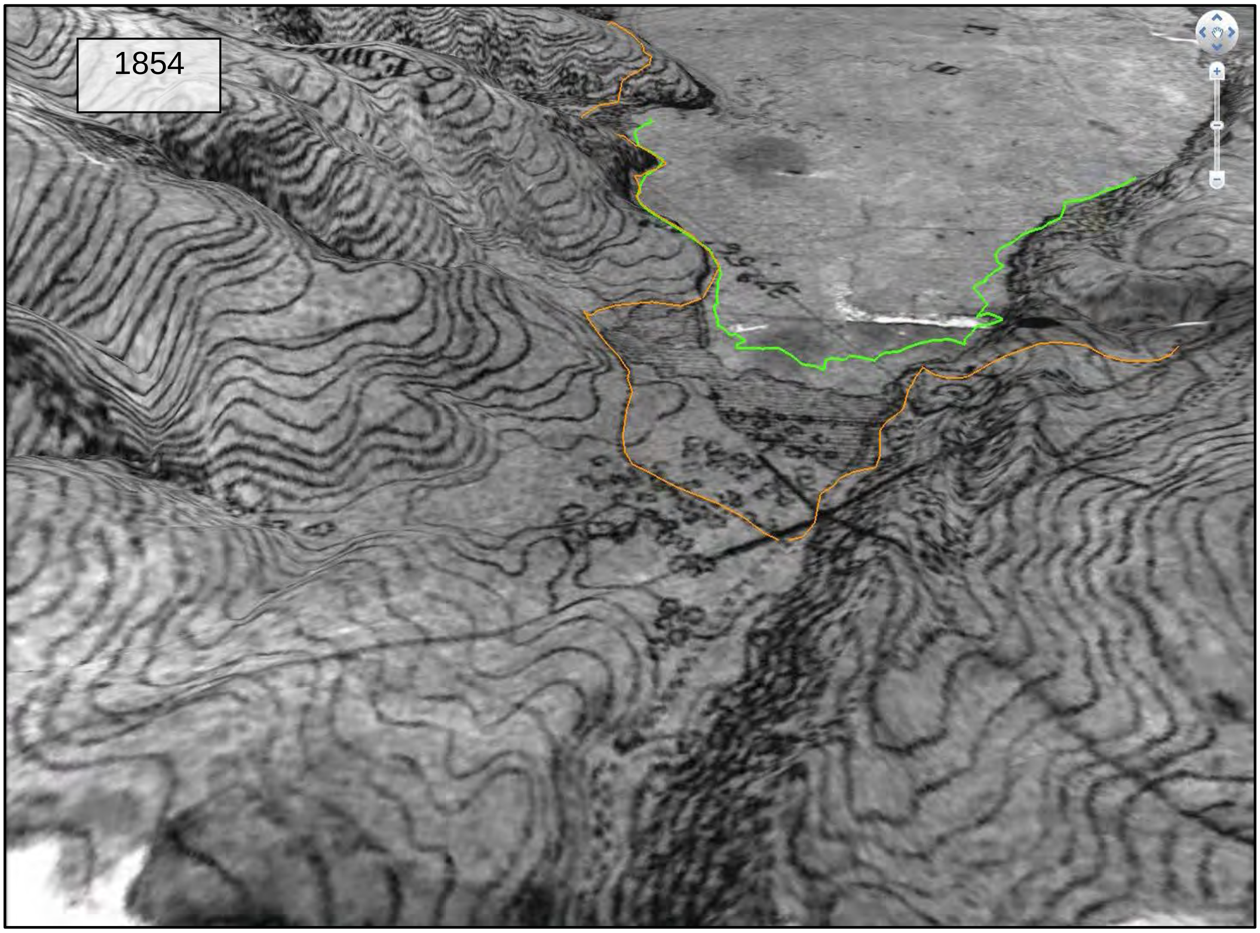


Figure 14. 1854 US Coast and Geodetic Survey T-Sheet Southward View of Study Area

This three-dimensional overlay of the 1854 Coast and Geodetic Survey T-Sheet in **Figure 14** (Livingston 1995) looks southward down Lewis Gulch Creek toward the head of the north end of Bolinas Lagoon. It highlights the distribution of possible oak trees (small circles near the center of the image) on the alluvial fans of Wilkins Gulch and Lewis Gulch Creeks. It is possible that these trees could have been growing along former distributary channels that at one time occupied the toes of the alluvial fans. The green line shows the approximate 2013 edge of tidal marsh vegetation to open water. Sedimentation has built the deltas of the creeks outward toward the open water and upward in elevation. The orange line highlights the old trail shown on this map. The trail probably skirted the seasonally wet areas. A larger area of the map can be viewed in **Appendix B**.

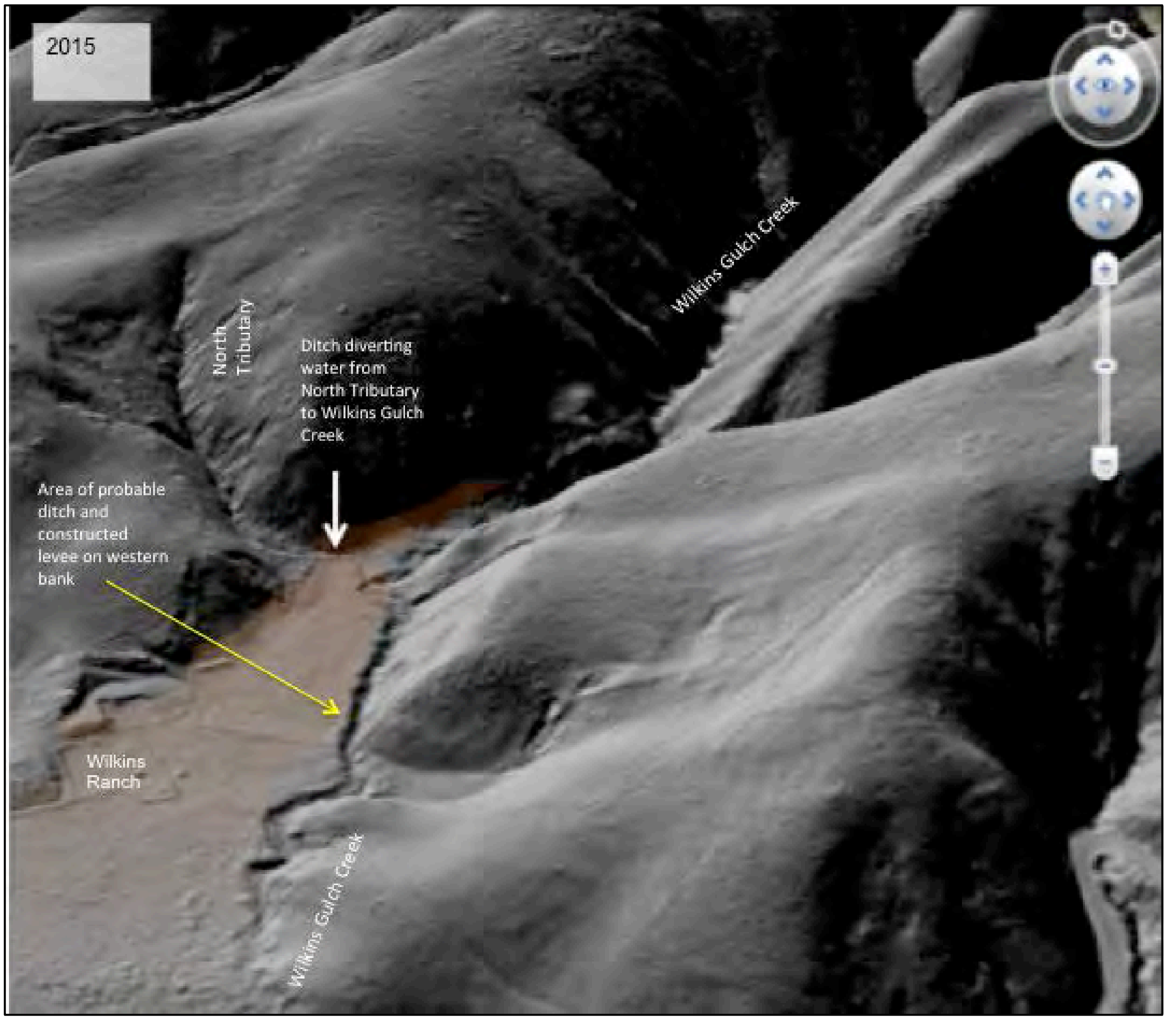


Figure 15. Wilkins Gulch Creek's Alluvial Fan

This LiDAR image (NoCal GeoES 2015 kmz file on Google Earth) in **Figure 15** looks northward from the base of the Wilkins Gulch Creek alluvial fan, shown in light orange. Much of the vegetation cover is removed in this imagery, which has been projected onto Google Earth. The white arrow shows where North Tributary of Wilkins Creek has been ditched and diverted across its alluvial fan and the Wilkins Gulch Creek fan. It is also possible to see how Wilkins Gulch Creek might have been ditched to flow along the extreme eastern edge of its fan, probably to maximize crop land or pasturage and enhance rapid drainage. The yellow arrow points to a reach of the creek that also had a constructed berm along on the west side of the channel. Riparian vegetation on the banks downstream of this point appeared to be more recent than the 1800s. Many small discontinuous swales and flow pathways were observed in the field while walking across the body of the fan.

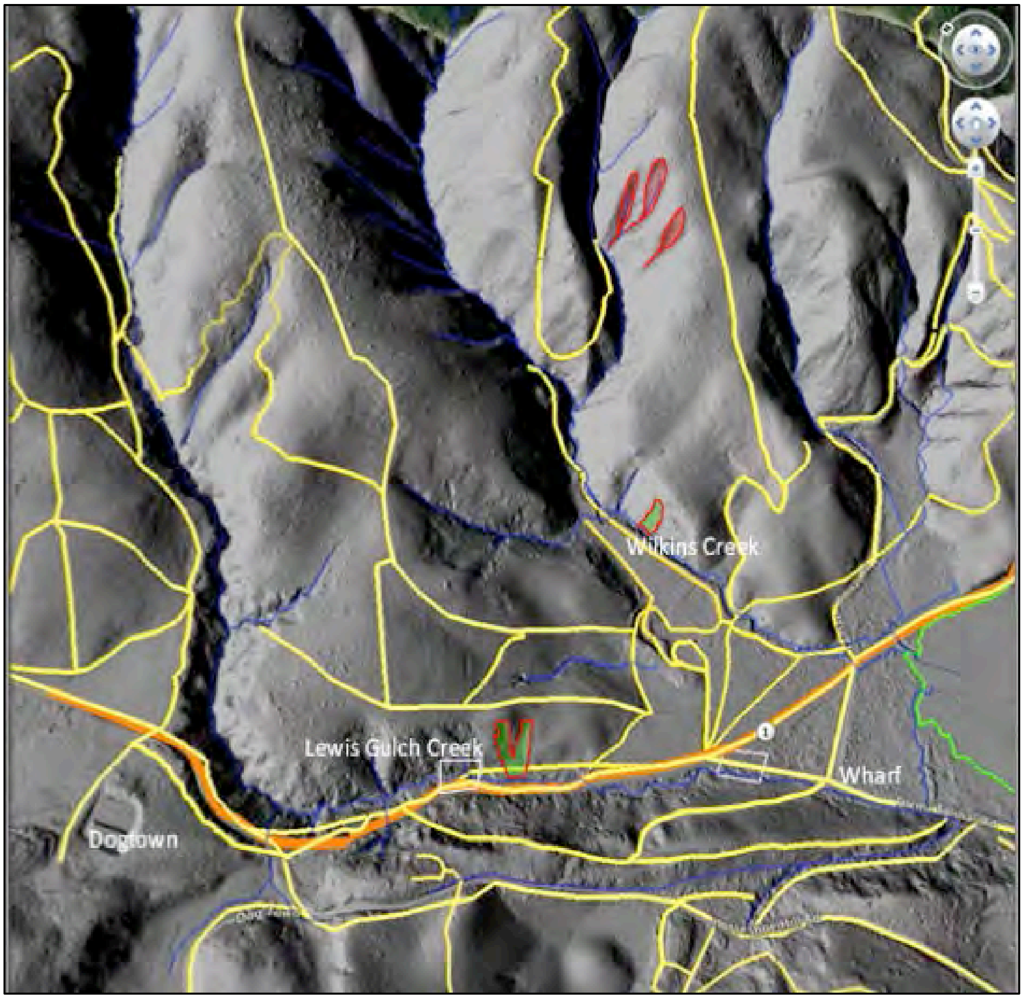


Figure 16. Historic and Current Roads

This LiDAR image (NoCal GeoES 2015 kmz file on Google Earth 2015) in **Figure 16** shows the current and former road networks. The image highlights an extensive network of modern paved and old dirt ranch roads, which are all marked in yellow, except for SR 1, which is highlighted in orange. Most of the roads originally were dirt roads to access ranches, timber, copper mines, the head of the Bolinas Lagoon, and the towns of Bolinas and Dogtown (later named Woodville). Creeks are shown in blue. The approximate 2013 edge of tidal marsh vegetation is shown in green. Cattle ranching and dairying was one of the earliest land practices, probably starting with settlement by Rafael Garcia in 1834. Redwood logging followed shortly thereafter in 1849 and subsided by 1858. During this period sedimentation of the Bolinas Lagoon rapidly increased, principally caused by the denudation of the Bolinas Ridge hillsides and the construction and repeated use of haul roads for transporting timber by oxcarts to the wharf at the head of the lagoon where they were rafted to schooners anchored in deeper water. Mining in the creek north of Lewis Creek Gulch, called Copper Mine Gulch, kick-started the town of Dogtown in 1863. The Lagoon reportedly became increasingly shallower at the embarcadero. In 1870, Ingram built the lighter wharf for shallow draft boats. It is unclear if it was in the same location or slightly south of the original embarcadero wharf location. The LiDAR image makes it clear that landsliding (debris flows, earthflows, stream bank slumps, and road cut-and-fill failures) in the steep inner gorges of the canyons is an important and pervasive process. Some typical examples of debris flows are shown as red polygons and examples of earthflow are shown as green polygons outlined in red. Many of these features are apparent in the LiDAR, but mapping these episodic sediment sources was beyond the scope of the project. Along the apex of the alluvial fans the substrate is likely a mix of alluvium and coarse sediment from debris flow deposits. Numerous gullies, observed during the field reconnaissance, were caused by road runoff and former periods of heavy grazing. Head cuts (or nick points caused by incising channels) were observed in the streambeds of Wilkins Gulch and Lewis Gulch Creeks as well as in numerous tributaries shortly upstream of their confluences with these main channels. The two white boxes indicate the probable locations of some of the earliest stream crossings in the study area as indicated by the 1854 map in **Figure 17**. The downstream white box coincides with the intersection of the 1854 trail, which is shown as an orange line on **Figures 13** and **16**.

Figure 17. Detail of 1854 Map of the Berry Grant

This 1854 detail of the Berry Grant Map in **Figure 17** made for Bethuel Phelps (Livingston 1995) shows Lewis Gulch Creek (highlighted in blue) relative to the road to Sausalito, which is a black dotted line, and the Olema Bolinas Road, which is a black dashed line. The dotted line probably represents the orange line showing the trail that skirted the wetlands in **Figure 13**. The map indicates that the mouth of the creek was at the northwestern corner of the Bolinas Lagoon (then referred to as "Baulinas Bay"). There were two crossings on Lewis Gulch Creek. The lower crossing might have been located near the vicinity of the present intersection between SR 1 and Olema Bolinas Road. The other was further up the drainage. The white rectangles shown on **Figure 16** indicate the possible locations of these two crossings depicted in **Figure 17**. At some later time, the creek was probably ditched to the west side of the road and the lower crossing was eliminated. The upper crossing was probably eliminated by relocation of the road. Livingston (1995) indicates that a reproduction of the full map is located in the Point Reyes National Seashore Collection.

Figure 18. Detail of 1867 Survey Plat

This 1867 image in **Figure 18** shows a portion of the 1867 "Plat of the Survey of the relocation of the Road from Bolinas to Olema" by Hiram Austin projected onto a 2013 Google Earth Image (Livingston 1995). All efforts were made to align the road in the map to the existing Horseshoe Hill Road but it caused the alignment of the large eastward bend in the creek to be poorly aligned. The upper bend in the historical Lewis Gulch Creek, shown in black, does not align well with the modern creek, but its orientation appears consistent. Dark blue lines indicate the location of modern stream courses. The light blue line indicates an adjusted alignment of the 1867 Lewis Gulch Creek that takes the distortion into account. The downstream end of Lewis Gulch Creek is directed towards the northward side of its alluvial fan, along the base of the hills near Wilkins Ranch. It is possible that this might have been the historical location of Lewis Gulch Creek. Two alternative hypotheses are also plausible. One, it might have been diverted toward the Wilkins Ranch to power a sawmill or to supply water to the dairy. Two, it might have originally had a number of distributaries that it periodically occupied as it approached the delta into the Bolinas Lagoon. If the latter hypothesis represented the original natural condition, ranchers may have tried to try to eliminate the wet conditions and multiple channels in their fields by ditching the channel to one side of its valley. This was a common practice, and it was demonstrated to be the likely case on the Wilkins Gulch Creek alluvial fan in **Figure 15**.

Figure 19. Detail of Eskoot's 1868 County Records Survey

This image shows a portion of an 1868 County Records Survey from Alfred Eskoot (Livingston 1995) projected onto a 2013 Google Earth image. The map shows historical features in black and the current stream alignments in blue. The map also shows the Wilkins barn, H. Ingram's House, a landing at the head of the Bolinas Bay, and Salt Creek. It does not show Lewis Gulch or Wilkins Gulch Creeks. There is no indication of a creek mouth at the location of the "landing at the head of the Bolinas Bay", possibly indicating excessive sedimentation in the area, or that the creek had been moved. Much of the current alignment of SR 1 is shown to be surveyed. It also shows the location of proposed culverts on Salt Creek and upper Lewis Gulch Creek. This may have been the reconnaissance survey for initial construction of the road to Sausalito along the Bolinas Lagoon that was constructed in 1870. It was later designated as SR1. Later maps, such as **Figure 20,** show the crossover road continuing northwestward uphill (red line on **Figure 20** and connecting to a ridge road (Horseshoe Hill Road) that parallels Lewis Gulch Creek. This implies that the present day SR1 alignment north of the crossover road was not completed until sometime following 1973.

Figure 20. Map of Marin County, Austin and Whitney 1873

Figure 20 shows that the mouth of Lewis Gulch Creek was just beyond what is now the intersection of the crossover road and Olema Bolinas Road. The building shown just north of the crossover road is likely the Wilkins barn that was documented as being close to the embarcadero and used to house milled lumber. The Wilkins Ranch residence was not built until 1875. Wilkins Creek can be seen to be flowing toward what is now the intersection of the crossover road with SR 1. The yellow dotted line is highlighting a mapped trail that connected Horseshoe Hill Road to the wharf.

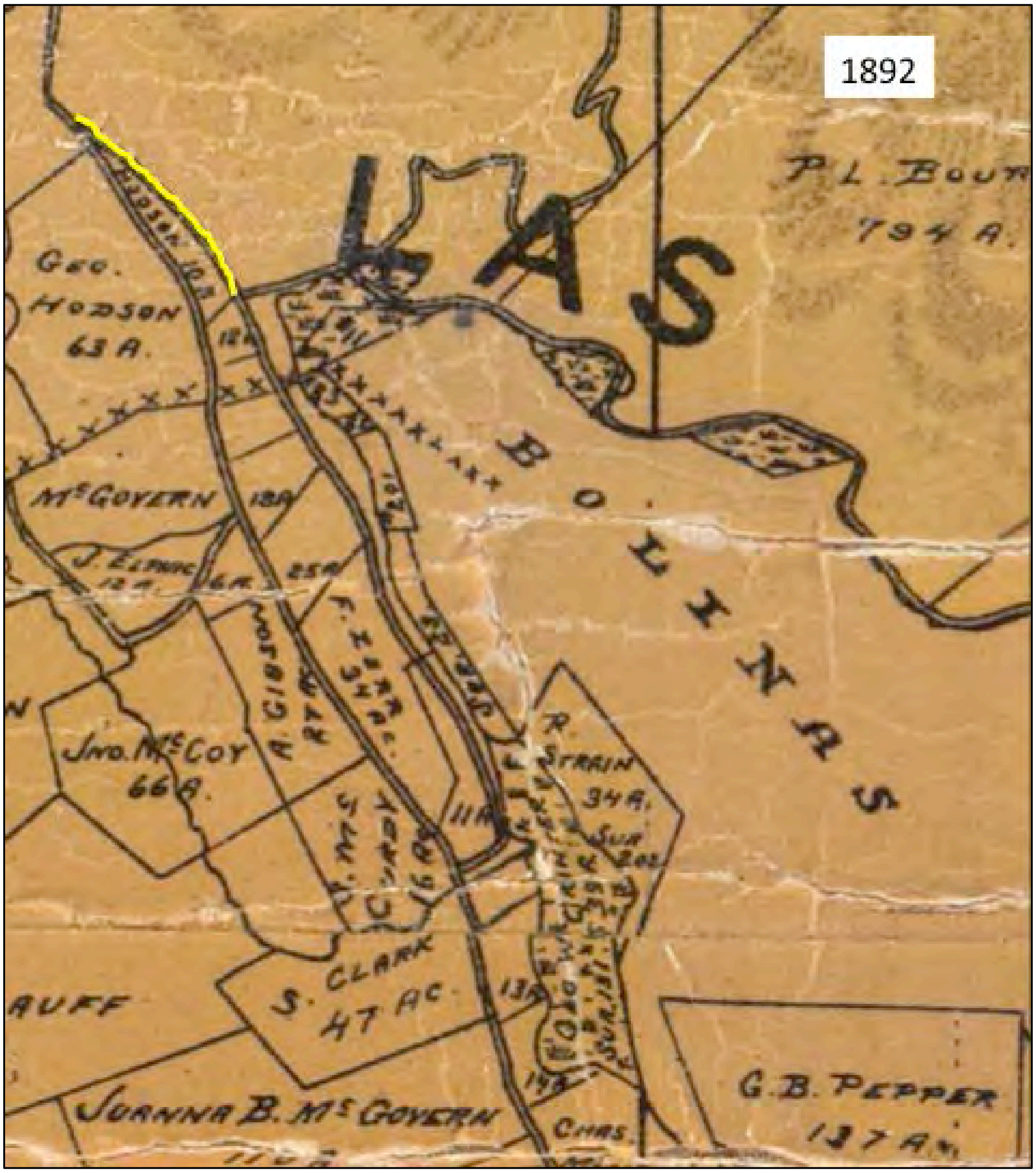


Figure 21. Detail of 1892 Map of Marin County

This 1892 map by Dodge in **Figure 21** (David Rumsey Map Collection) shows most of the present day alignment of SR 1 along the east side of the Bolinas Lagoon, and it shows a new connection of SR1 (yellow line) that connects much farther north to Horseshoe Hill Road than where it was previously intersected as shown in Figure 20. The present day SR1 alignment that creates the Y at the Wilkins property had not been constructed yet; therefore, the crossover road was still the main access route from the east sore of the Bolinas Lagoon to Bolinas. The map also shows that the Olema Bolinas and Fairfax Bolinas Roads have been constructed by this time. Wilkins had been given grant to construct the Fairfax Bolinas Road in 1878. It might have been completed by 1884. The map shows the extension of marshland into the Bolinas Lagoon, much of which was accomplished through reclamation activities by building dikes along its margin (Van Kirk 2000)

Figure 22. Wilkins Ranch Photograph, 1880

The photo in **Figure 22** (Livingston 1995) shows the Wilkins Ranch looking from the east side of Wilkins Gulch Creek towards the west. In the lower left corner of the creek banks are evident with a lack of vegetation and the eroding dirt road. The creek has the appearance of a possible old ditch undergoing incision and bank erosion at this location.

Figure 23. Current Wilkins Ranch Area Photo Collage

Figure 23 is a photo collage of the Wilkins Ranch area in 2015. Image (A) shows a 2015 view from approximately the same location as shown in **Figure 22** photographed in 1880**;** yet, it was taken in front of the creek because willows growing along the stream course now block the viewshed. The 2013 Google Earth Image (B) shows the vantage point of the 1880 photo. Image (C) shows the view from the fence location (blue arrow) shown in the foreground of **Figure 22**. The Wilkins Gulch Creek channel is more incised and wider now than it was in the 1880s. The creek is now a braided channel through the willow grove at this site.

The Wilkins Ranch appears this 1906 photograph by G. K. Gilbert. Note that the barn has yet to have an addition. Pilings from the lighter wharf can be seen on the left. U. S. Geological Survey Library, Menlo Park.

Figure 24. Wilkins Ranch Photograph, 1906

The photo in **Figure 24**) shows the Wilkins Ranch from the north end of the Bolinas Lagoon (Livingston 1995). Note the lack of trees along the margin of the shoreline in the area that is now considered the Y, except along the riparian corridor of Lewis Gulch Creek just upstream of the lighter wharf in the left side of the photo. The willow groves along the downstream end of Wilkins Gulch and Salt Creeks can also be seen toward the right central part of the photo. The hillsides are primarily grasslands with little brush or tree cover. The trees in the background hillsides look like snags; perhaps they reflect the fires of 1890 and 1904, which burned through parts of the Wilkins Ranch and destroyed bridges and culverts along the Fairfax Bolinas Road (Fraser 1880; Livingston 1995). Fires would have accelerated sediment supply and sedimentation rates to the lagoon.

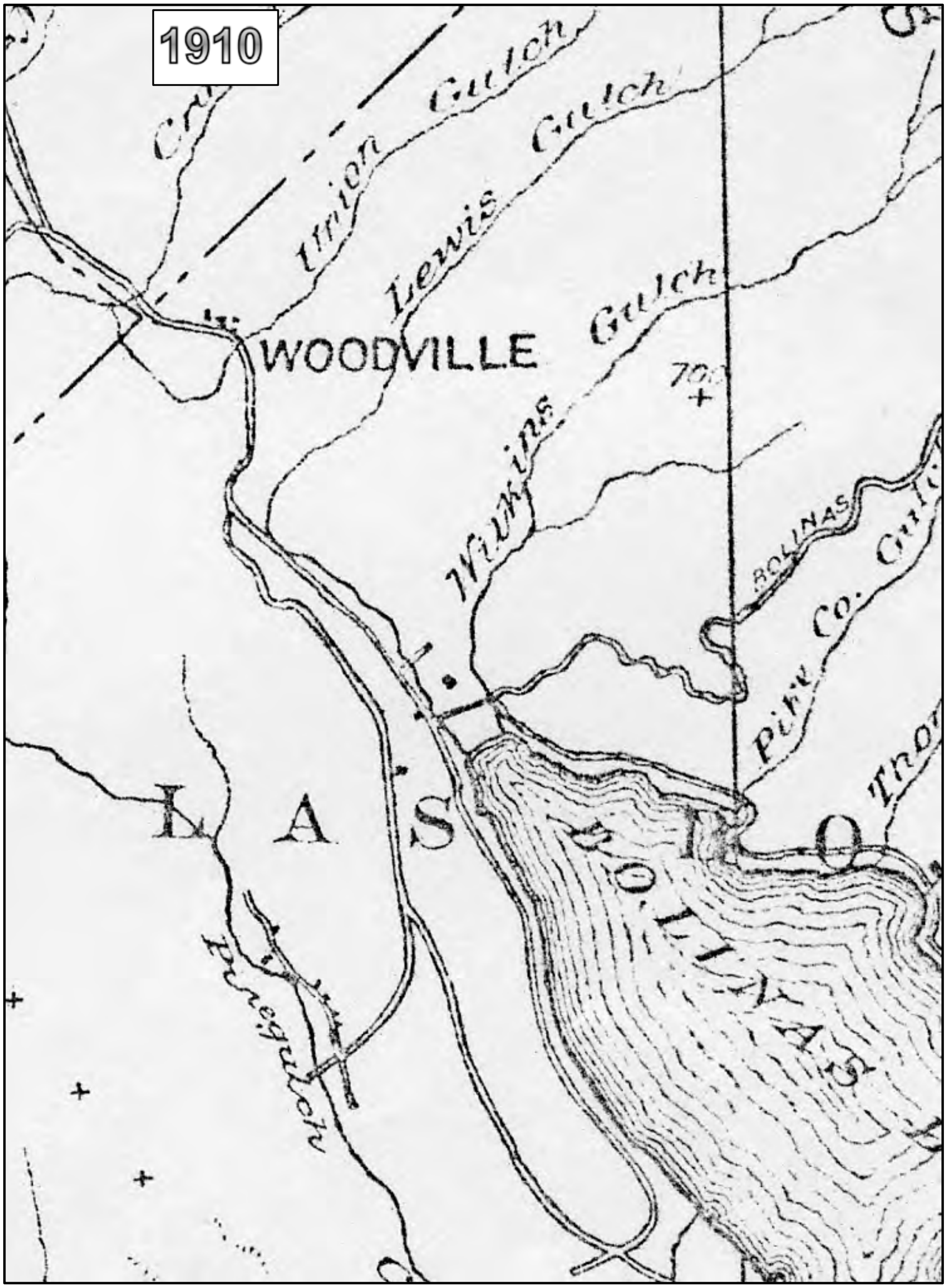


Figure 25. Detail of 1910 Hiking Map

This map in **Figure 25** (Source: Livingston 1995) shows Lewis Gulch Creek continuously on the north side of the Olema Bolinas Road. It also shows a spur road crossing the Lewis Gulch Creek. The spur road might be the driveway into the Wilkins House. The building between the spur road and the crossover road also appears in the 1873 map in **Figure 20**. It is unclear what became of the building.

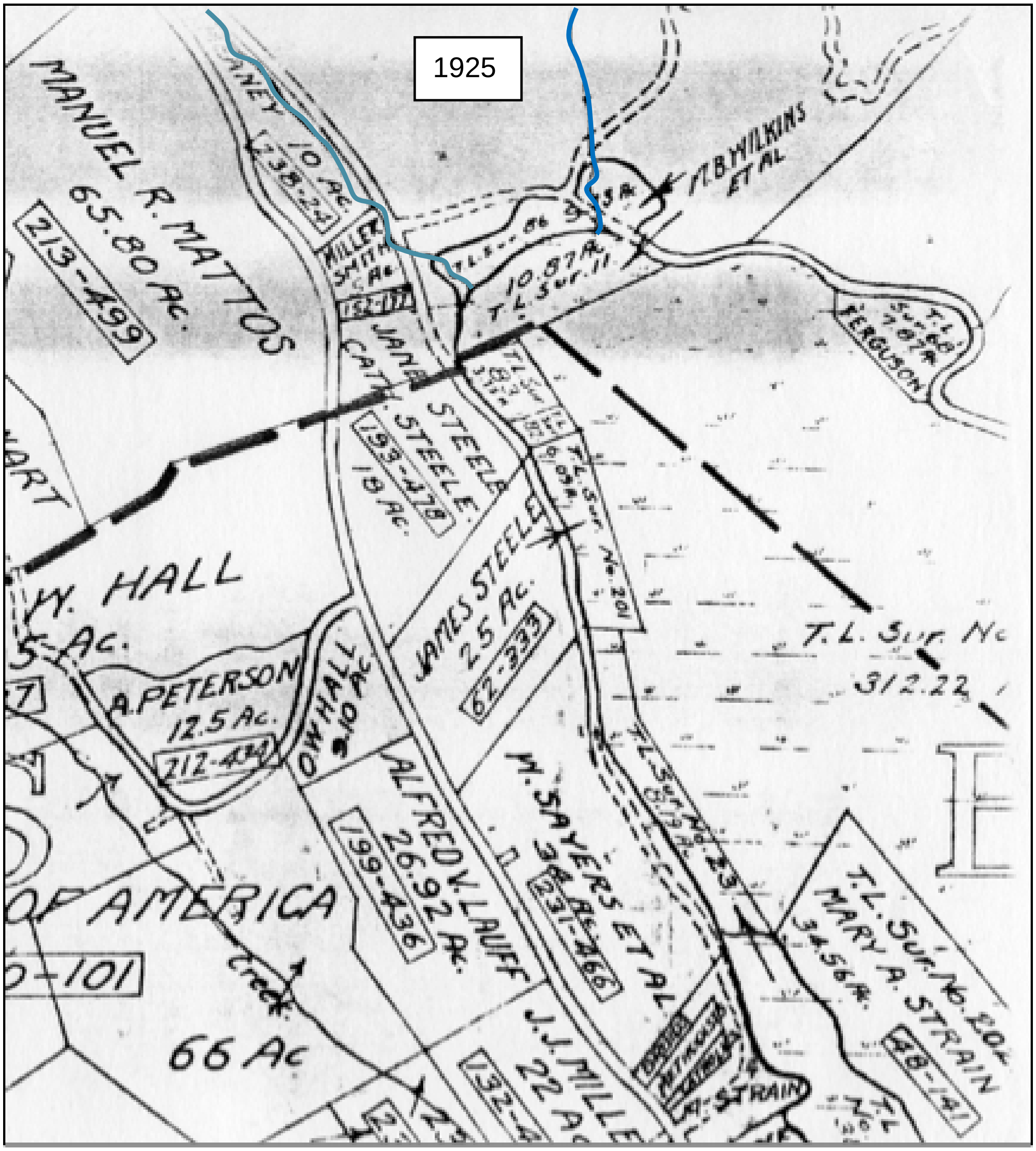


Figure 26. Detail of 1925 County Surveyor's Parcel Map

The 1925 County Surveyor's Parcel Map in **Figure 26** (Livingston 2015) shows Lewis Gulch Creek highlighted in light blue and Wilkins Gulch Creek in dark blue. Lewis Gulch Creek is flowing toward the intersection of the crossover road and Olema Bolinas Road, but north of the crossover road, it is on the western side of Olema Bolinas Road as opposed to the eastern side as shown in **Figures 17, 20, and 25**. Wilkins Gulch Creek is shown to be directed into the Salt Creek embayment and crossing both the Fairfax Bolinas Road and SR 1. If mapping of the creek is correct on the 1910 (**Figure 25**) and the 1925 maps, this indicates that Wilkins Gulch Creek was ditched and diverted to the wetlands in Salt Creek before 1925. It is not known if the diversion was made to bring freshwater to the site or to transport sediment to help fill the embayment.

Figure 27. Photo of Olema Bolinas Road

Figure 27 is an undated photo (E.A, Cohen and Stinson Beach Historical Society) that shows the Olema Bolinas Road and the original SR1 alignment now referred to as the crossover road. When the road was constructed, it was built up on a berm above the average elevation of the land to reduce the potential for flooding. Ultimately the road berm slowed the conveyance of floodwaters to the lagoon, eventually increasing backwater flooding and sediment deposition upstream of the road. Lewis Gulch Creek appears to be on the east side of the Olema Bolinas Road and only grasses and herbs appear to be growing north of the crossover road.

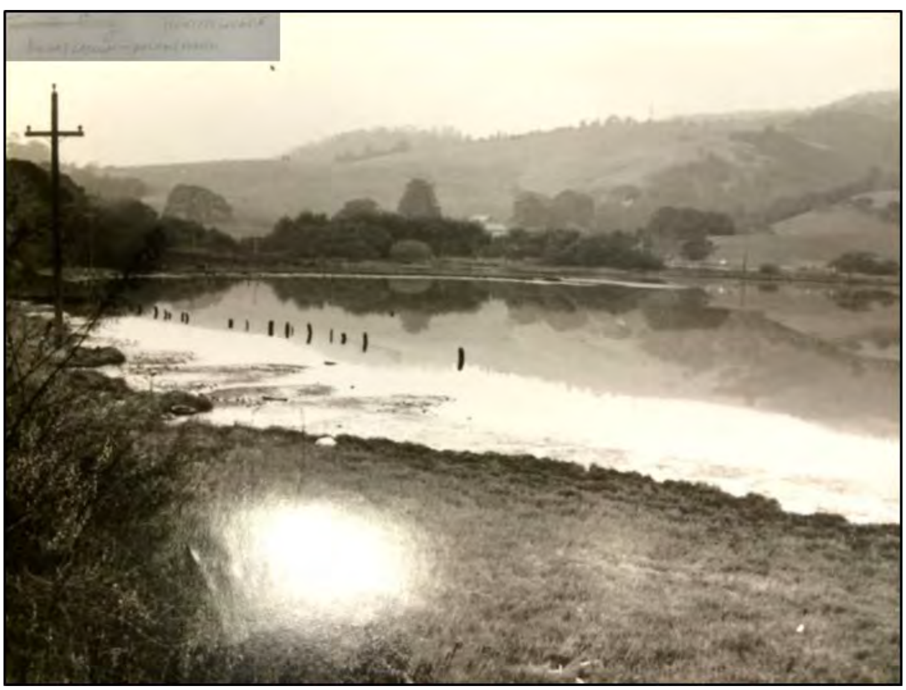


Figure 28. West Side of Bolinas Lagoon

The undated photo shown in **Figure 28** (Marin History Museum) was taken along the western shoreline of Bolinas Lagoon looking northward. It shows remnant pilings of the lighter wharf, a well-developed alder forest north of crossover road, and a willow grove near the outlet of Wilkins Gulch Creek. This photo may have been taken in the late 1950s or 1960s.

Figure 29. Aerial Photo, 1943

The October 1943 aerial photo in **Figure 29** (Marin County Geographic Information System Department) was projected onto Google Earth. The photograph shows the two distributary ditches at the lower end of Wilkins Gulch Creek, and it shows that neither the alder forest north of the crossover nor the willow grove at the lower end of Wilkins Gulch Creek has not yet developed, but two smaller patches exist upstream. One patch has taken hold at the position of the creek in the 1906 photo point (shown in **Figure 22** and **Figure 23**). Based on the mapping of the older ranch roads, the upstream edge of the willow patch coincides with an area just upstream of an early bridge crossing used to access Wilkins Ranch. It is probable that the bridge structure contributed to the bank erosion and channel widening that occurred at the creek site pictured in 1906 (**Figure 24**). The grove of willows at Salt Creek has not yet developed, but the pond area still has large areas of open water that were probably becoming decreasingly tidal and increasingly brackish. A few alder trees are starting to appear on the far south side of the crossover road.

Figure 30. Detail of 1952 Aerial Photo

Figure 30 is an excerpt of a photo taken in June 1952 that may have been taken a few years before the current alignment of SR 1 was constructed to extend through the lower Wilkins Ranch (Marin History Museum). This photo shows the crossover road as still the only connection to the Olema Bolinas Road as similarly mapped in 1892 (**Figure 21**) and 1910 (**Figure 25)**. The Y does not exist yet. The alder forest is continuing to expand on the north margin of the Bolinas Lagoon. Lower Salt Creek has been ditched, probably to provide better drainage. The dark color of the land just north of the crossover road may indicate a higher groundwater table along the toe of the alluvial fans of Wilkins Gulch and Lewis Gulch Creeks.

Figure 31. Detail of Foley's Wilkins Ranch

Figure 31 is an undated excerpt of a larger photograph (Bolinas Museum) taken southwest of the intersection of SR 1, the crossover road, and Fairfax Bolinas Road. The person who supplied the photo believed the photo was taken sometime around 1949–1952 (Photo by Jim Foley). It may have been taken about 1957, during preparations for extending SR 1 through lower Wilkins Ranch. These might have been rushes, which would indicate a high water table. Note the establishment of dark colored vegetation on the north side of crossover road. Note also the location of the Oyster House at the end of crossover road.

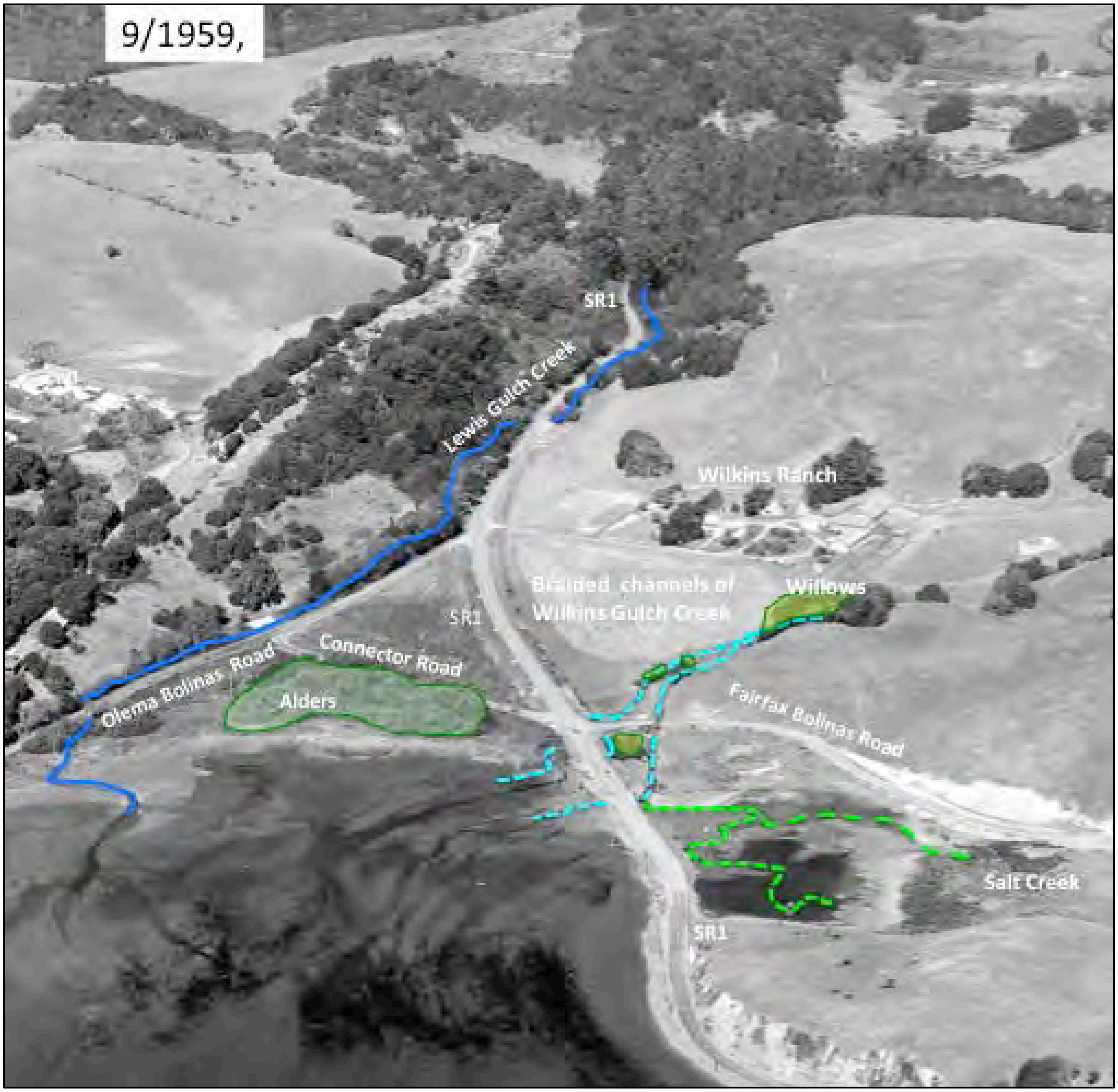


Figure 32. 1959 Aerial Photograph of North End of Bolinas Lagoon

The September 1959 photo shown in **Figure 32** (Livingston 2015) shows the new SR 1 extension through the lower Wilkins Ranch. The two distributary ditches of Wilkins Gulch Creek are shown as a dashed light blue line, and the small patches of willows pointed out on **Figure 31** are evident and indicated in yellow-green. The alder forest, shown as a sage green polygon, has become well developed south of the crossover road, but it still has not taken hold in the north side of the Y. The Salt Creek pond does not appear to have a willow grove yet, except perhaps one just beginning to form at its eastern margin along the toe of the alluvial fan.

Figure 33. 1968 Aerial Photograph

Figure 33 is a photograph from February 1968 that (Source: Marin County Geographic Information System Department) shows the same grouping of alders seen in the 1959 image in **Figure 32**. The western distributary ditch of Wilkins Gulch Creek at the yellow arrow is less pronounced than the eastern one at the green arrow, potentially indicating that the western one is starting to become abandoned due to sedimentation. This is consistent with its current status.

4.2.2 Summary of Findings from Historical Maps and Photographs

The captions of each figure in the preceding section previewed the conclusions that can be drawn from these historical maps and photographs. A summary of the land use development and change over time is presented here; more detailed discussions of the implications and significance of these changes on the hydrology and geomorphology is provided in Section 5.

Water diversions, road construction, logging and woodcutting, dairying, and ranching have had a profound influence on the study area's streams. The map and photo documentation presented indicates that active changes to the landscape were occurring before the 1854 T-Sheet mapping was conducted. Ranching in the area began as early as 1834, and with it came changes in vegetation and construction of roads and trails. Logging in the watershed occurred between 1849 and 1858.

The expansive network of haul roads needed to extract logs from the steep hillsides and deliver them to the wharf at Bolinas Lagoon is still evident today in LiDAR imagery. As logging tapered off, copper mining began in the watershed to the north of the study area. Goods to and from the mines were transported on the local roads.

Expanding the road network to reach distant trees and shortening the travel distance between locations was partially necessitated by the need to both get logs to the wharf (built along the northwestern area of the lagoon) and loaded onto ships, and the need to accommodate the influx of people traveling to Bolinas from Sausalito. By 1854 road berms were being constructed along the current SR1 footprint in order to shorten the route around the head of the lagoon (1854 T-Sheet map). The toe of the alluvial fan on Salt Creek appears to have been artificially separated from its historical margin with Bolinas Lagoon by the placement of the road berm. The road fill and a small culvert installed to drain the creek effectively cut off the lagoon from Salt Creek. As a result, tidal influence to this area was constricted, and the area was converted from a tidal marsh area to a freshwater-to-brackish pond.

When the 1854 T-Sheet map is compared to later maps and photographs, it is clear that mature trees were present on the alluvial fan surfaces in 1854 and that the shoreline of the lagoon was further inland than it is today. If maps from 1867 are correct, it appears that Lewis Gulch Creek still flowed out onto its now-abandoned alluvial fan east of SR1 where large trees are drawn in on the 1854 T-Sheet map (**Figure 14**).

The practice of draining and reclaiming land, and moving channels to the sides of their valleys was commonplace from the mid-1800s through the early 1900s. The photo of the Wilkins Ranch house and barn in 1880 (**Figure 22**) indicates that Wilkins Gulch Creek had already been altered by removal of vegetation on the banks and/or relocation of the channel against the eastern hillslope. By 1892 (**Figure 21**), it appears that the pre-development shoreline had been pushed further into the lagoon by diking in attempts to gain additional farmable land. The 1906 photo (**Figure 24**) shows that the mature trees drawn on the 1854 T-Sheet map (**Figure 13**) are no longer present. This further indicates that the land around the ranch was cleared to increase usable farmland.

Lewis Gulch Creek's stream flow was similarly changed around this time. The downstream extent of Lewis Gulch Creek was pushed against the western hillslope between 1910 and 1925. The 1925 map (**Figure 26**) shows Lewis Gulch Creek crossing back across to the eastern side of road near the intersection of Olema Bolinas Road and the crossover road.

Additional manipulation of lower Wilkins Gulch Creek is evident when comparing changes between the 1910 (**Figure 25**) and 1925 (**Figure 26**) maps. The creek was ditched to flow to the east side of Bolinas Fairfax Road and then under SR1 at the current-day culvert location. It is possible that the culvert or lack of a culvert near the junction with the crossover road (where the creek flowed previously) had failed or the road was being flooded. The culvert at SR1 may have been newer or larger at the time and so seemed like a better location to convey the flow of Wilkins Gulch Creek to the lagoon. Another hypothesis is that Wilkins Gulch Creek flow was used to deliver freshwater to the pond east of Bolinas Fairfax Road to flush it of salty water for cattle usage. Fill appears to have been placed around the west edge of the pond on Salt Creek prior to 1957 as interpreted from the photos in **Figures 30 and 31**. This may have been done to provide a staging area for the SR 1 construction. Fill may have been placed around the east side of the pond in an attempt to increase farmable or grazing land.

As ranching and farming activities decreased around Wilkins Ranch, vegetation began to reclaim the land. By 1943 (**Figure 29**), an alder forest was becoming established along the shoreline of the lagoon between Lewis Gulch and Wilkins Gulch Creeks, where fresh groundwater emerges from the alluvial fan. By 1959 (**Figure 32**), willow groves appear to be establishing around the pond on Salt Creek. The extension of SR1, shown in **Figure 32** between the crossover road and Olema Bolinas Road was believed to have been constructed in 1957. Earlier connections from the cross over road to Horseshoe Hill Road occurred sometime before 1873 (**Figure 20**) and 1892 (**Figure 21**). The compacted road fill from the SR1 extension is believed to inhibit some of the shallow subsurface groundwater flow, thus promoting wetland vegetation and allowing it to become established in absence of routine land clearing. Such land clearing would have been made difficult by saturated soils. When comparing more recent aerial photos to the 1943 (**Figure 29**) and 1952 (**Figure 30**) aerial photos, it seems apparent that the land upslope of where the road was constructed was drier at the time.

As the community of Bolinas was made more accessible by road network improvements, more people permanently settled in that vicinity. The increased human settlement influenced the local hydrology and runoff by changing groundwater withdrawals from well pumping, vegetation cover, evapotranspiration from agricultural practices, impervious surfaces from roads and structures, and topographic changes from roads, berms, culverts, bridges, and ditches that altered flood and sediment conveyance. In the study area, the population has remained low and has likely decreased during the last 100 years. **Table 3** summarizes the extent of development using data from the SF Estuary Institute's EcoAtlas (SFEI 2015) within the study area. It shows each watershed's drainage area, number of people residing, and the percent of land development. Wharf Creek has the smallest drainage and the greatest percent development, 19.6 percent. This creek was not included in the field surveys. Wilkins Gulch Creek has the largest drainage area, the fewest people, and the lowest percent development, 8 percent, which is very close to the 8.4 percent of Lewis Creek Gulch. Salt Creek has the second highest percent developed land cover, principally due to Fairfax Bolinas Road. Salt Creek and Wharf Creek are likely to have the flashiest runoff of those in the study area. The percent of developed land cover in a watershed will be useful information for modeling the influence of urban runoff, when that stage of project development is reached.

Table 3. Watershed Development

Watershed	Drainage Area (mi^2)	Percent Developed Land Cover	2010 Census Human Population
Wilkins Gulch Creek	0.68	8.0	1
Salt Creek	0.15	17.0	0
Lewis Gulch Creek	0.62	8.4	16
Wharf Creek	0.08	19.6	6

Source: SFEI ECOATLAS 2015: http://www.ecoatlas.org/regions/ecoregion/bay-delta

4.3 Current Hydrology and Geomorphology

This section presents the results of the field surveys, data analysis, hydrological modeling, synthesis with historical research findings, geology, and geomorphological perspectives presented in preceding sections. **Figure 4** illustrates the streams, stream reaches, and other features that are referenced here. **Figures 34** through **37** present watershed-specific, maps of each stream, watershed, and other relevant details.

4.3.1 Hydrology

This section first presents some general findings from the field surveys and then discusses the hydrology of each stream or water body in the study area.

4.3.1.1 General Findings

The upper watersheds consist of mixed conifer forest along the Bolinas Ridge, and oak-bay woodlands occupy the drainage along Wharf Creek and the west side of Lewis Gulch Creek. Oak woodlands and grasslands generally characterize areas within the alluvial fans. In some reaches, the streams have a corridor of riparian trees (i.e. red alder, willows, maple, and buckeye). In other areas, the trees are lacking. The lower alluvial fan segments upstream of the road crossings have a variety of habitats, as described in the Biological and Cultural Resources Technical Memorandum. Each stream drains through a box culvert to the Bolinas Lagoon. Downstream of the box culverts, the channels flow through alder groves, arroyo willows, cattail marsh, saltmarsh bulrush, saltgrass flats, and saltmarsh pickleweed mats and transitions from freshwater to saltwater with subtidal channels continuing through the mudflats.

All four streams have been altered by road berms upstream of the head of tide and of the freshwater/saltwater transition zone. A short distance beyond the outlets, the deltas of Lewis Gulch, Wilkins Gulch, and Salt Creeks merge together at the northern margin of Bolinas Lagoon. Road berms, ditch diversions, desilting activities, and culverts in the study area have altered the natural flood and sediment conveyance to the Bolinas Lagoon and have prevented flooding from naturally occurring. High flows coupled with high tides greatly increase the likelihood of flooding; yet, the amount of flow required from the various streams to cause flooding in the study area is unknown. Hydrologic modeling will be needed to predict how development may interfere with flow and be affected by SLR.

