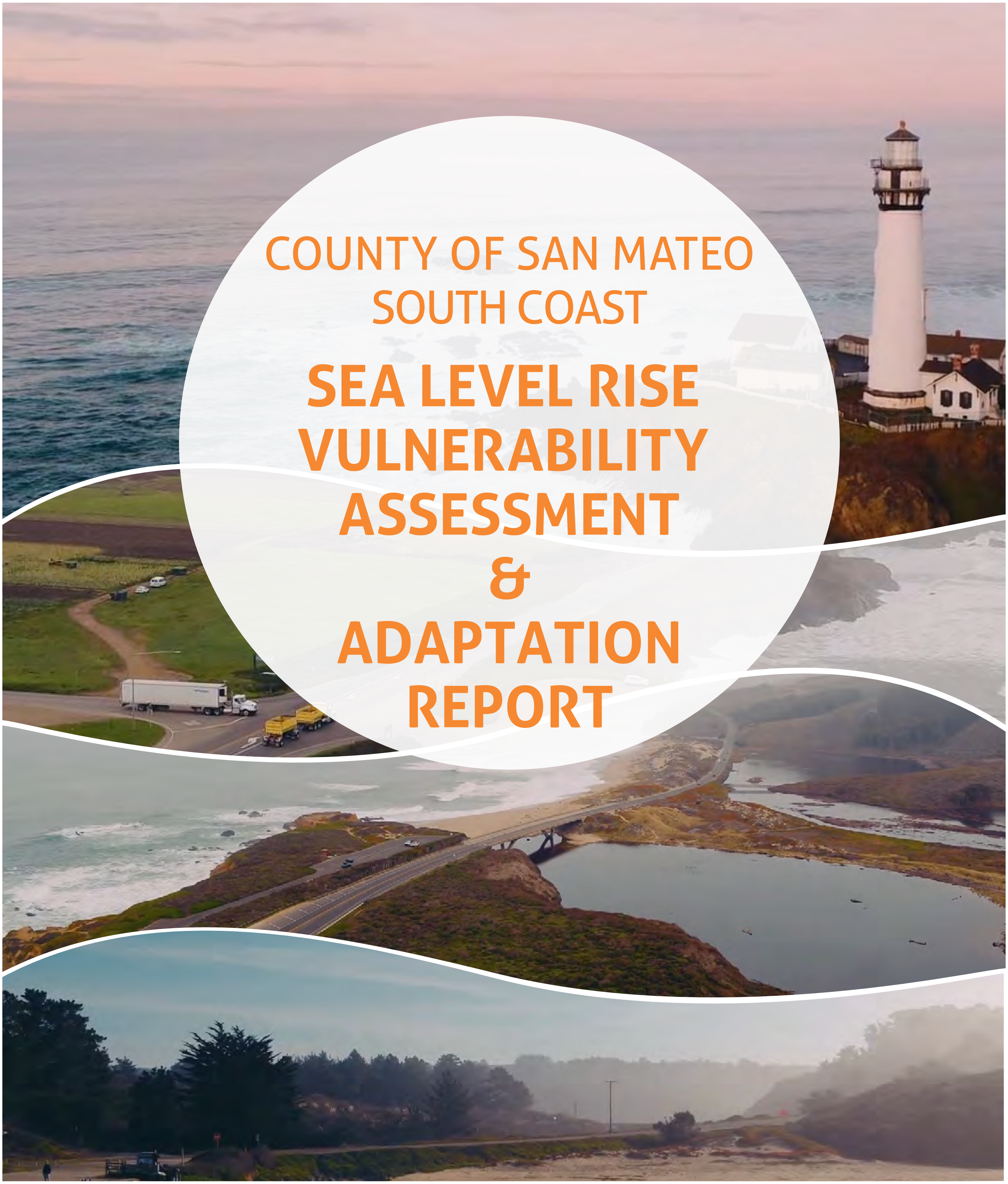
COUNTY OF SAN MATEO
SOUTH COAST

SEA LEVEL RISE VULNERABILITY ASSESSMENT & ADAPTATION REPORT



COUNTY OF SAN MATEO CALIFORNIA

SEA CHANGE
SAN MATEO COUNTY

OFFICE OF SUSTAINABILITY
COUNTY OF SAN MATEO

SAN MATEO RESOURCE CONSERVATION DISTRICT

integral consulting inc.

County of San Mateo South Coast

Sea Level Rise Vulnerability Assessment and Adaptation Report

Swan Dive Media, 2021

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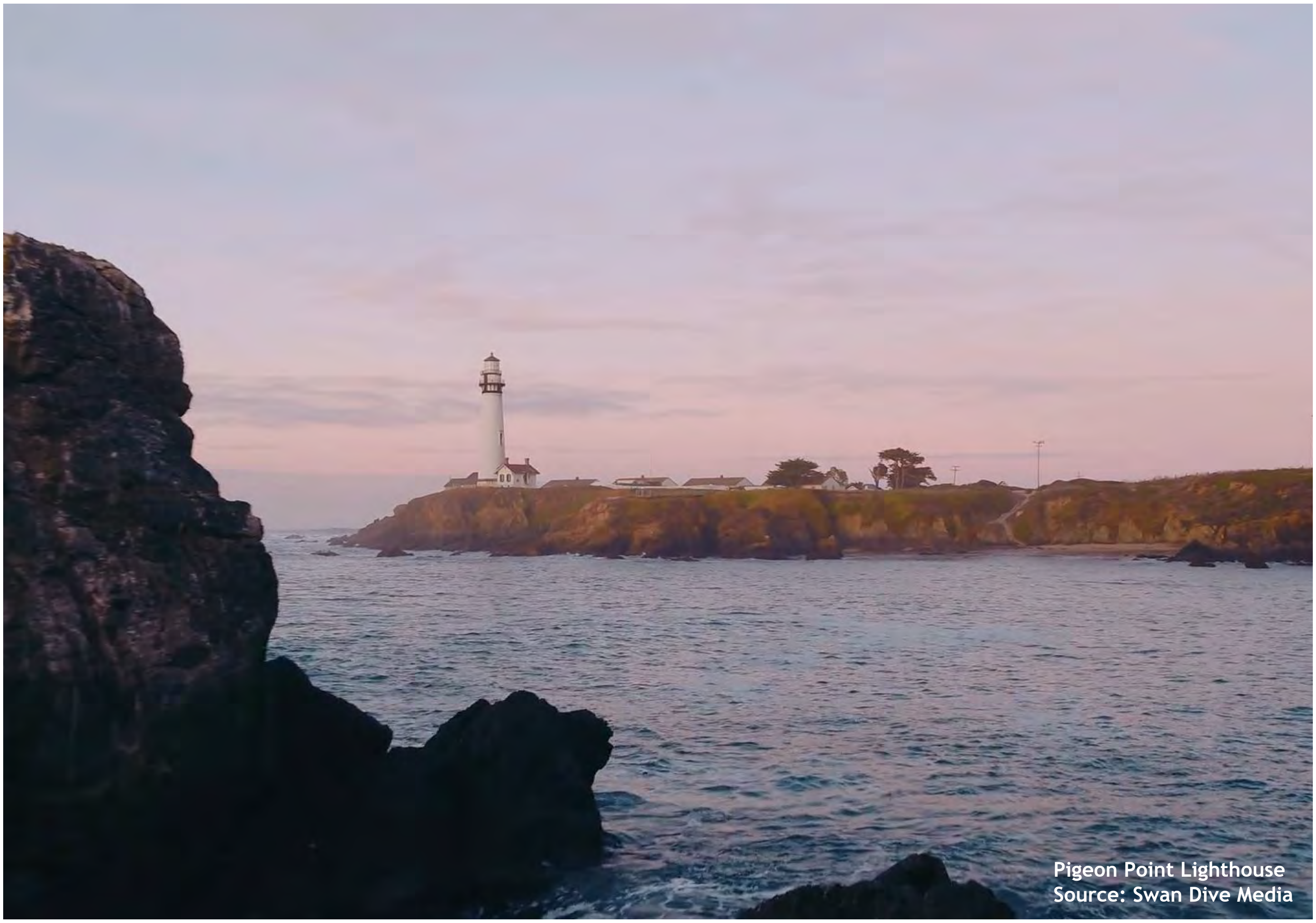

Pigeon Point Lighthouse
Source: Swan Dive Media

EXECUTIVE SUMMARY

SEA CHANGE
SAN MATEO COUNTY

EXECUTIVE SUMMARY

Rising sea levels mean that the South Coast of San Mateo County, which extends from southern Half Moon Bay down to the south county line with Santa Cruz, will experience considerable challenges from the increased extent of storm wave flooding and from eroding beaches and cliffs, anticipated to significantly impact community assets.

This document includes an introduction and overview of sea level rise science, an overview of the South Coast's past and present social and geographic settings, including a summary of social vulnerability, a sea level rise vulnerability assessment, and an adaptation report. The vulnerability assessment provides projections of the extent of coastal hazards and of the physical and economic impacts to community assets like buildings, roads, farmland, and coastal access infrastructure. The adaptation report provides an overview of sea level rise adaptation strategies and provides an example adaptation pathway for an at-risk stretch of State Route 1.

This vulnerability assessment found significant sea level rise exposure in the agricultural community of Pescadero, which is intersected by two creeks influenced by the coastal environment, and at Martin's Beach, which sits directly on the coast. Also at risk to sea level rise impacts are the cultural areas and materials of Native Peoples, particularly in the areas of Pescadero, Año Nuevo, and Franklin Point. State Route 1, a critical corridor to the South Coast region, is already impacted by sea level rise hazards, but will be increasingly exposed to erosion and flood over time, with over four miles of roadway exposed by 4.9 feet of sea level rise. Increasing flood and erosion impacts to coastal trails and coastal access infrastructure like parking lots and restrooms will reduce public coastal access in the future. All the projected sea level rise could negatively impact communities if no adaptation measures are taken.

In response to the findings of the vulnerability assessment, the adaptation portion of the report provides an overview of adaptation measures that may be appropriate for the South Coast, as well as guidance for planning and implementing adaptation pathways in an equitable and community-oriented way. Government, communities, and other stakeholders may use this information as a reference document as they pursue site-specific adaptation measures. However, it is important to understand the limitations of this document.

All coastal hazard data used in this assessment are based on models which attempt to predict what will happen in the future using best available science, but which are unlikely to completely capture exact future conditions. For example, flood models used in this assessment do not account for riverine or stormwater flooding, nor do they account for how development changes or future adaptation measures may change flood extents. Likewise, erosion models do not consider local geologic conditions, which greatly influence erosion patterns. Because models provide only a best guess of what may happen in the future, this vulnerability assessment is meant to be used to help stakeholders understand areas that are susceptible to sea level rise impacts, prioritize areas for adaptation, and guide future site-specific assessments that can direct specific adaptation measures.

It is hoped that this vulnerability assessment and adaptation report will provide governments and South Coast communities with a valuable tool for pursuing responsive, evidence-based, and community-vetted adaptation solutions that reduce risk for all South Coast community members.

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ACRONYMS AND ABBREVIATIONS

AADT	Annual Average Daily Traffic
ABV	Assessed Building Value
ALV	Assessed Land Value
BFE	Base Floor Elevation OR Base Flood Elevation
Caltrans	State of California Department of Transportation
CAL FIRE	State of California Department of Forestry and Fire Protection
CAPG	California Adaptation Planning Guide
CCC	California Coastal Commission
CEQA	California Environmental Quality Act
CoSMoS	USGS Coastal Storm Modeling System
CFD	Community Facilities District
County	County of San Mateo
County Line	San Mateo / Santa Cruz County Line
CSLC	California State Lands Commission
DEM	Digital Elevation Model
EMHW	Extreme Monthly High Water
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FMMP	Farmland Mapping and Monitoring Program
GGNPC	Golden Gate National Parks Conservancy
GHG	Greenhouse Gases
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change

LiDAR	Light Detection and Ranging
MBNMS	Monterey Bay National Marine Sanctuary
MHW	Mean High Water
MLW	Mean Low Water
NAVD88	North American Vertical Datum 1988
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OPC	Ocean Protection Council
OSM	Open Street Map
POST	Peninsula Open Space Trust
RCD	Resource Conservation District
RCP	Relative Concentration Pathway
Sea Change SMC	County of San Mateo’s Sea Level Rise Initiative
SVI	Social Vulnerability Index
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
UST	Underground Storage Tank
WTP	Willingness to Pay

DEFINITIONS

1% Annual Chance Storm: Often called a 100-year storm event, this is the storm with a 1% chance of occurring in any given year. It is the basis for the FEMA regulatory flood maps. In rivers, it is based on streamflow, and on the open coast, it is based on wave run-up.

Accessory Structure: Also referred to as non-primary structures. A structure of secondary importance or function on a site. This may include garages, sheds, barns, and outhouses.

Adaptation: Anticipating the adverse effects of climate change and taking appropriate action to prevent or minimize impacts.

Adaptation Pathway: A planning approach addressing the uncertainty and challenges of climate change decision-making. It enables consideration of multiple possible futures and allows analysis and exploration of the robustness and flexibility of various options across those multiple futures.

Adaptive Management: A process of iteratively planning, implementing, and modifying strategies for managing resources in the face of uncertainty and change. Adaptive management involves adjusting approaches in response to observations of their effect and changes in the system brought on by resulting feedback effects and other variables.

Adaptive Capacity: The ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.

Artificial Reef: An erosion reduction structure that mimics the function of a natural reef. An artificial reef is typically submerged in the water and causes waves to break offshore, reducing the wave energy that reaches shore.

Base Flood Elevation: The computed elevation to which floodwater is anticipated to rise during a 1% annual chance storm. Base flood elevations are shown on FEMA Flood Insurance Rate Maps and on the flood profiles. The base flood elevation is the regulatory requirement for the elevation or flood-proofing of structures.

Bluff: A steep shoreline slope composed of soft unconsolidated materials found in marine terrace deposits above the hard consolidated geologic formations.

Causeway: The elevation of a road surface from low ground to avoid hazard exposure and impacts.

Coastal Erosion: Loss of land in the dunes or cliffs along the coast caused by wave impacts.

Coastal Flooding: Flooding along the coast caused by a large 1% annual chance storm wave event and typically includes wave uprush with a momentum that can cause damages.

Coastal Zone: A regulatory zone established by State Legislature and shown on maps prepared by the California Coastal Commission for which the California Coastal Act establishes policies and regulations.

Cliff: Hard consolidated rock made up of different mudstones or sandstones.

Climate Change: A shift from normal climate weather patterns caused by natural processes or human activity.

Cobble Berm: The use of rounded rocks called cobbles to dissipate wave energy and reduce or slow erosion.

Dune Restoration: The process of both restoring and assisting in the development of new coastal dunes and may include beneficial placement of sand to form back-beach dunes.

Easement: An easement gives an organization, such as a utility, the right to access and use property in specific situations for a specific purpose, such as electrical transmission lines or sewer mains. Riparian corridors around creeks and streams are environmental easements. Where an easement is across private property, it is included in the parcel fabric of the County and usually called out in property deeds.

Economic Benefit: Economic benefits may be market or non-market. Market benefits are measured using market values. For example, to value a private residence, one would use the market price of the home. Non-market benefits are used to measure resources that do not have a set market price. For example, access to beaches is free in California, but numerous studies indicate that visitors are willing to pay to go to the beach. This willingness to pay is a non-market value.

Economic Cost: In this report, costs are measured as replacement or repair costs, or as the market value of lost land. For example, this study measured the costs of roads at replacement cost. Where no market price information was available, non-market valuation or proxy value data were used.

Economic Impact: Measures of the spending and economic activity resulting from a policy change or external stressor. Importantly, economic impacts include both costs and benefits.

Emissions Scenario: Scenarios representing alternative rates of increase of global greenhouse gas emissions, which are dependent on rates of economic growth, the success of emission reduction strategies, and rates of clean technology development and diffusion, among other factors.

Erosion: The wearing away of land by natural or human forces. Natural forces include wave action, tides, currents, animal burrowing, stormwater runoff, or the wind. Human forces include development, trampling of vegetation or soft soils, water leaking from pipes or channelization of stormwater along informal trails, and other non-natural forces.

Fiscal Impact: A measure of not only tax revenue impacts, but also changes in costs to a county or city from a policy change. For example, if increased beach recreation requires increased public safety costs, such as lifeguards, a fiscal impact analysis would also incorporate these changes. Fiscal impacts are calculated from the perspective of the organization that will incur the costs or receive the benefits.

Flood: A general and temporary condition of partial or complete submersion of normally dry land areas or structures from the overflow of inland, tidal, or storm wave waters.

Flood Insurance Rate Map (FIRM): The official map on which the Federal Insurance Administration has delineated areas of special flood hazards and the applicable risk zones.

Global Climate Model: A numerical representation of the climate system that is based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes, and that accounts for all or some of its known properties.

Groins: A sand retention structure is oriented perpendicular to the coast in a cross-shore direction and is designed with the purpose of trapping and retaining sediment to widen the beach and reduce erosion.

Hazard: A naturally occurring phenomenon capable of causing damage to infrastructure or loss of property and life. Hazards consist of both sudden phenomena and slow phenomena. In the case of coastal cliff erosion, areas with faster coastal erosion (removal of earth material by natural processes) or more rapid landward erosion of the cliff edge (cliff edge retreat) are considered to have higher hazards.

Horizontal Flood Control Levee: A levee that uses ecological restoration and incorporates other open space and civic functions.

Maladaptation: Inadvertently increases the vulnerability to sea level rise hazards and can be a result of badly planned adaptation actions or decisions that place greater emphasis on short-term outcomes ahead of longer-term threats.

Net Benefit: An estimate of the economic benefits minus the economic costs. Typically, net benefits are discounted over time.

Offshore Breakwaters: A structure designed to reduce erosion by reflecting, breaking, and dissipating wave energy. Breakwaters are typically visible throughout all tidal cycles and can be used for navigational purposes.

Parcel: A unit of land within the San Mateo County Tax Assessors database. Each parcel has a distinct Assessor's Parcel Number (APN).

Planning Horizon: The future time periods associated with certain climate impacts that serve as reference points for strategic adaptation planning.

Primary Structure: A structure of chief importance or function on a parcel. Some parcels may have more than one primary structure if there are multiple separate dwelling units, such as an accessory dwelling unit (ADU).

Property at Risk: The total fair market value of the land and structure on a parcel (adjusted to 2021 dollars).

Revetment: A sloped retaining wall made of boulders, stone, concrete, blocks, or riprap that is built to protect an embankment, bluff, or development against erosion by wave action and currents.

Right-of-Way: Land dedicated to a transportation thoroughfare such as a street or highway. This land is generally not included in the parcel fabric of the County.

Riparian Area. Riparian areas are vegetated areas located along creeks and form the transitional boundaries between land and water environments.

Risk: The combination of the likelihood of a hazard event and a community's vulnerability to that hazard. Risk equals the probability of climate hazard occurring multiplied by the ability of a community to withstand that event.

Sand Nourishment: Maintaining or increasing local sediment to widen beaches, mitigate coastal erosion, and offset the secondary consequences of coastal armoring.

Seawall: A vertical structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. It is usually a vertical wood or concrete wall as opposed to a sloped revetment.

Sector: A category of natural or built resources, such as land use and structures, agriculture, roads and parking, or open space and recreation.

Sector Profile: A summary or description of existing sector resources to be impacted by future sea level rise and coastal hazards.

Setback: The location of new development away from a hazardous or sensitive landform. Development can be located a certain distance from a bluff edge, line of vegetation, dune crest, roadway, or path. Development can also be located a certain elevation above which development must be sited.

Soil Nail Tie-back Walls: A type of coastal armoring protection constructed with an outer layer of sprayed concrete that derives its strength from soil nails and tiebacks that are drilled into the cliff and used to bind the structure to the cliff behind.

Tax Revenue Impact: A measure of the changes in taxes because of a policy change. This report estimates changes in sales taxes and transient occupancy taxes resulting from changes in beach tourism/recreation. These form a component of the fiscal impact.

Tidal Flooding: Flooding caused during predictable high tides that occur with some regularity.

Vulnerability: Structural, infrastructural, environmental, or social conditions that make communities less able to withstand the negative impacts of a hazard.

Vulnerability Assessment: The process of identifying exposure, sensitivity and adaptive capacity to sea level rise hazards in an area or a system.

DISCLAIMER

This report is part of an ongoing process to understand and prepare for coastal hazards. The maps and associated analyses are intended as planning tools to illustrate projected hazard exposure to existing infrastructure, land use types, and other resources associated with a variety of future sea level rise and coastal hazard scenarios. The assessment has been conducted on a regional scale, and this level of precision should serve as a screening tool to identify areas that may require more detailed site-specific analysis. This report is advisory and not a regulatory or legal standard of review for actions that the County of San Mateo or any other regulatory agencies may take.

There are inherent uncertainties associated with modeling and projecting future hazards and their potential impacts. Maps produced for this report are based on model outputs and cannot account for all complex and dynamic ocean, terrestrial, and anthropogenic processes or for future adaptation approaches such as shoreline protection upgrades. In addition, these maps do not include projected flooding from riverine rainfall-runoff events or flooding precipitated by land use change or other factors. Flooding due to sea level rise and the various coastal hazards is possible in areas outside of those projected, and even the best projections cannot guarantee the safety of an individual or structure. The contributors and sponsors of this product do not assume liability for any injury, death, property damage, or other effects of flooding.

Although every effort was made to review all resource sector and infrastructure data received from other sources, neither the County of San Mateo nor its consultant, Integral Consulting Inc., can verify the completeness of all spatial data. For this reason, we do not accept responsibility for any errors, omissions, or positional inaccuracies. Users of the data displayed in the maps are strongly cautioned to verify all information.

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PROJECT OVERVIEW

Rising sea levels mean that the South Coast of San Mateo County, which extends from southern Half Moon Bay down to the south county line with Santa Cruz, will experience considerable challenges from the increased extent of storm wave flooding and from eroding beaches and cliffs (OPC, 2018). As sea levels rise in the future, threats from coastal hazards will create a multitude of impacts on communities, economies, and natural habitats in the region unless adaptation measures are put into place.

This report documents the projected extents of coastal hazards, projected impacts to assets, and economic impacts to different resource sectors, then begins to identify feasible adaptation strategies and approaches that may reduce sea level rise risk over time. Key findings are described in Table 1-2.

Background

In 2015, under the leadership of Supervisor Dave Pine and Supervisor Don Horsley, the County of San Mateo Office of Sustainability (OOS) launched the SeaChange SMC Initiative with the purpose of increasing the resilience of the County's economy, environment, and communities through collaborative planning and projects. In 2018, the County finalized a Sea Level Rise Vulnerability Assessment for the northern open coast and the bayside portion of the county in coordination with cities, agencies, businesses, community groups, and others. However, due to a lack of suitable coastal hazard modeling data, the southern open coast of the county, known as the South Coast, was not included. This assessment focuses on the South Coast region of the county, from the southern end of Half Moon Bay down to Año Nuevo State Park, filling the data gap of the original assessment.

Vulnerability Assessment Goals

This assessment contributes to resilience planning in the South Coast area through achieving the following goals:

- Map assets and future risk scenarios
- Identify exposed assets
- Identify feasible adaptation strategies
- Build community awareness
- Facilitate collaboration

The results of the report are intended to help county and city officials, community-based organizations, community members, and other stakeholders understand what is at risk, prioritize areas for adaptation actions, understand the tradeoffs between different strategies, and present a roadmap for future actions.

Outreach and Engagement

To maintain an inclusive stakeholder process, input from numerous community groups, government agencies and departments, and community members helped guide the assessment. OOS, along with project consultants Integral Consulting Inc. and the San Mateo Resource Conservation District, conducted the following outreach and engagement activities:

- Focus Group 1—County of San Mateo Departments (April 2021)
- Focus Group 2—Caltrans and State Parks (May 2021)
- Interviews with Local Growers and Agricultural Landowners (April–May 2021)
- Pescadero Roundtable (May 2021)
- Outreach Video Launched (June 2021)
- Community Meeting 1 (June 2021)
- Sustainable Pescadero (August 2021)
- Coastside Land Trust Educational Web Series (September 2021)
- Meeting with the City of Half Moon Bay (September 2021)
- Meeting with Caltrans (October 2021)
- Community Meeting 2 (March 2022)

Vulnerability Assessment

This study, focused on the South Coast of San Mateo County bordering the Pacific Ocean, completes the sea level rise vulnerability assessment for all of San Mateo County and provides detailed information on the projected exposures of different community and resource sectors to coastal hazards and associated economic impacts. The study area includes all areas between southern Half Moon Bay and the south county line that are exposed to sea level rise and coastal hazards with 4.9 feet of sea level rise and a 1% annual chance storm.

This study used the best available scientific projections of coastal hazards and sea level rise along with the most spatially accurate locations of important land uses, development, and key infrastructure to identify what could potentially be impacted now and in the future. The vulnerability assessment carefully considers modeled projections of existing and future coastal extents of cliff and dune erosion, storm wave impacts, tidal flooding, and estuary-related flooding for four different sea level rise scenarios: a baseline scenario without sea level rise and a 1% annual chance storm, 0.8 feet of sea level rise and a 1% annual chance storm, 1.6 feet and a 1% annual chance storm, and 4.9 feet and a 1% annual chance storm. The latter three scenarios represent the short-term (~year 2030), mid-term (~year 2050), and long-term (~year 2100), respectively.

It should be noted that model outputs cannot account for all complex and dynamic ocean, terrestrial, and anthropogenic processes or for future adaptation approaches such as shoreline protection upgrades, and that this model does not account for projected flooding from riverine rainfall-runoff events or flooding precipitated by land use change or other factors. Because there are inherent uncertainties associated with modeling and projecting future hazards and their potential impacts, this hazard data and resulting asset exposure analyses are not intended to be used for site-specific decisions, but rather to identify areas at risk of exposure that may require more detailed analyses.

The resource sectors considered in this vulnerability assessment include: Land Use and Structures; Agriculture, Roads and Parking; Parks, Recreation, and Coastal Access; and Significant Facilities.

Data for these resource sectors were provided primarily by the County and other publicly available sources.

The vulnerability assessment was based on a geospatial analysis that analyzed the exposure of each resource sector with each coastal hazard type over different sea level rise scenarios. Social, structural, and environmental sensitivities are discussed where they have been identified. Economic analyses were based on reported information from the County Assessor's office and relevant reports from various county, state, and federal agencies that were publicly available. The project team verified findings through focus group engagement and targeted communication with land and business owners and managers.

Table 0-1. Feasibility of Adaptation Strategies

Feasibility of Adaptation Strategies		
Strategy	**Overall Regulatory Viability**	**Feasibility** (Considering Cost, Benefits, and Regulatory Constraints)
Revetments	**Yes**	**High**
Seawalls	**Yes**	**Low**
Soil Nail Tie-back Walls	**Yes**	**Low**
Horizontal Flood Control Levees	**Yes**	**Low**
Artificial Reefs	**No**	**No**
Groins (Sheet-Pile, Concrete, Rubble)	**No**	**No**
Offshore Breakwaters	**No**	**No**
Sand Nourishment	**No**	**Low**
Dune Restoration	**Yes**	**High**
Cobble Berms	**Yes**	**High**
Setbacks	**Yes**	**High**
Elevate	**Yes**	**High**
Realignment of State Route 1	**Yes**	**Medium**
Causeway	**Yes**	**Medium**

Note: This table is distilled from Table 5-3 *in the Adaptation Planning Section. Assumptions of a particular strategy's regulatory viability and feasibility are based on local knowledge and professional opinion.*

Adaptation Planning

The vulnerability assessment can help inform the development of an adaptation framework for the South Coast region that reduces hazard risks to local communities and visitors while continuing to support existing agricultural activities, providing new economic opportunities, and being socially acceptable to the community. Community engagement to date indicates a strong community preference for nature-based solutions that maintain access to the coast and transportation connectivity. The high interest and engagement of South Coast residents reiterates the importance of vetting any proposed adaptation solution with the community.

The adaptation section provides a summary of a wide range of potential adaptation strategies, considerations of secondary consequences, and a narrowed range of strategies that the study team has evaluated as most ecologically, financially, and regulatorily feasible, though site-specific studies will be necessary to assess feasibility and effectiveness of each strategy. Table 0-1 outlines some of the adaptation strategies that may be feasible for the South Coast. Considerations not included in Table 0-1 include how long each feasible strategy would remain effective in reducing risk, lead time to plan, design, permit, finance, and construct.

Key Findings

The South Coast study area encompasses 2,288 acres of land. Within the study area are 1,970 parcel-owned acres and 123 primary structures, including 109 residences, as well as numerous significant community facilities including a fire station, a gas station, a hotel, and a lighthouse. There are 13 state, county, and city parks located in this area, as well as a multitude of public and private beaches that are popular destinations for locals and tourists alike.

The key findings in Tables 0-2 and 0-3 describe assets that will be exposed to hazards at different sea level rise horizons (0.0, 0.8, 1.6, and 4.9 feet of sea level rise with a 1% annual chance storm), which can be associated with current, near-, mid-, and long-term planning ranges, respectively. Readers should note that many assets are exposed to multiple hazards and may be impacted by multiple coastal hazards at one time.

Notable assets projected to be impacted by sea level rise-related hazards include State Route 1, which is a key access route for the region, and crucial for the local agricultural and tourism economies, the communities of Martin’s Beach and Pescadero, oceanfront homes west of State Route 1, State Park and agricultural lands, and several significant facilities, including the CAL FIRE Station, Gazos Gas Station, and Pescadero County Corporation Yard.

Table 0-2. South Coast Vulnerability Snapshot

South Coast Vulnerability Snapshot		
What Is at Risk?	**What Is Exposed by the Long-term Sea Level Rise Horizon?**	**Potential Impacts and Consequences**
Sections of the State Route 1 Corridor	• 4.5 miles of highway	• Disruptions in emergency service • Disruptions to the primary transportation network • Reroutes increase vehicle miles traveled
Coastal Access and Recreation	• Park and open space land • Trails • Coastal access locations	• Permanent loss of pocket beaches • Loss of coastal marsh habitats • Potential loss in intertidal habitat • Rerouting of trails
Cultural Resources	• Año Nuevo State Park • Pigeon Point Light Station State Historic Park	• Potential loss of cultural heritage, maritime history, and areas of anthropological interest
Residential Communities	Homes, in the communities of: • Martin's Beach • Pescadero • Cliffside areas west of Hwy 1 between Pescadero Point and Bean Hollow	• Estuarine flooding may make interior conditions unsuitable for habitation • Coastal erosion and storm wave impacts may damage homes
Significant Facilities	Five facilities: • Gazos Creek Alliance Gas Station • Pigeon Point Lighthouse • Pescadero CAL FIRE Station • Pescadero County Corporation Yard • Ritz-Carlton Hotel and Half Moon Bay Golf Links	• Disruptions in emergency service • Loss of culturally significant facilities • Loss in tax revenue

Key Areas of Concern and Trigger Points

The list below outlines some of the key areas in the South Coast that are vulnerable to sea level rise. Note, this analysis is for screening purposes only, and more site-specific analysis should be conducted.

Current Vulnerabilities

- Box culvert under State Route 1 at Bean Hollow Beach (also known as Arroyo de Los Frijoles Beach) poses a safety issue due to sand and debris buildup blocking the culvert.

- Flooding of Pescadero Creek and Butano Creek can lead to interrupted transportation service along Pescadero Creek Road and threaten the community of Pescadero. This flooding can also impact access for the Pescadero Corporation Yard and the CAL FIRE Station on Pescadero Creek Road.

Near-Term Vulnerabilities, between 0-0.8 feet of sea level rise + 1% annual chance storm (Present to 2030)

- Dune erosion through Pescadero Beach dunes is a threat to State Route 1 and will likely affect Pescadero Marsh North Pond habitat.
- Cultural materials and heritage at Franklin Point and Año Nuevo Point are threatened by dune erosion. Potential losses include cultural areas and materials with importance to Native Peoples and the burial grounds of shipwrecked sailors.
- Coastal wave flooding is a threat to the front row of homes at the community of Martin's Beach.
- The Pigeon Point Light Station and Interpretive Center could become threatened by cliff erosion. Note that site-specific analysis suggests the Light Station is likely out of the hazard zone in this horizon.

Mid-Term Vulnerabilities, between 0.8-1.6 feet of sea level rise + 1% annual chance storm (2030 to 2060)

- Coastal wave flooding and coastal erosion could threaten the entire community of Martin's Beach.
- Cliff erosion between Bean Hollow and Pescadero Bridge is projected to threaten State Route 1.
- Cliff erosion between the county line and Elliot Creek could threaten State Route 1.
- Loss or interruptions to State Route 1 could pose a significant access and business operations issue for both locals and tourists. This would have substantial impacts on emergency service access, as well as impacts to the shipping of agricultural produce to distribution centers in Monterey County.
- The Pigeon Point Light Station Hostel buildings could become threatened by cliff erosion, though more site-specific analysis is needed to fully understand when impacts are likely to occur.

Long-Term Vulnerabilities, between 1.6-4.9 feet of sea level rise + 1% annual chance storm (2060 to 2100+)

- The Ritz-Carlton Hotel and Half Moon Bay Golf Links could be threatened by cliff erosion.

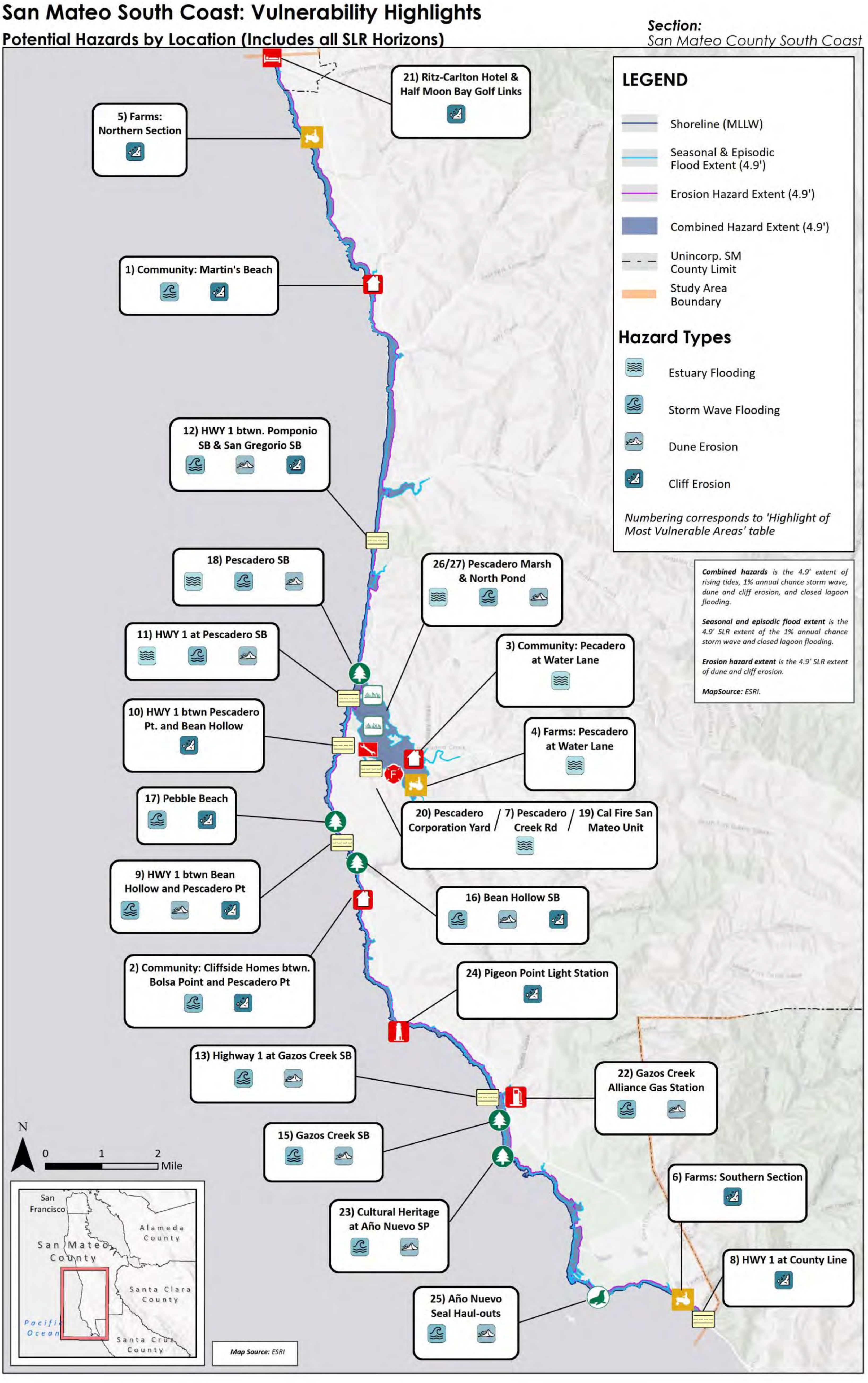
Table 0-3. A highlight of areas exposed to coastal hazards by level of sea level rise

A Highlight of Most Vulnerable Areas			Likelihood and Severity by Sea Level Rise Horizon			
Category	**Hazard Exposure**	**Adaptive Capacity**	**Current**	**0.8 ft**	**1.6 ft**	**4.9 ft**
Communities						
1) Martin's Beach Community	Coastal Erosion, Storm Wave Flooding	MED				
2) Cliffside Homes between Bolsa Point and Pescadero Pt	Coastal Erosion, Storm Wave Flooding	LOW				
3) Pescadero—Vicinity of Water Lane	Estuary Flooding	MED				
Farms						
4) Farms at Pescadero Creek Road and Water Lane	Estuary Flooding	HIGH				
5) Northern Section Cliffside Farms and Ranches	Coastal Erosion	HIGH				
6) Southern Section Cliffside Farms and Ranches	Coastal Erosion	HIGH				
Transportation						
7) Pescadero Creek Road	Estuary Flooding	MED				
8) State Route 1 at County Line	Cliff Erosion	LOW				
9) State Route 1 between Bean Hollow and Pescadero Point	Coastal Erosion, Storm Wave Flooding	MED				
10) State Route 1 between Pescadero Point and Pescadero bridge	Cliff Erosion	MED				
11) State Route 1 at Pescadero Beach	Dune Erosion, Estuary Flooding, Storm Wave Flooding	LOW				
12) State Route 1 between Pomponio State Beach and San Gregorio State Beach	Dune or Cliff Erosion, Storm Wave Flooding	MED				

A Highlight of Most Vulnerable Areas			Likelihood and Severity by Sea Level Rise Horizon			
Category	**Hazard Exposure**	**Adaptive Capacity**	**Current**	**0.8 ft**	**1.6 ft**	**4.9 ft**
13) State Route 1 at Gazos Creek State Beach	Dune Erosion, Storm Wave Flooding	MED				
14) State Park Formal Parking Areas	Coastal Erosion, Storm Wave Flooding	HIGH				
Parks and Recreation						
15) Gazos Creek State Beach	Coastal Erosion, Storm Wave Flooding	MED				
16) Bean Hollow State Beach at Arroyo de los Frijoles	Coastal Erosion, Storm Wave Flooding	LOW				
17) Bean Hollow State Beach at Pebble Beach	Coastal Erosion, Storm Wave Flooding	LOW				
18) Pescadero State Beach	Coastal Erosion, Storm Wave Flooding	HIGH				
Significant Facilities						
19) CAL FIRE San Mateo Unit	Estuary Flooding	MED				
20) Pescadero Corporation Yard	Estuary Flooding	MED				
21) Ritz-Carlton Half Moon Bay and Half Moon Bay Golf Links	Cliff Erosion	Hotel: LOW Golf Course: HIGH				
22) Gazos Creek Alliance Gas Station	Coastal Erosion, Storm Wave Flooding	MED				
Cultural and Historical						
23) Cultural Areas and Materials at Año Nuevo State Park	Coastal Erosion, Storm Wave Flooding	VERY LOW				
24) Pigeon Point Light Station	Cliff Erosion	LOW – MED				

A Highlight of Most Vulnerable Areas			Likelihood and Severity by Sea Level Rise Horizon			
Category	**Hazard Exposure**	**Adaptive Capacity**	**Current**	**0.8 ft**	**1.6 ft**	**4.9 ft**
Habitat						
25) Año Nuevo Seal Haul-Out Areas	Coastal Erosion, Storm Wave Flooding	HIGH				
26) North Pond	Coastal Erosion, Storm Wave Flooding, Estuary Flooding	LOW - MED				
27) Pescadero Marsh	Coastal Erosion, Storm Wave Flooding, Estuary Flooding	MED - HIGH				

Green—Minimal to no projected impacts due to sea level rise.
Yellow—The chance for disruptions or damages is moderate.
Red—The chance for disruptions or damages is significant.
Dark Red—The chance for disruptions or damages is very high.



Map 1. A highlight of areas most exposed to sea level rise-related hazards, according to this study's screening

Data Gaps and Recommended Next Steps

Data Gaps

The South Coast is dependent on water for its agricultural sector and for general development. Geospatial data on the surface water reservoirs and their respective water rights is currently lacking.

Sea level rise impacts on potable water supply are an ongoing concern for many residents of Pescadero, though it is uncertain exactly how saltwater intrusion to groundwater may occur with rising seas. Because of limited access to data on water supply (largely wells), wastewater (largely septic), and groundwater modeling data, these assets could not be evaluated. The County is aware that this issue needs to be studied.

Reporting for the analysis is largely quantitative, based on numbers, area, and value of features affected. Many of these features and areas may hold significant cultural and social value, and wherever possible, this was described qualitatively.

Recommendations for Next Steps

Chapter 7 provides an expanded overview of the next four steps that the County should take to best act upon the findings of this assessment. In addition, step 5 outlines several areas for additional research or analysis that the County or another stakeholder may carry out in the future to support adaptation work.

Step 1. Develop Project Concepts and Adaptation Plans

Step 2. Acquire Funding to Implement Projects

Step 3. Continue Community Engagement, Outreach and Education around Sea Level Rise

Step 4. Update Policies to Facilitate Adaptation and Resilience

Step 5. Conduct or Support Additional Studies and Research


Bolsa Point Ranch
Source: Swan Dive Media

INTRODUCTION

SEA CHANGE
SAN MATEO COUNTY

1 INTRODUCTION

This chapter provides background and project purpose with a discussion of the sea level rise and climate change work that has been conducted at the regional and state levels. It then provides a detailed vulnerability assessment that estimates the range of projected physical and economic impacts in the project area. The assessment informs the final component of the project, a detailed adaptation study, which proposes a range of strategies that will build resilience to coastal hazards on the South Coast of San Mateo County.

1.1 ORGANIZATION OF THIS REPORT

Section 1, Introduction, provides a background and context for this assessment; the state of the science; and a summary of statewide, regional, and local initiatives on climate, sea level rise, and planning.

Section 2, Setting, describes the physical and social setting, existing coastal processes and hazards, and resource sectors to be evaluated.

Section 3, Methodology and Approach, describes the process used to assess the county's vulnerability to sea level rise.

Section 4, Vulnerabilities by Resource Sector, presents the core findings of the vulnerability assessment by sector.

Section 5, Adaptation Planning, provides an overview of adaptation planning, explains some of the necessary considerations for choosing adaptation options, and describes many of the adaptation options suitable for the South Coast.

Section 6, Next Steps, describes recommendations based on the results of this report for actions that the County, cities, asset managers, and other stakeholders can take over the near and long terms.