Channels on alluvial fans tend to be inherently unstable features and prone to episodic deposition, erosion, and shifting courses. In general, loss of surface flow into porous substrate across the body of large, deep alluvial fans is common, because the channel is no longer within a confined valley and the depth of the alluvium to bedrock can increase. Resurgence of groundwater and increased streamflow at the alluvial fan toes is also common because the height of the water table at the valley floor (or at the transition to the water level of the lagoon)functions as a base level control, forcing water to resurface as the level of the channel decreases above the water table elevation. This is why ponds and wetlands are often observed at the toes of alluvial fans. These general characteristics apply to the study area channels within their alluvial fans (shown on **Figures 34-37**). The channels that dissect the alluvial fans have highly variable dimensions and degrees of entrenchment. During large storms, they transport a large amount of sediment from the steep upstream canyon reaches where there are localized, high sediment inputs from eroding banks and from active landslides along the hillsides. Eroding banks and landslides are supplying creeks with large woody debris. In the middle of the fans, channels have diminishing discharge (losing reaches), and increasing discharge toward their toes (gaining reaches). Wilkins Gulch, Lewis Gulch, and Salt Creeks become intermittent in the middle segments of their alluvial fans. Some reaches of the Salt Creek tributaries are discontinuous and might be considered ephemeral rather than intermittent.

In general, alluvial fans build upward by spreading water and sediment on their surfaces through multiple distributary channels. Wilkins and Lewis Gulch are disconnected from flooding because the single-thread channels are incised, and the alluvial fans have, for the most part, been abandoned, except at their toes. Therefore, the single channels are far more efficient at transporting sediment toward and into Bolinas Lagoon than if the sediment were to be distributed on the fan surface. Much of the sediment load is deposited in the roadside ditches on the upstream side of the culverts and in the culverts under the roads. During flood events, these culverts under the roads may become overwhelmed by the high sediment supply, causing water to back up and flood the roadway. This problem is exacerbated during high tide when channel velocities are reduced or halted at culvert outlets, causing any bedload to be deposited. If a new channel cannot be eroded through the sediment deposits in the channel or culvert following high tide, roadway flooding and sediment deposition will only worsen. Once a channel is entrenched (as most reaches are through their alluvial fans), downstream flooding is exacerbated because flood peaks arrive more quickly and have a greater discharge when they do arrive. At the toes of the alluvial fans on Wilkins Gulch Creek and Salt Creek, there is notable sediment deposition occurring in the braided channels within the willow groves, upstream of SR1 and Bolinas Fairfax Road. Eventually, without continual maintenance, sediment deposited in this area will increasingly affect the functionality of these culverts and exacerbate roadway flooding. Although the lower portions of the alluvial fans of Wilkins and Lewis Gulch Creeks have active sediment deposition, the majority of channel length across the middle and upper portions of the alluvial fans are not considered to be active because the channels are entrenched and prevent sediment deposition outside of the channel on the fan surface.

Streamflow during the 2015 winter-spring re-emerges at the toes of the three fans (on Wilkins Gulch, Lewis Gulch, and Salt Creeks). Mean lower low water (MLLW) establishes the base level at the toes of the fans to which freshwater is graded. Fresh groundwater is less dense than saltwater and flows above it into the lagoon. High tides likely have little influence on the average elevations of the groundwater table because the tide is at its highest for a very short time, but seasonal variations in rainfall that can last for months have the greatest effect on where groundwater re-emerges as surface flow. Willow groves at the alluvial fan toes on both Wilkins Gulch Creek and Salt Creek may represent the extent of perennially wet conditions during non-drought years. Based on the LiDAR topography, the upper extent of these willow groves occurs near elevations of 25 to 30 feet.

4.3.1.2 Wilkins Gulch Creek

As shown on **Figure 34**, Wilkins Gulch Creek divides into distributaries about 0.1 mile upstream of SR 1. It has two distributaries that drain through different culverts into the Bolinas Lagoon. The western distributary drains toward SR 1 and then parallels it in an inboard road ditch until it flows southward into a 4-foot-high by 7-foot-wide box culvert at the intersection of SR 1, Fairfax Bolinas Road, and the crossover road. At the outlet of the culvert, the channel divides into delta distributaries that flow through very short reaches of freshwater to tidal water ecotones to the lagoon. The most western delta distributary is ditched where it parallels SR 1. The eastern distributary (which is 0.1 mile upstream from SR 1) subdivides with several branches converging to join the western distributary at the box culvert inlet, with one branch flowing into the western distributary. The eastern branch becomes a ditch that was constructed to send flow to the watershed of Salt Creek through an 8-foot-wide by approximately 3-foot-high box culvert beneath the Fairfax Bolinas Road, where it then drains as partially ditched delta distributaries to a pond in the Salt Creek drainage. The pond is flanked by two separate willow groves. The eastern Wilkins Gulch Creek distributary ditch appears to be filling with materials, ranging from sand to medium-sized gravel, upstream of Fairfax Bolinas Road.

4.3.1.3 Salt Creek and Salt Creek Pond

Salt Creek has two main tributaries that converge in the Salt Creek willow grove and drain toward the pond that is about 150 feet north of SR 1 and about 25 feet south of the edge of the Fairfax Bolinas Road. Salt Creek tributaries deposit sediment at the head of their alluvial fans as they historically would have. Discontinuous channels occur through the length of the fan body, until merging into a single thread channel within the Salt Creek willow grove at the base of the fan. As shown on **Figure 35**, the Salt Creek Pond is fed by seasonal flow and groundwater from Salt Creek. The volume of water in the pond appeared minimal during the reconnaissance visit. Both Salt Creek and the eastern distributary of Wilkins Gulch Creek (discussed above) drain to Bolinas Lagoon through a 4-foot-high by 10-foot-wide box culvert that is about 270 feet south of the intersection of the Crossover Road, Fairfax Bolinas Road, and SR 1. The details of the extent or frequency of de-silting activities in the box culverts or ditches in this vicinity is not known, though the California Department of Transportation (Caltrans) is known to clear out silt in and around the culvert under SR 1 on occasion. Efforts to obtain details from Caltrans on the frequency of its de-silting activities and the quantities of sediment removed have been unsuccessful to date.

4.3.1.4 Lewis Gulch Creek

As shown on **Figure 36**, Lewis Gulch Creek drains from the hills east of SR 1 into an incised channel that parallels the northeast side of SR 1, crossing beneath it in a 58-inch-diameter corrugated metal culvert about 0.11 mile north of the SR 1 and Olema Bolinas Road intersection. The creek then flows another 1.8 miles in an inboard ditch along the southwest side of Olema Bolinas Road and makes an abrupt eastward turn into a 5-foot-wide by 4-foot-tall box culvert beneath Olema Bolinas Road. At the inlet of the box culvert, Lewis Gulch Creek is joined by Wharf Creek via a roadside ditch.

4.3.1.5 Wharf Creek

As shown on **Figure 37**, the drainage area of Wharf Creek is about 0.10 square miles. Wharf Creek flows southeastward from its 400 foot-high headwaters in the Punta de los Reyes Ridge toward the base of its hills where it is diverted into an inboard road ditch along Olema Bolinas Road, disconnecting it from its fan and buried culvert (under Olema Bolinas Road). At the point where the creek meets the roadside ditch, flow (along with an abundance of sand) is carried northward toward the inlet of the Lewis Gulch Creek box culvert. At the outlet of the box culvert, flow and sediment from both Lewis Gulch and Wharf Creeks is transported eastward in a 250 feet-long ditch toward Bolinas Lagoon. Both the inboard ditch along the road and the one on the outboard side of Olema Bolinas Road (for a distance of 275 feet) are periodically dredged by Marin County Department of Public Works in an attempt to maintain channel capacity. Details on the frequency of desilting and quantities of sediment removal were unobtainable from Marin County.

4.3.2 Geomorphology

This section provides a detailed description of the geomorphology of Wilkins Gulch Creek, Lewis Gulch Creek, Salt Creek, and Wharf Creek based on observations made during the field surveys and the background research conducted on each of the drainages. As discussed in Section 3 – Methods, each stream was divided into reaches for the purposes of characterizing the geomorphology. Those reaches are labeled on **Figures 34 through 37** and referenced here.

The study area streams are in various evolutionary stages of downcutting, aggrading, and widening as the channels adjust to current and legacy land use impacts in their watersheds. Spatial and temporal variations on these evolutionary stages exist throughout the study area, particularly because the streams have artificially altered supplies of sediment and woody debris. As described in Section 3 – Methods, the Rosgen System of stream classification was applied to each cross section surveyed; however, the degree of variation in the channel shape greatly affects the designated type assigned to that particular cross section. In general, most reaches reflect the characteristics of certain stream types. The incised channels of Wilkins Gulch and Lewis Gulch Creeks that have down-cut through the alluvial fans and have actively eroding banks are more typical of unstable G- and F-type channels. Within the reaches, there may be some very short stretches of the channel where bar deposits are forming new inner bench floodplains and thus a B- or C-type channel is potentially developing within the F-type channel. B-type channels are a moderately entrenched form often found in canyons or confined reaches with steep gradients of 2 to 10 percent. This form can be found in just a few sites along the alluvial fan reaches and more commonly in the narrow, less-steep canyons of Wilkins Gulch and Lewis Gulch Creeks. C-type streams are slightly entrenched channels with moderate to high sinuosity and alternating depositional bars. A-type channels commonly are step-pools or cascades found mostly upstream of the study area where the stream gradient is 4 percent or greater. The steep canyon of Wilkins Gulch Creek or the small ephemeral, headwater tributaries to the mainstem creeks are A-type streams.

4.3.2.1 Wilkins Gulch Creek

Most of the field survey of Wilkins Gulch Creek was performed on the alluvial fan upstream of SR 1. During May of the 2015 drought year, the creek was essentially dry from a few hundred feet downstream of the head of the fan to the downstream willow grove. Continuous flow was observed from two tributaries flowing into the upper extent of the survey area. The survey extended 250 feet upstream of the head of the fan, where the channel was confined with a narrow canyon and had abundant exposed bedrock in its bed and banks (A4/A1–B4/B1-type channel). **See Figure 34** for additional details.

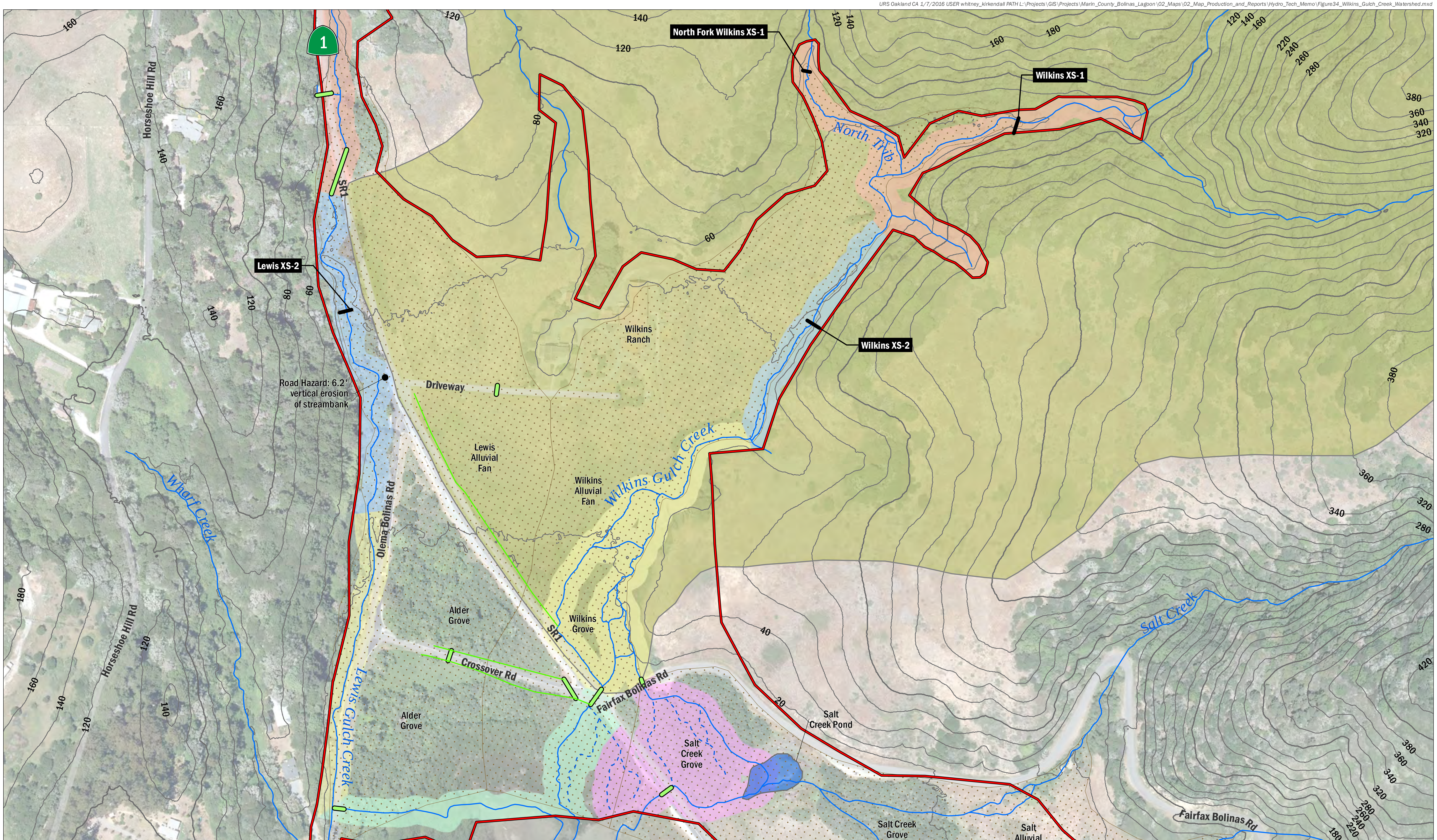
Landsliding was observed on the eastern slope of Wilkins Gulch Creek along much of the length of the alluvial fan. Earthflows and slumps are the predominant mechanism of sliding, triggered naturally by earthquakes, fire, and steep conditions, but accelerated by legacy land use activities (logging, grazing, northern tributary flow diversion, and possible ditching of Wilkins Gulch Creek to the eastern side of its valley to increase farmable land).

Reach 1

Reach 1 of Wilkins Gulch Creek extends 800 feet from the apex of the fan to the confluence with the Northern Tributary. In general, this reach is characterized by alternating periods of incision and the deposition associated with debris flow deposition and large woody debris. The channel indicates that lateral migration is causing areas of bank erosion. Most of the reach is indicative of a B4-type stream channel.

Feet 0 65 130 260 1 in=225 ft

URS Oakland CA 1/7/2016 USER whitney_kirkendall PATH L:\Projects\GIS\Projects\Marin_County_Bolinas_Lagoon\02_Maps\02_Map_Production_and_Reports\Hydro_Tech_Memo\Figure34_Wilkins_Gulch_Creek_Watershed.mxd



AECOM

Marin County

Bolinas Lagoon Restoration

Study Area	Cross Section
20ft Contour	Culvert
Roadside Drainage Ditch	Alluvial Fan
Stream	
Estimated/Undefined Stream Course	

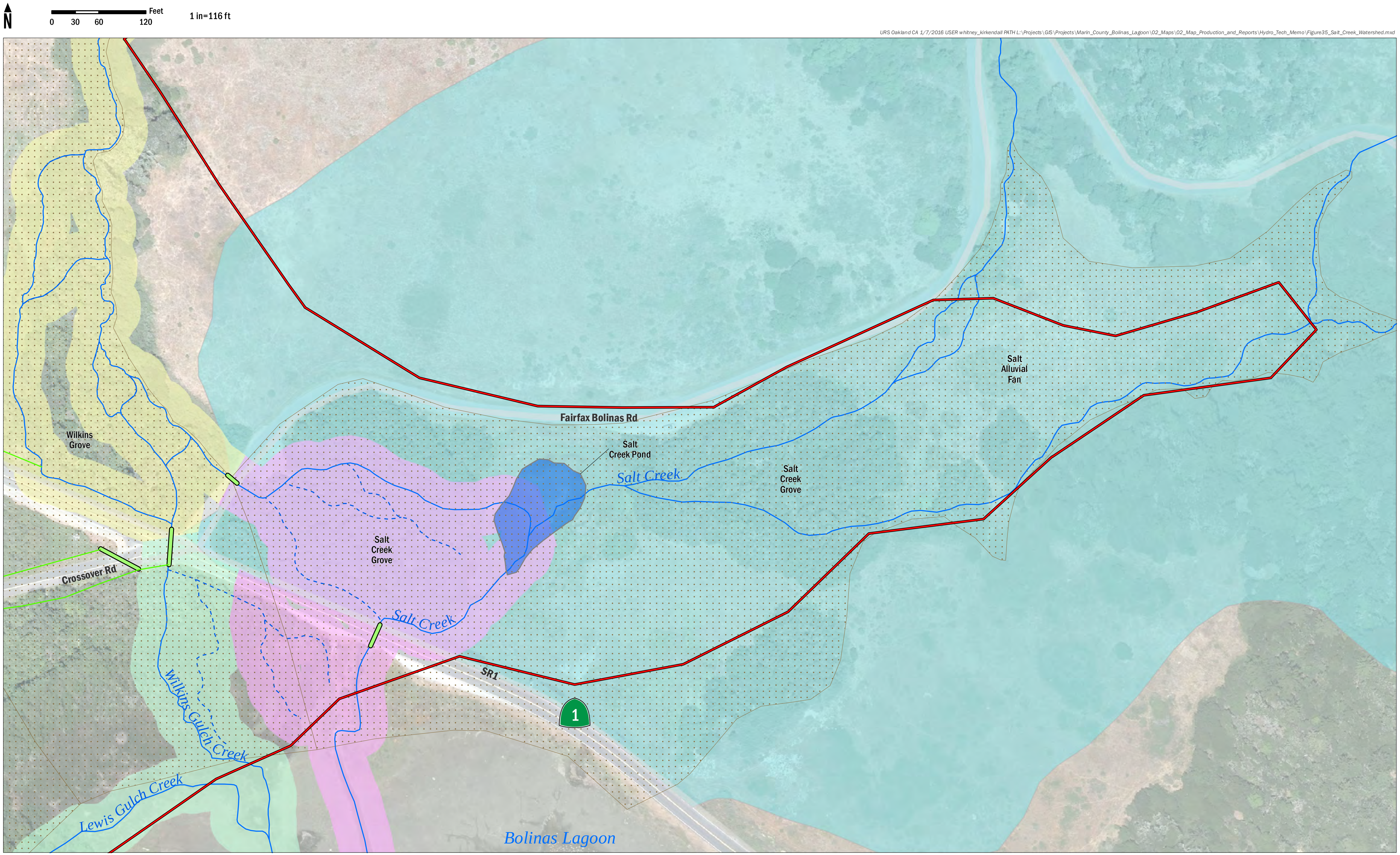
Reach: Reach 1, Reach 2, Reach 3, Reach 4A, Reach 4B

Watershed: Wilkins Gulch Creek (0.68 sq mi)

Data Sources:
1. Contours, ARRA Golden Gate LiDAR, USGS, 2010
2. Streams, Watersheds, AECOM, 2015

FIGURE 34

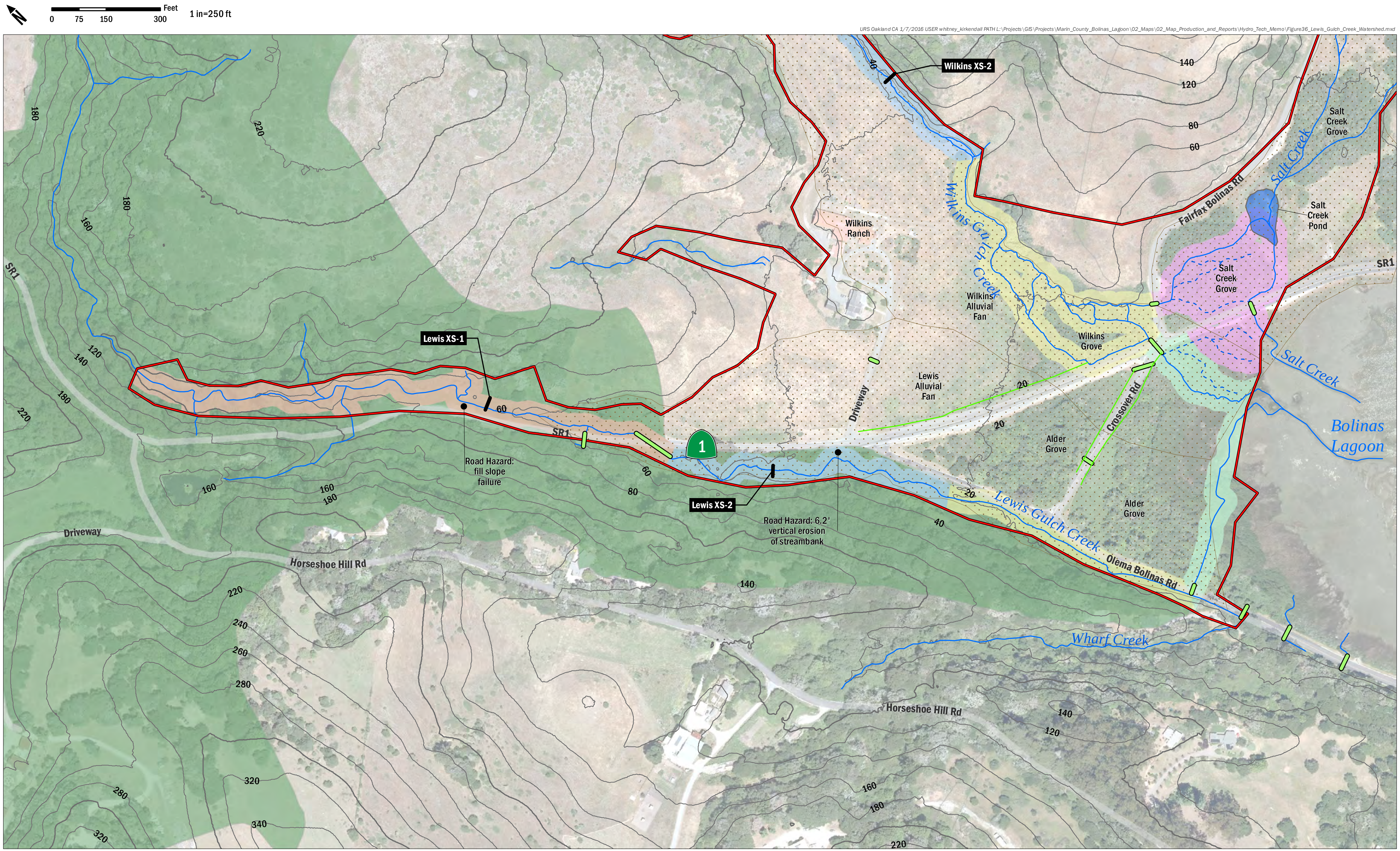
Wilkins Gulch Creek Watershed



AECOM
Marin County
Bolinas Lagoon Restoration

Data Sources:
1. Contours, ARRA Golden Gate LiDAR, USGS, 2010
2. Streams, Watersheds, AECOM, 2015

FIGURE 35
Salt Creek Watershed

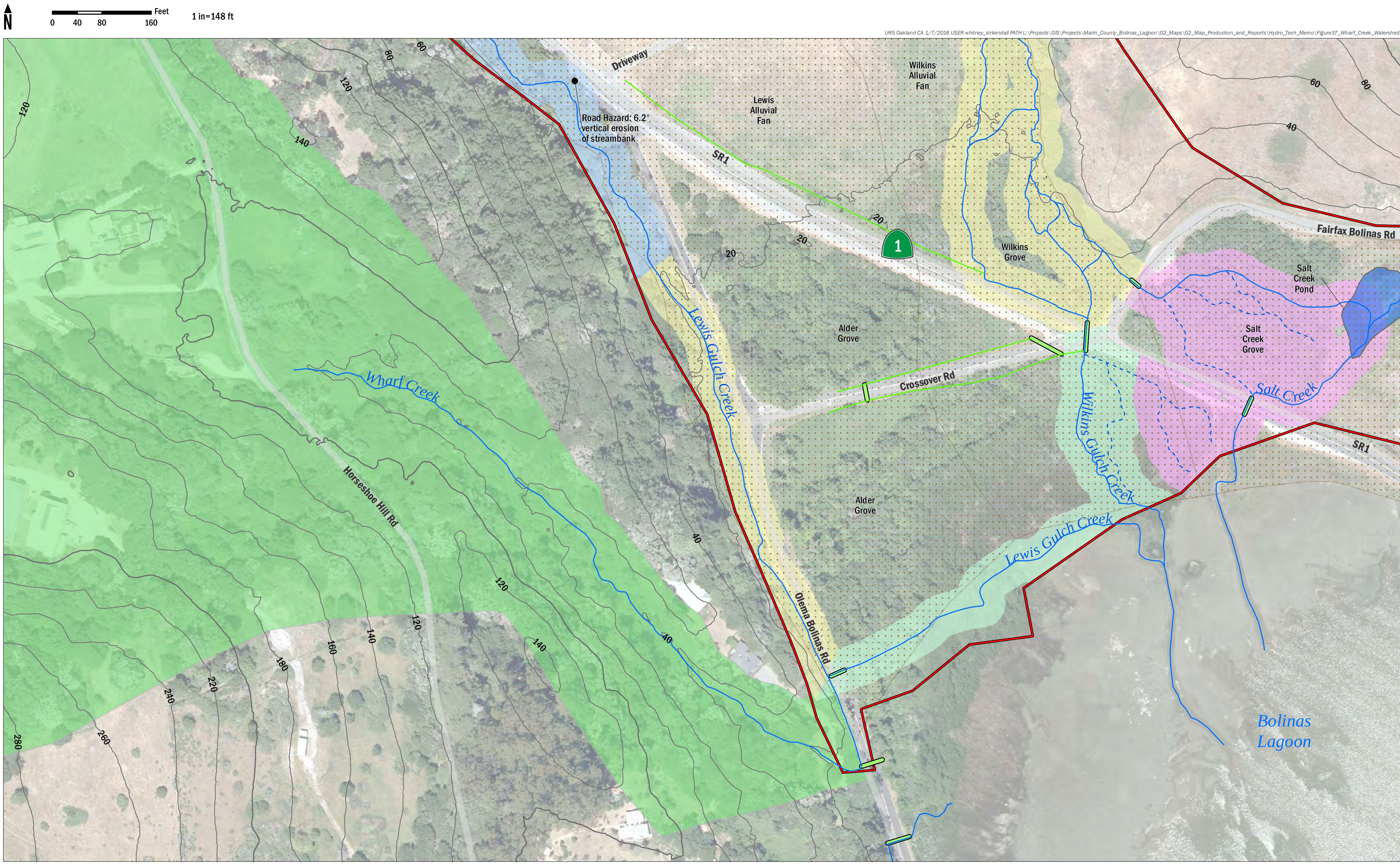


AECOM
Marin County
Bolinas Lagoon Restoration

Study Area
20ft Contour
Roadside Drainage Ditch
Stream
Estimated/Undefined Stream Course
Cross Section
Culvert
Alluvial Fan
Reach
Reach 1
Reach 2
Reach 3
Reach 4A
Reach 4B
Watershed
Lewis Gulch Creek (0.62 sq mi)

Data Sources:
1. Contours, ARRA Golden Gate LiDAR, USGS, 2010
2. Streams, Watersheds, AECOM, 2015

FIGURE 36
Lewis Gulch Creek Watershed



AECOM

Marin County

Bolinas Lagoon Restoration

Study Area

20ft Contour

Roadside Drainage Ditch

Stream

Estimated/Undefined Stream Course

Cross Section

Culvert

Alluvial Fan

Reach

Reach 1

Reach 2

Reach 3

Reach 4A

Reach 4B

Watershed

Wharf Creek (0.08 sq mi)

Data Sources:
1. Contours, ARRA Golden Gate LiDAR, USGS, 2010
2. Streams, Watersheds, AECOM, 2015

FIGURE 37

Wharf Creek Watershed

The width of the valley at the lower end is about 200 feet, where there is a confluence from an eastern tributary. Wilkins Gulch Creek is incised within its older alluvial deposits. This fan is not an active alluvial fan because of the channel incision. At the fan head, the survey team noted evidence of debris flow run-out deposition. Sediment sizes ranged from clay- to boulder-sized (256 inches in diameter). About 1 cubic foot per second (cfs) of flow was observed in the very upper part of this reach. About 325 feet downstream of the apex, the creek became dry. Channel braiding, as evidenced by mid-channel bars, was apparent within the upper area of episodic debris flow deposition within the incised channel (D3-type channel). Similar braiding conditions were observed near the small downstream eastern tributary confluence where the sediment size ranged up to large cobble (D4-type channel).

Two tributaries enter this reach, including the northern tributary (identified on **Figure 34**) and the eastern tributary. The northern tributaries flow was diverted into a ditch that has filled with sediment (see **Figure 38)**. A berm at the western downslope edge of the ditch was created to separate the flow in the ditch from the alluvial fan. Diversion of flow from the northern tributary into Wilkins Gulch Creek probably occurred very early in the history of the ranch, perhaps in the 1880s, but certainly before 1943, as indicated by the aerial photos. As a result of the diversion, Wilkins Gulch Creek adjusted its channel geometry to accommodate increased flow and sediment load by incising and/or widening its channel. Presently, the diversion ditch is on the verge of abandoning its artificial confluence and flowing down onto the fan, where any flow will likely infiltrate into the fan (probably what the drainage did historically). There is some evidence that the ditch was maintained by sediment removal while the ranch was operable. The eastern tributary has a 10- to 11-foot-deep actively eroding head cut that has eroded approximately 40 to 50 feet from the confluence with Wilkins Gulch Creek (G-type channel). A smaller head cut is present near the headwaters of the same drainage. These features are shown on **Figure 39**. Erosion here has deposited a significant volume of bedload to the main stem of Wilkins Gulch Creek.

Figure 38. North Tributary to Wilkins Gulch Creek

Figure 39. Gully Erosion in a Tributary to Wilkins Gulch Creek

Reach 2

Reach 2 of Wilkins Gulch Creek extends about 675 feet from Reach 1 to the upper extent of the willow grove that coincides with a very small eastern tributary. Valley width at the lower end is about 425 feet. The F-type channel is incised within its alluvial fan, and there is no evidence of flooding onto the fan since the mid-1950s. There is possible evidence of constructed berms along the lower end of the reach to prevent flooding onto the pastureland upstream of the barn. The upper half of this reach appears to have the capacity to transport most of its sediment load to the middle reach. The lower half appears to be aggrading, losing much of its flow to subsurface recharge of the fan, as indicated by the much smaller width and depth of the channel and because during the time of the field survey the entire reach was dry.

An effort was made to determine whether the creek through this reach is in its historical and natural position on the fan. The conclusion was that the stream has most likely moved against the hillside to maximize agricultural land use, but this conclusion cannot be relied on without further investigation. Most of the riparian vegetation growing on the western banks was probably cleared along the lower reach and perhaps along the upper reach. **Figure 22** shows a photo of the Wilkins Ranch during the 1880s. In the photo, Wilkins Gulch Creek appears to be unnatural, perhaps a ditch, and certainly has been cleared of any riparian vegetation. Today, this area is overgrown by willows.

Throughout Reach 2, channel width and depth varies from bend to bend. A number of inactive to active landslides that range in size from small inner gorge slumps to earthflows extending at least 200 feet upslope. The inner gorges of the eastern hillsides along the creek are supplying an abundant amount of sediment through raindrop impact erosion, raveling (the gravitational downhill movement of sediment—rolling or bouncing, for example—without the addition of water), and sliding; sediment supply from bank erosion fluvial processes is relatively minor.

Various land practices that have occurred along this reach cannot be fully explained. For example, the middle of Reach 2 has an approximately 100-foot-long berm along its western side, and an abundance of debris (e.g., lumber, pipes, household trash) lines the creek banks in some areas. For example, it is not known if this berm was built to prevent floods from spreading out of the channel, if it was created by excavating the channel as a diversion, if it was created by plowing and clearing the field for pasturage or if it was constructed for some other reason.

Reach 3

Reach 3 of Wilkins Gulch Creek extends about 875 feet to the SR 1 culvert. This reach is characterized by emerging groundwater in the upper portion of the reach and aggradation in the middle to lower portions of the reach within the willow grove. Throughout the entire willow thicket, the channel mode appears to be aggrading, and there are many smaller subsidiary distributaries. Historically, this area was shown to support large trees, possibly an oak savanna.

The creek divides into three main distributaries off of the main channel along the middle to lower end of the reach. These distributaries likely formed as the channelized portion of the stream (against the toe of the hillslope) filled with up with bedload. The middle and eastern distributaries currently carry most of the flow. The eastern distributary and ditched channel against the toe of the hillslope appear to transport most of the sediment from Wilkins Gulch Creek, whereas the western distributary seems to carry groundwater from the western side of the valley flat. The area where the middle and eastern distributaries flow into a 7-foot-wide by 4-foot-high box culvert coincides with the approximate position of the 1854 upland boundary of the tidal marsh. The channel slope into the box culvert appears to be relatively steep compared to the average slope further up the drainages. The outlet of the culvert does not appear to have much if any positive drainage towards the lagoon. A well-defined channel leading through the thick wetland vegetation was not found. As a result the box culvert remains submerged in ponded water and sediment. Periodic attempts to improve drainage by excavating the inlet and outlet of sediment are apparent. It appears that wetland vegetation keeps growing through the deposited sediment blocking flow through the culvert.

The eastern ditched channel may have been channelized to carry sediment and water from Wilkins Gulch Creek to the Salt Creek tidal embayment for one or multiple possible reasons including to possibly fill in the cutoff tidal bay, drain and remove surface water from the Wilkins lower alluvial fan to easily cultivate the land, to provide freshwater to the pond for cattle, and or to drain the creek to the only road culvert located at Salt Creek. The constructed channel was placed at a higher elevation than the valley floor between the base of the hillslope and a fence line that cuts through the willow grove from east to west. The channel appears to be nearly full of sand to gravel sized sediment, thus the formation of more distributaries is likely in the future. This segment of the reach ends at Bolinas Fairfax Road where the channel flows through an 8-foot wide by approximately 2.5-foot tall open grated box culvert that serves as a cattle guard.

Reach 4

Reach 4 comprises two separate stream segments of Wilkins Gulch Creek. The first (western) segment (4A) flows from a concrete box culvert under SR 1 through a thicket of willows toward the lagoon. Reach 4A does not appear to have any one defined flow path toward the lagoon. A shallow drainage swale was present alongside SR 1 with standing water, but flow exiting the culvert appears to fan out into the thick wetland vegetation and willows facing the lagoon. Opposite the willow thicket (on the lagoon side), a small tidal channel was mapped leading from the direction of the culvert toward a larger tidal channel that drains Lewis Gulch Creek.

The second (eastern) segment (4B), which flows from the cattle guard/box culvert under Bolinas Fairfax Road to the Salt Creek Pond, has been ditched to run northwest along a pullout adjacent to a pond before leading into the Salt Creek willow grove. It is uncertain if there are any other distributary channels within the willow grove that may route water around the periphery of the pond to the culvert on SR 1. It then drains through a concrete box culvert under SR 1 to the Bolinas Lagoon. The inlet and outlet of the SR 1 culvert on Salt Creek is known to be periodically dredged a short distance from the road because it is prone to filling with sediment.

4.3.2.2 Salt Creek

Salt Creek has three main ephemeral drainages that convene on an active alluvial fan, as shown on **Figure 35**. Small channels carry flow across the fan surface to Salt Creek Pond when the soil is sufficiently saturated or when runoff is great enough to overcome the infiltration capacity of the porous soils of the fan. For the channels at the eastern side of the fan, recent channel flow was evident at the time of the field survey. Flow from the northern-most tributary appeared to flow approximately 450 feet downstream from the head of the fan into the Salt Creek willow grove upstream of the pond. It appears that all the sediment conveyed from the headwaters of Salt Creek is distributed on the fan surface before reaching the pond. The channels form naturally across the surface of the alluvial fan. Across the alluvial fan, most surface flow in the upper, steeper portion converts to groundwater and then reemerges near the willows and pond. Water from Salt Creek merges with residual flow from Wilkins Gulch Creek at the pond before flowing through a box culvert under SR 1 (4 feet high by 10 feet wide by 24 feet long).

The Salt Creek pond occurs at an elevation equivalent to the mean higher-high water (MHHW) tidal elevation (5.6 feet). The pond receives tidal water when tide levels are high enough to overcome the elevation difference that separates the pond from the excavated channel on either side of the SR 1 culvert. Sediment deposition from the incoming higher-high tides accumulates in the channel. As a result, pond salinity levels fluctuate with diurnal and seasonal tidal influences. Salinity levels increase in the pond when the box culvert has been cleared out and higher-high tides bring in an influx of saltwater. Salinity levels decrease when seasonal groundwater levels are higher (such as in the winter and spring), when subsurface streamflow moving through the alluvial fan resurfaces near the willow grove, filling the pond with freshwater. Salinity levels likely increase when the water table decreases, lowering the pond level and increasing the concentration of salts. During the biological field assessments conducted in April 2015 (see the Biological and Cultural Resources Technical Memorandum prepared for this project), the salinity of the pond was 7 parts per thousand). No groundwater emergence was observed and tidal inflow did not appear to have occurred in recent months.

4.3.2.3 Lewis Gulch Creek

The field survey of Lewis Gulch Creek extended from the Bolinas Lagoon to approximately 1,300 feet upstream of the culvert crossing under SR 1. **Figure 36** shows the stream, the reaches, and other relevant details. The SR 1 culvert crossing is near the head of the inactive alluvial fan. The culvert under SR 1 consists of a 100-foot-long by 58-inch diameter corrugated metal pipe with a paved invert (lined with cement-based slurry). The length of the assessed creek is divided and described as four reaches.

Reach 1

Reach 1 comprises the upper 1,300 feet of stream down to the SR 1 culvert. Two small ephemeral tributaries enter the reach from the west-facing slope. A confined valley bottom characterizes the reach, which is mostly a B4-type channel. The lower half of the reach is further confined by SR 1 road fill placed in the valley bottom. During the field survey, the upper half of the reach was flowing while most of the lower half was dry to intermittently flowing. Bedrock was observed in the channel bottom in the upper portion of the reach. Numerous low terraces are present along the stream and represent prior large flood/depositional events, such as the large storms of 1982/83 and 1997. Two higher terraces in the upper section of the reach (3 to 7 feet above the channel bed) may have been deposited following a woody debris jam that blocked the channel. A small partial debris jam was seen in the streambed near the downstream location of the terraces. There are few locations where a small floodplain exists, as indicated by more recent sand deposition on the floodplain.

Sediment sources along the reach appear to be predominantly from landslide slumps and bank erosion of older terrace deposits. At least three slumps were observed along the left bank (looking downstream). Most of the slumps extend 10 feet up the slope and 15 to 20 feet along the stream bank. The stream appears to be actively eroding the toe of the west-facing hillslope on the meander bends, thus leading to small slope failures. At the upper extent of the reach, three gullies run down the hillslope from the highway to the creek. Two appear to be older and no longer flow. The third appears to convey runoff from SR 1 and possibly Horseshoe Hill Road. One of the gullies has been filled with riprap. There is one location where the creek meanders from the east side of the valley to the west side, where bank erosion is compromising a portion of SR 1 road fill that has a scarp in the bank next to the road. **Figure 36** identifies the road hazard.

Given the confined state of the valley, this reach will likely continue to transport most of its gravel-sized sediment to downstream areas.

Reach 2

Reach 2 extends approximately 860 feet downstream of the SR 1 crossing from the approximate apex or head of the alluvial fan. At the time of the field survey, streamflow was present from the culvert half way down the reach where it became intermittent and dry by the end of the reach. The reach follows along the USGS-mapped San Andreas Fault trace shown on several figures in Section 4.1 of this memo. This reach has broader alluvial terraces than Reach 1 because the valley is less. In a couple of locations, relic primary or secondary channels were observed on the terrace surface between SR 1 and the channel. The elevation and orientation of the channels suggests that the channels may have been connected to relic channels on the alluvial fan east of SR 1. Several factors may have caused channel incision into the alluvial fan, including valley flood flow constriction, earthquake down-dropping, and channel manipulation. As a result, the reach seems to largely serve as a sediment transport reach, conveying gravel-sized rock to Reach 3. Much of the channel length appears to be a B4- to F4-type channel. Channel alteration may have occurred along a 50-foot-long segment of stream downstream of Lewis Gulch Creek Cross Section 2, where the channel appeared unusually straight and box shaped (G4 stream type), as if it was excavated to direct the creek away from the left bank terrace (**Figure 40**). Historical research suggests that the stream may have been redirected in locations where structures or other infrastructure was built along the northwest bank of the stream.

Sediment input in the reach is largely from bank erosion of the terraces at a of couple locations where the channel meanders against the hillslope and roadway. Midway in the reach, the channel has meandered laterally to the point where the 6-foot-high eroded stream bank is within 5 feet of the edge of the SR 1 pavement. It is identified as a road hazard on **Figure 36.**

Figure 40. Section of Lewis Gulch Creek near Cross Section 2

Reach 3

Reach 3 runs approximately 750 feet along Olema Bolinas Road to the culvert leading to the lagoon. The stream has been channelized and straightened to a narrow area between the road and the adjacent hillslope to the west (**Figure 41**). This reach is mostly an F4/G4-type channel. Because the channel lacks the competence and capacity to carry the bedload, the reach is prone to aggradation. Marin County Public Works periodically dredges accumulated sediment in this reach as it fills the channel and begins to more frequently flood the roadway. It is believed that much of the larger gravel transported downstream is deposited in this reach. This reach lacks mature riparian vegetation unlike the other reaches, partially due to the frequent stream clearing following storm damage. At the time of the field survey, streamflow was not visibly present until shortly before the culvert inlet.

Figure 41. Aggradation of Stream along Olema Bolinas Road

Reach 4

Reach 4 extends from the concrete box culvert under the Olema Bolinas Road to the delta in the Bolinas Lagoon, approximately 590 feet downstream. The concrete box culvert (5 feet wide by 4 feet high by 25 feet long) was 50 to 60 percent filled with mostly sand-sized sediment at the time of field survey. Most of the length of the stream in the reach has been channelized to convey flow across the lower alluvial fan toward the center of the fan (F/G-type stream). Marin County Public Works periodically dredges accumulated sediment 250 feet downstream of the Olema Bolinas Road. A gate and access road on the right bank (looking downstream) provides equipment access to clear the channel. Sediment appears to have been excavated out of the channel and placed on the lagoon side of the access road, creating a levee berm that is visible in the LiDAR imagery (**Figure 14**). The actively maintained portion of the channel stops at a sharp jog in the creek where a deep pool exists. Not many deep pools are present along Lewis Gulch Creek. Bed sediment in this reach consists mostly of small gravel and a high percentage of sand and silt. Much of the recent sand deposition appears to be coming from Wharf Creek roadside ditch. The ditch was observed to have an abundant amount of sand on the streambed.

Most of Reach 4 runs through a mature alder grove before exiting into a tidal marsh area. The channel is a typical tidal channel that is narrow and deep with near vertical banks. Small gravel was present in the lower portion of the reach, indicating that a significant amount of bedload transport to the lagoon is actively occurring. Larger-than-expected gravel in the lower reach and a largely incised and/or entrenched channel seem to indicate the lack of capacity of Lewis Gulch Creek to process, distribute, and store the current bedload discharge. A small levee that is less than 1 foot high was present along the lower segment of the reach in the tidal marsh; it was not determined whether the levee was naturally formed or a relic disposal berm from former dredging.

4.3.2.4 Wharf Creek

Wharf Creek was not observed during the May field survey because its influence on the Study area is small compared to that of the other watersheds (see **Figure 37**), and because time and access were limited. Hence, the source of the sediment observed along the roadside ditch that deposits in lower Lewis Gulch Creek was not determined. An abundance of sand was observed in the Lewis Gulch Creek box culvert at the time of the reconnaissance. Much of it seemed to be coming from Wharf Creek because there was a predominance of similar sized sand in the roadside ditch and along the opposite side of the road where water flowed over the road.

The channel upstream of Olema Bolinas Road might be incised. It is confined within a relatively narrow and steep valley. USGS mapping shown in Section 4.1 of this memorandum indicates that Wharf Creek parallels two ridgeline faults. Unlike the other creeks in the Study area, Wharf Creek does not have an extensive alluvial fan. What little alluvial fan the creek may have had has been disturbed by construction of Olema Bolinas Road. A nonfunctional buried culvert (likely a 14-inch corrugated metal pipe similar to other nearby culverts) under Olema Bolinas Road once conveyed flow to the lagoon. A small man-made ditch is evident leading from the former culvert outlet across the delta. The culvert is also undersized and cannot convey the flow and sediment load of the stream. Rather than replace or continually clean the culvert, the creek was redirected to flow northward to Lewis Gulch Creek. During small to large storms, water and sediment have difficulty making the abrupt, 90-degree turn at the roadside ditch. As a result, water and sediment overflow the roadside ditch and flow across and down the road.

4.4 Cross Sections and Bankfull Geometry

As discussed in Section 3 – Methods, a primary objective of the project is to determine the bankfull discharge and hydraulic geometry of Wilkins Gulch and Lewis Gulch Creeks, which are the largest drainages that influence flooding in the study area. (Modeling of stream sediment discharge rates from surveyed cross sections is a more involved analysis that was not conducted as a part of this task.) Photographs and the accompanying plots of cross sections, longitudinal profiles, and pebble counts surveyed in Wilkins Gulch Creek, Lewis Gulch Creek, and North Tributary to Wilkins Gulch Creek are provided in **Appendix C**.

Bankfull hydraulic geometry is needed for stream restoration designs. Having good estimates of bankfull discharge at the head and toe of the fans will be important for designing and constructing stable channels. Channels constructed with appropriate bankfull geometry and capacity for a given location in the study area will be more likely to adequately carry the stream bedload discharge without problems of aggradation or degradation, as currently occurs in stream reaches in the study area. This use of appropriate bankfull geometry and capacity is particularly important when designing channels through road culverts. Successful integration of a bankfull channel through culvert structures would reduce or potentially avoid future costs of dredging sediment or adding scour protection at the inlet or outlet of the structure. The outlets must be high enough and sufficiently sized that they will not have reverse flow from the lagoon during tidal surges or king tide conditions that create longer periods of backwater flooding and sediment deposition. Bankfull discharge near the head of the fans will be useful in determining the channel dimensions necessary to transition the existing stream to a newly realigned segment or back to the top of the alluvial fan surface. Bankfull flows are used to determine the appropriate rock size or channel roughness necessary to maintain the appropriate bankfull geometry. Bankfull discharge is also necessary in determining any potential fish passage issues.

Channels with broad floodplains that are greater than 2.2 times their bankfull width tend to have the most stable form. Channel stability is defined as a channel that transports its water and sediment while maintaining its cross-sectional area without aggrading or degrading under a given climatic regime. The more entrenched a channel is, the more unstable it is. Channels that are deeply incised into their valley flats or alluvial fans can significantly lower the water table and cause an increase in bank erosion through the loss of riparian vegetation that helps stabilize the stream bank

4.4.1 Wilkins Gulch Creek and North Tributary of Wilkins Gulch Creek

Table 4 shows the field measurements taken at Wilkins Gulch Creek and North Tributary cross sections. These measurements include drainage area, hydraulic geometry, stream gradient, Rosgen Stream type, and sediment size class of the surface streambed for 50 percent and 84 percent of the count. Cross Section 1 at the head of the fan has a drainage area that is about 0.05 mi^2 smaller than Cross Section 2, yet its discharge (46.8 cfs) is nearly 40 percent larger than the discharge downstream (28.3 cfs).

The difference between the two cross sections verifies that a significant amount of flow recharges the groundwater in the fan between the two sections, which are roughly 675 feet apart. The upper cross section is a moderately entrenched B4a channel dominated by gravel-sized sediment, where 50 percent of the bed material (D50) is finer than 35 mm (medium gravel) and 84 percent (D84) is finer than 170 mm (large cobble). The channel gradient at Cross Section 1 (0.0430) is about 2.5 times steeper compared to Cross Section 2 (0.0167).

The smaller channel at Cross Section 2 is an entrenched F4 stream type influenced by gravel and smaller cobble. The streambed is overly wide compared to its floodprone width. From the observations made during the field survey, the site appears to have undergone sequential periods of incision, followed by excessive bank erosion and subsequent sediment deposition. This sequence is probably due to the over-widened condition but also to the waning discharge that seems to continue, as indicated by smaller cross-sectional area downstream. The survey team’s hypothesis of what started the initial channel incision is that some portion of Wilkins Gulch Creek was diverted into a man-made ditch at the side of the alluvial fan. The ditch was probably not sized appropriately and a head cut propagated upstream into naturally formed reaches.

At the head of its alluvial fan, North Tributary of Wilkins Gulch Creek is a steep, gravel-cobble-dominated, step-pool channel with a gradient greater than 6 percent. It is classified as an A4 stream type. It has a small drainage area of about 0.02 square mile and a bankfull discharge of 5.1 cfs. An unknown amount of this flow makes it across the diversion ditch to Wilkins Gulch Creek. Historically, this channel was probably not connected to Wilkins Gulch Creek but flowed onto the alluvial fan, where most of the flow infiltrated into the ground.

4.4.2 Lewis Gulch Creek

Cross Section 1 of Lewis Gulch Creek is approximately 425 feet upstream of the head of the alluvial fan and has a drainage area of about 0.59 mi^2. This drainage area is slightly larger than that of Wilkins Gulch Cross Section 1, yet its bankfull discharge is 45.3 cfs, about 1.5 cfs less. These bankfull discharges seem reasonably similar; however, Lewis Gulch Creek might be slightly less because its flow may be lost to the narrow alluvial valley in the canyon and/or to fractured and faulted bedrock along the stream course. The stream gradient of 0.031 at Lewis Gulch Creek is about half that of Cross Section 1 at Wilkins Gulch Creek, but its D50 and D84 streambed are a bit coarser: 58 mm and 130 mm, respectively. The hydraulic geometry of Lewis Gulch Creek is shown in **Table 5**. The stream classifies as either C4b with an unusually low W/D ratio or an E4b with very low sinuosity. This site might have been backwater sedimentation behind a blockage from a past large debris jam or landslide. This site was one of the few areas where there was sufficient floodprone width along the canyon to create relatively stable channel geometry.

Lewis Gulch Creek Cross Section 2 has a slightly larger drainage area than Cross Section 1, yet bankfull discharge is 56 percent smaller. The stream gradient of 0.0187 is flatter than the upstream cross section (roughly half as steep), but the streambed surface is nearly the same, having a D50 and D84 of 59 mm and 110 mm, respectively. The G4c stream type indicates that the channel is entrenched and unstable, probably actively incising its streambed. The incision is probably related to maintenance practices of digging out the sediment along the inboard ditch of Olema Bolinas Road. If sediment removal did not continue, the channel on the lower alluvial fan toe would continue to aggrade. If it was not in a ditch and flowing freely on the toe of the fan, it would likely become braided and form multiple D-type channels transitioning from the willow/alder grove to tidal delta. In its existing state, the channel incision is dewatering the alluvial fan, which contributes to flooding, loss of summer flow, and to diminished diversity and habitat on the fan surface. Additional hydraulic parameters for each cross section are shown in **Table 6**.

Table 4. Wilkins Gulch Creek and North Tributary Hydraulic Geometry[1]

	Drainage Area (mi^2)	Bankfull Discharge (cfs)	Bankfull Cross Sectional Area (ft^2)	Bankfull Width (ft)	Bankfull Depth (ft)	Velocity (ft/s)	Stream Gradient	Sediment Size D50/ D84 (mm)	Rosgen channel type based on modified W/D threshold ratio of 10 +/-3 [2]
North Trib. of Wilkins Gulch Cr. Xsec 1 head of alluvial fan	0.02	5.1	2.5	3.9	0.6	2.0	0.0689	51/ 96	A4
Wilkins Gulch Cr Xsec 1 at head of fan	0.56	46.8	11.5	15.1	0.8	4.1	0.0430	35/120	B4a
Wilkins Gulch Cr Xsec 2 middle fan	0.61	28.3	8.7	13.2	0.7	3.2	0.0167	43/75	F4

Notes:

1) Unless noted in the column headers, data in the table above was measured or calculated from the 2015 field surveys performed for this project by Collins and Pearson.
2) The Rosgen channel types have a modified W/D threshold ratio of 10 +/-3 based on personal communication with D. Rosgen.