Appendix A. Planning Background

Appendix B. Sector Profiles and Resource Sector Maps

Appendix C. Maps of Specific Vulnerable Areas

Appendix D. Pescadero Marsh Habitat Migration with Sea Level Rise

Appendix E. Vulnerability Assessment Table of Results

Appendix F. Dune Erosion Modeling Methodology

Appendix G. Model Comparison Memo

1.2 PROJECT PURPOSE

The purpose of this study is to identify and project existing and future exposure and vulnerability to coastal hazards and sea level rise along the South Coast of San Mateo County. As sea level rises, the dynamics of coastal erosion, wave, and fluvial flooding will shift, increasing the risk of damages to the South Coast and its unique landscape, developments, cultural heritage, transportation corridors, and recreation opportunities.

This study provides a technical analysis that identifies South Coast assets exposed to coastal hazards exacerbated by sea level rise, building upon the 2018 Sea Change Vulnerability Analysis that analyzed the Bayshore and the Coastside from Half Moon Bay North.

The primary goals of this effort are to assess overall exposure to sea level rise, identify sensitivities and impacts, provide actionable adaptation strategies, build public awareness, and promote stakeholder collaboration. This regional-level analysis intends to identify near-term, mid-term, and long-term exposure from the effects of sea level rise to inform future planning and investments.

This study examines coastal hazard vulnerabilities with up to 4.9 feet of sea level rise. (See Table 3-1 and Table 3-2 for more details).

However, sea level rise projections for 2100 range from 2 to 10 ft, with recent science identifying this higher level as the worst-case scenario.

1.3 PROJECT APPROACH

This vulnerability assessment draws on the best available science and research methodologies to explore how the County and its communities, as well as built and natural assets, will be impacted by present and future hazards associated with sea level rise and coastal storms. In doing so, the assessment will increase understanding of the type and scale of potential impacts that could occur under different sea level rise scenarios up to 4.9 feet and support the County in making informed adaptation decisions to reduce long-term sea level rise risk.

The assessment seeks to accomplish the preceding goals through the following:

- **Compiling an inventory of built and natural assets**
- **Analyzing the risk and hazards associated with sea level rise-exacerbated erosion and flooding** projected for up to 4.9 feet of sea level rise, without any action.
- **Developing exposure maps and sector profiles** to identify specific areas and asset types at risk from current and future impacts.
- **Providing an overview of adaptation options** and approaches to adaptation planning including secondary impacts, cost-benefit analysis, and key decision-maker considerations.

- **Building awareness** by engaging stakeholders in a discussion of the complex and multifaceted challenges associated with equitable sea level rise adaptation.
- **Laying the groundwork for adaptation planning** by taking policy and project actions to increase resiliency over time.

By completing the vulnerability assessment phase of the Sea Change SMC initiative, this report lays the foundation for further developing a South Coast adaptation strategy. Additional work and research will be needed to develop targeted and granular adaptation options for each community and resource which can lead to an integrated framework for action and coordinated efforts.

1.3.1 Overview

This vulnerability assessment used the best available data for assets and coastal hazard projections, and involved extensive geospatial data gathering, a compilation of existing data and information, and review and application of the best available coastal hazard modeling science.

1.3.2 Resource Sectors

This study identified five overarching sectors to categorize sea level rise along the South Coast of San Mateo County:

- **Land Use and Structures**—describes the overall composition and characteristics of the vulnerable coastal areas, parcels, and structures.
- **Agriculture**—includes planted fields, grazing lands and protected coastal prairie, orchards, and developed agricultural lands.
- **Transportation and Parking**—includes all state, county, and local roads, as well as their rights-of-way and associated bridges and culverts. Also included are all formal public parking areas.
- **Parks, Recreation, and Coastal Access**—includes all state, county, and local parkland, as well as protected open space areas. Also includes the trails, bathrooms, structures, and other amenities associated with these areas.
- **Significant Facilities**—Significant facilities include the Gazos Creek Alliance Gas Station, Pigeon Point Lighthouse, Ritz-Carlton Hotel, CAL FIRE Station, and the Pescadero Corporation Yard.

The five sectors share many common features and geographic areas, and elements in each sector are linked to others through the many systems and networks that bind any community and natural environment. However, categorizing and reporting assets, infrastructure, and impacts by sector can increase the understanding and nuance of specific exposures. By breaking impacts down by specific sectors and hazards, the project team was able to refine methods and define more applicable ways to describe exposure. The goal here is to accurately identify the thresholds and tipping points for moving from one type of adaptation approach to the next.

The profiles provide a summary of the hazards impacting each sector, complete with maps projecting the timing of exposure associated with various sea level rise scenarios. The profiles summarize current sea level and hazard conditions, as well as anticipated hazard impacts at 0.8, 1.6, and 4.9 feet of sea level rise.

Modeling of potential erosion and flooding impacts is based on a large coastal wave storm scenario (1% storm/100-year). A 1% annual likelihood storm could happen in any given year. However, the extent of the damages would not likely occur everywhere across the entire county shoreline from a single event given the different shoreline orientations and wave directions.

The sector profiles, found in Appendix B, Vulnerabilities by Resource Sector, are intended to summarize key projected impacts for each sector. Each sector profile provides the findings and recommendations that can be used to identify vulnerabilities and consider possible solutions and policy directions.

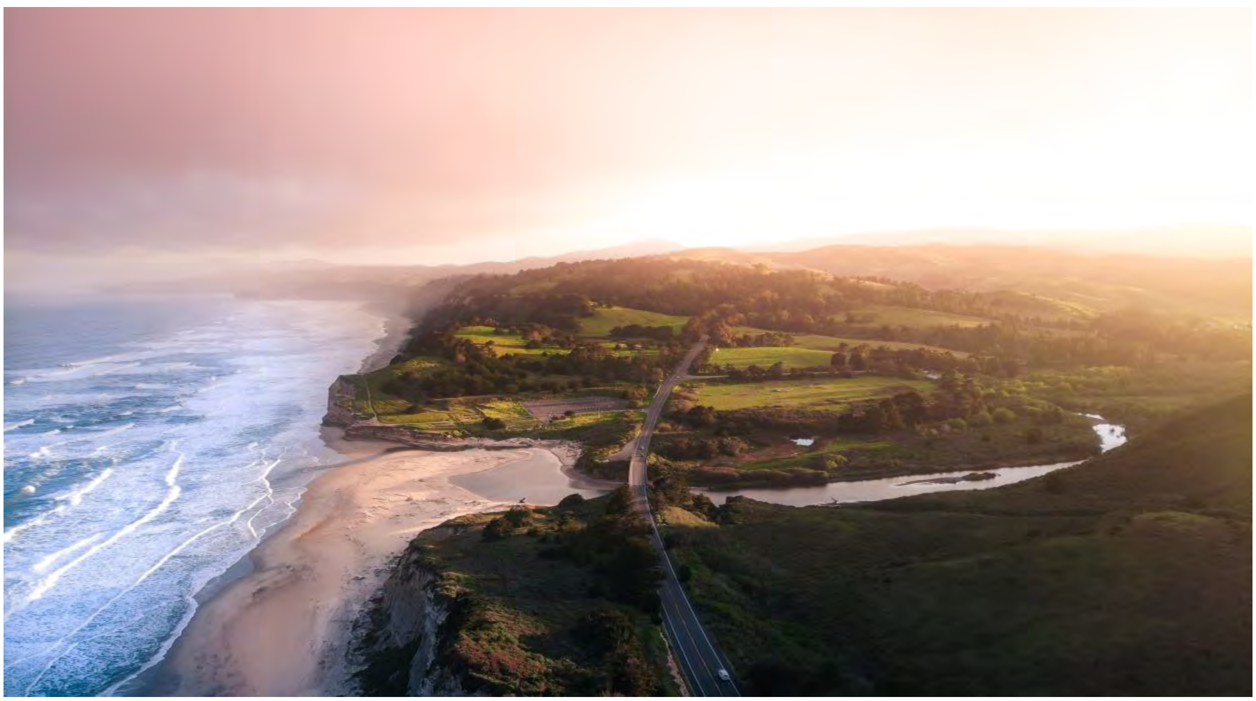


Figure 1-1. State Route 1 at San Gregorio State Beach
Source: Ethan Dow, 2021

1.4 STUDY AREA DESCRIPTION

San Mateo County lies at the center of the San Francisco Peninsula, with shorelines along both the open Pacific Ocean coast and the more sheltered San Francisco Bay. The broader South Coast region covers approximately 160–200 square miles with 40–50 percent of the county's land mass. In contrast to the north county and bayside areas, land uses along the South Coast are more rural in character and include many miles of public beaches, state park facilities, working agricultural lands, diverse wetland ecosystems, and small residential communities.

Scenic State Route 1 winds its way along the South Coast, providing the primary transportation corridor. This stretch of highway is known for its coastal views, public open spaces, and agricultural lands. The highway is characterized by frequent ups and downs along tall bluff-backed shorelines and headlands that drop down to dune-backed beaches, bar-built estuaries, and coastal creeks. This stretch of highway often faces travel interruptions, including partial loss of service due to erosion.

Locals and tourists alike enjoy a vast number of outdoor recreation options that include tide pooling in the rocky intertidal, surfing, and engaging with the agricultural lands via farm stands, pumpkin patches, and specialty greenhouses. The region is also known for its ecological diversity. Pescadero Marsh is known for its important habitat as a spawning ground for steelhead trout, coho salmon, and tidewater goby, as well as other fish, amphibians, reptiles, and migratory and native birds. Undisturbed beaches sheltered by bluffs and coastal headlands provide important haul-out and nursing habitat for a host of marine species such as elephant seals. These natural assets and the limited urban development in this area can be partially credited to the fact that a large portion of the coast is protected open space held by public agencies or land trusts.

Figure 1-2. Town of Pescadero. Historic Pescadero Community Church

Source: Ana Miscolta-Cameron, 2022

Approximately 9,198 residents live (U.S. Census 2020) within the two primary census tracts in the unincorporated South Coast (census tracts 6137.02 and 6138, and excluding 6137.01, which is considered Half Moon Bay). This area encompasses several small towns, with the largest being Pescadero (Figure 1-2), pop. 595 in the wider Pescadero area (U.S. Census 2020). The coastal area also includes other small communities such as Martin's Beach (Figure 1-3), a private beach community nestled in a shallow cove with approximately 50 cabins and approximately 20–30 permanent residents, and the cliffside homes near Pescadero Point and Bean Hollow.

Figure 1-3. Martin's Beach
Source: San Mateo RCD

1.4.1.1 Geographic Region

The study area is defined as the projected inland extent of coastal hazards with 4.9 feet sea level rise between south of Half Moon Bay down to the southern county line with Santa Cruz (Map 2). The study area was further broken down into three contiguous sub-regions for mapping and reporting purposes, as shown on Map 2.

Northern: Miramontes Point in south Half Moon Bay to the northern end of Pescadero State Beach, and generally extending less than a quarter of a mile inland (~563 upland acres within the combined hazard zones).

Central: Northern terminus of Pescadero State Beach to Bean Hollow Beach and extending approximately 2 miles inland to include Butano and Pescadero Marsh areas as well as portions of the community of Pescadero (~856 upland acres in the combined hazard zones).

Southern: Bean Hollow Beach to the southern county line with Santa Cruz County and generally extending less than a quarter of a mile inland (~630 upland acres in the combined hazard zones).

Throughout this report the following terms are used to refer to related but distinct areas:

South Coast: Generally defined as the area from south of Half Moon Bay to the county line and extending from the coast to the crest of the Coast Range around Skyline Blvd (SR 35). Includes the communities of Pescadero, San Gregorio, La Honda, Loma Mar, and others.

Study Area: This area is defined as all areas that intersect the extent of coastal hazards and sea level rise by 2100 (4.9 ft).

Map 2. San Mateo South Coast Study Area and Sections

1.4.1.2 Coastal Hazards

The study team evaluated the following coastal hazards in combination with future sea level rise conditions:

- **Coastal wave flooding**—from a 1% annual chance storm event (also called a 100-year storm event)
- **Coastal erosion**—dune and cliff erosion
- **Estuary flooding**—potential flooding from a seasonal beach closed lagoon
- **Combined hazards**—the furthest inland extent of all hazards listed above

The inland extents of each of the hazard zones can vary throughout the study area due to terrain elevation, wave climate, and geomorphology. Throughout most of the study area, the hazard zones are restricted to a narrow strip along the coast (Map 3). However, in some locations, the hazard zones extend much further inland as low-lying areas along coastal streams and lagoons are projected to experience more extensive flooding.

The sea level rise scenarios for this study were selected to utilize the best available models (not always the most recent) and align them as closely as possible to the recently updated 2018 State of California OPC and California Coastal Commission (CCC) guidance. The chosen scenarios included the following sea level rise and temporal range values:

Table 1-1. Probabilistic projections for future sea level rise years by horizon

From OPC 2018 Guidance	Projected Sea Level Year	
Sea Level Rise (ft)	Low Risk Aversion	Medium–High Risk Aversion
0 (Baseline)	2000	
0.8	2040	2030
1.6	2065	2045
4.9	2100+	2085

Source: OPC Guidance (2018). Projected sea levels using the San Francisco tide gauge (Kopp et al. 2014).
All sea level rise years are referenced to high emissions scenarios

1.5 BEST AVAILABLE SCIENCE FOR SEA RISE LEVEL

Global models indicate that California will see substantial sea level rise during this century, with the exact magnitude depending on such factors as global emissions, the rate at which oceans absorb heat, melting rates and movement of land-based ice sheets, and local coastal land subsidence or uplift.

Table 1-2. Probabilistic projections for future sea level rise elevations by years

From OPC 2018 Guidance	**Projected Sea Level by Year (in feet)**				
Year	Median (50% Probability)		1-in-200 Chance (0.5% Probability)		H++
	Low Emissions	High Emissions	Low Emissions	High Emissions	
2030	-	0.4	-	**0.8**	1.0
2060	1.0	1.1	**1.6**	2.6	3.9
2100	1.6	2.5	5.7	6.9	10.2

Source: OPC Guidance (2018). Projected sea levels using the San Francisco tide gauge (Kopp et al. 2014)
H++ = High-end sea level rise considers rapid Antarctic ice sheet mass loss, and the uncertainty projections are not determined
***Bold** indicates the sea level rise elevations used in this study.*

1.5.1 Relative Sea Rise Level

Sea level rise is not the same everywhere around the world. Because of local differences in tectonic uplift, isostatic rebound, subsidence caused by oil, gas, and groundwater extraction, and saltwater intrusion, the land itself is moving vertically. According to OPC (2018), California experienced about 7 in. of sea level rise from 1905 to 2005, and the rate of increase is projected to continue to increase over this century. In 2012, the National Research Council (NRC) projected that areas south of Cape Mendocino in California may see increases in sea levels of between 17 and 66 in. by 2100. In San Mateo County, particularly on the San Francisco Bay side, an important component of relative sea level is subsidence, or sinking of the land, due to groundwater extraction. The subsidence compounds the impacts of sea level rise, causing the relative rates of sea level rise to increase.

Map 3. The study area is defined as the coastal hazard extent at 4.9 feet of sea level rise

The National Oceanic and Atmospheric Administration (NOAA) has only been recording tide gauge water levels at Pillar Point Harbor since 2010. Given the short duration of the record, these data cannot be used to estimate past and future relative sea level rise trends. San Francisco Station 9414290, the station nearest the South San Mateo County coast and with readings extending to the mid-1800s is used below (Figure 1-4). The relative sea level rise trend in this graph shows 1.97 mm/yr. with a 95% confidence interval of ±0.18 mm/yr. based on monthly mean sea level data from 1897 to 2020, which is equivalent to a change of 0.65 feet in 100 years (NOAA 2021). These measured local relative sea level rise trends, when compared to the global average, provide estimates of land motion. In this case, the land is rising, just not as fast as sea levels.

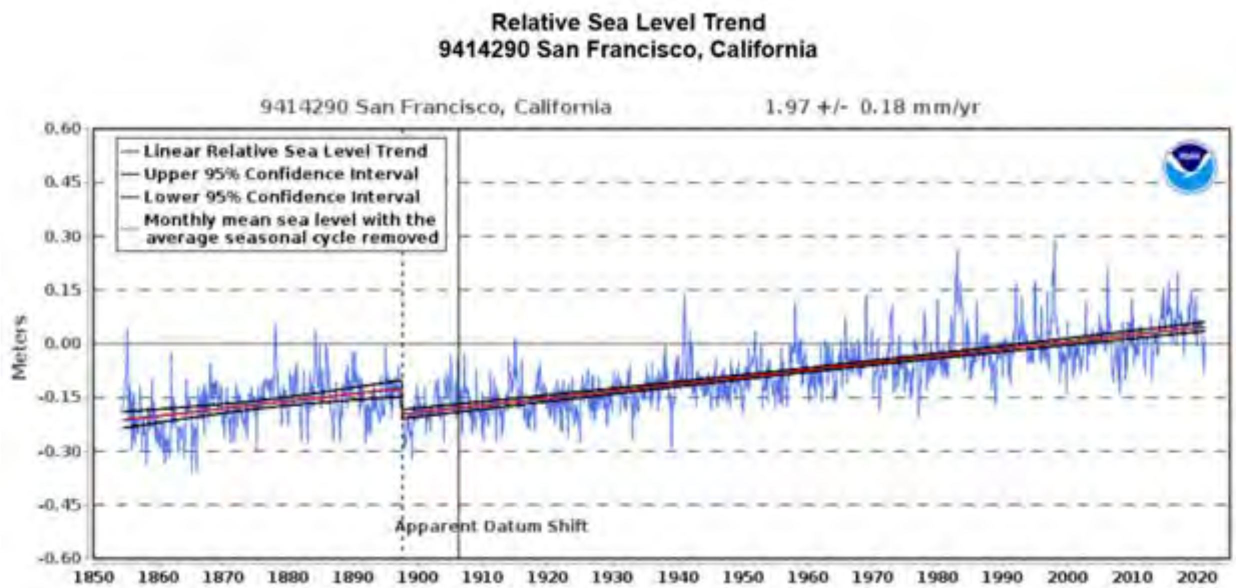


Figure 1-4. Relative sea level trend for the NOAA San Francisco tide gauge (Station 9414290)

1.6 CLIMATE CHANGE AND SEA LEVEL RISE POLICY GUIDANCE

Substantial climate change research in California has been under way for decades and researchers continue to refine and downscale global climate change model projections to support regional California planning efforts. Key climate change impacts are projected to include increased temperature, uncertain/volatile precipitation changes, wildfire, and accelerating sea level rise.

Recent research from Antarctica, based on previously underappreciated processes linking atmospheric and ocean warming, suggests a heightened probability of increased sea level rise rates due to large portions of ice sheet collapse. These findings moved then-Governor Brown to form a working group to develop a scientific sea level rise update for California, completed in 2017. This report provided probabilistic projections for future sea levels at three tide gauges throughout the state for 2030, 2050, and 2100 based on different greenhouse gas (GHG) emission scenarios.

Based on the updated sea level rise science, in 2018, the OPC and CCC both issued guidance documents that are meant to guide local jurisdictions on sea level rise planning. They are:

- State of California Sea-Level Rise Guidance Year 2018 Update, adopted by OPC in 2018
- CCC Sea Level Rise Policy Guidance, certified by the Coastal Commission in 2018

It is expected that both the projections and modeling of sea level rise that these reports rely on will be revisited and revised over time as the science evolves.

1.6.1 IPCC AR6 Climate Change 2021

The Sixth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) addresses the most up-to-date physical understanding of the climate system and climate change, bringing together the latest advances in climate science, and combining multiple lines of evidence from paleoclimate, observations, process understanding, and global and regional climate simulations.

California relies on the recommendations of this report and its summary for policymakers, which is intended to provide a high-level summary of the understanding of the current state of climate science. The summary identifies how climate is changing, the impact of human activities on climate and how to reduce these impacts, the state of knowledge about possible climate futures, and climate information relevant to regions and sectors.

1.6.2 Coastal Commission Guidance

In 2018, CCC adopted the Sea Level Rise Policy Guidance to aid jurisdictions in addressing sea level rise in local coastal programs, coastal development permits, and regional strategies (Figure 1-5). The document outlines specific issues that policymakers and developers may face because of sea level rise, such as extreme weather events, challenges to public access, vulnerability, and maintaining consistency with the California Coastal Act. The policy guidance document also lays out six recommended planning steps to incorporate sea level rise into policies and regulations, develop strategies to reduce identified vulnerabilities, and inform further adaptation planning.

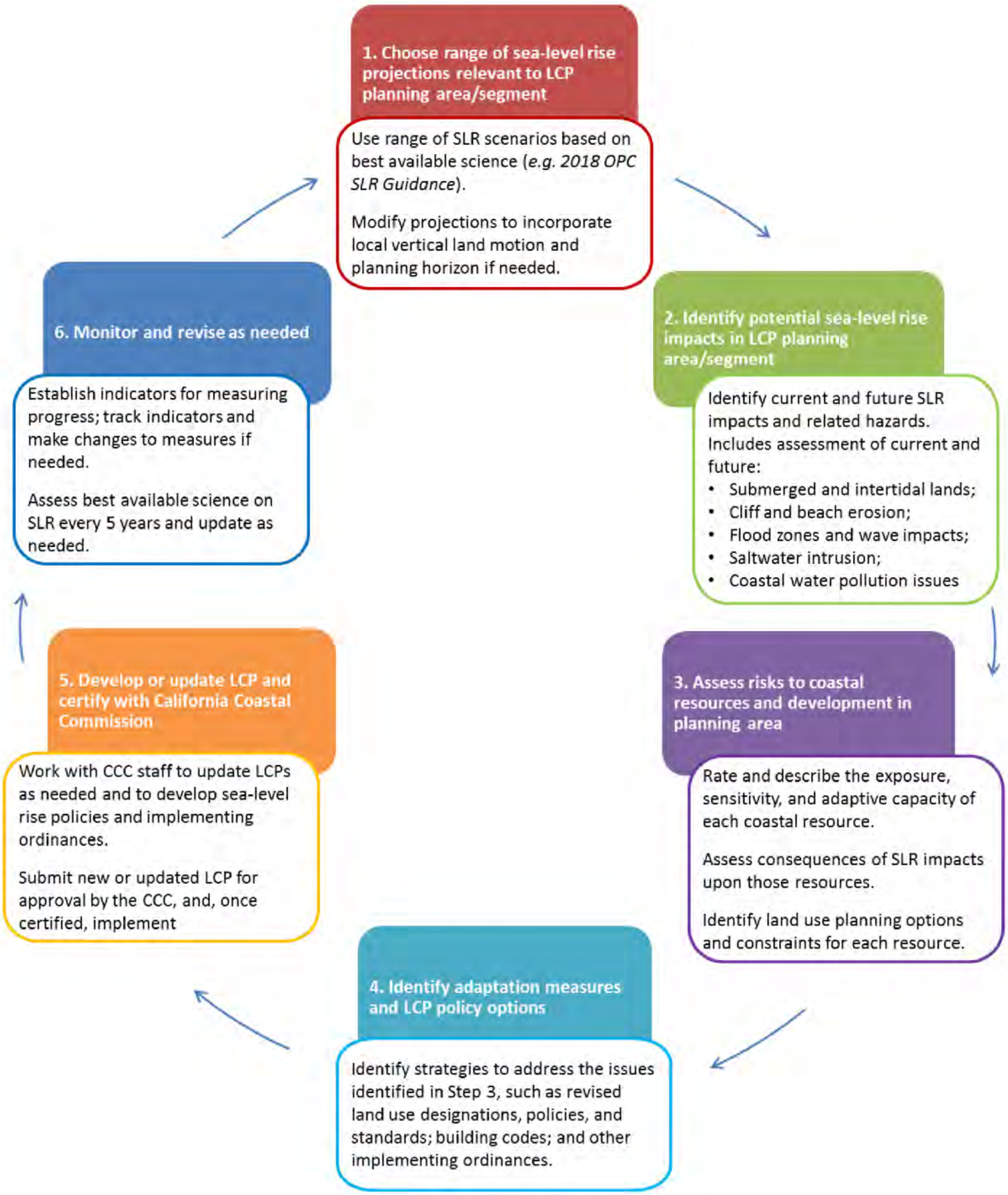


Figure 1-5. California Coastal Commission (CCC) Sea Level Rise Policy guidance 2018

1.6.3 Ocean Protection Council Guidance

The 2018 Ocean Protection Council (OPC) update to the State of California Sea-Level Rise Guidance is a follow-up to the 2017 science update mentioned above. This guidance reflects advances in sea level rise science and provides a science-based methodology to guide state and local agencies as they incorporate sea level rise into their planning, permitting, and investment decisions.

The updated guidance provides:

1. A synthesis of the best available science on sea level rise projections and rates for California based on foundational modeling work completed as part of the Fourth California Climate Assessment
2. A stepwise approach for state agencies and local governments to evaluate those projections and related hazard information in decision-making
3. Preferred coastal adaptation approaches.

1.6.4 California's Fourth Climate Change Assessment (2018)

Biennially, the California Energy Commission funds the California Climate Change Assessment to better understand climate change impacts on natural resources and urban settings. The State completed its most recent assessment of statewide climate change impacts in 2018. Much of the research and data gathered from the modeling results (discussed below) form the basis for the OPC and CCC's current guidance on sea level rise.

As an initial part of the Fourth Climate Change Assessment, the State commissioned Scripps Institution of Oceanography at the University of California, San Diego to develop a new suite of sea level rise projections that reflect the latest scientific findings and the emission reduction pledges made at the 2015 United Nations Framework Convention on Climate Change Conference in Paris, France. The updated sea level rise projections are summarized in OPC's 2017 Rising Seas in California report, which was written to be more applicable to policymaking, and was integrated into the recent OPC State of California Sea-Level Rise Guidance (2018).

In recent years, scientists have advanced their understanding of rates of ice melt and its impacts on global sea levels. The rate at which ocean levels rise will largely depend on the rate of ice melt. The uncertainties associated with the rate at which ice melts have resulted in a wide range of sea level rise projections for the latter half of the century. Recent science has found that the rate of ice melt has been accelerating. One recently discovered cause for this acceleration is the melting of the sea ice surrounding the continents. Sea ice has historically buttressed the land ice from rapid melting. As the sea ice disappears, the rate of melting on the continents accelerates. The discovery of this new ice melt mechanism, particularly in Antarctica, has resulted in more extreme sea level rise scenario projections (H++ Scenario) with more than 10 feet of sea level rise by 2100 (DeConto and Pollard 2016). Using several scenarios of future GHG emissions (known as Relative Concentration Pathways), projections of future sea level rise in California range from less than 1 to 10 feet by 2100 (OPC 2018) (Figure 1-6).

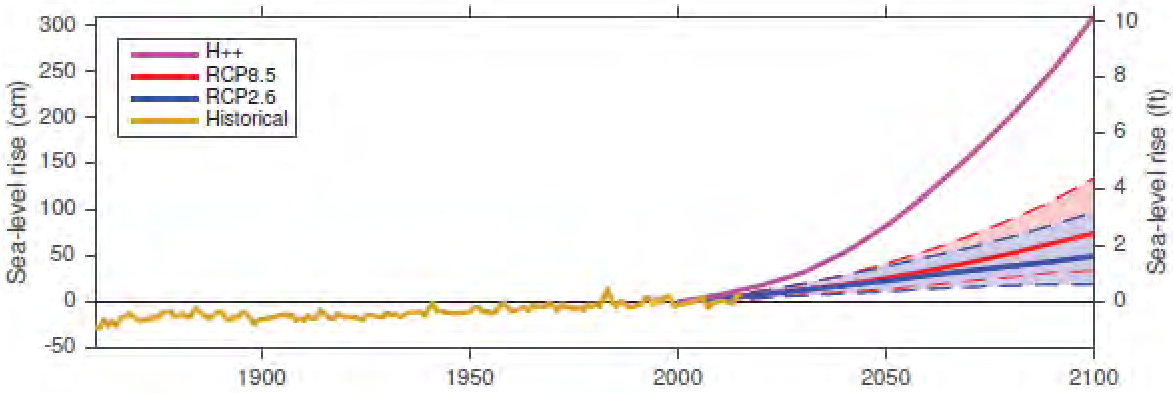


Figure 1-6. Projected relative sea level rise trend at San Francisco, California
Source: OPC 2018

1.6.5 Cal-Adapt (2011 and continuously updated)

The development of the Cal-Adapt tool was a key recommendation of the 2009 California Climate Adaptation Strategy. Cal-Adapt was designed to provide access to the wealth of data and information that has been and continues to be, produced by the State of California's scientific and research community. The data available on this site offer a view of how climate change might affect California at the local level. Cal-Adapt empowers users to work with visualization tools, access data, and participate in community sharing to contribute their knowledge.

The site has been developed by the Geospatial Innovation Facility at the University of California, Berkeley with funding and advisory oversight by the California Energy Commission and California Strategic Growth Council. The data used within the Cal-Adapt visualization tools have been gathered from California's scientific community and represent peer-reviewed, high-quality science.

1.6.6 State and Regional Planning Efforts

State and public entities are tasked with balancing their existing responsibilities while strategically and collaboratively planning for climate change. The State has supported local jurisdictions in planning for climate impacts and sea level rise by issuing planning guidance and funding research to help understand how climate impacts will affect communities, developments, infrastructure, and natural assets.

This assessment leverages much of the excellent work that has already been completed or is presently under way in the San Mateo County region. Plans and reports considered when producing this vulnerability assessment, whether completed or ongoing, are listed below and described in more detail in Appendix A.

1.6.7 San Mateo County Sea Level Rise Policy for County Facilities

In response to the County's 2018 Sea Level Rise Vulnerability Assessment, the San Mateo County Board of Supervisors adopted a policy in 2019 that sea level rise is considered in all county-owned and operated assets, design and construction projects, leases, and property acquisitions. All projects must consider local and regional sea level rise adaptation and flood mitigation projects that could reduce impacts on county-owned assets prior to developing plans to modify existing facilities.

The County of San Mateo Office of Sustainability is currently in the process of developing sea level rise vulnerability assessment templates to complete upon beginning a new project that falls under the policy to help departments comply with the policy in a consistent and trackable manner.

State Level

- **California State Parks Sea Level Rise Adaptation Strategy (2021)**
- **The Nature Conservancy and Coastal Conservancy's Conserving California's Coastal Habitats (2018)**
- **Assembly Bill 691 (2013)**
- **Caltrans Climate Change Vulnerability Assessments – District 4 (2018)**
- **Caltrans Adaptation Priorities – District 4 (2020)**

County Level

- **Sea Change San Mateo County (2015 and ongoing)**
- **California Coastal Trail Planning (2003 and ongoing)**
- **Government Operations Climate Action Plan (2021)**
- **Community Climate Action Plan (2022)**
- **Local Hazard Mitigation Plan (2021)**
- **Connect the Coastside Plan (2021)**
- **San Mateo Crop Reports (2019)**
- **SMC Parks Dept. Visitor Use/Non-Use Study (2016)**

Local Level

- **Tunitas Creek Beach Preferred Plan/Beach Improvement Project (2021)**
- **Butano Creek Channel Stabilization and Habitat Enhancement at Cloverdale Road Bridge (estimated completion September 2021)**
- **Pescadero Hydrologic Analysis (2020)**
- **Butano Channel Reconnection Project (2019)**
- **Groundwater Studies for the San Mateo Plain Subbasin (2018)**
- **City of Half Moon Bay Sea Level Rise Vulnerability Assessment (2016)**
- **Solutions to Flooding on Pescadero Creek Road (cbec eco engineering, Stillwater Sciences, 2014)**
- **Caltrans Concept and State Road 1 Relocation Planning, Pescadero to San Gregorio rerouting (2008)**
- **Pigeon Point Light Station State Historic Park General Plan (California State Parks, ESA Consulting, 2017)**

Bean Hollow
Source: Integral Consulting

SETTING

2 SETTING

This section describes the historic and contemporary social setting of the South Coast and provides an overview of the concept of social vulnerability as it applies to hazard risk on the South Coast. In addition, this section provides background on each of the resource sectors analyzed later in this vulnerability assessment. For information about the physical setting of the South Coast, including climate, geology, current coastal hazards, and habitats, see Appendix A.

2.1 HISTORICAL AND CULTURAL SETTING

2.1.1 A Brief Cultural History of the South San Mateo Coast

Prehistorical

Just before the end of the last glacial period, world sea levels were lower by about 300 feet, and coastlines were many miles further from where they are now. Interpretation of sediment profiles from southern San Francisco Bay indicates that between 17,000 and 7,000 years ago, warming trends in the global environment caused a rapid rise in sea levels as glacial ice melted (Atwater et al. 1977). Sea level reached its approximate current level around the Middle Holocene, approximately 6,000 years ago, and then began to stabilize. With this predictable climate and sea level came more predictable seasonal food availability, and multiple waves of early human settlers came to this area.

Native Peoples

There is a long history of human settlement on the South San Mateo Coast, oral and written histories, as well as cultural areas and materials, have provided a narrative of rich and diverse history. The Ramaytush (ra-MY-toosh) Ohlone lived in 10 independent tribes on the San Francisco Peninsula for thousands of years and continue to live in the region, though displacement is a significant concern.

The Ohlone People maintained and preserved large areas of forest and meadowland here, and used selective burring, pruning, and hand-tending practices to enrich soils and encourage better harvests of seeds, roots, and other edibles, as well as suitable materials for clothing, tools, baskets, and bows. Over the millennia, native burning and forest thinning practices also limited the spread of coniferous forests into meadowlands, and the Central Coast landscape had a very different composition than it does today.

European Contact

Europeans first made contact with this area in the 1700s. Throughout the eighteenth century, Spanish colonizers established missions, and along with them came the subjugation of the Native Peoples and vast changes to the landscape. The mission period brought culturally destructive policies and practices to Native Peoples, leading the Ramaytush Ohlone to lose much of its population as well as its land. During the mission period, Pescadero served as a cattle ranch station for Mission Santa Cruz, and many of the local people were forcefully and coercively transitioned into a mix of ranching, agricultural, and timber harvesting work.

The cattle ranch period of the Pescadero region saw the arrival of many foraging cows, pigs, and goats that feasted in the vast meadowlands of the area. Over time, their grazing practices reduced the renewal and continuation of the oak woodlands that once abounded here, and with them came many non-native Eurasian types of grass and the encroachment of coniferous forests into meadowlands (Hylkema 2013).

Early American Period

Following the Mexican-American War (1846–1848), Mexico was forced to relinquish to the United States government any claim to California. California became a U.S. state, and with the cattle ranchers came many fishermen, lumberjacks, and other tradespeople supplying food, lumber, and other building materials to the growing city of San Francisco. The California gold rush period brought great numbers of people and wealth to the State, and with this came many permanent settlers to the San Mateo County Coast. The proximity to San Francisco also meant that the area was a popular vacation destination, being only a one-day stagecoach ride from the city. By the early 1900s, ambitious plans to build a rail line connecting San Francisco to Santa Cruz were under way. Following the great San Francisco earthquake and other financial disasters, the rail line was never completed, but portions of the former rail grade can still be seen today in the areas between Tunitas Creek and Half Moon Bay.

Maritime History

The San Mateo South Coast has a rich maritime history and has numerous locations of significant cultural and historical resources. Just south of Pigeon Point is an area that was notoriously treacherous in the early days of sailing in California. Two clipper ships were lost on the rocks between Año Nuevo and Pigeon Point during the 1850s, and other maritime tragedies occurred in later years. Most famously, this area is the location of the shipwreck of the American clipper ship *Sir John Franklin* in 1865. Events like these lead to the construction of a fog whistle on Año Nuevo Island in 1872 and a five-story light tower in 1890 (taken down by the state in 1976), and the Pigeon Point Light Station, which was first lit on November 15, 1872. The lighthouse is a popular tourist destination and is on the National Register of Historic Places, is a California Landmark, is a State Historic Park, and is still an active U.S. Coast Guard aid to navigation.

Modern Period

In more recent times, tourism and agricultural activities continue to play an important role in the region’s identity and economy. Open space preserves and parks have become the primary caretakers of open space on the South San Mateo Coast. This landscape has a vastly different composition than the one stewarded by Native Peoples prior to European colonization. The harvest practices of Native Peoples interacted with and supported a landscape that was far more biologically rich and complex. Today, open spaces contain a far greater quantity of invasive shrubs and other non-native plants. State, county, and nonprofit organizations are increasingly recognizing the importance of collaborating with Tribes to conserve and restore the health of the lands and to provide an opportunity to share history and culture.

Current Challenges

The South Coast's proximity to Silicon Valley has resulted in incredibly high costs of living and high property values, which have further reduced housing options for Native Peoples, agricultural workers, and other lower-income residents, in many cases resulting in displacement or precarious living conditions (Silicon Valley Community Foundation 2017). Coastal farms and ranches are actively sought after by wealthy buyers for private estates. This has inflated land prices, making it harder for farmers to get started in the Bay Area. Assessed values have also created added tax stress as well. As of 2020, 46% of San Mateo County's farms had disappeared since 1990 (POST 2021). POST's Farmland Futures Initiative promotes agricultural land preservation by providing acquisitions, a reliable lease, infrastructure funds, and other support.

A survey by the Silicon Valley Community Foundation in 2017 found that the median household income for a farmworker family is approximately $26,000; this is in a county with a median household income of nearly $133,600 according to 2021 estimates. Many resident South Coast farmworkers struggle to find affordable housing and only one-third of farm laborers are living in housing designated for farmworkers. The other two-thirds must compete for market-rate housing in a region where rental prices rival and even exceed those in cities like San Francisco and San Jose (Silicon Valley Foundation 2017). Puente de la Costa Sur, a nonprofit resource center for residents, provides crucial community services to farmworkers in the South Coast region.

2.2 COMMUNITY VULNERABILITY IN THE SOUTH COAST

Underserved communities, particularly low-income households, people of color, older adults, people with disabilities, agricultural and nursery workers, and non-English speakers, bear a disproportionately high-risk burden in relation to climate change and natural hazards, generally facing higher exposure to and impacts from hazards with fewer resources to withstand and recover from them. These impacts may include immediate threats to life and safety, exposure to contaminants released through flooding, exposure to flood-induced mold growth and development or exacerbation of respiratory issues, uninsured property damage, displacement or homelessness, job loss, transportation isolation, and difficulty accessing response and recovery resources.

Census and local data sources can provide a starting point for understanding social vulnerability to coastal hazards in the South Coast, though quantitative data often fails to fully capture the nuances and depths of how social processes facilitate outcomes during hazard events (See the section on Social Vulnerability Index below for more discussion on this subject).

The unincorporated South Coast is comprised of two census tracts (6137.02 and 6138), and this report describes demographic data at this relatively coarse geographic scale that may understate the levels of vulnerability at the local scale.

The American Community Survey 5-year estimates for 2020 indicate that nearly half of households in the northern tract and nearly a quarter in the southern tract have incomes of less than $75,000, which is slightly over half of the 2021 county median household income of $133,600. In San Mateo County, high costs of living that follow a rising median income leave low- and medium-income households with increasingly less disposable income, and in some cases, force them into precarious living conditions that make them more vulnerable to sea level rise impacts.

According to a 2017 report by the Silicon Valley Community Foundation, many agricultural and nursery labor families live in unsafe, unhealthy, and crowded living conditions, which exacerbate their risk to coastal hazards. One family of five profiled owned and lived in a dilapidated trailer with infestation and leak issues. At the time of the report, they paid $1,100 a month to park their trailer on a rented plot of land near the ocean in Pescadero, plausibly a flood-prone area. The two adults in the home each earned $11/hour as nursery workers in Half Moon Bay and had very little if any disposable income at the end of the month. Their story highlights how extreme, everyday stressors can inhibit people's ability to withstand and recover from shocks like flooding or landslide events. When people do not have savings, they have few options for alternative shelter should a hazard damage or destroy their home and are unlikely to be able to pay for property or rental insurance. Chronic illnesses resulting from lack of access to healthcare (also documented in the Silicon Valley Community Foundation report) further increase vulnerability to shocks like hazard events, particularly as displacement, mold and contaminant exposure, and psychological stress are likely to worsen existing health conditions.

Individuals with limited English language ability may have difficulty receiving and understanding important hazard-related communications, inhibiting their ability to prepare for, react to, and evacuate from a hazard area. They may also have difficulty accessing and navigating recovery resources, such as FEMA Individual Assistance or private insurance claims. The South Coast region at large is home to many limited English-speaking community members, with 19% of individuals in the northern tract and 7% in the southern tract estimated to speak English "less than very well." These figures likely represent an underestimate since people of color are often undercounted in census data and Latinos are estimated to be undercounted by a net rate of 4.99% (U.S. Census Bureau 2022).

Limited mobility or cognitive or sensory disability can be a major source of vulnerability for individuals, particularly if they do not have live-in support and robust social networks to warn, physically aid, and evacuate them in hazard events. It is estimated that 12.5% of people in the northern tract and 8.6% of people in the southern tract have at least one disability. Elderly residents may experience mobility challenges, though they may not identify as having a disability. Over a quarter of the population in the northern tract and 17.8% in the southern tract are 65 and older, indicating potentially decreasing mobility.

Census data should serve only as a starting point for carrying out community-based vulnerability assessments and identifying opportunities for vulnerability reduction through social network building, community-based emergency response and planning, and provision of community resources. Decision-makers should meaningfully engage socially vulnerable communities early in the process when developing risk reduction measures (See Section 5.5.3 for Social Equity Considerations).

Table 2-1. South Coast Social Vulnerability Indicators

South Coast Social Vulnerability Indicators		
Demographic Statistic	**Census Tract 6137.02 (Northern)**	**Census Tract 6138 (Southern)**
Residents 65 years and older	28.4%	17.8%
Supplemental Nutrition Assistance Program Participation	4.5%	1.7%
Household incomes < $75,000	44%	23.8%
Individuals speaking English “less than very well”	19%	7%
People with at least one disability	12.5%	8.6%
With a hearing difficulty	4.3%	4.3%
With a vision difficulty	2.7%	2.7%
With a cognitive difficulty	1.7%	2.6%
With an ambulatory difficulty	5.3%	5.1%
With an independent living difficulty	6.5%	4.5%
With a self-care difficulty	0.2%	2.5%
Renter-occupied housing units	47%	26.4%
Worked outside county of residence	25.7%	31.8%

2020 American Community Survey 5-Year Estimates

2.2.1 Using Social Vulnerability Indices

Within the State of California, decision-makers have turned to social vulnerability indices (SVIs) to understand where high-risk populations live. While this approach is valuable as a starting point for understanding community vulnerability to sea level rise and other natural hazards, it may not fully capture all the dynamic community characteristics that can produce vulnerability or resiliency. Relying on census tracts for this analysis is also made difficult by the fact that the South Coast is a relatively rural area and comprises only two census tracts that span from the coast to the crest of the Santa Cruz Mountains, and approximately 2% of the population of the census tracts falls within the coastal hazard zone area. As a result, the overall SVI listed below may be misleading and may not capture the nuance of potentially vulnerable populations.

San Mateo County Social Vulnerability Index (also known as the Community Vulnerability Index [CVI])

Northern Tract (including portions of Half Moon Bay)
2019 Overall SVI Score: 29.2
A score of **29.2** indicates a **moderate to high** level of social vulnerability.

Southern Tract (including Pescadero)
2019 Overall SVI Score: 23.6
A score of **23.6** indicates a **low to a moderate** level of social vulnerability.

Possible scores range from 0 (lowest vulnerability) to 100 (highest vulnerability), with the most vulnerable census tracts in San Mateo County having a score of 62.

The CVI indicates the relative vulnerability of every San Mateo County census tract based on seven measurements, including health insurance coverage, education, supplemental security income, gross rent as a percentage of income, poverty, unemployment, and disability.

What is known from firsthand communication with residents and community groups is that income disparity on this stretch of coast is very high, and the social vulnerability statistic may be artificially inflated by the high wealth households that own coastal property. Within the rural South Coast region, the census tract with Pescadero is classified as having a relatively low to moderate SVI score. This score is likely a significant underestimate as it may not capture or properly weigh the level of vulnerability to certain higher-risk populations such as undocumented people and racial minorities, who are often undercounted in the census. The 2017 Silicon Valley Foundation Report qualitatively demonstrates very high levels of vulnerability in the Pescadero area, documenting extremely precarious living conditions among Latino farm and nursery workers. Policymakers and practitioners should consult qualitative documents like this report and consult with communities and community-based organizations wherever possible to help ground truth and test SVIs.

2.2.2 Visiting Populations

Beyond its impact on residents, regional flooding associated with sea level rise will also impact visitors, employees, and commuters. Limited data exist on the demographics of visitors to the area; however, given the low population density of the area and an estimated 1.2 million park visits to the area, it can be assumed that most of the people arriving at a local park come from more distant locations and those demographics would reflect the wider region. Regional visitation is linked to statewide demographic trends (King et al. 2011), and the population of California has been growing, increasing by 2.3 million people between the 2010 and 2020 censuses. In addition, California is becoming more diverse, with the Latino or Hispanic population growing by around 11%, and those who identify as being two or more races growing by 217.3% (U.S. Census 2020). The Association of Bay Area Governments (2015), which tracks population projections for the Bay Area, projects that by the year 2040, the Bay Area will expand to include approximately 9.3 million residents. As climate changes increase the length and severity of inland temperatures, the coastal areas, parks, and beaches will likely become more of a draw for inland residents wishing to leave prolonged heatwaves. These considerations are important for designing equitable and inclusive adaptation strategies that can provide benefits for all.

2.3 ASSET AND RESOURCE SECTOR CONDITIONS

The San Mateo South Coast study area encompasses 2,288 acres of land. This area is defined as all areas within the South Coast that are vulnerable to sea level rise and coastal hazards by 4.9 feet of sea level rise. Within this area are 1,970 parcel-owned acres and 123 primary structures, including 109 residences, as well as numerous significant community facilities including a fire station, a gas station, a hotel, and a lighthouse. There are 13 state, county, and city parks located in this area, as well as a multitude of public and private beaches that are popular destinations for locals and tourists alike.

Based on the unique characteristics of the South San Mateo County coastline, this study grouped assets and resources into the following sectors:

- **Land Use and Structures**—describes the overall composition and characteristics of the vulnerable coastal areas, parcels, and structures.
- **Agriculture**—includes planted fields, grazing lands and protected coastal prairie, orchards, and developed agricultural lands.
- **Transportation and Parking**—includes all state, county, and local roads, as well as their rights-of-way and associated bridges and culverts. Also included are all formal public parking areas.
- **Parks, Recreation, and Coastal Access**—includes all state, county, and local parkland, as well as protected open space areas. Also includes the trails, bathrooms, structures, and other amenities associated with these areas.
- **Significant Facilities**—Significant facilities include the Gazos Creek Gas Station, Pigeon Point Lighthouse, Ritz-Carlton Hotel, CAL FIRE Station, and the Pescadero Corporation Yard.

2.3.1 Land Use and Structures

This section describes the physical setting of the land use and structures sector within the combined coastal hazards zone, detailing the quantity of land use and ownership groups represented, and the number of structures associated with each subcategory.

Land Use and Ownership

Land Ownership History

The history of post-colonization land ownership in the South Coast can trace its way back to the original Mexican Land Grants, and many of the place names that we use today can trace their origins to this time. Along this stretch of coast were a handful of large ranchos, each many thousands of acres, including Rancho Cañada de Verde y Arroyo de la Purísima, Rancho Punta del Año Nuevo, Rancho Pescadero (also called Rancho San Antonio), Rancho Butano, Rancho

San Gregorio, and Rancho Miramontes. Following the Mexican–American War in 1948, the U.S. government acquired these ranchos, partitioning them and selling them over time. Many of the resulting parcels were quite large and sold mostly to those with interests in agriculture and logging.

Current Land Ownership

For this rural stretch of coast, the average parcel size in the study area (the furthest extent of the combined hazard zone) is approximately 35.6 acres, with 20 parcels of more than 100 acres (many adjoining parcels have a single owner, making the average area of ownership significantly larger).

There are 2,288 acres of land combined within the study area and nearly half is under the ownership of California State Parks with 1,096 acres, and another 110 acres owned by POST, with this land largely preserved as open space. Private property is less common on this stretch of coast and makes up only 630 acres of the hazard zone area, yet it is disproportionately represented in affected land use groups, with 171 affected parcels (or 72% of the total study area parcels). Of these properties, 73 parcels are residential properties, largely single-family homes on 1- to 5-acre lots. The primary residential areas are located at Martin's Beach, San Gregorio, Tunitas Creek, and Pescadero. Agricultural parcels are the second most numerous at 56, and the remaining are open space, vacant, commercial, or city and county ownership. The average size of private property in the study area is 29.7 acres, but the distribution skews to the smaller side, with a median parcel size of 3.9 acres.

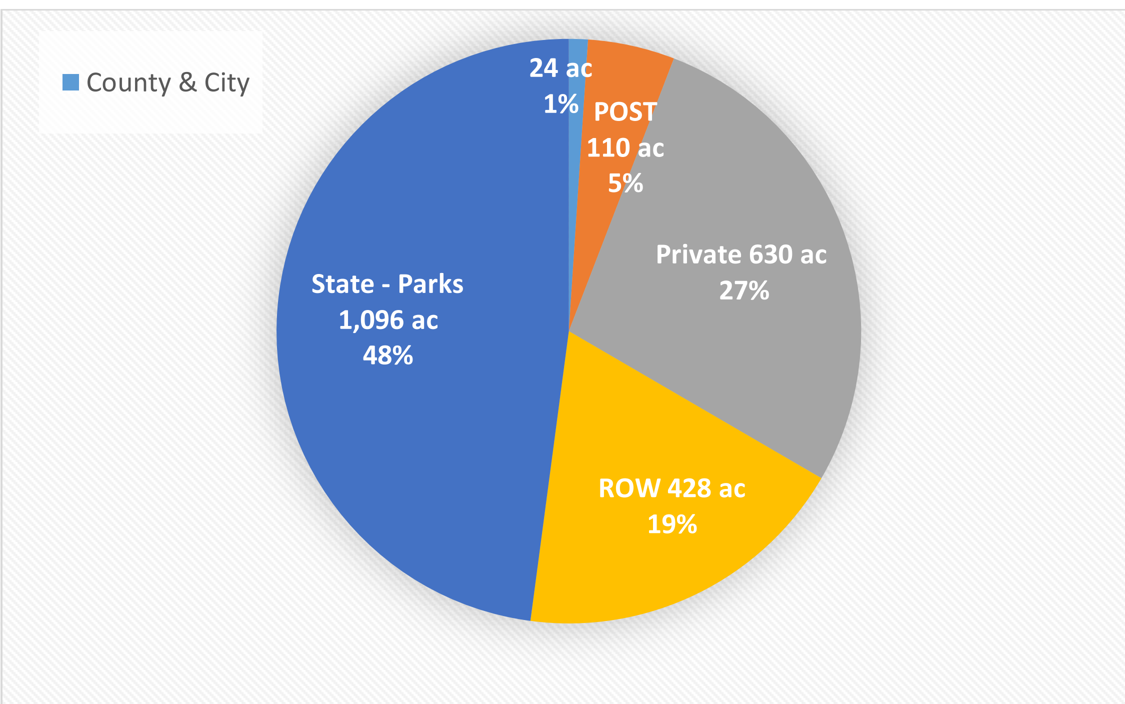


Figure 2-1. Land ownership within the study area in acres

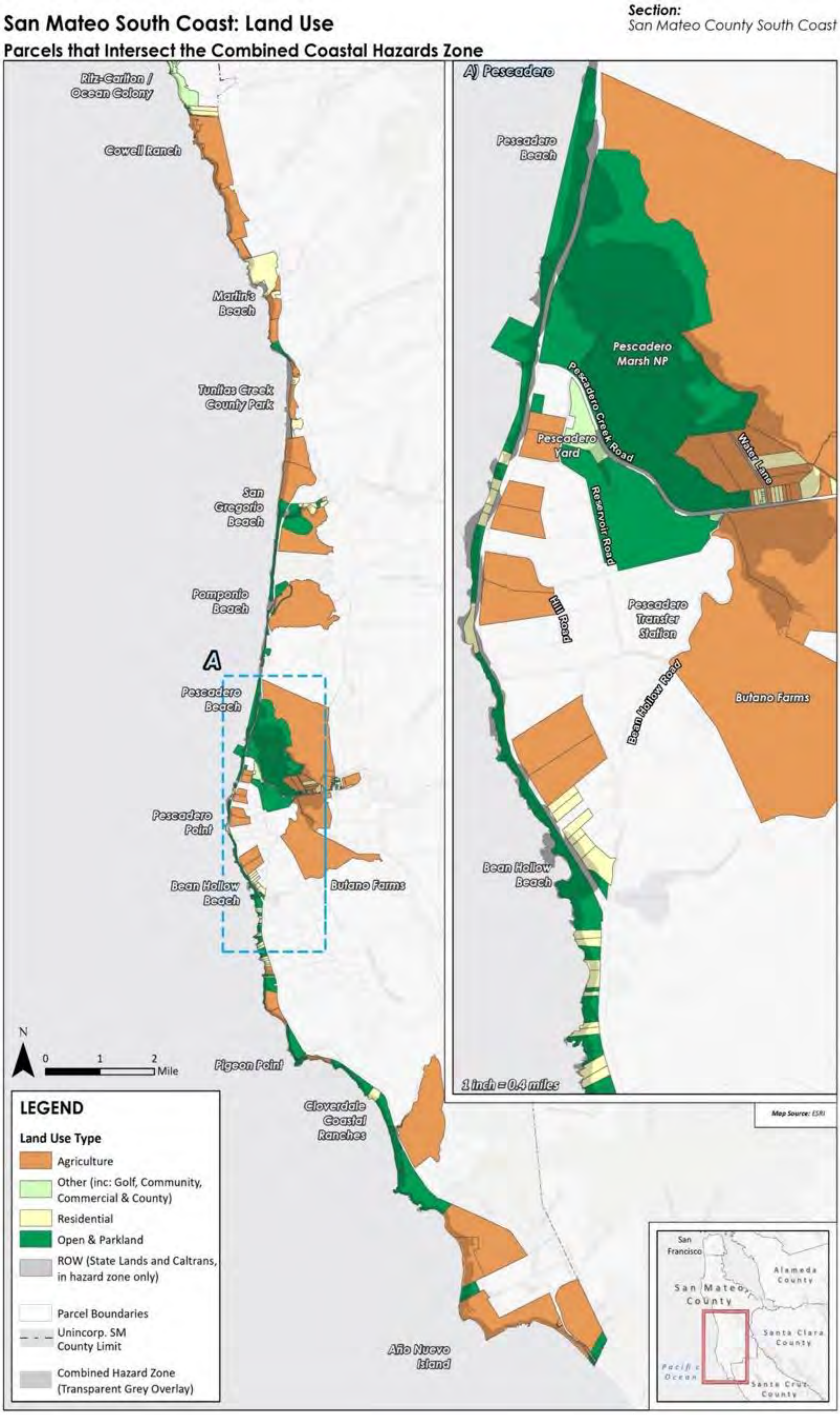
ROW *= right-of-way. Only includes state and county-maintained rights-of-way.*
Private land may include land with agricultural easements and other trust agreements but remains in private ownership.

County & City*: San Mateo County and City of Half Moon Bay.*

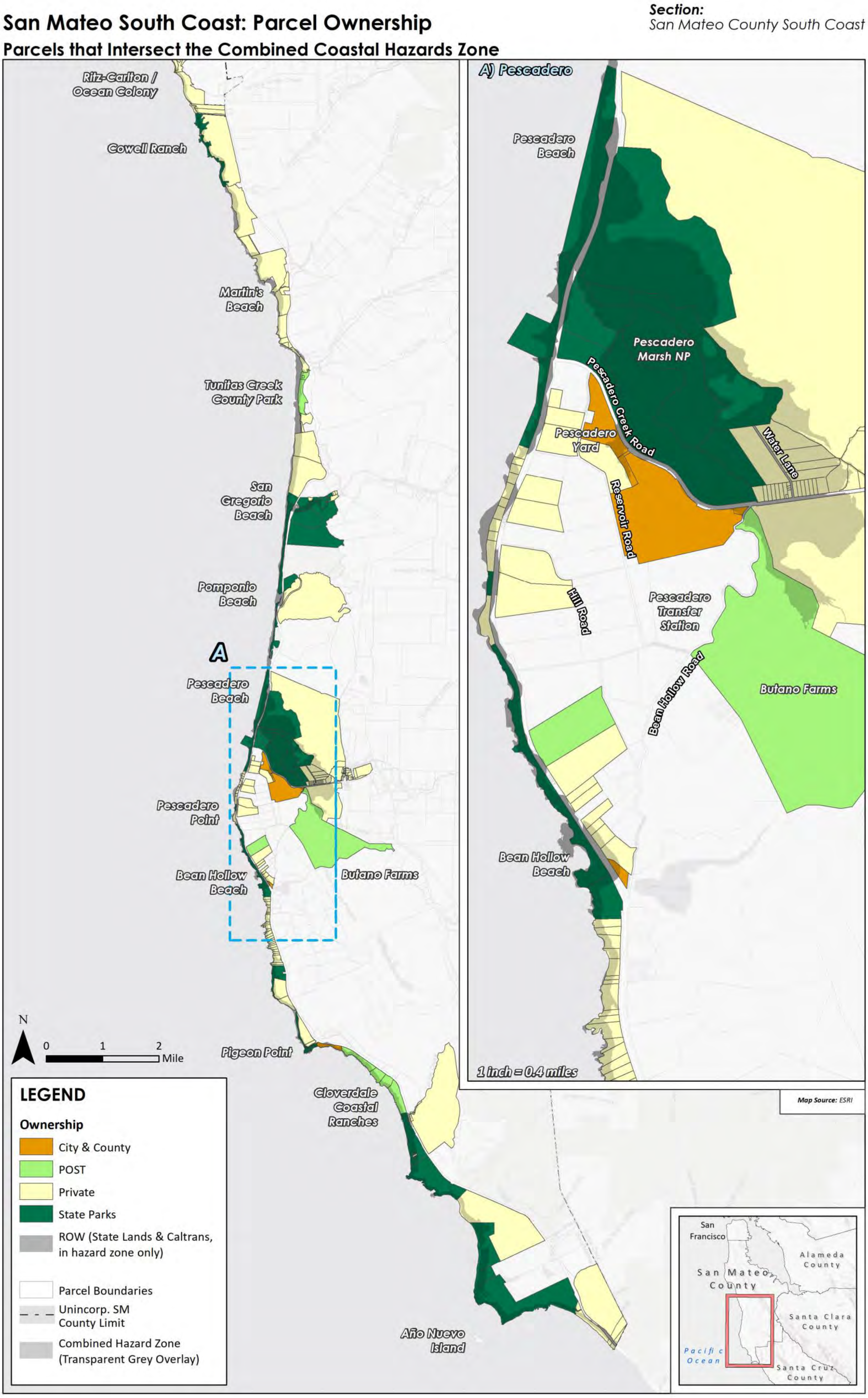
POST*: May include land that is owned by POST but leased and managed to private, non-profit or government entities.*

Land Use Existing Conditions

Map 4 and Map 5 illustrate the land use types and ownership categories on the South San Mateo County Coast study area.



Map 4. Land use types in the study area
Source: County Assessor.



Map 5. Land ownership types in the study area

Source: County Assessor.

Open space and parkland primarily include land managed by the State of California, with some land also managed by San Mateo County, the City of Half Moon Bay, and POST. Through lease agreements, some state parks and POST land may have agricultural land within their parcels.

While private residential properties represent only 5% of the study area on the South Coast, single-family homes represent most structures. Representing the remaining 1.2% are parcel-based land uses categorized as "other," which includes golf courses, community and county facility land, and commercial land such as the Ritz-Carlton Hotel in Half Moon Bay.

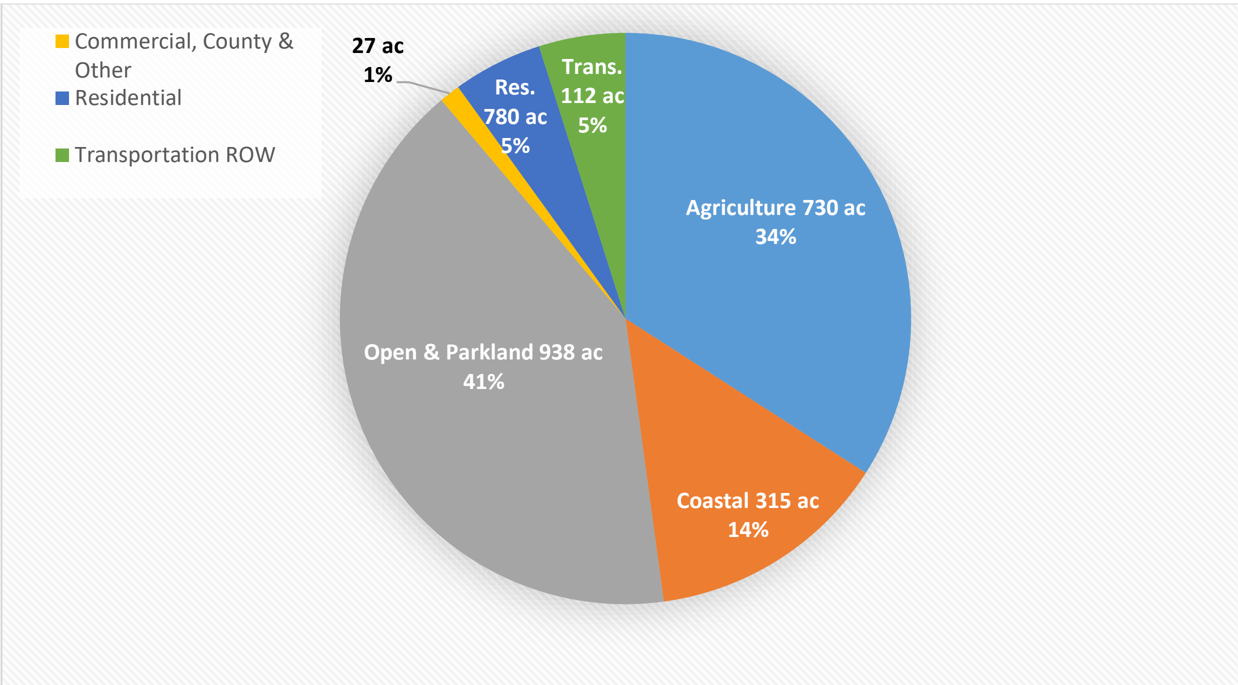


Figure 2-2. Land uses within the study area in acres

Source: County Assessor.

Area of study is defined by the area above 0 ft. elevation within the combined hazard zone

***Agriculture** includes fields and ranches, as well as open areas—primarily land along bluffs and in gullies. Many properties within the study area are zoned for agricultural uses but allow for residential development as compatible uses. These lands are considered "agriculture" for these purposes*

***Open & parkland** are primarily parkland managed by the State of California. Also includes parkland managed by the San Mateo County, City of Half Moon Bay, and POST. May include some vacant land. State parks and POST land may have agricultural land use through lease agreements*

***Commercial, County, & Other** includes golf courses, community and county facility land, and commercial land*

***Residential** are properties that are primarily for residential uses. These properties may include large open spaces or multi-use (i.e., light agriculture) areas.*

Transportation rights-of-way *include both parcel and non-parcel areas within the transportation corridor. These areas are primarily managed by the Caltrans and San Mateo County Public Works.*

Coastal *includes non-parcel coastal areas and primarily lands seaward of parcel boundaries occurring along the beach. Primarily lands managed by the State of California Department of Parks and Recreation.*

Structures Existing Conditions

There are 123 primary structures located within the study area. Most of these exposed structures are residences (including accessory dwelling units, or ADUs), represented by farmsteads, and single-family homes. The remaining non-residential structures include a fire station compound, a gas station, a hotel, and a lighthouse facility. Non-primary structures such as garages, bathrooms, barns, and sheds are not included in the primary structure count below.

Table 2-2. Structures by total count and area within the study area

Building Type	Number of Structures	Total Sq. Ft.
Fire Station	2	6,645
Commercial	4	9,789
Farmstead	12	15,988
Hotel	1	17,277
Parks	7	13,188
Single Family	43	85,545
Structures on Single-Owner Land	54	56,770
Grand Total	**123**	**205,203**

Non-primary structures or outbuildings (bathrooms, barns, garages, and sheds) are not included.

Structures on Single-Owner Land *includes Martin's Beach and Tunitas Creek Beach communities.*

Farmstead *includes residential structures on agricultural properties. Residents are primarily engaged in agricultural activities.*

2.3.2 Agriculture

Agricultural History

Throughout the late 1800s and early 1900s, San Mateo County was an important agricultural producer and provided local produce to the growing city of San Francisco. According to the 1880 U.S. Census, 960 individuals of the 8,700 living in San Mateo County owned or leased their farms. The agriculture sector was the foundation of the County's economy and employed many non-farmers as well, including merchants, grocers, tradesmen, skilled laborers, service workers, bankers, and construction workers (Moebus & Crowler 2014). The agriculture sector of San Mateo has shrunk considerably since the late 1800s, largely due to a multitude of economic and environmental forces. These include the increasing value of coastal real estate and pressures related to water access, changes to transportation and water conveyance in the state, and increasing competition from other agricultural regions. Despite this, growers on the South Coast have remained in part because of the rich soil and cool damp weather, ideal for growing cool-weather vegetables such as Brussels sprouts, leeks, peas, and artichokes. The area has the added benefit of being close to many potential consumers and financiers in the urban San Francisco Bay Area and has received support from both organizations and government entities who take an interest in supporting local agriculture.

Figure 2-3. A field of collard greens growing on the South Coast, an area ideal for growing cool-weather vegetables like Brussels sprouts, leeks, peas, and artichokes

Source: San Mateo RCD

Agricultural Conditions Today

The South Coast continues to hold on to a small number of working farms, with approximately 10 separate growers in the coastal hazard area, as well as several properties that are leased for grazing. In the wider South Coast region, there are a couple dozen working farms, including some large greenhouse operations and a research and incubator farm at the former Campbell's mushroom facility. Though critical to the wellbeing of the agricultural sector, farm labor is challenging to find and maintain due in large part to the lack of affordable housing in the region.

Many of the farms that remain along the coast have received some support from conservation easement programs. One of the most influential is the Williamson Act, which was passed by the California State legislature in 1964 to protect prime farmland. The Williamson Act stipulated that farmers who committed to keeping their land in agricultural production could only be taxed based on actual use of that land. The amount of the assessed value reduction depends on several factors, including the length and type of contract, the type of land, the use of land (crop production or grazing), and the location of the land. Other programs in the county also support farmers, such as the California Farmland Conservation Program, or Proposition 40, the POST Farmland Futures Initiative, and the San Mateo RCD.

Table 2-3. Acreage of Williamson Act land by general classification category

Agricultural Land Use	Acres in Williamson Act
Developed	5
Open—Coastal Prairie*	119
Ranchland	42
Field Crops	95
Grand Total	**260**

The Williamson Act, also known as the California Land Conservation Act of 1965, enables local governments to enter contracts with private landowners to restrict specific parcels of land to agricultural or related open space use. Agricultural land not in Williamson Act agreements may lie in other land trust agreements.

Williamson Act lands are reported based on parcel acreages and these spatial extents do not match the Farmland Mapping and Monitoring Program (FMMP) data set. Classifications of land uses were made manually and verified with the FMMP data set.

General classification categories are based on interpretations of County Assessors' parcels land use categories and aerial photographs.

**These areas could serve as ranchland as well*

Agricultural Land Uses

The study area encompasses 551 acres of agricultural land within the South Coast. This area includes 120 acres of planted fields, 387 acres of open and grazing land, and 44 acres of developed agricultural land. Planted fields on coastal bluff areas comprise 30 acres, where the primary crops that are grown generally rotate between Brussels sprouts, leeks, and fava beans. Planted fields in the vulnerable low-lying areas east of Pescadero Marsh comprise 90 acres, with the primary crops being herbs, pumpkins, and squash. Most of the locally grown crops are transported to Santa Cruz and Monterey counties where they are packaged and shipped. Nearly all agricultural water needs are dependent on annual rainfall and surface retention and storage.

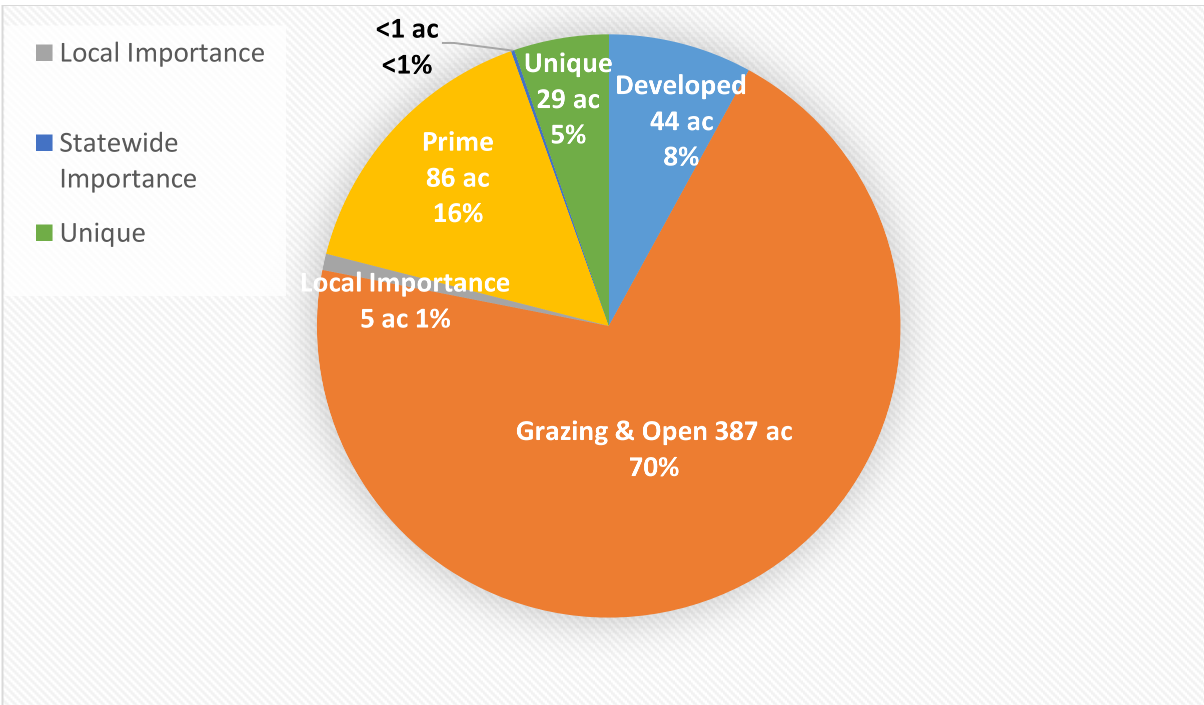


Figure 2-4. Agricultural classifications in the study area in acres
Source: Farmland Mapping and Monitoring Program

Prime Farmland*: Irrigated land with the best combination of physical and chemical features able to sustain long-term production of agricultural crops.*

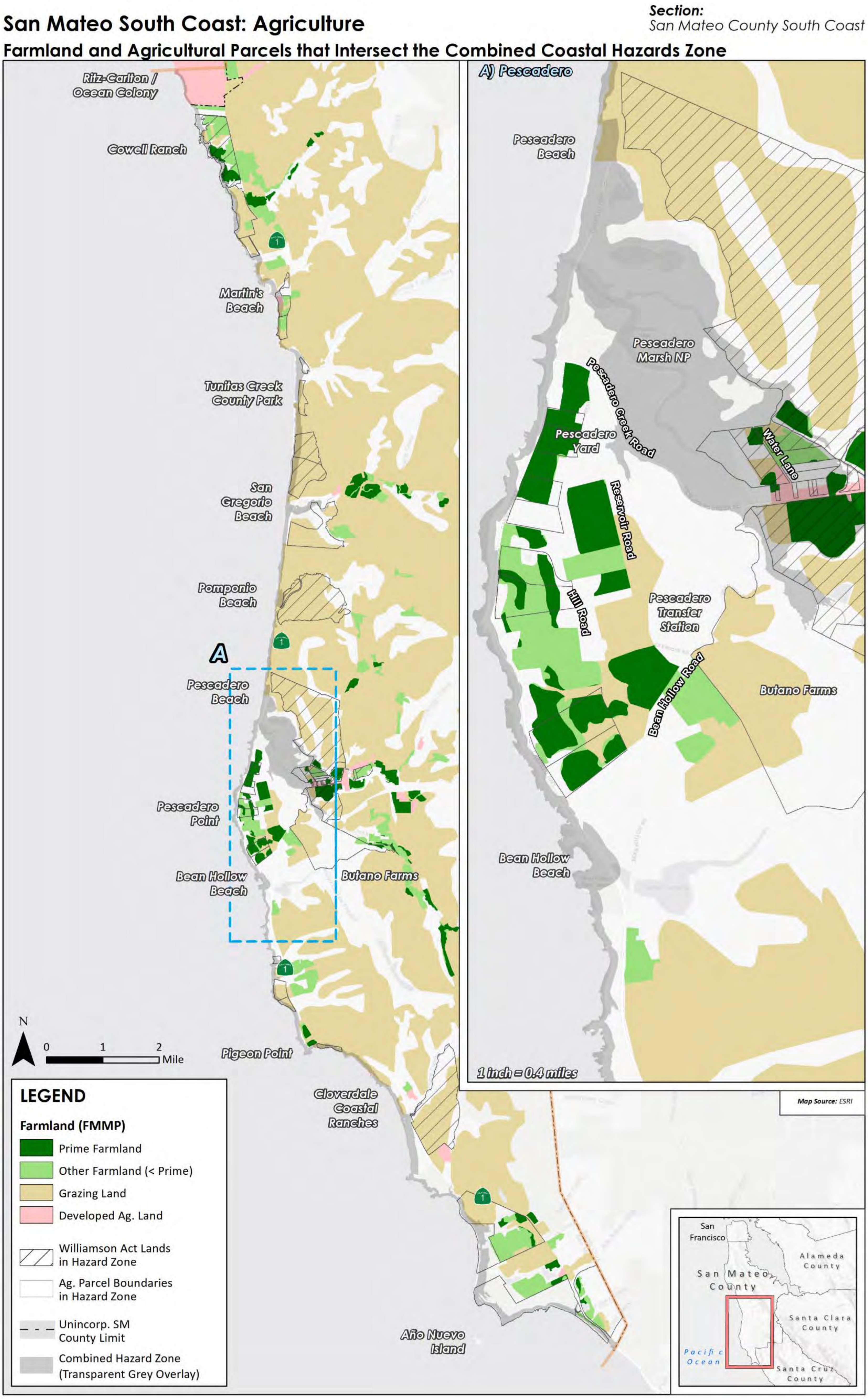
Farmland of Statewide Importance*: Irrigated land similar to Prime Farmland that has a good combination of physical and chemical characteristics to produce agricultural crops.*

Unique Farmland*: Lesser quality soils used to produce the state's leading agricultural crops.*

Farmland of Local Importance*: This includes land that is or has been used for irrigated pasture, dryland farming, confined livestock and dairy, poultry facilities, aquaculture, and grazing land.*

Grazing & Open*: Land on which the existing vegetation is suited to the grazing of livestock. May include agricultural land that is dedicated open space.*

Developed*: Agricultural land that is occupied by structures, with a building density of at least one unit to 1.5 acres.*



Map 6. Farmland and agricultural parcels in the study area (the extent of the combined hazard zone)

Agricultural data source: FMMP

2.3.3 Roads and Parking

State Route 1, also known as Highway 1 or the Cabrillo Highway, is the primary transportation corridor that links the South Coast to Half Moon Bay, Santa Cruz, and areas beyond. Constructed in 1939, this road runs north–south between the County line and the City of Half Moon Bay and is intersected by a handful of state routes and county roads, the major ones being State Road 84, or San Gregorio Road, and Pescadero Creek Road. In addition to these, there are also a couple dozen driveways and other local access roads that connect coastal homes and properties to state and county roads.

Many of the roads through the study area are a popular draw for tourists and travelers, and they also draw many bikers. State Route 1 serves as the primary mode of access to numerous parks, beaches, farm stands, and other scenic locations along the coast. It is especially noted for its scenic qualities and is designated as an “All American Road” by the U.S. Department of Transportation, a special classification within the national scenic byways program and one of only three in California. State Route 1 serves as the primary accessway for residents and workers in coastal communities as well as for emergency vehicles and disaster evacuations. It is also an important thoroughfare for transporting garden, dairy, and stock-raising products from the Central Coast.

This stretch of coast sees significantly less traffic than the highway sections north of Half Moon Bay. The lowest traffic volumes are experienced at the county line, with a few thousand average annual vehicle trips per day, and this increases towards the northern section of the study area to just over 10,000 average annual vehicle trips per day (Caltrans 2019).

Table 2-4. Estimated annual average daily traffic (AADT) along State Route 1 in the study area

Estimated AADT in the Study Area (2019)	
Section of Road	**AADT***
Southern Section (average)	**5,000**
County Line (Southern Section	5,000
Central Section (average)	**6,275**
Junc. Pescadero Creek Road	5,150
Junc. 84—San Gregorio Road	7,200
Northern Section (average)	**9,200**
Junc. Tunitas Creek Road	7,600
Junc. Verde Road	8,050
Half Moon Bay City Line—Miramontes Point Road	11,950
Average	**7,492**

**Average of daily traffic travel in both directions*

Approximately 5% of movements are trucks, and half of those truck movements are tractor-trailers.

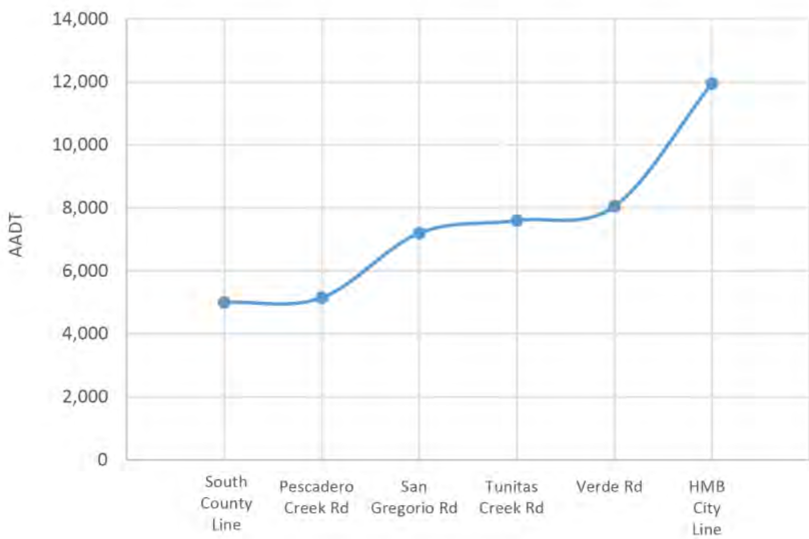


Figure 2-5. Chart of Annual Average Daily Traffic (AADT) along State Route 1 in the study area

2.3.4 Parks, Recreation, and Coastal Access

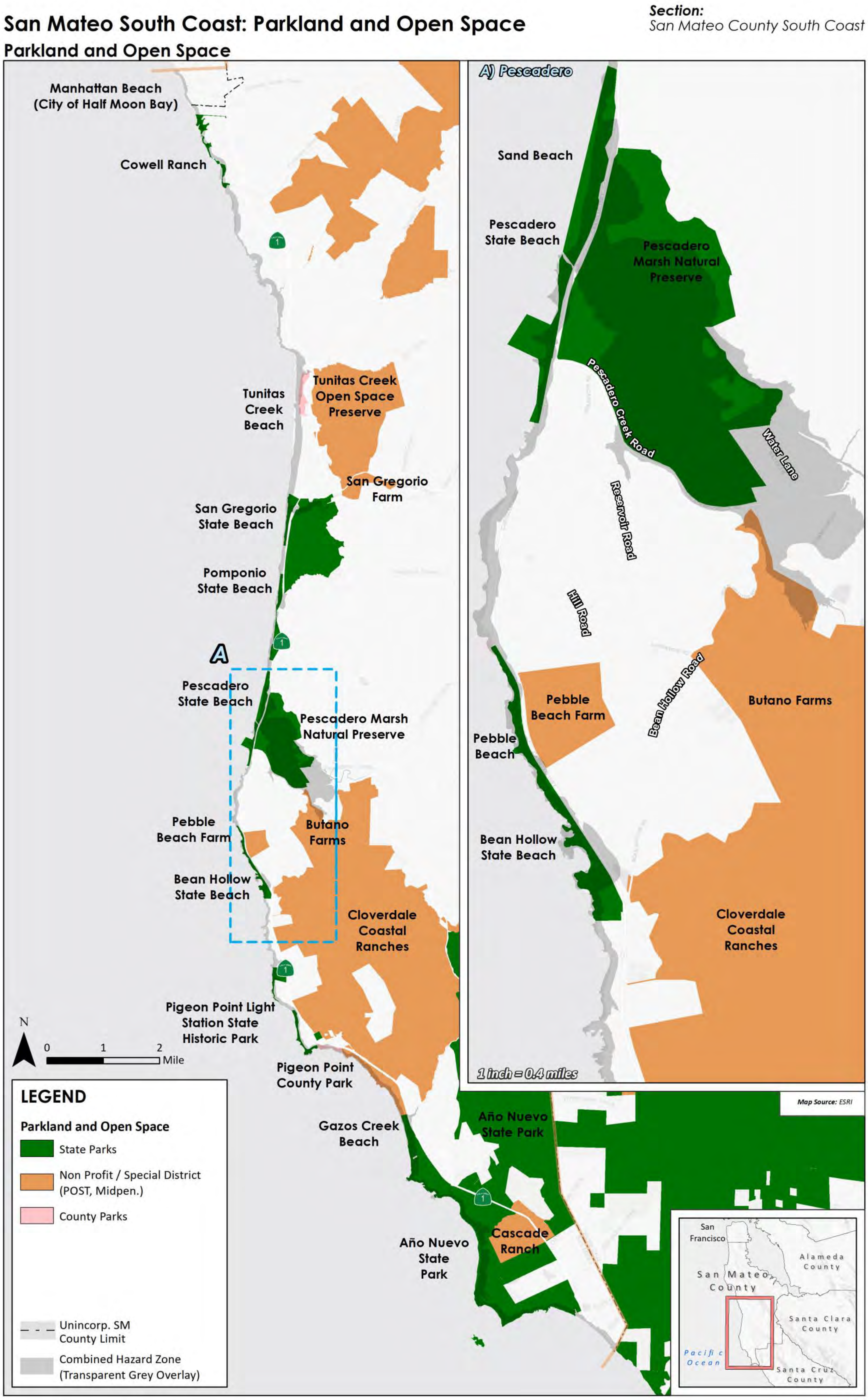
This sector comprises a unique mix of assets that include natural, cultural, and recreational resources, as well as public coastal access opportunities. There are 18 individual park and open space entities in the study area that have been aggregated into 10 distinct park and open space areas for clarity (see Map 7). Most of these areas are owned and managed by California State Parks, with about 10% of the area is owned or managed by POST, California State Coastal Conservancy, San Mateo County Parks, and the City of Half Moon Bay Parks and Recreation Department. The small number of private properties with public beach access in the study area were not analyzed as part of this sector.

All the State Park beaches have parking access (see Transportation and Parking sector), and most also have restrooms and picnic areas. It is estimated that parks within the study area attract more than 1.2 million visitor days per year, and of the park areas, Pigeon Point Light Station (including adjacent park areas at Bolsa Point and Cloverdale Coastal Ranches) and Pescadero State Beach, attract the most beach visits, each with estimated yearly visits of 250,000 or more.

There are several very large park areas with land in coastal South San Mateo County, including Año Nuevo State Park at ~6.5 square miles (the second largest state park in the county), and Pescadero State Beach and Pescadero Marsh Nature Preserve, with a combined size of just over 1 square mile.

Coastal recreation in the county includes activities on the beach, hiking, jogging, picnicking, biking, surfing, kayaking, wildlife viewing, tide pooling, and surf fishing. Environmental education also accounts for a significant number of visitors, with school trips and summer programs often making destinations of the popular state parks of Año Nuevo and Pigeon Point Light Station.

There are no publicly accessible recreation surveys for every park in the study area. However, the County of San Mateo has conducted similar surveys in county parks and found that the most popular reason for visiting a park is to walk or hike (~47%), and for beachgoers, relaxing on the beach was most popular, followed by tide pooling (San Mateo County Parks Department 2016). This roughly corresponds with the survey for the Pigeon Point Light Station Historic Park Plan, which found ~42% arriving for trails, ~40% for the beach, and the remaining arriving for picnicking and environmental education (California State Parks 2017).



Map 7. Parkland and open space in the San Mateo South Coast study area
Source: California Protected Areas Database

2.3.5 Significant Facilities

Several significant facilities serve multiple different uses important to South San Mateo County and the surrounding local coastal communities. These facilities are identified as significant because they either provide essential public services, have significant asset value, or both. These significant facilities range from cultural and historical landmarks such as the postcard-worthy Pigeon Point Lighthouse to a tourism-serving hotel like the Ritz-Carlton in Half Moon Bay, generating significant revenues and transient occupancy taxes. In addition, development critical to public safety such as County Fire Station #59 in Pescadero and the County Pescadero Corporation Yard, and the locally significant fueling station, the Gazos Creek Alliance Gasoline Station are included as significant facilities. These facilities are located throughout the study area and will all be impacted by coastal hazards differently. For these reasons, vulnerabilities and facility descriptions are described individually and in greater detail throughout the significant facility vulnerability section and sector profile.

2.3.6 Data Gaps

The study does not include two important sectors—**water supply** and **wastewater/septic**—because of a lack of available location data, though future studies might convert historical permit data to address this data gap. The study team recommends that additional work converting historical permits and other data to geographic information system (GIS) data sets for water supply (largely wells) and wastewater (largely septic systems) be conducted to inform future vulnerability and adaptation planning.

The study team evaluated two additional resource sectors, **habitat,** and **cultural resources**, qualitatively—with habitat for reasons of insufficient suitable geomorphic habitat evolution modeling and cultural resources for concern over the sensitivity of specific-location data becoming public and potentially exploited (e.g., archeological looting). Preliminary quantified habitat evolution analysis has been conducted for Pescadero Marsh.