Table 5. Lewis Gulch Creek Hydraulic Geometry[1]

	Drainage Area (mi^2)	Bankfull Discharge (Q) (cfs)	Bankfull Cross Sectional (A) (ft^2)	Bankfull Width (s) (ft)	Bankfull Depth (d) (ft)	Velocity (u) (ft/s)	Stream Gradient	Sediment Size D50/ D84 (mm)	Rosgen channel type based on modified W/D threshold ratio of 10 +/-3 2
Lewis Gulch Cr Xsec 1 in canyon	0.59	45.3	9.1	8.0	1.1	5.0	0.0310	58/ 130	C4b or E4b
Lewis Gulch Cr Xsec 2 at middle of fan	0.61	25.2	6.7	7.0	1.0	3.7	0.0187	59/ 110	G4c

Notes:
1) Unless noted in the column headers, data in the table above was measured or calculated from the 2015 field surveys performed for this project by Collins and Pearson.
2) The Rosgen channel types are based on modified W/D threshold ratio of 10 +/-3 per a personal communication with D. Rosgen.

Table 6. Bankfull Hydraulic Parameters of Cross Sections in Wilkins Gulch Creek and Lewis Gulch Creek

	Width Flood-prone Area (A) (ft)	Entrench-ment Ratio	W/D Ratio	Manning's n, calculated from Mecklenberg (2006) or estimated from Rosgen (2009)	Wetted Perimeter (P) (ft)	R (Hydraulic Radius calculated from Mecklenberg (2006) (A/P) (ft)	Threshold GrainSize [1] calculated from Mecklen-berg(2006) (mm)[1]	Resistance Factor calculated from Mecklen-berg (2006) U/U*	Relative Roughness calculated from Mecklen-berg (2006) (~d/D84	Shear Velocity calculated from Mecklen-berg (2006) ft/s)
North Trib. of Wilkins Gulch Cr. Xsec 1 head of alluvial fan	6.7	1.7	6.1	0.125	4.8	0.5	110	4.4	2.0	1.08
Wilkins Gulch Cr Xsec 1 at head of fan	21.7	1.4	19.8	0.062	15.7	0.7	97	4.8	1.9	1.01
Wilkins Gulch Cr Xsec 2 at middle fan	15.6	1.2	20	0.043	14.0	0.6	32	5.6	2.7	0.58
Lewis Gulch Cr Xsec 1 in canyon	35.2	4.4	7.1	0.052	9.2	1.0	94	5.3	2.6	0.99
Lewis Gulch Cr Xsec 2 at middle of fan	10.1	1.5	7.2	0.048	8.1	0.8	47	5.3	2.7	0.70

Notes:
1) The threshold grain size is the size that is at the threshold of motion at bankfull, which is often similar to D50.

4.4.3 Bankfull Discharge Estimates

The results of the published regional curve analyses are listed in **Tables 7, 8,** and **9**, each of which presents different aspects of the hydraulic geometry of the stream reaches listed in the table. Predictions of bankfull parameters were made for the Salt Creek, Wharf Creek, and Wilkins Gulch and Lewis Gulch Creeks where the creeks meet SR 1 and Olema Bolinas Road (herein referred to as at the head of tide). Predicted bankfull and flood discharge (at the floodprone elevation near the study area) is predicted for the sites for comparative purposes. The Dunne and Leopold regional curve does not reliably predict width, depth, and cross-sectional area for drainage areas less than 0.1 square mile or bankfull discharge for less than 0.2 square mile. Their predictions of width and depth were developed by using the 1.5-year RI of flow for gaged sites around the Bay Area before 1978. Many of the sites had weir or bridge structures that influenced natural channel geometry and some also had an entrenched channel form. Predictions of these parameters for this report use the Collins and Levanthal regional curve developed for Marin and Sonoma Counties (2013) that was developed by surveying bankfull elevation and natural channel dimensions at relatively stable stream sites rather than identifying the 1.5 RI. The average RI interval of bankfull flow for the Marin and Sonoma sites was about 1.2 to 1.3 years.

The location (hydro-physiographic province) and condition (relative channel stability) of the stream from which data was collected to build a regional curve is important to consider for channel design. Use of regional curve data collected from channels altered by human intervention (e.g., grade control structures, channel/floodplain constriction) or following recent channel imbalances (e.g., recent flood induced scour or deposition) may over- or under-predict discharge or hydraulic geometry from that of naturally self-formed channels. As a result, use of such data could result in building a restored channel that is too deep or too wide setting in motion a series of channel adjustments (incision or aggradation) that may reduce the potential for successful restoration.

The field-measured bankfull discharges of Cross Section 1 of North Tributary of Wilkins Gulch Creek, the main stem of Wilkins Gulch Creek, and Lewis Gulch Creek are all greater than the predicted bankfull discharges. This is likely because of the greater mean annual rainfall at the watersheds of Bolinas Ridge compared to the average rainfall for the Collins and Leventhal data set (2013) or the Dunne and Leopold curve for the San Francisco Bay area (1978) with a data set averaging 31 inches of mean annual rainfall. The measured bankfull discharges of Cross Section 2 of Wilkins Gulch and Cross Section 2 on Lewis Gulch Creek were both less than the predicted amounts by roughly 4.7 cfs to 7.3 cfs because the cross sections were in losing reaches of alluvial fans.

The bankfull discharges for all the channels at the head of tide are predicted to be about 37 to 39 cfs for Wilkins Gulch Creek, 32 to 34 cfs for Lewis Gulch Creek, 9 cfs for Salt Creek, and 5 cfs for Wharf Creek. For Wilkins Gulch and Lewis Gulch Creeks, the predictions of discharge at the head of tide are smaller than the measured discharge at the Cross Section 1 sites. If the discharge derived from the cross section at Wilkins Gulch Creek is added to the discharge of North Tributary, the total is 51.9 cfs, which is 12.8 to 13.3 cfs larger than the predicted amount at the head of tide. Lewis Gulch Creek Cross Section 1 is about 11.2 to 11.4 cfs above the average predicted amount at head of tide of the two regional curves. It is not presently known if all the flow that discharges to the heads of the alluvial fans actually re-emerges as surface flow at the toes of the alluvial fans. It is possible that antecedent soil moisture, year-to-year variability in the height of the water table, and diurnal fluctuations of base level play a role in actual bankfull discharge at the upper limit of the tides. The combined total bankfull discharge to the study area from all four streams at the head of tide is predicted to be about 86 cfs.

Table 7. Predictions of Hydraulic Geometry from Regional Curves – Bankfull Discharge and Cross Sectional Area

Location	Drainage Area (mi^2)	Bankfull Discharge, calculated from 2015 field survey (cfs)	Bankfull Discharge from Dunne & Leopold (1978) San Francisco Bay Area Regional Curve (flood frequency analysis curve using 1.5 yr RI) (cfs)	Bankfull Discharge predicted using drainage area from 2013 Collins & Leventhal (2013) Marin & Sonoma Counties (field analysis indicates 1.2-1.3 yr RI) (cfs)	Bankfull Cross Sectional Area, from 2015 field survey (ft^2)	Bankfull Cross Sectional Area from Dunne & Leopold (1978) San Francisco Bay Area Regional Curve (flood frequency analysis curve using 1.5 yr RI) (ft^2)	Bankfull Cross Sectional Area, predicted using drainage area from 2013 Collins & Leventhal (2013) Marin & Sonoma Counties (field analysis indicates 1.2-1.3 yr RI) (ft^2)
North Trib. of Wilkins Gulch Cr. Xsec 1 head of alluvial fan	0.02	5.1	NA	1.1	2.5	NA	0.5
Wilkins Gulch Cr Xsec 1 at head of fan	0.56	46.8	30.9	30.9	11.5	17.0	8.2
Wilkins Gulch Cr Xsec 2 middle fan	0.61	28.3	33.4	33.5	8.7	20.0	8.8
Wilkins Gulch Cr at head of tidal marsh	0.71	NA	38.6	39.1	NA	21.0	10.0
Salt Creek at head of tidal marsh	0.15	NA	NA	8.6	NA	8.5	2.8
Lewis Gulch Cr Xsec 1 in canyon	0.59	45.3	32.4	32.5	9.1	16.0	8.6
Lewis Gulch Cr Xsec 2 at middle of fan	0.61	25.2	33.3	33.4	6.7	18.0	8.8
Lewis Gulch Cr to head of tidal marsh	0.62	NA	33.9	34.1	NA	19.0	8.9
Wharf Cr (before Olema Bolinas Road)	0.08	NA	NA	4.5	NA	4.5	1.6

Note: Unless noted in the column headers, data in the table above was measured or calculated from the 2015 field surveys performed for this project by Collins and Pearson.

Table 8. Predictions of Hydraulic Geometry from Regional Curves – Bankfull Width and Depth

Location	Drainage Area (mi^2)	Bankfull Width, measured during 2015 field survey (Collins & Pearson) (ft)	Bankfull Width from Dunne & Leopold (1978) San Francisco Bay Area Regional Curve (flood frequency analysis curve using 1.5 yr RI) (ft)	Bankfull Width predicted from Collins & Leventhal (2013) Marin & Sonoma Counties (field analysis indicates 1.2-1.3 yr RI) (ft)	Bankfull Depth, measured during 2015 field survey (ft)	Bankfull Depth from Dunne & Leopold (1978) San Francisco Bay Area Regional Curve (flood frequency analysis curve using 1.5 yr RI) (ft)	Bankfull Depth predicted from 2013 Collins & Leventhal (2013) Marin & Sonoma Counties (field analysis indicates 1.2-1.3 yr RI) (ft)
North Trib. of Wilkins Gulch Cr. Xsec 1 head of alluvial fan	0.02	3.9	NA	2.1	0.6	NA	0.2
Wilkins Gulch Cr Xsec 1 at head of fan	0.56	15.1	13.0	9.8	0.8	1.3	0.8
Wilkins Gulch Cr Xsec 2 middle fan	0.61	13.2	14.0	10.2	0.7	1.4	0.8
Wilkins Gulch Cr at head of tidal marsh	0.71	NA	14.5	11.0	NA	1.5	0.9
Salt Creek at head of tidal marsh	0.15	NA	8.5	5.4	NA	1.0	0.5
Lewis Gulch Cr Xsec 1 in canyon	0.59	8.0	13.3	10.1	1.1	1.2	0.8
Lewis Gulch Cr Xsec 2 at middle of fan	0.61	7.0	13.6	10.2	1.0	1.3	0.8
Lewis Gulch Cr to head of tidal marsh	0.62	NA	13.6	10.3	NA	1.4	0.9
Wharf Cr (before Olema Bolinas Road)	0.08	NA	5.7	4.0	NA	0.8	0.4

Note: Unless noted in the column headers, data in the table above was measured or calculated from the 2015 field surveys performed for this project by Collins and Pearson.

Table 9. Predictions of Hydraulic Geometry from Regional Curves – Drainage Area and Bankfull Velocity

Location	Drainage Area (from Google Earth Pro) (mi^2)	Velocity calculated from 2015 field measurements (ft/s)	Velocity, calculated by Q_{bkf}/A from Dunne & Leopold (1978) San Francisco Bay Area Regional Curve (flood frequency analysis curve using 1.5 yr RI) (ft/s)	Velocity, calculated by Q_{bkf}/A from Collins & Leventhal (2013) Marin & Sonoma Counties (field analysis indicates 1.2-1.3 yr RI) (ft/s)	Estimated Discharge at Floodprone Width determined at cross sections from Mecklenberg Spreadsheet (2006) (cfs)
North Trib. of Wilkins Gulch Cr. Xsec 1 head of alluvial fan	0.02	2.0	NA	2.1	18
Wilkins Gulch Cr Xsec 1 at head of fan	0.56	4.1	1.8	3.7	221
Wilkins Gulch Cr Xsec 2 middle fan	0.61	3.2	1.7	3.8	147
Wilkins Gulch Cr at head of tidal marsh	0.71	NA	1.8	4.0	NA
Salt Creek at head of tidal marsh	0.15	NA	NA	3.0	NA
Lewis Gulch Cr Xsec 1 in canyon	0.59	5.0	2.0	3.9	198
Lewis Gulch Cr Xsec 2 at middle of fan	0.61	3.7	1.8	3.9	109
Lewis Gulch Cr to head of tidal marsh	0.62	NA	1.8	3.9	NA
Wharf Cr (before Olema Bolinas Rd)	0.08	NA	NA	2.3	NA

Note: Unless noted in the column headers, data in the table above was measured or calculated from the 2015 field surveys performed for this project by Collins and Pearson.

The field-measured cross-sectional areas for the Cross Sections 1 were smaller than the Dunne and Leopold regional curve. This result likely reflects that the latter was determining discharges for a flow that is larger than the likely bankfull frequency, which is expected to be closer to 1.2 or 1.3 years. The field-measured areas are larger than the Collins and Leventhal regional curve because average annual rainfall is expected to be higher in Bolinas along Bolinas Ridge than the rainfall of the sites used to make the regional curve. Variations in bankfull width and depth are shown in **Table 8**.

Bankfull velocity for all cross sections was higher than that predicted using the Dunne and Leopold (1978) Bay Area regional curve. This may indicate that the streams of the study area represent streams with steeper gradients than the data used to derive the Bay Area regional curve, or that the Bay Area curve did not include much data for smaller coastal watersheds similar to those in the study area. Bankfull velocity at the Lewis Gulch Cross Section 1 site was 28% greater than the prediction from the Collins & Leventhal (2013) Marin & Sonoma Counties regional curve (**Table 9**). This result suggests that the bankfull elevation (and thus cross sectional area) was overestimated. Various factors could lead to identification of a high bankfull estimate; one example would be a debris jam downstream that had a backwater effect into the area where the cross section measurements were collected. In such an instance, it is best that additional cross sections be surveyed to gain better confidence in the bankfull estimates. However, the values determined for all the cross sections fall within the realm of average bankfull velocities for wadeable streams. Additional cross section surveys would be necessary to determine if unique values (such as that determined for Lewis Gulch Creek Cross Section 1) are suspect and to reaffirm the values collected at the few other cross sections.

The flood discharges that could occur (as predicted by this analysis) at the floodprone elevation of the field-measured cross sections are shown in the last column of **Table 9**. Cross Sections 1 of North Tributary has 18 cfs, and Wilkins Gulch Creek has an estimated 221 cfs. In combination, they have 239 cfs that could hypothetically come from the Wilkins Gulch Creek channel if the alluvial fan were fully saturated during an extremely large event. During such an event, it is possible that the heads of the fans could be influenced by debris flows and debris flow torrents that could substantially change the channel morphology and strongly influence sediment loading. Cross Section 1 for Lewis Creek Gulch has a predicted 198 cfs. The combined total of floodprone discharges from the upper cross sections of Wilkins Gulch, and Lewis Gulch Creeks, and North Tributary is 437 cfs. These do not include estimates from Salt and Wharf Creeks, but if we multiply the bankfull discharges predicted by Collins and Leventhal by 4.5, which is about the magnitude of difference between the bankfull discharges and the predicted floodprone discharges at the measured sites, they would have about 40 cfs and 26 cfs. The combined total estimated discharge to the study area relevant to a large flood that potentially reached the floodprone elevation of all four creeks is 503 cfs.

To compare and better predict the bankfull discharges of the four channels at the head of tide, an additional regional curve was created from very local creeks in the general vicinity. The data for the regional curve are shown in **Table 10**. Unfortunately, very little additional data were available. The results of having four additional stream sites of potentially similar geographic characteristics can be seen on **Figure 42**, which shows a regional curve for local coastal streams.

On **Figure 42**, all the data points that have a drainage area of less than 1 mi^2 represent bankfull discharge from field measurements for this study. A red X and a red O are considered outliers and are therefore removed from the regression because the cross sections were taken in the middle segments of the alluvial fans, where surface flow is lost to subsurface infiltration. The ones removed from the regression were Wilkins Gulch Creek Cross Section 2 and Lewis Gulch Creek Cross Section 2. A purple X is a data point from bankfull cross sections measured by Collins and Leventhal (2013) for Olema Creek West Fork, East Fork Olema Creek, and Bear Valley Creek. The data point with the largest drainage area is the estimated bankfull discharge of a 1.3-year recurrence for Redwood Creek at SR 1.

Table 10. Bankfull Discharge of Local Coastal Streams near Bolinas

Site	Drainage Area (mi^2)	Bankfull Discharge (cfs)
Bear Valley Creek[1]	1.79	92
East Fork Olema Creek[1]	1.17	130
Olema Cr. John West Fork[1]	3.02	276
Lewis Gulch Cr. Xsec 1	0.59	45
Lewis Gulch Cr. Xsec 2	0.61	25
Wilkins Gulch Cr. Xsec 1	0.56	47
Wilkins Gulch Cr. Xsec 2	0.61	28
North Tributary Wilkins Gulch Creek	0.02	5
Redwood Creek at SR 1 Bridge[2]	7.10	337

1) Collins & Leventhal (2013), Marin & Sonoma Counties

2) Northern Hydrology and Engineering (2015)

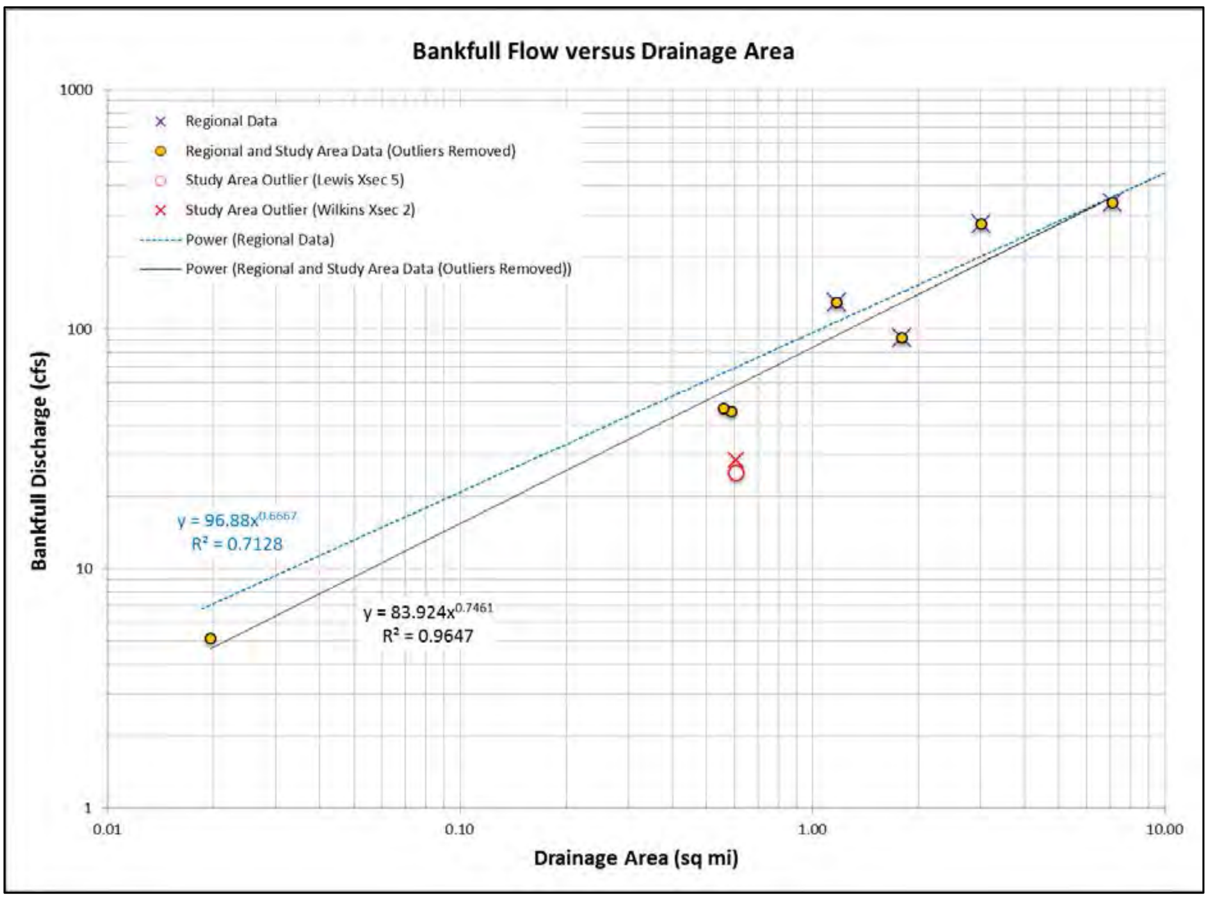


Figure 42. Regional Curve of Local Coastal Streams near Bolinas

The recurrence interval is extrapolated from peak annual flow recurrence intervals reported by Northern Hydrology and Engineering (2013). The black regression line represents all the data points (other than the red outliers), and the blue regression line shows what the regression would be without the addition of any of the study area data. The study area data has smaller watersheds than the regional data and probably help refine the regional predictions. The estimates of the study area discharges seem reasonable given the very small regional data det. Clearly, more data points on nearby streams and streams in the study area could help refine the regression and may cause it to be more statistically robust. The two regression equations shown on **Figure 42** were used to derive the predictions shown in **Table 11**.

The results of the curve for local coastal streams indicate that bankfull flow to the study area channels is greater than that predicted by the other methods. The likely explanation for higher predicted runoff using the study area and local coastal stream data (versus other regional predictions) is that there is a more pronounced orographic effect on the Bolinas Ridge producing higher runoff rates than similar drainages in Marin and Sonoma Counties (Collins and Leventhal 2013 regional curve) or the Bay Area (Dunne and Leopold 1978 regional curve). The locally predicted bankfull flows might be too large for Salt and Wharf Creeks because they do not have the same kind of orographic influences or resulting rainfall that the Bolinas Ridge or other creeks have. The black regression line that includes the study area channels (shown in black) is steeper than the blue regression line that excludes them (shown in blue). The R^2 value of 0.96 compared to 0.71 also indicates that there is better fit to the data when the study area channels are included, but only the upper Cross Section 1 data were included in both plots because the loosing reaches of Wilkins Gulch and Lewis Gulch Creeks are considered outliers. They are shown on the plot in red, but are not used in the analysis.

From the regression line that includes the study area data, the locally predicted bankfull flows for Wilkins Gulch and Lewis Gulch Creeks at the head of tide are 65 and 59 cfs, respectively. These values are 14 to 18 cfs greater than the Cross Section 1 measurements taken near the head of the alluvial fans (47 cfs for Wilkins Gulch Creek and 45 cfs for Lewis Gulch Creek). The regression line that did not include the study area data predicts that head of tide bankfull flows would be about 25 to 30 cfs greater than the bankfull flows at Cross Section 1.

Table 11. Bankfull Predictions from Regression Equations of Local Regional Curve

	Bankfull Discharge, calculated from regression Equations with study area Streams (cfs)	Bankfull Discharge, calculated from regression Equations without study area Streams (cfs)	Bankfull Discharge, calculated from Collins Leventhal (2013) (cfs)	Bankfull Discharge from Dunne and Leopold (1978) (cfs)
Wilkins Gulch Cr. at Head of Tide	65	77	39	39
Lewis Gulch Cr. at Head of Tide	59	70	34	34
Salt Cr. at Head of Tide	21	28	9	NA
Wharf Cr. at Head of Tide	13	18	5	NA
Total Study Area	157	193	86	ND

4.4.4 Bankfull Discharge and Hydraulic Geometry Conclusions

The study area cross sections confirmed the observations that the downstream reaches on the middle fan segments had smaller bankfull dimensions than the upper cross sections and that they are indeed losing reaches. **Table 9** shows that there is a broad spread in the bankfull discharge predictions, and it is not clear which estimate is best. It is suspected that more rainfall falls within the study area watersheds than watersheds of similar size elsewhere in Marin County because of the orographic effect caused by the Bolinas Ridge. Rainfall records clearly indicate that Mt. Tamalpais receives more rainfall than other areas of the county. Similarly high rainfall probably occurs in the upper watersheds of the study area, which translates to higher than average runoff – especially given the steep terrain of the upper watersheds. When comparing predicted discharges using local streams and the study area data to the Sonoma and Marin Counties or Bay Area regional curve predictions, it is evident that regional variations in runoff exist. However, with such a limited data set of cross sections in the study area and limited data available for other local streams (particularly with small drainage areas like those in the study area), it is not possible to rely on one prediction over the other.

At the toe of the alluvial fan, groundwater conversion to surface flow from a larger catchment area should cause the bankfull discharge to be greater than that at the measured cross sections. The total flow near the toe of the alluvial fans, particularly on Wilkins Gulch Creek, is complicated by the dissemination of flow into distributaries. Total bankfull flow from both Wilkins Gulch and Lewis Gulch Creeks is further confounded by potential backwater flooding caused by high tides. In addition, as sea level rises in the lagoon the existing culverts will not be able to drain.

As noted above, in Wilkins Gulch and Lewis Gulch Creeks, indicators of flooding above the floodprone elevation seemed absent at all surveyed cross sections. This absence is likely due to the lack of extreme floods in the last 30 years and the continued downcutting of the channels that is exacerbated by the maintenance dredging upstream of the culverts and along the roadway ditches. The floodprone width is an essential design element that should be considered in any stream restoration design. Having sufficient floodprone width maximizes the potential for a channel to remain stable during such large flood events. Since, by definition, the floodprone width is a measure at twice the maximum bankfull depth, reasonably accurate estimates of bankfull geometry – such as those developed in this effort – are important to determining the minimum floodplain width that will greatly increase the potential for the stream to remain stable at flood stage. Due to the unstable state of the channels in the study area and fact that most reaches are entrenched, it is recommended that measurements from a nearby reference stream be used to inform future channel redesign for streams within the study area.

Although bankfull geometry is more critical for channel and structure design, it may be less important to have adequate floodprone widths if streams are restored in such that that they permit active alluvial fan processes with inherent instabilities, such as sediment deposition, lateral migration, channel abandonment. With an active alluvial fan, the channels would be allowed to splay out over the entire fan surface, freely developing and constantly changing channel shape and pattern. The channel(s) would have the freedom to adjust to climatic changes such as SLR, drought and deluge, and alterations in sediment and flow regimes. Shifts in aggradation, degradation, and channel forms, such as braided or single-threaded, would be acceptable within a floodplain and alluvial fan/delta system that is adapting to an upland advancing tidal-freshwater transition zone.

4.5 Integration of Results

Section 4 has thus far presented results on four major topics: geology, historic geomorphology and land use, current hydrology and geomorphology, and stream cross sections and bankfull geometry. Before moving on to a discussion of these results in Chapter 5, it is important to integrate these results into a concise picture of their combined effects on hydrology and geomorphology of the study area. The effects of geologic and seismic activity and more recent (over the last 200 years or so) large-scale land use/land cover changes are complex, interactive, and known to vary spatially and temporally. The most important and notable of these effects and their interactions are summarized in the bullet list below.

- Winter/spring runoff increases from:
  - Road building that increases impervious surfaces from paved and compacted dirt conditions, creates additional channels from parallel drainage ditches, and converts subsurface flow to surface flow at road cuts;
  - Channel entrenchment that has resulted in the loss of floodplain and alluvial fan surface connectivity, both of which spread floods and convert surface flow to subsurface flow through infiltration processes;
  - The reduction in evapotranspiration from loss of vegetation during the period of logging and heavy grazing; and
  - Gullying and headward extension of channel networks during the period of heavy grazing and conversion of native bunch grasses to non-native annuals, resulting in an increased drainage density (channel length per unit area). Road and farm ditches and the connection of formerly disconnected channels on fans [such as the Northern Tributary of Wilkins Gulch Creek] also contribute to increased drainage density.)
- Summer/fall stream flow decreases from:
  - The greater proportion of winter/spring runoff (discussed in the previous set of bullets) reduces the amount of base flow and groundwater available for dry season (summer/fall) streamflow; and
  - The lower groundwater elevation and reduced groundwater supply that result from drawdown along the deeply incised channels and from the lesser total amount of groundwater storage (for the reasons mentioned above).
- Summer/fall groundwater decreases in upper and middle fans from:
  - Channel incision and entrenchment that is causing loss of connection to floodplain and alluvial fan surfaces; and
  - Decreased infiltration caused by loss of distributaries, which results in faster delivery of surface flow in single-thread channels.
- Summer/fall groundwater decreases in lower segments of alluvial fans and braided channel sections in Wilkins Gulch Creek due to sediment deposition in man-made ditches that have been over-widened by excessive bank erosion.
- The zone of groundwater conversion to surface flow at the toe of the fans might have narrowed, but will move up valley with rising sea levels.
- Sediment delivery from the watersheds to the lagoon spiked after the large-scale logging and clearing efforts from 1840 to 1900 and then gradually declined (Byrne and Reidy 2005; PWA 2006). Current sediment delivery remains higher than pre-European settlement but lower than in the late 1800’s.

- Sediment production remains higher than natural background level (except perhaps in the event of tectonic shifting) from:
    - Incised channel conditions and insufficient floodprone width;
    - increased landslide activity from land use impacts;
    - Loss of root strength from reduction in adjacent mature riparian trees, which adds cohesion to help resist bank erosion;
    - Legacy stream and hillside disturbance from logging, dairying, and associated roads and trails;
    - Stream and hillslope erosion due to wildfire;
    - Loss of alluvial fan and floodplain functions that spread and store sediment and increase surface water infiltration;
    - Ditches that lack appropriate hydraulic dimensions that cause channels to entrench; and
    - Dirt roads from ranching and logging activities and paved roads with inboard ditches, both of which often directly convey more sediment to the stream channels and cause erosional problems from structures placed at stream crossings.
- Landslide activity increases from:
    - The effect of road cuts that remove lateral support;
    - Stream incision at the toe of some hillsides where lateral support is removed; and
    - Legacy logging and the reduction in root/soil cohesion.
- Flooding in the study area increases from:
    - Channelization and entrenchment of streams that deliver larger peak floods at a faster rate;
    - Increased drainage density from paved and dirt roads and associated ditches;
    - Numerous stream crossing structures that are undersized or clogged and cause backwater flooding
    - Ditches that lack appropriate cross sectional, profile, and planform hydraulic dimensions that cause unplanned adjustments of hydraulic geometry, such as sedimentation and loss of capacity or excess shear forces that lead to bank slumping, loss of riparian vegetation and potential formation of woody debris dams that exacerbate flooding;
    - Impingement of floodplain by road berms, which trap backwater flooding upstream of culverts and elevates the water level; and
    - Recent and continuing sea-level rise, at rates that are expected to accelerate.

5 Discussion

The contents of this technical memorandum are being integrated with other technical memorandums and studies to form a larger document, the Site Conditions Report. However, this section highlights the most important conclusions from this memorandum and places the work in context. As part of the work conducted under this task, the authors are preparing a separate memorandum about the recommendations for how to incorporate the results and findings presented herein into the next step of the project, which is alternatives development and analysis.

5.1 Impacts of Geologic, Land Use, and Other Changes on Hydrologic and Geomorphic Processes

Climate, geology, seismic activity, and human land use management have had profound impacts on the stream geomorphology in the study area. The Coast Ranges are subject to natural variation ranging from years of extreme drought to extreme deluge. On occasion, intense and/or prolonged winter rainfall has contributed to new sliding and reactivation of landslides that might have initially been triggered by earthquakes, especially in the very steep hillsides of the Bolinas Ridge. Natural landsliding has provided a high supply of sediment that over thousands of years has created the large alluvial fans at the base of the steep drainages. Sedimentation rates have been influenced naturally by upstream sediment supply, transport and storage/trapping by vegetation, local fault block subsidence, but also by land use activities that involved extensive logging, grazing, channel ditching and diversion, and road construction. In some areas of steep topography in the study area, sliding has been accelerated by road cuts and stream bank erosion of the toe support of the hillside.

Excerpts from the local newspapers since the 1800's have documented years of flooding with mudflows that inundated the streams and roads. Records of frequent and devastating fires were also documented to have affected much of the western portion of the study area, particularly Wilkins Gulch watershed. Human-caused fires, extensive logging, ranching, road building and other alterations have affected storm runoff timing, duration, and intensity in the watershed. The changes in amounts and types of vegetation on the landscape, compaction of soils, and alteration or diversion of surface and stream flows has resulted in an increase in the rate and amount of runoff. More concentrated runoff increases the shear forces and potential for erosion and subsequent downstream sediment deposition.

The location and stream type or channel dimension of Wilkins Gulch and Lewis Gulch Creeks prior to human disturbance is difficult to determine given the complexity of the geology and faulting in the study area that influenced the stream morphology. The geologic and fault maps show many variations in location and activity of faults that would affect stream morphology. The Quaternary sedimentary and Cretaceous Franciscan bedrock within the study area and its surroundings is highly fractured, mechanically weakened, and is disjointed and or relocated by tectonic shearing from the various faults in the region, the active ones being the only ones depicted in this technical memo.

Tectonic down-dropping and subsequent headward erosion of a previous stream draining into the north end of the Bolinas Lagoon may also be the initial and natural cause of a redirection of Lewis Gulch Creek from a northward flow into present day Pine Gulch Creek and into its current channel. Ruptures along the San Andreas Fault near the head of the Lewis Gulch Creek alluvial fan may also be responsible for redirecting stream flow from the alluvial fan to the present day location against the hillside west of SR1 where an active fault trace is presumed to be located. The corresponding amount of alluvium generated by such incision and stream capture has been depositing on the down-dropping Holocene graben. The Lewis Creek alluvial fan is fairly well matched in size and elevation with the Wilkins Gulch Creek fan. Yet, based upon the topography indicated in the 1854 T-Sheet map x and the location of projected active faults (Figure 12), the Wilkins Gulch Creek fan appears to only have what used to be its previous delta being influenced by Holocene down-dropping of the graben. It seems likely that most of the Holocene alluvium deposits in the fan of Lewis Gulch Creek represent channel incision as a major source of sediment supply, whereas the Holocene alluvium of the Wilkins

Gulch Creek fan represents mostly material generated by steep hillslope erosion and landslides as its major source.

Prior to the large-scale land use changes and development described herein, geologic and seismic activity and the local climate of the time likely had a larger influence on streams delivering high rates of sediment to the Bolinas Lagoon. It is the stream sediment regime of the early Holocene epoch that formed the vast alluvial fans that cover most of the study area. The streams likely flowed across the surface of the fans depositing sediment and alternating channel shape and location periodically in response to large flood events. In the early 1800's the sediment input to the lagoon from the streams flowing over the alluvial fans may have had a lower rate of accretion than is present today. The reason this may have occurred is that a largely undisturbed naturally formed alluvial fan covered in vegetation is more efficient at redistributing and trapping fluctuations in sediment supply than a straightened channelized or single threaded stream. Once the streams of the study area were pushed to the side of the valley (either by natural or human induced means) the channel length decreased and corresponding slope increased along with the erosive energy. Where channel incision becomes deep enough, flood flows are prevented from escaping the channel. The combined effect increases erosion along the channel reaches in the project area and transports that sediment to the lagoon.

As a consequence, the sedimentation rates in the lagoon increased above the rates prior to large-scale land management changes. There might be substantial differences in the rates of accretion during the Holocene era between Wilkins Gulch and Lewis Gulch Creeks due to the effect of the down-dropping Holocene graben. Byrne et al. (2005) determined that a five meter-long core sample taken at the A3 site at the lower edge of the saltmarsh at the northeast side of Wilkins Gulch Creek (**Figure 10**) was characterized by an increase in sand percentages and a corresponding decrease in silt and clay. The sediment cores indicate that from1850 to 1906 deposition rates averaged 12 mm/year and about 8.0 mm/year since then. Insofar as most of the redwood logging took place in the 1850's, Byrne et al. (2005) reported that it seemed likely that at least part of this increase in sediment is attributable to agricultural activities in the watershed, such as dairy farming and logging. Whereas most of the lagoon's depositional environment is heavily dominated by tidal sources, the deposition rates in the extreme north end of the Lagoon near the study area were reported to be associated with sediment supply from the Lewis Gulch and Wilkins Gulch Creeks (PWA 2006; Byrne and Reidy 2005).

Historically the relocation and straightening of channels away from the alluvial fan and dredging of the streams to maintain channel capacity altered channel hydraulics in such a way that larger quantities of sediment and bedload were transported to the lagoon. Periodic flooding of the ranch land and buildings and the desire to maximize usable and reliable farmland likely drove folks to channelize or otherwise relocate Wilkins Gulch Creek against the hillslope. It is unclear if Lewis Gulch Creek was moved over against the hillslope for the same reasons, to make way for the construction of the road that is now SR1, or if a fault rupture, such as that from 1906, captured the flow along the length of the fault.

The sudden alteration of channels by either human or natural means made them more susceptible to erosion as a result of an altered cross-sectional area and channel roughness as well as a steeper slope. Whether or not the streams were constructed in an incised state or they incised on their own is not clear. What is known is that both Wilkins Gulch and Lewis Gulch Creeks have incised so much through the upper and mid portions of their alluvial fans that flood flows no longer have access to the fan surface. The stream alterations significantly altered the sediment regime such that, where the majority of sediment was once more deposited on the upper- to mid-fan surface, it is currently transported further downstream to the channel segments in the lower portions of the alluvial fans.

As landscape-altering activities in the watershed (e.g. logging, road construction, fires, and farming) subsided, vegetation cover increased slowly helping to stabilize formerly disturbed areas. While the altered contouring of the land in some areas still has a negative effect on channel morphology and sediment supply, the increased vegetation cover in some areas (such as the previously logged areas, the willow groves, and transition zones to tidal marshes) have helped reduce channel erosion. Subsequently, the sediment supply rate to the lagoon has fallen. Byrne et al. (2005) reports that for the period between 1906 and 2005 the average sediment deposition rate was 7 mm/year. Over that period, however, sediment deposition rates were not uniform. Rather, after the earthquake, the deposition rate increased greatly, but as the lagoon filled, the deposition rate has decreased substantially. Byrne expects that rates will eventually be reduced to less than 6 mm/year.

It is presumed that a decrease in sedimentation rates from terrestrial sources is associated with decreased erosion rates upstream on both Lewis Gulch and Wilkins Gulch Creeks. Decreased sedimentation rates in the lagoon in more recent times may be attributed, at least from Wilkins Gulch Creek, to trapping of sediment within the Salt Creek Pond, increased sediment storage in the transition zones above the tidal elevations or in the braided channel area of Reaches 3 and 4, and the lack of a prominent well defined channel to carry flow directly to the lagoon. Wetland and marsh vegetation in the lower Reach 4 distributaries can easily grow within the channels and trap sediment (i.e. vegetation is not scoured from the channels due to higher flows). Periodic dredging of Lewis Gulch Creek could also temporarily remove some sediment that would otherwise be conveyed to the lagoon. Depending on how deep the dredging occurred the channel may store sediment for a short period of time until sufficient channel geometry is reestablished to more effectively convey sediment to the lagoon. Currently the single threaded and incised Reach 4 of Lewis Gulch Creek is capable of conveying small gravel sized sediment to the lagoon.

Previous watershed disturbances within and upstream of the study area still influence road flooding in the study area. The placement and design of culverts and orientation, shape, and size of the channel leading to and from the roads contribute to road flooding issues. For example, without routine clearing of the ditched portion of Wilkins Gulch Creek to Salt Creek (Reaches 3 and 4B) the channel eventually filled with sediment and overflowed its banks depositing sediment on the fan between the channel and SR1. It is likely the roadway to Bolinas flooded until a culvert was installed when SR1 was extended north. However the road surface is too low to install a culvert with sufficient height and capacity to overcome the buildup of sediment on the fan above the culvert and rapidly growing vegetation that slows flood flows and increase flood stage. As a result over time the culvert was and continues to be overrun by sediment and vegetation growth.

The SR1 culvert on Salt Creek/Reach 4B of Wilkins Gulch Creek is also undersized and over run by historic sediment deposition on the inlet side that inhibits tidal exchange to the Salt Creek Pond. With limited tidal prism and poor drainage, sediment from the lagoon builds up within the culvert and outlet channel. Dredging of sediment from the immediate vicinity of the culvert does little to alleviate the problem.

The Lewis Gulch Creek culvert on Olema Bolinas Road has issues with sediment deposition within and up and downstream of the culvert. The problem is compounded by the 90-degree redirection of streamflow at the entrance to the culvert, which reduces the efficiency of the channel to convey flow and sediment. As a consequence storm flow will "back up" at the entrance to the culvert increasing the stage of flood flows upstream of the culvert and allowing sediment to be deposited in the channel, thereby exacerbating the road flooding.

Wharf Creek likely flooded Olema Bolinas Road whenever branches or sediment overwhelmed the small undersized culver beneath the road. This was probably a frequent occurrence because the channel slope abruptly changes from steep to flat at the culvert entrance. Once the culvert plugged so badly that it could not be cleaned, it was abandoned and redirected 90 degrees to flow along a roadside ditch to Lewis Gulch Creek. Similar to the channel/culvert issue on Lewis Gulch Creek, sediment and flow cannot make such an abrupt turn when transitioning from a steep to low or moderate slope. During large storm flows the result is that water and sediment overrun the roadside ditch and flow across and down the road surface.

Cross section and profile surveys of Wilkins Gulch and Lewis Gulch Creeks, conducted as a part of the project, indicate that considerable variability exists in channel hydraulic geometry and discharge within the study area and also when compared to regional data. The variability is in part due to the influence of human disturbances including channelization, floodplain encroachment, and instream structures combined with natural influences such as landslides and effects of the alluvial fans. Even with a limited number of surveyed cross sections, the loss of streamflow to groundwater within and along the length of the alluvial fans was evident. Streamflow was greater at the head of the alluvial fans for both streams than at mid-points along the fans. Streamflow then increases towards the toes of the alluvial fans in response to surfacing groundwater as the streams get closer to the lagoon. The conclusions and predictions in this memo indicate increases in flow at the head of tide (near the toe of the alluvial fans), but these increases are directly related to the larger drainage area (the independent variable using the regional curve predictions). As a result it is likely that flow rates at the head of tide are higher than those predicted in Section 4.4.3. When this project moves toward actual engineered design alternatives, additional stream surveys may be warranted within the study area and in nearby reference streams to provide more precise discharge and hydraulic geometry predictions, especially if the desired restoration alternative involves channel or flood conveyance structure design.

5.2 Effects of Future Sea-Level Rise

Future SLR is expected in Bolinas Lagoon. The magnitude, timing, and rate of the many modeled projections of SLR vary depending on the source and model used. **Table 10** lists the range of projected SLR between 2000 and 2100. Projections indicate anticipated SLR upward of 2.0 feet by 2050 and 5.5 feet by 2100 (CO-CAT 2013[3]). More recent 2015 predictions from National Atmospheric and Space Administration scientists suggest that these rates might be conservative and sea level rise could be as much as 18 feet or higher (National Geographic, 2015.) However, the Marin County-selected 2013 projections shown in Table 10 are used as the basis of this study.

Table 12. Projected Sea-Level Rise South of Cape Mendocino Using 2000 as a Baseline (CO-CAT 2013)

Time Period	Projected Sea Level Rise
2000–2030	4 to 30 centimeters (0.13 to 0.98 feet)
2000–2050	12 to 61 centimeters (0.39 to 2.0 feet)
2000–2100	42 to 167 centimeters (1.38 to 5.48 feet)

This anticipated 2100 SLR of 5.5 feet would regularly inundate up to an elevation of 11.1 feet a the current MHHW elevation of 5.6 feet. **Figure 43** illustrates an example of these tidal changes by showing the MHHW elevation as it is now and as projected to be by 2050 and by 2100. This would flood portions of the crossover road, Olema Bolinas Road, and SR 1 and would greatly affect any stream drainage infrastructure along the roadways. **Figure 44** is a similar figure showing the projected elevations of the highest regular high tides instead of the means; these regular highest tides would likely cause increased flooding.

Interestingly, portions of the mid- and end-century SLR projections along the margin of the lagoon bounded by paved roads do not look radically different than the Federal Emergency Management Agency (FEMA) existing Flood Hazard Zone 1 boundary that presently is reported to have a one percent chance of flooding from stream flows (**Figure 45**). The main difference is that FEMA (2015) does not show flooding upstream of the Salt Creek culvert in the Salt Creek watershed. The implication is that stream flooding coinciding with projected SLR is very likely to push the flood boundary well upstream of the projected tidal elevations in **Figure 43** and **Figure 44**.

Much will depend on the tidal-freshwater transition zones, on how both water and sediment is delivered and stored, the shape of the channel and surrounding topographic morphology, and whether in-stream structures (if used) can convey water and sediment unhampered in either direction. Such a transition zone is likely to become a deposition zone with braided channels and distributary channels regressing landward as sea level rises. King tides, storm surges (especially

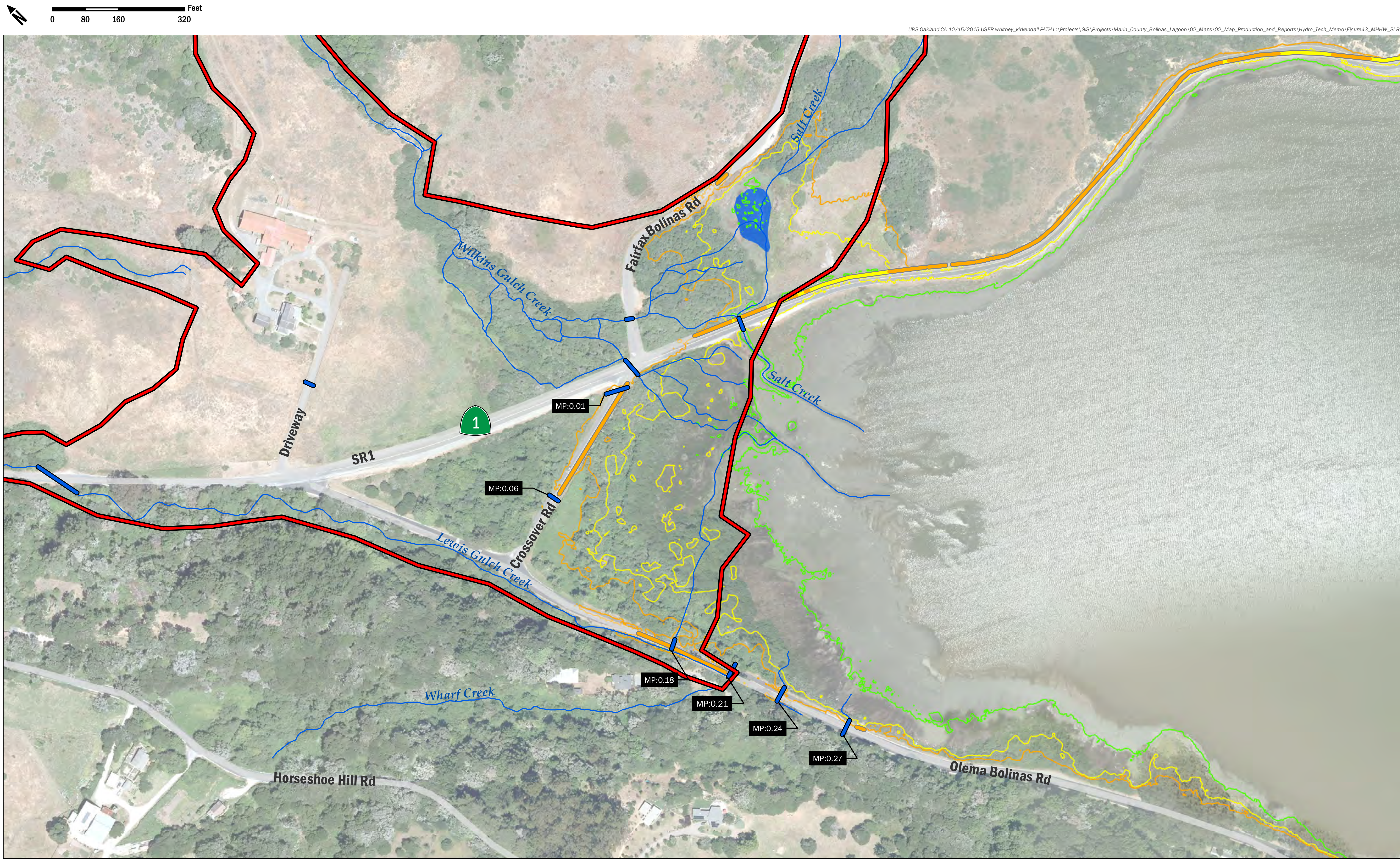
[3] The CO-CAT projections are among the modeled projections used by the Our Coast Our Future Project, which was recommended by Marin County for use in the current project's assessment of SLR.

those associated with El Nino conditions), and wind-wave run-up would also flood greater areas than those shown in **Figure 43** and **Figure 44**. Looked at another way, what are currently extreme events are a preview of what would become regular occurrences under projected SLR.

As SLR increases, the backwater effect of the lagoon on streamflow (i.e., water in the lagoon slowing outflows from the streams, especially at high tides) would move up into the stream drainages. During storm events, the bedload is transported downstream, and depending on the channel morphology, some portion of it would be deposited where the streamflow meets the sea level of the lagoon. Finer sediment may be carried out further into the lagoon with the outgoing tide via subtidal channels. With 2100 SLR projected to be immediately adjacent to SR 1 and to the county roads, any bedload carried downstream to that point under existing conditions would be deposited within culverts or other drainage structures under the road. The tidal delta would also expand from the current location and elevation to normalize with the projected elevation. If the road drainage structures do not have adequate capacity to accommodate the sediment, road flooding will dramatically increase. Maintenance needs, frequency, and costs of any drainage structures to clear sediment and reestablish drainage would increase.

Upstream of the 2100 mean higher high tide elevation, the existing configuration of the stream channels would change as aggradation occurs in the lower reaches. This change would be due to the same backwater effect discussed above. As channels aggrade with sediment from backwater flooding problems associated with the culverts, some presently incised reaches may once again flood onto the adjacent terrace. In some cases, flooding may be such that the channel would alter its flow path and readopt. Vegetation changes may also affect the channel morphology, as alder and willow species that grow on the stream banks in a freshwater environment die because of higher salinities and are replaced by saltmarsh species. As the trees die and contribute woody organic debris, more sediment would likely become trapped and culvert clogging would increase.

This general description must be considered partial. It is difficult to anticipate exactly how the streams may react to SLR because the lower reaches of the streams have been modified by land use and maintenance dredging activities, and some streams (Lewis Gulch Creek and Wilkins Gulch Creek downstream of SR 1). Further, without maintenance records and more complete information on the frequency and extent of flooding, it is difficult to be more precise. However, efforts to obtain both of those types of information have been ongoing.