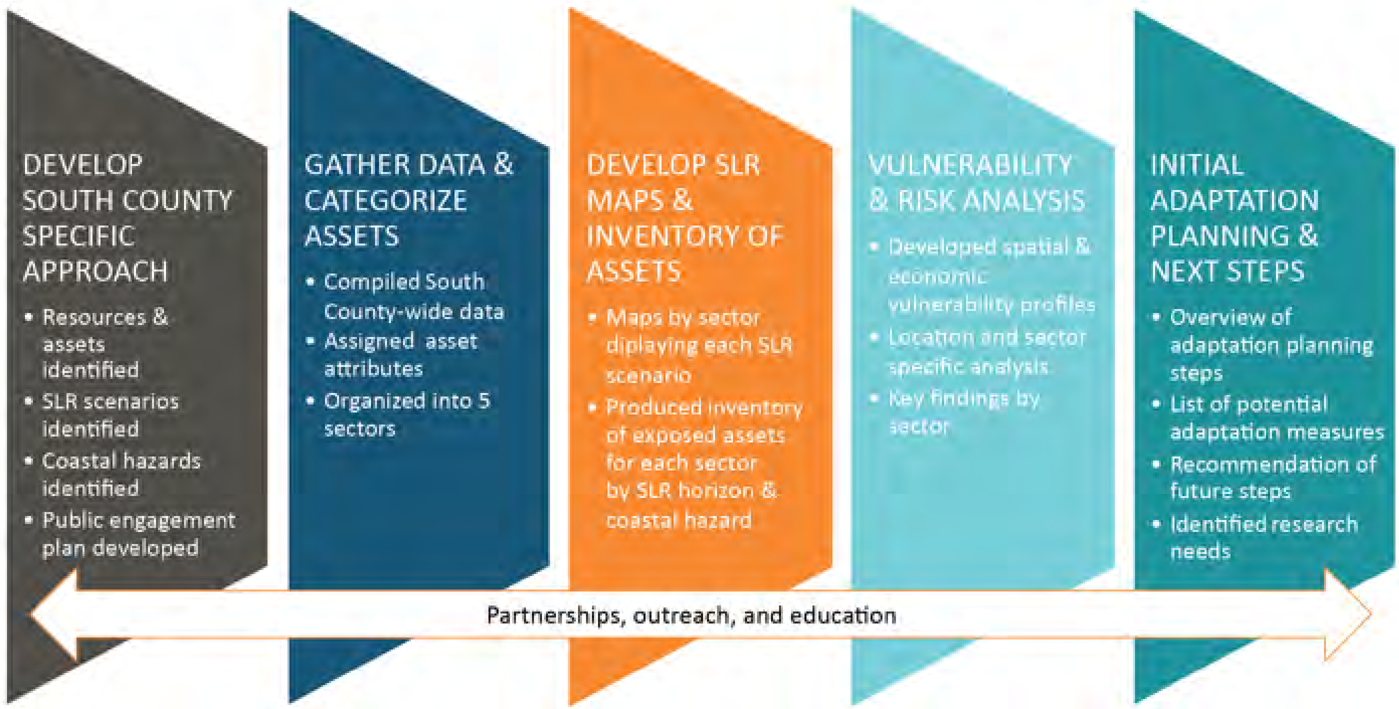
Martin's Beach
Source: San Mateo RCD

METHODOLOGY & APPROACH

SEA CHANGE
SAN MATEO COUNTY

3 METHODOLOGY AND APPROACH

This section summarizes the assessment's methodology and approaches for assessing sea level rise (SLR) and coastal hazard vulnerabilities for the South Coast. The steps of the methodology and approach are outlined below:



The methodology and approach of the assessment is set within a framework of best practices used in other sea level rise vulnerability assessments and flood risk management plans. The development of the assessment involved the identification of the best available data on coastal hazards, assets and resources, and economics. Guidance from the community and regional stakeholders was solicited to identify assets and resource availability as well as to determine where to focus attention on resources and sectors.

3.1 COMMUNITY OUTREACH AND STAKEHOLDER ENGAGEMENT

Throughout this project, the project team led a series of public and stakeholder meetings and conducted personal interviews. The study team conducted one-on-one interviews with local growers and agricultural landowners to discuss concerns from the agricultural community. These interviews were intended to expand the County's understanding of historical and future challenges to the agricultural sector, with an emphasis on how climate change impacts may affect the sector. Throughout the assessment process, the consultant team and the County also worked to increase general community awareness of the project through engagement on social media, public meetings, and a short video on sea level rise, which is published at the OOS YouTube channel. Conversations fostered by these meetings augmented the scientific research and provided on-the-ground and up-to-date status on specific plans and areas of concern laying a foundation for future study.

Timeline of Community Outreach and Stakeholder Engagement

Table 3-1. Sea level rise horizon comparison between the South Coast study and Sea Change

Hazard Type	Study							
	South Coast Study				2018 Sea Change Study			
	Term (SLR elevations in feet)							
	Baseline	Near	Mid	Long	Baseline	Near	Mid	Long
Cliff Erosion	0	0.7	1.3	4.6	-	-	-	4.6
Dune Erosion	0	0.8	1.9	4.9	-	-	-	4.6
Storm Wave Flooding	0	0.8	1.9	4.9	0	-	3.3	6.6
Estuary Flooding+	0	0.8	1.9	4.9	0	-	3.3	6.6
Tidal Flooding	0	0.8	1.9	4.9	0	-	3.3	6.6

Baseline reference years may vary between hazard types.

Storm wave flooding is based on a 1% annual chance storm event

Erosion is based on historical erosion rates accelerated with sea level rise.

+ Sea Change estuary flooding is based on USGS Coastal Storm Modeling System *(CoSMoS) modeling that is associated statistically with a 10-year coastal storm event and typically a 5- to 10-year creek flooding event. This study based estuary flooding on beach berm crest elevations for closed lagoons.*

3.2 SEA LEVEL RISE SCENARIOS AND COASTAL HAZARD MODELING

California Ocean Protection Council (OPC) guidance advises evaluating a range of near- to long-term sea level rise scenarios based on the level of risk tolerance for a particular area of interest. The 2018 OPC guidance advises evaluating up to 6.9 feet of sea level rise by 2100 as a long-term horizon. The study team instead selected 4.9 feet as the high-end scenario because it is consistent with the scenarios available within coastal erosion models. Table 3-1 identifies the scenarios chosen for this study and how they differ from the initial work presented in the 2018 Sea Level Rise Vulnerability Assessment. Apparent in this table is that the South Coast study uses one additional near-term and a lower mid-term scenario than the 2018 report. The reason for this difference is related to a County and stakeholder desire to home in on the nearer-term vulnerabilities for the South Coast to better inform near- and mid-term planning horizons.

3.2.1 Coastal Hazard Models

The study team evaluated a range of coastal hazards and sea level rise scenarios. These hazards are listed in Table 3-2. While hazards in this vulnerability assessment were analyzed individually, it is important to understand that coastal hazards are the result of many combined processes.

It is also important to acknowledge impacts that were not included in this assessment, such as potential saltwater intrusion into groundwater aquifers. Groundwater models are very sensitive to a range of geologic and morphologic conditions, and there is limited data available on subsurface geology.

Table 3-2. Coastal hazard models used in the assessment

Coastal Hazard		Description	Source	Year Developed	Year Data
Coastal Erosion	**Dune Erosion**	Inland migration of the typical dune-backed beach profile	**Integral**, developed for **this study**	2020	2018
	Cliff Erosion	Inland migration of the top of the bluff due to coastal erosion	**Philip Williams and Associates**, developed for the **Pacific Institute**[1]	2012	1998-2010
Coastal Storm Flooding		Flooding that is caused by waves overtopping and filling low-lying areas. Elevations based on FEMA BFEs	**Integral**, developed for **this study**	2020	2018
Tidal Flooding		Tidal flooding based on an expected monthly recurrence	**Integral**, developed for **this study**	2020	2018
Estuary Flooding	**Closed Lagoon Flooding**	Flood extents based on a raised beach berm crest elevation and resulting closed lagoon flooding	**Integral**, developed for **this study**	2020	2020
Combined Hazards	**All hazards listed above**	Based on the first instance of a hazard among all hazards listed above	**Integral**, developed for **this study**	2020	from all above

[1] Revell et al 2011.

3.3 SEA LEVEL RISE AND COASTAL HAZARD MODELING METHODOLOGY

The methodology for modeling sea level rise-related coastal erosion, coastal storm flooding, rising tides, estuary flooding, and combined hazards is presented in this section. Modeling of hazards relied on a high-resolution digital elevation model (DEM) collected by the County in 2017, and an additional high-resolution DEM was used for Pescadero area based on 2020 topographic and bathymetric data to account for the Butano channel restoration that was completed in 2019. All data were quality controlled by comparing potentially impacted asset locations with available high-resolution aerial imagery and topography.

3.3.1 Coastal Erosion

3.3.1.1 Dune Erosion

Dune erosion is the retreat of dunes because of wave attack during storms. The extent of dune erosion is represented as the landward migration of the “crest” of the dune field.

The study team considered three models from the Pacific Institute from 2008, and the U.S. Geology Survey’s (USGS) CoSMoS COAST from 2015 and CoSMoS Long Term Shoreline Change (a preliminary dataset from 2020). The study team decided that none of the three available models were ideal for this assessment.

The study team considered the resolution of the Pacific Institute data overly coarse and conservative for some of the locations of interest in the South Coast (e.g., Bean Hollow Beach) and unfit for this scale of analysis. It can present extreme scenarios since it assumes that the dune will erode based on the maximum total water level elevation without consideration of the duration of the storm event. The model does not consider changes in geology or landform once the dune is completely eroded, nor does it consider when dune erosion would encounter concrete such as Highway 1.

The CoSMoS COAST model suffers from linear interpolation issues related to connecting coarse resolution transects (~100m) and does not provide spatially explicit results along an irregular coast. As a result, the results do not have adequate resolution to match the shoreline.

The CoSMoS Long Term Shoreline Change model (preliminary dataset) has much-improved transect spacing from the previous CoSMoS COAST model (~20 m vs ~100 m), however, it has numerous issues related to poor bluff-top and dune-crest feature delineation. Features are located either too far upslope or downslope from the known dune crest, and false detections occurred along the offshore rock, coastal promontories, and small drainage areas. The study team found dramatic swings in erosion extents (<100 m between horizons), especially in dune-backed beaches and drainages. Finally, no existing conditions (or baseline) for dune-crest edge features are currently available as part of this dataset.

As an alternative to the existing datasets, the study team developed their own dune erosion model using the U.S. Army Corps of Engineers (USACE) Coastal Engineering Manual (2006), Revell et al. 2011, and the revised FEMA Pacific Coast Flood Guidelines (FEMA 2018). Both the USACE and FEMA methods consider two contributions to erosion affecting a sandy shoreline: episodic storms and long-term sea level rise erosion (chronic erosion). Episodic erosion is storm-induced erosion resulting from short-duration, high-intensity events. Storms often result in significant erosion, retreat, or removal of backshore dunes and may result in greater landward propagation of waves and flooding. This method also considers chronic erosion associated with sediment supply and thus includes the following: (1) sea level rise, (2) land subsidence, (3) changes in sediment supply due to watershed modifications, coastal structures, and development, and (4) decadal adjustments in rainfall, runoff, and wave climate associated with global warming. The FEMA guidance for modeling of episodic erosion is based on well-accepted coastal engineering and science and is appropriate for use in hazards determination. Chronic erosion due to sea level rise, which is not addressed directly by FEMA, can be incorporated into a model using standard coastal engineering methods outlined in the USACE Coastal Engineering Manual (2006). The Pacific Institute method combined both methods into projecting dune erosion hazards with sea level rise (Revell et al. 2011).

Map 8 provides an overview of the locations and transects of dune erosion modeling in the study area.

More details on these methods can be found in Appendix F.

Map 8. Dune erosion transects

3.3.1.2 Cliff Erosion

Cliff erosion is the retreat of cliffs, usually because of wave attacks during storms and terrestrial-based erosion processes. The extent of cliff erosion is represented as the landward migration of the cliff-top edge. Note that coastal erosion is episodic, not constant, making it difficult to estimate the position of the cliff top for any given future year. The cliff erosion hazard area is determined for multiple reaches throughout the study area, and the furthest extent of the modeled cliff top edge includes a factor of safety derived from statistics and applied to each reach.

The study team initially considered three different models to represent cliff erosion: The Pacific Institute from 2008, CoSMoS COAST from 2015, and CoSMoS Long Term Shoreline Change, a preliminary dataset from 2020.

The CoSMoS Long Term Shoreline Change Cliffs model (preliminary dataset 2020) has much-improved transect spacing from the previous CoSMoS model (~20 m vs ~100 m), however, it has numerous issues related to poor bluff-top feature delineation. Features are located either too far upslope or downslope from the known bluff-top, and false detections occur along the offshore rock, coastal promontories, and small drainage areas. In addition, no existing hazard conditions (or baseline) are mapped for cliff-backed shoreline segments, and across future horizons, and in some locations, positive shoreline change (accretion of the bluff top) occurs. Finally, the connection of transect results along areas with an irregular-shaped coastline create some poor representation of erosion that the study team considered overly coarse.

The study team ultimately selected the Pacific Institute Coastal Erosion model (2008) for this analysis because it is spatially explicit and consistent with the models used in the related SeaChange Report (2018) for the rest of the open Pacific Ocean coastline in the county. Though conservative, it does consider the geology and geomorphology of the coast and model results provided an existing and projected future coastal erosion hazard zone. This dataset uses scenarios generated from a downscaled regional global climate model, developed as part of the Second California Climate Change Assessment (Cayan et al. 2008). It represents the most spatially explicit and best available science for this rural region of coastline. Its erosion model-related shoreline change rates for each geological unit applied changes in total water levels exceeding the toe elevation to predict future cliff and dune erosion hazards.

The study team for this report utilized the Pacific Institute's high sea level rise scenario (4.6 feet by 2100) associated with a 1% annual storm, which mapped a maximum erosion extent as well as a factor of safety derived from the statistics of the historic erosion rate that made this a worst-case scenario. The study team reconciled erosion model projections from cliff erosion into a single erosion layer for inclusion into the analysis and mapped coastal erosion horizons of 0.8 feet plus 1% annual chance storm, 1.6 feet plus 1% annual chance storm, and 4.9 feet plus 1% annual chance storm onto the coastal area. The last scenario illustrates significant shoreline regression (purple line on Map 3). It should be noted that these results should be considered a screening-level analysis and any structures, land uses, or infrastructure in the projected hazard zone should be evaluated carefully at a site-specific level. The Pacific Institute erosion scenarios look at the shoreline geology and assume how far it would erode over time, but they do not take any existing shoreline protection or seawalls into consideration. This means the erosion modeling may overestimate exposure because erosion rates will be significantly reduced if shoreline protective devices are maintained in place.

3.3.2 Coastal Storm Flooding

Coastal storm flooding is represented as the furthest extent of storm wave flooding during a 1% annual chance storm wave event.

The study team initially considered USGS CoSMoS Wave Flooding for this analysis. Overall, the CoSMoS storm wave flooding model is effective at replicating existing storm wave events along the narrow beaches along the South Coast when compared to the FEMA flood maps. However, in wider beach areas, such as Pescadero, there are numerous locations where even in a 100-year wave event with sea level rise, the beach is erroneously projected not to flood. In areas adjacent to creek mouths and bar-built estuaries, the extent of wave flooding appears to be too far inland.

After a detailed review of all available CoSMoS technical documentation of the Central Coast wave run up results, the study team determined that the wave run up also included a potential fluvial (watershed) flow event. Because the coastal confluence flood results of both the wave run up and the fluvial flow were mapped together, it was difficult to know what influence a fluvial event had on the wave flooding hazard extent.

In most low-lying areas (e.g., Pescadero), the study team determined that the coastal confluence flooding was approximately a 5 to 10-year return period fluvial event. Thus, the fluvial flooding component was significantly less than projected FEMA fluvial flood extents and thus confusing to interpret and communicate to non-technical stakeholders. Ultimately, the study team determined that the underprediction along wide sandy beaches and the inability to separate the two different physical processes (wave run up and coastal confluence) made the data inappropriate for this study's purposes.

To resolve these issues, Integral Consulting mapped the existing 1% annual chance coastal wave flood using FEMA's regulatory base flood elevations (BFEs) and elevated those based on the sea level rise horizons. Results were mapped on the 2018 high-resolution County topographic using the GGNPC 2017 LiDAR DEM as an elevation source. With this method, the team was able to parse out the areas under influence of coastal wave flooding from those experiencing fluvial influence. Table 3-1 in the previous section shows the various BFEs in the study area. To differentiate coastal wave flooding from estuary flooding, a consistent breakpoint was required. This break occurs along a gradient that varies widely in time and space, and for this reason, a simple and consistent location was used—State Route 1. Coastal storm wave flooding was clipped by the seaward location of the roadbed, which generally occurs under bridges. All flooding inland of State Route 1 was reported as estuary flooding rather than storm wave flooding (Figure 3-1).

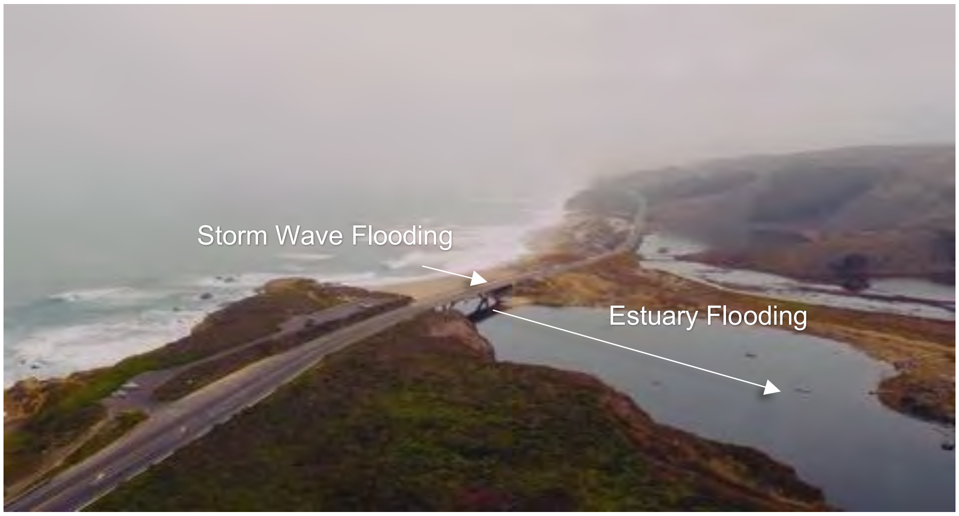


Figure 3-1. Coastal storm wave and estuary flooding extents

Note, for modeling purposes storm wave flooding extents were clipped at State Route 1. There is a complex interaction between these two processes.

Source: Swan Dive Media, 2021

3.3.3 Rising Tides

A rising tide is represented as the furthest extent of tidal flooding with sea level rise. The extent of tidal flooding is represented by the mean high water (MHW) level based on the tidal statistics from water levels at the Pillar Point Harbor Tide Gauge (MHW= 4.99 ft NAVD88). Mean high water is the average of the high tides each tidal day over a set period. These hazard zones show the projected maximum extent of what could be tidally inundated daily under a given sea level rise scenario.

The study team projected the effects that sea level rise will have on tidal flooding by analyzing maximum tidal extents across the County of San Mateo and GGNPC 2017 LiDAR DEM, adding each sea level rise elevation to the base MHW elevation. Results were comparable to the CoSMoS model average conditions (daily/background conditions with spring tide); however, they were mapped at a higher resolution.

3.3.4 Closed Estuary Flooding

Estuary flooding is the temporary flooding of low-lying lands near the study area estuaries as a result of the barrier beach seasonally closing the lagoon while watershed inputs and wave overtopping raise the lagoon water levels.

The estuaries along the South Coast are bar-built estuaries, unique to the broader Central California Coast. These bar-built estuaries change seasonally; in the calm summer months, a sand bar forms in front of the estuary, closing it off; in winter months, the estuary is reopened by rainfall events. The seasonal closure leads to closed lagoon flooding that can reach the elevation of the barrier beach as the estuary fills like a bathtub based on watershed inputs and wave overtopping.

During the winter, watershed flows breach the barrier beach berm and restore tidal action to the estuary. During high rainfall and runoff events, fluvial flooding can be compounded by high estuary water levels (from high tides or sea level rise), which has the potential to expand the spatial extent and depths of fluvial flooding in these estuaries. There are many documented storms in the town of Pescadero that have caused flooding in the low-lying portions.

The study team considered the CoSMoS Groundwater model (2020) for the assessment, but upon review of the draft results, draft technical methods report, and discussions with the USGS modeling team, it was determined that the groundwater model did not consider the seasonal changes in the bar-built estuary conditions and thus was inapplicable for this assessment.

As a result, Integral Consulting developed a geomorphic approach to estimating this flooding based on the closed sand bar berm crest elevations. This approach assumed that wave overtopping and watershed discharge would be sufficient to fill these estuaries. As sea levels rise, it is assumed that there would be enough sediment in the littoral (beach) system to raise beach berm crest elevations as sea levels rise, and closed lagoon flooding extents would expand.

For purposes of this report, the study team focused primarily on the changes in potential closed lagoon flooding. To understand the potential extents of existing and future flooding from this closed barrier beach estuary flooding, the team made three key assumptions. The first assumption was that the elevation of the barrier beach is physically determined by sand grain size, sediment supply, and wave exposure, all of which change annually and interannually. Upon review of available topographic data, the study team assumed that for existing conditions, the elevation of the barrier beach for the bar-built estuaries at Gazos Creek and San Gregorio Creek was 14 feet NAVD88. For the mouth of Pescadero Marsh, which has slightly higher wave energy and an adjacent headland that traps sand, the team assumed a maximum existing beach berm elevation of 16 feet NAVD88 for existing conditions.

Table 3-3. Estuary/creek system berm crest elevation assumptions

Estuary / Creek System	Beach Berm Crest Elevation Assumed (Feet NAVD88)
Gazos Creek	14
Pescadero Creek	16
San Gregorio Creek	14

The second assumption was that sediment supply would be maintained and allow for the berm crest to rise as sea levels rise. This meant that the sea level rise elevation change was added to the existing berm crest elevations.

The third and final assumption relates to this closed lagoon flooding and that there would be enough fluvial flows and wave overtopping to fill the estuary to the berm crest elevation. In many of the smaller, more topographically constrained estuaries like San Gregorio, this assumption is likely valid during typical years. However, in the larger Pescadero and Butano Marsh systems the volume of water from the watershed and wave overtopping necessary to fill the entire system would have a low likelihood of occurrence. Without substantially more technical work and monitoring data, the team proceeded with this assumption as it still represents a valid, albeit rare, potential extent of the closed estuary flood hazard.

3.3.5 Combined Hazards

For this assessment, combined hazards represent the furthest spatial extents of all existing and future coastal hazards considered in this assessment. Map 3 in the previous section shows the extent of combined hazards by 4.9 feet of sea level rise. For ease of communication in the vulnerability assessment, the projected future extents of each hazard are combined for mapping and illustration purposes. Specific impacts are unlikely to reach the full extents of all hazards at the same time. However, results do show the assets and resources at risk from combined hazards at sea level rise elevation.

Disclaimer

This analysis is not intended to be used for site-specific decisions but rather to identify areas at risk of exposure that may require more detailed analyses. These results should be considered a screening-level analysis and any structures, land uses, or infrastructure in the projected hazard zone should be evaluated carefully at a site-specific level. Please see full disclaimer on page *xxi* for more information.

3.4 ASSET AND RESOURCE DATA COLLECTION

The assets data included a broad array of built assets, land use categories, and natural resources. The study team first collected and considered available data from the County and expanded its efforts to include available federal, state, and open-source public data libraries. The study team obtained the most up-to-date data directly from the source at the time of evaluation and performed quality assurance. In some cases, the study team merged multiple data sets into one to capture the most detailed and up-to-date conditions.

With input from the San Mateo County Office of Sustainability, the study team identified the following sectors and measures of impact for analysis (Table 3-4. Data sets and sources used in the assessment

Sector	Categories	Metric	Source	Year (data)	Notes
Land Use and Structures		Number of parcels, area of parcels, $ value	San Mateo County	2019	

Sector	Categories	Metric	Source	Year (data)	Notes
	Parcels: Residential, Agriculture, Commercial, County, Open Space	(based on assessed value)			
	Structures: Residential (single family, single family on community land, farmsteads), Commercial, County, State Parks	Number of structures, areas of structures	San Mateo County, Bing	2017/2019	Spatial locations updated manually. Outbuildings coded manually
Agriculture	Developed, Grazing and Open, Local Importance, Prime, Statewide Importance, Unique	Area by type	California Department of Conservation - FMMP Database	2021	
	Williamson Act	Area	California Department of Conservation - Williamson Act	2019	
	Agricultural Land	$ Value	San Mateo County Assessors	2019	
	Planted fields by crop type and season	Area by crop types	San Mateo County Agriculture / Weights and Measures	2021	
Transportation and Parking	Roads: Residential Driveway, Secondary Road, Service Road, Track (off-road), State Route 1	Length by type	Open Street Map, San Mateo County	2019	

Sector	Categories	Metric	Source	Year (data)	Notes
	State Route 1	Area of road, cohesive sections of affected road, length along ocean facing edge, area of right-of-way	Open Street Map, Caltrans	2019	Area of State Route 1 created manually
	Bridges	Number of bridges, length of bridges	Open Street Map, Caltrans	2019	
	Culverts	Number of culverts, length of culvert	Caltrans	2019	
	Parking Lots	Number of lots, area of lots, number of spaces	Open Street Map	2019	Spatial locations and attributes updated manually
Parks, Recreation, and Coastal Access	Open Space	Area by park	State of California and GreenInfo Network	2021	Includes State, County, and POST owned lands. Some adjacent park areas have been combined for reporting
	Trails	Length of trail by type and park	Open Street Map, San Mateo County	2019	Spatial locations and attributes updated manually
	Coastal Access	Number of locations, length access trail	CCC, Open Street Map	2018	Spatial locations and attributes updated manually

Sector	Categories	Metric	Source	Year (data)	Notes
Coastal Armoring	Gabions, Riprap, Seawalls	Number of features by type, condition, and ownership, length by type, condition, and ownership	CCC	2018	Spatial locations and attributes updated manually
Habitat	Entire Study Area: General Habitat Types	Area by type	TNC	2018	Developed with input from CalVeg
	Pescadero Area: water, mud, low marsh, mid marsh, high marsh, episodically flooded, uplands	Area by type	Integral	2021	Areas developed with input from CCWG and State Parks
Hazardous Materials	Underground and aboveground storage tanks	Number of sites by type	Geotracker, input from San Mateo County	2021	
Social	Demographic Categories	Estimated number of people, % of socially vulnerable populations	US Census Bureau, American Community Survey	2020	
Cultural		Reported qualitatively	Association of Ramaytush Ohlone, State Parks	N/A	Not reported quantitatively due to the sensitive nature of locations

Table 3-4. Data sets and sources used in the assessment

Sector	Categories	Metric	Source	Year (data)	Notes
Land Use and Structures	Parcels: Residential, Agriculture, Commercial, County, Open Space	Number of parcels, area of parcels, $ value (based on assessed value)	San Mateo County	2019	
	Structures: Residential (single family, single family on community land, farmsteads), Commercial, County, State Parks	Number of structures, areas of structures	San Mateo County, Bing	2017/2019	Spatial locations updated manually. Outbuildings coded manually
Agriculture	Developed, Grazing and Open, Local Importance, Prime, Statewide Importance, Unique	Area by type	California Department of Conservation - FMMP Database	2021	
	Williamson Act	Area	California Department of Conservation - Williamson Act	2019	
	Agricultural Land	$ Value	San Mateo County Assessors	2019	
	Planted fields by crop type and season	Area by crop types	San Mateo County Agriculture / Weights and Measures	2021	

Sector	Categories	Metric	Source	Year (data)	Notes
Transportation and Parking	Roads: Residential Driveway, Secondary Road, Service Road, Track (off-road), State Route 1	Length by type	Open Street Map, San Mateo County	2019	
	State Route 1	Area of road, cohesive sections of affected road, length along ocean facing edge, area of right-of-way	Open Street Map, Caltrans	2019	Area of State Route 1 created manually
	Bridges	Number of bridges, length of bridges	Open Street Map, Caltrans	2019	
	Culverts	Number of culverts, length of culvert	Caltrans	2019	
	Parking Lots	Number of lots, area of lots, number of spaces	Open Street Map	2019	Spatial locations and attributes updated manually
Parks, Recreation, and Coastal Access	Open Space	Area by park	State of California and GreenInfo Network	2021	Includes State, County, and POST owned lands. Some adjacent park areas have been combined for reporting
	Trails	Length of trail by type and park	Open Street Map, San Mateo County	2019	Spatial locations and attributes updated manually

Sector	Categories	Metric	Source	Year (data)	Notes
	Coastal Access	Number of locations, length access trail	CCC, Open Street Map	2018	Spatial locations and attributes updated manually
Coastal Armoring	Gabions, Riprap, Seawalls	Number of features by type, condition, and ownership, length by type, condition, and ownership	CCC	2018	Spatial locations and attributes updated manually
Habitat	Entire Study Area: General Habitat Types	Area by type	TNC	2018	Developed with input from CalVeg
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Hazardous Materials	Underground and aboveground storage tanks	Number of sites by type	Geotracker, input from San Mateo County	2021	
Social	Demographic Categories	Estimated number of people, % of socially vulnerable populations	US Census Bureau, American Community Survey	2020	
Cultural		Reported qualitatively	Association of Ramaytush Ohlone, State Parks	N/A	Not reported quantitatively due to the sensitive nature of locations

3.5 VULNERABILITY ASSESSMENT METHODOLOGY

The vulnerability assessment analyzes the spatial intersection, or overlay, of the hazard data with the asset data sets, and discusses sensitivities as applicable. The study team overlaid all land, structures, and infrastructure data sets with the sea level rise and coastal hazard zones to quantitatively assess both the count of assets affected, as well as to assess potential economic impacts. For each resource sector and measure of impact, individual data sets had reporting criteria including number, length, area, and groups affected. Data sets were queried, and appropriate summary statistics indicating groupings of features affected were calculated by sea level rise elevation and coastal hazard type. Results were collated into tables and were interpreted into the sector profiles and results (see Appendix E for a master spreadsheet of all features, groupings, hazards, and sea level horizons reported in the study). As with all regional-scale analyses, there are various assumptions and limitations to the application of the results. Due to the nature of data available and to respect the privacy of individual residents and landowners, this study did not analyze private property in depth.

3.5.1 Land Use and Structures Sector Methodology

Land use and structure exposure to coastal hazards and sea level rise was assessed based on the spatial intersection, or overlay, of the hazard data with the parcels and structure data sets. Land-use type and areas for the study area are based on the County assessor parcels data and were accessed in 2019. Land use types are based on an aggregation of the County assessor property use codes, with categories grouped into agriculture, commercial and hotel, county and fire station, parks and open space, and residential. The study team verified data for spatial location of structures with the Microsoft Bing structures data set. The property use categories for structures are related to parcel land uses but with some manual attribute coding to provide detail for the study. Structures were categorized as county and fire station, commercial and hotel, farmsteads, parks and open space, single-family residential, and residential on community land. The study team distinguished between primary and accessory structures by comparing the size and placement of the structures on the site, as well as consulting other sources such as Google Street View. All non-primary structures (also known as accessory structures) such as garages, barns, and other outbuildings were coded as non-primary structures and are generally filtered in the report findings. Land outside of parcel boundaries, including the open coast beaches, creeks, and road areas, are coded as rights-of-way. To provide clarification on the grouping of property codes and the relationships to structures, each table in the report includes a descriptive subtext.

3.5.2 Economics

Potential economic damage or losses were determined based on the County's 2019 tax-assessed value (hereinafter assessed land value, or ALV) and tax-assessed improvements/building value (hereinafter assessed building value, or ABV), as well how the hazard may damage these land and structures. The sections below describe the way values as well as potential damages and losses have been derived, as well as how the study addressed special situations when no taxable values are available.

3.5.2.1 Evaluation of Economic Losses

The study team estimated potential economic damages using distinct methodologies according to hazard type. The economic analysis of erosion damages takes monetary values from the assessor's land and buildings data sets and multiplies them by the percentage of land area that intersects the erosion hazards zone. The economic analysis assumes that there is a linear relationship between the amount of land degraded by erosion and the loss in the asset's value. Where properties comprise more than one parcel, the value of each parcel has been determined spatially, as a proportion of the total property area, and then the damage calculation is performed on the individual parcels. For buildings, the asset value is assumed lost when the land it occupies is eroded. One other limitation in estimating the value of oceanfront property is that shoreline parcel boundaries may vary significantly along the coastal edge, with some parcel's boundaries ending at the top of the bluff, others extending to the beach, and where offshore rock may exist, extending out to sea. As a result, the modeled damage for the present day (at 0 feet of sea level rise) is not zero for all properties.

Flood damage to structures was estimated by applying USACE depth damage curves, which estimate damages as a percent of the total value of the structure and contents. The assumption is that flooding occurs once per sea level rise scenario, or approximately once every 25 years. Flooding of this frequency and magnitude could be viewed as a worst-case scenario. Flood damage due to lagoon or ocean flooding can only occur if the land has not already been eroded, either under a given sea level rise scenario or at an earlier sea level rise horizon. In some places (e.g., Martin's Beach), wave flood damage occurs at present (with 0 feet of sea level rise), but these properties are subject to erosion at the 0.8-foot sea level rise horizon. As a result, flood damage is not included in damage estimates for these buildings for the 0.8-, 1.6-, or 4.9-foot sea level rise horizons.

3.5.2.2 Valuation of Land without Taxable Value

For land areas without an ALV, such as parks and beach reserves, a spatial valuation was derived by multiplying the spatial area in acres by a value of $40,000 per acre. This figure is the median value per acre of parcels for recent sales of land within San Mateo County to State Parks or the POST. The true value of a parcel of open space or parkland may vary based on a range of factors including the dominant vegetation type, location, elevation, biodiversity, and connectivity of land parcels.

3.5.2.3 Valuation of Buildings without Taxable Value

For buildings without an ABV, values were imputed from other sources as described below:

- All outbuildings, such as barns and detached garages, were allocated a value of $10,000 per structure. This is a conservative replacement cost for a freestanding outbuilding such as a garage or shed.
- Restrooms associated with parks and open space areas were allocated a value of $20,000 per structure. This is the assumed median value of a vault toilet structure for the purposes of this analysis but will vary by structure. This figure relies on published reports and direct conversations with California State Parks, as well as similar cost estimates published by the U.S. Forest Service (USFS 2022).

- Significant buildings such as the Pigeon Point Light Station and the CAL FIRE buildings were valued with reference to external sources or via consultation with stakeholders.
- Government buildings that could not be valued based on secondary sources were allocated a value of $100,000 per primary structure. This is a representative value for government buildings in the study area.
- Leased buildings at Martin's Beach and Tunitas Creek Beach, which are part of larger properties and do not have individual valuations, were allocated a value of $200,000 per primary structure. This figure was based on the approximate annual lease value for a cabin at Martin's Beach applied over a 30-year mortgage timeframe.

3.5.2.4 Treatment of Property Tax Exemptions

Property tax assessed values may be subject to a range of exemptions. Some exemptions have a fixed monetary value, such as the California Homeowners' Exemption, which is valued at $7,000 per property. Other exemptions, based on land use and ownership, are equal to the tax assessed value and have the effect of reducing the taxable value of a property to zero, as is the case for some POST properties.

Exemptions have the effect of lowering the tax-assessed values for both land and built assets. Conceptually, part of the value of this exemption is attributable to the land component of the property and part is attributable to the buildings or improvements on that property. The proportion attributable to each component is a factor of how highly developed the property is, and the size of the land parcel.

3.5.2.5 Treatment of Fixed Value Property Tax Exemptions

The approach taken in this report is to add the value of fixed monetary exemptions to the property value to derive a net value, and then to calculate the relative contribution of land and buildings to the net value. The net taxable value of a property is given by the following formula:

$$Net\ value = ALV + ABV + Value\ of\ exemptions$$

The contribution of land value to the value of exemptions, termed the land value ratio (LVR), is given by the formula below:

$$LVR = \frac{ALV}{Net\ value} * Exemptions$$

The same procedure applies to the calculation of the building value of exemptions (BVR), for estimation of the proportion of the exemption value that is attributable to buildings.

3.5.2.6 Treatment of Exemptions That Greatly Reduce Taxable Property Value

For parcels with no built infrastructure (apart from fences), an exemption that reduces the total taxable value to zero is equal to the value of the land, or ALV. For these parcels, the ALV was applied to the value of the land parcel. For properties where the tax exemption is equal to the sum of the ALV and ABV, the ABV was used as the value of built structures, with adjustments where multiple structures were found on the same property. These adjustments are described in the next section.

3.5.2.7 Valuation of Properties with Multiple Parcels or Buildings

Some landholdings extend over multiple properties, which are in turn made up of multiple land parcels. It is necessary to split these values to assign the economic costs of coastal hazard damage to individual land parcels or structures. This section describes how properties were split between parcels and properties on the same valuation.

3.5.2.8 Valuation of Land Parcels for Properties with Multiple Parcels

In cases where a property consists of multiple parcels of land, the total ALV has been split across the multiple parcels based on the spatial area of those parcels.

3.5.2.9 Valuation of Buildings for Properties with Multiple Structures

For buildings, the process of allocation of property-level ABV to individual structures is more complex. First, the value of outbuildings is subtracted from the ABV for the property. The ABV is then split between the remaining structures:

$$Building\ value\ (non-outbuilding) = \frac{ABV - \$10\ 000 * number\ of\ outbuildings}{(number\ of\ primary\ buildings)}$$

3.5.2.10 Caveats and Limitations of Economic Valuation

This study used the best spatially available economic and coastal modeling data to estimate the value of land and built features within the study area, and the extent to which these could be impacted by a range of coastal hazards under a set of future sea level rise scenarios. The economic values presented in this report represent estimates that are useful for future planning and adaptation purposes but may not accurately reflect all coastal hazard impacts at the property level.

Omission of the Ritz Carlton Hotel from Economic Analyses

Due to its significant economic scale relative to the rest of the South Coast, the Ritz-Carlton Hotel has been omitted from the economic reporting. To provide perspective, the hotel is 12 times more valuable than the next most valuable property in the study area and is worth as much as all other assessed properties in the study area combined (not including government land). As a result, hotel impacts can outweigh, and therefore overshadow, the potential economic damages and losses to the other land areas and structures in the study area.

Exclusion of Flood Damages to the Land

Estimated damages due to erosion account for approximately 94% of economic damage in this study. This is due in part to limitations in available data for valuation of damages to land, which means that it was not possible to estimate flood damages to affected land. It is relatively easy to estimate the loss of land or buildings due to erosion, as the asset is no longer present once it has been affected by erosion. It is more difficult to value the impacts of flooding on land as they depend on a range of factors including:

- Depth of flood
- Duration of flood
- Frequency of flood
- Seasonal timing of flood
- Velocity of floodwater flow
- Salinity or turbidity of the floodwaters
- Sensitivity of the receiving environment to flood

This report has therefore not attempted to quantify the damage due to periodic flooding of land. This would require site-specific information as well as detailed information about the sensitivity of the existing land to the flooding. For example, prime agricultural land may be rendered unusable by relatively infrequent flood events if that flooding occurs during germination or harvest season. Conversely, land that has been paved for parking or driveway areas may not be greatly affected by short-term flooding. Estimation of full land damage costs was not possible in the current study.

Likely Underestimation of Fair Market Values

For several reasons, the land and building values included in this report are likely to underestimate the full market value of properties vulnerable to coastal hazards within the study area. A key factor is that the values used in the analysis were tax-assessed values, rather than sales prices or fair market value figures. These figures were used at the request of the County to improve consistency with other reports and analyses, and due to the lack of suitable market values.

While tax-assessed values provide a reasonable relative measure of value, assessed value in California is often significantly lower than market value for a variety of reasons, in particular Proposition 13, which limits any increase in assessed value to 2% a year. These values are reset to market values when a property is sold. It is possible to estimate the current likely sales price of a property by using annual index tables from the San Mateo County Assessor's Office, but this process may obscure changes in the value of individual properties over time. For example, high-value coastal properties may experience large price fluctuations that are more closely aligned with corporate salaries and share price fluctuations than broader trends in real estate prices. Coastal property in the study area is tightly held, with few property transactions each year. Some properties have not been sold since the 1980s, so any attempt to escalate past sales figures to a present-day value is subject to substantial variation.

3.5.3 Agriculture Sector Methodology

This analysis considers agricultural susceptibility to coastal hazards in terms of the spatial area of agricultural land exposed to these hazards and estimates potential economic losses using tax-assessed property values (after adjusting for tax exemptions). Future potential climate change-related impacts to water resources, such as predicted increased variability in precipitation patterns, as well as effects from extreme heat and other climate variables are not described here. Other factors such as access to labor, distribution, and potential changes in market forces are also not described here.

The study team relied primarily on the California Natural Resources Agency FMMP data set of 2018 for identifying agricultural land projected to be impacted by coastal hazards. This data set is the most current inventory of agricultural resources in the state and classifies agricultural land uses based on soil quality and irrigation status, with the highest quality land identified as "prime farmland." For the study area, prime farmland encompasses most of the lands in production of Brussels sprouts, artichokes, leeks, pumpkins, and herbs, and has a U.S. Department of Agriculture Storie Index rating of 80–100.

Economics

This assessment collected information about the production value and net profitability of agricultural land in the study area, but these data were only available for the entire county as a whole and were not available at a sufficient level of spatial detail to estimate the productive losses for individual land parcels. Values of agricultural land were based on the San Mateo Assessors data set, accessed in 2019. Land values for agricultural properties reflect their potential future productive value, so productive losses are already incorporated into projected loss estimates provided in this summary.

Caveats and Limitations of Economic Valuation

Valuation of changes in the productive value of agricultural land, such as the conversion of high-value cropping land to lower-value crops or to grazing land or unproductive open space were also not included in the current study. This is an area of potential future work, although discussions with agricultural stakeholders suggest that the availability of water for irrigation is the greatest factor in the productivity of land within the region.

3.5.4 Roads and Parking Sector Methodology

Roads and parking susceptibility to coastal hazards and sea level rise was assessed based on spatial intersection, or overlay, of the hazard data with the road centerline and parking lot area data sets. To provide more accurate results for State Route 1, the study team analyzed both the entire road area, centerline, and the distance along the ocean-facing edge of the road for reporting distances of road affected. Open Street Map (OSM) provided the primary data set used for obtaining the spatial locations and attribute classifications of the transportation network. This data set was verified using transportation data from the County of San Mateo. Parking lots were also provided by OSM with manual verification of spatial locations. The spatial location of the rights-of-way areas and culvert locations was provided by Caltrans.

Economics

For roads, a per-foot measure of value is applied where the erosion hazard intersects the feature. Unit prices per linear foot used in the valuation are as follows and are based on conversations with Caltrans District 5 in 2018 and Caltrans District 4 in 2021.

- Non-highway roads: $280 per foot
- State Route 1: $500 per foot.

Parking lot relocation has been calculated by multiplying the square feet of parking area affected by all hazards with a replacement cost, assumed to be $5 per square foot.

Both parking and road repaving assumes that there is adequate space within the right-of-way or in nearby areas for placement of the feature. The use of replacement value does not consider other factors such as the connectivity of remaining road segments, negotiation of easements, land acquisition costs, engineering design costs, or environmental reviews. Some of these processes may take many years to complete depending on the complexity and may conclude that replacement of individual sections like-for-like is not feasible or desirable.