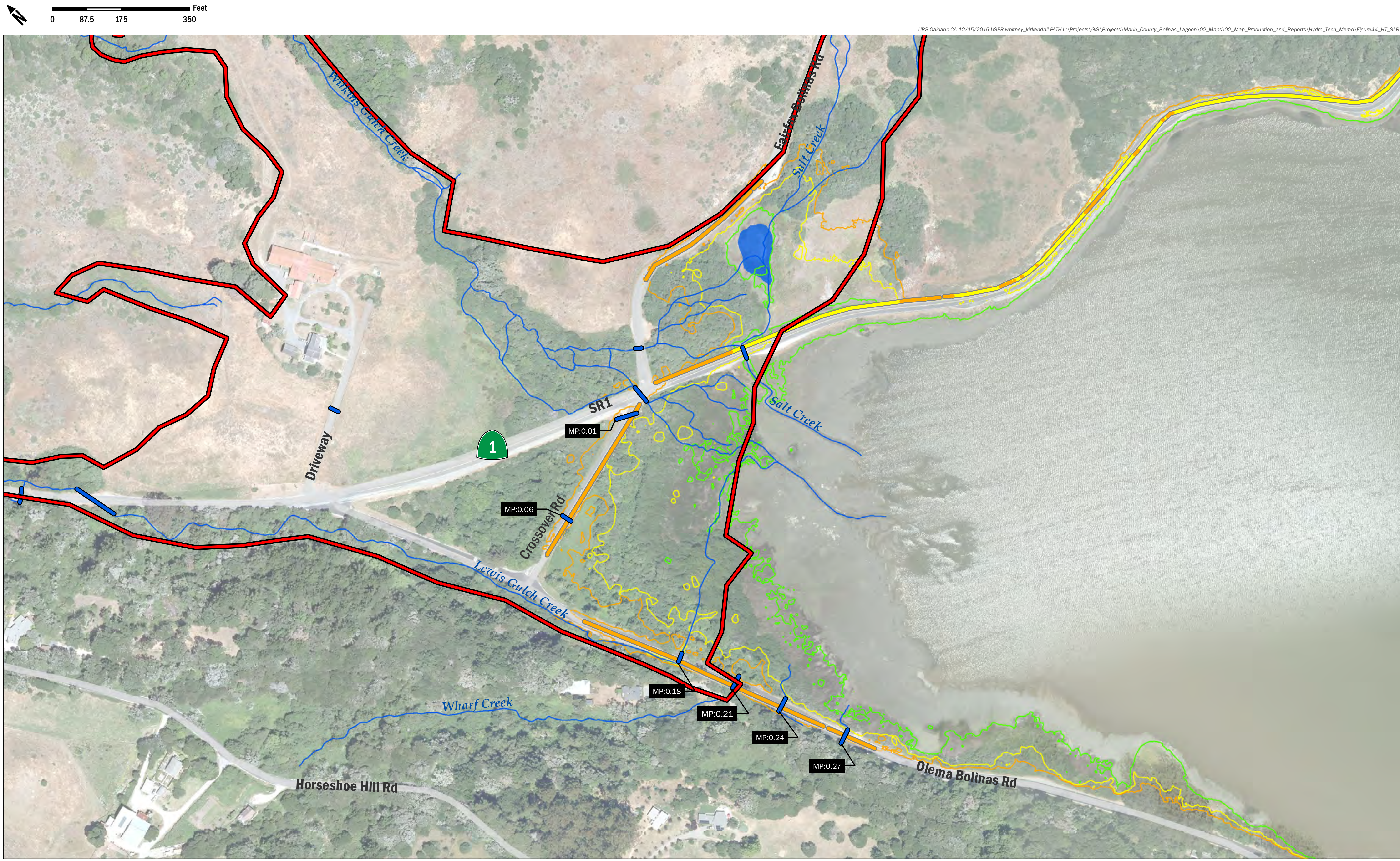
AECOM
MCOSD
Bolinas Lagoon Restoration

Study Area
Water Feature
Culvert
Mean Higher-High Water (MHHW), 5.60 Ft
Mid-Century Sea Level Rise (MHHW + 3 Ft), 8.60 Ft
End-of-Century Sea level Rise (MHHW + 5.5 Ft), 11.1 Ft

Roads Impacted by Sea Level Rise
Mid-Century Scenario
End-of-Century Scenario

Data Sources:
Elevation, San Francisco Bay LiDAR, USGS, 2010-2011
Sea Level Rise Data: Projections from Our Coast; Our Future (2015)

FIGURE 43
Sea Level Rise Projections for Mean Higher-High Water



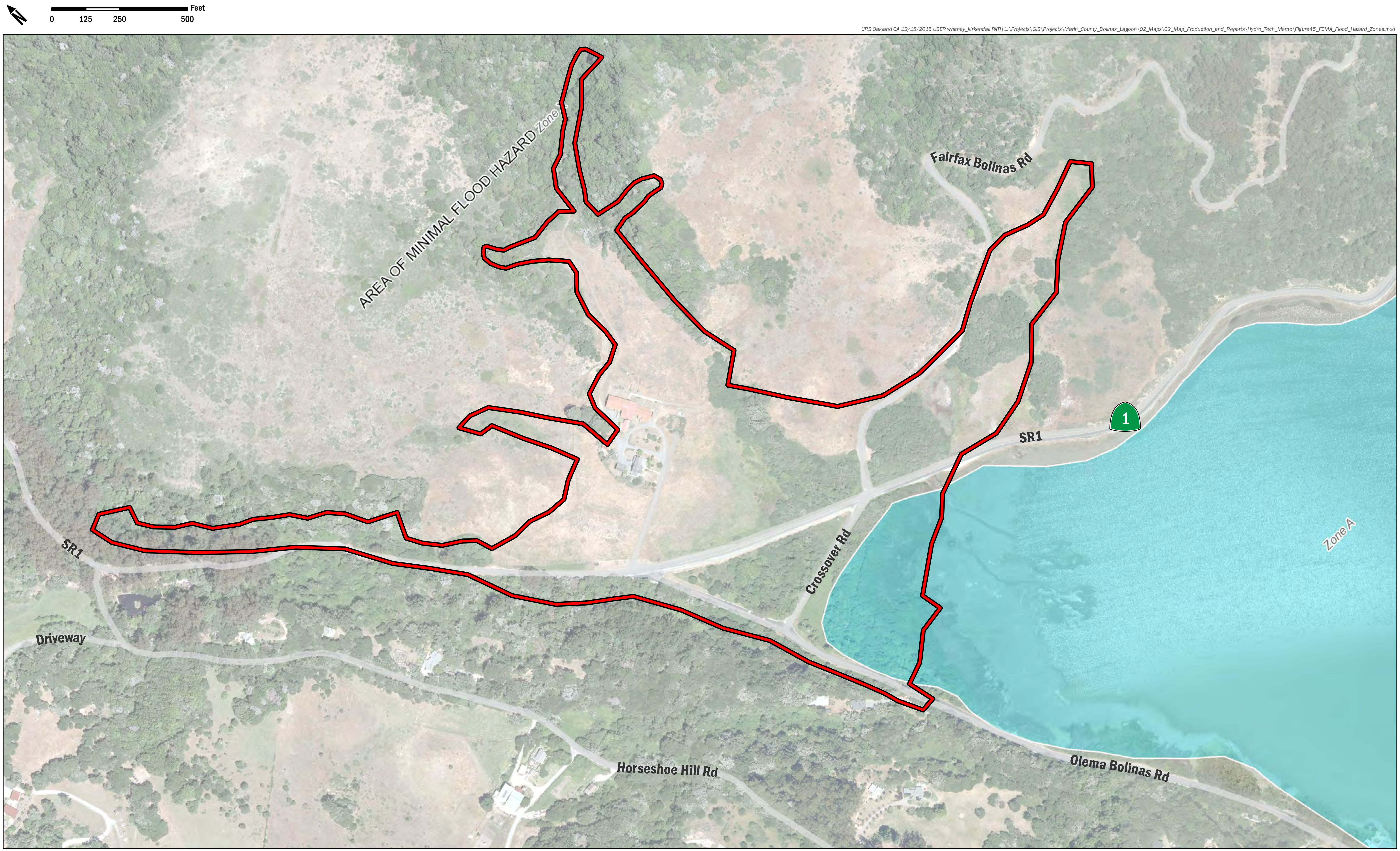
AECOM
MCOSD
Bolinas Lagoon Restoration

Study Area
Water Feature
Culvert
High Tide (HT), 5.60 Ft
Mid-Century Sea Level Rise (HT + 3 Ft), 9.40 Ft
End-of-Century Sea level Rise (HT + 5.5 Ft), 11.9 Ft

Roads Impacted by Sea Level Rise
Mid-Century Scenario
End-of-Century Scenario

Data Sources:
Elevation, San Francisco Bay LiDAR, USGS, 2010-2011
Sea Level Rise Data: Projections from Our Coast; Our Future (2015)

FIGURE 44
Sea Level Rise Projections for Highest Tides



AECOM
MCOSD
Bolinas Lagoon Restoration

Study Area
1% Annual Chance Flood Hazard
Regulatory Floodway
Special Floodway
Area of Undetermined Flood Hazard
0.2% Annual Chance Flood Hazard
Future Conditions 1% Annual Chance Flood Hazard
Area with Reduced Risk Due to Levee

Data Sources:
National Flood Hazard Layer (NFHL), FEMA, 2015.
Note:
Not all features shown in the legend appear in the project vicinity.

FIGURE 45
FEMA Flood Hazard Zones

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Appendix A.
Summary of Literature Statements

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APPENDIX A - SUMMARY OF LITERATURE STATEMENTS

	PROCESSES							LAND USES						HISTORICAL INFORMATION AND ACCOUNTS	
Year(s)	**Storms**	**Sedimentation**	**Landsliding**	**Drought**	**Earthquake**	**Fire**	**People**	**Roads**	**Logging**	**Dairy/ Ranching**	**Other**	**Mining**	**Stream Changes**	**Notes *[italicized comments represent opinions and interpretations made by Laurel Collins of Watershed Sciences]***	Reference
400-1850		X												Sedimentation rate is 4 mm/year for the period AD 400 to AD 1850	16
< 1800					X									Prior to the period of American settlement, Bolinas Lagoon was not a deep water Lagoon persisting in equilibrium with slowly rising sea level. On the contrary, natural disturbances in the form of earthquakes and possibly even a major tsunami, have repeatedly disturbed what was a relatively shallow lagoon throughout the period of record The earthquakes in particular were important in that they caused the tectonic subsidence responsible for the continued existence of the lagoon. If the earthquake record is reliable, five major earthquakes have affected the lagoon during the last 1600 years. The indicated mean recurrence interval is Ca. 300 years, although the time between the second and third quakes was only 130 years.	16
1817							X							Establishment of the Mission San Rafael Archangel contributes to the demise of the Miwok culture in the Olema Valley.	6
1834							X							Rafael Garcia's residence is reported as first known "white" residence on Bolinas Bay. *[Possibly first introduction of stock to Bolinas Lagoon area?]*	5
1835							X							Rafael Garcia first settled in Tomales Baulines in 1835. His brother in-in-law was Gregorio Briones.	2
1836							X							Rafael Garcia, claimant for Tomales and Rancho Baulines	1
1837-1850										X				Cattle raising was the most important work carried on at the Baulines Rancho. Briones and Garcia's became known as the cattle barons of the County.	1
1841							X							Gregorio Broines petitioned General Vallejo for all of Rancho Baulines east and west of the lagoon. Vallejo ordered a survey of the land and Captain Richardson rode from Sausalito to supervise and draw the map.	2
1842										X				Briones applied to the govenor of Monterey to graze the land and locate his house on the land	2
1846							X							Pablo Briones, son of Gregorio, secures the grant to the ranch after showing the governor the map of the land and assuring him that his father had two corrals at Bolinas, a vineyard, two orchards (probably apple and cherry), and a thousand acres of land cultivated and fenced.	2
1849									X					In 1849 the first lumberjacks at Bolinas were Charles Lauff. He founded a sawmill at Dogtown, 2 miles north of the Lagoon.[2] The trees were equal to those at Corte Madera (Mill and Tam Valley). On Bolinas Ridge were redwoods the size of those in Calaveras forests. By 1849 lumberjacks thronged Bolinas, and the pastorale was over.[2] At first all the trees had to whip sawed.[1] According to the diary of Bolinas lumberman, Captain Oliver Allen, the grand trees averaged 6 feet in diameter.[5] Lumbermen arrived by boat late in 1849. They used a large building which stood about 100 yards north of the present Rancho Baulines, near the head of the lagoon, and close by the embarcadero, or wharf, where the timber was loaded onto rafts and lightered to larger boats anchored in deeper water near the sand bar. A saw mill on a flat at Dogtown was constructed that removed 8,000 board feet a day.[6] A large building was built about 100 yards north of the WIlkins ranch house for shipping large timber to San Francisco.[6] All of the ranches from Five Brooks southward used the head of the lagoon for their primary shipping port.[6] The timber was rafted down the bay and over the bar where a vessel was anchored ready to receive it.[14] It was used in the construction of wharves and warehouses in San Francisco....[14] The company had quite a large building located about one hundred yards north of the present residence of W.W. Wilkins.[14]	1, 2, 6, 14
1850							X	X	X					Bolinas census indicates 200 residents.[2] *[Conversely]* , the U.S. Census in 1850 counted only 188 people in the county.[14] Site 221 of the California State Historical Preservation registry indicates the lighter wharf was built in the early 1850s to load lumber on lighters to be floated out to deeper water near the channel, where it was transferred to seagoing vessels for shipment to San francisco.[4] The original Olema-Bolinas Road between Dogtown and the intersection at the Bolinas Cemetery followed the route now known as Horseshoe Hill Road. This was the trail the bridal party used in 1850, traveling from Upper Bolinas at Casa Briones to Woodville and northward to Olema.[14]	2, 4, 14

APPENDIX A - SUMMARY OF LITERATURE STATEMENTS

Year(s)	Storms	Sedimentation	Landsliding	Drought	Earthquake	Fire	People	Roads	Logging	Dairy/ Ranching	Other	Mining	Stream Changes	Notes *[italicized comments represent opinions and interpretations made by Laurel Collins of Watershed Sciences]*	Reference
	PROCESSES							LAND USES						HISTORICAL INFORMATION AND ACCOUNTS	
1851-1859									X					According to Munro-Fraser, 15 MMBF was cut in the immediate vicinity of Bolinas. The first two million was not milled, but rafted down the bay and over the bar to a waiting vessel for transport to San Francisco where it was used in the construction of wharves and warehouses. The building for this operation was located 100 yards north of the Wilkins residence. The 13 MMBF was milled by four mills between 1851 and about 1859 from that "belt of redwood."	14
1851									X					The circular saw was introduced about a year after Sausalito Peninsular had been cut over. *[It is noted in ref #8 that dairymen commonly located ranches next to springs and piped the water to various outlets as needed. It seems likely that flow from Lewis Creek had to be piped to the ranch and sawmill for year round use.*] Saw-Mills--In 1851 Captain Hammond built the first saw mill in this section, which was located on the present site of Woodville.(Munro-Fraser, 1880).[14]	1, 14
1852		X											X	By 1852 the lagoon had so silted in through indiscriminate logging that lumber ad to be lightered to wharves in deeper water.[2] The lighter wharf site at the head of the lagoon is historical landmark no 221.[5] [*On the website for this landmark they show it at the eastern side of the lagoon head . This seems to be in disagreement with all maps and photos that indicate that it was on the west side of the head of the lagoon.]* In 1852 this mill *[Captain Hammond's at Woodville]* was reconstructed ...and a circular saw put in, giving it a capacity of twenty thousand feet .(Munro-Fraser, 1880). [14]	2, 5
1853									X					Two other mills were apparently built in the vicinity of Bolinas lagoon, the first in December 1853. JUL.. Moultrie built a steam circular saw on Peck's ridge with a capacity of 12,000 feet daily in 1853.[5] Various outfits placed sawmills in the surrounding area. on Peck's Ridge, on Randall Ranch to the north, and in Gulches draining to Bolinas Lagoon to the south.[6]	5
1854								X						*[A wooded valley can be seen upstream of the head of the Bolinas Lagoon on the he 1854 Coast and Geodetic Survey map.* [8] *Another 1854 map, made for the Berry grant for Bethuel Phelps* [6] *, shows the full extent of Lewis Creek. At Salt Creek area the1854* [6] *map seems to indicate the beginning of a levy extending from south to north that crosses the inlet. The levee is in the position of today's Hwy 1.]* The topography of the north basin in 1854 was apparently not very different from what it is today, i.e., largely intertidal.[16]	8, 6,16
1855-1976											X			*If we extrapolate the San Francisco sea level data to Bolinas Lagoon, the rise in sea level during the period 1855 to 1976 was ca. 18 cm*	16
1856									X					The County history estimated that some 13 million board feet of redwood were cut by 4 mills *[over a broader area]* in the County. The Surveyor-General's annual report for 1856 recorded that 3 of the mills were in Bolinas.	5, 6
1858							X		X					The second saw mill was built in 1858 which was the last year of recorded lumbering in the area. In 1858 John Rutherford and D.B.L. Ross built their sawmill just south of the Randall house in Olema Valley. The 1858 Platt showed 5 American residences on the east side of the lagoon and a steam sawmill located near the road on the northeastern portion of the Rancho Baulines.[5]	5
1859									X					The 1859 Surveyor-General's report showed that the County no longer had any saw mills in operation.	5
1860								X	X	X				Although the previous year's Surveyor-General's report showed that the County no longer had any saw mills in operation the 1860 census listed 7 men in Bolinas township in the redwood and Oak lumber industry.	2

APPENDIX A - SUMMARY OF LITERATURE STATEMENTS

	PROCESSES							LAND USES						HISTORICAL INFORMATION AND ACCOUNTS	
Year(s)	Storms	Sedimentation	Landsliding	Drought	Earthquake	Fire	People	Roads	Logging	Dairy/ Ranching	Other	Mining	Stream Changes	Notes *[italicized comments represent opinions and interpretations made by Laurel Collins of Watershed Sciences]*	Reference
1863										X		X		Copper mining Wilkins property north of Wilkins Cr in stream that is tributary to Pine Gulch Cr at Dogtown, which was later named Woodville.[2] The tributary called Copper Mine Gulch where they tunneled 700' into hillside.[2] No copper recovered. Oliver Allen cut 2 million feet of lumber at his Dogtown mill. or 20,000 feet/day. Logs were hauled to the mill by oxcart, and lumber carted to schooners at the head of the lagoon.[2] Sawmills were set up at Dogtown and along the ridges, most of the redwood going to San Francisco for wharf pilings.[2] Union Copper Mine started at Union Gulch which was later purchased and named Copper Mine Creek by Wilkins' in the Late 1860's.[6] Ore was shipped to England for reduction.[6] Stockmen are complaining of short pasturage on and about the hills in this vicinity and are apprehensive that the coming winter will be a hard time for cattle. The fact is the ranches have been over stocked for many years--the grass not being permitted to seed is giving place to weeds and will soon disappear unless some change or system be adopted... (Marin Journal, 30 May 1863).[14]	2, 6, 14
1866									X	X				By the late 1860s oak and laurel cordwood was Dogtown's main output.[2] According to family account, Wilkins built his large barn soon after purchasing the property in 1866.[6] Over a fifteen year period, Bolinas Point provided active employment to ten or fifteen small vessels for transporting wood and lumber from Bolinas Bay (Marin Journal, 16 June 53 1866).[14]	2, 6, 14
1867								X						Lewis Creek, which used to be called Burks Gulch is shown on an 1867 map that shows a relocation of the old road over clay hill near its large northwestward to southeastward bend. Lewis Creek appears to be oriented more southeastward in its valley than its southward course today along the west side of its valley. The current State Highway follows the route of the first County road constructed in 1867 with the exception *[in the project area]* of the intersection adjacent to Bolinas Cemetery to a point south of Dogtown, now known as Horseshoe Hill Road, which was the original county road until bypassed by the current Olema-Bolinas Road. *[This apparently does not mention the cutoff at the Wye.]*	6
1868													X	The Wilkins barn is shown on the first survey, Alfred Eskoot's 1868 map of Bolinas Lagoon Road. *[A culvert is shown along the survey on what appears to be a a tributary to Lewis Creek.]*	6, 9
1869								X		X				A group of Bolinas pioneers, including Wilkins and Easkoot, petitions the supervisors for a road from Sausalito.[2] Wilkins purchases head of Bolinas Lagoon from Pyle.[6]	2,6
1870								X		X	X			Wilkins did not continue to operate the dairy, in 1870 he leased it to Angelo Pedrotti, a Swiss immigrant who managed 150 cattle, 8 horses and colts, plus all the teams, carts, machinery, tools, and implements on the tract.[6] *[According to Pearson tech Memo Susan Kirk (ref 14) the Sausalito and Bolinas Road was built in 1870.]* Thomas Barfield suggested that not only did the Grinter Brothers dike the land, they also reclaimed the marshland by “diverting Gregorio’s (Pine Gulch or Bolinas) creek” (Gilroy, 1970). Making land by moving creeks from place to place behind a dike was apparently common, as ranchers on Humbolt Bay did the same.[14] The 1870 Bolinas Township, Olema Post Office, listed 13 wood choppers and one logger. For the same census, the Bolinas Post Office district listed eight wood choppers.	6, 14
1871	X							X		X				A December 1871 storm in Marin County caused damage to roads and bridges estimated at $50,000, the dams on Lagunitas Creek at the paper mill and the powder mill were carried away, and roads, including the one from Sausalito to Bolinas, were described as “horrible” (Marin Journal, 30 Dec. 1871). *[According to Pearson tech Memo Susan Kirk (ref 14)he Sausalito and Bolinas Road was badly damaged in the 1871 storms.]*	14
1872	X													A January 1872 headline read: “Rain! Rain! Rain! (Marin Journal, 6 Jan. 1872).	14

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	PROCESSES							LAND USES						HISTORICAL INFORMATION AND ACCOUNTS	
Year(s)	**Storms**	**Sedimentation**	**Landsliding**	**Drought**	**Earthquake**	**Fire**	**People**	**Roads**	**Logging**	**Dairy/ Ranching**	**Other**	**Mining**	**Stream Changes**	**Notes *[italicized comments represent opinions and interpretations made by Laurel Collins of Watershed Sciences]***	Reference
1873		X						X	X		X			The 1873 map of Marin shows the San Rafael Trail Winding up Samuel Weeks canyon and coming out in what is now Fairfax.[2] [*Map 32 shows the Weeks property , which is along a creek south of the Bolinas Wye.] T*he big timber and milled lumber business of that early period "died out," and was replaced after that time with an active firewood business (Marin Journal, 1 May 1 873).[14] In 1870, Robert Ingram, who lived near the head of the Bay on the western channel, constructed a wood wharf to accommodate small lighters.[14] At that time, about 50,000 cords of wood were shipped annually from Bolinas.[14] Conveyed by lighters to the landing near the point, the wood sold for $3.50 to $6.00 a cord (Marin Journal, 6 Aug. 1870).[14] In the spring of 1873, wood was selling at Bolinas at $11 a cord and the demand exceeded the supply (Marin Journal, 1 May 1 873).[14] By the fall of 1872, eucalyptus was planted along the road into Bolinas.[14] *[Stereo aerial photos indicate that there is an increase in delta building at the outlet of Lewis Creek. Active landslides can be observed.]*	2, 14
1874	X													A "severe storm" in late 1874, described as a freshet, caused Bolinas Creek (Pine Gulch) to overflow its banks, taking out Stephen McGovern's house and destroying his trout ponds (Marin Journal, 3 Dec. 1874).[14]	14
1875							X				X			Wilkins fine house was built.[6] The Grinters are gradually increasing their trout stock to an important interest and their work of reclaiming the marshland bordering on Bolinas Bay goes quietly on meanwhile. Large areas of very productive soil are annually reclaimed from the dominion of the sea (Marin Journal, 21 Oct. 1875).[14]	6, 14
1878								X						Wilkins is awarded a grant to construct the San Rafael Bolinas Road that took an unplanned route through the Wilkins property in 1878. The road was built to replace the steep, prehistoric San Rafael trail, which crossed Bolinas Ridge from the Weeks Ranch to the confluence of Cataract and Lagunitas Creeks, now site of Alpine Dam. The road started at the head of Bolinas Lagoon near WIlkins Ranch and followed an easy grade near Wilkins' southern boundary to the summit of the ridge, then down to the aforementioned creeks, and on to San Rafael via Ross.[6]	6
1878	X		X											Olema Items - As we write, the rain is pouring down in torrents. Our roads are almost impassable. Being built along steep hillsides, the earth is constantly sliding in and in some instances the roadbed itself is included in the slide. Then the rapidly formed streams, changing their course by being clogged with debris, cut and destroy the heretofore supposed solid road on the land and a literal slough is formed. Heavy caves all along Olema creek have widened the bed fully three times its former width and village lots are going toward the bay, while every day house moving is in order to preserve them from the general destruction (Marin Journal, 21 Feb. 1878).[14] Much of this loss was caused by a cloud burst, which occurred on Sunday, two or three weeks ago. The shower lasted less than twenty minutes, yet over three inches of rain fell. On the broad sides of hills, the water was six inches deep, not in places, but everywhere and the ravines, where centered the flood from different directions, were washed out bodily and turned into these yawning and unsightly chasms (Marin Journal, 7 March 1878). The water was so high that it was "flowing over and along the roadway" in front of Mr. Ingram's house, located near the head of the Bay on the western side.	14
1879	X												X	Olema--The storm of last week was by far the heaviest of the season. It rained without a moment's intermission for fully fifty hours.... Olema Creek, which in 1865 was a mere rivulet and as late as 1870, a small brook, is now like a river, its banks varying from ten to fifteen feet in height and almost perpendicular, while the bed has more than quadrupled in width....By reason of these washouts along the creek and the upland, the marsh and delta on the Howard ranch are filling in at the rate of one to two feet each year (Marin Journal, 13 March 1879).	14

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1880									X					According to a local historian "In the days of this pristine forest primeval it was not an uncommon thing to find trees 50 feet in circumference, and the lumber was all first class . . . But it is all gone, naught of it will ever return."[3] *[An 1880 photo shows Wilkins Creek in the foreground near theWIlkins barn. The creek appears to be in a ditch that is bare and eroding. It completely lacks vegetation. Today, the spot where the picture was taken is in a willow forest. The ditch has clearly incised and eroded its banks since the 1880s. In the background, sections of the hills west of Lewis Creek have been cleared of trees for pasturage.]*	3
1881								X		X			X	Wilkins is awarded a grant to construct the San Rafael Bolinas Road that took an unplanned route through the Wilkins property in 1878.	6
~1884								X					X	Wilkins loses two fingers while building a bridge at his ranch. In 1884 the County changed the route of the San Rafael Bolinas Road to pass through Fairfax for a saving of mileage. This road, now called the Fairfax-Bolinas Road has changed little on the west side, except for a widening of about 12 feet and paving.	6
1887	X							X						On the Bolinas road a bridge near the Wilkins spring was carried off during excessive rains in February 1887 (Marin Journal, 17 Feb. 1887).	14
1890						X								Fire was a consideration in summertime. Flames laid to waste the grasslands on Wilkins Ranch, and the stage driver was obliged to leave the road, sliding down the naked ridge, thirteen bridges burned.[3] The fire crossed the Bolinas and San Rafael road, destroying eight bridges. All the feed on the Wilkins ranch was "licked up" and smoke was visible in San Rafael with some reports that the flames could be seen at night.	2, 3, 14
1894	X		X							X				Wilkins was milking about 80 cows at this point. The power for the modern refrigerator is all supplied by a water powered generator, which also ran the separator and the sawmill. Later the system powered electric milking machines and lights in the house and barns.[6] The Storm....Heavy Landslide at Bolinas....On Monday James Hayes brought information from Bolinas to the effect that a heavy and serious landslide had occurred at that place on Friday morning at 2 o'clock in the vicinity of the point, doing a vast amount of damage.[14] Mr. A'Dean's house was completely wrecked, and also the house of Albert Sayers....Mr. Wheeler's house was carried forty feet by the slide and now stands in the public highway.[14] The barn of Mr. Stump was badly wrecked and Mr. Sheagreen's house badly damaged.[14] The roads between San Rafael and Bolinas being practically impassable, Hayes was obliged to bring the mail on horseback... .(Marin Journal, 25 Jan. 1894).[14]	6, 14
1895												X		A prospect shaft was sunk at Copper Mine Creek (formerly called Union Gulch), revealing a 12-foot veins of sulpherets of copper and iron. 50 tons was taken from the mine.	6
1900							X		X	X		X		Copper Mine gulch was leased again by Wilkins to Wildcat Pearson but mine had poor results. Wilkins Ranch was producing 2,250 lbs of butter per month from 64 cows. Eventually the number rose to 125.[6] For the Bolinas Township in 1900, no person listed his occupation as lumber or logging related.[14]	6, 14
1897-1901										X			X	*[1897-1901 photo of Wilkins Ranch shows the pasture nearly due south of the Wilkins Ranch house. There does not seem to be any trees or apparent channels within the plowed pasture. This does not preclude that sedge might have been growing in the low areas.]*	
1901										X				W.W. Wilkins at the head of the Bay had 64 cows. For Bolinas, sixteen dairies, ranging in size from fewer than 20 cows to 75, were listed, totaling about 760 cows.	14
1902										X		X		1 mile NE of Dogtown. Wilkins leased mining rights to Thomas Whitelaw who imported machinery to extract ore from the old Union shaft. He promised to build a fence high enough to keep Wilkins cattle out of the diggings. the property.	2

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1904						X		X				X	X	1904 Wilkins drove wildcatters ("Wildcat" Pierson who was given the property by Whitelaw) off . Ridgeland flames got out of control in 1904 . . . .[2] A fire similar to 1890 occurred in 1904.[6] It destroyed bridges and culverts on the Fairfax Bolinas Road.[6] This fire burned over the northeastern side of the bay from north of the Wilkins Ranch through the ranches of Bourne, Weeks, and Morse to the Stinson place at the southeastern end of the bay and from the bay's shores to the ridge. How intense the burn was in the canyons is unknown, but "not a blade of grass" remained on the prairies.	2, 6, 14
1850-1906		X												Sedimentation rates in the lagoon were 12 mm/year for the period 1850 to 1906.	16
1906														Due to the earthquake the cattle run at the slightest sound.[2] Unless they calm down their milk season will end earlier. Eucalyptus trees near Woodville on Sam McCurty's property were reported by the State Earthquake Investigation Commission to be offset 10 feet.[2] Landslides had blocked roads everywhere. The San Andreas Fault across Pepper Island (later Kent Island) had been easy to trace because the vegetation on both sides of it had acquired different colors.[2] The ground east of the trace is depress about 1 foot, and this depression has so changed the relation of certain plants to the tides that they now find the conditions of life unfavorable and are dying out."[2] The fault passed under the sand spit and thence to the ocean.[2] *[1906 photo of the head of the lagoon shows that the area of the future triangle does not have any trees growing in it. Pilings from the lighter wharf can still be seen along the northwest side of the head of the lagoon. The delta that presently exists along the ditch outlet of Lewis Creek is not apparent.]* The earthquake started a number of landslides. A few of these were on the line of the fault, especially where its trace intersected a cliff facing Bolinas Lagoon. Others were from cliffs of earth or weak rock bordering the ocean, one of the bays, or a creek.[13] Dr. Southworth has found that navigation improved in the lagoon, the water being deeper than formerly, for the same normal state of the tide, and this observation is confirmed by Mr. Morse, who now at high tide sails over a portion of McKennon Island which could not formerly be crost by boat.[13] It will be observed with all this testimony , with the single exception of Mr. Morse's observation of water levels near his house, tends to show a general sinking of the land east of the fault, and a general rising of that to the west of it.[13]	2, 13
1906														It may be possible that the area of subsidence is limited on the northeast [side of the lagoon] along an old line of dislocation which coincides approximately with the northeast side of the lagoon.[13] This dislocation has not been determined by a study of the geologic structure, but is indicated by the physiography, and was presumably concerned in the making of the basin occupied by the lagoon.[13] The trend of the fault trace on Pepper Island [Kent Island] is N34oW, and if continued would bring the trace to the shore at the head of the lagoon, but its actual position on the mainland is farther west, indicating that there is either a swerving or an offset in the part not seen.[13] Near the shore the fault occasioned a number of landslides which obstructed the road until removed; and beyond the road occasioned by the landslides the trace consists of a number of sub parallel cracks occupying a belt of several yards in width.[13] There is also a nearly parallel branch of the trace of the fault-sag lying a little farther west, but this could be followed only a short distance, and has since been largely obliterated by plowing.[13]	13

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1906			X		X					X				Mr. Nunes, who cultivated this sag, states that it once continued a pond or marsh, and this he had drained, but the water stood there again after the earthquake, showing that the earthquake had caused the depression of the bottom of the sag.[13] The diffused cracks on the main line soon gather and descend into a narrow belt and descend into a narrow sag [this is probably Lewis Creek], containing the barn and other buildings of the Steele place *[property boundary along the northwestern shore and northward of the head of the lagoon]* .[13] After following the sag for a short distance, the trace intersects one of the roads leading from Bolinas to Woodville and immediately begins to ascend the narrow ridge bounding the sag *[wet depression]* on the east.[13] Crossing this ridge obliquely, it *[the fault trace]* skirts for 0.25 mile the western border of a much larger sag, in which the water of Pine Gulch Creek gathers before it enters the canyon from which it is named.[13] This wall it descends obliquely, and, just before entering the bottom of the sag *[probably Pine Gulch Creek watershed]*, intersects and offsets a line of eucalyptus trees marking a township and property boundary.[13] The ridge phase *[of faulting behavior]* dominates in this region, and near the line of eucalyptus trees the trace itself has a small offset to the west.[13] Now for nearly half a mile the trace follows a valley bottom, being divided along the way by two or three branches.[13] Back of the Steele place near the north end of the bay, the hillside started eastward toward the bay, bulged upward and cracked into several fissures from thirty to a hundred feet along by from five to eighteen inches wide.[14] In the bay opposite the hillside on the Steele place, the bottom has risen into a long island, near which the bottom of the bay has sunk so that the water is now ten feet deep where muddy shoals formerly extended.[14]	6, 13, 14
1914											X		X	Commercial electrical power from Marconi Wireless Telegraph Company is delivered to the Wilkins Ranch area. *[Does this mean that water or at least the same amount was no longer diverted?]*	
1917												X		Copper Mine Gulch active again under Chetco Mining Company.	6
1918												X		A total of 22,500 lbs of ore was removed during the two years of mining. Then it ended but the road from Dogtown to the site can still be traced.	6
1920										X				Butter is no longer produced at Wilkins Ranch. Next generation of Wilkins family sold chickens and vegetables to supplement meager income. Two orchards of apples and pears had been established.	6
1921	X													The Christmas storm of 1921 resulted in thousands of dollars in damage. Scores of trees were uprooted, roofs were blown from buildings, poles and wires were torn down, and windows broken. Flooding caused considerable damage (Independent Journal, 29 Dec. 1921).	14
1923						X								identified as “Mann’s Greatest” swept thousands of acres in the fall.[14] All four of these fires [1890, 1904, 1923, 1945] burned through Wilkins Gulch and with the possible exception of the 1923 fire, along the southwestern face of Bolinas Ridge above the Bay.[14]	14
1925	X		X					X						A storm in February 1925, described as the “heaviest wind and rain storm in years,” caused damage in Marin County estimated at over $330,000.6 Heavy rains caused washouts and landslides, delaying for several days Northwestern Pacific Railroad service and causing streams to overflow and drainpipes and sewers to become clogged.6 The road from Bolinas to Willow Camp (Stinson Beach) was under “water and slush” (Marin Journal, 12 Feb. 1925). Damage at Bolinas was minimal, although a high tide and four-inch rain flooded the Presbyterian. . . (Marin Journal, 19 Feb. 1925).6	6
1928								X						In October 1925, a bond election . . .for $5,500 for the Bolinas Road to Dogtown (Marin Journal, 18 June 1925; 1 Oct. 1925).14 Road building was delayed until James Currie got the contract, as well as the contract for grading and graveling five miles of the Olema-Bolinas road (Marin Journal, 19 Jan. 1928).14	14
1943													X	*[Aerial photograph indicates that there we multiple ponds/wetlands at the Stage Coach gulch area that used to be tidal marsh. Much of the area west of the Highway 1 crossing, that used to be tidal marsh is now probably a mixture of brackish to freshwater. Wilkins Creek does not seem to have the extensive patch of willows at its downstream end near where it crosses Highway 1 and Fairfax-Bolinas Rd.]*	12

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1945						X						X		In the fall of 1945, the "worst fire in the history of Marin County," burned . . . . . A huge fire in 1945 burned from Stinson Beach almost to Novato, taking much of the Wilkins Ranch and Timber. The remaining structures at the Copper Mine were destroyed. it appears that the northeast side of the Bay was again burned, as the fire moved down the state highway from Olema to Stinson Beach.[14]	6, 14
1950's									X					Kenneth Wilkins family went into the firewood business cutting oak, bay, and fir cordwood on the hills of the ranch.[6] *[Some eroding banks can be observed on the outside bends of Wilkins' Upstream of the fence line near the barn.]* [12]	6, 12
1952?												X		Copper successfully mined from Woodville.	2
1954								X						*USGS 1954 7.5" quad still shows only the old Hwy 1 connector and the pasture at Wilkins Ranch is still intact.*	
1955	X		X					X	X					The last sawmill in the area was in Palomarin run by the Golden Rule Church (see Idependent Journal, 20 August 1955).[6] The Independent Journal accounts of the 1955 storm were extensive and included photographs. The first report appeared on December 19 with headlines reading: "Worst Storm in 30 Years Hits Here; Rampaging Winds Wreak Havoc; High Water Inundates many areas."[14] Damage in the Bolinas area was generally to roads. Ten-year resident Hurford Sharon said the storm was "one of the worst" he had seen at Bolinas (Independent Journal, 19 Dec. 1955).[14] A slide closed the road at the end of Bolinas Bay....Streets in Bolinas were partly flooded (Independent Journal, 19 Dec. 1955).[14] The road from Stinson Beach to Bolinas was still closed this noon as state highway road crews worked to clear dirt, rocks, and debris that blocked the highway at several points just north of Stinson Beach. The only way to get from Stinson to Bolinas today was via Olema. The slides started yesterday (Independent Journal, 21 Dec. 1955).[14]	6, 14
1956	X		X											This storm caused minor damage at Bolinas, but soils were saturated and when the area was hit with a severe storm in January 1956, major damage resulted. The word often used to describe this storm and its effects was "mud," and tons of it. State Highway 1 was closed by slides. The Division of Highway sent out a timber crew to deal with a huge slide near Bolinas. Fourteen trees came down into the roadway and were found standing in a "mountain of ooze." The timber crew had to cut and haul away the trees before the bulldozer could plow away the mud. One highway crew had to work constantly just north of Bolinas, where a "steady flow of mud" kept the road closed near the Oyster House restaurant *[at the end of the old T at Bolinas Y]* .	14
1956-1958?									X				X	*[An extensive storage pad made from land fill has been constructed along the northeast edge of Old Stage Gulch. Cannot tell what is being kept at the area. Perhaps materials to construct the Highway 1 extension through Wilkins property or repairing the road after the damage from the a956 storm or the slide near the oyster house? Low growing vegetation is starting to grow in the wetter low ground areas of the triangle at the Wye. It looks like there might have been a structure in the triangle directly across from a building that is located at the intersection of Old Hwy 1 and Bolinas-Olema Road.]*	17
1957														*[Possible date of Highway 1 extension through Wilkins Ranch]*	18
1959									X				X	*[1959 photo shows the extension of Highway 1 through Wilkins' ranch and a concrete culvert beneath Stage Coach Gulch Creek. The extensive willow grove upstream of Highway 1 on Wilkins Creek is not present. An inboard ditch paralleling Highway 1 along the Wilkins property and the "double ditch" system draining the Wilkins Ranch can be clearly seen. The alder forest in the triangle section of the Wye is still not present. Lewis Creek can be seen draining from the ditch along the Olema-Bolinas Road. It has created a distinct sediment delta downstream of its culvert outlet. The tributary behind WIlkins barn is gullied. The tidally influenced pond east of Highway 1 in Salt Creek watershed is much larger than its present day footprint and there are minimal willows in the area.]*	12
1960's										X				Dairying ends at the Wilkins Ranch	6

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1964	X		X											The newspaper accounts of the ‘64 storm began on December21 with reports of power failures and minor flooding (Independent Journal, 21 Dec. 1964).However, the following day’s account reported heavy rainfall and thousands of people fleeing coastal flooding (Independent Journal, 22 Dec. 1964). Mann entered the fifth day of the storm with 12 inches of rainfall and mud was beginning to “ooze” off steep hillsides (Independent Journal, 23 Dec. 1964). Things eased up a bit over Christmas, but rain continued to fall and soils became saturated. New Year’s Day was the 15th consecutive day of measurable rain in Mann County, bringing December’s total to 12.22 inches, the heaviest since 1955, when 22.88 inches fell during that month. Of that 12.22 inches, 11.88 fell during the last fourteen days of the month (Independent Journal, 31 Dec. 1964). The rains returned in early January. The Mann Municipal Water District reported storing two billion gallons of runoff in five days and its lakes were flowing over their spillways (Independent Journal, 5 Jan. 1965). Mud slides, downed trees, high tides and flooding plagued the County. After three weeks of wind and rain, cleanup crews were finally able to get ahead of what some experts called the “thousand-year storm” (Independent Journal, 8 Jan. 1965).	14
1968													X	*[Gullying on tributary behind Wilkins barn does not appear to be as active and looks like vegetation is starting to take ahold. Also more low growing vegetation is starting to appear in the Wye triangle area and Wilkins Gulch Creek upstream of Highway 1.]*	12
1970											X		X	Wilkins ranch sold to Charney who transforms the ranch into a communal living experiment in creative agriculture and living. They worked an organic garden, grew crops, boarded horses, and rehabilitated the old water system carrying water from Lewis Gulch to the ranch system.	6
1973			X										X	The road to copper mine gulch is obliterated by fallen trees and slides, and the shaft itself is full of water. Tiny railroad tracks are twisted and rusty, a remnant of the ore cars that came and went a half a century ago.[2] Wilkins Ranch is transferred to the Point Reyes National Seashore.[6]	2
1978	X													The January and February storms of 1978 resulted in damage in Stinson Beach and Bolinas, not so much from water and mud coming from the hillsides, but from high tides and heavy surfs (Independent Journal, 11 Jan; 1978; 7 Feb. 1978).	14
1982		X						X						Mary Tiscornia believes that siltation as a result of the flooding in 1982 killed some of the oak trees near the Wilkins house.[6] Bolinas Bay flooded the highway between Stinson Beach and the Bolinas Y, leaving the pavement covered with debris. Rainfalls were record-breaking (Independent Journal, 5 Jan. 1982; 6 Jan. 1982).[14]	
1997	X													Memo from J. Pearson indicates coastal flooding	17
1906-2005		X												The average rate of 7 mm/yr for the period 1906 to 2005 will eventually be reduced to less than 6 mm/year. Byrne's long core analysis *[near Pine Gulch Creek delta]* indicates 9mm/yr. *(Byrne believed the latter rates were higher than most of the lagoon based upon his placement of the cores near the Pine Gulch Creek delta]*	16
2010							X							Approximately 3,700 people live in the Bolinas Peninsula area according to the SFEI 2010 EcoAtlas.	
2015				X										*Extended drought lasting 4-5 years continues through 2015,*	

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	APPENDIX A - SUMMARY OF LITERATURE STATEMENTS														
	PROCESSES							LAND USES						HISTORICAL INFORMATION AND ACCOUNTS	
Year(s)	**Storms**	**Sedimentation**	**Landsliding**	**Drought**	**Earthquake**	**Fire**	**People**	**Roads**	**Logging**	**Dairy/ Ranching**	**Other**	**Mining**	**Stream Changes**	**Notes *[italicized comments represent opinions and interpretations made by Laurel Collins of Watershed Sciences]***	Reference
7	San Francisco Earthquake and Fire of April 18b 1906and their effects of structures and structural materials, reports by Karl Gilbert, Richard Lewis Humphrey, John Stephen Sewell, and Frank Soulé, Washington Government Printing Office, 1907.														
8	1854 Coast and Geodetic Survey t-sheet. Collins' Power Point picture # 24, from: http://shoreline.noaa.gov/data/datasheets/t-sheets.html														
9	1868 Alfred Eskoot's Survey of the Bolinas Lagoon Road in Ref #6 and Collins' Power Point picture #25.														
10	1854 map of Berry Grant for Bethuel Phelps. Located in reference #6 and Power Point picture #27.														
11	San Francisco Estuary Institute's EcoAtlas website: http://www.ecoatlas.org/regions/ecoregion/bay-delta														
12	1943, 1953,1973,1976,1978, 1989 Stereo Aerial Photographs from County of Marin Geographical Information Systems Department.														
13	The California Earthquake of April 8, 1906: Report of the State Earthquake Commission by California Earthquake Investigation Commission, by Andrew Cowper Lawson, published by the Carnegie Institution of Washington, April 1908, V1. Viewed online: https://books.google.com/books?id=1bgQAAAAIAAJ&printsec=titlepage&dq=1908+lawson+quake+report&hl=en#v=onepage&q&f=false														
14	Kirk, Susan V. 2000. Historical Perspectives of Bolinas Bay (Lagoon). Prepared for Tetra Tech for The Bolinas Lagoon Ecosystem Restoration Feasibility Project.														
15	1892 map of Marin County by George Dodge. http://rumsey.georeferencer.com/map/EhKD01PXMg3H2i0ONqOrY9/201502161629-QqFczk/visualize														
16	Byrne, R. and L, Reidy, 2005. Recent (1850-2005) and Late Holocene (AD 400-AD 1850) Sedimentation Rates at Bolinas Lagoon, Marin County, California. A Report submitted to the Marin County Open Space District														
17	Email communication from Jason Pearson, AECOM.														
18	Email communication from Bolinas History Museum														

Appendix B.
Additional Historic Maps and Photographs

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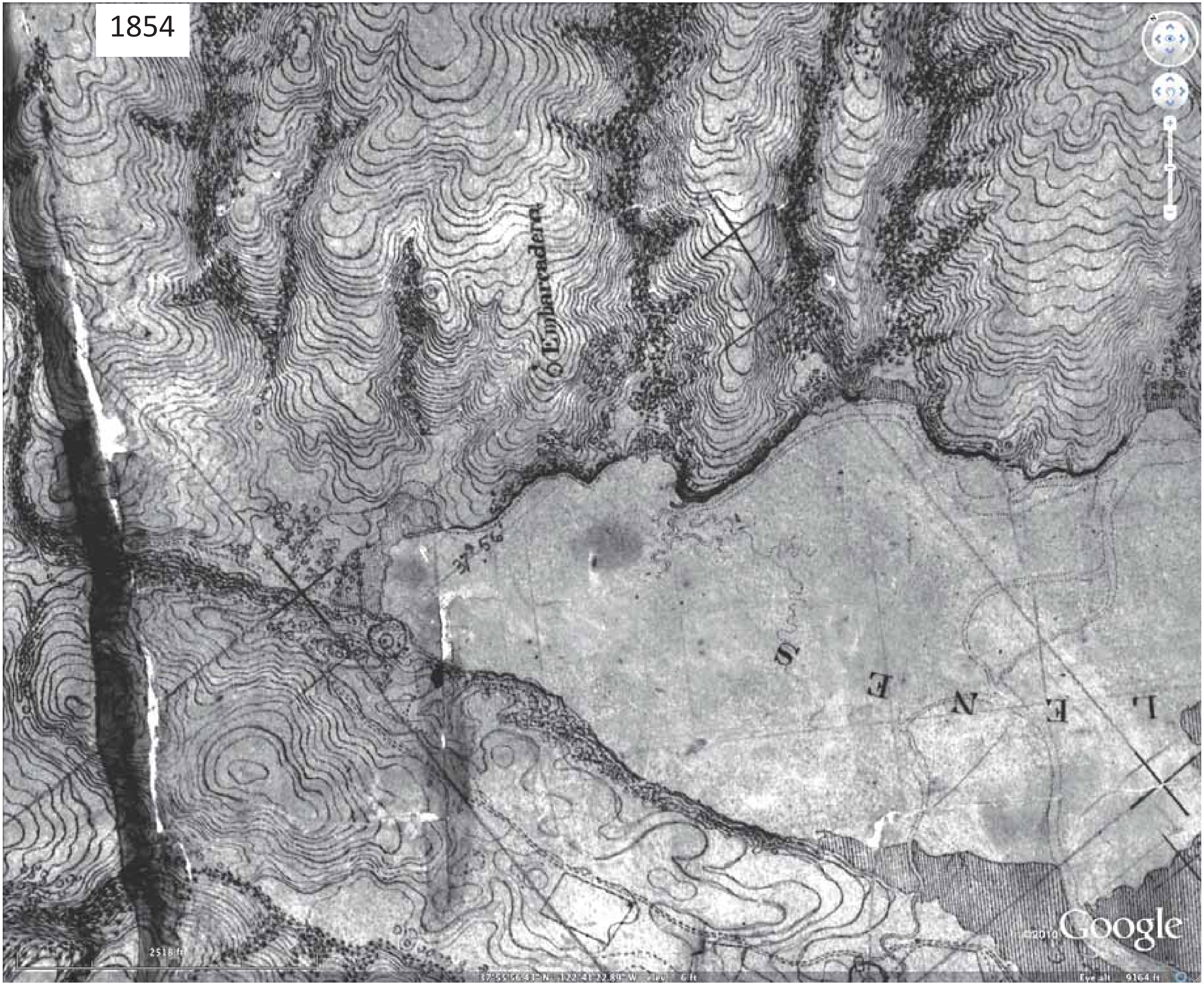
FIG. 28. — Sketch map of Bolinas Lagoon. Broken lines show fault-trace and its branches.

1840s, Diseno Rancho Baulines. http://content.cdlib.org/ark:/13030/hb8w1008dx/?order=2&brand=calisphere?



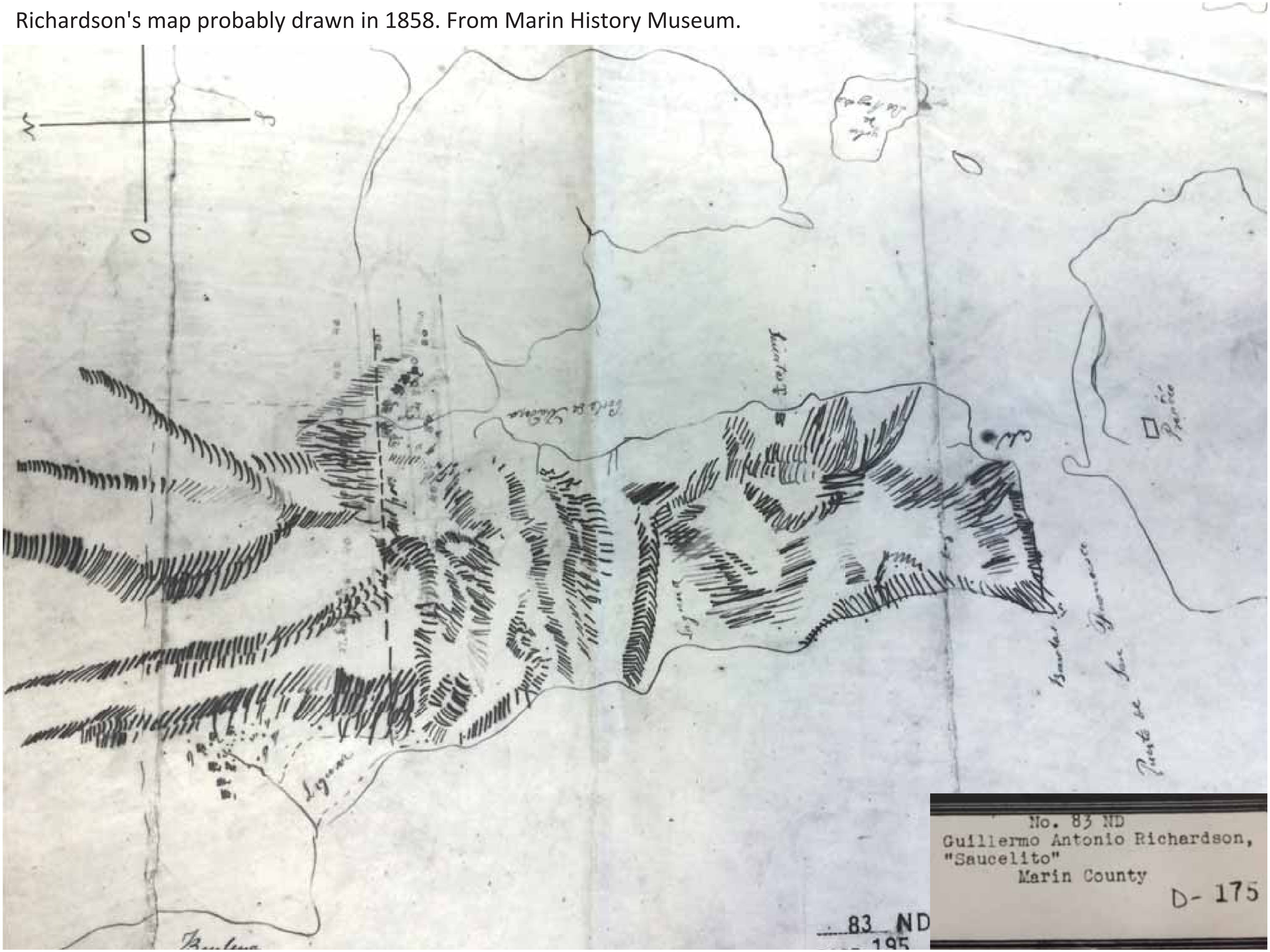
from website: http://shoreline.noaa.gov/data/datasheets/t-sheets.html

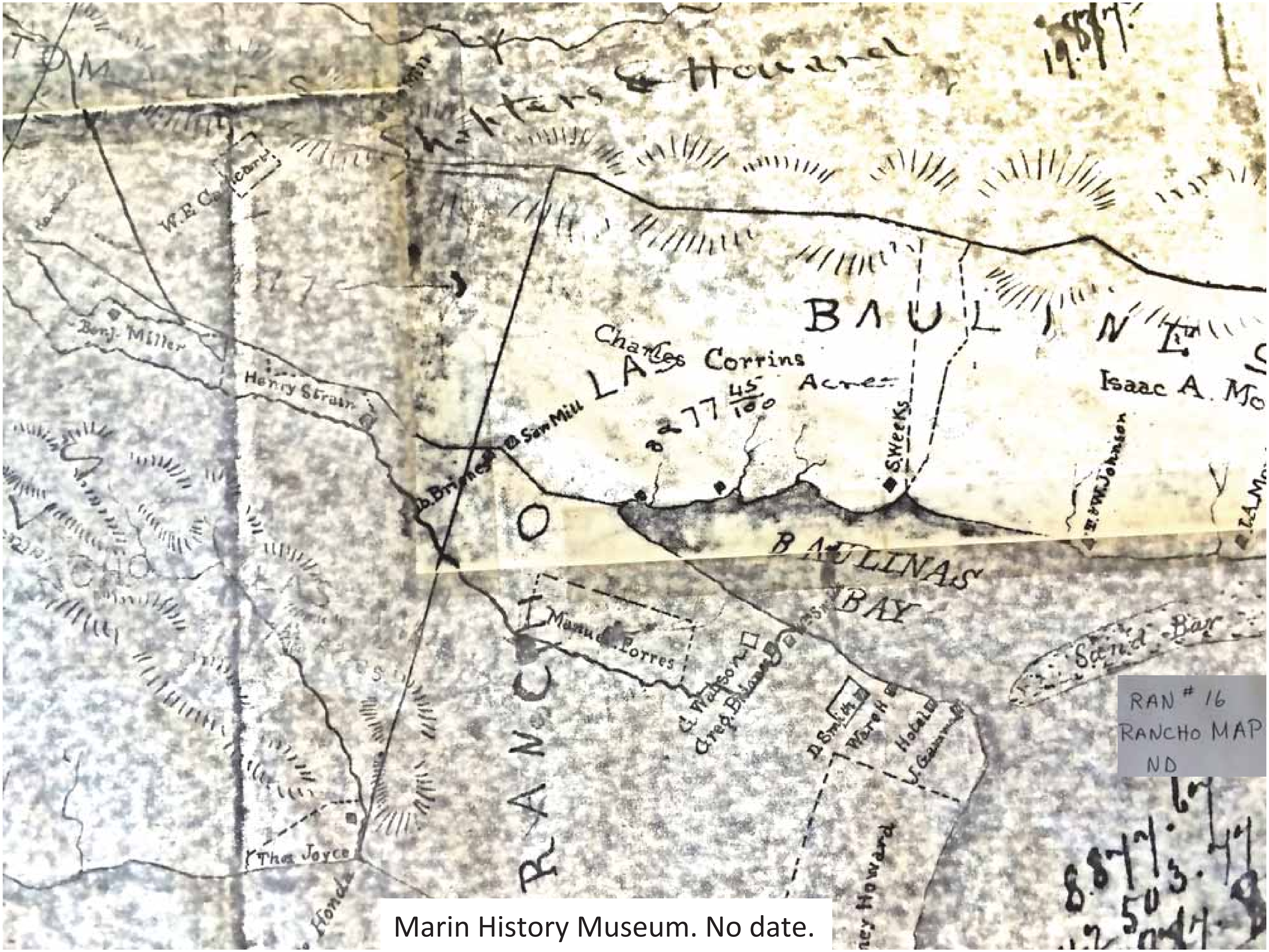
1854

Detail of a map of the Berry grant made for Bethuel Phelps in 1854.
Reproduction in the Point Reyes National Seashore Collection.

Map photographed from: The Good Life: Dairy Farming in the Olema Valley and Lagunitas Canyon, Historical Resource Study, by Dewey Livingston, National Park Service, 1995

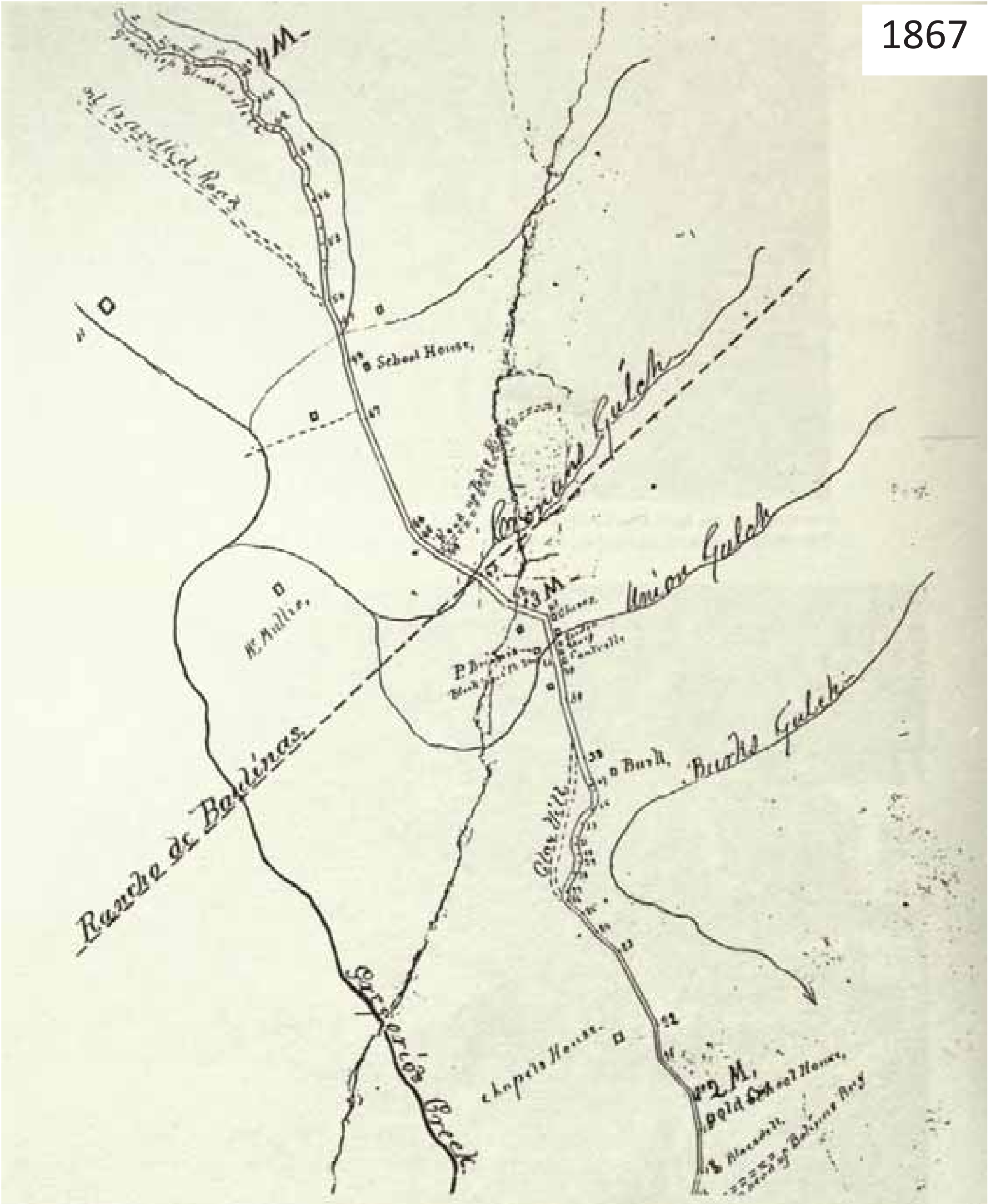
Richardson's map probably drawn in 1858. From Marin History Museum.





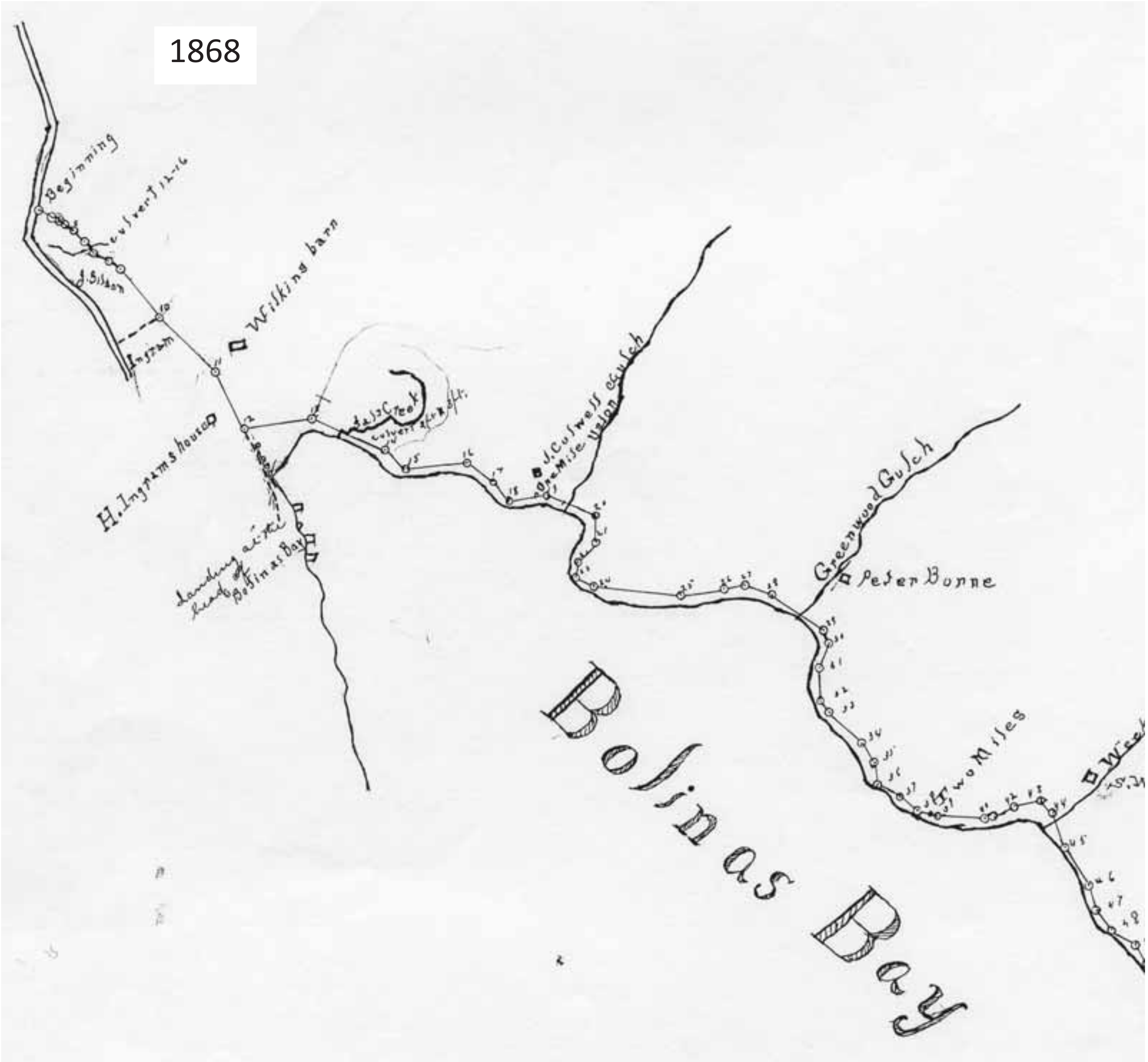
Marin History Museum. No date.

1867



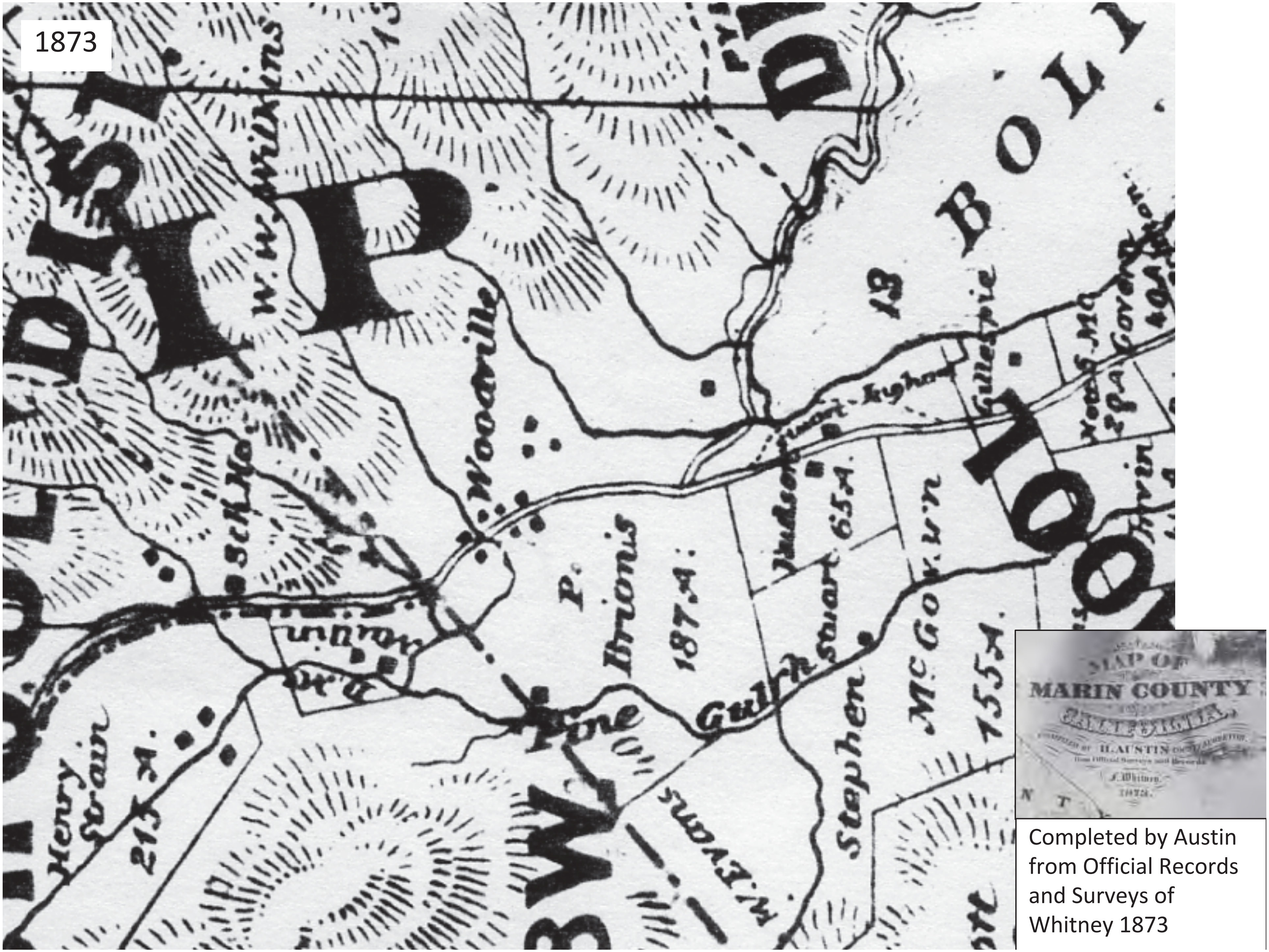
Detail of the 1867 "Plat of the Survey for the relocation of the Road from Bolinas to Olema" by Hiram Austin, showing the area around Dogtown. Note the new grade "up Strain's Hill," the school at the McCurdy Ranch, [David] McMullin's house and the house labeled Burk in what is more commonly called Lewis Gulch on the Wilkins Ranch. *California Historical Society Collection.*

Map photographed from: The Good Life: Dairy Farming in the Olema Valley and Lagunitas Canyon, Historical Resource Study, by Dewey Livingston, National Park Service, 1995



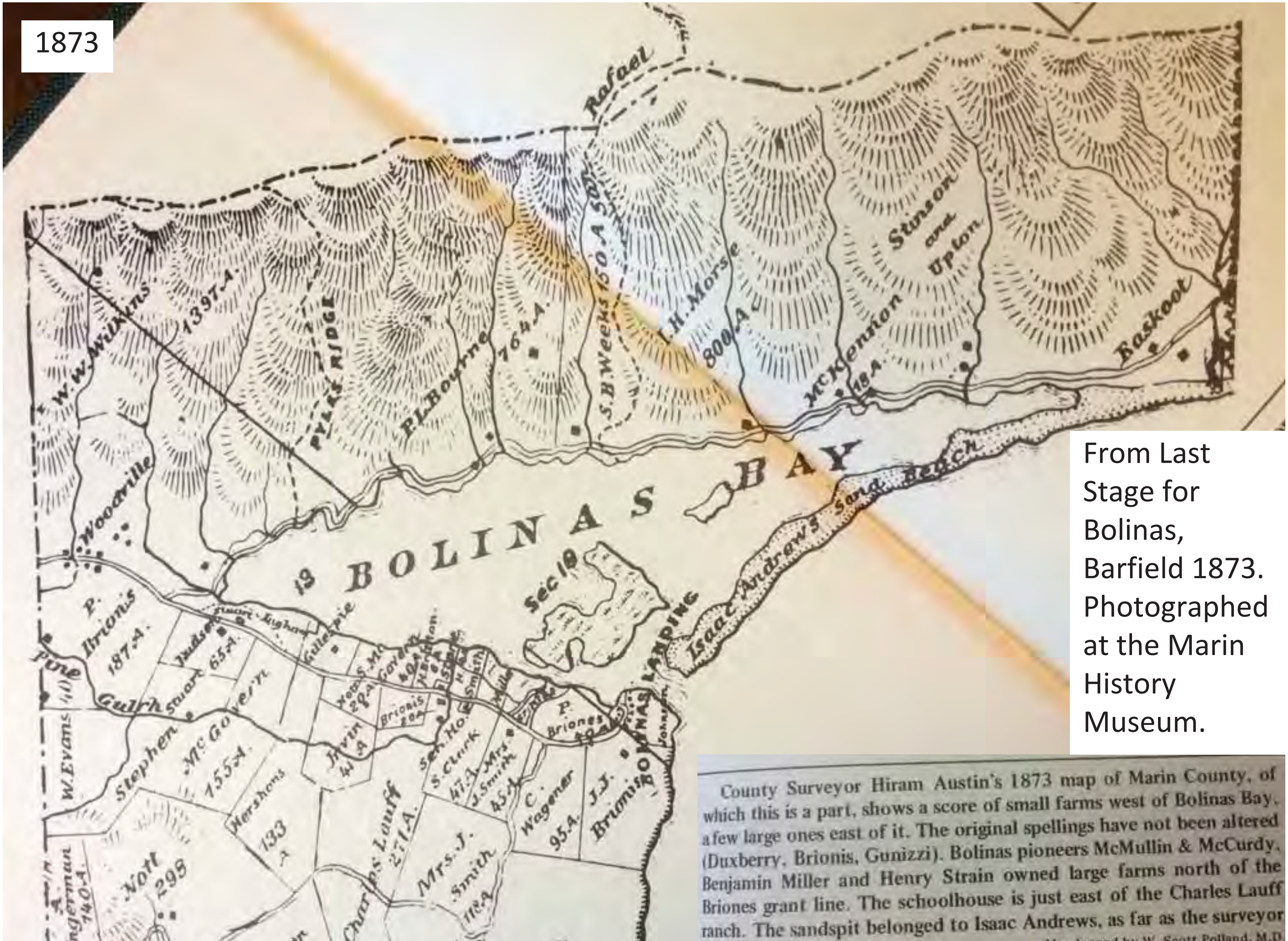
1868 map of Alfred Eskoot's Survey from County Records, from Dewey Livingston

1873



Completed by Austin from Official Records and Surveys of Whitney 1873

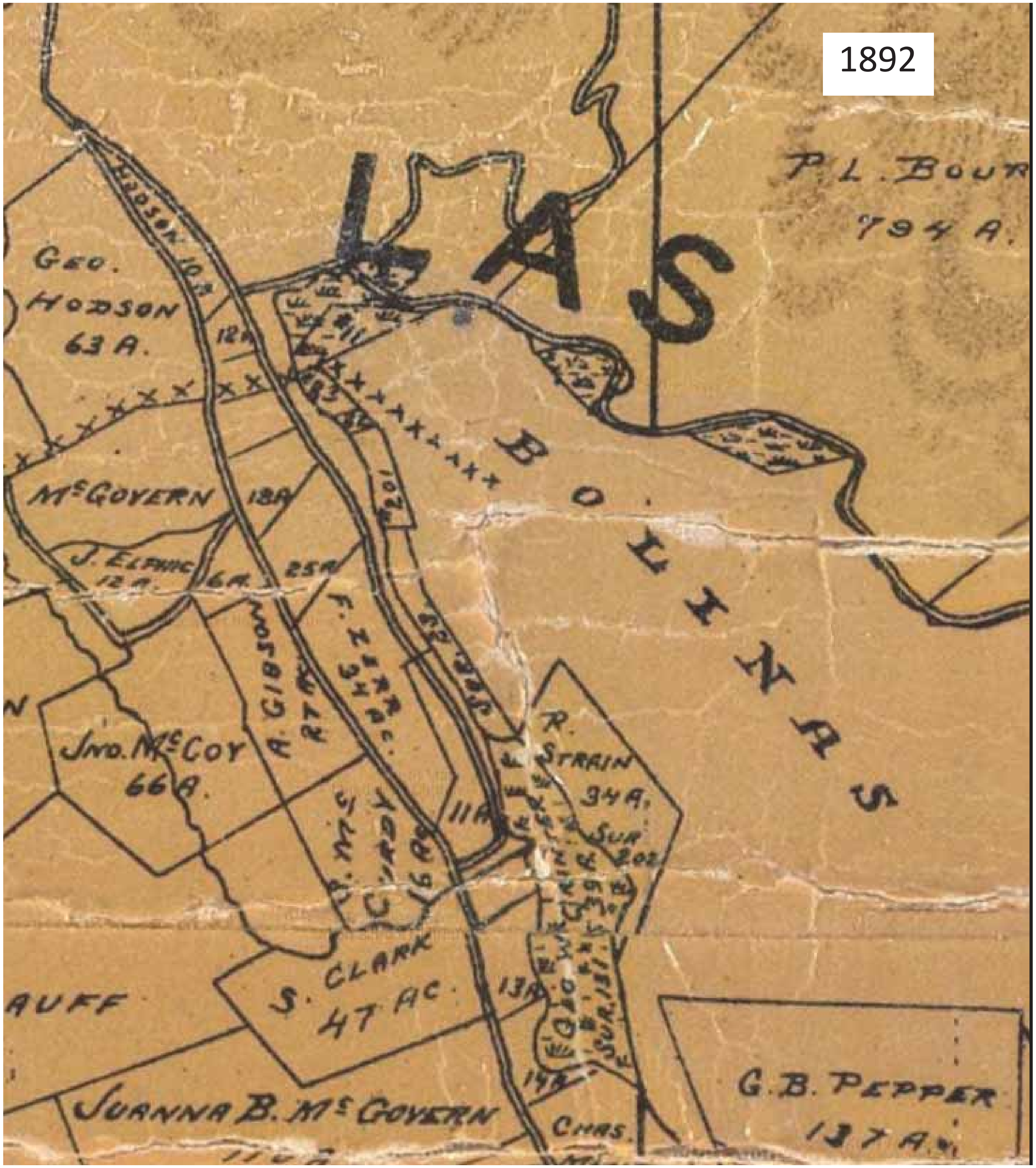
1873

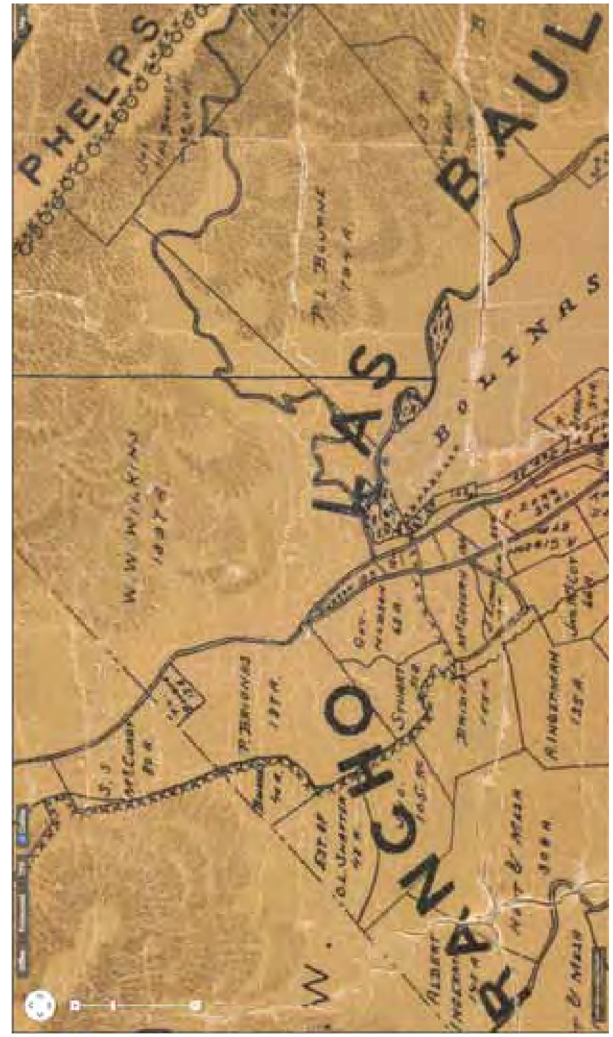


From Last Stage for Bolinas, Barfield 1873. Photographed at the Marin History Museum.

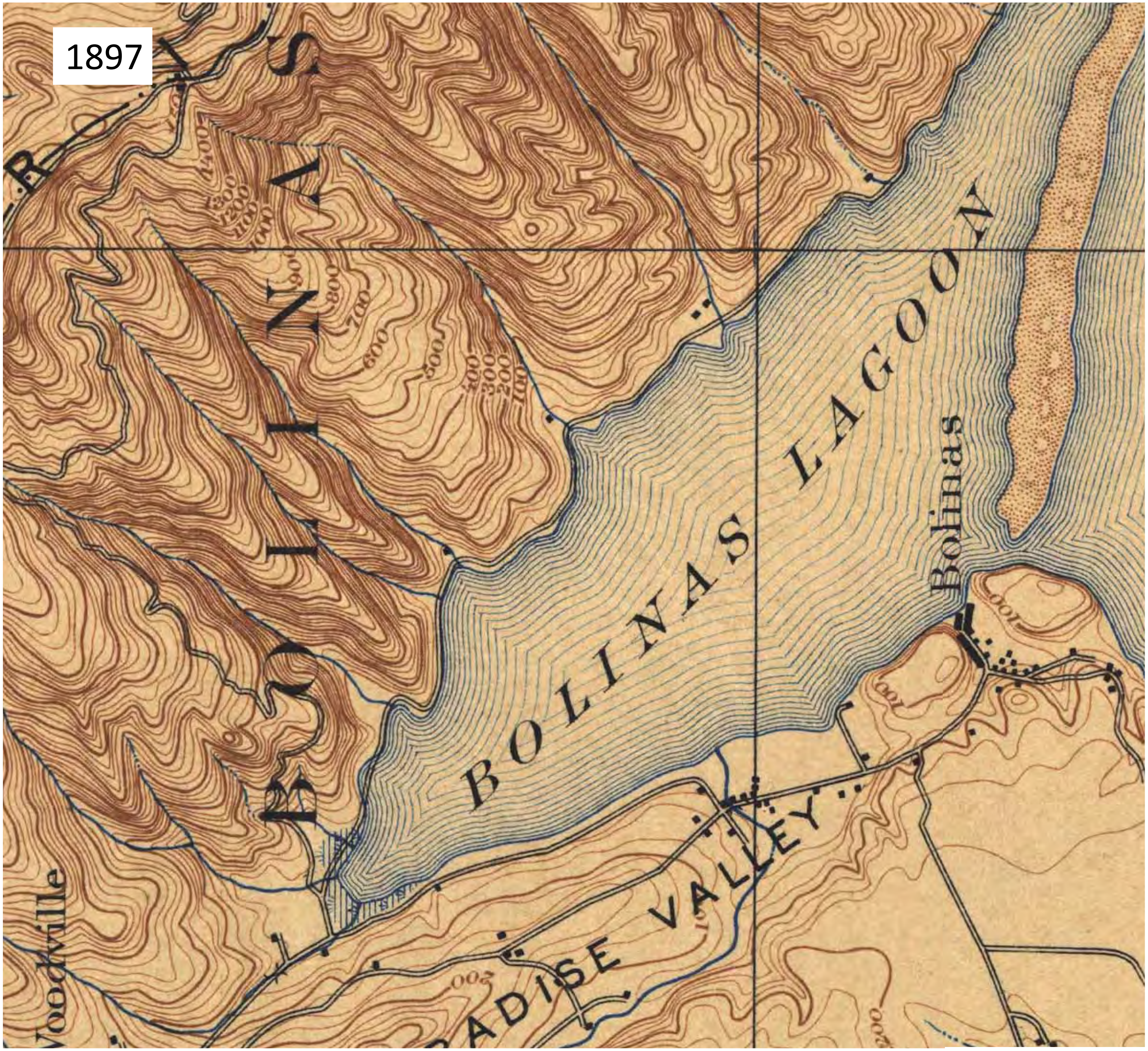
County Surveyor Hiram Austin's 1873 map of Marin County, of which this is a part, shows a score of small farms west of Bolinas Bay, a few large ones east of it. The original spellings have not been altered (Duxberry, Brionis, Gunizzi). Bolinas pioneers McMullin & McCurdy, Benjamin Miller and Henry Strain owned large farms north of the Briones grant line. The schoolhouse is just east of the Charles Lauff ranch. The sandspit belonged to Isaac Andrews, as far as the surveyor was concerned.

Map loaned by W. Scott Polland, M.D.

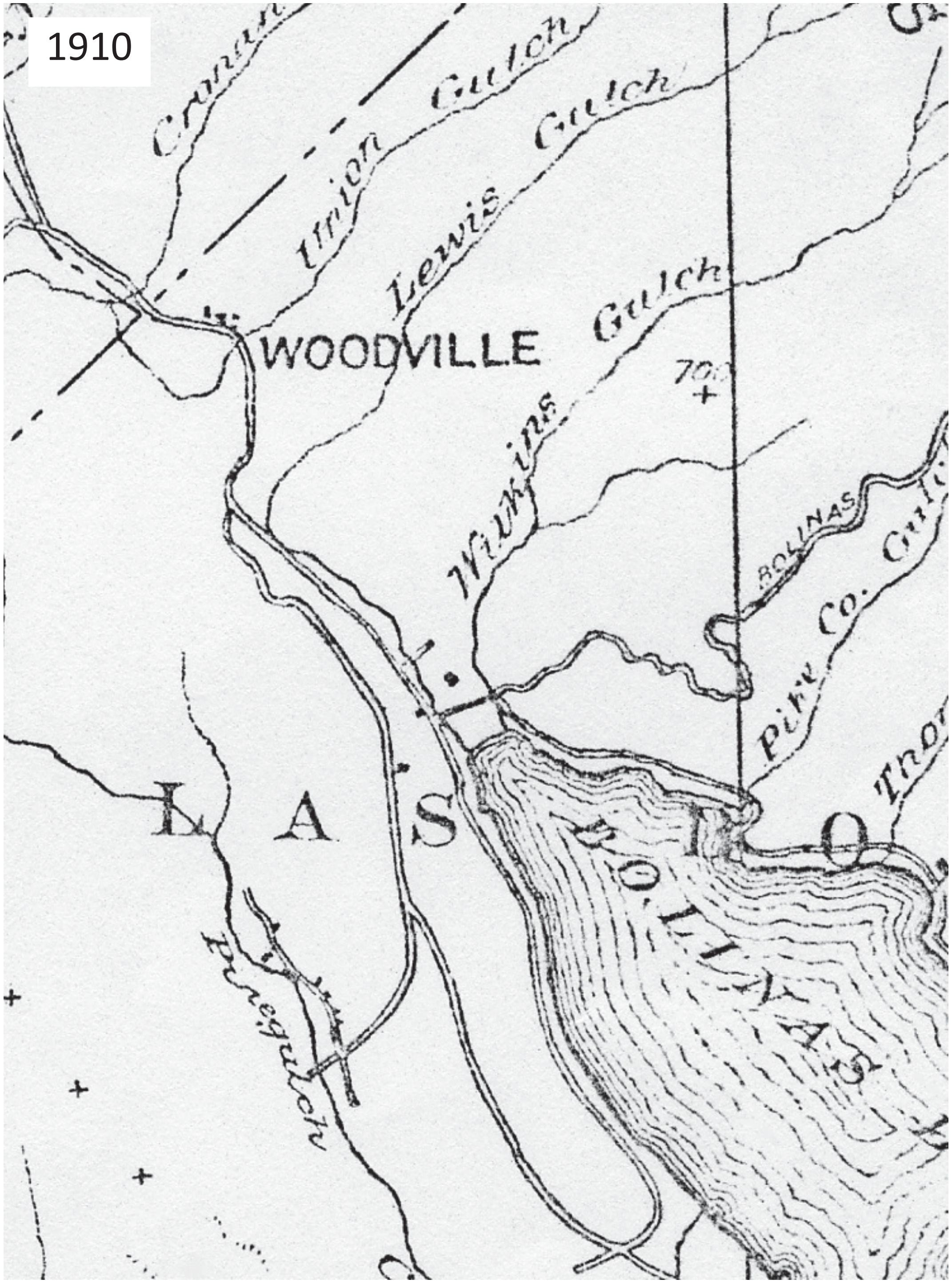




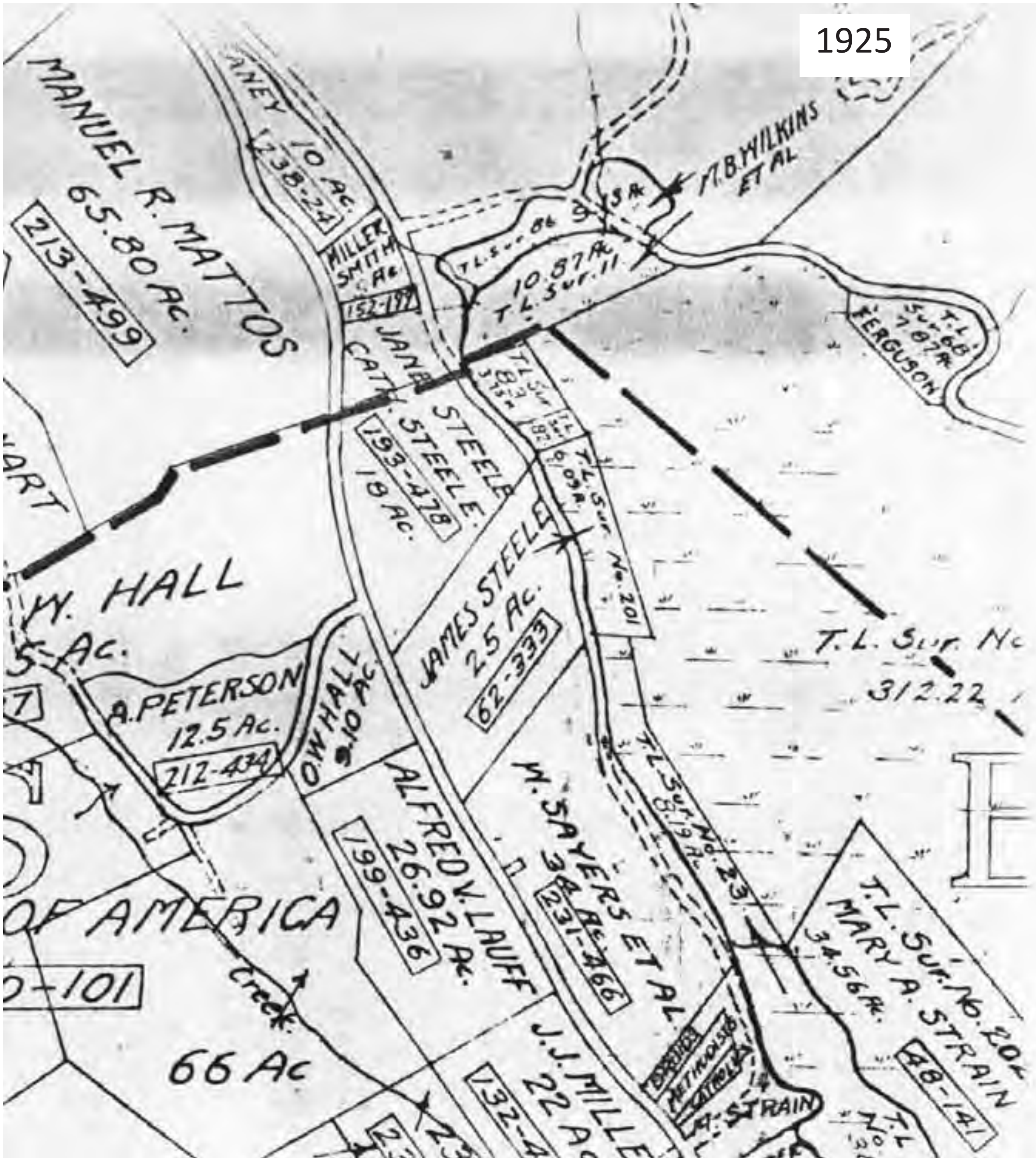
From http://rumsey.georeferencer.com/map/EhkD01PXMg3H2i0ONqOrY9/201502161629-QqFczk/visualize



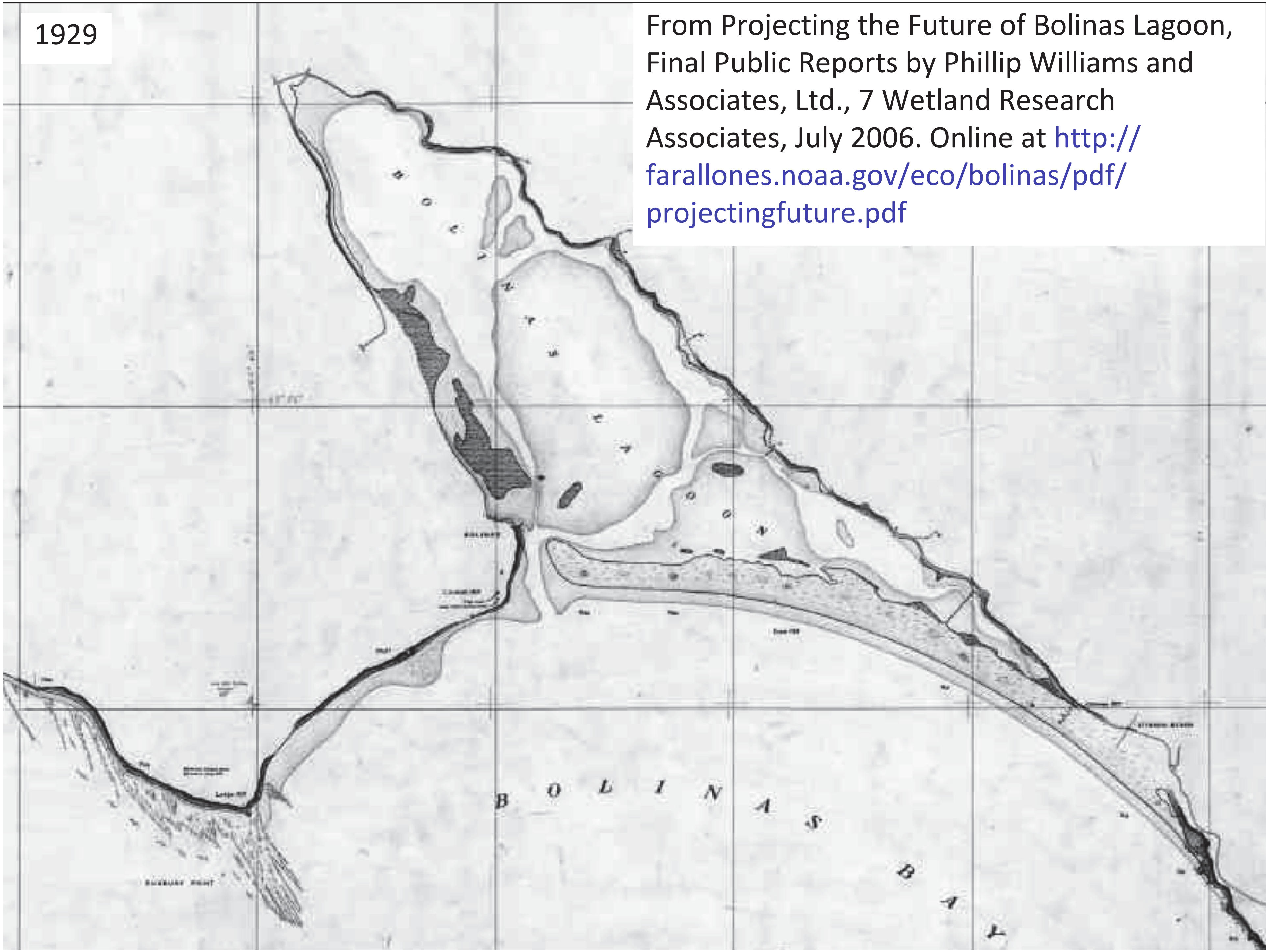
Detail of USGS 1897 15 min Tomales sheet



Denny's 1910 Hiking map from Dewey Livingston.

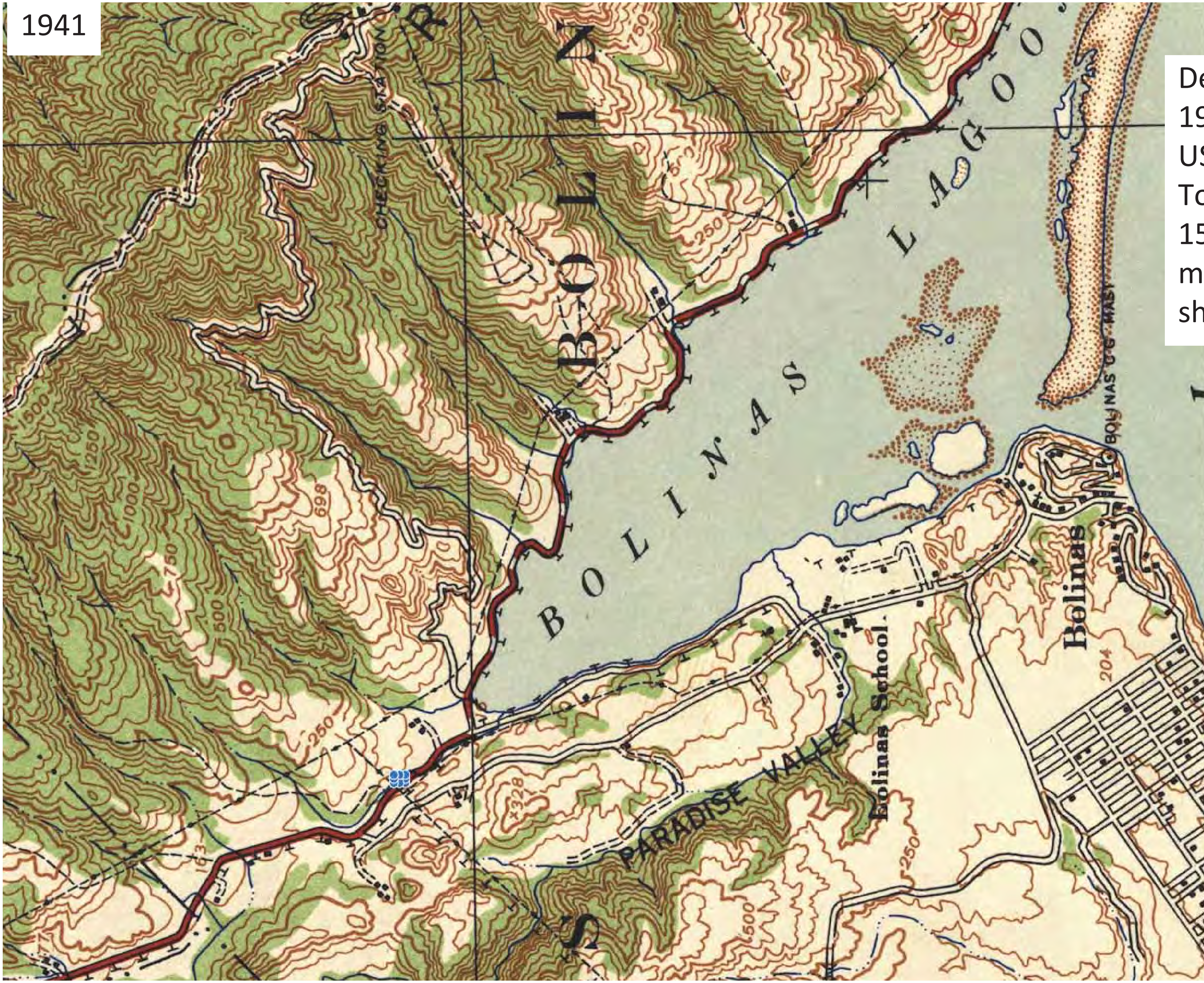


Detail of 1925 County Surveyor's Parcel Map



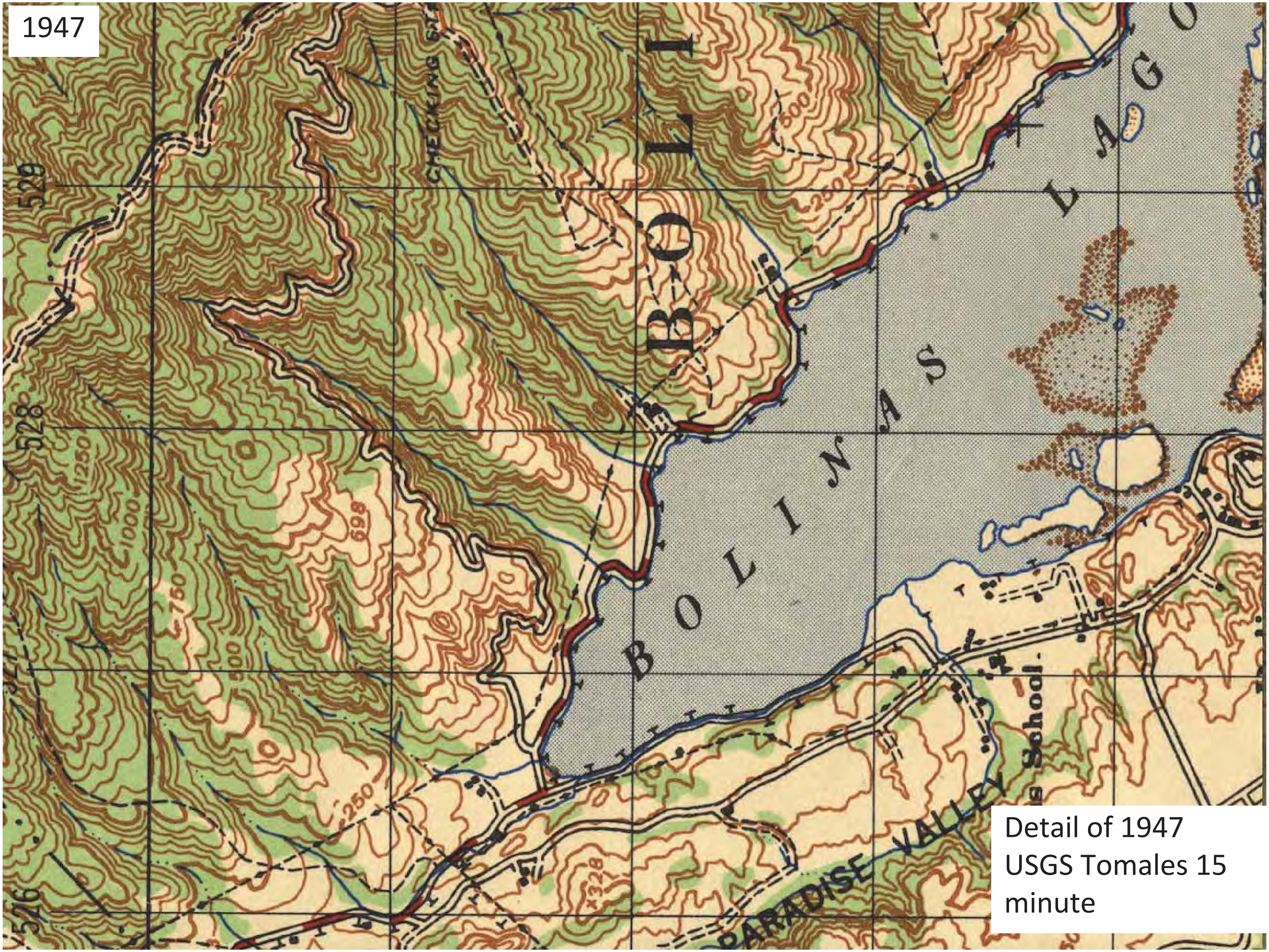
From Projecting the Future of Bolinas Lagoon, Final Public Reports by Phillip Williams and Associates, Ltd., 7 Wetland Research Associates, July 2006. Online at http://farallones.noaa.gov/eco/bolinas/pdf/projectingfuture.pdf

1941



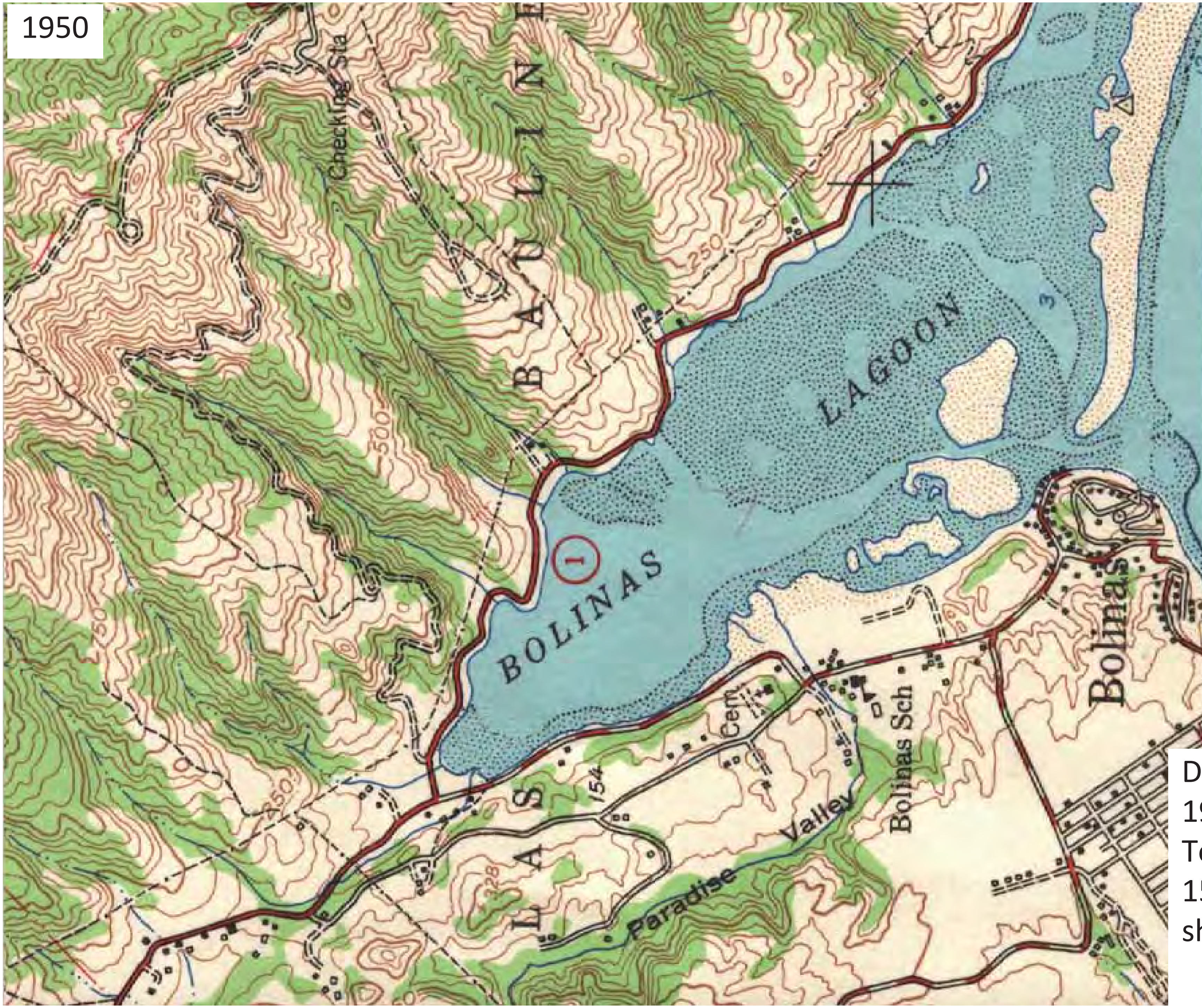
Detail of 1941 USGS Tomales 15 minute sheet

1947



Detail of 1947 USGS Tomales 15 minute

1950

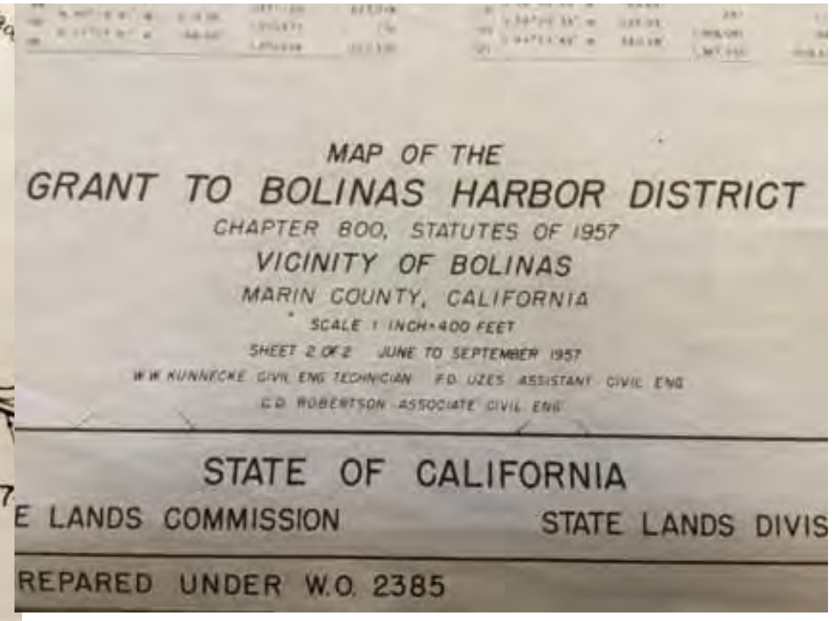


Detail of 1950 USGS Tomales 15 minute sheet

Detail of 1954 USGS Bolinas 7.5 minute quad

Detail of 1971 USGS Bolinas 7.5 minute quad

1957



September 1957, from Marin County Geographic Information System Department

A view to the northwest of the Wilkins Ranch taken around 1945. The implement shed in the center is gone, as is another small barn on the right in front of the milking barn. This photo and the six following were taken by appraiser Farrington Jones of San Anselmo. *Courtesy of Roy Farrington Jones.*

From the Good Life by Dewey Livingston.