Revetment placement was calculated as the linear feet of affected State Route 1 sections by $2,577 per foot (Caltrans 2008).

This report does not attempt to value the following items, which were either outside the scope of the present study or could not be attempted due to data limitations:

- Travel time costs due to road closures and diversions
- Economic costs associated with the closure of State Route 1 such as travel time costs and business
- Losses in potential State Parks parking revenue due to disruptions in service
- Health and emergency implications of the closure of State Route 1 or restricted access to emergency facilities through flooding at Pescadero.

3.5.5 Parks, Recreation, and Coastal Access Methodology

Parks, recreation, and coastal access susceptibility to coastal hazards and sea level rise was assessed based on the spatial intersection, or overlay, of the hazard data with parkland and trail centerlines. The data set for parkland and open space was sourced from California Protected Areas Database and depicts lands that are owned in fee and protected for open space purposes by public agencies and nonprofit organizations. Trail data was compiled from numerous sources including the County of San Mateo, OSM, and CCC.

Park visitation numbers were sourced from State Park planning reports, direct interviews with State Parks and City of Half Moon Bay staff, State Park-provided 2015–2019 park visitor attendance surveys, and the San Mateo County Parks Visitor study report, which details information on recreational use characteristics for county residents.

Economics

The validation of economic assumptions in the analysis of park and open space resources relies on published reports and direct conversations with California State Parks. Replacement cost of trail loss due to erosion is assumed to be $4 per linear foot. Individual park bathrooms were estimated at $20,000 per bathroom. The value of an acre of parkland is valued at $40,000 and was based on historical per acre sales prices for parcels incorporated into parkland in Southern San Mateo County.

This report does not attempt to value the following items, which are either difficult or inappropriate to quantify monetarily, or lacking data, or both:

- The value of cultural resources[2]
- Impacts on recreation due to changes in natural coastal resources.

The study does provide an estimate of recreational value associated with visitation to state parks, and use of trails within the region, but does not attempt to estimate the extent to which these values would be impacted by coastal hazards. The response to erosion or flooding of coastal recreation areas would be complex and be dictated by factors such as the availability of substitute sites for beach recreation or tide pooling, and whether natural features can naturally move landward or are constrained by hard infrastructure such as State Route 1.

3.5.6 Significant Facilities Methodology

The significant facilities methodology mirrors the land use and structures methodology and analyzes the spatial intersection, or overlay, of the hazard data with the asset data sets. The vulnerability assessment analyzes the exposure defined as the spatial intersection, or overlay, of the projected hazard extents and the asset data sets. Exposure is only one facet of vulnerability. This study does not consider specific characteristics of each building or make any assumptions on community or stakeholder adaptation choices.

[2] This was excluded in part due to cultural sensitivities around the location of these resources, as well as the inappropriateness of attempting to quantify them monetarily.

Pescadero Creek Rd. and Water Ln.
Source: Dave Kent

VULNERABILITIES BY RESOURCE SECTOR

SEA CHANGE
SAN MATEO COUNTY

4 VULNERABILITIES BY RESOURCE SECTOR

This section provides vulnerability assessment results and detailed descriptions of the projected risks from sea level rise and coastal hazards to the resource sectors identified in Section 2.6. These results include hazard exposures by resource sector and an evaluation of the potential costs in economic damages and losses assuming no action is taken to prevent or minimize the effects of sea level rise and coastal hazards.

Based on the unique characteristics of the South San Mateo County coastline, the sectors analyzed include:

- **Land Use and Structures**—describes the overall composition and characteristics of the vulnerable coastal areas, parcels, and structures.
- **Agriculture**—includes planted fields, grazing lands and protected coastal prairie, orchards, and developed agricultural lands.
- **Roads and Parking**—includes all state, county, and local roads, as well as their rights-of-way and associated bridges and culverts. Also included are all formal public parking areas.
- **Parks, Recreation, and Coastal Access**—includes all state, county, and local parkland, as well as protected open space areas. Also includes the trails, bathrooms, structures, and other amenities associated with these areas.
- **Significant Facilities**—includes the Gazos Creek Gas Station, Pigeon Point Lighthouse, Ritz-Carlton Hotel, CAL FIRE Station, and the Pescadero Corporation Yard.

This vulnerability assessment focused only on coastal hazards associated with sea level rise. Other climatic challenges such as a potential increase in seasonal temperatures, changes in the fog regime, increase in the variability and intensity of precipitation, threats related to wildfire, saltwater intrusion, changes to surface water quantity and quality, and changes to groundwater were not analyzed here. These impacts will likely create added challenges for the South Coast of San Mateo County's agriculture sector due to compounding vulnerabilities, logistics, and economic pressures (see Section 4.2, "Agricultural Land Vulnerabilities").

4.1 LAND AND STRUCTURES VULNERABILITIES

Many coastal communities dot the South Coast. Two of these communities are particularly vulnerable to sea level rise: Martin's Beach, which sits directly on the coast, and Pescadero, a low-lying inland town that will be affected by sea level rise through coastal impacts to the two creeks that flow through it.

Vulnerability Overview

- Martin's Beach community is currently exposed to wave flooding (0 feet sea level rise with 1% annual chance storm) and is projected to be impacted by coastal erosion with 0.8 feet of sea level rise.

- Most building damage identified by the analysis is at Martin's Beach and occurs at 0.8 feet sea level rise and a 1% annual chance storm.
- Most land damage due to coastal erosion identified by the analysis is at Pescadero Point and occurs at 0.8 feet sea level rise and a 1% annual chance storm.
- Pescadero at Water Lane and Pescadero Creek Road is currently exposed to estuary flooding and vulnerabilities will increase with sea level rise.

This section details the specific vulnerabilities to land use and structures on the South Coast of San Mateo County, highlighting some of the most affected areas and identifying critical sea level rise thresholds associated with coastal hazards. This section also provides an overview of the estimated economic damages associated with coastal hazards, including cliff and dune erosion impacts to land and buildings, as well as flood damage to buildings from both coastal wave and estuary flooding.

Table 4-1 illustrates the type and number of structures that will be impacted by combined coastal hazards based on rising sea level scenarios. Most structures in the study area are projected to be affected by coastal hazards currently or in the near-term, or at 0 and 0.8 feet of sea level rise. This is due to many structures in low-lying areas near Pescadero Creek Road, as well as the number of homes and cabins built on or within proximity to the coastal bluff.

Coastal erosion and storm wave flooding represent the greatest existing threats to residential properties around Martin's Beach and Tunitas Creek, with erosion and flooding risk escalating in the future. In Pescadero, estuary flooding is already a common issue and will be exacerbated as sea levels rise. Farmsteads in Pescadero and residential properties on agricultural land are also currently susceptible to flooding.

Park bathroom facilities around Bean Hollow Beach are exposed in the near-term, with structures at Gazos Creek and Pescadero State Beach also becoming exposed to coastal hazards at around 1.6 feet of sea level rise.

The San Mateo CAL FIRE Unit at Pescadero is also currently exposed to estuary flooding, and potential flooding will be exacerbated as sea levels rise. The Half Moon Bay Golf Links course is projected to be susceptible to cliff erosion with 1.6 feet of sea level rise and 1% annual chance storm (2060), and the Ritz-Carlton Half Moon Bay Hotel is susceptible to cliff erosion with 4.9 feet of sea level rise and 1% annual chance storm (2100). The Pigeon Point Lighthouse is projected to be susceptible to cliff erosion under 1 feet of sea level rise, and many cultural artifacts and heritage sites in the Pigeon Point and Año Nuevo State Park area are already at risk from coastal hazards. These significant facilities are discussed in greater depth in Section 4.5.

Table 4-1. Number of buildings newly affected at different sea level rise horizons

Horizon	Fire Station	Commercial and Hotel	Parks	Single-Family Residential	Grand Total
Existing with 1% annual chance storm	1	2		40	**43**
0.8 feet with 1% annual chance storm	1		4	48	**53**
1.6 feet with 1% annual chance storm		1	3	9	**13**
4.9 feet with 1% annual chance storm		2		12	**14**
Grand Total	**2**	**5**	**7**	**109**	**123**

Numbers are non-cumulative across horizons

Accessory buildings (garages and outbuildings) are not included.

Single family residential buildings include multiple residential buildings on one property (Martin's Beach and Tunitas Creek Beach) as well as farmsteads (residential buildings on agricultural properties).

Parks include two buildings on park property used for a hostel.

4.1.1 Damages and Economic Impact to Land and Structures due to Coastal Wave Flooding

Coastal wave flooding is the flooding of land and buildings due to storm wave run-up and can lead to direct damages and cleanup costs. A total of 18 structures are projected to be susceptible to coastal wave flooding by 4.9 feet of sea level rise. In the existing horizon, this includes the entire front row of 15 cabins at Martin's Beach as well as a single house near Pescadero Point. At the 4.9 foot horizon, the increase is due to flooding of one restroom facility and one building near Bean Hollow State Beach. These buildings are projected to be subject to cliff and dune erosion at lower sea level rise horizons, so they do not contribute to additional wave flooding damages.

The total cleanup cost associated with these damages to buildings represents $1,022,300. Table 4-2 shows the number of primary structures exposed to coastal wave flooding hazards and the estimated economic impact to structures. Throughout much of the study area, the extent of coastal wave flooding is confined by high dunes and cliffs. As wave flooding increases in depth and velocity with sea level rise, coastal erosion is projected to accelerate. Reporting and damages associated with coastal erosion are directly included here. No direct loss in value was associated with temporary wave flooding over what is primarily beach and dune land areas.

Table 4-2. Coastal wave flooding damages by sea level rise horizon

Sea Level Rise	**Acres**	**Number of Primary Buildings** (cumulative total)	**Damages to Buildings** Noncumulative $'000s (cumulative)
0 feet (existing)	739	16	$1,006,300
0.8 feet	27 (766)	0 (16)	$5.3 (1,011,700)
1.6 feet	17 (783)	0 (16)	$5.3 (1,017,000)
4.9 feet	72 (855)	2 (18)	$5.3 (1,022,300)
Total	**855**	**18**	**$1,022,300**

4.1.2 Damages and Economic Impact to Land and Structures due to Coastal Erosion

Coastal erosion occurs along cliffs and low-lying dune-backed beaches causing the permanent retreat of cliffs and permanent loss of land and structural damages. Cliff erosion poses the greatest potential risk to land values and buildings. A total of 86 structures are projected to be vulnerable to coastal erosion by 4.9 feet of sea level rise, with the majority of these located at Martin's Beach and around Pescadero Point. The total projected cost of damages due to loss of land and structures from coastal erosion by 4.9 feet of sea level rise is $85,300,000. Table 4-3 shows the area of land and number of primary structures affected by cliff and dune erosion.

Table 4-3. Coastal erosion damages by sea level rise horizon

Sea Level Rise	**Acres** Cliff/Dune/**Total** (cumulative total)	**Number of Primary Buildings** Cliff/Dune/**Total** (cumulative total)	**Erosion Damages to Land / Buildings** Noncumulative, (Cumulative) ($M)
0 (existing)	97 / 440 / **537**	0 / 1 / **1**	$13.2/ 1.6 ($20.5/ 1.6)
0.8 feet	342 / 136 / **478** (1,015)	66 / 1 / **67** (68)	$19.8/ 23.8 ($33.0/ 25.4)
1.6 feet	144 / 26 / **170** (1,185)	10 / 1 / **11** (79)	$6.5/ 5.7 ($39.4/ 31.0)

Sea Level Rise	Acres Cliff/Dune/**Total** (cumulative total)	Number of Primary Buildings Cliff/Dune/**Total** (cumulative total)	Erosion Damages to Land / Buildings Noncumulative, (Cumulative) ($M)
4.9 feet	334 / 96 / **430** (1,615)	5 / 2 / **7** (86)	$15.4/ 5.0 ($54.8/ 36.0)
Total	917 **/** 698 **/ 1,615**	81 **/** 5 **/ 86**	**$85.3**

Currently, dune erosion poses a risk to 440 acres of land, which is mainly public open space at low-lying beach areas. Only one primary building is currently subject to dune erosion, located at Tunitas Creek Beach, and the building is tagged for demolition. Two other cabins near Tunitas Creek Beach are affected at 0.8 and 1.6 feet of sea level rise. Overall, dune erosion hazards increase in severity and landward extent with sea level rise, but the areas of greatest concern do not change. Dune erosion damage to buildings does not increase substantially over sea level rise horizons. At 4.9 feet of sea level rise, dune erosion is predicted to cross State Route 1 near Gazos Creek, and without intervention would extend to the Gazos Creek Alliance Gas Station and State Route 1 Brewing Company.

Cliff erosion poses a substantially greater economic risk to land and structures across all sea level rise horizons. The largest increase of cliff erosion damage to buildings will occur in the near term, with a sea level rise of 0–0.8 ft. This is primarily through erosion of properties at Martin's Beach, where 46 primary buildings are affected. Six properties at the northern end of Tunitas Creek Beach are also affected at the 0.8-foot sea level rise horizon. The economic damages associated with erosion damage to properties at both locations may be underestimated, as these properties do not have individual tax assessments and were assigned a nominal value of $200,000 per primary building.

Cliff erosion projections at 0.8 feet of sea level rise result in a substantial loss of land value at Martin's Beach, Tunitas Creek Beach, and in clifftop properties at Pescadero Point, near Bean Hollow State Beach, and near Yankee Jim Gulch. Between 0.8 and 1.6 feet of sea level rise, the number of buildings affected by cliff erosion does not increase greatly, but land value losses increase in a relatively linear fashion.

Between 1.6 and 4.9 feet of sea level rise, there is another large increase in projected damages to land, while most buildings within the hazard areas have already been eroded. The sea level rise increment for this scenario is greater than the previous "step," so the increase in land damage losses increases in proportion to the magnitude of sea level rise.

Figure 4-1 shows a breakdown of dune erosion damages by land use.

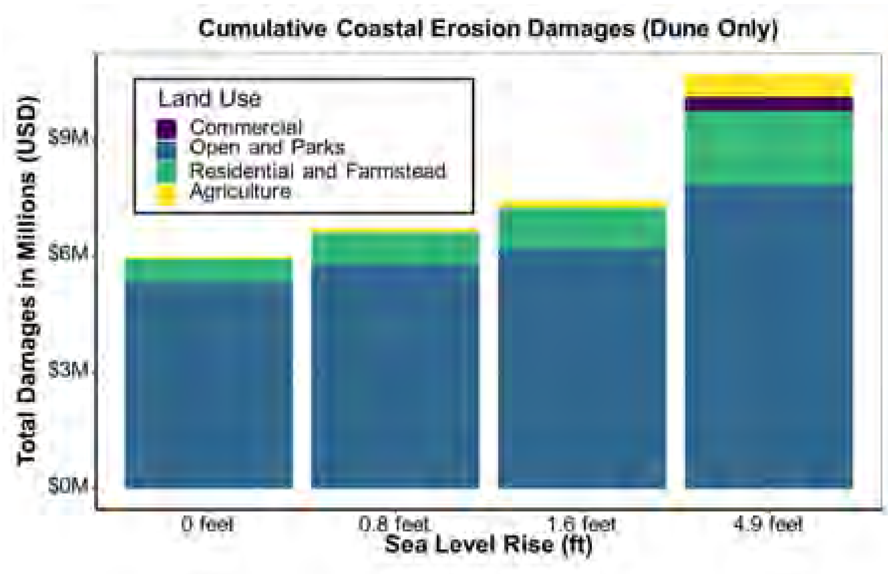


Figure 4-1. Dune erosion damages by sea level rise horizon
Reported damages are cumulative.

As shown in Figure 4-1, dune erosion mainly affects public open space, with lesser effects on low-lying agricultural and residential properties. Commercial facilities are not affected until sea level rise reaches 4.9 ft, at which point, there is also a comparatively large increase in the value of residential properties exposed to dune erosion, although the absolute magnitude of damages remains low relative to cliff erosion. The increase in dune erosion damages is relatively linear when considering land and building asset values. This does not consider lost agricultural productivity of the low-lying land, or impacts to State Route 1, which are addressed in Sections 5.2 and 5.3, respectively.

Figure 4-2 shows the breakdown of predicted damages to land and buildings due to cliff erosion, by land use category.

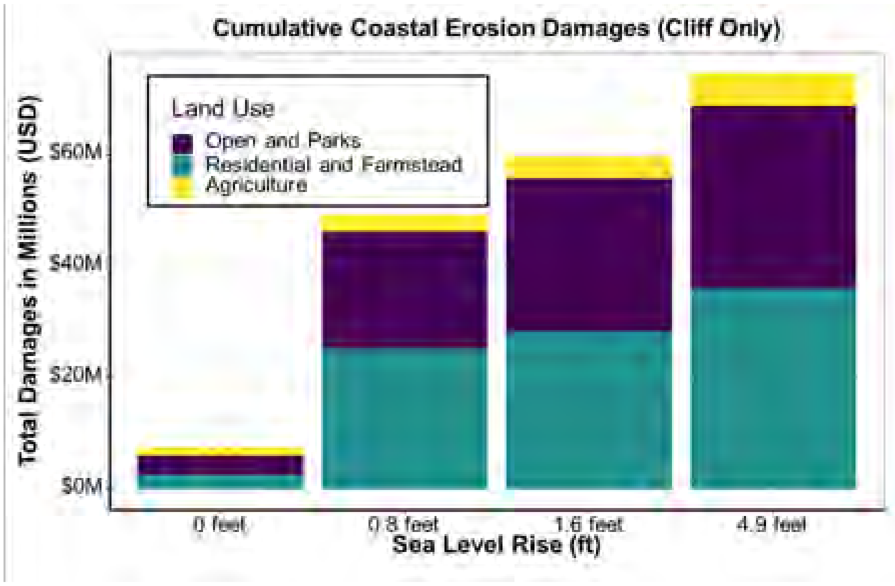


Figure 4-2. Cliff erosion damages by sea level rise horizon
Reported damages are cumulative.

Impacts due to cliff erosion are more heavily skewed towards residential land uses, reflecting the higher land, and building values for clifftop residential properties. Most of these impacts are projected to occur in the near term, with sea level rise between 0 and 0.8 feet. As previously highlighted, this large jump in economic damages may be understated, due to the relatively low nominal asset values assigned to buildings affected by erosion at Martin's Beach and Tunitas Creek Beach, where most erosion impacts are experienced at 0.8 feet of sea level rise.

At the 4.9-foot sea level rise horizon, the cost of damages due to cliff erosion are more than 7 times those due to dune erosion, and almost 75 times the estimated value of damages due to wave flooding. In part, this latter difference is because the entire building value is assumed lost once the cliff reaches the footprint of the building, whereas for wave flooding, the costs are estimated based on damage and cleanup costs.

Figure 4-3 separates the combined dune and cliff erosion impacts into land and building values.

The value of impacts to land are much higher than those associated with damage to buildings, which is due in part to the way erosion damages have been calculated, as a proportion of the tax-assessed value of land. Based on average tax-assessed values, much of the value of clifftop properties affected by erosion is attributed to the land component.

Land damages are concentrated in the near term, with 0 to 0.8 feet of sea level rise. This is in part because of projected dune erosion impacts at 0 feet of sea level rise, and partly because of the high value of clifftop properties in Martin's Beach, Tunitas Creek Beach, and at Pescadero Point. Projected impacts to the lighthouse at Pigeon Point comprise more than one-third of damages at the 0.8-foot sea level rise horizon.

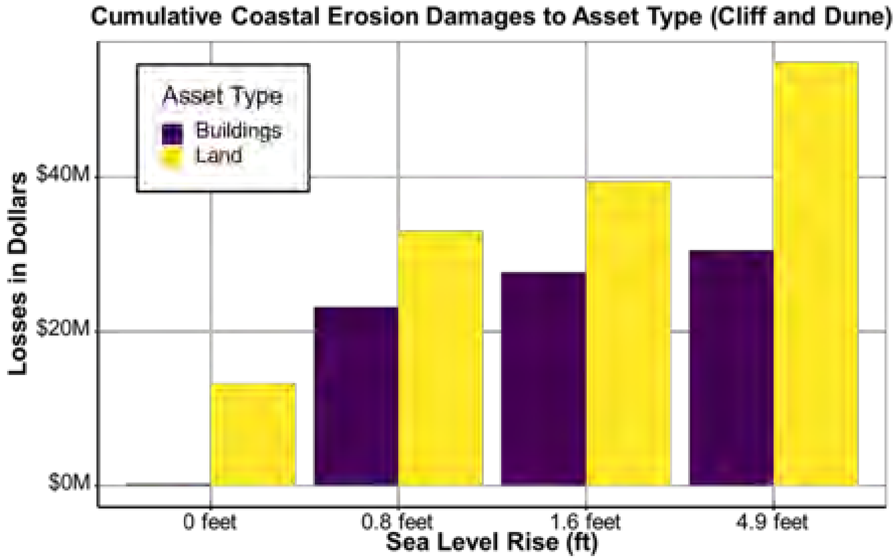


Figure 4-3. All coastal erosion damages by sea level rise horizon
Reported damages are cumulative.

4.1.3 Damages and Economic Impact to Land and Structures due to Closed Estuary Flooding

Estuary flooding is the temporary flooding of low-lying lands near the study area estuaries as a result of the barrier beach seasonally closing the lagoon while watershed inputs and wave overtopping raise the lagoon water levels. A total of 39 primary structures are projected to be vulnerable to estuary flooding by 4.9 feet of sea level rise, with the majority of these located near Pescadero Creek Road. The study team assumed four major estuary flood events (one for each sea level rise horizon), or one event approximately every 20 years. Cumulative cleanup damages to structures from these events is projected to be $4,452,400 by 2100 or 4.9 feet of sea level rise. Damages due to estuary flooding are shown in Table 4-4.

Table 4-4. Estuary flooding damages by sea level rise horizon

Sea Level Rise	**Acres** (cumulative)	**Number of Primary Buildings** (cumulative)	**Damages To Buildings ($'000s)** Noncumulative, (Cumulative)
0 (existing)	255	25	$404.8 (404.8)
0.8 feet	31 (286)	2 (27)	$830.1 (1,234.9)
1.6 feet	25 (311)	2 (29)	$1,084.9 (2,319.8)
4.9 feet	101 (412)	10 (39)	$2,132.6 (4,452.4)
Total	**412**	**39**	**$4,452.4**

Estuary flood damages are much lower than erosion damages but are about four times those associated with wave flooding. This reflects the number of low-lying properties around Pescadero that are currently exposed to episodic flood events from fluvial hazards. With greater sea level rise, these same properties will experience more frequent and more severe flooding as sea level rise will compound the fluvial flooding and expand current flood risks. This compound flooding will likely affect properties further inland that are outside the current flood extent. Fire station buildings, already affected by estuary flooding, will experience greater impacts under all projected sea level rise scenarios. Without intervention, Pescadero Creek Road will also be rendered inaccessible by estuary flooding on a more frequent basis affecting all residents of this community. Structures near Gazos Creek will begin to experience flood impacts between 1.6 and 4.9 feet of sea level rise.

The values included in the table above may understate the true values, as outbuildings such as sheds and garages have been assigned a nominal value of $10,000 per building. In the case of agricultural properties, these buildings could house expensive farm machinery. It is assumed for the purposes of this study that the machinery could be relocated outside the flooded area. The value of flood damages to agricultural land is also not included in the damage costs in this section, because of data limitations noted previously.

Figure 4-4 shows the breakdown of estuary flooding damages by land use. At all sea level rise scenarios, approximately half of the value of estuary flood damages is to residences in Pescadero and on agricultural properties near Pescadero Creek. Damages to the CAL FIRE facility and the Pescadero Corporation Yard increase in a relatively linear fashion with increased sea level rise.

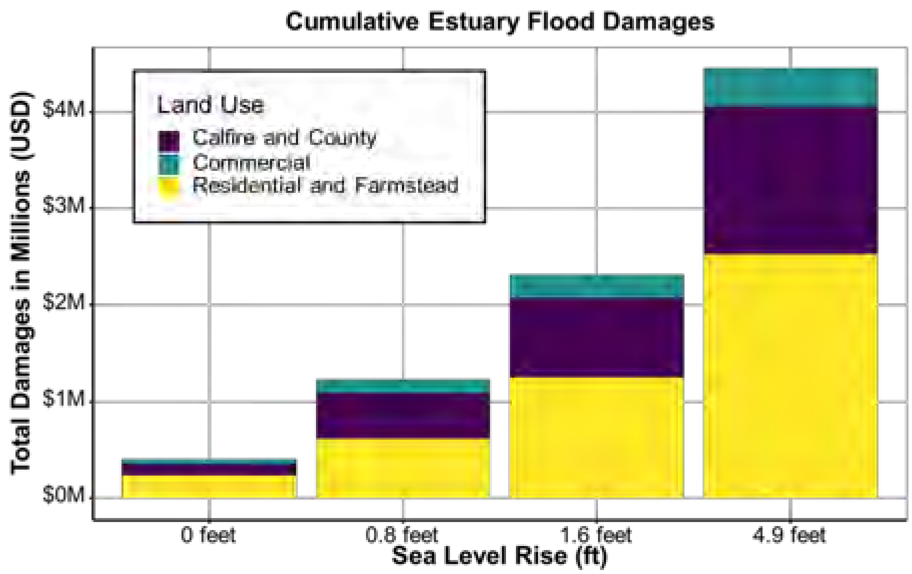


Figure 4-4. Estuary flooding damages by sea level rise horizon
Reported damages are cumulative.

4.1.4 Damages and Economic Impact to Land and Structures from Combined Hazards

Cumulative cleanup, damages, and losses from all hazards in the study area are projected to be $54,820,600 by 2100 or 4.9 feet of sea level rise. Table 4-5 summarizes damages to land and buildings by sea level rise.

Table 4-5. Combined coastal hazard damages by sea level rise horizon

Sea Level Rise	**Acres** (cumulative)	**Number of Primary Buildings** (cumulative)	**Damages to Buildings ($'000s)** Noncumulative, (Cumulative)	**Damages to Land ($'000s)** Noncumulative, (Cumulative)
0 (existing)	1,123	42	$1,609.7	$13,209.4
0.8 feet	261 (1,384)	53 (95)	$23,760.3 (25,370.0)	19,761.1 (32,970.5)
1.6 feet	155 (1,539)	13 (108)	$5,652.7 (31,022.7)	$6,458.1 (39,428.6)
4.9 feet	431 (1,970)	15 (123)	$4,958.9 (35,981.0)	$15,392.1 (54,820.6)
Total	**1,970**	**123**	**$35,981.0**	**$54,820.6**

Approximately 94% of the economic estimate of damage to land and property by 4.9 feet of sea level rise is associated with coastal erosion, representing around $85.3 million in predicted damage. Most of this damage, around $74.6 million, is due to cliff erosion hazards that primarily affect Martin's Beach and Tunitas Creek Beach, and the stretch of coastline between Bolsa

Point to Pescadero Point. Wave flooding and estuary flooding damages are comparatively minor in economic terms, although they have locally important impacts in Martin's Beach and Pescadero, respectively. Dune erosion impacts total around $10.7 million, and largely result from the expansion of wave flood hazards into public open space areas and into private properties around Tunitas Creek Beach, Bean Hollow Beach, and Gazos Creek Beach.

4.1.5 Hazard Impacts to South Coast Communities

Four distinct communities within the study area are projected to be impacted by sea level rise and coastal hazards into the future: Martin's Beach, Tunitas Creek, Pescadero, and the cliffside homes from Yankee Jim Gulch to Pescadero Point. The sections below provide a short description of the community as well as projected impacts.

4.1.5.1 Pescadero (Vicinity of Pescadero Creek Road and Water Lane)

Pescadero regularly experiences flooding when large rain events coincide with high tides and storms. Flooding of Pescadero and Butano Creeks is a significant near-term concern, affecting many homes, farms, and significant facilities off Pescadero Creek Road. Prior to settlement, this area would have flooded frequently, perhaps as often as every year or multiple times a year in wetter years. The frequency of this flooding has increased over time, with documentation that flooding on Pescadero Creek Road had become a chronic problem by the 1980s (Cook 2002).

In the frequently flooded area around Water Lane and Pescadero Creek Road, 27 parcels are on record, including 11 single-family residential properties, 11 agricultural properties (which may include residences), 1 shop/warehouse, and 4 vacant parcels. There are also 33 primary structures, including a mix of single-family homes and farmsteads.

Figure 4-5. Agricultural fields near Water Lane in Pescadero
Source: Dave Kent

Flooding has several negative implications for human and environmental health. As residents have documented, flooding can lead to mold and fungi growth, which can damage structures and cause respiratory issues. Flooding can also lead to the mobilization of contaminants from septic fields, as well as the release of toxic chemicals from households, farms, commercial buildings, and the fire station. Such releases can pose a health and safety risk and can also contaminate nearby agricultural fields. Leaks from septic tanks are especially problematic, as they may expose agricultural lands to *E. coli* bacteria.

Coastal hazard damages in Pescadero are projected at around $4.4 million with 4.9 feet of sea level rise, or approximately 4.9% of total estimated damages for the study area. Damages increase in a relatively linear fashion over the examined sea level rise scenarios, with no clear inflection point. The figures presented in this study are likely to be an underestimation of the true economic impacts in the Pescadero area, and for the region, as it was not possible to estimate economic damages from flooding to the land itself, which is the hazard of relevance to the Pescadero region.

4.1.5.2 Martin's Beach

Martin's Beach is a community situated in a small cove with a relatively narrow fronting beach. It is both a residential community and a popular recreation spot for surfers, birdwatchers, and beachgoers. The homes are built on three terrace levels from the back of the beach to the top of the bluff (Figure 4-6). There are 51 cabins and homes in Martin's Beach, with some residing in the community year-round. As of 2022, approximately 90% of the leases have expired but have been temporarily extended through 2022. As of March 2022, there are some leases that have been renewed with longer terms (San Mateo RCD, pers. comm., 2022).

Figure 4-6. Martin's Beach
Source: San Mateo RCD

Significant erosion events including landsides along the northern bluffs, and major slumps in the canyon to the south of the cove, have been observed following previous major storm events. The bluff where the community is built is highly prone to erosion, and the sea cliffs nearby have been estimated to have a natural historical erosion rate of approximately 4 feet per year (Griggs et al. 2005; Hapke and Reid 2007). Groundwater seeps and runoff can further weaken and mobilize the soil and lead to erosion that is not caused by waves but by terrestrial sources. Compounded with this, the impacts from storm wave flooding on this community will continue to escalate as sea levels rise.

Across the study area, Martin's Beach has the greatest concentration of residential building values at risk, and much of this exposure is either current or with 0.8 feet of sea level rise. The front row of houses already experiences wave flooding impacts (see Section 2.2.2.2). With only 0.8 feet of sea level rise, nearly all the homes in Martin's Beach are projected to be subject to erosion, resulting in around $9.5 million in economic damage.

Buildings at Martin's Beach account for more than one-quarter of building values subject to coastal hazards for sea level rise of 4.9 ft, and almost 40% of building values at risk if the Pigeon Point Lighthouse is excluded. In calculating coastal hazard damages, this study assumes that an eroded building is defunct and can no longer be subject to coastal wave flooding. If measures were taken to reduce the erosion risk to properties at Martin's Beach, wave flooding damages for the first row of ocean-facing homes will continue to be relevant and may increase in severity with sea level rise unless adaptation actions are pursued.

4.1.5.3 Tunitas Creek

Perched atop the steep cliffs north of Tunitas Creek are a collection of six privately owned cabins located on one property. These cabins are all located approximately 30 feet from the bluff top edge and are highly susceptible to damages from cliff erosion. Gullying of the soft terrace deposits is apparent at the top of the exposed bluff (Figure 4-7).

Figure 4-7. Tunitas Creek Camp
Source: Coastal Records Project, Copyright © 2008 Kenneth & Gabrielle Adelman. All rights reserved.

Figure 4-8. Tunitas Creek Camp, 2021
Source: Integral Consulting Inc.

Due to the proximity of the cabins to the cliff, they are predicted to experience erosion impacts with only 0.8 feet of sea level rise, resulting in potential damage and loss of the cabins worth around $1.5 million. At 1.6 feet of sea level rise, the erosion is projected to impact access road to these cabins. As previously noted, these cabins have been assigned a nominal value of $200,000 per structure in the absence of tax assessed values. The true economic losses may be more substantial. Given the relatively small structures and the availability of space on the landward or southern extent of the property, it may also be possible to relocate the structures outside the zone of greatest erosion risk.

4.1.5.4 Pescadero Area Cliffside Homes

Between Yankee Jim Gulch and the Pescadero Bridge are a series of cliffside homes on the coastal side of State Route 1. This area has a total of 22 homes with 19 being susceptible to coastal hazards.

Figure 4-9. Cliffside homes just south of Bean Hollow State Beach

Pescadero Point is the area with the highest localized economic impact from coastal hazards except for the Ritz-Carlton Hotel, which has been excluded from the economic reporting of the current study. This is due to the high value of property and structures within the area, and the proximity of the residential properties to the cliff edge.

With 4.9 feet of sea level rise, there is an estimated $29.4 million in damage in the cliffside home region, with almost half of this damage ($14.4 million) occurring at around 0.8 feet of sea level rise. Most of the estimated damage at this level of sea level rise ($11.0 million) is due to erosion damage to land. The methodology for this study assumes that as land is lost, there is a proportional relationship in the loss of land value. However, there is not a direct relationship between land area and value, and valuations for properties may be retained or continue to rise despite increasing risk due to coastal erosion, as these risk factors are not always incorporated into purchasing decisions. There also may be opportunities to relocate structures within the property if there is sufficient depth and the construction type is conducive to cost-effective relocation. Given these considerations, clifftop properties may retain or even increase in value until either the building is deemed unsafe to occupy by a licensed building inspector, there is a clear and imminent danger to the built structure, or erosion has reduced the land parcel to such an extent that a residential building cannot exist in that location. Once this has occurred, property values will be more reflective of the risk exposure of the property.

4.2 AGRICULTURAL LAND VULNERABILITIES

As sea levels rise, flood extents, depths, and durations in the low-lying areas of Pescadero will likely increase, impacting more agricultural land in the area. Land that is now profitably farmed may become less fertile as the soil salinity rises. Along bluff top agricultural areas, realignment of roads and trails could force relocation or loss of farmed areas, and as clifftop land erodes, some agricultural operators may lose access to arable land and structures along the coast, resulting in job loss for agricultural laborers who already experience socioeconomic challenges and precarious living conditions. All these impacts would reduce the economic stability of the South Coast region and weaken the area's cultural identity.

Vulnerability Overview

- Most of the agricultural land losses due to erosion are to grazing and open areas, largely in the northern and southern sections of the study area and comprises 353 acres by 4.9 feet of sea level rise.
- Estuary flooding has an impact on planted fields near Pescadero, affecting 125 acres by 4.9 feet of sea level rise.
- A majority of potentially affected agricultural areas have Williamson Act agreements, 269 acres total in affected areas by 4.9 feet of sea level rise.

This section summarizes the impacts of coastal hazards and sea level rise on agricultural land. By land area, the most affected agricultural land use type is grazing land on coastal bluffs, and the second most affected is planted fields in low-lying areas. A total of 23 parcels are under Williamson Act agreements, and these parcels represent 269 acres of agricultural land and a significant proportion of the total agricultural land in the coastal hazard study area. Table 4-6 illustrates how Williamson Act lands may be affected over sea level rise horizons

Table 4-6. Acres of Williamson Act lands by sea level rise horizon

Williamson Act Lands	
Sea Level Rise	**Acres (cumulative)**
0 (existing)	108
0.8 feet	60 (168)
1.6 feet	21 (190)
4.9 feet	80 (269)

Agricultural Land Use Classification System

Detailed in Section 2.6.2, this study relies on the state's FMMP database for agricultural land use classification. This is the most detailed data set available for describing agricultural land areas; however, there are some cases where non-agricultural lands along the adjacent bluff and riverine lands are described as agriculture. In addition, this data set does not align to parcel boundaries, and as a result, does not link directly to the parcel-based economic valuations. In addition, Williamson Act lands cannot be directly linked to the FMMP data set. The FMMP data set described the following agricultural areas in the study area:

Prime Farmland: Irrigated land with the best combination of physical and chemical features able to sustain long-term production of agricultural crops.

Farmland of Statewide Importance: Irrigated land similar to Prime Farmland that has a good combination of physical and chemical characteristics to produce agricultural crops.

Unique Farmland: Lesser quality soils used to produce the state's leading agricultural crops.

Farmland of Local Importance: This includes land that is or has been used for irrigated pasture, dryland farming, confined livestock and dairy, poultry facilities, aquaculture, and grazing land.

Grazing & Open: Land on which the existing vegetation is suited to the grazing of livestock. May include agricultural land that is dedicated open space.

Developed: Agricultural land that is occupied by structures, with a building density of at least one unit to 1.5 acres.

For this study, land classified under statewide importance, unique, and locally important are described as planted fields. Developed land (homes on agricultural land) is generally omitted from reporting but is still included as "agricultural land" for general reporting purposes.

4.2.1 Damages to Agricultural Land due to Cliff Erosion

Coastal erosion is a potential threat to 412 acres of agricultural land, including 30 acres of planted fields. Vulnerable agricultural areas to coastal erosion occur throughout the study area, with grazing land comprising the primary vulnerable bluff-top agriculture activity. The most at-risk agricultural fields are in both the extreme northern and southern extents of the study area.

Figure 4-10. Coastal fields in the northern section of the study area
Source: Coastal Records Project, Copyright © 2019 Kenneth & Gabrielle Adelman. All rights reserved.

Figure 4-11. Coastal grazing lands in the northern section of the study area
Source: Coastal Records Project, Copyright © 2002 Kenneth & Gabrielle Adelman. All rights reserved.

Cliff erosion will have permanent impacts on agricultural land through the direct loss of eroded land, or the indirect loss of land through the inland migration of rights-of-way into agricultural land from road and trail realignment, or other types of development. These spillover effects are not accounted for here.

Table 4-7 and Table 4-8 show the area of agricultural land affected by cliff and dune erosion hazards, respectively.

Table 4-7. Acres of agricultural land by type and sea level rise horizon due to cliff erosion

FMMP Based Cliff Erosion Hazards							
Horizon	**Developed**	**Grazing & Open**	**Local Importance**	**Prime**	**Statewide Importance**	**Unique**	**Grand Total**
0 (existing)		23.8					23.8
0.8 feet	16.6	121.6	1.1	1.4		1.6	142.3
1.6 feet	4.2	44.0	1.2	3.4		2.0	54.7
4.9 feet	8.1	129.0	2.9	11.3	0.2	4.9	156.4
Grand Total	**28.9**	**318.4**	**5.2**	**16.1**	**0.2**	**8.4**	**377.2**

Acres are noncumulative.

Dune erosion has relatively minor impacts on agricultural land, as areas affected by dune erosion are primarily public open spaces and not suitable or available for planting or grazing purposes.

Table 4-8. Acres of agricultural land by type and sea level rise horizon due to dune erosion

FMMP-Based Dune Erosion Hazards		
Horizon	Grazing & Open	Grand Total
0 (existing)	15.0	15.0
0.8 feet	3.1	3.1
1.6 feet	3.2	3.2
4.9 feet	13.0	13.0
Grand Total	**34.3**	**34.3**

Acres are noncumulative.

4.2.2 Damages to Agricultural Land due to Estuary Flooding

Estuary flooding is likely to cause temporary damage and disruption to about 139 acres of farmland, most of which occurs in the established floodplains of Pescadero and Butano creeks. These river flood processes may improve the quality of the soil by replenishing it with new sediment and reinvigorating some of the soils, although soil contamination is also a potential concern. However, closed lagoon flood events can also cause soil to be exposed to saltwater and other chemicals, which may lead to a shift from higher-value crops to lower value ones, or even an eventual abandonment of fields. Consequently, even if the amount of land dedicated to agriculture does not change, the impacts of sea level rise may reduce the economic value of total crop production.

Table 4-9. Acres of agricultural land by type and sea level rise horizon due to estuary flooding

FMMP-Based Estuary Flood Hazards					
Horizon	Developed	Grazing & Open	Prime	Unique	Grand Total
0 (existing)	8.9	29.4	27.7	14.1	80.2
0.8 feet	1.1	0.9	9.1	3.8	14.8
1.6 feet	1.2	0.9	7.1	0.4	9.6
4.9 feet	3.7	3.2	26.2	1.8	34.9
Grand Total	**14.8**	**34.4**	**70.2**	**20.1**	**139.4**

Acres are noncumulative.

4.2.3 Damages to Agricultural Land due to Storm Wave Flooding

Coastal storm flooding impacts 84.5 acres of agricultural land in the study area. However, exposure occurs along steep coastal bluffs that have little to no value for agriculture. A small number of low-lying areas along the southern stretch of the coast are exposed, including the grazing lands and protected coastal prairie lands between the Cloverdale Coastal Ranches and Bolsa Point. While storm wave flooding over these areas may cause temporary disruption to agricultural operations, only a limited area of cropland is affected by 4.9 feet of sea level rise and the planted fields in this area are currently fallow.

Table 4-10. Acres of agricultural land by type and sea level rise horizon due to storm wave flooding

FMMP Based Storm Wave Flood Hazards				
Horizon	**Developed**	**Grazing & Open**	**Local Importance**	**Grand Total**
0 (existing)	7.1	55.5	<0.1	62.7
0.8 feet	0.1	3.5	<0.1	3.5
1.6 feet	0.1	3.8	<0.1	3.9
4.9 feet	0.4	14.1	<0.1	14.4
Grand Total	**7.7**	**76.8**	**<0.1**	**84.5**

Acres are noncumulative.

4.2.4 Damages to Agricultural Land due to Combined Hazards

Combined hazards include the furthest extent of all hazards described above. Grazing and open land are projected to be the most affected agricultural category representing 70 percent of lands impacted by 4.9 feet of sea level rise.

Table 4-11. Acres of agricultural land by type and sea level rise horizon due to combined hazards

FMMP-Based Combined Coastal Hazards							
Horizon	**Developed**	**Grazing & Open**	**Local Importance**	**Prime**	**Statewide Importance**	**Unique**	**Grand Total**
0 (existing)	16.0	87.3	0.0	27.7		14.1	145.2
0.8 feet	10.9	108.8	1.1	10.5		5.3	136.6
1.6 feet	5.3	45.9	1.2	10.5		2.4	65.2
4.9 feet	11.6	144.7	2.9	37.5	0.2	6.7	203.7
Grand Total	**43.9**	**386.7**	**5.2**	**86.2**	**0.2**	**28.6**	**550.7**

Acres are noncumulative.

4.2.5 Economic Impact on Agricultural Land

Agricultural activity in the county is valued at $150 million a year and is an economic driver for the Pescadero area and crucial for local livelihoods (San Mateo County 2019a). This analysis estimates future economic impacts to agricultural land by crop types as categorized in the County's 2019 Crop Report (San Mateo County 2019a) but does not attempt to determine impacts to productivity, profitability, or impacts to farm jobs. This report values the direct loss of land due to erosion but does not attempt to value reductions in land value due to flood impacts. The latter would require detailed information about the existing use of all parcels, which is subject to commercial confidentiality restrictions. It would also require detailed information about future changes in land use resulting from coastal hazard impacts (e.g., flooding causing a conversion from high-value crops like Brussels sprouts to lower-value crops like peas or beans, or to grazing).

For economic reporting below, agricultural lands are categorized based on County Assessor's parcel land use designations and values rather than the FMMP data set. These boundaries may include areas on steep and rugged terrain that are not suitable for agriculture. Reporting is based on damages to the asset value of land and buildings, not to the income streams that the agricultural properties generate.