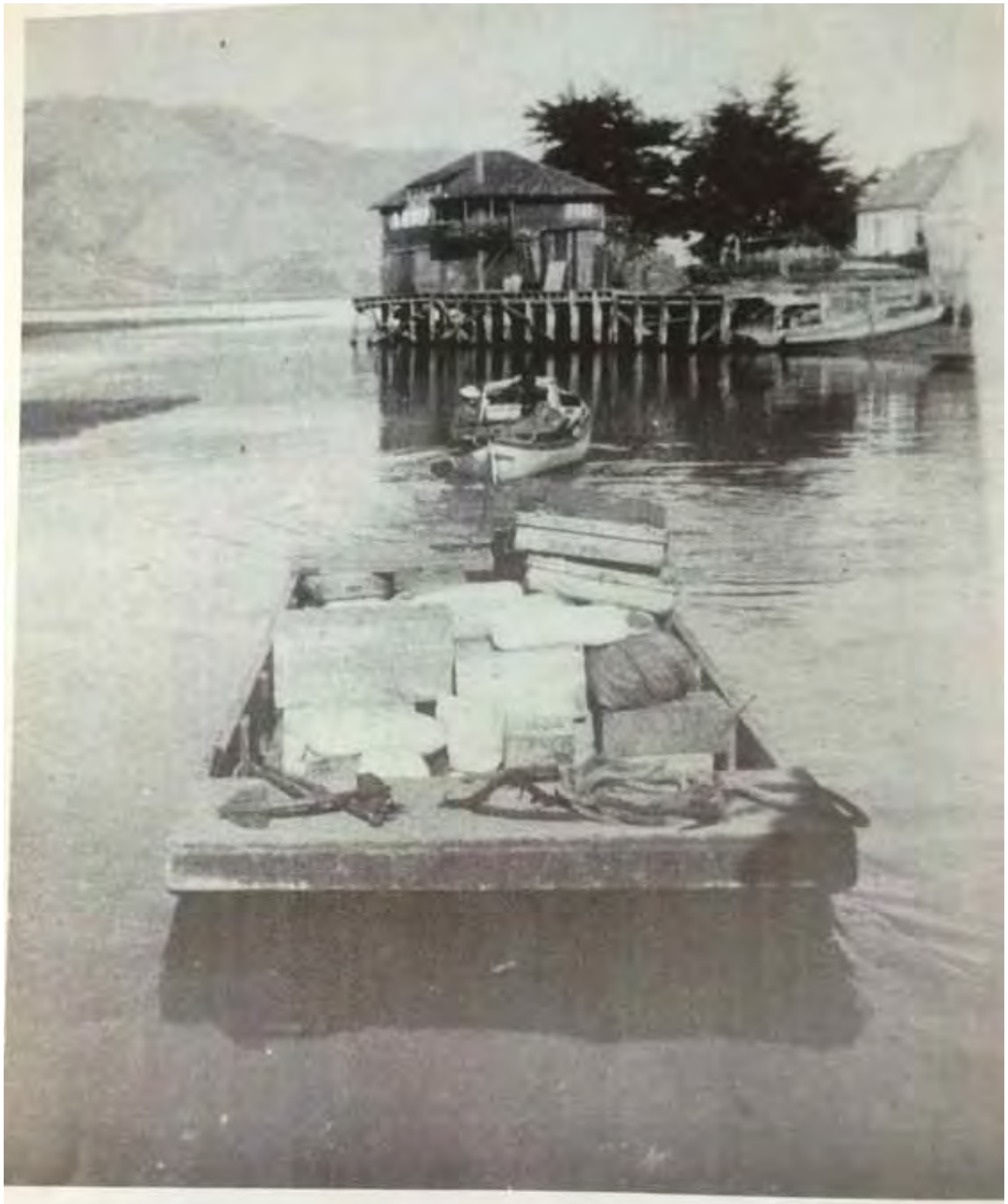
The Wilkins Ranch as it appeared between 1897-1901. *Kate Harlan Collection, Sausalito Historical Society.*

From the Good Life by Dewey Livingston.

1906

From The Good Life by Dewey Livingston.

The Wilkins Ranch appears this 1906 photograph by G. K. Gilbert. Note that the barn has yet to have an addition. Pilings from the lighter wharf can be seen on the left. U. S. Geological Survey Library, Menlo Park.



The Alice F tows a loaded lighter towards the ocean. Note the butter boxes. That's Nellie Waterhouse's studio in background.

From Last Stage for Bolinas, Barfield 1973. Photographed at the Marin History Museum.

Secondary cracks on the shore of Bolinas Lagoon.
From: San Francisco Earthquake and Fire of April 18, 1906 and their effects of structures and structural materials, reports by Karl Gilbert, Richard Lewis Humphrey, John Stephen Sewell, and Frank Soulé, Washington Government Printing Office, 1907. Also available at: http://library.usgs.gov/photo/#/

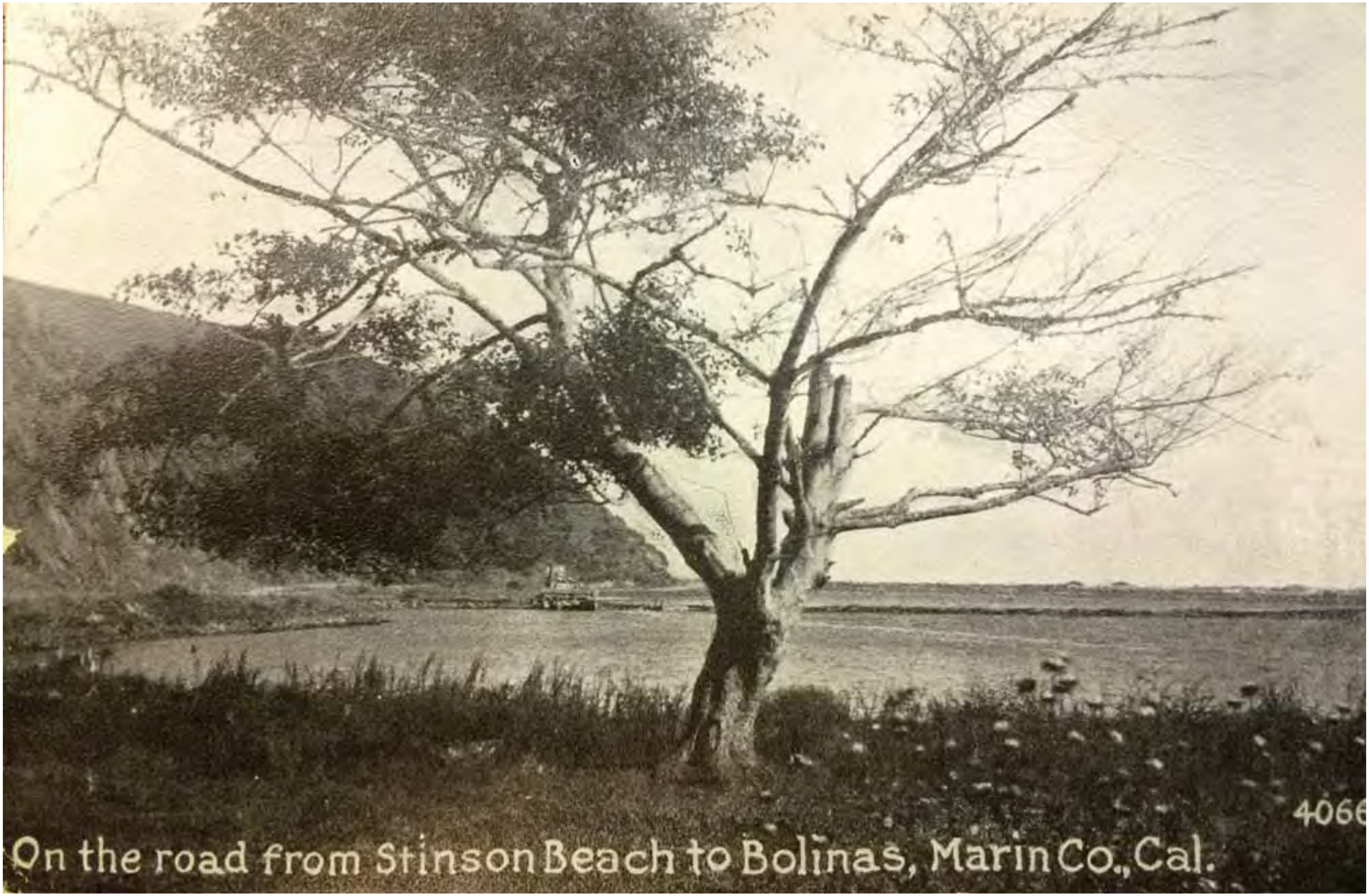
From: San Francisco Earthquake and Fire of April 18, 1906 and their effects of structures and structural materials, reports by Karl Gilbert, Richard Lewis Humphrey, John Stephen Sewell, and Frank Soulé. Washington Government Printing Office, 1907.

Secondary cracks with settling, Bolinas. Photographed by G.K. Gilbert. From: San Francisco Earthquake and Fire of April 18, 1906 and their effects of structures and structural materials, reports by Karl Gilbert, Richard Lewis Humphrey, John Stephen Sewell, and Frank Soule, Washington Government Printing Office, 1907.

Looking down Bolinas Bay and Lagoon toward Golden Gate. Village of Bolinas in foreground. H.W.F.
The California Earthquake of April 8, 1906: Report of the State Earthquake Commission by California Earthquake Investigation Commission, by Andrew Cowper Lawson, published by the Carnegie Institution of Washington, April 1908, V1.

No date, road from Stinson to Bolinas, picture taken of photo at Marin History Museum.

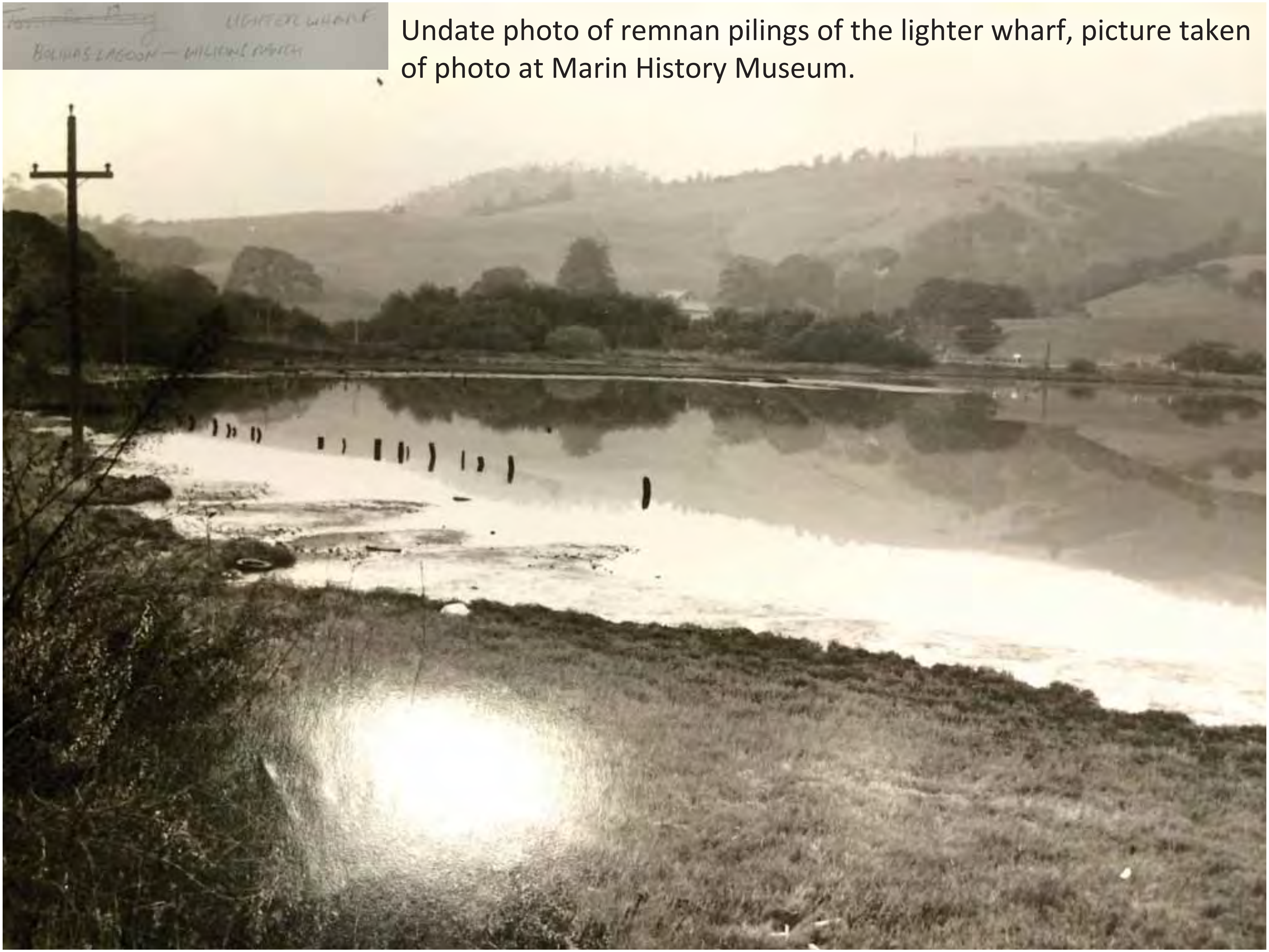
No date, the picture taken of photo at Marin History Museum.



From Stinson Beach historical Society

Undated photo from Dewey Livingston.

1949-1952

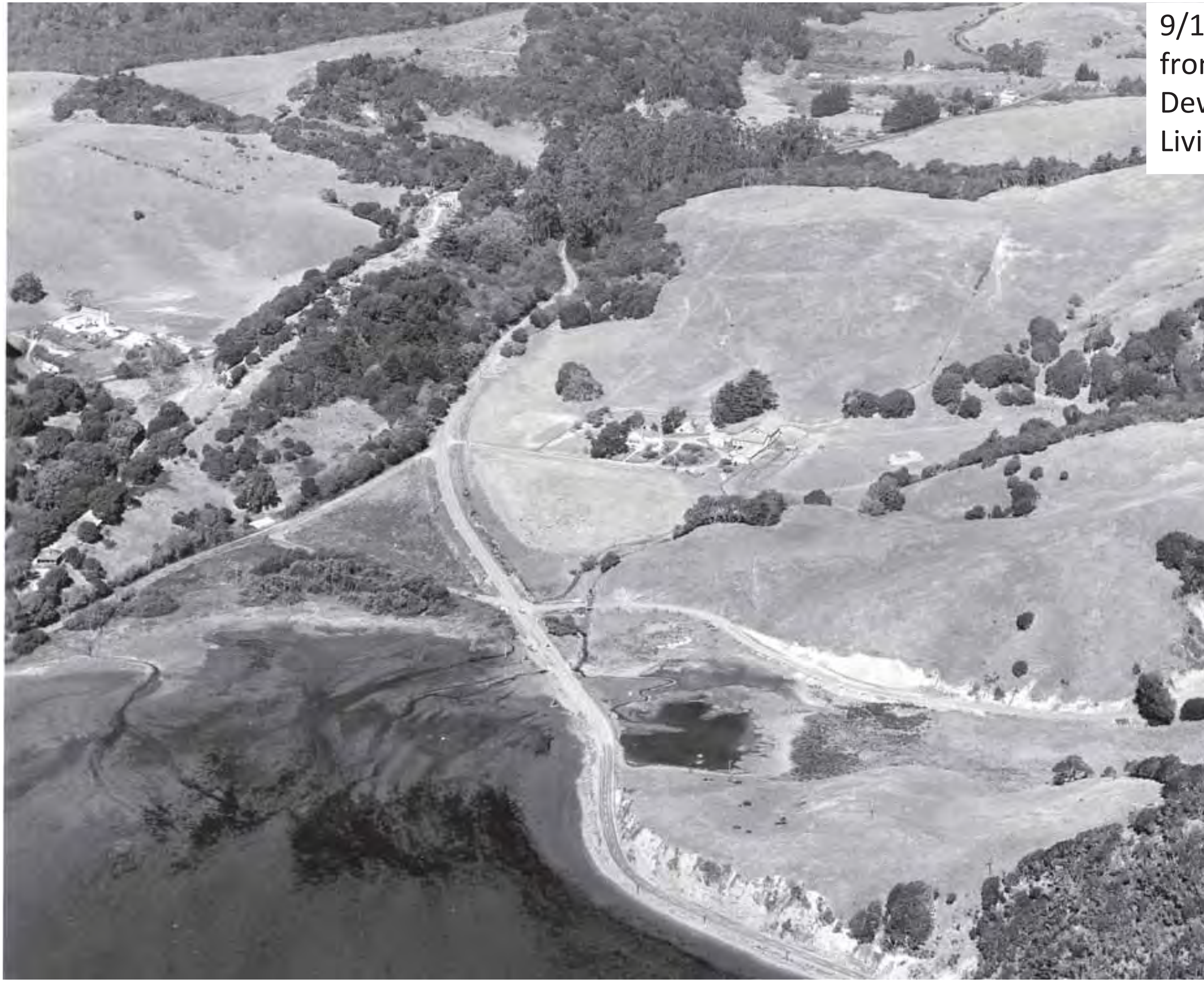


Undate photo of remnan pilings of the lighter wharf, picture taken of photo at Marin History Museum.

October 1943
Marin County
GIS Department

March 1950, picture taken of air photo at Marin History Museum.

June 1952, picture taken of air photo at Marin History Museum.



9/1959, from Dewey Livingston

8/2/60, picture taken of air photo
at Marin History Museum


4/18/63, picture taken of air photo at Marin History Museum.

Picture taken of air photo at Marin History Museum.

Appendix C. Data on Cross Sections and Bankfull Geometry

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APPENDIX C

Wilkins Gulch Creek

Figure C-1. Photograph of Wilkins Creek Cross Section 1 looking downstream.

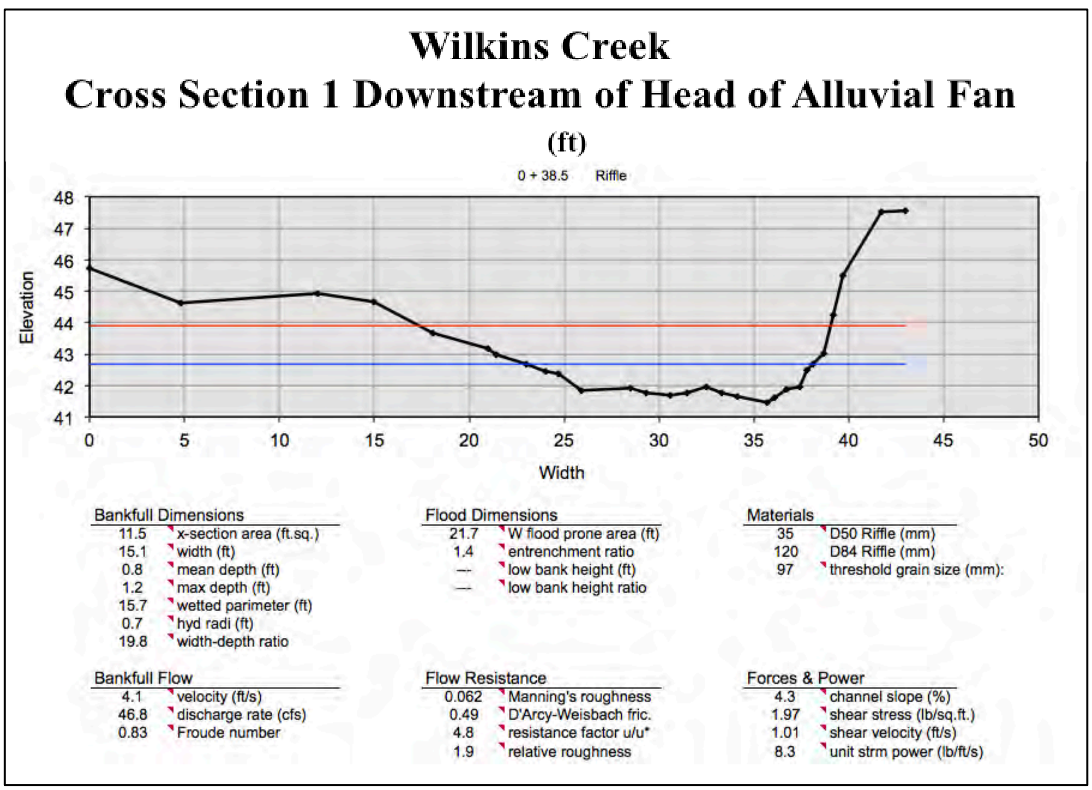

Figure C-2. Wilkins Gulch Creek Cross Section 1 looking downstream. The hydrologic parameters are listed below the cross section.

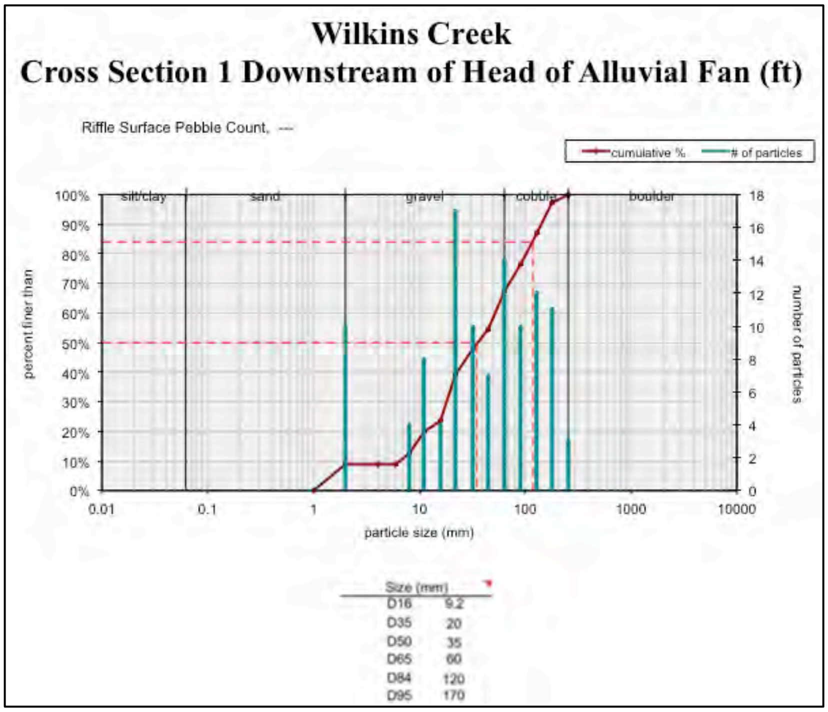

Figure C-3. Pebble Count at Wilkins Gulch Creek Cross Section 1.

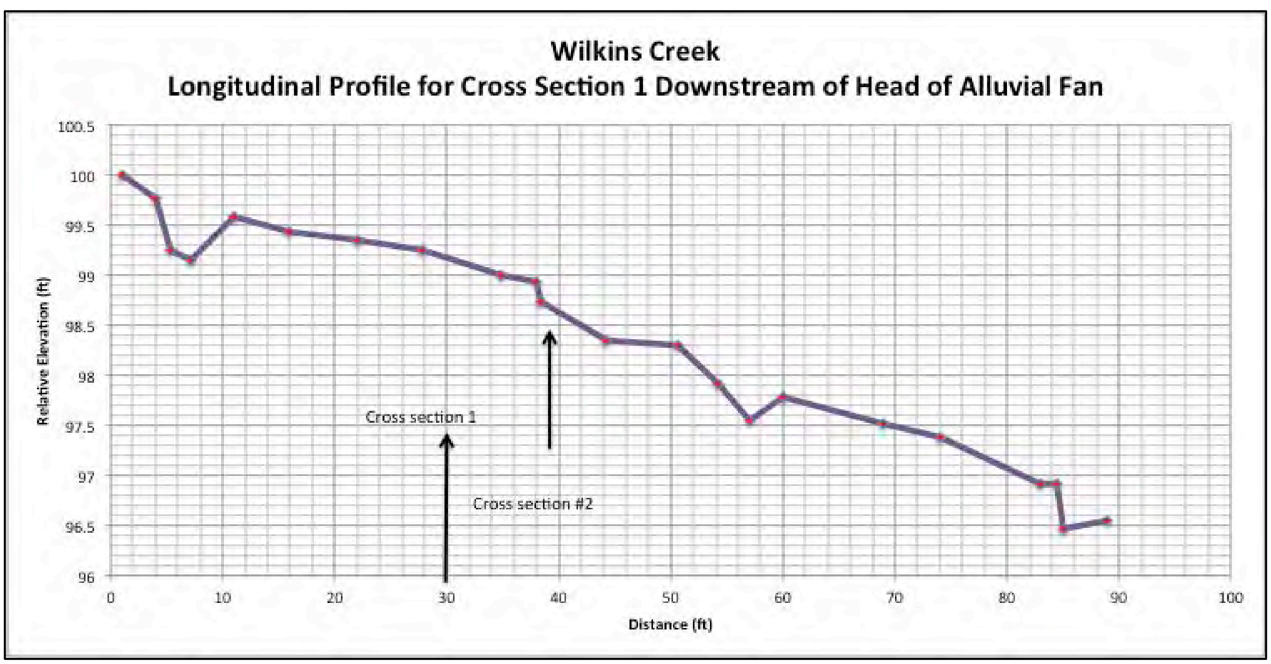

Figure C-4. Longitudinal profile of Wilkins Gulch Creek Cross Section 1.

Figure C-5. Photograph of Wilkins Gulch Creek Cross Section 2 looking downstream.

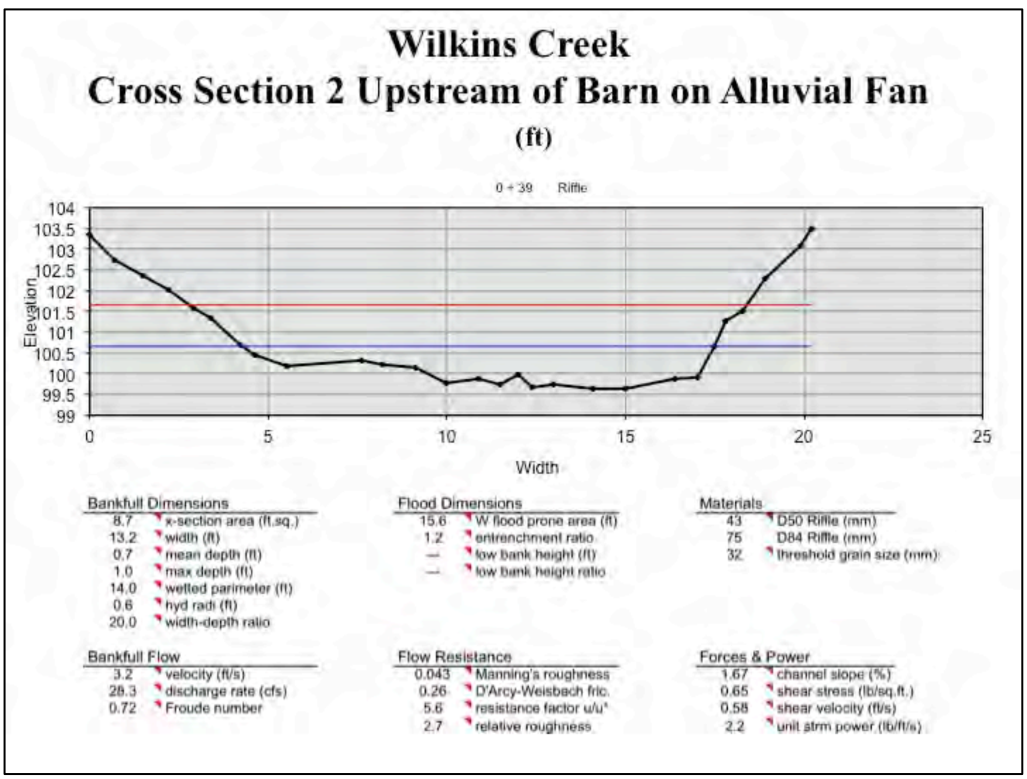

Figure C-6. Wilkins Gulch Creek Cross Section 2 looking downstream.

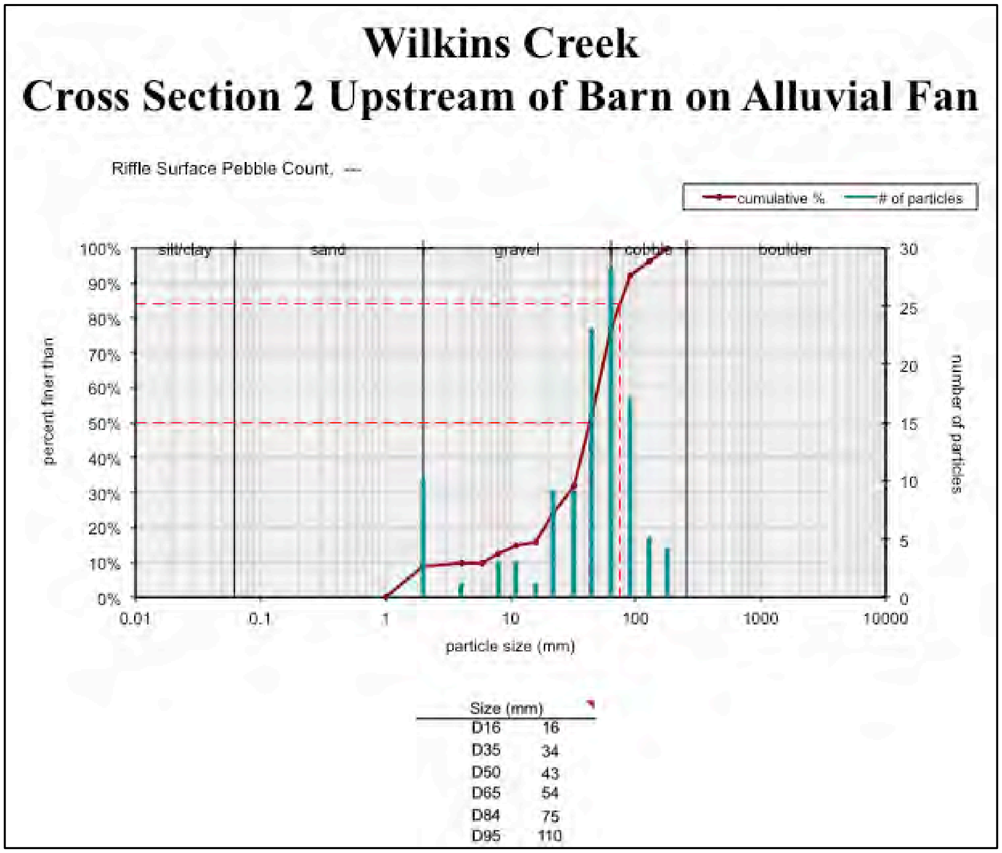

Figure C-7. Pebble Count Wilkins Gulch Creek Cross Section 2 looking downstream.

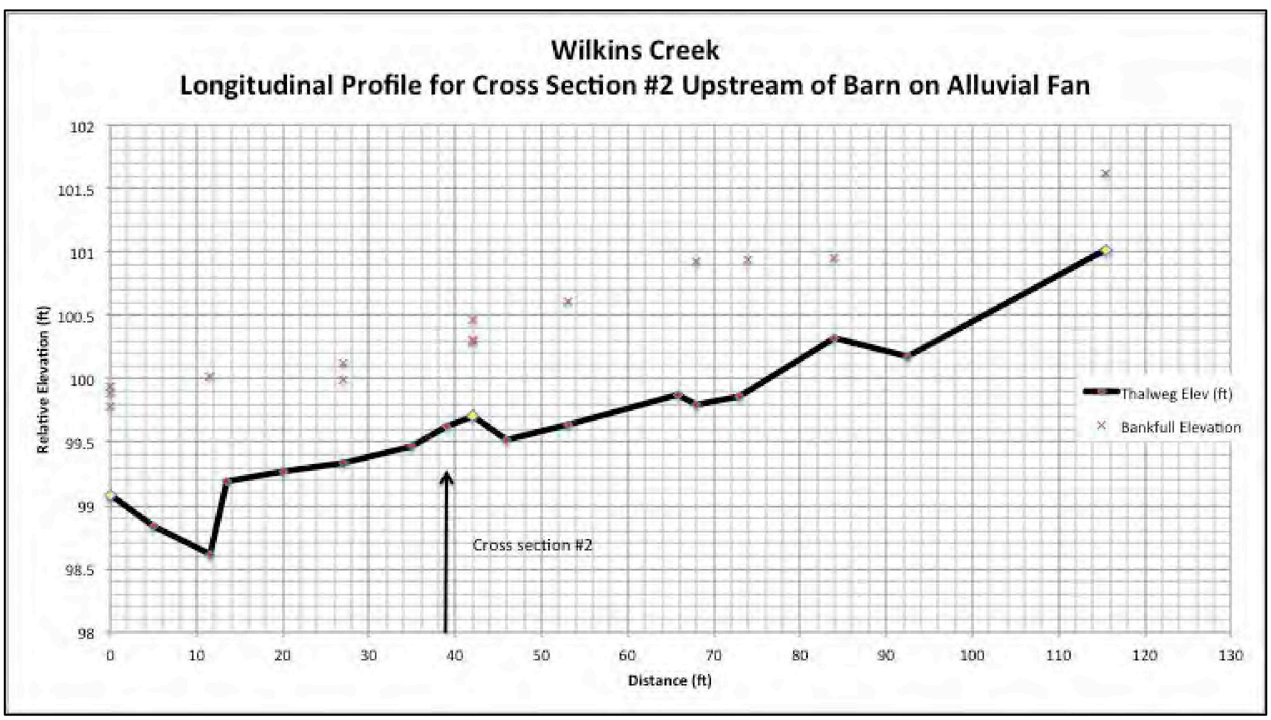

Figure C-8. A longitudinal Profile of Wilkins Gulch Creek

North Tributary

Figure C-9. Looking downstream at North Tributary of Wilkins Gulch Creek

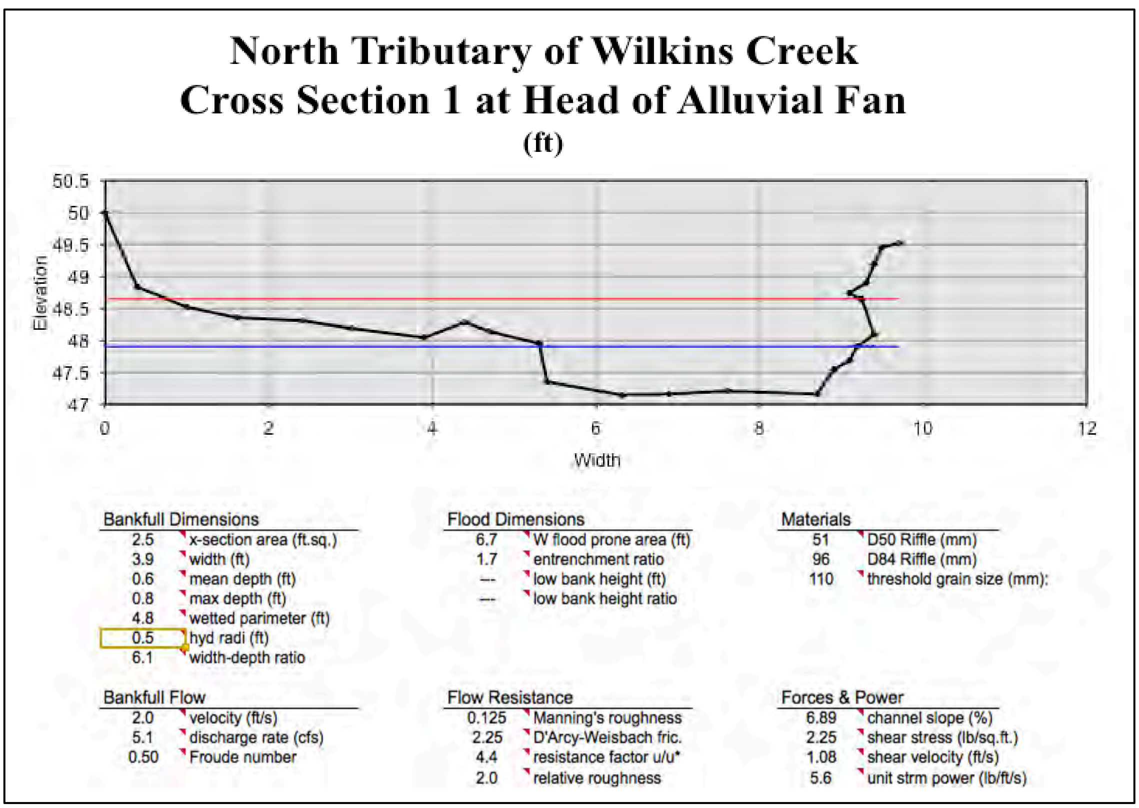

Figure C-10. Looking downstream at North Tributary of Wilkins Gulch.

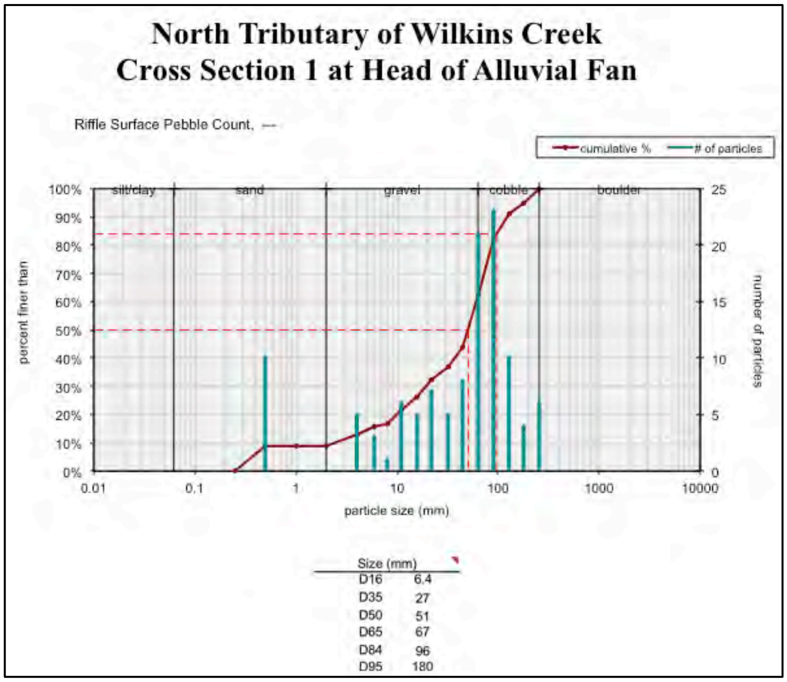

Figure C-11. Pebble Count North Tributary of Wilkins Gulch Creek.

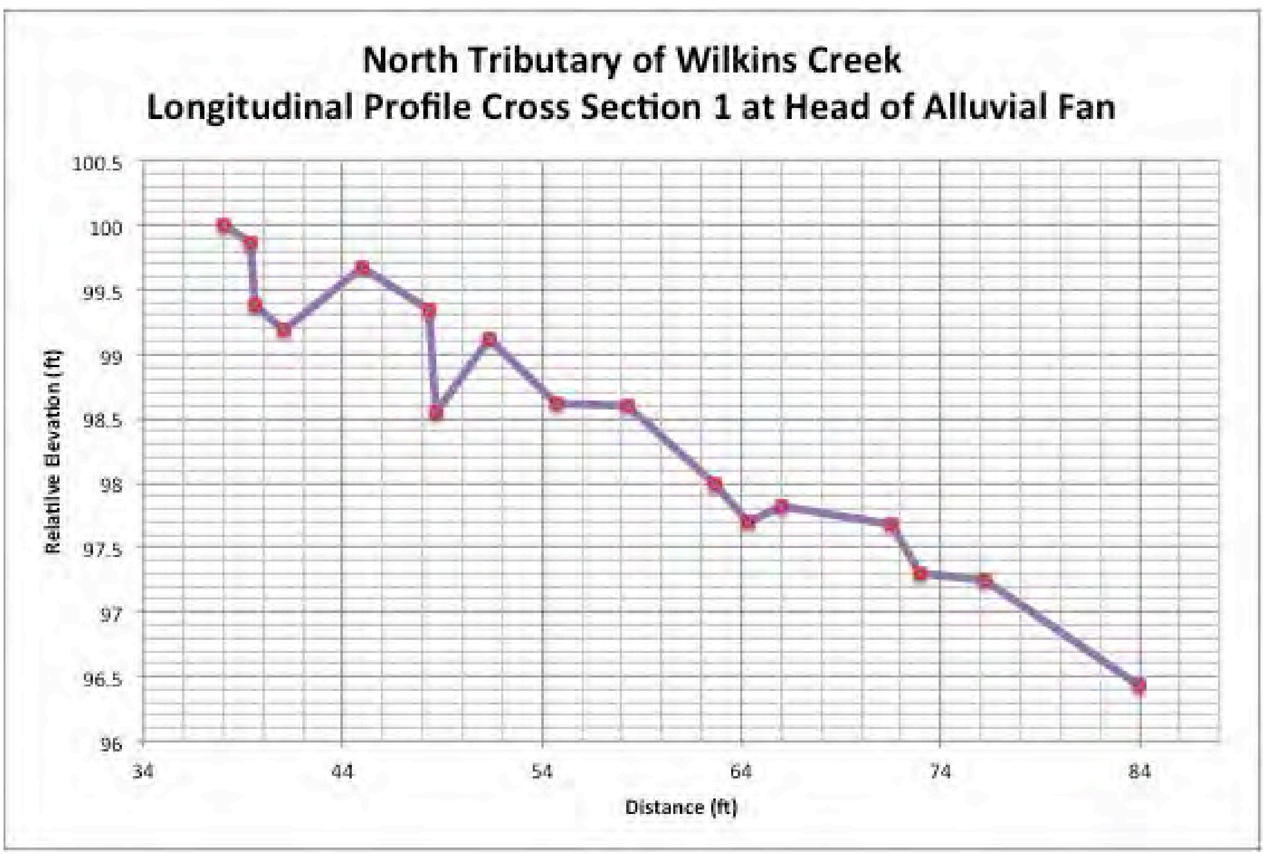

Figure C-12. Longitudinal profile of North Tributary of Wilkins Creek1.

Lewis Gulch Creek

Figure C-13. Looking downstream at Cross Section 1 of Lewis Gulch Creek.

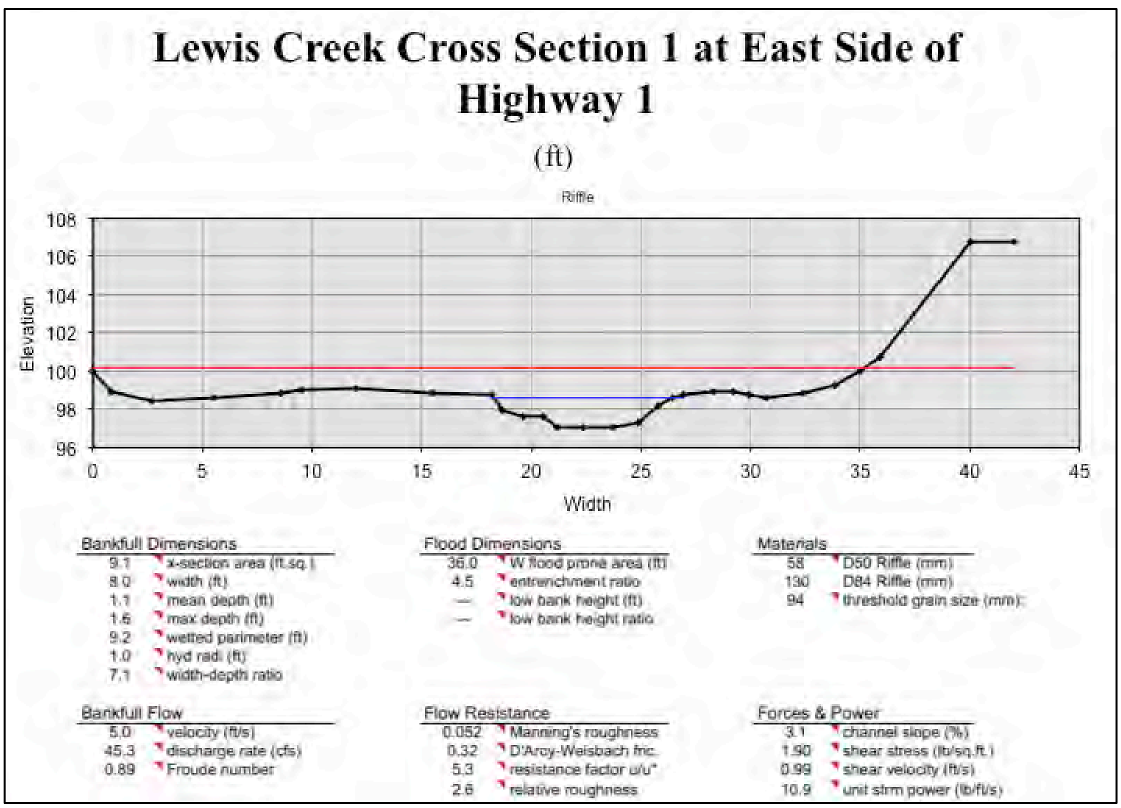

Figure C-14. Cross Section 1 of Lewis Gulch Creek is shown looking downstream. Hydrologic parameters are listed below. Hydrologic parameters are listed below the cross section.

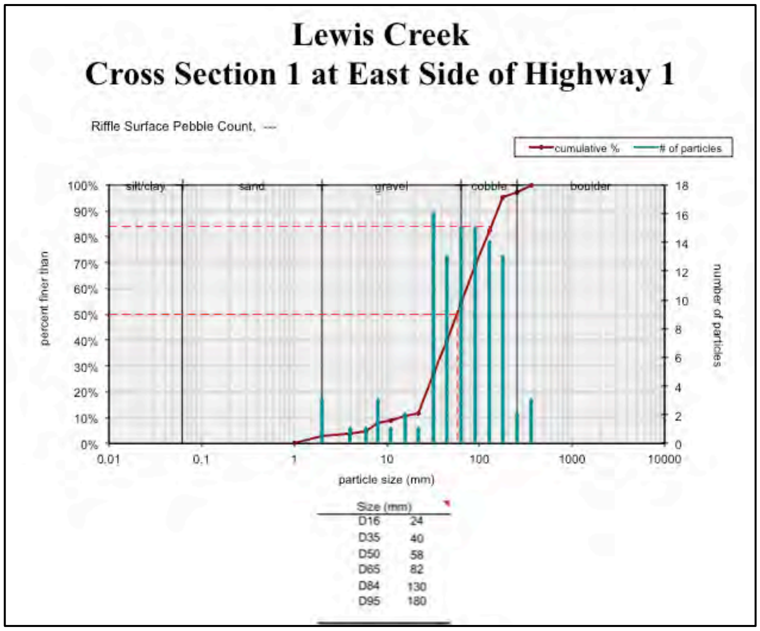

Figure C-15. Pebble count at Cross Section 1 of Lewis Gulch Creek is shown looking downstream.

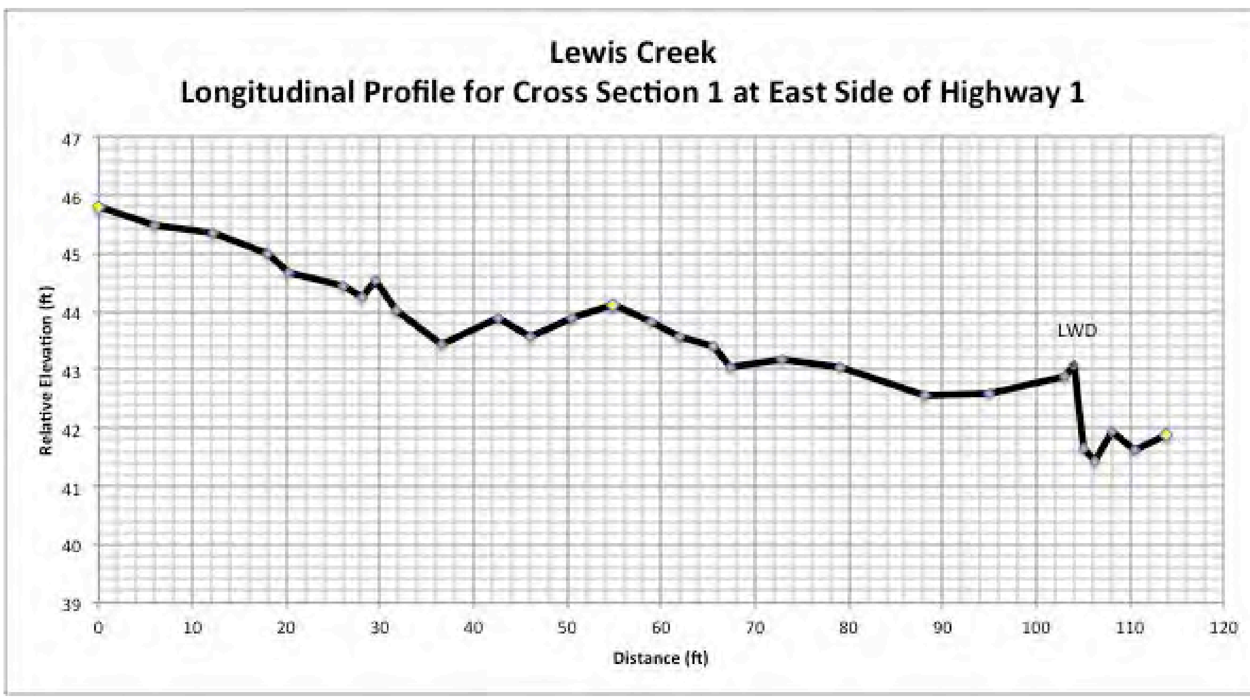

Figure C-16. Longitudinal profile of Lewis Gulch Creek Cross Section 1.

Figure C-17. Lewis Gulch Creek Cross Section 2 looking downstream

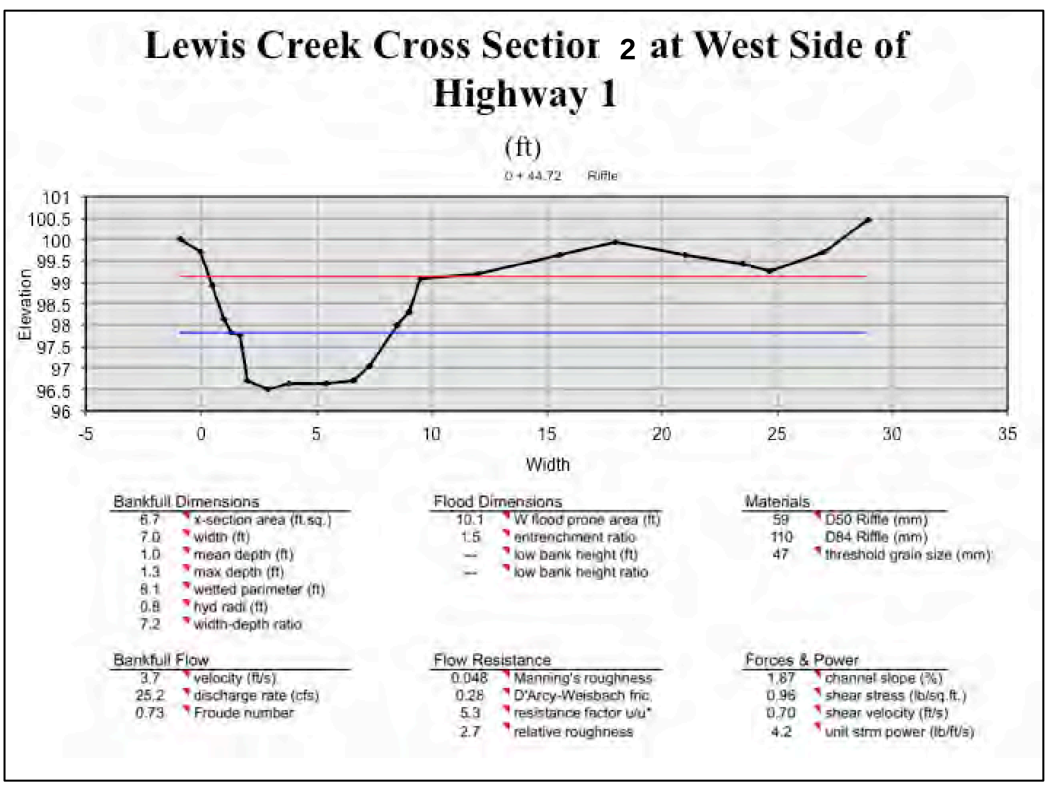

Figure C-18. Lewis Gulch Creek Cross Section 2 looking downstream.

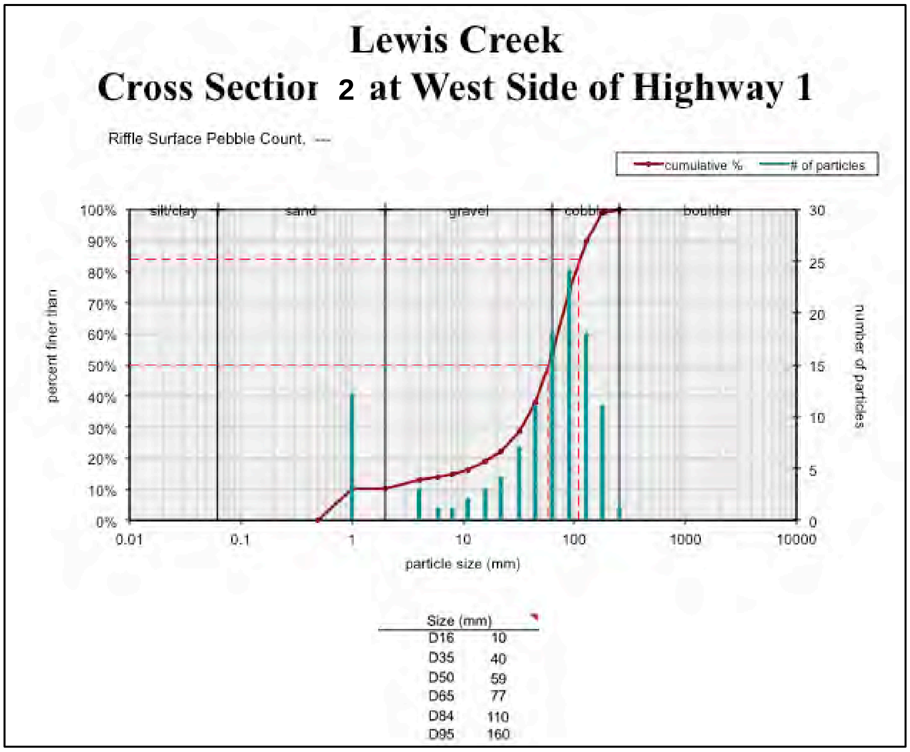

Figure C-19. Lewis Gulch Creek Cross Section 2 pebble count.

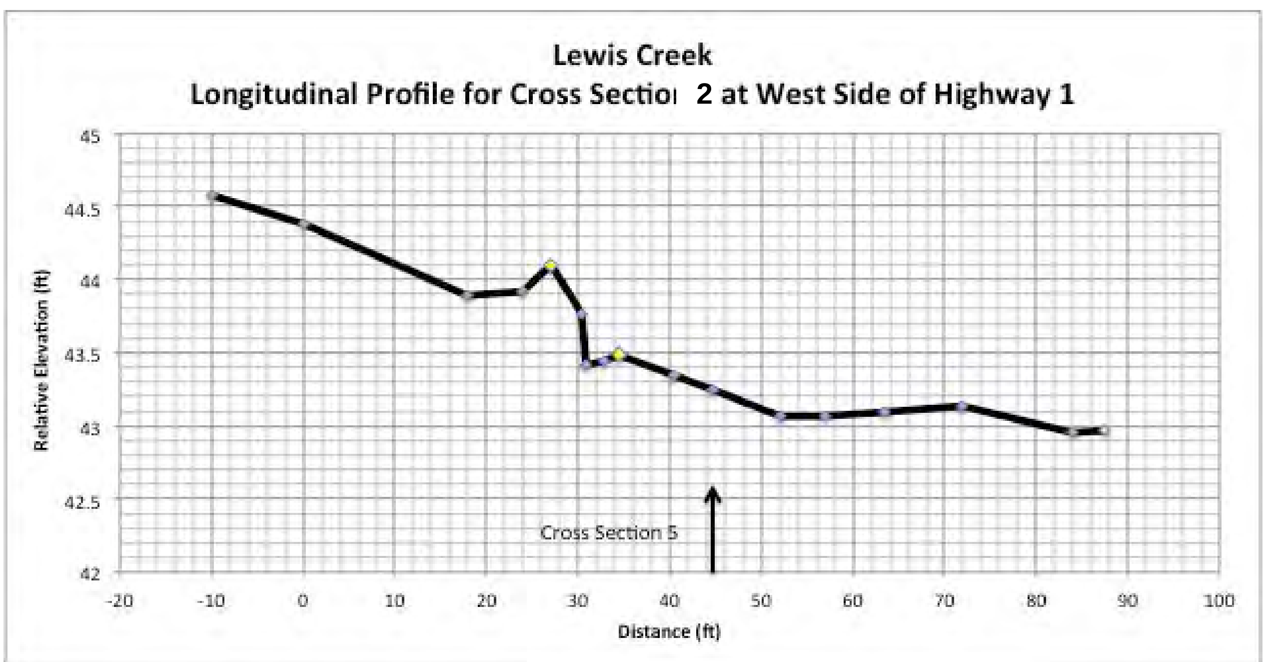

Figure C-20. Longitudinal profile of Lewis Gulch Creek Cross Section 2.

Appendix D. Rosgen Stream Classification System

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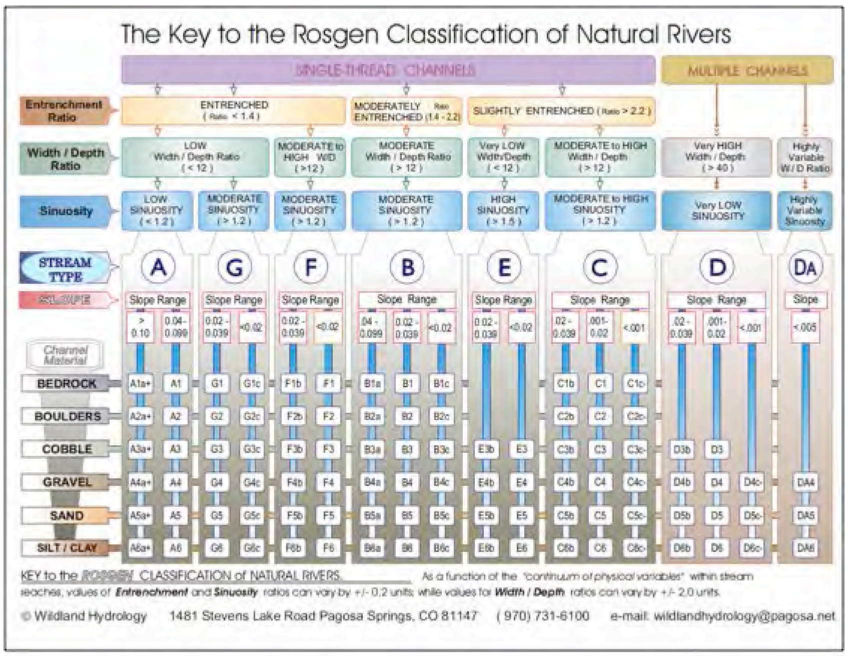
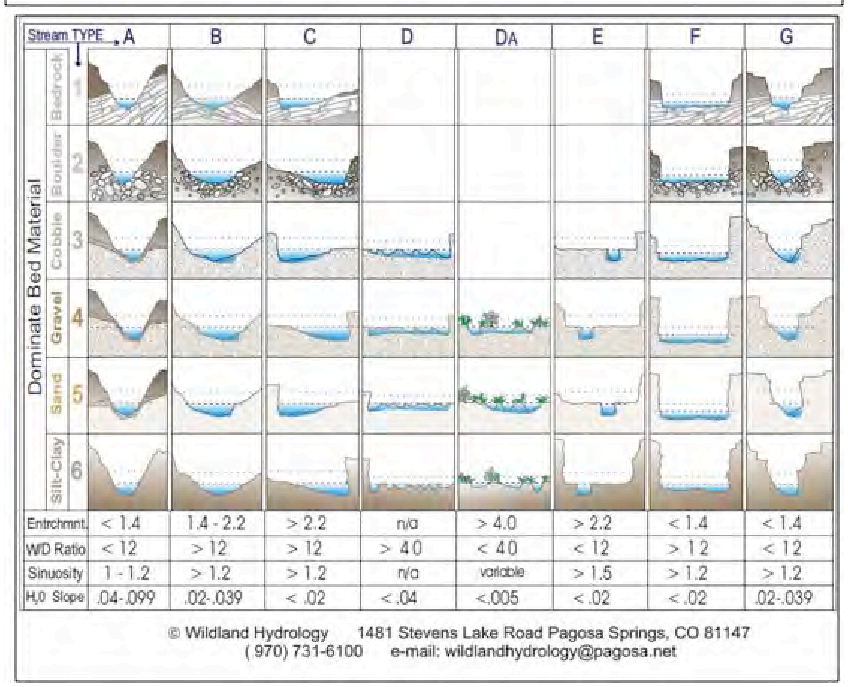
APPENDIX D

Rosgen Stream Classification System and Modification

Copyright permission received from Darcie Geenen in email to Laurel Collins, Sept 30, 2015.

The Rosgen System can be a useful guide for stream restoration design and to assess stream stability. The Rosgen System uses a letter to classify stream form and relative stability, and number to describe the dominant sediment size class of the streambed material. A graphical representation of the Rosgen System is shown above. These empirical ratios have thresholds that Rosgen uses in his classification system to identify different stream types.





A modified Rosgen Stream Classification System (Rosgen System) (Rosgen 1996) was used for Bay Area/Coast Range channels that was more appropriate, as opposed to snow melt channels where much of the classification was derived from channels with these kinds of conditions (Dave Rosgen, personal communication June 15, 2002). The modification changes the W/D ratio threshold to 10, rather than 12, and allows it to vary by +/-3 instead of +/-2. The threshold for entrenchment is not modified. Its threshold is less than 1.4 for entrenched streams, 1.4 to 2.2 for moderately entrenched streams, and greater than 2.2 for slightly entrenched streams. The threshold can vary by +/-0.2 units. C- and E-type channels are slightly entrenched and are considered to have the most stable form. D-type channels are streams with multiple threads, such as braided channels found on alluvial fans or unstable channels with high sediment supply. G-type channels are incising their streambed, and F-type channels are over widening their banks and have a minimal floodprone width.

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1333 Broadway, Suite 800
Oakland, CA, 94612
510-893-3600

Attachment C. Utilities and Parcel Ownership Technical Memorandum

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MEMORANDUM

To: Veronica Pearson & James Raives, Marin County Open Space District

From: David Halsing, AECOM

Date: December 9, 2015

Re: Bolinas Lagoon North End Restoration Project – Parcel Ownership and Utilities Summaries

This memorandum presents the results of two small subtasks associated with the Bolinas Lagoon North End Restoration Project in unincorporated Marin County near the community of Bolinas. Part of that project involves considering a number of changes to the existing roadways, stream channels, and culverts. These alternatives may thus involve actions that need to consider the owners of various land parcels in the area and the possibility that certain parts of the existing utility infrastructure may need to be worked around or relocated. To prepare for these considerations, this memorandum presents maps and tables of the current parcel ownership and the existing utilities within the Study Area.

Parcels and Ownership

The area in and around the study area for the Bolinas Lagoon North End Project is a complex mix of parcels under public and private ownership. As shown on **Figure 1**, many of the parcels include portions of Bolinas Lagoon itself, and others include Lewis Gulch Creek, Wilkins Gulch Creek, or other streams, drainage ditches, or other bodies of water. Each parcel is assigned an assessor's parcel number (APN) by the Marin County Assessor. Those APNs are used throughout this section to refer to the parcels; the APNs are shown on **Figure 1**.

The parcels owned by public entities are those owned by Marin County and the National Park Service (some in the Golden Gate National Recreation Area, others in the Point Reyes National Seashore). In addition while Marin County owns the portions of the lagoon that are below mean high water, the county has shared jurisdiction over the resource with the National Oceanic and Atmospheric Administration's Gulf of the Farallones National Marine Sanctuary. The California Department of Transportation (Caltrans) owns State Route 1 and also holds easements for up to 25-foot distances on either side of that highway.

The privately owned parcels are largely on the western side of the study area and vary quite widely in terms of size and slope. Where possible, the names and contact information of the private property owners were collected and used to obtain rights-of-entry for the field surveys; no field surveys were conducted on private properties without explicit permission of the owner(s).

Table 1 below summarizes the following characteristics of each parcel: ownership status, total acreage, acreage within the study area, acreage on land (i.e., above mean higher high water, MHHW, of Bolinas Lagoon), presence or absence of a stream or other waterway or water body (including areas above MHHW of Bolinas Lagoon). Where the names and other contact information of the private owner of a parcel were available, that information is compiled in the table as well.

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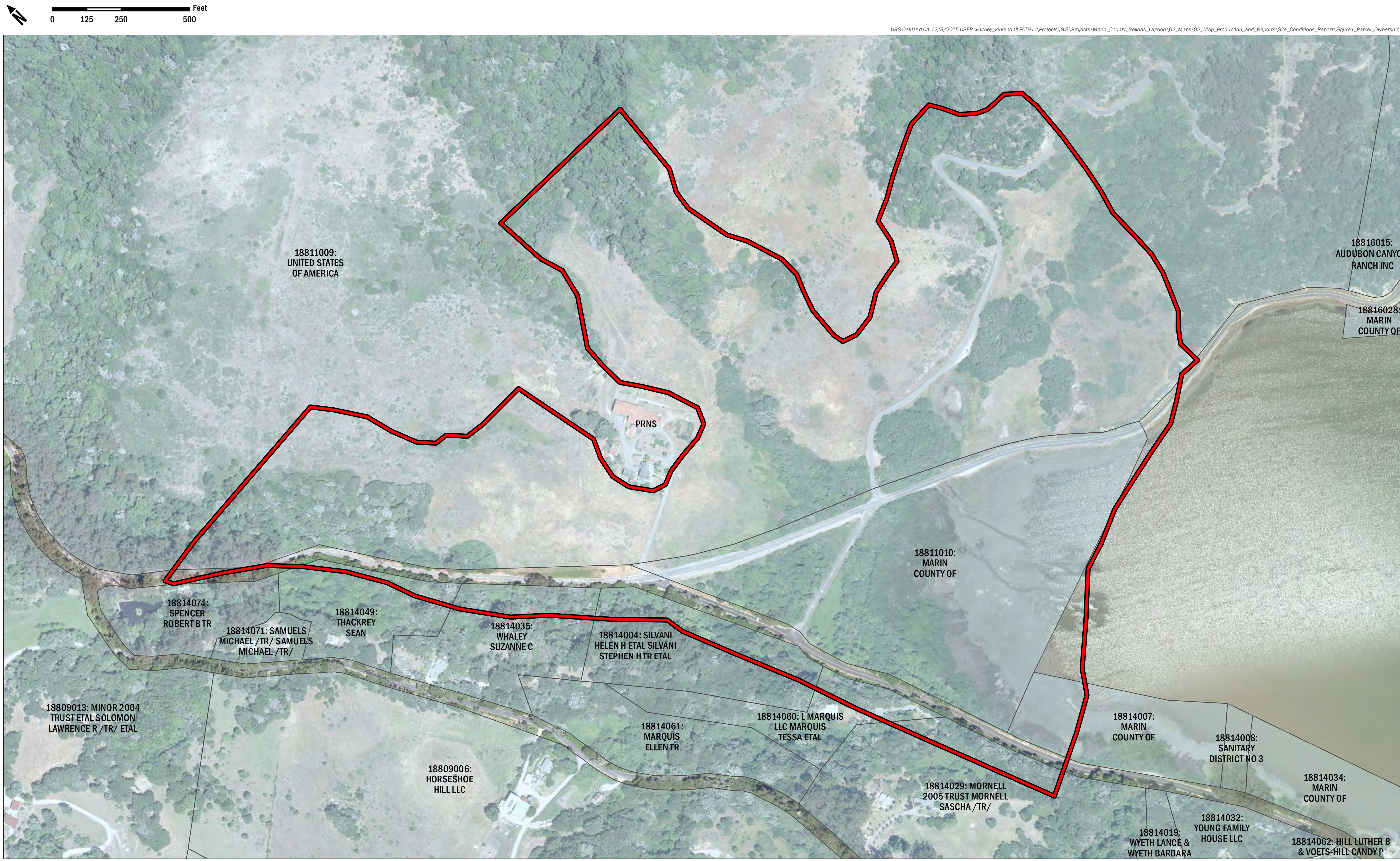
URS Oakland CA 12/3/2015 USER whitney_kirkendall PATH L:\Projects\GIS\Projects\Marin_County_Bolinas_Lagoon\02_Maps\02_Map_Production_and_Reports\Site_Conditions_Report\Figure1_Parcel_Ownership.mxd



AECOM

Marin County

Bolinas Lagoon North End Restoration Project

Project Boundary

Parcel Boundary

FIGURE 1

Parcel Ownership

Table 1. Parcel and Ownership Information

APN	Owner-ship Status	Owner Entity or Name	Address	Size (acres)	Acres in Study Area	Acres below MHHW in Study Area	Streams or Other Water Feature
18814035	Private	WHALEY SUZANNE C	630 HORSESHOE HILL RD, BOLINAS, CA, 94924	5.34	1.26	0.00	x
18814050	Private	BIRD-OTAKA FAMILY REVOC TRUST 2012	430 HORSESHOE HILL RD, BOLINAS, CA, 94924	2.78	0.00	0.00	
18814049	Private	THACKREY SEAN	660 HORSESHOE HILL RD, BOLINAS, CA, 94924	3.90	0.56	0.00	x
18816028	Public	MARIN, COUNTY OF	n/a	17.56	0.00	0.00	
18809006	Private	HORSESHOE HILL LLC	605 HORSESHOE HILL RD, BOLINAS, CA, 94924	68.01	0.00	0.00	
18814007	Public	MARIN COUNTY OF	n/a	4.91	1.34	0.92	x
18814056	Private	ROSENMAN JOHN E & ROSENMAN ANDREA M	n/a	2.65	0.00	0.00	
18814029	Private	MORNELL 2005 TRUST MORNELL SASCHA /TR/	480 HORSESHOE HILL RD, BOLINAS, CA, 94924	15.81	1.27	0.00	x
18814008	Public	SANITARY DISTRICT NO 3	n/a	0.61	0.00	0.00	
18811009	Public	UNITED STATES OF AMERICA	n/a	1376.4 1	67.78	0.03	x
18814019	Private	WYETH LANCE & WYETH BARBARA	1015 OLEMA BOLINAS RD, BOLINAS, CA, 94924	1.67	0.00	0.00	
18814034	Public	MARIN, COUNTY OF	830 OLEMA BOLINAS RD, BOLINAS, CA, 94924	6.27	0.00	0.00	
18814061	Private	MARQUIS ELLEN TR	530 HORSESHOE HILL RD, BOLINAS, CA, 94924	4.84	0.00	0.00	
18814062	Private	HILL LUTHER B & VOETS-HILL CANDY P	855 OLEMA BOLINAS RD, BOLINAS, CA, 94924	2.09	0.00	0.00	
18814032	Private	YOUNG FAMILY HOUSE LLC	945 OLEMA BOLINAS RD, BOLINAS, CA, 94924	4.62	0.00	0.00	
18814004	Private	SILVANI HELEN H ETAL SILVANI STEPHEN H TR ETAL	1299 OLEMA BOLINAS RD, BOLINAS, CA, 94924	5.59	2.00	0.00	x
18811010	Public	MARIN, COUNTY OF	n/a	22.01	22.01	7.88	x
18814060	Private	L MARQUIS LLC MARQUIS TESSA ETAL	1125 OLEMA BOLINAS RD, BOLINAS, CA, 94924	3.37	0.88	0.00	x
18814074	Private	SPENCER ROBERT B TR	730 HORSESHOE HILL RD, BOLINAS, CA, 94924	3.16	0.00	0.00	

Table 1. Parcel and Ownership Information

APN	Owner-ship Status	Owner Entity or Name	Address	Size (acres)	Acres in Study Area	Acres below MHHW in Study Area	Streams or Other Water Feature
18809013	Private	MINOR 2004 TRUST ETAL SOLOMON LAWRENCE R /TR/ ETAL	875 HORSESHOE HILL RD, BOLINAS, CA, 94924	99.59	0.00	0.00	
18809015	Private	MARTINELLI RODERICK P TR ETAL FBO ISSUE OF JORDON MARTINELLI GENEVIEVE TR ETAL	615 PARADISE VALLEY RD A, BOLINAS, CA, 94924	153.28	0.00	0.00	
18814071	Private	SAMUELS MICHAEL /TR/ SAMUELS MICHAEL /TR/	710 HORSESHOE HILL RD, BOLINAS, CA, 94924	1.05	0.00	0.00	
18816015	Private	AUDUBON CANYON RANCH INC	4990 STATE ROUTE 1, BOLINAS, CA, 94924	195.80	0.00	0.00	

Utilities

In theory, utility-related infrastructure may be above or below ground. In many developed areas, underground utilities often include gas, sewer, and water supply lines, telecommunications (e.g. internet and/or television cables), and so on. In some places, even power lines are placed underground to protect scenic values or to protect the lines themselves from extreme weather conditions. However, there does not appear to be any underground utility infrastructure in the Study Area. The project team evaluated the Marin County assessor's parcel maps, and there are no underground utility easements shown around the Bolinas Y. Similarly, there are no major gas pipelines on PG&E's publicly available maps of the area (http://www.energy.ca.gov/maps/infrastructure/natural_gas.html). The Marin County GIS Department's on-line map viewer includes the typical underground utilities for much of the county, but none appear in the general vicinity of the project Study Area. The water supply and water treatment for the community of Bolinas appear to be locally self-contained and do not connect with any larger municipal systems at the Bolinas Y.

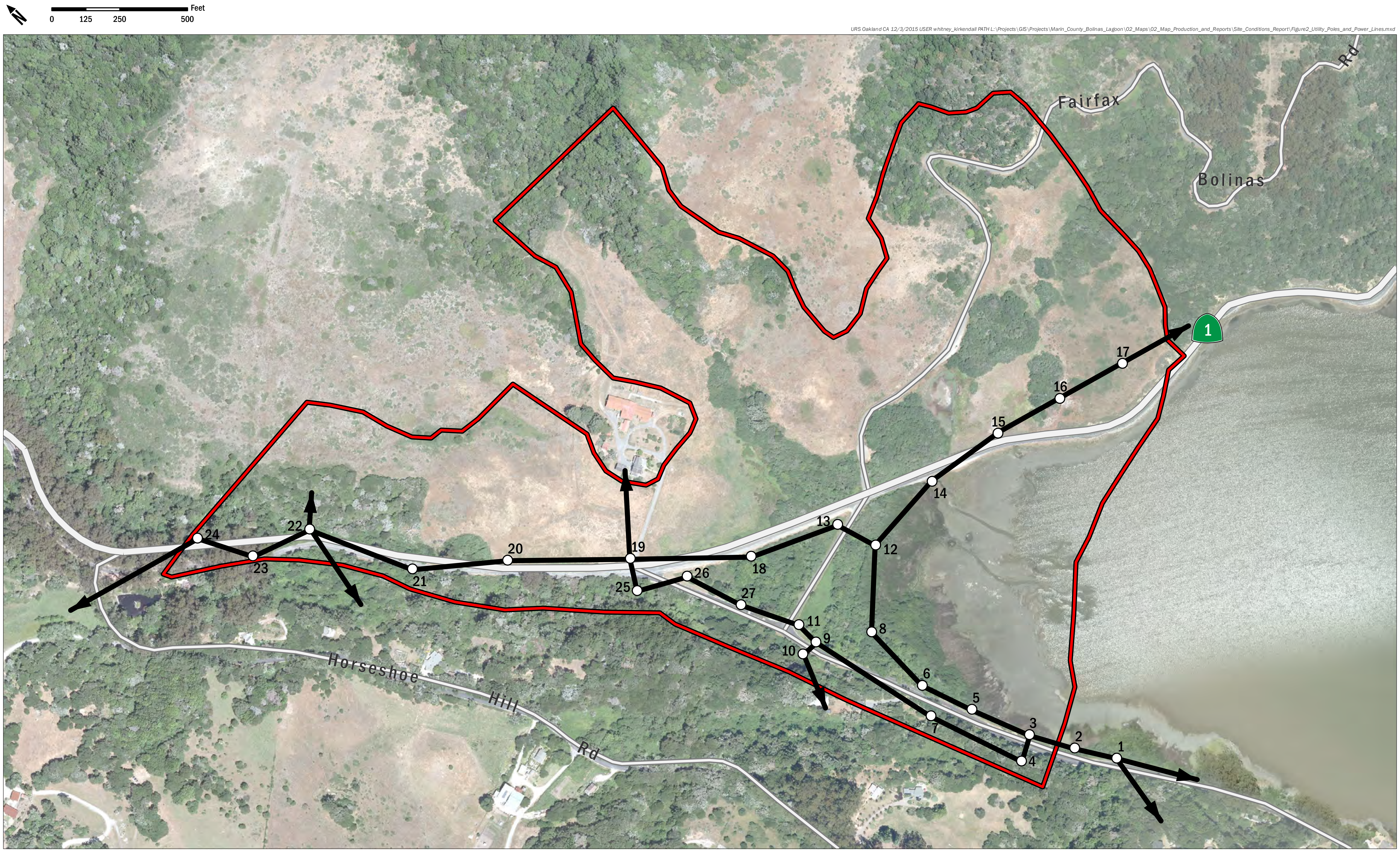
To completely rule out the possibility of underground utilities, the MCOSD could submit the Study Area to the Underground Service Alert (USA) system, which is a free service that requires online submission of the project boundaries to a clearinghouse for utilities such as PG&E, cable providers, and others. Preparation and coordination of the USA process to delineate any underground utilities in the Study Area could be done by AECOM under the "additional services as requested" task of the project scope, though it may be premature. When an actual project is being developed and a project footprint is established, getting USA clearance will be essential.

This brief assessment is limited to the aboveground utilities, which includes utility poles and power or telephone/telecommunications lines that are suspended from those poles. According to PG&E's public website (http://www.energy.ca.gov/maps/infrastructure.html), there are no major electric transmission lines along State Route (SR) 1 or along Olema Bolinas Road. The power lines that are present must therefore be electricity distribution lines, which carry lower loads to smaller end users.

To evaluate the above-ground utilities, the project team conducted visual surveys, took photographs and videos, and made sketches of the utility lines and poles along SR 1, Olema Bolinas Road, and the crossover road. Then, a desktop analysis of aerial imagery was used as an independent check on the poles and lines. The results of these reconnaissance-level surveys are illustrated in **Figure 2**. There appear to be approximately 27 utility poles in and immediately adjacent to the Study Area. The approximate locations of the poles are shown, and these generally match with what is visible on the imagery. As the figure shows, two poles outside of the Study Area (on Olema Bolinas Road) were counted and mapped to provide a greater context for future planning. Note also that, as **Figure 2** shows, near the southern end of the Study Area on SR 1, the utility lines do not run immediately adjacent to the road, but instead extend up and over a bluff inland from the road alignment.

The utility lines appear to carry a mix of power and telephone/telecommunication lines that run along SR 1, with large spurs out to the community of Bolinas. There are also smaller delivery lines that branch off of the existing lines to serve the homes along these roads, as would be expected.

While no GPS points were taken of the pole locations, this level of planning is appropriate for the current scope, which is intended to inform the planning and development of a set of restoration alternatives by evaluating the level of effort of utility relocation that might be involved. As noted, PG&E is generally guarded about releasing details of its infrastructure, including for example, the names, voltages, and detailed locations of its power lines, circuits, and other infrastructure. Thus, all of this information must be viewed as preliminary; further investigation would be warranted once an actual project has been developed and considered, and the need for utility relocation has been evaluated.



AECOM

MCOSD

Bolinas Lagoon North End Restoration Project

FIGURE 2

Utility Poles and Lines

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Attachment D. Traffic Counts and Analysis Technical Memorandum

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MEMORANDUM

To: David Halsing

From: Swathi Korpu/Phong Vo

Date: December 15, 2015

Re: Bolinas Lagoon North End Restoration Project – Roadway/Intersection Modification Traffic Analysis

This memo documents the traffic analysis completed for Bolinas Lagoon North End Restoration Project in unincorporated Marin County near the community of Bolinas. Part of that project involves considering a number of changes to the existing roadways, and the traffic counts and level of service analysis summarized here serve to inform future decisions about possible changes to the roads and intersections. The figure below shows the vicinity of the project and the three study intersections identified for the analysis.

Project Vicinity and Location of the Study Intersections

The study included traffic counts and analyses of three intersections under three scenarios:

1. Existing condition: how the roads are configured today
2. The future 2040 no-build condition: the current road configuration but with projected traffic levels in the year 2040

3. The future 2040 build condition: the projected 2040 traffic levels in a scenario where the crossover road has been removed

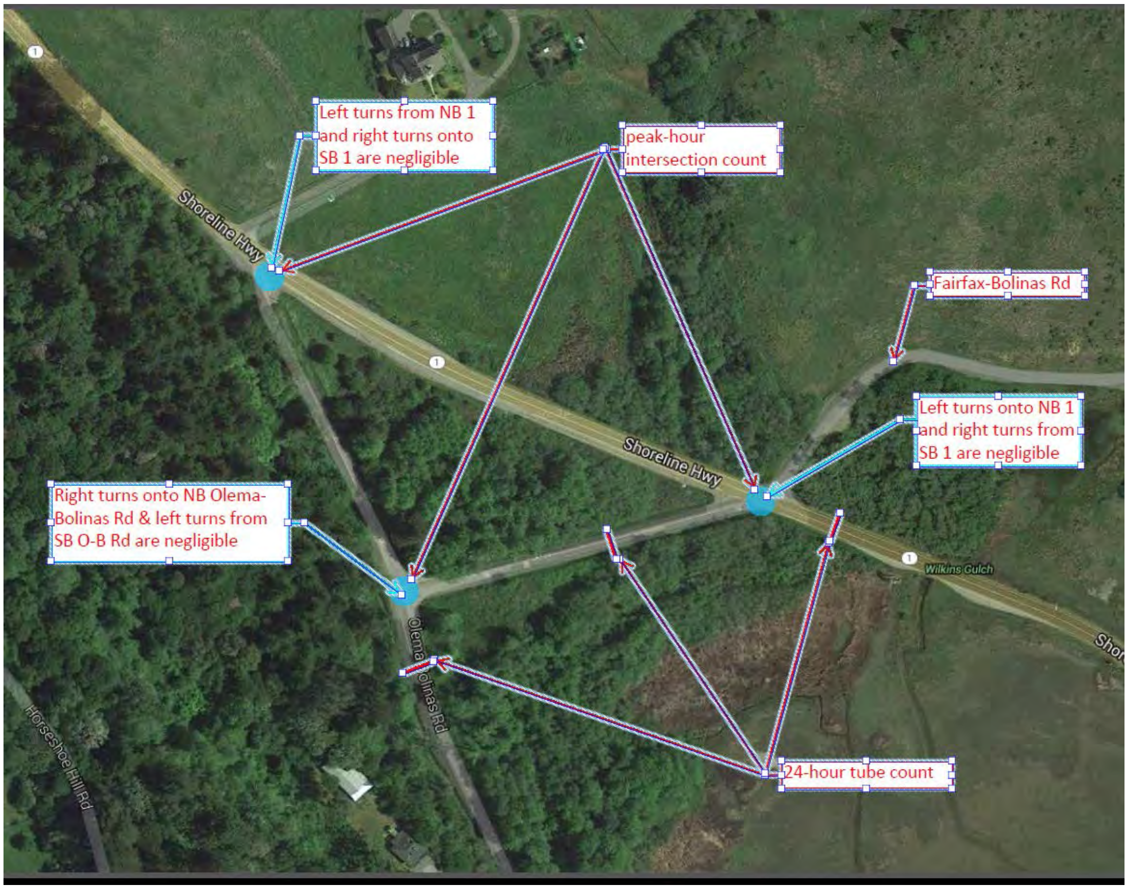
The intersections studied are

1. Shoreline Highway (State Route (SR) 1) with Fairfax – Bolinas Road (to the east) and the crossover road (to the west); this is a two-way stop
2. Olema Bolinas Road with the crossover road; this is a yield-only intersection
3. Olema Bolinas Road and SR 1; this is a one-way stop)

Methodology:

- Average Daily Traffic (ADT) bi-directional tube counts were collected at three locations (listed below) in June 2015. The tube counts were 24-hour counts collected continuously and aggregated in 15 min intervals for seven full days.
  1. On SR1 south of intersection with Fairfax-Bolinas Road and crossover road
  2. On crossover road between SR 1 and Olema Bolinas Road
  3. On Olema Bolinas Road south of the crossover road

  Several simplifying assumptions about traffic flows guided the choice of these three locations. The count locations and the assumptions about intersections are shown on the figure below.



- Using the ADT volumes from the tube counts, the traffic pattern was identified for weekday and weekend, and peak hours for both weekend and weekday analysis were selected. Those peak hours are as follows:

  Weekday AM: 8 am to 9 am
  Weekday PM: 3 pm to 4 pm
  Weekend AM: 11 am to 12 pm
  Weekend PM: 3 pm to 4 pm

- The turning movements were calculated for these hours based on the ADT volumes obtained.

- Future growth percentage was assumed as 1 percent per year for conservative purposes, though there is no growth identified from last three years based on Caltrans census data on SR 1 at this location. Further, the community of Bolinas has some restrictions against growth, and most of the land in the immediate vicinity is already held by public-sector entities, including the National Park Service.

- The Year 2040 no-build analysis was completed with the same lane configuration as currently exists and applies the annual 1 percent growth rate to the existing volumes.

- For the future 2040 build scenario, the crossover road (the south leg of the triangle of roads shown on the figures above) was assumed to be removed. That would force all of the traffic movements to form a single intersection (at SR 1 and Olema Bolinas Road) into which the projected 2040 traffic was routed. That simulated the future build traffic volumes (again including the annual 1 percent growth rate) at that intersection (labeled as intersection 3 above).

- The Synchro software HCM 2000 analysis procedures (from the Transportation Research Board manuals for that software package) were used to conduct the Level of Service (LOS) analysis.

Results:

All of the intersections operate at LOS A or B in the existing conditions, the 2040 no-build conditions, and the 2040 build conditions. Levels of Service range from A to F, with LOS A and B representing the highest levels of service and represent the lowest amounts of delay due to traffic congestion. The analysis results are tabulated in Table 1 below, which shows the average seconds of delay per vehicle and the current and projected LOS at each intersection.

Table 1: Calculated Level of Service for Weekdays and Weekends during peak hours, based on 24 hour counts collected over seven days.

Int. No.	Intersection/Condition	Weekday		Weekend	
		AM, LOS	PM, LOS	AM, LOS	PM, LOS
	Existing				
1	SR 1 and crossover road/Fairfax – Bolinas Road	8.7, A	8.7, A	8.9, A	9.4, A
2	Crossover road and Olema Bolinas Road	9.2, A	9.3, A	9.8, A	9.6, A
3	Olema Bolinas Rd and SR 1	9.1, A	9.5, A	10.8, B	10.9, B
	2040 No-build				
1	SR 1 and crossover road/Fairfax – Bolinas Road	8.9, A	8.8, A	9.1, A	9.7, A
2	Crossover road and Olema Bolinas Road	9.3, A	9.6, A	10.2, B	9.9, A
3	Olema Bolinas Rd and SR 1	9.3, A	9.9, A	11.7, B	11.8, B
	2040 No-build plus project (i.e. crossover road removal)				
1	Full/New intersection (previously Int. #3)	9.5, A	10.7, B	13.0, B	12.9, B

Delay (average seconds/vehicle) and LOS at study intersections during peak hours (Source: AECOM)

Conclusion:

The results of the analysis indicate that the potentially greatest roadway modification – the removal of the crossover road – does not cause any substantially increased delays or changes in the levels of service. The projections for the future build scenario are that there would be an increase in average delay of 0.2 to 1.1 second at the SR 1 – Olema Bolinas Rd intersection at various weekend or weekday AM or PM peak hours. In only one case (the PM weekday hours) would the LOS decrease from LOS A to LOS B, as the average delay increases by 0.8 seconds. Therefore, no road volume improvements, such as pocket lanes or turn-only lanes or signals, would be needed at the intersection if the crossover road were removed.

Attachment E. Regulatory Environment

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MEMORANDUM

To: Veronica Pearson & James Raives, Marin County Open Space District

From: David Halsing and Kristin Tremain, AECOM

Date: June 1, 2016

Re: Bolinas Lagoon North End Restoration Project – Regulatory Environment

This memorandum presents the results of a task associated with the Bolinas Lagoon North End Restoration Project (project) in unincorporated Marin County near the community of Bolinas. The project aims to reduce current flooding of roadways and to develop infrastructure adaptations that address future sea-level rise and increased traffic safety. Through this process, the project aims to improve the ecological functions and habitat values of the tidal marshes, streams, riparian corridors, and upland habitats at the north end of the lagoon. The first part of AECOM project's scope was to perform a series of desktop analyses, field surveys, records and database searches, and other data collection efforts on a variety of topics. The results of those efforts are being presented to the Marin County Open Space District (MCOSD) and its partner agencies in a set of technical memoranda and a larger, integrative Site Conditions Report.

Regulatory Environment

The following agencies (listed alphabetically) are likely to have regulatory jurisdiction for the project:

- Bay Area Air Quality Management District
- California Coastal Commission
- California Department of Fish and Wildlife
- California Department of Transportation
- San Francisco Bay Regional Water Quality Control Board
- County of Marin
- National Oceanic and Atmospheric Administration – Marine Sanctuaries
- National Marine Fisheries Service – Endangered Species
- National Park Service
- State Historic Preservation Office
- State Lands Commission
- U.S. Fish and Wildlife Service – Endangered Species
- U.S. Army Corps of Engineers, San Francisco District

Table E1 below presents a matrix of the regulatory agencies likely to have jurisdiction over the project and the permits or consultations that would fall under their jurisdiction.

Table E1. Agencies with Jurisdiction or Regulatory Authority in the Study Area

Agency/Permit or Consultation	BAAQMD	CCC	CDFW	Caltrans	SFBRWQCB	County of Marin	GFNMS	NMFS	NPS	SHPO	USFWS	USACE
NEPA							X	X	X	X	X	X
CEQA	X		X	X	X	X				X		
Coastal Development Permit		X				X						
CWA Section 404								X		X	X	X
CWA Section 401					X							X
CWA Section 402					X							
CZMA		X										
ESA Section 7								X			X	X
EFH								X				
NHPA Section 106										X		X
LSAA (1602)			X									
CESA Section 2080 or 2081			X									
Encroachment Permit				X								
HREP 2014			X									
NPS Director's Order #77-1									X			
Tree Preservation						X						
Sanctuary Permit							X					

BAAQMD = Bay Area Air Quality Management District
CCC = California Coastal Commission
CDFW = California Department of Fish and Wildlife
CEQA = California Environmental Quality Act
CESA = California Endangered Species Act
CWA = Clean Water Act
CZMA = Coastal Zone Management Act
EFH = essential fish habitat
ESA = Endangered Species Act
GFNMS = Greater Farallones National Marine Sanctuary
HREP = Habitat Restoration and Enhancement Act of 2014
LSAA = Lake and Streambed Alteration Agreement
NEPA = National Environmental Policy Act
NHPA = National Historic Preservation Act
NMFS = National Marine Fisheries Service
NPS = National Park Service
NWP = Nationwide Permit
SFBRWQCB = San Francisco Bay Regional Water Quality Control Board
SHPO = State Historic Preservation Officer
SWPPP – storm water pollution prevention plan
SWRCB = State Water Resources Control Board
USACE = U.S. Army Corps of Engineers
USFWS = U.S. Fish and Wildlife Service

NEPA/CEQA Compliance

The National Environmental Policy Act (NEPA) applies to discretionary projects that are funded, authorized, or carried out by Federal agencies or are located on Federal land. If Federal funding were obtained for the restoration project, then the Federal funding agency could be the lead Federal agency under NEPA. Otherwise, the Federal lead agency is a Federal Agency responsible for issuing a permit for the project. Title I of NEPA, Section 102 requires federal agencies to incorporate environmental considerations in their planning and decision-making through a systematic interdisciplinary approach. Specifically, all federal agencies are required to prepare detailed statements assessing the environmental impact of and alternatives to major federal actions significantly affecting the environment.

There are three levels of analysis under NEPA. In increasing levels of detail and analytical complexity, they are: a Categorical Exclusion, an Environmental Assessment, and an Environmental Impact Statement (EIS). Given that the potential for impacts would be extensive, it is very likely that a full EIS would be required for this project.

In the case of this project, the federal lead agency has not yet been selected and could be any of a number of agencies, depending on which agency provides funding, is a landowner, and/or issues a permit or other regulatory agreement.

The California Environmental Quality Act (CEQA) applies to discretionary projects proposed to be carried out or approved by State and local public agencies or are located on State or local public agency land (Public Resources Code [PRC] §21080). The project is in Marin County and the County has land use permitting authority over the portion of the project that falls within unincorporated County lands. Several different permits and approvals from the State will also be required for the project. Coordination with the State and public agencies would be required to confirm a lead agency role and the details of the required permitting.

As with NEPA, there are three levels of CEQA document that may satisfy the required CEQA clearance: a Categorical Exemption, an Initial Study, and an Environmental Impact Report (EIR). Again, it is very likely that an EIR would be required for a project at the north end.

Federal Agency Environmental Compliance

Federal Clean Water Act

The proposed action would result in fill and/or dredge of jurisdictional waters of the United States, including wetlands. As a result, this project would require authorization from USACE pursuant to Section 404 of the CWA.

CWA Section 404 establishes a program to regulate the discharge of dredged material or placement of fill material into waters of the United States, including wetlands. Waters of the United States include surface waters such as navigable waters and their tributaries, all interstate waters and their tributaries, natural lakes, all wetlands adjacent to other waters, and all impoundments of these waters. Activities that require a permit under Section 404 include, but are not limited to, placing fill or riprap, grading, mechanized land clearing, and dredging in waters of the United States.

The USACE Regulatory Branch issues several types of Section 404 permits. Most applicable to the proposed action are Nationwide Permits (NWPs) and Individual Permits. Projects with only minimal adverse effects, or that result in restoration or enhancement of aquatic habitat, can typically be authorized under USACE's NWP program to expedite the environmental compliance process, provided the project satisfies the terms and conditions of the particular NWP. Because the proposed project is intended to result in enhancement and restoration of aquatic habitat, it may be eligible for authorization under NWP

27 Aquatic Habitat Restoration, Establishment, and Enhancement Activities, but this cannot be determined until a conceptual alternative for the project is developed.

Federal Endangered Species Act

Species that are federally listed as threatened or endangered and that have potential to occur in the study area, are discussed in Section 4.2 of the Site Conditions Report and further detail is provided in Attachment A. Biological and Cultural Resources Technical Memorandum. Implementation of the proposed action may result in adverse effects to these species or their habitat. Wilkins Gulch Creek is Designated Critical Habitat (DCH) for threatened steelhead.

Because the action requires Federal permits and approvals, and because project implementation could potentially adversely affect Federally-listed species (pending further evaluation), Section 7 consultation with USFWS and NMFS is required. To obtain concurrence or Biological Opinions (with incidental take statements, as necessary) from USFWS and NMFS for the proposed action, the Federal lead agency would submit Biological Assessments to each agency, prepared by the applicant or their agent.

Under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), NMFS regulates essential fish habitat (EFH). Because the proposed action may have adverse effects to EFH, the lead agency would need to consult with NMFS under the MSFCMA, along with the Section 7 consultation.

Section 9 of the ESA prohibits “take” (i.e., harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct) of any threatened or endangered species. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering.

Section 7 of the ESA outlines procedures for Federal interagency cooperation to conserve Federally listed species and designated critical habitat. ESA mandates that all Federal agencies participate in the conservation and recovery of listed threatened and endangered species and that each agency ensures that any action it authorizes, funds, or carries out does not jeopardize the continued existence of a listed species or its critical habitat. Critical habitat is identified as specific areas that have the physical and biological features that are essential to the conservation of a listed species, and that may require special management considerations for protection. Section 7 outlines the required consultation procedures that provide Federal agencies with a mechanism for “incidental take,” provided the “taking” would not jeopardize the continued existence of any listed species, or destroy or adversely modify critical habitat. Depending on the anticipated level of impact to Federally listed species, the Federal lead agency and the USFWS and/or NMFS would engage in different levels of consultation.

The MSFCMA, also known as the Sustainable Fisheries Act (16 USC Section 1801 et seq.), requires NMFS and the eight regional Fishery Management Councils to minimize, to the extent practicable, adverse effects to EFH. EFH is defined as the waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity (50 CFR 600 et seq.). The EFH provisions of the MSFCMA are designed to protect fisheries habitat from being lost due to disturbance and degradation. NMFS and the regional Fishery Management Councils identify and describe EFH for each of the commercially managed marine and anadromous fish species in published fishery management plans.

The MSFCMA requires all Federal agencies to consult with NMFS (under the stewardship of the Secretary of Commerce) on activities or proposed activities that are authorized, funded, or undertaken by that agency that may adversely affect EFH. NMFS must then provide conservation recommendations to conserve and reduce impacts to EFH. Federal agencies are required to respond to EFH Conservation Recommendations. Guidelines from the MSFCMA direct NMFS to use a coordinated process to evaluate projects that may affect EFH under Section 305(b) of the MSFCMA (16 USC Section 1855[b]; 50 CFR 600 et seq.). EFH consultation would be included with the Section 7 consultation (16 USC Section 1536).

National Historic Preservation Act, Section 106

The proposed action may affect properties that are listed or eligible for listing on the National Register of Historic Places (NRHP) or affect archaeological resources.

Section 106 of the National Historic Preservation Act (NHPA) and implementing regulations at 36 CFR Part 800 require Federal agencies to take into account the effects of their undertakings on cultural resources (which include archaeological and architectural resources, and traditional cultural properties) that are listed in, are eligible for listing in, or are potentially eligible for listing in, the NRHP. During this process, the Federal agency is required to consult with the State Historic Preservation Officer (SHPO), and in some instances the Advisory Council on Historic Preservation, an independent Federal agency that advises the President and Congress on national historic preservation policy and administers the NHPA's Section 106 review process.

Federal National Marine Sanctuary Act (NMSA)

Although the Greater Farallones National Marine Sanctuary accepts permit applications for research, education, and salvage activities, if proposed project activities extend into their jurisdiction within the Gulf of the Farallones it is anticipated that a permit would need to be obtained for any investigations informing final design.

State Agency Environmental Compliance

Clean Water Act Section 401

The proposed action would result in fill and/or dredging of jurisdictional waters of the State, including wetlands. As a result, a Section 401 Water Quality Certification would be required for these actions

Under Section 401 of the CWA, an applicant for a Section 404 permit must obtain a certificate stating that proposed fill is consistent with the State's water quality standards and criteria. In California, the authority to grant water quality certification is delegated by the State Water Resource Control Board (SWRCB) to the nine RWQCBs. Due to its location, the project falls under jurisdiction of the San Francisco Bay RWQCB (SFRWQCB); therefore, the lead agency would consult with the SFRWQCB to obtain a Section 401 Water Quality Certification.

Clean Water Act Section 402

The proposed action could result in discharges of pollutants into waters of the State, which include "any surface water or ground water, including saline waters, within the boundaries of the State." An NPDES permit would be required for construction-related discharges to surface waters if the project is 1 acre or greater in size. Preliminary conceptual designs for the project estimate approximately 1 acre of disturbance.

In 1972, the Federal Water Pollution Control Act (also referred to as the CWA) was amended to provide that the discharge of pollutants to waters of the United States from any point source is unlawful unless the discharge is in compliance with an NPDES permit. The 1987 amendments to the CWA added Section 402(p), which established a framework for regulating municipal and industrial storm water discharges under the NPDES Program.

On November 16, 1990, the USEPA published final regulations that established stormwater permit application requirements for specified categories of industries. The regulations provide that discharges of stormwater to waters of the United States from construction projects that encompass 5 or more acres of soil disturbance are effectively prohibited unless the discharge is in compliance with an NPDES Permit.

Regulations (Phase II Rule) that became final on December 8, 1999, lowered the permitting threshold from 5 acres to 1 acre.

USEPA's Storm Water Phase II Final Rule provides the option for a Small Construction Rainfall Erosivity Waiver. This waiver applies to small construction sites between 1 and 5 acres, and allows permitting authorities to waive those sites that do not have adverse water quality impacts. Dischargers eligible for this waiver are exempt from Construction General Permit Coverage. In order to obtain the waiver, the discharger must certify to the SWRCB that small construction activity would occur only when the rainfall erosivity factor is less than 5 ("R" in the Revised Universal Soil Loss Equation).

Dischargers whose projects disturb 1 or more acres of soil or whose projects disturb less than 1 acre but are part of a larger common plan of development that in total disturbs 1 or more acres, are required to obtain coverage under the State of California's General Permit for Storm Water Discharges Associated with Construction and Land Disturbance Activities (Construction General Permit) (NPDES General Permit CAS000002, Order 2009-0009-DWQ as amended by 2010-0006-DWQ and Order No. 2010-0014-DWQ) (Construction General Permit) and subsequent revisions. Construction activity subject to this permit includes clearing, grading, and disturbances to the ground such as stockpiling or excavation, but does not include regular maintenance activities performed to restore the original line, grade, or capacity of the facility. The authority to regulate compliance with CWA Section 402 requirements is shared between the SWRCB and the nine RWQCBs. Most enforcement responsibilities are delegated to the RWQCBs; however, the permit registration forms and all reporting documentation are submitted to the SWRCB via the Stormwater Multi-Application and Report Tracking System (SMARTS) on-line database.

Compliance with the General Permit also requires on-site visual monitoring of stormwater and non–stormwater discharges and the submission of annual reports throughout the duration of the project. Depending on the risk level of the project, additional effluent monitoring or bioassessment sampling may be required. Once the project is complete, the applicant must submit a Notice of Termination (NOT) to the SWRCB via SMARTS, to be approved by the RWQCB.

California Coastal Act of 1976

The California Coastal Commission (Coastal Commission) has authority under the California Coastal Act of 1976 (Coastal Act). The Coastal Commission, in partnership with coastal cities and counties, plans and regulates the use of land and water in the coastal zone. The coastal zone covers an area on land that varies in width from several hundred feet in highly urbanized areas, up to five miles in certain rural areas, and offshore the coastal zone includes a three-mile-wide band of ocean. The Coastal Act includes specific policies (Division 20, Public Resources Code) that address issues such as shoreline public access and recreation, terrestrial and marine habitat protection, visual resources, landform alteration, agricultural lands, commercial fisheries, water quality, transportation, development design, ports, and public works, among others.

The proposed action would take place within the coastal zone. Development activities within the coastal zone generally require a coastal permit from either the Coastal Commission or the local government. Development activities are broadly defined to include construction of buildings, divisions of land, and activities that change the intensity of use of land or public access to coastal waters, among others.

California's coastal management program is carried out through a partnership between state and local governments. Implementation of Coastal Act policies is accomplished primarily through the preparation of local coastal programs (LCPs). Development within the coastal zone cannot begin until a coastal development permit has been issued by either the Coastal Commission or a local government that has a Commission-certified LCP.

Along with the other State agencies (RWQCB and CDFW), the Coastal Commission has jurisdiction over wetlands and other waters in the coastal zone. The category "jurisdictional waters" includes wetlands and other waters, as well as any adjacent riparian areas. Wetlands and other waters that fall within the California coastal zone as defined by the Coastal Act are subject to confirmation by the CCC.

The Coastal Commission wetland delineation guidelines differ from USACE guidelines in that they rely on single-parameter approach (the presence of hydric vegetation or hydric soil), rather than a three parameter approach (presence of hydric vegetation, hydric soils and hydrology), to establish jurisdiction over wetlands.

Special-status plant communities are also protected by the Coastal Commission (California Public Resources Code, Section 30240) as Environmentally Sensitive Habitat Areas (ESHA's) under Local Conservation Plans (LCP's). The Coastal Act provides a definition of "environmentally sensitive area" as: "Any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments" (Section 30107.5).

California Endangered Species Act

State-listed threatened or endangered species potentially occur in the project area. Implementation of the proposed action may result in adverse effects to these species or their habitat. For species listed as "Fully Protected," CDFW cannot issue take authorization and requires the project proponent to completely avoid these species.