Figure 4-12 and Figure 4-13 summarizes the economic damages associated with agricultural land and structures for all coastal hazards.

Economic damages to agricultural land and buildings due to erosion, and to buildings due to flooding, increase in a relatively linear fashion across all sea level rise scenarios.

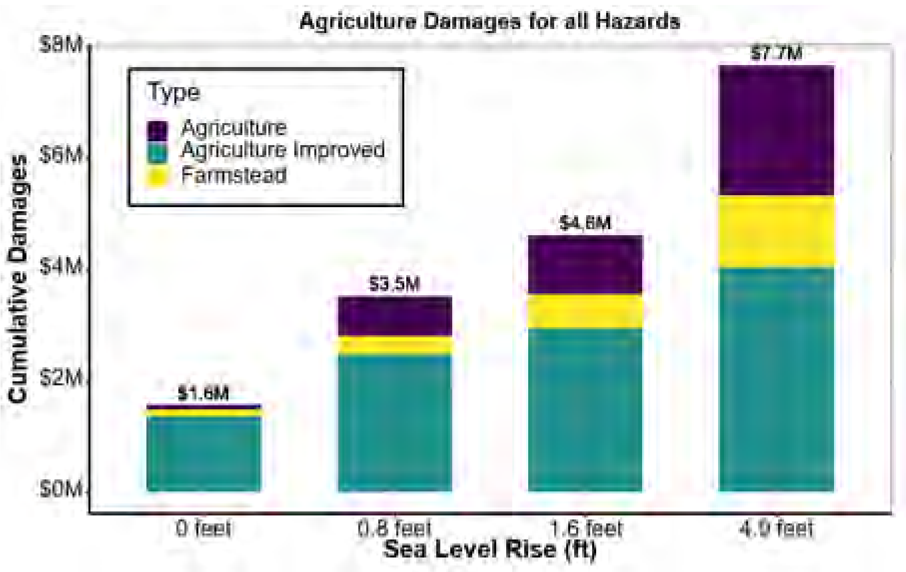


Figure 4-12. Agricultural land and structure values by type and sea level rise horizon

Results are cumulative.

Agriculture improved is a tax assessor designation and indicated that the parcel includes "improvements" such as structures.

The Agriculture category represents the land area that does not have structures

Farmstead is a residential structure on agricultural land

As is typical in agricultural settings, most of the value in a property is associated with land values. This is reflected in the values shown in the figure above. By 4.9 feet of sea level rise, damages to agricultural buildings ("farmsteads") largely from closed estuary flooding comprise $1.3 million, or about 17% of all agricultural damages.

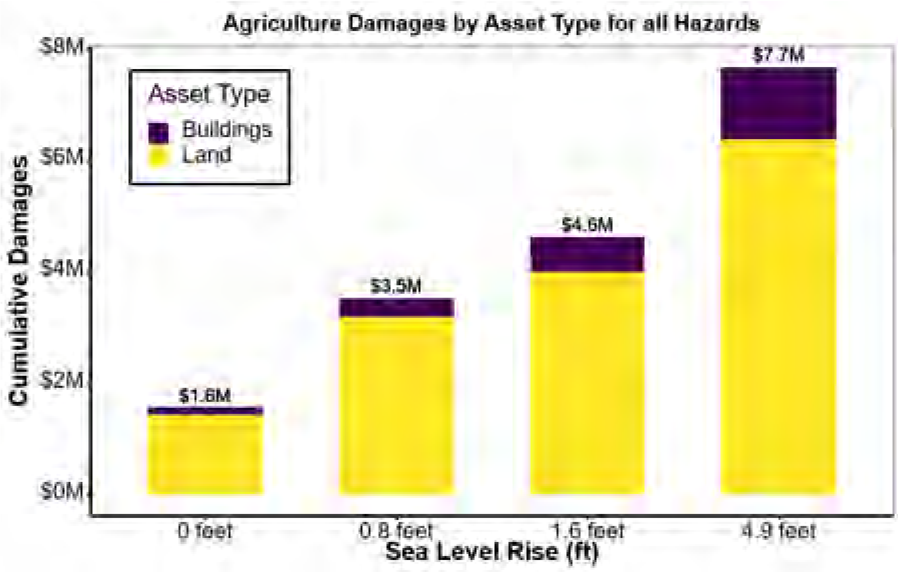


Figure 4-13. Agricultural land and structure values by sea level rise horizon
Results are cumulative.

4.3 ROADS AND PARKING VULNERABILITIES

Erosion is already threatening parts of State Route 1, and impacts are projected to worsen in the future with higher sea levels. This could affect the integrity of the roadway, leading to the need to stabilize or relocate stretches of State Route 1. Impacts to State Route 1 are most concentrated in the central portion of the study area and significant impacts are seen around 1.6 feet of sea level rise. For the northern and southern sections of the study area, significant impacts are between 1.6 and 4.9 feet of sea level rise.

Vulnerability Overview

Table 4-12 provides an overview of miles of road that are projected to be impacted by different sea level rise horizons.

- Approximately 4.5 miles of State Route 1 roadway are vulnerable to coastal erosion by 4.9 feet of sea level rise. The most impacted area is from Bean Hollow Beach to Pescadero Creek Bridge, with almost 2 miles projected to be exposed.
- Estuary flooding has an impact on Pescadero Creek Road, affecting almost 1 mile by 4.9 feet of sea level rise.
- Eleven state park parking lots are projected to be exposed to coastal erosion and storm wave flooding by 4.9 feet of sea level rise.

This section summarizes the impacts of coastal hazards on roads and parking. Over the long-term, the greatest threat in terms of potential costs and community impacts are from coastal erosion threatening State Route 1. Over the short-term, fluvial flooding around Pescadero from Pescadero and Butano creeks represents a significant issue for the county transportation network, affecting 0.9 mile of Pescadero Creek Road and 0.47 mile of Water Lane. In addition, 0.25 mile of State Route 1 is projected to be affected around North Pescadero Marsh.

The stretch of highway running from the county line to Miramontes Point Road in Half Moon Bay is approximately 26.4 miles long, with approximately 20% of this roadway running within proximity to the coastal bluffs or in low-lying areas parallel to a beach. This proximity to the coast makes State Route 1 susceptible to coastal erosion in numerous sections of the road, with susceptibility increasing as sea levels rise. Currently, Caltrans has placed riprap revetments near two sections of the highway along the bluffs of Pescadero State Beach in the central portion of the study area.

Table 4-12. Newly impacted roads (miles) by type and sea level rise horizon in combined hazards

Sea Level Rise	Distance in Miles			
	Local and Residential Service Roads	County Roads	State Route 1	Grand Total
0 (existing)	1.95	0.92	0.65	3.52
0.8 feet	1	0.08	0.22	1.31
1.6 feet	0.67	0.04	0.73	1.43
4.9 feet	2.12	0.13	2.9	5.16
Grand Total	**5.75**	**1.17**	**4.5**	**11.42**

The distance is determined along road centerlines.

4.3.1 State Route 1 Vulnerabilities

Threats from Coastal Erosion to State Route 1

Multiple sections of the coastal highway traverse sections that are highly vulnerable to coastal erosion. As has been experienced in other areas of the coast such as Big Sur, if a major erosion event were to impact State Route 1, the required cleanup and repairs could last for an extended period, and access to and from the south coast area could be significantly impeded. Any major erosion event affecting the highway would entail detours via smaller local roads and would create significantly longer travel times as well as other inconveniences and potential issues for health and safety response times. Table 4-13 provides an overview of the sections of State Route 1 that are susceptible to coastal hazards.

Table 4-13. Sections of State Route 1 susceptible to erosion

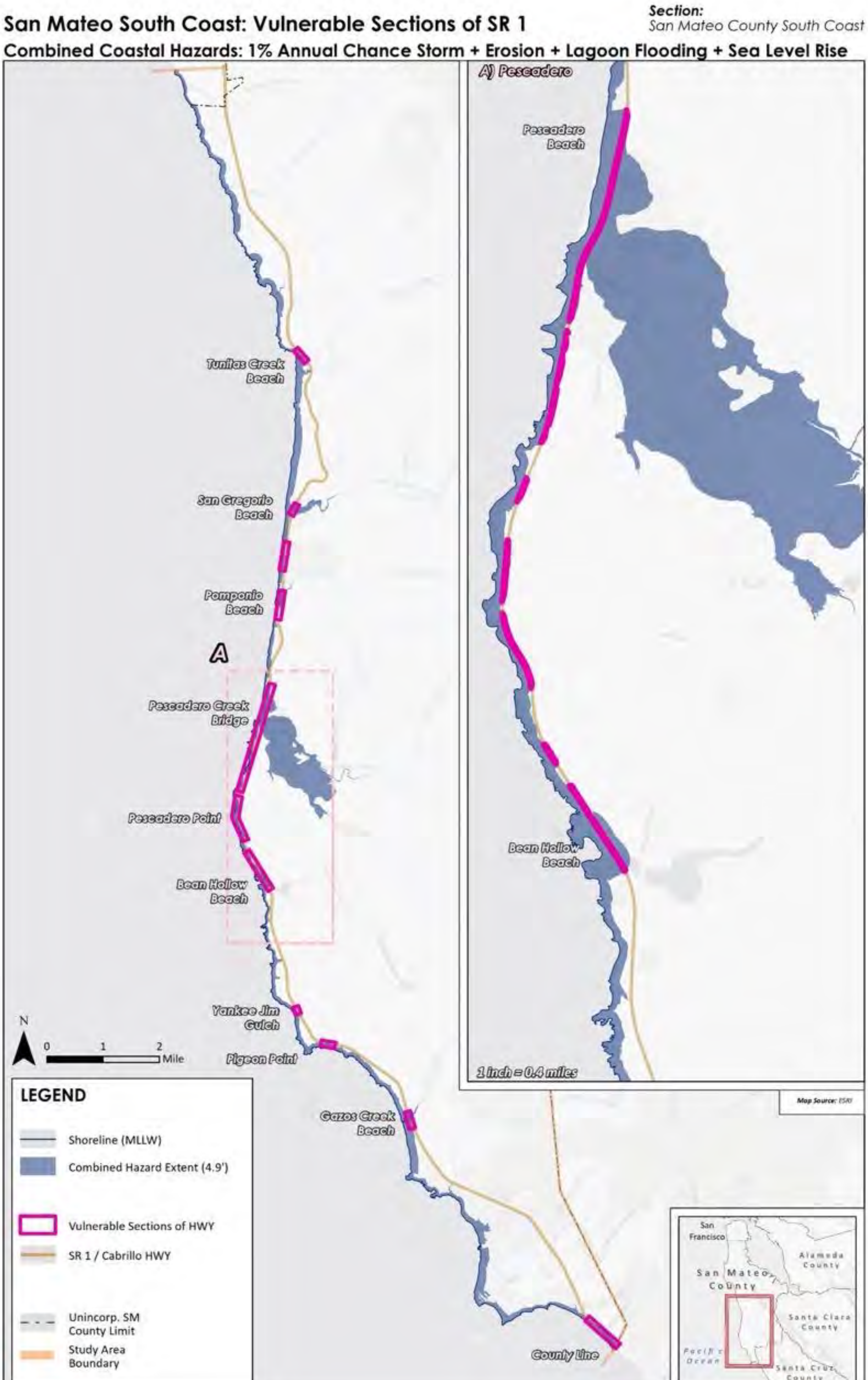
STATE ROUTE 1		Sea Level Rise Horizon				Conditions			
Highway Sections Susceptible to Erosion	**Approximate Length in Feet of Highway Section**	**Current**	**0.8 ft**	**1.6 ft**	**4.9 ft**	**Shore Type**	**Portions Armored?**	**Protection from Dunes?**	**Caltrans Prioritization Status**
		Approximate Length of Road Affected in feet							
SOUTH									
County Line to Elliot Creek	3,260	0	300	1,960	2,900	Cliff			Priority 2
Vicinity of Gazos Creek	1,800				1,300	Dune with Lagoon		YES	Priority 4
Pigeon Pt Viewpoint	1,500				800	Cliff			
Vicinity of Yankee Jim Gulch (Pistachio Beach)	640				200	Dune		YES	
Total Feet Affected in South Section		**0**	**300**	**1,960**	**5,200**				
CENTRAL									
Vicinity of Bean Hollow	1,500	300	1,100	1,300	1,500	Dune	YES	YES	
Bean Hollow Beach to Pescadero Point	6,000			1,000	3,600	Cliff			
Pescadero Point to Pescadero Creek Bridge	8,800			1,300	6,500	Cliff	YES		Priority 2 & 3
Vicinity of Pescadero State Beach	3,500	950	2,300	2,500	3,500	Dune		YES	Priority 2
Vicinity of North Pescadero State Beach	2,800				400	Cliff			Priority 2
Total Feet Affected in Central Section		**1,250**	**3,400**	**6,100**	**15,500**				
NORTH									
Vicinity of Pomponio Beach	1,300	500	830	1,300	1,300	Dune with Lagoon		YES	Priority 2
Between Pomponio and San Gregorio	7,600				1,300	Cliff			Priority 2
Vicinity of San Gregorio Beach	400				400	Dune with Lagoon		YES	Priority 2
Vicinity of Tunitas Creek	2,500				1,300	Cliff			
Total Feet Affected in North Section		**500**	**830**	**1,300**	**4,300**				
Grand Total		**1,750**	**4,530**	**9,360**	**25,000**				

Lengths determined using the ocean-facing edge of the road for improved accuracy.

Excludes bridge lengths

Blank cells indicate "NO."

Caltrans prioritization status for detailed climate change adaptation assessment is considerate of temperature impacts, sea level rise, wave flooding, coastal erosion, and network criticality



Map 9. Sections of State Route 1 vulnerable to coastal hazards and sea level rise

Caltrans Identified Priorities

As part of Caltrans District 4 Climate Change Vulnerability Assessment (2018), the agency has assessed and prioritized potential climate change-related vulnerable assets and areas in the State Highway System. Priority scores were generated for each potentially exposed asset, ranging in value from 1 to 5, with 1 representing a greater priority for the asset. This assessment focused on bridges, large culverts, small culverts, and roadways.

Table 4-14. Caltrans prioritization of State Route 1 road features

Caltrans Prioritization for Detailed Climate Change Adaptation Assessments	
Road Feature	Prioritization Status
Bridges	
Gazos Creek	1
Pescadero Creek	1
San Gregorio Creek	1
Large Culverts	
Pomponio Creek	1
Roadways	
County Line	2
Gazos Creek	4
Pescadero Point to San Gregorio Creek	2

Source: Caltrans Adaptation Priorities Report, District 4, December 2020

Multiple small culverts were also identified, but not indicated here.

Caltrans prioritization status for detailed climate change adaptation assessment is considerate of temperature impacts, sea level rise, wave flooding, coastal erosion, and network criticality.

Potential Impacts of Sea Level Rise to State Route 1

State Route 1 is the main arterial accessway for emergency services for the San Mateo South Coast region, and Pescadero Creek Road is the main accessway between the Pescadero area and State Route 1. Both vital networks are susceptible to the effects of sea level rise, and impediments due to flooding or erosion can have serious consequences. These transportation networks link local people to their homes, jobs, and essential services. If this access is disrupted, the people most impacted include the elderly, disabled, and those living in poverty, who are more likely to rely on community services that require functioning transportation infrastructure.

The implications of a damaged, flooded, or otherwise unusable transportation network could negatively impact the entire county. For example, one damaged or compromised section of

State Route 1 could easily impact the South Coast's largest economic sectors and potentially add hours to travel times.

4.3.2 Pescadero Creek Road Vulnerabilities

Historically, fluvial flooding within the Butano Creek floodplain has been the primary hazard along Pescadero Creek Road. During the rainy season, flooding would block Pescadero Creek Road one or more times, with flooding often lasting for days. Flooding was linked to a buildup of silt, as well as vegetation and debris, within the Butano Creek waterways. Prior to the dredging of silt from Butano Creek and Marsh during the 2019 restoration, the creek had very little capacity to handle rainstorm runoff, and the water has nowhere to go but up and over the road. This flooding often closed the main route into and out of the town of Pescadero and flooded farmland and homes. Since then, the restoration flood levels have been reduced. In the future, this fluvial flooding compounded with sea level rise will likely cause more frequent flooding and potentially greater extents of flooding to the road.

Potential Impacts of Sea Level Rise to Pescadero Creek Road

If Pescadero Creek Road is inaccessible, travelers must take alternative routes into the Pescadero area from State Route 1. These routes are much longer and narrower and are associated with travel times 2-3 times longer. It has also been estimated that an ambulance, fire engine, or police vehicle could require an extra hour or more in transit time when Pescadero Creek Road floods. Those who attempt to drive through a flooded portion of the road face risks to personal safety.

4.3.3 Parking Area Vulnerabilities

There are four low-lying beach access parking lots that are projected to be affected by coastal wave flooding and dune erosion. These include Bean Hollow at Arroyo de los Frijoles, Gazos Creek State Beach, the North lot at Pescadero State Beach, and Pomponio State Beach. Numerous informal parking lots on the side of the road are also projected to be affected by dune erosion and flooding.

Only public parking areas within the hazard zone are analyzed in this study. Formal private parking areas such as those at Martin's Beach are not included. Both Año Nuevo and San Gregorio have very large lots that can accommodate up to 125–150 vehicles; both lots are outside the hazard zone. Off-street and informal lots of significant sizes are located throughout the study area and are generally not included unless indicated.

Figure 4-14. Landslide used as a makeshift beach accessway at the Rockside Parking Area at Pescadero State Beach

Source: Coastal Records Project, Copyright © 2010 Kenneth & Gabrielle Adelman. All rights reserved.

Figure 4-15. Erosion and the loss of parking area at the Rockside Parking Area at Pescadero State Beach

Source: Ana Miscolta-Cameron, 2022.

Table 4-15. State Parks parking lots in the coastal hazard zone

Parking Lot Name	Estimated Number of Spaces	Total Lot Size (sq ft)
South		
Gazos Creek State Beach	30	14,913
Pigeon Point State Historic Park—Main	24	7,529
Pigeon Point SHP—Off-Street West*	40	8,885
Pigeon Point SHP—Off-Street East*	12	2,750
Central		
Bean Hollow State Beach—Arroyo de los Frijoles	24	9,097
Bean Hollow State Beach—Pebble Beach	32	17,146
Pescadero State Beach—Rockside	70	46,990
Pescadero State Beach—River Mouth South	14	3,272
Pescadero State Beach—River Mouth North	36	18,991
Pescadero State Beach—Beach	70	22,675
North		
Pomponio State Beach	86	32,224
Grand Total	**438**	**184,471**

**Informal Parking Area*

4.3.4 Economic Impact

The area experiencing the most severe erosion along the State Route 1 corridor is between Pescadero and San Gregorio, with erosion approaching the roadbed in numerous locations. Authorities have delayed the erosion with coastal armoring and are studying the feasibility of a reroute further inland. The CCC has asked Caltrans to study all possible alternatives for providing transportation in the future, including potentially replacing 8.75 miles of State Route 1 with an inland bypass between Pescadero and San Gregorio (Caltrans 2008).

This study considers only economic damages associated with physical impacts on road and parking assets and does not consider the impacts on services caused by road damage or blockage. For example, this study does not examine the time costs or vehicle expenses associated with taking different routes if a road is not passable. This study also includes damage costs only for those sections of roadway or parking lots that are directly affected, and not any section of roadway that is “stranded” by virtue of damage to connecting sections of road.

Any adaptation study would need to consider factors mentioned above, as well as the need for agricultural market access and emergency services and health facilities access.

The impacts associated with loss of road connectivity may also be substantial, with flow-on effects on property values and residential populations in some local areas.

Table 4-16. State Parks parking lots exposure to coastal hazard by sea level rise horizon

Parking Lot	0 (existing)	0.8 ft	1.6 ft	4.9 ft
Bean Hollow State Beach—Arroyo de los Frijoles				
Gazos Creek State Beach				
Pescadero State Beach—Beach				
Pomponio State Beach				
Bean Hollow State Beach—Pebble Beach				
Pescadero Creek Mouth South				
Pescadero State Beach—Rockside				
Pigeon Point State Historic Park				
Pescadero State Beach—Creek Mouth North				
Pigeon Point Off-Street West*				
Pigeon Point Off-Street East*				

Red—Erosion only
Purple—Coastal Wave and Erosion
** Informal Parking Area*

4.4 PARKS, RECREATION, AND COASTAL ACCESS VULNERABILITIES

Coastal access points, beaches, and trails, and parking and restrooms, are already impacted by flooding and erosion, and sea level rise is projected to exacerbate these impacts.

Vulnerability Overview

- By relative impact, Pescadero State Beach is the most impacted park with over 95% of the park area projected to be impacted by coastal erosion and storm wave flooding by 4.9 feet of sea level rise.
- By the total land area affected, Pescadero Marsh Nature Preserve is the most impacted park, with 478 acres projected to be impacted by estuary flooding and dune erosion. Higher tide elevations with sea level rise could have significant habitat implications for this nature preserve.
- With 7.8 miles of coastline, including many miles of beaches used for elephant seal haul-outs, Año Nuevo State Park is highly susceptible to coastal erosion and coastal wave flooding.

This section summarizes the impacts of coastal hazards on parks, recreation, and coastal access. State Parks and other protected land areas make up approximately half of the study area coastline and represent the largest land use group projected to be impacted by sea level rise. Visitors from near and far flock to the South Coast every year and the study team estimates that approximately 1.2 million park visits take place each year in the coastal parks and open space areas. Many miles of coastal trails, coastal access locations, park facilities and restrooms, and park parking lots (depicted in the Roads and Parking section) are in the study area. In addition, significant stretches of the California Coastal Trail wind through the study area, including the Half Moon Bay Coastside Trail, Arroyo de los Frijoles Trail (Bean Hollow State Park), Mel's Lane & Pigeon Point Bluffs Trails near the Lighthouse, and the Atkinson Bluff Trail and Año Nuevo Point Trail at Año Nuevo State Park.

4.4.1 Parks and Open Space Vulnerabilities

Table 4-17. Park and open space by sea level rise horizon and coastal hazard type

Parks and Open Space					Sea Level Rise Horizon						Hazard Type		
					0 (current)	0.8 ft	1.6 ft	4.9 ft	Total	Percentage of Total Parkland Affected	Coastal Erosion	Storm Wave Flooding	Estuary Flooding
Park Name	Ownership or Management	Estimated Yearly Visits	Approximate Total Area of Parkland (acres)	Feet of Coastline	Approximate Additional Area Affected by Combined Coastal Hazards (acres)						Approximate Additional Area Affected by 4.9 feet of Sea Level Rise (acres)		
Año Nuevo State Park and **Gazos Creek State Beach**	State Parks	130,000	4,335	41,000	224	42	43	125	434	10.0%	92	236	11
Bean Hollow State Beach and **Pebble Beach Farm**	State Parks, POST	78,000	150	9,000	25	6	5	8	44	29.5%	8	25	0
Cowell Ranch State Beach and **Cowell-Purisima Trail**	State Parks, County Parks, Coastal Conservancy	41,000	55	8,100	18	12	5	7	41	75.3%	7	18	0
Pescadero Marsh Nature Preserve and **Butano Farms**	State Parks, POST	63,000	1,514	NA	450	5	4	19	478	31.6%	2	0	476
Pescadero State Beach	State Parks	254,000	91	9,000	74	6	3	4	87	95.7%	5	75	2
Pomponio State Beach	State Parks	103,000	400	8,000	16	6	2	6	31	7.6%	6	15	7
San Gregorio State Beach	State Parks	132,000	452	4,900	38	15	4	12	69	15.3%	3	16	45
Pigeon Point Light Station State Historic Park including **Pistachio Beach**, **Pigeon Point County Park**, and coastal **Cloverdale Coastal Ranches**	State Parks, POST, County Parks	280,000	234	21,300	61	18	18	33	130	55.6%	35	70	0
Tunitas Creek Beach	County Parks	58,000	52	4,000	6	5	2	6	20	37.5%	6	6	0
Manhattan Beach and **California Coastal Trail** at Ocean Colony	City of Half Moon Bay	150,000		4,000									
Total		**1,289,000**	**7,282**	**109,300**	**912**	**116**	**86**	**220**	**1,334**		**163**	**462**	**542**

All yearly visits numbers are rounded to the nearest thousand and estimates are based on State Parks Statistical Reports, County Planning Documents, State Park General Plan Reports, Park Staff Surveys, and Conversations with Park Staff. Estimates were averaged form the years where data were available, typically 2014–2019. For smaller park areas, estimates were determined through comparisons with similar parks.

***Tunitas Creek Beach County Park** has limited access and is in the design phase as of 2021.*

***Cowell-Purisima Coastal Trail** is managed by the San Mateo County Parks District and California Coastal Conservancy and portions lie on private land. The park and trail have limited weekday access.*

***Manhattan Beach and California Coastal Trai**l do not have designated property areas. California Coastal Trail is managed by the City of Half Moon Bay Parks District and the portion in the study area falls on private land.*

***Pigeon Point** is composed of the State Park property at the light station area, as well as the areas north and south of the light station that are both County parks and POST land.*

4.4.2 Trail Vulnerabilities

Table 4-18. Linear feet of trail in the coastal hazard area

Trail Type	Linear Feet	Miles
Multimodal and Cycleway	15,475	2.9
Foot Path	62,558	11.8
Dirt Track	4,171	0.8
Steps	807	0.2
Grand Total	**83,010**	**15.7**

Multimodal and Cycleway: Half Moon Bay Coastside Trail (paved) and Cowell-Purisima Trail (unpaved)

Dirt tracks: Multipurpose for both hiking, biking, and vehicle access

Steps: Provide coastal access from steep bluffs and cliffs

The lengths above include some trails on private lands that are not included in Table 4-19.

Table 4-19. Trails in the coastal hazard area by park and sea level rise horizon

Trails Affected by All Coastal Hazards		Sea Level Rise (feet)				Length (feet)	
Park Name	**Trail Name**	**0 (existing)**	**0.8**	**1.6**	**4.9**	**Total Affected**	**Grand Total in Park**
Año Nuevo State Park, South	Año Nuevo Point Trail*	1,557	1,632	1,920	2,364	7,473	12,950
	Cove Beach Trail	47	46	49	39	181	181
	Equal Access Boardwalk	148	376	72	101	697	1,206
	New Year's Creek Trail	171	69	222	348	809	3,324
Año Nuevo State Park, South—All		**1,923**	**2,123**	**2,262**	**2,852**	**9,160**	**17,661**
Año Nuevo State Park, North	Atkinson Bluff Trail*	456	3,579	3,069	3,205	10,310	10,769
	Atkinson Bluffs Service Road	78	28	170	559	835	3,110
	Franklin Point Trail*	1,286	477	470	192	2,425	3,572
	Gazos Creek Beach Access*	144	40	40	158	382	613
	North Whitehouse Creek Trail				54	54	3,090
	South Whitehouse Creek Trail	25	37	47	96	206	988
Año Nuevo State Park, North—All		**1,989**	**4,162**	**3,796**	**4,264**	**14,212**	**22,141**
Bean Hollow State Beach	Arroyo de los Frijoles Trail*	179	2,164	1,641	1,028	5,011	5,146
	Bean Hollow Beach Access*	230	284			514	514
Bean Hollow State Park—All		**409**	**2,449**	**1,641**	**1,028**	**5,526**	**5,660**
Cloverdale Coastal Ranches (POST)	Pigeon Point Vista Trails	**52**	**335**	**873**	**694**	**1,953**	**5,304**
Cowell Ranch State Park	Cowell-Purisima Trail*‡	**67**	**5,182**	**5,278**	**4,551**	**15,079**	**23,038**
Gazos Creek State Beach	Gazos Creek Beach Access*	**348**	**28**			**376**	**376**
Manhattan Beach & Vicinity (Half Moon Bay)	Coastside Trail*	**54**	**743**	**1,756**	**991**	**3,544**	**4,527**
Pescadero Marsh NP	Butano Trail	3,251	34	61	61	3,406	4,140
	North Pond Trail	784	74	25	382	1,265	3,419
	Round Hill Trail	1,505	13	23	66	1,606	2,492
	Sequoia Audubon Trail	5,881	287	142	164	6,474	6,755
Pescadero Marsh Natural Preserve—All		**11,421**	**408**	**250**	**673**	**12,752**	**16,805**
Pescadero State Beach	Pescadero Bluffs	267	1,706	727	804	3,504	3,504
	Pescadero Bridge Crossing+	621	1	1	411	1,034	1,034
	Pescadero State Beach	198				198	198
Pescadero State Beach—All		**1,086**	**1,707**	**728**	**1,215**	**4,736**	**4,736**
Pigeon Point County Park	Pigeon Point Viewpoint Trails	**689**	**511**	**488**	**696**	**2,385**	**2,790**
Pigeon Point Light Station State Historic Park	Council Circle	77	8	281	197	563	563
	Mel's Lane*		392	367	196	955	1,806
	Pigeon Point Bluffs*	1,624	104	40	58	1,827	1,827
	Station Road	60	567	624	220	1,471	1,471
Pigeon Point Light Station State Historic Park—All		**1,761**	**1,070**	**1,313**	**672**	**4,816**	**5,667**

Trails Affected by All Coastal Hazards		Sea Level Rise (feet)				Length (feet)	
Park Name	**Trail Name**	**0 (existing)**	**0.8**	**1.6**	**4.9**	**Total Affected**	**Grand Total in Park**
Pomponio State Beach	Pomponio	250	174	542	1,380	2,346	**2,385**
San Gregorio State Beach	San Gregorio	24	904	73	207	1,208	**1,909**
Tunitas Creek Beach	Tunitas Creek Beach (old)	1,393	195	82	247	1,916	**3,850**
Grand Total—feet		**21,464**	**19,991**	**19,082**	**19,470**	**80,008**	**189,521**
Grand Total—miles		**4.07**	**3.79**	**3.61**	**3.69**	**15.15**	**35.89**

** Indicates that it is a designated section of the California Coastal Trail.*

Half Moon Bay Coastside Trail lies on the private property of the Half Moon Bay Golf Links.

+ Pescadero Bridge Crossing traverses bridge overpass; this section is considered in the hazard zone for reporting purposes.

‡ Cowell-Purisima Trail includes an unofficial trail segment that connects the Cowell-Purisima Trail to the Half Moon Bay Coastside Trail.

Lateral beach walking trails are not included.

Trail lengths include spur trails.

The County of San Mateo is currently redeveloping Tunitas Creek Beach Park.

Trails exclusively for private coastal access are not included.

4.4.3 Impacts on the California Coastal Trail

The California Coastal Trail is a 1,250-mile continuous interconnected public trail system along the entire California coastline. Portions of the trail network within the study area have been designated as California Coastal Trail, but these sections are discontinuous, and State Route 1 serves as the *de facto* California Coastal Trail for the remainder of the South Coast area. The formalized trails include the Half Moon Bay Coastside Trail (also referred to as the California Coastal Trail), the Cowell-Purisima Trail, the Arroyo de los Frijoles Trail at Bean Hollow State Beach, Mel's Lane Trail at Pigeon Point Light Station, and the Atkinson Bluff Trail and Año Nuevo Point Trails at Año Nuevo State Park. Lateral beach portions of the trail stretch from San Gregorio to Pomponio State Beaches, Pescadero State Beach, and Gazos Creek State Beach.

Northern Section of the California Coastal Trail

The California Coastal Trail in Half Moon Bay is well formalized and traverses approximately 4.7 miles through the city, and 0.8 miles from Miramontes Point to the city line within this project's study area. Heading south, there is a short informal connection over private property that is not part of the California Coastal Trail. Then the trail reconnects to the Cowell-Purisima trail at Cowell Ranch State Park, which extends for another 3 miles and ends at an area just north of Martin's Beach. There are two formal beach access points along this stretch of trail leading to Manhattan Beach, Pelican Point Beach, and Three Rocks Beach in Half Moon Bay, and Cowell Ranch Beach further south. In the near-term (less than 1 foot of sea level rise), just over 1 mile of this highly used coastal trail segment is susceptible to erosion. This susceptibility increases with sea level rise and eventually 3.5 miles out of 4.2 total miles are susceptible by 4.9 feet of sea level rise.

Central Section of the California Coastal Trail

At Bean Hollow State Beach, coastal erosion and wave flooding threatens nearly the entire portion of beach. Portions of the Arroyo de los Frijoles Trail and coastal access around to Arroyo de los Frijoles are affected. At Pescadero State Beach, coastal erosion and coastal wave flooding threatens nearly the entire extent of Pescadero State Beach. At Pescadero Marsh Natural Preserve, most of the marsh trails are affected by fluvial flooding including the Butano Trail, North Pond Trail, Round Hill Trail, and Sequoia Audubon Trail. Dune erosion through Pescadero Beach dunes is projected to be a threat to the North Pond Habitat. The vault toilets at Pescadero State Beach and Bean Hollow State Beach (Arroyo de los Frijoles) are potentially affected by storm wave flooding. The trail access parking lots at Arroyo de los Frijoles and Pescadero State Beach are projected to be affected by coastal wave flooding and erosion.

Southern Section of the California Coastal Trail

At Año Nuevo State Park, coastal wave flooding is extensive at Año Nuevo Point under existing conditions. Dune erosion is extensive for the areas north of Franklin Point, affecting coastal access trails from Franklin Point to Gazos Beach. Erosion here is also a threat to cultural materials and areas. At Pigeon Point Light Station State Historic Park, coastal wave and cliff erosion impact the Pigeon Point bluffs as well as access to Pistachio Beach in the future, though more site-specific analysis is needed to understand sea level rise horizon of likely impact. The restrooms at Pomponio State Beach are susceptible to storm wave flooding under existing conditions.

Table 4-20. Park restrooms and vault toilets by sea level rise horizon

Park Name	0 (existing)	0.8 ft	1.6 ft	4.9 ft	Grand Total
Bean Hollow State Beach	1			1	**2**
Pescadero Creek State Beach	1		2		**3**
Pigeon Point Light Station State Historic Park			1		**1**
Pomponio State Beach	1				**1**
Grand Total	**3**		**3**	**1**	**7**

Red—Erosion Only
Blue—Wave Only

4.4.4 Economic Impact

4.4.4.1 Impact on Parkland and Facilities

This assessment estimated physical impacts on open space and parklands and wave and erosion damage as shown in Table 4-21. Building value damages include erosion and wave flood damages to restroom facilities and to buildings at Pigeon Point, including the lighthouse (at 0.8 feet of sea level rise). For more information on the lighthouse, see section 4.5.1.

Table 4-21. Damages to park and facilities

Sea Level Rise	**Trail damages due to erosion ($'000s)** Noncumulative, (Cumulative)	**Damages to Park Buildings ($M)** Noncumulative, (Cumulative)	**Damages to Park Land ($M)** Noncumulative, (Cumulative)
0 (existing)	17.5 (17.5)	$0.0	$8.8
0.8 feet	94.2 (111.7)	$8.8 (8.8)	$9.2 (18.0)
1.6 feet	82.6 (194.3)	$3.5 (12.4)	$3.4 (21.4)
4.9 feet	89.7 (284.0)	$0.0 (12.4	$6.8 (28.2)
Total	**284.0**	**$12.4**	**$28.2**

Potential land damages to park facilities in the present day are primarily due to dune erosion ($5.3 million in estimated damage). At 0.8 feet of sea level rise, cliff erosion becomes the primary contributor to lost values to parks and recreation resources.

4.4.4.2 Non-market Values

In addition to impacts on assets with existing market values, coastal hazards may result in a range of impacts on recreational opportunities. People gain unpriced benefits from participation in recreational activities which are known as non-market values. The non-market value cannot be determined from a market price, which is for services and goods that can be bought and sold. To determine the non-market values, economists suggest using the concept of willingness to pay (WTP), which is defined as the value of an individually consumed non-market good as the amount that an individual consumer would be willing to pay to consume the good or use the service (e.g., see Raheem et al. 2009 and Barbier et al. 2011). The analysis below relies on numerous studies of non-market value discussed below.

In California, beaches below the high-water line are in public trust and open to the public for free. As such, there is no market value for access. There is also no market information for the value of recreation above the high-water line in public open space and park areas, although parking fees provide a weak proxy for this information. The recreational value of beaches in California has been studied extensively. This non-market value is typically measured in terms of WTP for a trip to the beach. Economists can measure WTP by estimating the travel cost to and from the site (revealed preference) or by asking visitors how much they would be willing to pay (stated choice). This WTP is typically expressed as a “day-use value.” This value is then multiplied by an estimate of visitation to derive a recreational value for an area. Estimates of day-use value vary by study and by beach width. Following Kildow and Pendleton (2006) this study used a median value of $41.87 per visitor per day (in 2015 dollars) rounded to $40 per person per day.

Table 4-22 uses an estimate of State Park’s attendance for the past five years. No adjustment has been made for potential future growth in attendance. Because the potential impacts to recreation vary significantly by the type of recreation, this analysis breaks down the primary recreational activity of visitors into several different types depicted in in Table 4-22. This table represents approximate usage and is based on conversations with park rangers and other local officials, as well as the study team’s local knowledge and experience.

Table 4-22. Non-market values based on the estimated number of park visits per recreation activity

Aggregate Yearly Park Visits	Recreation Type	Percentage of Visits	Estimated number of visits per activity	Estimated Annual Aggregate Nonmarket Value ($millions/year) at $40/visit
1,289,000	Beach Recreation	30%	386,700	$15.5 M
	Surfing	10%	128,900	$5.2 M
	Kayaking	5%	64,450	$2.6 M
	Fishing	15%	193,350	$7.7 M
	Hiking	30%	386,700	$15.5 M
	Tide-Pooling	10%	128,900	$5.2 M
	Total	**100%**		**$51.6 M**

Applying a non-market value of $40 per visitor per day yields a total recreational (non-market) value of $51.6 million. Most of these visits are associated with hiking, beach recreation, and fishing. Based on the modeled coastal hazards, it is likely that beach recreation values could be substantially impacted. Impacts on fishing and hiking will depend on whether these activities and their associated assets (e.g., hiking trails, parking lots, and beach access points) can move inland as the shoreline retreats.

In addition to recreational values, the study area provides many other ecosystem services and public trust resources (sensitive natural and cultural resources) beyond beach recreation, which are difficult or potentially inappropriate to assign monetary values to.

4.5 SIGNIFICANT FACILITY VULNERABILITIES

Vulnerability Overview

- The CAL FIRE Station #59 has experienced frequent flooding in the past. San Mateo County is planning to relocate the station out of the high-risk flood zone. The proposed location near Pescadero High School is significantly less prone to flooding. This site it outside of the sea level rise flood zone, but proximate to FEMA 100- and 500-year flood zones.
- The Pigeon Point Lighthouse facility is at risk from coastal erosion, but more site-specific analysis is needed to understand the level of sea level rise that would affect this facility.
- The Ritz-Carlton Hotel in Half Moon Bay may be affected by coastal erosion by 4.9 ft of sea level rise. The City of Half Moon Bay has launched a study to refine the coastal cliff erosion model and more accurately determine the level of risk to the hotel, nearby golf course, and recreation trail.

All properties identified in this section are already affected by coastal hazards to some extent. With sea level rise, these impacts will increase, and new structures will be impacted (Table 4-23).

Table 4-23. Significant facilities by sea level rise horizon

Horizon	CAL FIRE Station	Gazos Creek Gas Station and State Route 1 Brewery	Ritz-Carlton Hotel	Pigeon Point Lighthouse	Grand Total
Existing	1	0	0	0	1
0.8 ft	1	0	0	4	5
1.6 ft	No additional structures impacted.	1	0	3	4
4.9 ft	No additional structures impacted.	1	1	No additional structures impacted.	2
Grand Total	**2**	**2**	**1**	**7**	**13**

No structures at Pescadero Corp. Yard are projected to be affected.

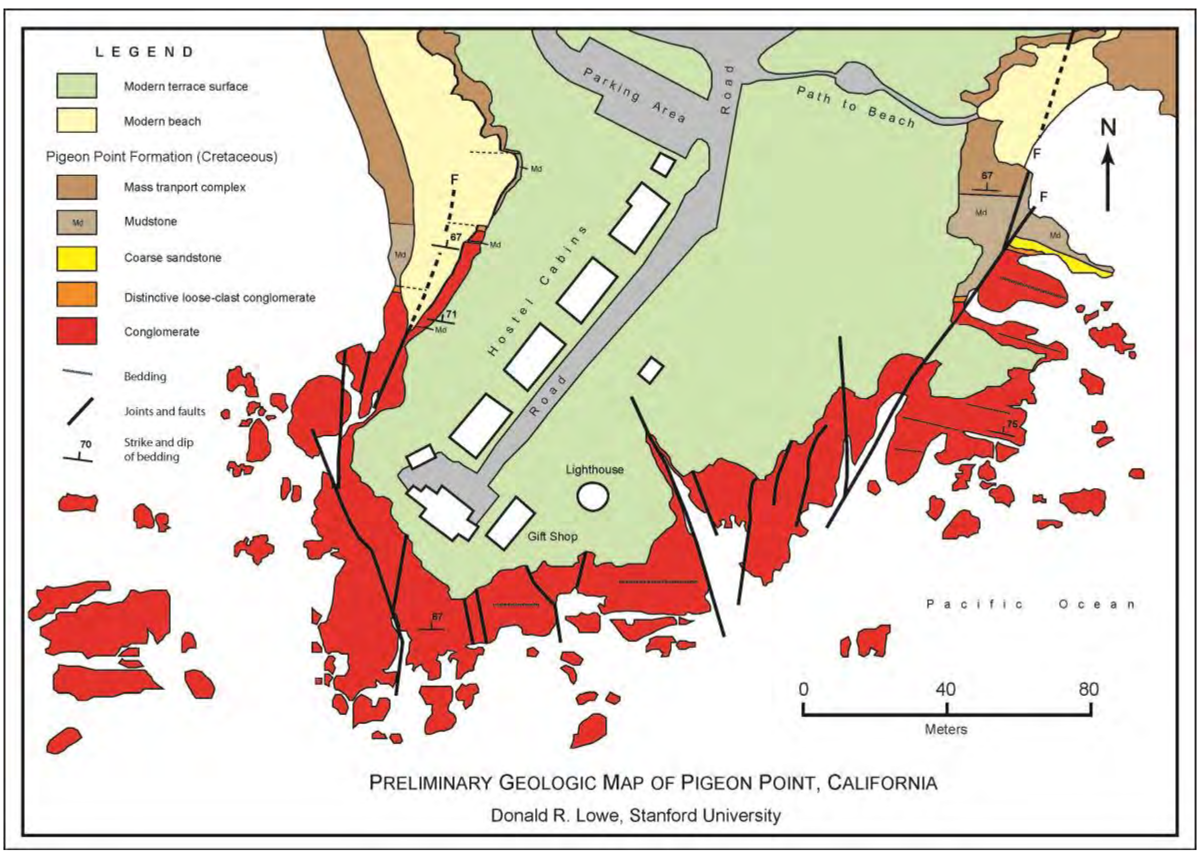
Note: The results reported here are for screening purposes only and a site-specific assessment is recommended

4.5.1 Pigeon Point Lighthouse

The iconic Pigeon Point Lighthouse is listed on the National Register of Historic Places and is a California Landmark. Construction was completed in October 1872 at a cost of $184,625 (California State Parks 2017). The fog signal became operational in 1871, with the lighthouse first being lit on November 15, 1872. Under an agreement with the U.S. Coast Guard, California State Parks assumed responsibility for the light station property in 1980. The keepers' bungalows were converted to a hostel in 1981. In late 2001, the tower was closed to the public because of structural damage to the iron work at the top of the tower. California State Parks received full title to the property from the U.S. Coast Guard and Department of the Interior in 2011 and in 2021 received $18+ million in state funds to fully restore the tower to preserve a key piece of California's maritime history (Barrow 2022, pers. comm.).