The California Endangered Species Act (CESA) (Fish and Game Code Section 2050 et seq.) generally parallels the main provisions of the Federal ESA and is administered by CDFW. Under CESA, the term "endangered species" is defined as a species of plant, fish, or wildlife that is "in serious danger of becoming extinct throughout all, or a significant portion of, its range" and is limited to species or subspecies native to California.

Sections 2080 and 2081 of the Fish and Game Code cover the "take" of State threatened and endangered species. One of two CESA-compliance processes is generally followed when take of a State-listed species may occur, the Section 2080.1 consistency determination or Section 2081 incidental take permit processes. If all listed species potentially affected by the proposed action are protected under both the Federal ESA and CESA, the California legislation encourages cooperative and simultaneous consultation between USFWS and CDFW to coordinate the Federal ESA Section 7 process and the CESA process so that consistent and compatible findings result. In this circumstance, authorization for take under CESA would be provided by a Section 2080.1 consistency determination. Section 2080.1 allows an applicant who has obtained a Federal incidental take statement through Section 7 consultation to request that CDFW issue a consistency determination stating that the Federal document is "consistent" with CESA. A Section 2081 incidental take permit is required if agreement cannot be reached about consistency, for example if the Biological Opinion allows for incidental take of a fully protected species or if the project may affect a species that is only listed by the State.

California Fish and Game Code Section 1602

The proposed action would substantially divert or obstruct the natural flow or substantially change the bed, channel, or bank of a river, stream, or lake or use materials from a streambed. As a result, a notification of Streambed Alteration Agreement pursuant to Section 1600 et seq. of the Fish and Game Code must be submitted for this project.

CDFW's Lake and Streambed Alteration Program (Fish and Game Code Section 1600 et. seq.) requires any person, State or local governmental agency, or any public utility who proposes a project that would substantially divert or obstruct the natural flow or substantially change the bed, channel, or bank of any river, stream, or lake or use materials from a streambed to notify CDFW.

After CDFW determines that the project would need a Lake or Streambed Alteration Agreement, project activities within jurisdictional waters may not begin until a Lake or Streambed Alteration Agreement is developed and the project described in that agreement is reviewed under CEQA. By working with CDFW to develop a draft Lake or Streambed Alteration Agreement, the project applicant can modify the project features to avoid or lessen potential impacts on fish and wildlife resources. This would simplify CEQA review of the project and expedite the issuance of a final agreement.

Habitat Restoration and Enhancement Act of 2014

The proposed action may, under some design alternatives, qualify as a small-scale, voluntary habitat restoration project. As a result, a Request to Approve Habitat Restoration or Enhancement can be submitted to CDFW for this project. This permit eliminates the need for a Lake or Streambed Alteration Agreement or CESA permit.

The Habitat Restoration and Enhancement Act of 2014 (Act; Assem. Bill No. 2193, approved by the Governor on September 26, 2014) established a simplified permitting process through CDFW for landowners, State and local government agencies, and conservation organizations for implementing small-scale, voluntary habitat restoration projects. Restoration and Enhancement projects approved by CDFW would not require additional permits from CDFW, such as a Lake or Streambed Alteration agreement or CESA permit. CDFW would approve complete applications within 30 days for projects that have already received a CWA 401 Water Quality Certification; and 60 days for those projects not already having the CWA 401 Water Quality Certification (i.e., Fish & Game Code, §§ 1652 and 1653)

Habitat restoration or enhancement projects, as defined by the Act, are projects with the primary purpose of improving fish and wildlife habitat that also meet the eligibility requirements for the SWRCB's Order for CWA Section 401 General Water Quality Certification for Small Habitat Restoration Projects. Projects approved under the Act must also be consistent with widely recognized restoration practices, avoid or minimize incidental impacts, and result in measurable environmental benefits. Voluntary restoration projects up to 5 acres in size and 500 cumulative linear feet of streambank or shoreline can be authorized under Sections 1652 or 1653 if they are eligible to qualify under the State Water Board's General 401 Water Quality Certification for Small Habitat Restoration Projects. Permit approval time is 30 days for projects with a State Water Board General 401 Certification; and 60 days for approval for projects eligible for the Water Board's General Certification, but receiving other types of approval from the SWRCB/RWQCBs. This permitting process allows for use of monitoring plans and/or reports from other permits.

Preliminary consultation with CDFW would be needed to provide the opportunity for agency feedback to confirm the project qualified for a Section 1653 Habitat Restoration or Enhancement Project Approval from CDFW. To obtain approval, the applicant would submit a Request to Approve Habitat Restoration or Enhancement Project. CDFW would have 60 days to approve the project if the director determines that the written request includes all of the required information.

Encroachment Permit

Encroachment permits are issued by Caltrans to other agencies or parties that perform construction activities within its right-of-way. Under an encroachment permit, Caltrans requires the agency or party to implement an appropriate stormwater protection program. Caltrans retains ultimate responsibility for ensuring that the portion of the project within the Caltrans right-of-way is in compliance with Federal, State, and local stormwater protection regulations. Project activities may encroach upon Caltrans rights-of-way over State Route 1 thus requiring an encroachment permit.

Local Agency Environmental Compliance

Bay Area Air Quality Management District Regulations

The Clean Air Act (CAA) establishes national ambient air quality standards. Under the CAA, the USEPA is responsible for setting and enforcing the Federal ambient air quality standards for atmospheric pollutants. Most regulatory responsibilities under the CAA are delegated to State, regional, or local government bodies. For the project, the Bay Area Air Quality Management District (BAAQMD) has the authority to issue permits and ensure compliance with air quality regulations.

Any Federal agency providing financial assistance, issuing a license or permit, or approving or supporting in any way a proposed project located in a nonattainment or maintenance area for a criteria air pollutant is required to issue a conformity analysis. The conformity analysis must certify that the Federally permitted project is consistent with the State Implementation Plan (SIP) developed pursuant to the CAA. A conformity analysis is required unless the proposed action's emissions are below the Federally established *de minimis* emissions thresholds, and the proposed action's emissions do not reach the level of 10 percent or more of the regional emissions budget for any given pollutant in the nonattainment area. This is also applicable to short-term, construction-related emissions, and therefore applies to the project.

Because the project would not require the construction or operation of a major stationary source that is adding new emissions units or modifying existing emissions units, the project would not require an Authority to Construct or a Permit to Operate from the BAAQMD. However, if the project requires the use of equipment (i.e., a generator) with an internal combustion engine with a rated brake horsepower greater than 50 horsepower that would operate less than 12 months at one location, a portable permit would be required that would allow the portable equipment to be operated within the BAAQMD.

The CAA requires areas with unhealthy levels of ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and inhalable particulate matter to develop SIPs to comply with the national ambient air quality standards (42 USC §7410 et seq.). Federal agencies must conform to SIPs, meaning they must ensure that Federally supported activities would not cause or contribute to a new violation, increase the severity of an existing violation, or delay timely attainment of any standard in any area (42 USC §7506(c)(1)(B)).

A Federal action conforms with the applicable SIP if: (1) the total of direct and indirect emissions from the action are compliant and consistent with the requirements of the SIP; and (2) one of a list of enumerated, pollutant-specific requirements is satisfied (such as accounting for the Federal action's projected emission of any criteria pollutant in the SIP, or offsetting ozone or nitrogen dioxide emissions in the nonattainment area) (42 CFR §93.158(a)). Ultimately, a conformity analysis may require revising the SIP, implementing mitigation measures to bring the Federal action's emissions levels down, or altering the project to reduce emissions to levels within the budgets established by the SIP for specific pollutants.

Marin County Code of Ordinances

Tree Removal Permits

The Native Tree Protection and Preservation ordinance under the Marin County Code of Ordinances does not apply to properties located in the coastal zone, and a Coastal Permit may instead be required for the removal of trees and vegetation. The project would need to comply with the Marin Countywide Plan for tree removal.

Roads and Bridges

As described in Title 13 of the Marin County Code of Ordinances, roadway modifications and any bridges if determined as part of the selected alternative, would be designed and built in compliance with the requirements outlined. Excavation, grading and filling would be compliant with Chapter 23.08 and stormwater runoff pollution, described in Chapter 23.18.

Chapter 23.08.025: Marin County Grading Ordinance

The Marin County Grading Ordinance under Chapter 23.08.025, establishes the minimum requirements for all grading and filling work done within the unincorporated County lands.

Applicable Laws, Policies, and Plans Not Requiring Specific Permit or Approval

Federal

Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA), first enacted in 1918, implements domestically a series of treaties between the United States and Great Britain (on behalf of Canada), Mexico, Japan, and the former Soviet Union that provide for international migratory bird protection. The MBTA authorizes the Secretary of the Interior to regulate the taking of migratory birds; the act provides that it shall be unlawful, except as permitted by regulations, "to pursue, take, or kill any migratory bird, or any part, nest or egg of any such bird…" (USC Title 16, Section 703). This prohibition includes both direct and indirect acts, although harassment and habitat modification are not included unless they result in direct loss of birds, nests, or eggs. The current list of species protected by MBTA includes several hundred species, and essentially includes all native birds. The act offers no statutory or regulatory mechanism for obtaining an incidental take permit for the loss of nongame migratory birds.

Bald and Golden Eagle Protection Act

The Bald and Golden Eagle Protection Act (16 USC 668-668d, 54 Stat. 250) as amended, provides protection for the bald eagle (*Haliaeetus leucocephalus*) and golden eagle (*Aquila chrysaetos*) by prohibiting the taking, possession, and commerce of such birds, their nests, eggs, or feathers unless expressly authorized by permit pursuant to Federal regulations.

Executive Order 11990 (Wetlands Policy)

Executive Order 11990 is an overall wetlands policy for all agencies that manage Federal lands, sponsor Federal projects, or provide Federal funds to State or local projects. The order requires Federal agencies to follow avoidance, mitigation, and preservation procedures with public input before they propose new construction in wetlands. Executive Order 11990 can restrict the sale of Federal land containing wetlands; however, it does not apply to Federal discretionary authority for non-Federal projects (other than funding) on non-Federal land.

Before implementing an action that is located in a wetland or may affect a wetland, Federal agencies must demonstrate that there is no practical alternative and that the proposed action includes all practical measures to minimize harm to the wetlands. To demonstrate compliance with Executive Order 11990, the Federal lead agency must make such a demonstration if appropriate, provide the opportunity for early public review, and disclose its findings in the project EIR and/or subsequent NEPA documents.

Projects requiring compliance with Executive Order 11990 (except USACE projects) are likely to require a permit under CWA Section 404. The assessment of effects of the proposed action on wetlands should be closely coordinated with the Section 404 process.

Executive Order 11988 (Flood Hazard Policy)

Executive Order 11988 is a flood hazard policy for all Federal agencies that manage Federal lands, sponsor Federal projects, or provide Federal funds to State or local projects. It may be applicable if Federal funding is obtained for the project. It requires that all Federal agencies take necessary action to reduce the risk of flood loss; restore and preserve the natural and beneficial values served by floodplains; and minimize the impacts of floods on human safety, health, and welfare.

National Park Service Director's Order #77-1

This Director's Order establishes the policies, requirements, and standards through which the National Park Service (NPS) meets its responsibilities under Executive Order 11990 (Wetlands Policy) to protect and preserve wetlands. Under the NPS Director's Order #77-1, the NPS classified wetlands according to the U.S. Fish and Wildlife Services "Classification of Wetlands and Deepwater Habitats of the United States" (Cowardin) (Report FWS/OBS-79/31; Cowardin et al. 1979). Under this definition, a wetland must have one or more of the following three attributes:

1. At least periodically, the land supports predominantly hydrophytes (wetland vegetation);

2. The substrate is predominantly undrained hydric soil; or

3. The substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

State

California Native Plant Protection Act

Sections 1900-1913 of the Fish and Game Code (California Native Plant Protection Act of 1977) establish criteria for the preservation, protection, and enhancement of endangered or rare native plants of the State. The California Native Plant Protection Act protects endangered and rare species, subspecies, and varieties of wild plants native to California. This act requires all State agencies to use their authority to carry out programs to conserve endangered and rare native plants. Provisions of the California Native Plant Protection Act prohibit the taking of listed plants from the wild, and require notification of the CDFW at least 10 days in advance of any change in land use. The project sponsor is required to conduct botanical inventories and consult with the CDFW during project planning to comply with the provisions of this act and sections of CEQA that apply to rare or endangered plants.

California Native Plant Society Species Designations

The California Native Plant Society (CNPS) is a Statewide nonprofit organization that seeks to increase understanding of California's native flora and to preserve this rich resource for future generations. CNPS has developed and maintains lists of vascular plants of special concern in California. CNPS-listed species have no formal legal protection, but the values and importance of these lists are widely recognized. CNPS List 1 and List 2 species are considered rare plants pursuant to Section 15380 of CEQA, and it is recommended that they be fully considered while preparing environmental documents relating to CEQA.

Porter-Cologne Water Quality Control Act

Under the Porter-Cologne Water Quality Control Act, the RWQCBs have jurisdiction over State water quality permitting activities. The Porter-Cologne Water Quality Control Act specifies water quality provisions and discharge requirements for regulating the discharge of waste that could affect the quality of waters of the State. Under the Act, the SWRCB has the ultimate authority over State water rights and water quality policy. However, the appropriate RWQCB is tasked with setting waste discharge requirements for projects and for updating basin plans (water quality control plans) for protected waters of the State. Waters of the State are defined as “any surface water or groundwater, including saline waters, within the boundaries of the State (Water Code section 13050(e)) which includes all waters within the State’s boundaries, whether private or public, including waters in both natural and artificial channels.”

Under the Act, RWQCB must prepare and periodically update water quality control basin plans. Each basin plan sets forth water quality standards for surface water and groundwater, as well as actions to control nonpoint and point sources of pollution to achieve and maintain these standards. Projects that affect wetlands or waters must meet RWQCB waste discharge requirements, which may be issued in addition to a water quality certification under Section 401 of the CWA.

California Register of Historical Resources

PRC Section 5024.1 establishes the California Register of Historical Resources (CRHR). The register lists all properties considered to be significant historical resources in the State. The CRHR includes all properties listed or determined eligible for listing on the NRHP, including properties evaluated under Section 106. The criteria for listing are similar to those of the NRHP. CEQA (PRC) Section 21084.1 requires a finding of significance for substantial adverse changes to historical resources and defines the term “historical resources.” CEQA Section 21083.2 and CEQA Guidelines Section 15064.5(c) provide further definitions and guidance for archaeological sites and their treatment. The lead agency is required to follow the established guidelines during the CEQA process.

California Native American Graves Protection and Repatriation Act

The California Native American Graves Protection and Repatriation Act (California Health & Safety Code Section 8010 et seq.) establishes a State repatriation policy intent that is consistent with and facilitates implementation of the Federal Native American Graves Protection and Repatriation Act. The act strives to ensure that all California Indian human remains and cultural items are treated with dignity and respect, and states an intent for the State to provide mechanisms for aiding California Indian tribes, including non-Federally recognized tribes.

Local

Marin County Department of Planning and Development would require compliance with local plans and ordinances, such as County general plans, zoning ordinances, grading plan, and various use permits.

Attachment F. Additional Studies Memorandum

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MEMORANDUM

To: Veronica Pearson & James Raives, Marin County Open Space District

From: David Halsing and Kristin Tremain, AECOM

Date: June 1, 2016

Re: Bolinas Lagoon North End Restoration Project – Additional Studies and Data Needed

This memorandum presents the results of a task associated with the Bolinas Lagoon North End Restoration Project (project) in unincorporated Marin County near the community of Bolinas. This memorandum presents a list of the AECOM project team's assessment of additional studies, surveys, or other data collection efforts which are likely to be needed to assess any onsite or offsite information necessary to adequately inform the project design. The project aims to reduce current flooding of roadways and to develop infrastructure adaptations that address future sea-level rise and increased traffic safety. Through this process, the project aims to improve the ecological functions and habitat values of the tidal marshes, streams, riparian corridors, and upland habitats at the north end of the lagoon. The first part of AECOM project's scope was to perform a series of desktop analyses, field surveys, records and database searches, and other data collection efforts on a variety of topics. The results of those efforts are being presented to the Marin County Open Space District (MCOSD) and its partner agencies in a set of technical memoranda and a larger, integrative Site Conditions Report.

The existing conditions studies, technical memoranda, and Site Conditions Report covered a number of subjects including biological resources, cultural resources, current and historical hydrology and geomorphology, traffic counts, utilities, and parcel ownership. All of these studies and data collection efforts were intended to be preliminary and conducted at reconnaissance levels that would be sufficient to inform the development of conceptual designs for a range of alternatives of possible future projects. Once a restoration alternative is selected for further design and environmental clearance, it is likely that additional data and other surveys would be needed. The MCOSD recognized this likelihood and thus directed that the scope of the current project include this brief memorandum about additional studies and data needed.

The range of possible design alternatives is not yet known, but at the very least, the alternatives will consider a number of changes to the existing roadways, culverts, stream channels, uplands, wetlands, and riparian corridors. The specifics of these alternatives will shape the types, spatial extent, and levels of detail of the information needed for subsequent design, permitting, and environmental clearance. However, many of the possible alternatives and their components are likely to need very similar information, and the below list of studies can be used for preliminary planning and budgeting future project stages. Note, however, that the extent and level of detail (as well as cost) needed are likely to vary depending on the alternative selected. For example, the degree of geotechnical investigations needed for an alternative with a causeway would be more extensive than one that instead included improved culverts.

Table 1, below, presents these suggestions for future planning. Each item in the table is given a brief title or description, a justification or explanation of why it is necessary, and a rough estimate of the expected costs. Items that are marked with an asterisk are additional studies that may not be necessary but could further inform project design. Following the summary table, more detailed explanations of the studies and their costs and rationales are provided.

Table 1. Additional Studies and Data Needed

Item	Data Collection Effort or Study	Justification	Approximate Cost Range & Notes
1	Geotechnical investigations (borings and cone penetrometer testing); piezometer installation along roadway for structural design[1]	Assess subsurface conditions and the ability of existing roadbeds and areas adjacent to them to support additional fill (e.g., concrete box culverts, piles for a causeway).	$123,000 for borings and/or Cone Penetrometer Testing (CPT) at 10 locations plus lab analysis, county permits, and geotechnical report
2*	Groundwater monitoring for salinity and determining groundwater profile and annual fluctuations; piezometer installation along alluvial fans in anticipated flow direction, plus equipment and monitoring	Preliminary ecological assessments indicate that existing roadbeds and culverts interfere with groundwater flow and have created barriers to natural gradients, which affect vegetation. It would be important to verify and refine these conclusions prior to restoration actions being implemented. Monitoring budget includes two years' time.	$66,000 for 10 hand-augured test wells; or $92,000 for drilled piezometers including permits, installation, monitoring equipment, data download and analyses, and reporting
3	More detailed hydrologic and geomorphic surveys, instream flow monitoring*, and reference reach assessment/surveys	Preliminary stream geometry surveys and simplified hydrologic analysis provide an understanding of existing conditions, but more detailed information would refine alternatives development (i.e., evaluating bankfull geometry, etc.). In-stream flow monitoring would help determine the flow losses to the alluvial fan at various discharges and times of the year to further determine any necessary design considerations for appropriate channel sizing along the length of the alluvial fan. A reference reach assessment could be necessary. This would involve identifying and surveying a stream reach outside of the project study area, to be used as a reference reach for sizing aspects of a newly designed channel within the study area.	$139,000 - $160,000 for additional stream cross-sections[2] and other analyses of local hydrology, stream gage installation and monitoring, and reference reach surveys
4*	Upstream sediment source surveys	Upstream sediment source surveys would involve the assessment of general upper stream/watershed geomorphic conditions, in order to determine whether there are any potential large sediment sources currently not visible on the aerial or LiDAR imagery. Potential sediment sources, if present, could dramatically alter the amount of sediment supplied to the project site in the future.	$16,000 for field work, desktop surveys, analysis, mapping and reporting

Table 1. Additional Studies and Data Needed

Item	Data Collection Effort or Study	Justification	Approximate Cost Range & Notes
5	Hydrology & hydraulic (H&H) modeling of watershed(s) included in the project; sediment transport modeling	Preliminary stream geometry surveys provided estimates of bankfull flood elevations; however, a comprehensive H&H modeling analysis could be necessary for determination of various design discharges (e.g. 2, 50, 100 year recurrence interval), and for the assessment of existing and proposed flood extent for each recurrence event. Modeling results would be used at a later point to design stream channels, floodplains, and stream-road crossing structures.	$25,000 for model set up, parameterization, initial runs and alternatives, and report on results; data collected from cross section surveying and profile data (Item 6) and sediment data collected in the more detailed field stream assessments (item 3) would feed into this analysis
6	Detailed topographic land surveys	Existing LiDAR data accuracy is limited to portions of the study area that are not in steep or complex terrain or covered with dense vegetation; however, much of the study area along the streams contains dense vegetation and complex topography, not accurately represented in the LiDAR datasets. Initial hydrology and geomorphology surveys were coarse and not tied into established benchmarks. More detailed land surveys would establish current, detailed elevations for use in design and planning of any restoration alternatives.	$67,000 total for a detailed topo survey for Lewis Gulch and Wilkins Gulch Creeks and blending of LiDAR data with traditional survey data to produce a comprehensive topographic surface
7	Full cultural resource surveys and records searches/ geoarchaeological studies for selected project footprint; California Dep't of Recreation 523 form (site records)	These records will eventually be required for the California Environmental Quality Act (CEQA) and Section 106 consultation with the State Historic Preservation Office.	$20,000 for surveys, record searches, geoarcheological studies
8	Delineation of Jurisdictional Wetlands; riparian corridor surveys	Determine the extent and location of jurisdictional wetlands and non-wetland waters of the U.S. for Clean Water Act Section 404 and 401, as well as the California Coastal Commission. This could also include determination of whether the area qualifies as an Environmentally Sensitive Habitat Area under the Coastal Act.	$25,000 for all desktop and field surveys as well as necessary reports (e.g., Approved Jurisdictional Determination)
9	Rare plant surveys	Will be required for CEQA, the Federal Endangered Species Act (ESA), the California ESA, and permitting	$19,000 for all desktop and field surveys as well as necessary reports
10	Targeted wildlife surveys	Initial surveys classified wildlife habitats and noted species observed, they also noted special-status species that would be expected to occur in the area, but CEQA, the Federal ESA, and the California ESA would require targeted wildlife surveys of the area of a particular footprint to generate enough information to rule out or rule in a number of special-status wildlife species	$40,000-$50,000 for all desktop and field surveys as well as necessary reports

Table 1. Additional Studies and Data Needed

Item	Data Collection Effort or Study	Justification	Approximate Cost Range & Notes
11	U.S. Fish & Wildlife Service (USFWS) protocol-level surveys for California red-legged frog	Not recommended; there are recent records nearby and suitable habitat present; recommend inferring presence	$0
12	USFWS protocol-level surveys for other Federal ESA listed species	Protocol-level surveys could demonstrate presence or absence of ESA-listed species, which could shape their consideration under federal and state permitting. Alternatively, infer presence and obtain CEQA and ESA clearance for them.	Up to $60,000 depending on the species selected; protocol-level surveys require multiple long (including overnight) visits during multiple seasons as well as reporting
13	Maintenance records (culvert clearing; road repairs) and as-builts for roads and culverts in the selected project area	Efforts to obtain these as part of this scope have met with partial and limited success; these will be important for determining how much and what types of improvements in drainage might be required to address current flooding issues	Very low; Marin County Open Space District staff could perform tasks
14	Traffic accident study	A review of State and County vehicle accident reports and accident history, along with any related traffic studies would provide insightful information to further assess the means to improve safety in the project design.	Estimated at $5,000
15	Noise study	A noise consultant would conduct a brief noise assessment to determine what the increase in noise would be for the design alternatives. While the project would not lead to a net increase in the amount of noise, raising the roadway onto bridges or a causeway would likely increase the noise transmission to the human and animal receptors in the area.	Up to $10,000
16	Underground utility records searches and queries	Preliminary searches had limited success in obtaining this information from publicly available information and from various sources; more formal coordination between utility providers (e.g., the Underground Service Alert (USA) system) is necessary to verify locations or demonstrate absence of underground utilities once a project footprint is known.	Up to $3,000 for coordination time

*Data collection may not be necessary, but could further inform project design.

1 = Note that the geotechnical investigation borings and groundwater wells may in some cases could be combined to significantly lower the listed costs here; these estimates assume separate implementation.

2 = Cross sections used for additional bankfull analysis and flow monitoring would be conducted at the same cross sections surveyed for the H&H analysis to reduce costs.

Additional Studies and Data Needed

1. Geotechnical Investigations

Geotechnical investigations, including borings and/or cone penetrometer testing, would provide necessary information on subsurface conditions, and the ability for existing road beds and areas adjacent to them which may be proposed for road beds as part of the alternatives, to support additional fill (e.g., relocated roads, concrete box culverts, piles for a causeway). The geotechnical investigations would assess soil and rock type, stability, seepage, depth to bedrock, and other aspects of the local geology. Geotechnical investigations would be performed within the study area and could include locations where the roadway and crossing structures intersect suspected fault locations. Data obtained during geotechnical investigations would provide important information that would inform the development of designs for the alternatives, particularly for those aspects that involved roadway modifications.

As shown in Table 1, the geotechnical investigations scoped here would involve borings and/or Cone Penetrometer Testing (CPT) at 10 locations, as well as laboratory analysis of soils data collected. However, the number and depth of the investigations will vary depending on the complexity of the geology where borings are necessary and the alternative selected. For example, the areas under and around State Route (SR) 1may not need to be extensively studied if no changes were being considered to that roadway.

The process of geotechnical borings would involve a drill rig drilling down to various depths within the study area and extracting soil boring samples. The depth of the borings would depend on the substrate material, potential for liquefaction, and the depth to the bedrock or old bay clay. A geotechnical engineer would be onsite during boring activities to ensure proper boring techniques by the boring rig, as well as to confirm how deep the bores would need to go. The geotechnical engineer would log the geologic strata extracted from the cores. Once core samples were obtained, they would be sent to a laboratory for analysis. Laboratory analysis could include grain size analysis; testing of Atterberg limits (the critical water contents of fine grained soil, including shrinkage, plasticity, and liquid limits), soil moisture, soil density; and unconfined or confined compressive strengths to see how soils respond at depths.

CPT testing would involve a closed, hydraulically pushed stem, pushed into the ground to test for properties such as core pressure and shear strength. CPT is a faster way to obtain data without laboratory analysis because it does not require core samples to be obtained. However, more information could be extracted from a geotechnical boring. Typically, a single 50-foot deep boring could be dug in a day, whereas 3 or 4 CPTs at the same depth could be obtained in the same amount of time. CPT testing could be conducted at selected locations to augment information from borings at other locations.

Estimated costs would include:

- Geotechnical Borings = $103,000 – includes borings with a drill rig and/or CPT Testing (assumes one 50-foot well per day for a total of 10 days or 10 wells total), $3,000 for processing of Marin County well permits, $22,500 development of Caltrans traffic control plans/permit and for the traffic control during the drilling.
- Laboratory Tests = $13,000 for lab fees
- Consulting/Engineering/Environmental = $7,000 – includes staff time for coordination, oversight, monitoring during field investigations, data analysis, and data report.

Total Estimated Cost: $123,000

2. Groundwater Monitoring

Groundwater monitoring would provide important information on groundwater elevations and salinity levels as they change throughout the season. The surface water to groundwater interaction is not clearly understood in the study area, with regards to how the depth to groundwater and coinciding profile would change throughout the year at the top to the toe of the Wilkins and Lewis Gulch alluvial fans. The groundwater profile and elevations may further inform the understanding and design of channels, off channel pools/ponds, and vegetative communities that may be integrated into the restoration plans. Similarly, salinity values at some locations in the study area may fluctuate through the tidal cycle and/or year. The presence or absence of salinity is a significant factor influencing vegetation communities and wildlife habitat suitability. Salinity measurements were taken in the pond east of Fairfax-Bolinas Road, in the ditch north of SR 1 (draining Wilkins Gulch Creek) and in the Bolinas Lagoon. No salinity was measured in Wilkins Gulch Creek, west of Fairfax-Bolinas Road, within the northern portion of the Bolinas “Y”, or in the southwest portion of the study area.

The preliminary assessment of steam flows, wetland vegetation, and surface water salinity levels obtained during the reconnaissance surveys indicate that existing roadbeds and culverts interfere with groundwater flow and have created barriers to natural gradients, which could impair vegetation restoration. However, these assessments were anecdotal and limited, because the samples were taken at only a few locations and were not collected at the same points in the tidal cycles or at uniform depths. Further, salinity values taken in spring of an extreme drought year likely do not reflect values under more typical climate conditions. To understand groundwater and salinity levels in the project area, groundwater monitoring wells could be installed in a manner in which a profile gradient could be constructed from one location to another (e.g. from the top to the toe of the alluvial fans) and monitored to understand tidal influence and seasonality.

There are two types of groundwater monitoring wells that could be used: test wells and piezometers. Test wells measure the shallow or local water table elevation and salinity level in locations where the water table is known to be near the ground surface throughout the year. Test wells placed at several locations would provide an overall picture of groundwater levels in an area to assist in understanding the groundwater profile in regards to barriers (roads) in the project area, as well as to assist in the decision making regarding habitat restoration in the project area. A test well is made by placing a slotted PVC pipe in an augured hole, usually no more than 10 feet deep. The holes are often hand-augured, and in those cases, drill rigs are not necessary. The hole is then backfilled with gravel and clay and sealed with a bentonite plug. A pressure transducer or automatic water level logger can be placed in the well to measure the water pressure which can be correlated to the water depth. Automatic monitoring equipment can also monitor salinity, electrical conductivity, and water temperature. Loggers can record each parameter at a desired time interval (e.g. every 2, 6, 12, or 24 hours). Assuming wells can be hand-augured they are relatively inexpensive at approximately $2,500 per well, including approximately $1,000 per well for monitoring equipment.

Estimated costs for the test well approach:

- Well Installation via hand auguring = $27,000. This assumes 10 wells at $2,500 per well, derived from two people auguring two 10-foot wells per 8-hour day ($125/staff hour) plus supplies, then an additional $2,000 for travel time.
- County Permits = $3,000 total
- Consulting/Engineering/Environmental $36,000 – includes staff time for coordination, installation oversight, permit application preparation, periodic data downloads (quarterly for a two-year period), data analysis, and a data report for a two-year period of monitoring.

Total Estimated Cost: $51,000

Machine drilled and installed piezometers are necessary where the depth to the groundwater table is deeper than could otherwise be augured by hand. Automatic water level and water quality data loggers can be used to measure the depth to the water table, salinity, and water quality at desired time intervals. Piezometers are sealed PVC pipe 20 - 40 millimeters in diameter, with narrow slots cut in the bottom 25 centimeters to allow water entry. Because piezometers are drilled into an aquifer, they are usually installed at a depth greater than 10 feet. When three or more are installed at the same depth, the horizontal groundwater profile (and thus flow direction) can be determined; when installed at different depths at the same site, vertical water movement is monitored, indicating whether the site is acting as a recharge or discharge area, or an area of lateral water flow.[1]

Costs to drill and install piezometers are generally dependent on how many days the drill rig is required, and site conditions determine how many can be installed in a day. The conservative assumption here is that only one well could be drilled each day and that 10 wells would be needed for the study area as a whole.

Estimated costs for the piezometer approach:

- Well Installation and monitoring equipment for 10 wells = $50,000. This assumes $4,000 per day to drill and install one 50-foot well plus $1,000 per well for monitoring equipment
- County Permits = $3,000 total
- Consulting/Engineering/Environmental $39,000 – includes staff time for coordination, oversight during piezometer installation, permit application preparation, well monitoring, periodic data downloads (quarterly for a two-year period), and data analysis (for a two-year period).

Total Estimated Cost: $77,000

Note, however, that in the piezometer approach, the geotechnical investigations could be combined with the well placement at a reduced cost, should some of the geotechnical bores be located near the ideal piezometer locations. Placing the piezometers is relatively easy and fast once the drill rig is in place. If there were to be borings for the geotechnical investigations, the piezometers could probably be placed for an extra 10-15% of that cost.

3. More Detailed Hydrologic and Geomorphic Surveys

More detailed hydrologic and geomorphic surveys would provide a stronger understanding of stream hydrology and geomorphology in the project area and allow for refinement of model building and the correct sizing of structures and channels that may carry runoff in the future. The preliminary stream geometry surveys and simplified hydrologic analysis gave an understanding of existing bankfull conditions, but more detailed information would refine alternatives development, such as evaluating streamflow, culvert capacity, and related needs. Additional details to be collected could include obtaining additional cross sections, profiles, pebble counts, and bulk sediment samples to assess changing conditions along the length of the existing channels. Some of the information such as cross sections and profiles may be collected in conjunction with the topo surveys in order to reduce costs. (Note, however, that what is "needed" depends almost entirely on the restoration design alternatives. For example, if the

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[1] *Environmental Issues: Groundwater monitoring bores. NSW Government Office of Environment and Heritage. Page last updated 11 October 2013.* Available: http://www.environment.nsw.gov.au/salinity/basics/bores.htm

roadways are going to be elevated and culverts removed, then the stream(s) could be allowed to fan out and not be confined to a channel. In that alternative, the need for detailed hydrologic modeling for channel design and water conveyance structures would be obviated or simplified. Similarly, it may be appropriate to survey and analyze only one or two of the streams in the study area (Wilkins or Lewis Gulch Creeks). To be conservative, the costs here assume both Wilkins and Lewis Gulch Creeks are surveyed and that channel and conveyance structures will be included in a design alternative.)

Additional stream surveys could provide more precise discharge and hydraulic geometry predictions, especially if the desired restoration alternative involves channel or flood conveyance structure design. Additional cross section surveys, especially during or shortly following runoff events, could refine estimates of local bankfull discharge, hydraulic geometry, and improve the statistical analysis of the hydrological modeling described in item 2. Additional cross section surveys would help to determine if unique values are suspect and to reaffirm the values collected at the few other cross sections. Preliminary data results suggest that bankfull elevation (and thus cross sectional area) was overestimated in the reconnaissance level study. Various factors could lead to identification of a high bankfull estimate; one example would be a debris jam downstream that had a backwater effect into the area where the cross section measurements were collected. It is best that additional cross sections be surveyed to gain better confidence in the bankfull estimates.

To accommodate this, stream gages could be put in Wilkins and Lewis Gulch Creeks at a minimum of three locations along the length of the alluvial fan and monitored for a short period, if deemed necessary. Stream gage surveying would allow detailed modeling of the freshwater flow in the study area offering additional insight into how flows decrease and potentially increase as water moves downstream from the top of the alluvial fan to the bottom near the lagoon. This type of water monitoring differs from groundwater salinity monitoring (described above), which focuses on installing in-ground wells to measure the salinity of the groundwater in the project area, and for understanding groundwater flow and barriers – both natural and manmade by previous roadworks installations – that impact the directionality of water flow and habitat restoration of vegetation.

The most useful approach would be to gage the streams and measure flows that clarify the discharge under various flow conditions, especially bankfull discharge and greater, such as when the alluvial fan is saturated. At each monitoring site a water level recorder would be installed in a relatively stable riffle (with little to no cross sectional changes expected in the coming monitoring period) to record stream stage at 15-minute intervals to capture the peaks of each storm discharge. Water velocity measurements would be recorded at various water level stages to determine the discharge for the given cross sectional area. As above, if the channel does not need to be constructed and is instead allowed to flow free and form itself beneath an elevated causeway, there would be no need to develop the channel dimensions. A selection of some of the alternatives should be chosen before deciding which studies to pursue.

A reference reach assessment may be necessary to identify and survey a stream reach to be used as a reference reach for sizing each aspect of a newly designed channel within the project site. The reference stream should be the same channel type, valley type, be located in the same physiographic province, and be stable or in good functioning condition. Preliminary site assessments indicate that a suitable reference reach does not exist within or upstream of the study area. Nearby watersheds in the coast range would be checked for similar stream types as might be restored onsite to via a desktop and field investigation. Once an appropriate stream was identified, all aspects of the stream would be measured, including cross sections, longitudinal profile, pebble counts, and bulk bedload samples.

Additional data collected could include (not included in estimated cost below):

- Further investigation of Wharf Creek to determine potential impacts of flooding and sediment supply to project site.
- Analysis of regional stream gage data from the Point Reyes National Seashore could be sought to help refine estimates of bankfull discharges if deemed necessary for future restoration design.
- Determine where more land might be available around the entire Bolinas Lagoon for creating migration space and horizontal levees to accommodate rising sea level.

Estimated costs include:

- Additional bankfull field analysis would require 7-9 days field for 2 tech experts ($3k/day for two staff) and 3 days data entry and analysis ($1,500/day for one staff) = $26 - 32K) to survey Lewis and Wilkins Gulch Creeks.
- Flow monitoring: Equipment installation at 6 locations (top, middle, and bottom of fan for each stream). Equipment check/data download would occur monthly from Oct. – March; bimonthly checks would occur April - September. Velocity measurements, a minimum of 5 events, would be conducted in conjunction with equipment checks/downloads. Cost estimate includes monitoring equipment & installation ($5k/install), field visits at up to 9 days for two technical experts ($3k/day for two staff), pigmy/flo-mate equipment rental 5 days ($250/day), and 8 days of data entry/analysis ($1,500/day for one staff) = $71,000.
- Reference reach assessment: Would include 5-10 days looking for a reference reach location, followed by 5 days of surveying, and 4 days of data entry & write-up for two staff totaling $3/day = $42,000 – 57,000.

Total Estimated Cost: $139,000 - $160,000 depending on extent of additional analysis and streams surveyed.

4. Upper Watershed Sediment Source Surveys

Another source of information would be desktop and field surveys of geomorphic and stream conditions farther upstream than the initial reconnaissance surveys covered. This would identify and partially quantify the sediment sources including landslides, to provide information on the physical conditions that could dramatically alter the amount of sediment supplied. Sediment supply affects much of the existing alluvial fan and channel morphology, so understanding the rates of sediment supply flux within the creeks upstream of the study area would inform restoration alternative design. A report and maps of the upper watersheds and their sediment sources would be produced.

Surveys could include the three main watersheds of Lewis Gulch Creek, Wilkins Gulch Creek, and Salt Creek. Because of its small size and limited access the Wharf Creek watershed could be omitted or included to the extent possible in the surveys of Lewis Gulch Creek.

Estimated costs include:

- Desktop Mapping = $1,500
- Field Work Surveying = (3 days [1 per watershed] at 12 hours each, 2-person team) = $8,500
- Analysis and Reporting = $4,000
- Project Management

Total Estimated Cost: under $16,000

5. Hydrology and Hydraulic Watershed Modeling

Hydrologic and hydraulic modeling will be necessary to inform project designs. These designs need to address what flow volumes would need to be carried by any streams or culverts, and to assess how proposed project alternatives would interact with and accommodate existing flows and future flows. It would also inform how the stream-lagoon interface would be affected by sea level rise (SLR).

Preliminary stream geometry surveys and simplified hydrologic analysis conducted during the reconnaissance-level surveys provide an understanding of existing hydrology and watershed hydraulics. However, the hydrology and watershed hydraulics of the project area would be modeled in order to assess the effectiveness of alternatives considered for project development. Examples could include evaluating stream flow and culvert capacity design standards.

All four streams in the study area have been altered by diversions, ditching/channelization, culverts, road berms upstream of the tidal head, and other modifications. This has altered the natural flows and sediment conveyance to the Bolinas Lagoon. High flows coupled with high tides greatly increase the likelihood of flooding; yet the amount of flow required from the various streams to cause flooding in the study area is unknown. In order to most accurately model the watershed, additional cross section surveys, as described in item 3, will be needed for creating the model. Data collection from more detailed hydrologic surveys (item 3) would be input into the models to provide best fit and are not included in this cost estimate.

The Army Corps of Engineers HEC-HMS model will be used to generate flow data in the two creeks (Lewis Gulch Creek and Wilkins Gulch Creek). HEC-HMS simulates precipitation-runoff processes including infiltration, several transformation options to convert excess rainfall to runoff, and runoff routing. Model inputs include precipitation and watershed characteristics (e.g., land cover, soil type). Velocities and water depths in the creeks will be estimated using the Army Corps of Engineers HEC-RAS model. HEC-RAS performs one-dimensional steady and unsteady river hydraulic calculations. The model can be used to calculate water surface elevations and velocities including the effects of bridges, culverts, and instream structures such as weirs. Inputs include stream cross-sections, flows, Manning's n-values, sediment/bedload characteristics, and the characteristics of structures such as weirs and bridges. The model can include basins and tidal conditions. For both models sensitive parameters will be varied over a range of uncertainty and the corresponding range in output provided. Following model output, additional model simulations could be developed and run for an initial set of three project restoration alternatives. Additional costs for more or different alternatives would vary widely depending on the changes proposed on the alternative.

Estimated costs would include:

- Model Set Up and Calibration/Parameterization = $7,000
- Initial Model Runs and Output = $11,000
- Analysis and Results Reporting = $6,000
- Project Management = $1,000

Total Estimated Cost: $25,000

6. Detailed Topographic Land Surveys

Detailed topographic surveys would be necessary to establish current, detailed elevations of the study area for use in project design and planning alternatives, including restoration. Existing LiDAR data is good for the lagoon and portions of study area not in deep canyons or deep vegetation, but much of the study area was not covered by LiDAR surveys. The topographic surveys would specifically cover the main stems of Lewis Gulch Creek and Wilkins Gulch Creek, and portions of the largest tributaries to each. Detailed topographic surveys would establish current, detailed elevations for use in design and planning of any restoration alternatives. The ground survey data would be blended with the existing LiDAR data to produce a seamless topographic surface for design.

Estimated costs include:

- Research and Survey Control = $7,500 (50 staff hours @ $150/hour)
- Obtaining Topographic Data = $42,000 (280 staff hours @ $150/hour)
- Data Correction, Compilation, Transmittal = $3,750 (25 staff hours @ $150/hour)
- LiDAR & Ground Survey Data Surface Assembly = $9,750 (65 staff hours @ $150/hour)
- QA/QC, Safety Plans, Project Management = $1,500 (10 staff hours @ $150/hour)
- Equipment and Vehicle Costs = $2,500

Assuming similar surveys are desired for all of the area inside the Y (as opposed to just the stream channels), the costs could increase by approximately $18,000.

Total Estimated Cost for Topographic Surveys of Stream Channels: $67,000

7. Full Cultural Resource Surveys and Record Searches

Full cultural resource surveys and records searches for a selected project footprint will be required for CEQA and Section 106 consultation with the State Historic Preservation Office. A cursory site visit was conducted to gain a baseline understanding of what type of resources may be present in the project area. Using a project footprint much like that used for the preliminary studies, a full cultural resources survey would entail 2 cultural resources crew members for 4 days of surveys, a total of 8 person-days, each at 8 hours plus travel time (8 person-days * 10 hours/person-day * $125/hr = $10,000). This would include one day for the built environment and three one-day surveys for buried resources. A smaller project footprint could allow the extent of surveys to be similarly reduced.

Wilkins Ranch would warrant special consideration in this effort. While the structures themselves were omitted from most of the field surveys already conducted for this project, much of the ranch’s lands were included. If the structures and/or the lands would be affected by any alternative under consideration, they would need to be included in the Area of Potential Effect (APE), and the following steps would apply. The ranch would be evaluated and the crew would conduct pedestrian surveys of the buildings to photograph and document each part of it and note architectural characteristics to evaluate the resource. If the ranch and its structures could be definitively excluded from the APE, then a smaller footprint area and a reduced level of effort would be needed.

The cultural resource specialists may also conduct additional archival research such as going to libraries and any sources of historical societies to do research. Much of this was done prior to the field surveys (including the hydrology and geomorphology surveys), but those were somewhat targeted efforts that should be augmented as described here.

The survey level of effort would increase if cultural resources are found, which would require further evaluation and recording. This estimate does not include the costs of those processes, which are unknown at the present time.

Native American consultation is likely to be necessary under California's Assembly Bill (AB) 52. AB 52 requires a formal offering of site visits and project information to any tribes that request it, as well as ongoing coordination with tribes as appropriate. No Native American cultural resource sites have been identified in the project area yet; however, known resources in the greater region may warrant Native American participation. The estimates below include a placeholder value for these costs, which are quite uncertain.

Estimated costs include:

- Field Surveys ($10,000, as above)
- Historical Buildings/Structures ($1,500)
- Archival Research ($1,500)
- Records Search and Processing (<$1,000)
- CDR 523 Form Evaluation for Wilkins Ranch
- Native American Consultation (estimated at $3,000; likely range is $1,500 – 4,500)
- Project Reporting and Management ($3,000)

Total Estimated Cost: $20,000

8. Rare Plant Surveys

Rare plant surveys would be required for CEQA, the Federal Endangered Species Act (ESA), the California ESA, and permitting. Rare plant surveys would differ significantly from the reconnaissance surveys, as they would include multiple series of surveys with all unknown plants keyed out to species.

Rare plant surveys would involve three rounds of surveying throughout the growing season (early season, mid-season, and late season surveys) by two botanists for up to 3 days per round of surveys (8 hours per day plus 2 hours travel time at $100/person-hour, plus expenses). In addition, reference populations would be identified and surveyed during each of the three survey events to compare the reference population phenologies (periodic biological phenomena, such as flowering or setting of seeds, correlated with climatic conditions) with the phenologies of those species being surveyed for in the study area. Prior to the surveys, the species with moderate or greater potential to occur would be researched and reference populations would be identified. Following field work, a results memo would be prepared for each survey. Maps would be prepared to support the findings.

Estimated costs would include:

- Desktop-Level Research and Review ($2,000)
- Field Surveys and Data Collection ($7,000)
- Data Analysis and Mapping ($3,000)
- Report Preparation ($5,000)
- Project Management ($2,000)

Total Estimated Cost: $19,000

9. Delineation of Jurisdictional Wetlands and Riparian Corridor Surveys

The wetlands survey that was conducted for the site condition surveys was done at a reconnaissance level to map and characterize the various habitats and vegetation communities and to list the species directly observed. It did not include delineations of jurisdictional wetlands and other waters of the United States. In addition, the 2014/2015 winter left Marin County in a severe drought, making it the third consecutive year of drought. This condition is believed to have had a negative effect upon presence and growth of rare plant species, the composition of vegetation communities, and the extent of freshwater wetlands and water resources. The extent and location of jurisdictional wetlands and non-wetland waters of the U.S. regulated by the Clean Water Act Sections 404 and 401, as well as the California Coastal Commission would be determined by conducting a formal wetland delineation. Additionally, the riparian corridors should be surveyed and mapped to determine jurisdiction under the California Fish and Game Code Section 1602.

The total estimated cost of a jurisdictional wetland delineation is outlined below. Alternatively, because so much of the project area is wetland (it is almost all marsh and swamp both sides all roads where designs are in play), it would be less costly to "concede" rather than delineate at a fine scale the boundaries of wetlands within the defined project footprint. Delineation would require a lot of time and effort to delineate boundaries that are actually at the margins or outside of the project area. The cost of delineating small upland inclusions within the area of nearly complete wetlands may be higher than just treating them as wetland.[2]

Estimated costs for a full delineation, with similar costs and assumptions as for the rare plant surveys listed above, would include:

- Field Surveys and Data Collection
- Data Analysis and Mapping
- Report Preparation
- Project Management

Total Estimated Cost: $20,000-$25,000

10. Targeted Wildlife Surveys

Initial reconnaissance surveys classified wildlife habitats, noted any species observed, and took into consideration the potential for special-status species that would be expected to be in the area. CEQA, the Federal ESA (FESA), and the California ESA (CESA) would require targeted wildlife surveys of the area of any particular alternative footprint to generate enough information to rule out or rule in a number of special-status wildlife species. The study area provides habitat for special-status wildlife species and nesting birds protected under the California Fish and Game (CFG) Code and the Federal Migratory Bird Treaty Act (MBTA). Focused surveys could provide additional information on these species and their observed presence or potential to occur in the study area. Species that may require targeted surveys would include:

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[2] Baye, Peter. Pers comm. 2 October 2015.

- Foothill yellow-legged frog (CESA Species of Special Concern);
- Black rail (CESA Threatened); and
- Burrowing owl (CESA Species of Special Concern).

Protocol-level surveys often require multiple, long (including overnight) visits during multiple seasons as well as reporting and agency communication. Additional species, including nesting birds protected under the MBTA and associated CFG Code Section 3503 and 3503.5, and potentially additional species identified during agency consultation, could require additional surveys and reporting.

Estimated costs would include:

- Desktop-Level Research and Review
- Field Surveys and Data Collection
- Data Analysis and Mapping
- Report Preparation
- Agency Consultation
- Project Management

Total Estimated Cost: $40-50,000 for all desktop and field surveys as well as necessary reports for three to four species or groups of species that use similar habitats.

11. U.S. Fish & Wildlife Service (USFWS) Protocol-Level Surveys for California Red-Legged Frog

Given the high quality California red-legged frog (CRLF) habitat in the study area and the existing CNDDB records, CRLF individuals are most likely present in the study area. Therefore, it is recommended that presence be inferred and initiate formal agency consultation. There would be no cost to conduct surveys, as they would not be needed if presence were inferred.

Alternatively, focused CRLF surveys could be conducted for additional costs. This option would be useful if additional efforts were desired to understand specifically where in the study area CRLF occur, which could provide additional useful data and a more informative approach to project design alternatives and species-specific habitat restoration.

12. USFWS Protocol-Level Surveys for Other Federal ESA Listed Species

The study area provides potential habitat for special-status plant and animal species listed under the FESA, such as steelhead trout and others. Protocol-level surveys could be necessary for species protected under FESA:

- California freshwater shrimp (FESA Endangered); and
- Steelhead (FESA Threatened).

Efforts would include field surveys, survey report preparation, and agency consultation. Protocol-level surveys may require multiple, long (including overnight) visits during multiple seasons, as well as reporting and agency consultation.

An alternate option for steelhead, as described for CRLF above, given that critical habitat is present in the project area, would be to infer presence and conduct consultation with the National Marine Fisheries Service. This alternative would be less costly, as the desktop-level research, field surveying, and data analyses would not be necessary if presence were inferred.

Estimated costs would include:

- Desktop-Level Research and Review
- Field Surveys and Data Collection
- Data Analysis and Mapping
- Report Preparation
- Agency Consultation
- Project Management

Total Estimated Cost: up to $60,000 for desktop and field surveys and reporting on the above-listed species.

13. Maintenance Records

Maintenance records and more complete information on the frequency and extent of flooding, as well as determining the extent of dredging activities and amount of sediment removed from ditches and culverts in the study area would allow for a better understanding of flooding in the lagoon area, particularly as SLR increases. As SLR increases, the backwater effect of the lagoon on streamflow (i.e., water in the lagoon slowing outflows from the streams, especially at high tides) would move up into the stream drainages. With year-2100 SLR projected to be immediately adjacent to State Route 1 and to the county roads, any bedload carried downstream to that point under existing conditions would be deposited within culverts or other drainage structures under the road. The tidal delta would also expand from the current location and elevation to normalize with the projected elevation. If the road drainage structures do not have adequate capacity to accommodate the sediment, road flooding will dramatically increase. Maintenance needs, frequency, and costs of any drainage structures to clear sediment and reestablish drainage would increase.

Efforts to obtain these as part of this scope have met with partial and limited success; these will be important for determining how much and what types of improvements in drainage might be required to address current flooding issues.

Estimated costs would include:

- Desktop-level research and review
- Data collection
- Mapping
- Project management

Total Estimated Cost: Very low; Marin County Open Space District staff could perform tasks

14. Traffic Accident Study

Review existing accident reports and history, along with any related traffic studies, would provide further information to assess means to improve safety in the project design.

Estimated costs would include:

- Review of Marin County and California traffic accident reports and data within the study area; Review historical reports and communication with relevant agencies; and
- Produce a memo reporting the results of the data analysis and project implications.

Total Estimated Cost: up to $5,000

15. Noise Study

To determine what the increase in background noise would be along the roadways with each of the different design alternatives, a noise consultant could be hired to conduct a brief noise assessment. While the project would not lead to a net increase in the amount of noise, raising the roadway onto bridges or a causeway would likely increase the noise transmission to the human and animal receptors in the surrounding area.

Estimated costs would include:

- Noise assessment and modeling
- Noise assessment report
- Project management

Total Estimated Cost: up to $10,000

16. Underground Utility Searches and Records Queries

Preliminary searches had limited success in obtaining utility information from publicly available sources; more formal coordination between utility providers (e.g., the Underground Service Alert (USA) system) is necessary to verify locations or demonstrate absence of underground utilities once a project footprint is known.

Estimated costs would include:

- Site visit to mark project boundaries prior to utility providers' inspection
- Coordination and follow up with utility providers

Total Estimated Cost: Up to $3,000 for coordination time.

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