The lighthouse is made of brick, is 115 feet tall, and is tied as the tallest lighthouse on the West Coast. The entire site includes the historic Lighthouse, historic oil house (interpretive node), Carpenters Shop (park store), Fog Signal Building (interpretive center), 52-bed Pigeon Point Lighthouse Hostel managed by Hostelling International, restroom and filter building, shipwreck exhibit, and a picnic area overlooking the bluffs.

Figure 4-16.Pigeon Point Light Station
Source: Swan Dive Media, 2021



Map 10. A geologic map (preliminary) of Pigeon Point depicting geological formations and faulting
Source: Donald R. Lowe, Stanford University

Bluff erosion is an ongoing problem at the park. Terrestrial causes of erosion are evident, especially around the informal social trails, and surface drainage issues have contributed to this erosion as well (California State Parks 2017). As part of the Pigeon Point Park General Plan, consultants remapped USGS historical rates for years 2050 and 2100 from a refined bluff top edge. This study shows erosion affecting the Light Station, Interpretive Center, and Store by 2100, with the hostel and other structures onsite just out of the erosion hazard zone (Map 11).

Most existing erosion models that assess the Pigeon Point area, including this one, assume a uniform geology when making erosion risk projections, despite Pigeon Point having more complex geologic characteristics that affect the likely speed of erosion. Dr. Donald Lowe at Stanford University (Map 10) has completed a preliminary geologic map of the area, which demonstrates a non-uniform geology. Because local conditions may be inconsistent with those assumed by a model, a site-specific geotechnical analysis is needed to help scientists better model future levels of erosion risk to Pigeon Point.

In 2021, State Parks released a Sea Level Rise Adaptation Strategy that provides a framework for how the department will incorporate sea level rise considerations into existing park operations. The Strategy is not park-specific, but rather provides a department-wide approach to SLR adaptation planning. State Parks uses models from the USGS CoSMoS system to evaluate projected exposure to future sea levels. The projections that are selected for analyses are based on the recommendations included in the State of California Sea Level Rise Guidance, which was released by the Ocean Protection Council in 2018.

Map 11. Pigeon Point bluff erosion hazard study, 2017

Source: Pigeon Point Light Station State Historic Park General Plan, 2017

Other challenges: Water from the current well on site was deemed unsafe for drinking per California Department of Public Health standards in 2013. In addition, this shallow 15-foot well would also go dry seasonally. Since 2013, all the site's potable water needs have been supplied by hauling water by truck from an offsite source and then pumping it into an existing tank. The existing shallow well and storage tank are uphill on U.S. Coast Guard property, east of State Route 1 and outside of the coastal hazard zone. In 2021, a new water supply well was drilled on POST property east of the U.S. Coast Guard property. As of 2022, State Parks had tested the well yield and water quality and plan to pursue well development at this location (Case 2021, pers. comm.; Rohlf 2022, pers.comm.; Barrow 2022).

4.5.2 Ritz-Carlton and Half Moon Bay Golf Links

Located at Miramontes Point in Half Moon Bay, this six-story building has 271 rooms and is the largest hotel in Half Moon Bay. The hotel project was first approved by the city in 1972, before the California Coastal Act was passed in 1976, and was indicative of the period of California coastal development where coastal access and preservation of natural coastal lands was not prioritized. After first approval, the site lay dormant for some time, but reemerged in the 1990s and construction was completed in 2001.

The hotel and golf course site are underlain by the Purisima Formation, a siltstone and mudstone unit that is moderately susceptible to coastal erosion. This bedrock unit is overlain by approximately 15 feet of marine terrace deposits consisting of sand and clay, which is in turn overlain by 3 to 10 feet of artificial fill (CCC 2005). A geotechnical investigation in 2005 found that the bluff retreated approximately 30 feet in the 10 years between 1963 and 1973, and another 10–15 feet between 1973 and 1998, when the site was armored. This riprap was then removed in 2002. The average erosion rate was calculated to be approximately 0.75 feet per year, and passive erosion could reduce the beach width seaward of the 18th green by at least 37 feet within 50 years, and by approximately 52 feet within 70 years, assuming the rate remains unchanged with sea level rise (CCC 2005). At its closest point, the hotel sits 130 feet from the bluff edge, and more than 200 feet in other locations.

Prior to construction of the hotel, a vertical seawall was in place to protect the 18th green of the Old Course from erosion. As portions of the bluff episodically eroded, slumped, and retreated, this undermined the concrete slab beneath the 18th green and the hanging slab broke off and fell to the beach during the winter of 1995–1996. An unpermitted structure was placed for erosion protection in late 1998, but later removed in 2003–2004 (CCC 2005), and the remaining caissons from the original structure were removed in 2018.

In 2004, the hotel filed a permit to erect a 270-foot long riprap and concrete seawall on the beach and coastal bluff adjacent to the 18th green of the Old Course. The CCC denied this permit *"because the project would substantially alter the natural landform of the coastal bluff and would result in significant adverse impacts to visual resources, shoreline sand supply, and public access in conflict with Chapter 3 policies of the Coastal Act."* (CCC 2005). The CCC recommended alternatives such as reconfiguration of the green or more substantial reconfiguration of the golf course to relocate the green further inland. The CCC states that if the hotel structure were in danger of erosion, a vertical seawall could be designed to avoid or minimize shoreline aesthetic, habitat, and coastal access impacts, and could be designed to mimic the form of the adjacent natural bluff (CCC 2005).

Figure 4-17. Ritz-Carlton Hotel and Half Moon Bay Golf Links at Miramontes Point in the City of Half Moon Bay

Foundation piers (now removed) can be seen at the end of the point.

Source: Google Earth, 2018

Wave energy dissipation is afforded by three rocks just offshore. As sea levels rise, the three rocks will be further inundated, thus reducing their wave breaking capabilities and increasing the wave energy hitting Miramontes Point. This may impact bluff erosion rates. The tops of these rocks are 10–15 feet in height (NAVD88). Further analysis may be necessary here.

At 4.9 feet of sea level rise, the Ritz-Carlton Hotel is projected to be affected by coastal erosion. This facility provides substantial revenues to the City of Half Moon Bay in the form of property and tourism occupancy taxes, and through fees associated with golf course usage. The hotel is also a driver of visitation to the broader region. Economic damages to the Ritz-Carlton and adjacent golf courses have not been included in the figures presented in the tables and figures of this report, and no attempt to include fiscal impacts of these damages has been undertaken. The City of Half Moon Bay is conducting a more detailed site study at this location.

4.5.3 CAL FIRE Station 59

CAL FIRE Station 59 was built in the mid-1960s, its site selected in part due to water access and proximity to State Route 1 and Pescadero. However, it was also built in a low-lying floodplain of Butano Creek and has experienced increasingly frequent flooding events over time. As a result, the existing barracks has become threatened with interior flooding on an annual basis, causing plumbing backups, and in several cases, mold growth, which has required the building to be gutted. In addition, seasonal flooding of the adjacent Butano Creek blocks fire personnel direct access to the Pescadero community. In 2013, the San Mateo County Board of

Supervisors accepted a recommendation to authorize $6 million in Measure A funding to build a 7,800-square-foot fire station in another location. The process to locate and design a new station on land adjacent to Pescadero High School located at 350 Butano Cutoff is in design and environmental review as of 2021 (San Mateo County 2021). The project will include the demolition of the barracks at the existing station and renovation of the existing apparatus bay (where fighting vehicles are stored), which will remain on site.

Figure 4-18. CAL FIRE Station # 59 in Pescadero, 2021
Source: Integral Consulting Inc.

4.5.4 Pescadero Corporation Yard

The Pescadero Corporation Yard houses the County vehicle fleet for the region as well as a maintenance facility and a fueling station on the premises with above-ground fuel tanks located on site.

Figure 4-19. Pescadero Corporation Yard, 2021
Source: Integral Consulting Inc.

The elevation of the Pescadero Corporation Yard ranges from 6.8 to 8.2 feet above sea level based on NAVD88. Under the 4.9 feet of sea level rise scenario, the parking areas and fuel pumps are impacted by coastal hazards, but the two buildings on the premises are not directly affected. However, access to and from the corporation yard will be blocked by estuary-related flooding along Pescadero Creek Road, rendering it unusable during floods and in emergencies. The County owns adjacent properties at higher elevations that may be accessible via Bean Hollow Road if road modifications are made, so there is some adaptive capacity for relocation.

4.5.5 Gazos Creek Alliance Gas Station

The Gazos Creek Gas Station is the only fueling location between Half Moon Bay, 23 miles to the north, and Santa Cruz, 25 miles to the south. This significant facility includes a gas station with pumps open 24/7, the Highway 1 Brewing Company and restaurant, and RV parking. The Gazos Creek Gas Station also has underground storage tanks (USTs) regulated by the U.S. Environmental Protection Agency and may need to consider how rising sea levels may affect these tanks (see the section on potential hazardous materials concerns below). The Gazos Creek Gas Station faces issues like those of the Pescadero Corporation Yard described above and is prone to estuary flooding as well. However, due to its proximity to the ocean, the property may eventually be susceptible to dune erosion along with storm wave flooding by 4.9 feet of sea level rise.

The Gazos Creek Gas Station represents a scenario found elsewhere throughout the County and the state, where a transportation corridor such as State Route 1 serves as a *de facto* barrier or levy protecting upland development. If waves were to overtop State Route 1 or if dune erosion were to degrade the integrity of the road, both unlikely but possible scenarios, impacts to the Gazos Gas Station would increase significantly.

Figure 4-20. Gazos Creek Alliance Gas Station and State Route 1 Brewing Company, 2021
Source: Integral Consulting Inc.

Entrances to the gas station lie at ~15–18 foot elevation and are projected to be susceptible to estuary flooding from Gazos Creek by 1.6 feet of sea level rise. The site is also projected to be exposed to wave flooding if waves overtop State Route 1, or if dune erosion passes State Route 1. Dune erosion is projected to impact the site by 4.9 feet of sea level rise.

Potential Hazardous Materials Concerns Related to Above and Underground Storage Tanks

During a flood event, the USTs at Gazos Creek, and above-ground storage tanks at the CAL FIRE Station and the Pescadero Corporation Yard could be disrupted in numerous ways.

Buoyancy: If the tank is surrounded by floodwater or fully saturated soils, it is subjected to buoyancy forces that can offset the restraints and forces holding the tank in place. Unanchored storage tanks can shift within the surrounding fill material or even lift out of the ground, resulting in a rupture or separation of the connecting pipes and potential leaks.

Erosion and Scour: Rapidly moving water, such as that from storm waves or high-velocity fluvial flows can erode the soil around the storage tank and potentially lead to rupture.

Displacement: Leaks can also occur if floodwater enters an opening to the tank, such as through fill pipes, vent pipes, gaskets, etc. This can cause displacement of the fuel inside the storage tank, releasing it into the environment.

Electrical System Damage: Extended contact with floodwaters may cause damage to electrical equipment associated with USTs, potentially affecting automatic tank gauging systems, panel boxes, emergency shutoff switches, and motors.

Until the mid-1980s, most USTs were made of bare steel, which is likely to corrode over time and allow UST contents to leak into the environment. Faulty installation or inadequate operating and maintenance procedures also can cause storage tanks to release their contents into the environment. The greatest potential hazard from a leaking UST is petroleum seeping into the soil and contaminating the nearby marsh, as the site sits directly adjacent to Pescadero Creek with fluvial connections to Pescadero Marsh and the Pacific Ocean. A leaking fuel tank could present other health and environmental risks, including potential impacts to groundwater.

Design interventions and flood preparedness procedures can be used to help mitigate these disruptions.

4.6 HABITAT AND CULTURAL RESOURCES VULNERABILITIES

This section provides a qualitative discussion of potential impacts to habitat, organized by general habitat types. Given that quantitative analysis of habitat migration and change with sea level rise was not conducted for the entire study area, no sector profile was created. An analysis of habitat migration with sea level rise for Pescadero March can be found in Appendix D.

The general habitat types in the South Coast include beaches, rocky intertidal, backshore bluffs, and low-lying bar-built estuaries associated with the various creek outlets. Climate change could affect all sensitive biological resources and habitats in the study area. As with all habitats, there is a broad suite of physical and ecological processes responsible for creating and maintaining the habitats in their present location. Many of the habitat impacts of climate change extend beyond sea level rise. Other impacts of climate changes such as temperature, precipitation, drought, and wildfire risk may play a compounding or even larger role on future habitat conditions. It is impossible to comprehensively predict climate impacts to habitats as there is a complex interplay of variables for which future predictions remain uncertain (e.g., fog). However, coastal hazards and sea level rise as projected within the future hazard extents may directly influence just over 2,000 acres of natural habitat within the South Coast.

Simply reporting acreages of habitat areas inside future hazard extents severely misrepresents the vulnerability of these areas. If a wave overtops the Pescadero Creek beach berm for example, that saltwater volume diffuses into the entire estuary, not stopped by a line on the map. If the dunes at the Año Nuevo State Park erode, then the sand is redistributed either inland or along the coast and the dune may migrate inland or the beach widen downcoast. If the Pescadero Marsh wetland is inundated further, then it remains a wetland, but the spatial distribution of wetland habitats will migrate. If a freshwater wetland gets exposed to tides, then a brackish estuarine wetland should gain area. Estuarine habitat is exposed to brackish water and coastal flooding as well as tidal flooding. Climate changes may support existing native species, or pests and exotic species, including potential range shifts and exposure to new diseases. All these dynamic interactions may have ecological impacts beyond the physical changes projected into the future.

Conceptually, the combined influence of sea level rise and climate changes may result in three different species response patterns. First, species may shift inland and to higher elevations to avoid coastal hazards and sea level rise. With this consideration, there may be development or other impediments to inland migration, which may result in the net loss of species, as discussed further below in the discussion of beach habitat. Second, temperature changes may shift species toward the cooler coast resulting in more interaction with coastal processes for some species. Third, species may shift latitudes along the coast, to find temperature and precipitation thresholds more conducive to their individual species life history (Loarie et al. 2008). The faster the climate changes, the more difficult it is for species to migrate, particularly for non-mobile plants and vegetation. Some species may adapt in place to climate change and others will be outcompeted by invasive species.

Federal studies, like the Climate Change Vulnerability Assessment for the North-Central California Coast (Hutto et al. 2015) identify regional beaches as being overall moderately to highly vulnerable to climate change. Specifically, the report finds that exposure is very high, sensitivity is moderate to high, and adaptive capacity is moderate. If beach migration is limited, beaches and the species they support could be lost altogether. However, adaptation measures such as beach or dune nourishment and the protection of retreat areas would improve the adaptive capacity and slow the progression of beach loss (Hutto et al. 2015).

4.6.1 Cultural Resources

The South Coast is the ancestral home of the Ramaytush Ohlone and is rich in cultural areas, cultural materials, and natural resources that are of high importance to them. Important cultural materials include remnants of tools and weapons made from Monterey Chert, sourced from Año Nuevo. Many of the cultural areas in the region have helped archaeologists better understand past ecological and climatic conditions that Ohlone People lived with before European colonization. Some of these cultural resources are at risk to sea level rise impacts, though these assets may not be as visible or measurable to non-Native landowners or land managers and therefore don't often appear in typical sea level rise vulnerability assessments. To identify and reduce potential sea level rise impacts to cultural resource like these, it is important for government and other landowners to collaborate, coordinate, and share information with the Ramaytush Ohlone, via the Association of Ramaytush Ohlone (ARO), so that these cultural resources can continue to be identified and protected as much as possible.

4.6.2 Bluffs

The shoreline along the South Coast consists of rocky intertidal pools interspersed with sandy beach areas. The bluffs and adjacent shoreline host many sensitive bird and animal species, including the marbled murrelet, western snowy plover, cormorants, and marine mammals. Nearshore habitats seaward and below the bluffs may face increasing sea levels, causing additional erosion of material from the cliffs and increased depth and duration of flooding.

Sensitive plant habitats within bluff areas include the Central Coast riparian scrub, coastal sage scrub, and coastal bluff scrub. Upland scrub habitats, which are adapted to the Mediterranean climate, will face increasing temperatures and potentially long periods of extreme heat and drought. The projections of mild increases in precipitation may create more fuel for wildfires to spread during periods of drought.

4.6.3 Native Plant Communities

As designated by the California Native Plant Society, native plant communities include coastal sage scrub, chaparral, willows and riparian vegetation, and rare plant species. Projected temperature increases and changes in precipitation are likely to stress native plant communities. Any restoration or native planting initiatives should consider native species that are more heat tolerant. Coastal hazards and sea level rise will impact these communities in different ways, depending on their location. For example, plant communities that exist on the bluffs will be increasingly vulnerable to cliff erosion as sea level rise increases. The vulnerability of riparian vegetation will increase as coastal flooding and tidal flooding extends further up the reaches of creeks, altering the suitability of riparian habitat as sea level rise increases, which could result in additional estuarine or marsh habitat in these areas.

4.6.4 Bar Built Estuaries

Bar built estuaries are found throughout the South Coast including at San Gregorio Creek, Pomponio Creek, Pescadero Creek, and many others. The estuaries cycle seasonally between open and closed conditions based on the amount of sand at the inlet. During the summer when waves are calm and the stream flows are low, these estuaries tend to close as beach sand builds up and separates the ocean and the estuary which then fills like a bathtub creating closed lagoon flooding. When the winter rains raise streamflow, the barrier beach opens, and the estuary becomes exposed to tidal conditions. As winter wave energy and stream flows decline, the sand begins forming at the mouth of the creek and the amount of tidal flooding decreases becoming more of a freshwater outflow until enough sand on the beach accumulates closing the inlet and restarting the closed estuary flooding.

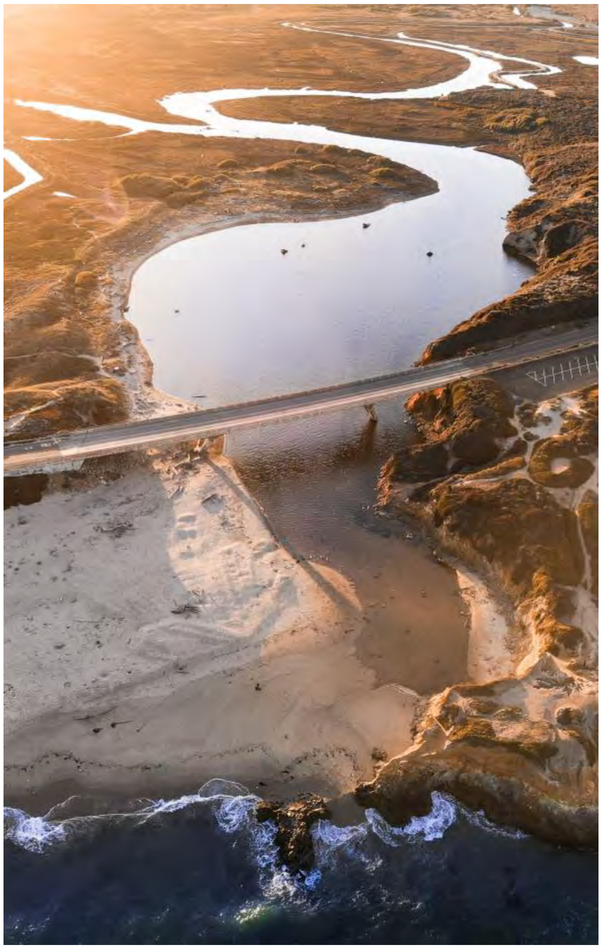


Figure 4-21. Bar built estuary at the mouth of Pescadero Creek

Note the mouth is in a closed condition with the beach forming a barrier to outflows. The wet-dry line though indicates that wave overtopping is also contributing to filling the lagoon.

Source: Ethan Dow 2021

Habitats in these bar-built estuaries are largely determined by the duration and depth of flooding across the various elevations of the marsh. Thus, topography and the relationship between depth of flooding and the duration become important. Various plant species in each type of habitat exist based on these relationships. In general, the habitats within these estuaries move from subtidal habitats that are always submerged, to mudflat habitats that are mostly submerged, to intertidal habitats that exist within the tidal range, to low marsh vegetated habitats, to higher marsh habitats that are only occasionally submerged, and finally to upland habitats that are dry. Secondary factors such as sediment and organic accretion within the estuaries can also alter different areas in the estuaries raising and lowering elevations.

As sea levels rise, it is generally anticipated that the depth and duration of flooding will increase. This means that the estuary habitats will shift toward more subtidal and mudflat habitats over time.

There remains substantial uncertainty as to the estuary influences from other climate variables such as changes in precipitation, saltwater exchange, evaporation, extreme heat, and sedimentation.

A quantitative analysis of habitat migration with sea level rise for Pescadero Marsh can be found in Appendix D.

4.6.5 Año Nuevo State Park

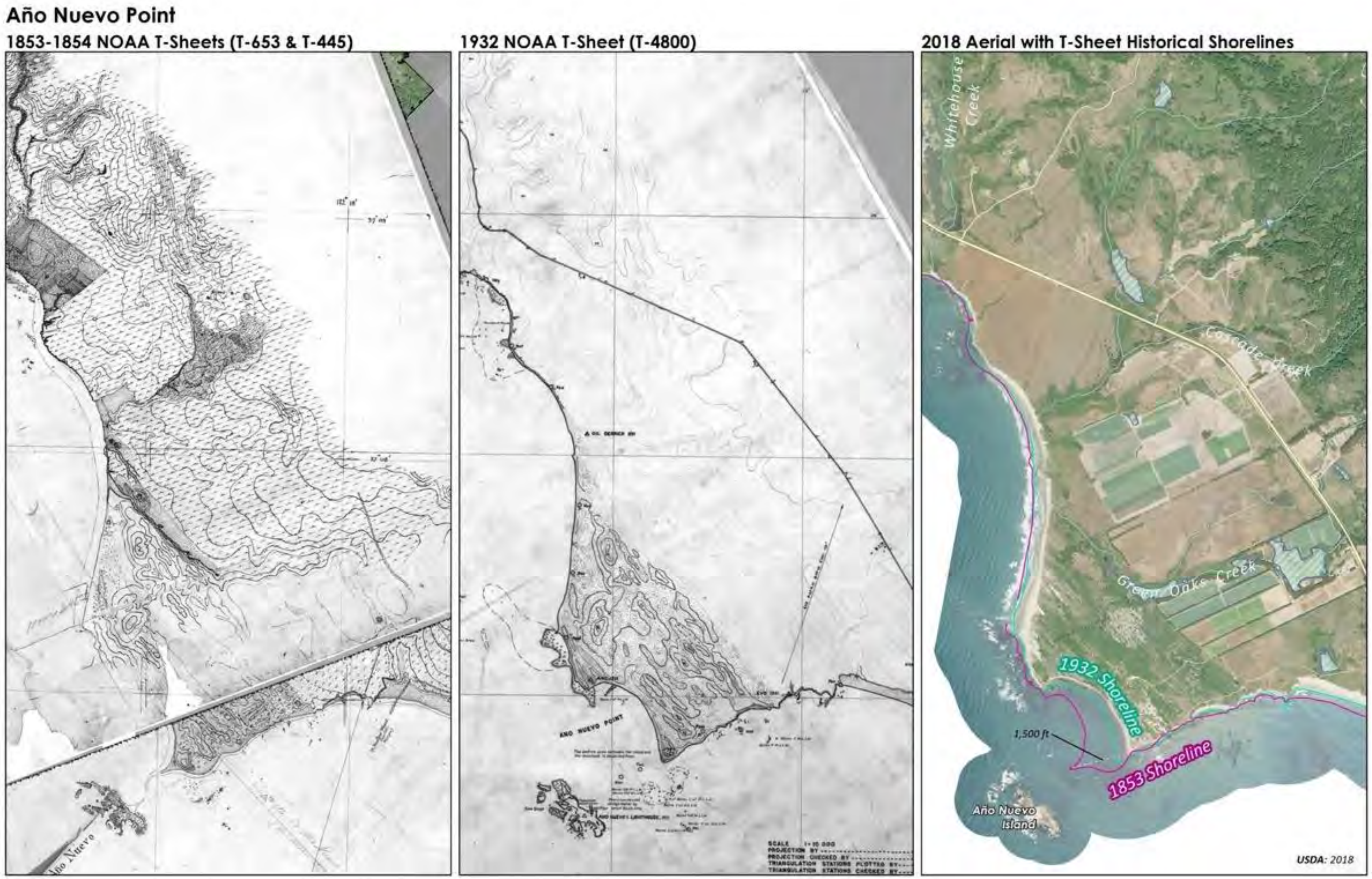
Año Nuevo Point

Año Nuevo Point is a wide and relatively low headland overlain by highly erodible sand, gravel, and silt, and capped with 5,000- to 6,000-year-old dune fields (USACE et. al. 2015). Historically, Año Nuevo Island was likely connected to the mainland, separating sometime between the late seventeenth and mid-eighteenth century (Griggs 2005). Evidence of this historical connection is present in the NOAA T-sheet and County Surveyor maps of the late 1800s, which show a peninsular sand spit extending to within 1,000 feet of Año Nuevo Island, which today is more than 2,500 feet distant from the mainland. Current research suggests that this peninsula experienced significant erosion in response to sea level rise and perhaps movements related to seismic activity along the San Gregorio Fault Zone (Griggs 2005). In either case, erosion of these dunes has been quite rapid, with historical rates estimated at 8 feet per year (Hapke et al. 2006). The dune field also became depleted from activities related to sand quarrying in the 1950s (Lajoie and Mathieson 1985; California State Parks 2021). This erosion and sediment loss, coupled with a FEMA BFE of 21 feet, has meant that modeled coastal wave flooding is significant over the Año Nuevo Point dune fields (see specific map in Appendix C).

Figure 4-22.Dune fields at Año Nuevo Point

Source: Coastal Records Project, Copyright © 2019 Kenneth & Gabrielle Adelman. All rights reserved.

In addition to the shoreline changes that are quantified over time, there has been a deflation or flattening of the once blowing sand dunes. This has been observed in the cultural records and anthropological documentation by State Parks and others (Hylkema 2019).



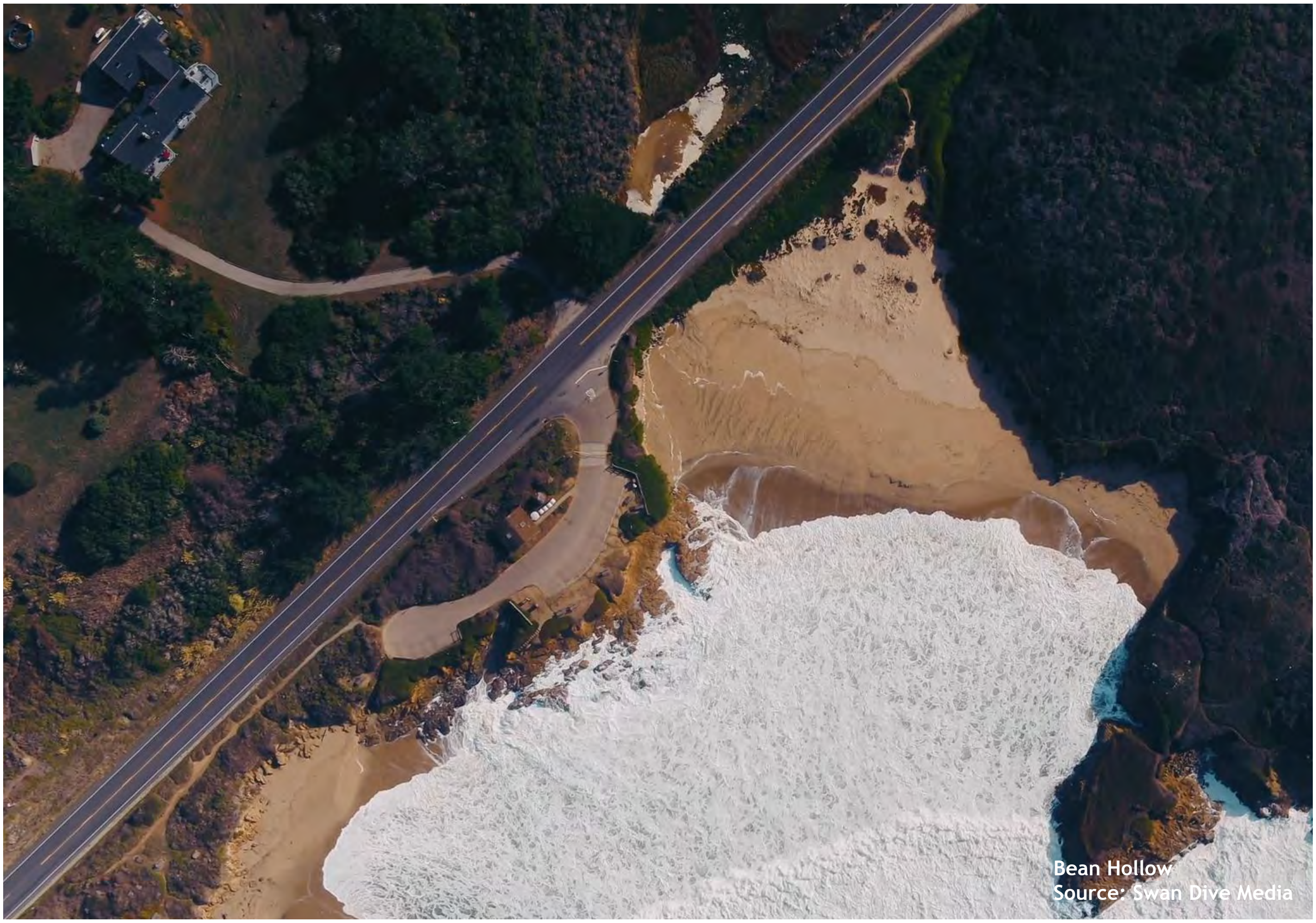
Map 12. Año Nuevo Point shoreline evolution, 1853, 1932, 2018

Año Nuevo Island

The Año Nuevo Island Light Station operated from 1890 to 1948 on the small island off the coast of modern-day Año Nuevo Point. Nearly all the buildings have significantly decayed and only remnants of the structures remain on the island. The protected area includes waters from the mean high tide line to 200 feet shoreward. All species are protected in this area. The island is an important habitat, occupied by many birds and used by several pinnipeds as haul-outs and rookeries.

Franklin Point Shipwreck Cemetery

Franklin Point Shipwreck Cemetery is a cultural site in memory of sailors of the ship “Sir John Franklin” which wrecked on the rocks off the point on January 17, 1865. The boardwalk and interpretive trail area are projected to be impacted by coastal erosion and storm wave flooding in the future.



ADAPTATION REPORT

SEA CHANGE
SAN MATEO COUNTY

5 ADAPTATION REPORT

Sea level rise risks can be mitigated by reducing vulnerability or exposure through the implementation of adaptive measures and community resilience building efforts. This section provides both a short- and long-term perspective on adaptation and poses questions that the community, natural resource and infrastructure managers and decision-makers should consider when designing adaptation strategies.

This section on adaptation planning is consistent with the adaptation framework identified in the 2020 California Adaptation Planning Guide (Figure 5-1), beginning with a summary of the key vulnerabilities (Section 5.1), summarizing the full range of possible adaptation strategies (Section 5.2), and then applying some important adaptation criteria (Section 5.4) to narrow the range of possible strategies into the more feasible strategies through time (Sections 5.5 to 5.7) to inform community engagement. The outcomes of these first few sections to identify feasible strategies are then applied in a case study to examine potential adaptation pathways for a particularly vulnerable stretch of State Route 1 (Section 5.8). Finally, the section wraps up by identifying potential funding mechanisms to support adaptation implementation (Section 5.9).

Figure 5-1. Steps in defining the adaptation framework and strategies from the California Adaptation Planning Guide 2020

5.1 BACKGROUND

Adaptation strategies fall into three main categories: protection approaches that attempt to stop erosion, accommodation approaches that allow for erosion and flooding while minimizing damages, and managed retreat or hazard avoidance, which relocates or realigns potentially vulnerable infrastructure. Communities that invest in adaptation understand that the alternative—inaction—will likely result in costly damage, cleanup, and emergency repairs.

The effectiveness of different adaptation strategies varies across space and time. Appropriate strategies will vary across communities and are determined by community values and priorities, the range of consequences, types of hazards present, backshore type, resource protection goals, development conditions, and the anticipated longevity of the proposed solution. No single adaptation strategy is considered the "best" option forever.

5.2 SUMMARY OF THE VULNERABILITY ASSESSMENT

The vulnerability assessment in Section 4 identified several sectors, communities, and significant facilities that are projected to be impacted by sea level rise. Potential vulnerabilities are largely caused by cliff erosion, a hazard that is challenging to address and that stakeholders might consider prioritizing in adaptation planning in the South Coast.

A snapshot of South Coast vulnerabilities with 4.9 feet of sea level rise is shown in Table 5-1. For full vulnerability assessment results, see Section 4.

Table 5-1. Snapshot of South San Mateo County vulnerabilities with 4.9 feet of sea level rise

San Mateo County South Coast Vulnerability Snapshot		
What is at Risk?	**Vulnerable with 4.9 feet of Sea Level Rise**	**Potential Impacts and Consequences**
State Route 1 Corridor	• 4.5 miles of the 26.4-mile-long stretch of highway	• Disruptions in emergency service • Disruptions to the primary transportation network connecting the community and all sectors • Reroutes may lead to an increase in vehicle miles traveled
Coastal Access and Recreation	• 1,334 acres of park and open space land • 15.7 miles of trail, and 39 coastal access points	• Permanent loss of pocket beaches • Loss of coastal marsh habitats • Potential loss in intertidal habitat • Rerouting of trails
Cultural Resources	Cultural artifacts and heritage at: • Año Nuevo State Park • Pigeon Point Light Station State Historic Park • Other locations	• Potential loss of cultural heritage, maritime history, and areas of anthropological interest
Residential Communities	123 homes, primarily in the communities of: • Martin's Beach • Pescadero • Cliffside areas west of State Route 1 between Pescadero Point and Bean Hollow	• Estuarine flooding may make interior conditions unsuitable for habitation (e.g., mold) • Coastal erosion and storm wave impacts may damage homes
Significant Facilities	• Gazos Creek Gas Station • Pigeon Point Lighthouse • Pescadero CAL FIRE Station • Pescadero County Corporation Yard • Ritz-Carlton Hotel and Half Moon Bay Golf Links	• Disruptions in emergency service • Loss of culturally significant facilities • Loss in tax revenue

5.3 POTENTIAL ADAPTATION STRATEGIES

Potential adaptation strategies include protect, accommodate, realign, or relocate, or combinations of all the strategies over time (Table 5-2). These strategies are implemented through specific projects often facilitated by the development of forward-thinking policies and guided by community preferences. During public outreach meetings, focus groups, and webinars presented on the project during the development of the vulnerability assessment, the County and stakeholders identified a preference for nature-based strategies when appropriate (see <u>Section 5.5.4 Community Input on Adaptation</u> for more details). The section below provides detailed descriptions of some of the most considered strategies along the California coast. Not all these strategies may be feasible.

Table 5-2. Adaptation planning strategies

Strategy	Description
Do Nothing	A policy of non-intervention, including allowing existing armoring to fail. This is not considered adaptation
Protect	Engineered structures (hard) or natural measures (soft) such as sand management to protect existing transportation infrastructure and coastal resources in their current location
Accommodate	Modify existing areas or design new corridor or infrastructure features to decrease future erosion hazard risks
Managed Relocation, Realignment, or Retreat	Relocate or realign existing transportation and critical public infrastructure out of erosion hazard areas to maximize access and use of coastal resources
Hybrid	Employ strategies from multiple categories

Choosing to “do nothing” or following a policy of “non-intervention” has no upfront costs but results in substantial disruption and economic costs over time if hazards repeatedly occur and are addressed under costly emergency responses. While many disaster-impacted communities rally around rebuilding their homes and businesses, without an approach that addresses the risks as part of rebuilding, communities are bound to relive disaster after disaster. Such a cycle is not only emotionally difficult for communities, but it is extremely costly for residents and governments over the long term.

The effectiveness of different adaptation strategies for different levels of sea level rise will vary across both spatial and temporal scales. A hybrid approach using strategies from multiple categories will likely be necessary, and the suite of strategies chosen will need to change over time. Nonetheless, it is useful to think about the general categories of adaptation strategies to help frame the discussion around adaptation and to consider the land use planning and regulatory options available to the County.

5.3.1 Consideration of Secondary Consequences

Successful adaptation planning takes a holistic view of risk and combines adaptation strategies in ways that mitigate risk across places and sectors and does not unintentionally reproduce risk elsewhere. It is important to consider the potential negative impacts of proposed adaptation actions. An adaptation measure may reduce the risk to one sector, but cause issues in another sector or lead to unintended hazard risks in some areas while increasing risk in other areas. Some adaptation measures may present secondary consequences, such as negative impacts to beaches, wetlands, and habitats, or social inequities, such as displacement, or disproportionate risks to certain populations. Decision-makers should consider these secondary consequences and mitigate or avoid them.

Often, adaptation selection requires decision-makers to choose between the preservation of coastal recreation and habitats versus the protection of the human-built upland land uses and infrastructure. In some situations, hybrid or nature-based approaches that balance the ecological preservation with risk reduction are available. Decision-makers should carefully consider the unique characteristics and community vision of the South Coast to balance short- and long-term interests, including preservation of coastal beaches and tide pools, coastal access, private property rights, and public infrastructure, recognizing that priorities may change over time. It is also critical to consider social justice and existing community inequities with every approach, which will be discussed in Section 5.5.3.

Identification of adaptation alternatives should consider a range of future time horizons. At some point, protection strategies become costly and time-consuming to maintain, and can lead asset holders to divert financial resources from more proactive longer-term strategies or realignments. If too much focus is placed on one time period—either the future or the present—vulnerabilities occurring in other time periods may be ignored, resulting in an increased likelihood of impacts from climate-induced hazards. It is important to develop easily measurable triggers (Section 5.7.1.1) that catalyze longer-term adaptation planning with enough lead time to avoid ongoing emergency responses. To do so, the County must first be able to make informed decisions based on this vulnerability assessment and other studies and determine its own level of risk tolerance.

5.3.1.1 Secondary Consequences of Protection Approaches

The California Coastal Act guides development in areas designated as a coastal zone, with the goals of protecting coastal zone environments and resources and maximizing public access to the shore, among others. Adaptation strategies need to be consistent with both the County's Local Coastal Program and Coastal Act policies and would likely need a coastal development permit to be able to be implemented. Some adaptation strategies are more likely to conflict with California Coastal Act provisions.

Coastal armoring, a protection strategy that attempts to reduce erosion by holding the shoreline in place using revetments, seawalls, or soil nail walls (see Section 5.3.2 for more detail), will adversely affect a wide range of public coastal resources and uses that the California Coastal Act protects.

The presence of coastal armoring structures such as riprap (Figure 5-2) can have negative environmental and social consequences when a footprint can bury beach or tidelands, or impede beach access and recreation. As sea levels rise, passive erosion or coastal squeeze occurs, resulting in a slow drowning of beaches and nearshore habitats. These impacts raise serious concerns about consistency with the public access, habitat, and recreation preservation policies of the California Coastal Act.

Figure 5-2. Coastal armoring adjacent to State Route 1 at Pescadero State Beach
Source: Google Earth, 2018

Coastal armoring structures may be placed in coastal waters or tidelands and harm marine resources and biological productivity, which conflicts with California Coastal Act *Sections 30230, 30231, and 30233*. Furthermore, coastal armoring structures often degrade the scenic qualities of coastal areas and alter natural landforms, which conflicts with California Coastal Act *Section 30251*. Finally, by disrupting landscape connectivity, infrastructure and armoring structures can prevent the inland migration of intertidal and beach species during large wave events. This disruption may prevent intertidal habitats, saltmarshes, beaches, and other low-lying habitats from advancing landward as sea level rises over the long term. A good example of this is the low-lying section of State Route 1 north of Pescadero Road, where blowing sand in the dunes routinely ends up on the highway rather than the pre-highway destination—North Pond and Pescadero Marsh. Currently, highway maintenance clears the road and deposits the material downcoast, disrupting the sediment supply into the marsh.

5.3.1.2 Passive Erosion

Wherever a hard structure is built along a shoreline undergoing long-term net erosion, the shoreline will eventually migrate landward to (and potentially beyond) the structure. The effect of this migration will be the gradual loss of beach in front of the seawall or revetment as the water deepens and the shore face moves landward while the backshore cannot erode. While private structures may be temporarily saved, the public beach is lost because of structure placement. This process of passive erosion is a generally agreed-upon result of fixing the position of the shoreline on an otherwise eroding stretch of coast and is independent of the type of seawall constructed. Passive erosion will eventually destroy the recreational and habitat beach area unless the shoreline is continually replenished. Excessive passive erosion may impact the beach profile such that shallow areas required to create breaking waves for surfing are lost.

5.3.1.3 Placement Loss

Figure 5-3. Example of Passive Erosion and Placement Loss

The green line indicates natural erosion with a wide sandy beach. The red line shows the passive erosion as over time the cliff erosion is slowed, but the beach in front of the armoring structure narrows.

Source: Integral Consulting, Inc.

Wherever a hard structure is built, there is a footprint of the structure. The footprint of this structure results in a loss of coastal area known as placement loss. This inevitable impact can bury the beach beneath the structure and reduce the usable beach for recreation or habitat purposes. For example, a 20-foot high revetment may cover up to 40 horizontal feet of dry sand beach. A vertical seawall or sheet pile groin typically has a smaller placement loss than a revetment or rubble mound groin.

5.3.1.4 Active Erosion

Active erosion from coastal armoring refers to interactions between coastal armoring and the physical processes that increase erosive forces. Some of these processes can include wave reflection, positive wave interference, which causes waves to get bigger before breaking, increased beach scouring, and “end effects.” In some cases, armoring may increase longshore currents, which increases the rate of beach loss in front of the structure, and in turn escalates the erosion effects at the “ends” of adjacent, unarmored sections of the coast. Active erosion is typically site-specific and dependent on the length of the structure, sand supply, wave direction, specific design characteristics, and other local factors. There is some debate in the scientific literature, particularly in areas where sediment transport direction can reverse, but there are clear indications in the Santa Barbara littoral cell of active erosion causing increases in longshore currents and resulting in seasonal coarsening of grain sizes and erosion hot spots (Revell et al. 2008).

5.3.1.5 Limits to Access

Depending on the type of structure, impacts to beach access may vary. Typically, vertical beach access (ability to get to the beach) on a cliff-backed coast can be impacted unless there are special features integrated into the engineering design of the individual structure such as stairs or contoured trails. However, if passive erosion occurs, lateral (along) beach access is usually impacted.

Figure 5-4. Example of Passive Erosion and Placement Loss Impacting Lateral Access at Stillwell Hall at Ford Ord in Monterey Ball

Left (2001) the revetment is blocking lateral access and causing passive erosion, note that there is no beach in front of the revetment.

Right (2005) following removal of the Stillwell Hall and the revetment, natural erosion processes restored the beach and allowed lateral access.

Source: Coastal Records Project, Copyright © 2019 and 2001 Kenneth & Gabrielle Adelman. All rights reserved.

5.3.1.6 Economic and Regulatory Issues

Economic and regulatory issues refer to the potential use of local, state, or federal subsidies to build or protect private property or obtain subsidized insurance coverage. An example of this includes when a private armoring structure covers a public beach, it results in a loss of public resources. Shoreline protective devices for private property should be confined to private property, but as sea level rises, and the tideline moves in, the footprint of the structure encroaches upon the public property and usability of the coastal margin, resulting in a loss of public resources. The public that used to use the beach is typically not directly compensated for this loss of valuable property, but the State Lands Commission may request leases (i.e., rent) from the owner of the protective device.

The potential economic impacts of a seawall that should be considered in an assessment of potential adaptation strategies include:

- Changes to property values
- Capital costs from seawall construction and recurrent costs associated with seawall maintenance and managing any off-site erosion impacts
- Erosion impacts on adjacent properties

- Visual amenity
- Loss of access to the recreational use of a beach.

5.3.1.7 Social Equity and Impacts to Underrepresented Communities

Another impact of shoreline protection is that it can create or exacerbate social inequity. Shoreline protection can lead to a loss of narrow public beaches and reduce public access and available space for free or low-cost recreation. For example, state beaches are free and serve opportunities to many, particularly low-income, minority, and underrepresented populations, from the local area, Bay Area, and Central Valley. Shoreline protection devices could result in a loss of public coastal access and reduce the number of people able to enjoy the coast for free or at low cost.

5.3.1.8 Ecological Impacts

Scientific studies have documented a loss of ecosystem services such as a narrowing and/or loss of specific beach ecological habitat zones and reduction in biodiversity when coastal armoring is present vs. natural beaches. This has shown to reduce habitat and cause biodiversity loss, with a reduction in kelp deposition on the beach, and result in the loss of sand crabs, shorebirds, and certain species of fish (Dugan et al. 2008).

5.3.2 Protection Approaches

Protection strategies attempt to “hold the shoreline in place” by employing some sort of engineered structure or another measure to defend development or infrastructure in its current location without changes to the development itself. Protection strategies can be divided into “gray” and “green” defensive measures, and then further divided into both “hard” and “soft” measures (Figure 5-5), as well as “protection” and “attenuation” strategies. A “gray” or “hard” approach is usually an engineered structure that can be positioned either alongshore (such as a seawall, revetment, or offshore breakwater) or cross-shore (such as a groin or harbor jetty). Green defensive strategies include beach nourishment or dune restoration that widen beaches to buffer storm erosion. These are often combined with cross-shore structures intended to trap sand and widen the beach upcoast of the structure, likely starving down coast beaches and accelerating erosion.

The location of protection determines the function. For example, an offshore breakwater is intended to stop wave energy whereas a revetment is intended to dissipate the wave energy at the shoreline and protect the cliffs, and a bluff top retaining wall is intended to protect the softer marine terrace deposits from wave overtopping that causes erosion.

Although the California Coastal Act allows protective devices for “existing development,” it also directs that new development be sited and designed not to require future protection that may alter a natural shoreline. Most protective devices are costly to construct, require increasing maintenance costs, and have secondary consequences to recreation, habitat, and natural defenses such as beaches and wetlands. Many of these consequences are forms of maladaptation, especially if the protective device is intended to be a long-term solution.

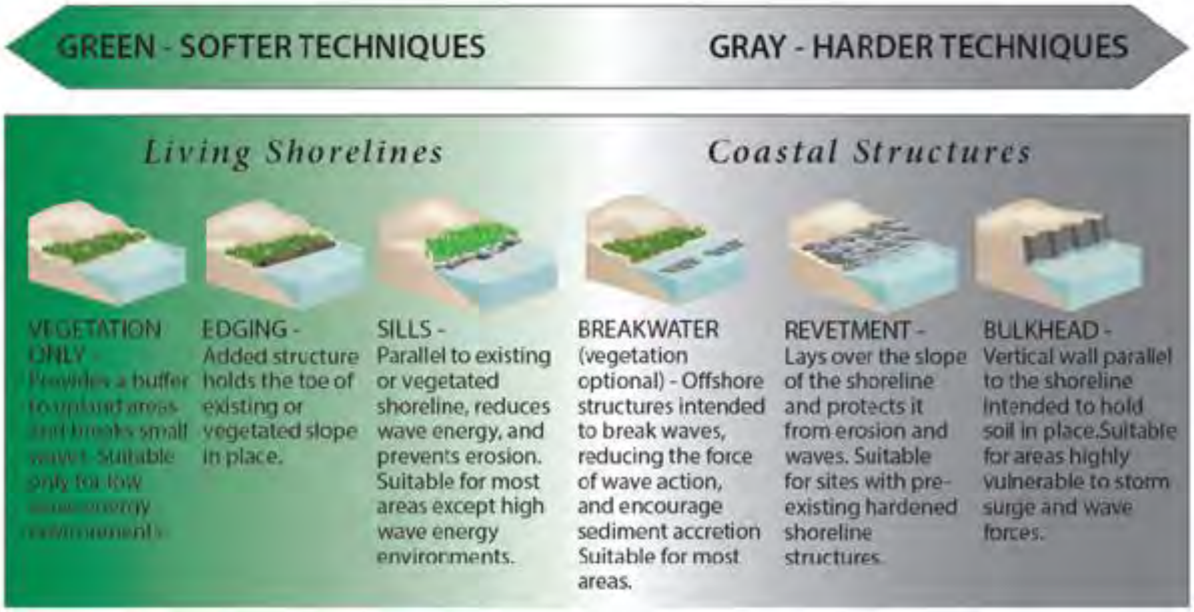


Figure 5-5. A range of green to gray adaptation strategies intended to mitigate erosion, flooding, or both
Source: NOAA Habitat Blueprint

5.3.2.1 Revetments

Revetments are engineered structures made with riprap or large rock boulders (Figure 5-6). These structures are designed to protect and stabilize areas vulnerable to erosion by absorbing and dissipating wave energy and minimizing wave run-up. An engineered revetment typically has layers: a filter layer and base rock, followed by the biggest armor stone, and then surface armor rocks placed in an interlocking pattern. Revetments require a wide footprint area, which can cover large areas of sandy beach and intertidal habitat. Most revetments are designed to be built at a 1:1.5 or 1:2 height to width ratio and thus a 30-foot high revetment can occupy a 45–60 foot wide area at its base.

Figure 5-6. Revetment to protect eroding cliffs along West Cliff Dr. in Santa Cruz
Source: Integral Consulting Inc.

Lifespan and Failure Mechanisms

The expected lifespan of these structures is about 20 years—a bit less than seawalls or soil nail walls—but lifespan is highly dependent on storm frequency, and the compounding effects of rising sea level, tides, and wave conditions. Revetments have several mechanisms for failure. One is a tendency to fail whereby "fugitive" rocks are liberated from their placement locations and fall to the foot of the structure. These fugitive rocks can then be mobilized during coastal storm events and loosen other rocks and create direct erosion. Fugitive rocks also pose a regulatory concern as they may fall into state lands or federal waters, which may conflict with regulations prohibiting the placement of foreign materials on public lands. Revetments are vulnerable to wave overtopping, whereby the sloping structure acts more like a wave ramp, leading to erosion at the top of the revetment and the soil behind. In addition, as riprap is a semi-porous material, erosion of the underlying filter layer may occur, liberating underlying soil and causing settling and development of sinkholes behind the structure. Revetments can also experience flanking and scouring, which can undermine the toe of the structure leading to settling and even collapse. While riprap is less expensive than other coastal armoring strategies such as seawalls and soil nail walls, it requires more constant maintenance to maintain adequate protection. Revetments may need to be supplemented with additional rock after large wave events.

Adaptability and Certainty of Success

Revetments have a limited capacity to adapt to changing conditions but can be elevated and extended by adding new material to provide extended functionality. Sourcing additional material can also be problematic, as large boulders of adequate size and geology may not be readily available in the local area, with some coming from as far away as the Sierra Nevada. Thus, there are high transportation (and GHG emission) costs associated with revetments, and these costs must be considered along with existing construction and maintenance costs. In the future, with higher sea levels creating more exposure of the revetments to wave energy, repairs or new revetments will require larger armor stones.

The certainty of success in the short-term is highly dependent on the foundation on which the structure sits, as well as the size, slope, internal structure, and method of construction. Over the long term, the efficacy of the structure may diminish through wear and tear, and it also may not provide the same level of protection with higher sea levels.

Revetments can be considered a maladaptive strategy as they cause placement loss of the beach, increase passive erosion, have negative impacts on native habitat, impair lateral coastal access, provide a false sense of security, incur high maintenance costs to maintain functionality, and may encourage development in high hazard locations.

Riprap is also physically difficult to remove once placed. These difficulties make it challenging to transition from revetments to another adaptation strategy.

Financial and Economic Considerations

Revetments may offer protection of vulnerable assets for the design life of the structure but require high upfront costs and lock in ongoing maintenance requirements. Historically, many of the protective structures are placed under emergency situations where they cost more and are poorly engineered, thus requiring larger investment over time to maintain protection levels. The cost of initial revetment construction is relatively high and depends on the height, length, and engineering characteristics of the rock (e.g., rock size, the volume of the structure). Indicative costs are on the order of $2,500/linear foot for dumped revetments, and $5,000/linear foot for engineered (individually placed) revetments (City of Imperial Beach, 2016).

Regulatory

In general, revetments are viable from an existing regulatory perspective, although the CCC prefers to avoid new coastal armoring, except under either emergency situations or as part of a more comprehensive management approach.

Feasibility

Revetments are potentially feasible in the South Coast area, depending on site-specific assessments.

5.3.2.2 Seawalls

Description

Seawalls refer to a variety of typically vertical coastal armoring structures designed to stop erosion. At the base of the sea cliffs, seawalls are designed to reflect and/or dissipate wave energy from the cliff, and along the bluff top, seawalls are designed to limit soil erosion from wave run-up and splash. Along the open coast, seawalls are typically constructed using thick concrete blocks or poured concrete and are occasionally made from sheet piles or wood. Recurved seawalls have a lip, which helps to change the reflected wave energy dynamics.

Figure 5-7. Seawall along West Cliff Drive in Santa Cruz
Source: Integral Consulting Inc.

Lifespan and Failure Mechanisms

Seawalls are typically constructed with an expected lifespan of approximately 30 years. The actual lifespan may vary depending on the specific locations, frequency of wave exposure, quality of construction, and whether the seawall undergoes regular monitoring, maintenance, and repairs to preserve its effectiveness. In the near term, seawalls typically have a very high certainty of success, but over time, the certainty of success diminishes as the frequency and duration of wave attack gradually weakens the structural integrity of the seawall and may scour the base resulting in eventual collapse.

Seawalls, like revetments, can experience active erosion impacts such as increased erosion at the end of the structure and scouring at the base. Scouring can undermine the toe of the structure leading to settling and potential collapse. Over time, concrete and reinforcing rebar can corrode and lead to cracking and decay of the structure. Seawalls can also fail from the inland direction as well, by trapping water on their landward side leading to soil loss and deteriorating the support or foundation of the wall. Similarly, wave overtopping can lead to water buildup landward of the wall resulting in the same water trapping issues.

Adaptability and Certainty of Success

Seawalls have a low adaptive capacity, with little ability to adapt to naturally changing conditions, but with additional engineering and substantial cost, these structures can often be elevated or improved to provide extended lifespan functionality. Initial design and engineering of a more substantial footing and base of the structure may facilitate future refinements in crest elevation. Seawalls can be considered maladaptive as they are rigid, encourage continued use and development in hazardous erosion areas, and may create more catastrophic consequences when they fail.

Financial and Economic Considerations

The cost of initial seawall construction is relatively high and depends on the height, length, and specifics of the engineering of the structure. Some additional construction costs may include any in-lieu fees that may be required (such as sand mitigation, beach recreation, or beach ecology fees). Indicative construction costs are substantially higher than for riprap revetments, on the order of $5,000–$10,000 per linear foot (City of Imperial Beach, 2016; Pers. Comm., City of Pacifica, 2021).

Once constructed, seawalls tend not to require a lot of maintenance, so the maintenance costs are relatively low until the latter half of the lifespan. Removal costs must be considered at the end of the seawall lifespan. Given the low adaptive capacity, it is likely that the structure would have to be removed or substantially retrofitted in the future. These costs may be moderate to high depending on the access and conditions at the time of removal. If the seawall is to be retrofitted, then it may reduce some long-term costs to over-build the base of the structure during initial installation to accommodate an increase in seawall elevation in the future.

The placement loss or impacts from the footprint of the structure on the beach is less than that of a revetment, so a change from existing revetments to a seawall could be considered a positive for beach recreation. Seawalls may also be preferred where there is a requirement to site the structure within a private property boundary.

Secondary Consequences

Seawalls, like revetments, tend to have substantial secondary consequences, particularly to beach access and especially over time. Reflected wave energy can increase the scour of the fronting beach, accelerating the loss of this habitat and recreational amenity. Engineers can partially address some of the access and scour concerns (Figure 5-7 above) in the short term by integrating stairs to provide vertical access or a recurved aspect at the top to help offset scouring and eventual loss of the beach in front of the structure. Over the long term, coastal squeeze is inevitable, and the beach and fronting habitats would eventually be lost.

Regulatory

In general, seawalls are viable from an existing regulatory perspective, although the CCC typically frowns on new coastal armoring, except under either emergency situations or as part of a more comprehensive management approach. Once the seawall is located below MHW, then the California State Lands Commission (CSLC) has regulatory authority.

Feasibility

Seawalls cost more and require more design and lead time to construct than revetments. Given the high cliff-backed shorelines, the seawalls would protect only the base of a cliff allowing for other land-based erosion to occur. Seawalls are unlikely to be feasible given the higher cost and advanced planning required to implement these along public rights-of-way.

5.3.2.3 Soil Nail Tie-back Walls

Description

Soil nail tie-back walls are a type of coastal armoring protection constructed with an outer layer of sprayed concrete, also known as Shotcrete or Gunite, and derive their structural strength from soil nails and tiebacks that are drilled into the cliff and used to bind the structure to the cliff behind. The sprayed concrete allows natural cliff forms to be maintained. These structures are designed to stop erosion and provide bluff stabilization. They can be more expensive to construct than riprap but have a much smaller horizontal footprint and can be designed with natural elements to improve access, enhance ecology, and reduce aesthetic concerns.

Some of the aesthetic concerns with seawalls and revetments can be mitigated for soil nail tie-back walls. Techniques can be used to mimic the color and texture of the surrounding natural cliffs, allowing the structures to blend into their surroundings. In high cliff-backed sections of the coast, this is one of the more feasible protection strategies, as the vertical seawalls and revetments do not address the erosion of the upper portion of the cliffs. As an example, the City of Santa Cruz constructed a soil nail wall to attempt to address ongoing erosion issues along properties adjacent to West Cliff Drive (Figure 5-8).

Figure 5-8. Soil tie-back wall in Santa Cruz contoured and textured to mimic the natural landforms
Source: Integral Consulting Inc.

Lifespan and Failure Mechanisms

Soil nail tie-back walls are typically constructed with an expected lifespan of approximately 30 years; however, expected lifespan may vary depending on the specific locations, frequency of wave exposure, quality of construction, management of water behind the wall, and whether the wall undergoes regular monitoring, maintenance, and repairs to maintain its effectiveness. In the near-term, soil nail walls typically have a very high certainty of success; however, over time, the certainty of success diminishes if the frequency and duration of wave attack on the structure gradually increases over time.

Soil nail tie-back walls, like seawalls, can experience active erosion impacts such as end flanking and scouring. Scouring can undermine the toe of the structure leading to settling and even collapse. Over time, the concrete and reinforcing rebar can corrode and lead to cracking and decay of the structure. These walls can also fail from the inland direction as well, by trapping water on their landward side leading to soil loss, water pressure buildup, and deteriorating the support or foundation of the wall. As a result, adequate drainage is necessary to minimize these issues. Similarly, wave overtopping, or misdirected stormwater can lead to water buildup landward of the wall, leading to further structural degradation.

Adaptability and Certainty of Success

Soil nail tie-back walls have a low adaptive capacity with little ability to adapt naturally to changing conditions. These walls can be considered maladaptive as they are rigid, encourage continued use and development in hazardous erosion areas, and may create more catastrophic consequences when they fail.

Financial and Economic Considerations

The initial cost of soil nail tie-back wall construction is higher than revetments and seawalls and depends on the height, length, quality, and quantity of concrete, aesthetic treatments, and specifics of the engineering of the structure. For a wall along the high bluffs in Pacifica, the cost was approximately $15,000 to $25,000 per linear foot, which is likely in the middle to upper range for these types of projects (Papendick and Marquez 2021, pers. comm.).

Some additional construction costs may include any in-lieu fees that may be required (such as sand mitigation, beach recreation, or beach ecology fees). In the short-term following construction, these walls tend not to need a lot of maintenance, so the maintenance costs are relatively low until the second half of the lifespan. Additional lifespan costs to consider include the removal cost. Given the low adaptive capacity, it is likely that the structure could be removed or substantially retrofitted in the future. Retrofitting costs would likely be much higher than those associated with other protective structures due to the need to remove the tiebacks, a process that may further exacerbate erosion and affect the access and habitat conditions at the time of removal.

The placement loss or impacts from the footprint of the structure on the beach is less than that of a revetment and may be less than that for a seawall, so a change from existing revetments or seawalls to a soil nail wall could be considered a positive for beach recreation. This is dependent on the extent of cliff-toe protection required, which may be equivalent in footprint to that of a seawall.

Secondary Consequences

Soil nail tie-back walls tend to have substantial secondary consequences, particularly to beach access over time. Reflected wave energy can increase the scour of the fronting beach accelerating the loss of this habitat and recreational amenity. A benefit of the soil nail wall approach is that additional design considerations can be integrated to improve access, aesthetics, and ecology. For example, a bench or terrace contoured into the structure may support or improve lateral access. Small pockets in the face could also provide some ecological benefits to roosting, nesting, or vegetation. This and other design factors such as recurved elements could be designed to help offset some of the secondary impacts of reflected wave energy and scour more so than other protection approaches.

Visual amenity impacts of these structures are relatively low, particularly when color and texture treatments are applied to match adjacent cliff faces.

Regulatory

In general, soil nail tie-back walls are viable from an existing regulatory perspective, although the CCC typically frowns upon new coastal armoring except under either emergency situations or as part of a more comprehensive management approach, usually applied in more urban settings. Soil nail tie-back walls could be potentially applied to all the high-backed cliffs in the area, although the costs of this approach may be comparable to those associated with realignment.

Feasibility

Soil nail tie-back walls cost more and require more engineering design and lead time to construct than seawalls but they may be the only feasible option to protect high cliff-backed shorelines from coastal and land-based erosion. However, given the extremely high cost, this strategy is not likely feasible except perhaps in some very specific erosion locations.

5.3.2.4 Levees

Levees are typically berms made of earthen materials and offer flood protection in riverine and tidally influenced estuarine locations (Figure 5-9). Multiple levees and dikes are currently in use within the Pescadero Marsh and provide some protection to the community of Pescadero. Levees are not applicable to the open coast high wave environment. Typical levees require at least 60 to 80 feet from the inside to outside toe, as well as additional 20 to 40 feet of right-of-way on each side to maintain good performance. One benefit to levees is that when properly designed, the top of the levee can serve as a walking or bike path. Levees, when vegetated can be considered an aesthetic improvement over-engineered structures like revetments, although they may reduce the views of neighboring properties depending upon their crest elevation.

Figure 5-9. Example of a levee constructed along the banks of the Humboldt River to help prevent flooding

Source: humboldtgov.org.

Horizontal Levees

Horizontal levees differ from traditional levees in that they have lower or flatter slopes that, while requiring more space, can allow for habitats to migrate upslope. Horizontal levees are considered a hybrid greener more nature-based approach. Constructing engineered horizontal levees made of natural and native material also provides habitat to shorebirds and other species and could prove promising in more open space areas where State Route 1 is set back far enough.

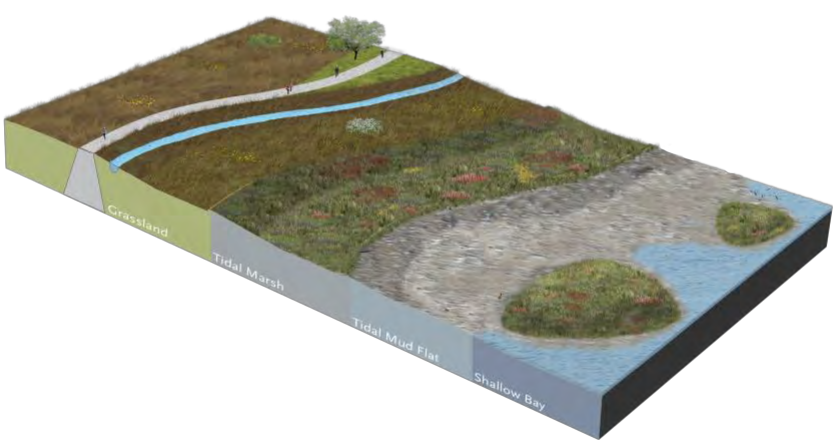


Figure 5-10. Artistic rendering of a Horizontal Levee.

Source: Bay Ecotarium

Lifespan and Failure Mechanisms

Over time, levees will experience erosion and scouring. Unless they experience significant hydrostatic pressures from a major flood event, they are usually less likely to catastrophically fail and more likely to experience slow erosion over time.

Adaptability and Certainty of Success

Levees have moderate adaptive capacity. With enough buffer space on either side of the levee toe, levees can be raised later if required. With minimal wave exposure, levees have a high certainty of near-term success and although the success may diminish slightly in the long-term, if there is a proper maintenance program set in place, the future certainty of success will remain high. Levees however do not protect from rising groundwater levels that may occur on the opposite side of the water body that they are designed to protect.

Financial and Economic Considerations

Levees have a moderate to high upfront cost depending on the proximity of fill material and the degree of soil conditioning needed, but the cost is significantly lower than open coast revetments and other structures. Typical costs can be as low as $300 and as high as $1,000 per linear foot (ESA 2018). Levees may require significant ongoing maintenance to retain their effectiveness depending on the velocity and frequency of storm flows.

Levee construction requires a substantial footprint, and therefore the highest costs are associated with purchasing sufficient land for construction. Costs increase with the size and complexity of the levee. In the Pescadero region, levee siting considerations would need to consider spatial impacts on natural habitats and productive agricultural lands.

Confinement of land area can have a high environmental impact, particularly when the hydrological regime is altered. Construction should consider the incorporation of native plants and wetland rehabilitation to reduce ecological impacts. Levees may also block views and have some negative aesthetic considerations depending on the terrain and where sightlines exist. In the Pescadero region, levee siting considerations would need to consider spatial impacts on natural habitats and productive agricultural lands.

Secondary Consequences

The displacement and confinement of land area can have a high environmental impact, particularly when the hydrological regime is altered. Construction should consider the incorporation of native plants and wetland rehabilitation to reduce ecological impacts. Levees can also block views and may have some negative aesthetic considerations depending on the terrain and where sightlines exist.

Regulatory

Stakeholders would need to consider the spatial impacts of levees on natural habitats and productive agricultural lands as well as recreational trail access benefits.

Feasibility

Levees may be a feasible option in Pescadero Marsh and other low-lying areas.

5.3.2.5 Groins

Sand retention structures such as groins are oriented perpendicular to the coast in a cross-shore direction and are designed with the intention of trapping and retaining sediment to widen the beach and allow the beach to reduce wave energy and reduce erosion (Figure 5-11). Sand retention structures are effective only in areas where there is a dominant sand transport direction. The trapping of sand upcoast of the retention structures creates sand “fillets” or wider beaches, which act as protective barriers to wave energy and increase coastal recreational resources. However, obstructing the naturally occurring transport of sediment along shore can deplete downcoast beaches of their sediment supply and shift erosion to those areas.

Figure 5-11. Groin at Newport Beach, California, showing fillet on upcoast side
Source: Coastal Records Project, Copyright © Kenneth & Gabrielle Adelman. All rights reserved.

Lifespan and Failure Mechanisms

Structurally, a groin must resist wave action, currents and scour effects, impact from debris, and pressures created by the differences in sand elevation both upcoast and downcoast. The expected useful lifespan of a rigid structure is highly dependent on its unique conditions but likely around 30 to 40 years.

Adaptability and Certainty of Success

Groins have low to moderate adaptive capacity. The certainty of success in the short term is medium and highly dependent on local wave-current conditions, as well as structure design such as porosity, height, and material strength.

Financial and Economic Considerations

Groins have similar construction costs to revetments, on the order of $3,000 to $5,000 per linear foot (City of Imperial Beach, 2016). The cost of sand retention structure construction varies depending on the height, length, quality, and source of materials, as well as specifics of the engineering of the structure. Some additional construction costs may include any in-lieu fees that may be required (such as sand mitigation, beach recreation, or beach ecology fees). Once constructed though, these structures tend not to need a lot of maintenance, so the maintenance costs are relatively low until the latter half of the lifespan when the structure either deteriorates or the upcoast side fills to capacity with sediment and results in sediment bypassing the structure. Additional lifespan costs to consider include the removal cost as given the low adaptive capacity, it is likely that the structure would have to be removed or substantially retrofitted in the future.

In addition to restricting alongshore sand movement, groins limit movement by beach users and can create rip currents or downcoast erosion. This may cause greater life safety hazards for swimming, surfing, and other water sports.

Secondary Consequences

Sand retention structures have the potential for substantial secondary consequences including downcoast erosion, limiting beach access, creating rip currents, and increasing hazards for swimmers and kayakers.

To minimize the downcoast erosion, it is important to fill or "charge" the retention structure with sand so that sand moving alongshore in the system is not trapped, but rather continues along a filled beach or "sand fillet." Occasionally, groins are used in connection with a sand placement program to help retain recreational beaches for longer periods of time. The loss of the beach from the footprint of the structure is another consideration. However, sand retention structures also result in beach widening. Therefore, when resulting beach widening is considered with the structure's placement loss, there is typically a net benefit for beach recreation.

Regulatory

The CCC has not approved any new sand retention structures in quite some time. Any projects that fall within the bounds of the Monterey Bay National Marine Sanctuary (MBNMS) require approval from them to proceed. The South Coast is within the MBNMS and obtaining permits could be a substantial regulatory hurdle. Groins would have limited application in the pocket beaches within the study area.

5.3.2.6 Offshore Breakwaters and Artificial Reefs

Offshore breakwaters and artificial reefs are constructed to reduce erosion by reflecting, breaking, and dissipating wave energy before waves impact the shoreline. The difference between these two types of structures is the elevation relative to the water level; breakwaters are visible through all tides and stop wave energy (Figure 5-12) whereas artificial reefs tend to be submerged during most of the tidal cycle and cause waves to break offshore and dissipate the wave energy before it reaches shore (Figure 5-13). In some cases, these strategies can create calm conditions shoreward of the structure allowing sediments to deposit and form a tombolo or sand structure that can connect to the offshore structure creating a wider beach and buffering erosion. Breakwaters are typically used for navigational purposes, particularly port and harbor construction, but other locations have also been built to enhance habitat, surfing, and dive recreation.

Figure 5-12. Breakwater helping to dissipate wave energy at San Pedro, California

Source: Daily Breeze: Army Corps of Engineers to Spend $14 million on San Pedro and Long Beach Breakwaters

Figure 5-13. Artificial reef emplaced at Narrow Neck, Australia
Source: seabreeze.com.au

Artificial reef structures have been constructed from riprap boulders, geotextile bags, oysters, used tires, concrete reef balls, and even scuttled ships to reduce erosion, enhance habitat and improve surf, diving, and fishing opportunities. In sheltered locations, oyster reefs have shown promise as a living shoreline. But along the energetic, open Pacific Ocean, oyster reefs and all the other materials aside from riprap boulders would likely do nothing to reduce erosion.

Artificial reef structures have been tested around the world to improve local surf conditions and reduce erosion. Most of these experiments have been conducted in Australia, with others in India, the U.K., and the U.S. mostly using geotextile bags placed or anchored to the ocean floor. The U.S. example, “Pratte’s Reef” (aka Chevron Reef) was constructed using small geotextile bags in Santa Monica Bay in 2000 as mitigation for the loss of a surf spot from the construction of the Hyperion Sewage Treatment Plant. It was removed in 2008 (as planned) for more than it cost to install after showing little to no success at recreating a surf spot or improving its habitat (Fontaine, 2008). In a recent example, an artificial reef was completed in 2019 on the Gold Coast of Australia at Palm Beach at a cost of USD $18.2 million using layers of rock (SWS Stormwater Solutions, 2019). Intended to focus wave energy and build a sand retention tombolo, its efficacy in reducing erosion is still being evaluated.

Lifespan and Failure Mechanisms

The lifespan of these structures and failure mechanisms depends on the type of materials, for instance, the geotextiles can be ripped or punctured by debris or vandalism, while rock reefs and offshore breakwaters have lasted for many decades. Failure of the rock mound breakwaters is typically caused by settling or deterioration similar to a revetment in which the structure sheds fugitive rocks and or flattens its slope allowing additional overtopping or less effective wave energy dissipation.

Adaptability and Certainty of Success

The effectiveness of these structures and their lifespan is uncertain and highly dependent on materials used in construction, wave conditions, bathymetry, and structural design. Any offshore structure would only provide localized erosion reduction.

Financial and Economic Considerations

The cost for any marine construction in an energetic wave environment is extremely high with maintenance costs varying based on the type of material and structure. For example, a reef on the Gold Coast, Australia, that was designed for erosion reduction and surfing amenities had a construction cost of approximately USD $18.2 million (SWS Stormwater Solutions, 2019). This did not include substantial design costs or many years of shoreline monitoring and sand nourishment, and this was only one component of a regional sand and erosion mitigation strategy. Multipurpose reefs that attempt to provide surfing amenities have had limited success and require extensive and costly design work. Fishing and diving structures have a greater likelihood of success and may not require the same level of design expertise. Costs remain high for all offshore structures.

Secondary Consequences

Secondary impacts are uncertain and likely very site specific, beyond the scope of this study. Some offshore structures may be beneficial in reducing erosion, widening beaches, improving offshore marine habitat, and enhancing surf. Others may also focus wave energy, increasing erosion, narrowing beaches, and degrading surf spots and habitats. Any offshore rock placement may change sandy habitat to rocky habitat, with associated ecological impacts.

Regulatory

From a regulatory perspective, particularly considering the Monterey Bay National Marine Sanctuary (MBNMS) regulations that discourage marine construction, the subtidal leases required from the CSLC, and the rural nature of the South San Mateo County Coast, it is unlikely under current regulations to be a viable adaptation strategy based on any cost–benefit analysis and the localized effect on reducing erosion.

5.3.3 Protection—Nature Based “Green” Approaches

Given the negative ecological impacts of coastal armoring solutions, many South Coast stakeholders prefer nature-based approaches. The goal of nature-based approaches is to decrease or slow down erosion and provide flood protection using natural physical processes. Nature-based features can be artificially designed, engineered, and constructed to mimic nature and may include sediment management. When implemented correctly, nature-based solutions can be more self-sustaining after the initial establishment phase, resulting in lower ongoing maintenance costs. Nature-based options may be legally required to mitigate the impacts of hard structures, are more favorably looked upon by permitting agencies, and can offer added benefits such as water filtration, wildlife habitat, and recreational opportunities.

The South Coast benefits from having an undeveloped shoreline where natural processes remain functional and could prove a great candidate for testing natural protection opportunities. Such pilots would be low risk due to the absence of substantial adjacent infrastructure, but high reward in terms of research value and development of effective nature-based adaptation strategies.

5.3.3.1 Sand Nourishment

Sand nourishment can occur either as one-off projects, or continuing programs. Sand nourishment refers to efforts to maintain or increase the local sediment to widen beaches, increase coastal recreational opportunities, mitigate coastal erosion, and offset the secondary consequences of coastal armoring (Figure 5-14). Sand nourishment programs tend to be cyclical and can take the form of large and expensive beach nourishments that place large volumes of sand to widen beaches. Smaller sand management programs can also be in the form of a sand bypass from a harbor (e.g., Pillar Point Harbor bypass to Surfers Beach), or a localized placement that adds sand at a specific location on a periodic basis. Such programs aim to create higher sand levels and improve coastal recreation and access. Sand may be transported downcoast to enhance beaches and coastal recreational opportunities away from the site of placement.

Figure 5-14. Beach nourishment ongoing at Ocean Beach in San Francisco, California

Source: USACE Ocean Beach Beach Nourishment

Sand management in California has historically been of four types—large construction-related sand placements, site-specific beach nourishments, small opportunistic placements, and routine sand bypassing associated with harbor maintenance and navigation. The most common sand management type in California is harbor bypassing, dredging sand from one side of a harbor to the other to maintain navigation channels and minimize erosion to downcoast beaches. This final type of sand management is being considered at Pillar Point Harbor in Half Moon Bay to alleviate some of the erosion issues downcoast at Surfer's Beach.

Lifespan

The lifespan of a sand management program varies depending on the size, volume, and location of placement and is dependent on seasonal and annual variability in wave climate. It is difficult to determine the lifespan for South County beaches given the wide range of uncertainty around each of the placements.

Adaptability and Certainty of Success

Beach nourishment programs are relatively adaptable and could be applied at many locations as needed. The certainty of success is very low as it is inevitable that the sand will eventually move downcoast, and the nourishment will do little to reduce cliff erosion. The primary benefit if conducted would not be primarily to reduce erosion, although it would have that effect, but rather to mitigate coastal armoring impacts by increasing sand supply to the small pocket beaches along the South Coast.

Financial and Economic Considerations

The cost of implementing a program, as opposed to one-time opportunistic nourishment, and repeating it periodically depends on the volume of sand required, the source of sand (onshore or offshore), and the transport costs needed to move the sand resources to the deposit site. Large beach nourishments can be on the order of 1 million cubic yards and can cost between $10 million and $30 million (SANDAG, 2009), likely to be too high to be viable, given the cost-benefit analysis in the South Coast, with limited reduction of erosion and low value of recreational use that would be achievable on this rural stretch of coast.

Nature-based sand nourishment projects are typically cheaper to construct than hard protective structures, but on a proportional basis, they have higher maintenance requirements than hard structures. Estimated costs range from $1,000 per linear foot for vegetation to $5,000 for approaches that incorporate dune construction and large-scale beach nourishment. Annual maintenance costs range between 10% and 40% of the installation cost (City of Imperial Beach, 2016), with higher maintenance costs associated with projects where sand is placed in high-energy environments.

Secondary Consequences

Secondary consequences associated with a sand nourishment program can be both positive and negative. On the positive side, sand nourishment expands the width of the beach, temporarily improves coastal and nearshore recreation, and provides minor reductions associated with less maintenance costs for coastal armoring. This enhanced beach width can improve recreation and sandy beach wildlife habitat. On the negative side, short-term construction impacts, including noise, aesthetics, and potentially turbidity would occur while in the longer-term, the ongoing cost of placing sand would likely escalate and the time between beach placement cycles would narrow. The temporary impacts of construction could reduce recreational opportunities, while imported sand does not provide the same habitat value. In addition, sand placement can cover rocky intertidal habitats.

Regulatory

The construction process of placing sand by truck or by barge and dredge may trigger nuisance complaints. From a regulatory perspective, the CCC and CSLC have previously permitted beach nourishment-type activities in California. However, MBNMS currently has a regulation prohibiting the placement of sediment in Sanctuary waters (defined as waters below MHW). This regulation is currently under review in consideration of various proposed adaptation projects in both Monterey and Half Moon Bay and may be revised. In some cases, it may also be possible to place the sand above MHW, reducing the impact and associated regulatory concerns. If this strategy shows promise and communities and decision-makers decide to explore sand nourishment for the South Coast, then additional discussions with MBNMS and USACE would be warranted.

Feasibility

Sand nourishment projects or programs are likely not feasible due to the associated regulations of the MBNMS, the high cost, and the inability to reduce cliff erosion.

5.3.3.2 Dune Restoration

Dune restoration is the process of both restoring and assisting in the development of new coastal dunes and may include beneficial placement of sand to form back-beach dunes. This can serve as a natural way to mitigate backshore erosion and maintain a wider beach. This process is suited for wider beaches and can be effective in slowing erosion in low to moderate wave energy sites. For any potential project, it would be necessary to determine if the topography and nearby land uses allow for the inland migration of dune habitat with sea level rise. In addition, careful consideration of existing beach width, wave climate, wind direction, and local habitat is recommended. A hybrid approach could involve the placement of cobbles or different center matrix of natural materials incorporated into the dunes (Figure 5-15).

Lifespan

The lifespan of a dune restoration varies depending on the size and volume and is highly dependent on seasonal and annual variability in wave climate. The lifespan of a dune that is restored using a more erosion-resistant core, placing cobbles at the toe, and planting dune vegetation will be longer than one without those measures. It is difficult to determine the lifespan for South County restored dunes given the wide range of conditions that may act on them in the future.

Adaptability and Certainty of Success

Dune restorations are relatively adaptable and could be applied at many low-lying locations as needed. The certainty of success is low to moderate as the dune will eventually erode if not maintained. The inclusion of a resistant core, basal cobbles, and a rigorous dune planting program will increase the certainty of success. Dune restoration is not intended to reduce cliff erosion, as a dune placed in front of a cliff would erode and provide little protection. The primary benefit would be to mitigate dune loss in the lower-lying recreational areas of the South Coast.

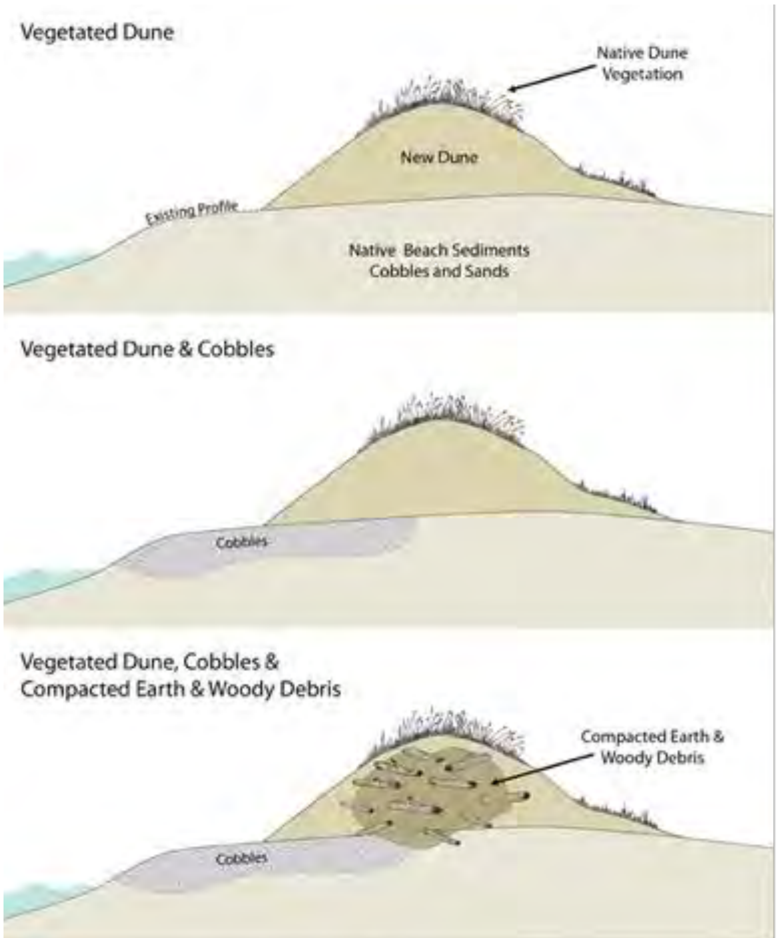


Figure 5-15. Examples of potential dune design concepts
Source: Integral Consulting Inc.

Financial and Economic Considerations

The cost of restoring, maintaining, or repairing dunes depends on the volume of sand required and the transport costs needed to move the sand resources to the deposit site. Dune restoration would be more cost-effective than beach nourishment, given that it is a smaller, location-specific strategy.

Nature-based dune restoration is typically cheaper to construct than hard protective structures, but the costs do increase with the amount of upfront construction, specifically whether resistant core, cobble base, and extensive planting is implemented. They should be relatively inexpensive to maintain but would require a monitoring program and repairs to be made when damaged. Estimated costs range from $1,000 per linear foot for vegetation planting only to much higher amounts for approaches that incorporate structured design with cobbles and resistant cores. Annual maintenance costs range between 10% and 40% of the installation cost (City of Imperial Beach, 2016), with higher maintenance costs associated with projects where sand is placed in high-energy environments.

Secondary Consequences

Secondary consequences associated with dune restoration can be both positive and negative. On the positive side, dune restoration provides protection to assets and creates dune habitat. An enhanced dune can improve dune wildlife habitat. On the negative side, restoring the dune may result in the loss of some of the open beach, which would impact recreation, and short-term construction impacts, including noise and aesthetics, would occur. Over time, the cost of repairing and replanting would likely increase and the time between these needed repairs would narrow.

Regulatory

From a regulatory perspective, the CCC and CSLC have previously permitted dune restoration activities in California. If the restoration would occur above MHW, there would be no regulation issues with MBNMS, but if it was below MHW then the MBNMS and USACE would have regulatory input.

Feasibility

Dune restoration projects are likely a feasible action in limited low-lying areas if they are constructed above MHW. They would not be successful for preventing cliff erosion.

5.3.3.3 Cobble Berms

Cobbles are rocks that are rounded as they move downstream along the bottom of the creeks, transported during high flow or extreme flood events. Cobbles range in size from baseball to watermelon size and behave differently than sand when subject to wave activity, providing a valuable natural defense by dissipating wave energy (Figure 5-16). Along with sand, cobbles are an important component of beach sediment on the Central Coast. The sediment is largely derived from watersheds and cliff erosion, both of which play an important role in beach resilience. Cobbles are usually found at the back of the beach or the toe of the cliffs.

During winter wave events, cobbles dissipate large wave run-up by absorbing the water into the void spaces between the rocks. If enough cobbles are present, it is called a dynamic revetment or cobble berm and it can substantially reduce the velocity of wave run-up that would otherwise cause coastal erosion. Cobbles have a high adaptive capacity by being able to move up vertically and inland during high wave events and naturally responding to wave conditions.

Lifespan

The lifespan of cobble berms varies depending on its size and volume and is highly dependent on wave climate. Cobble berms have a much longer lifespan than either nourished beaches or restored dunes. The lifespan of a cobble berm is difficult to determine for South County given the wide range of conditions that may act on them in the future, but feasibly they could last a decade and be a good interim measure to buy time while longer-term adaptation planning occurs.

Figure 5-16. Cobble berm in Ventura, California, provides protection to the beach from erosion
Source: Ventura River Ecosystem

Adaptability and Certainty of Success

Cobble berms are relatively adaptable and could be applied at as many locations as needed. The certainty of success is moderate to high in the short-term, but they would require repair or restoration periodically if they erode during large storm events. They could potentially provide some protection from cliff erosion by slowing basal notching of the cliff, but the cobbles, especially smaller ones, may accelerate cliff erosion via abrasion. If constructed, the primary benefit would be to provide short term protection for the coastal infrastructure along the South Coast while longer-term strategies are being planned.

Financial and Economic Considerations

The cost of creating, maintaining, and repairing cobble berms depends on the volume of cobbles required and the transport costs needed to move the cobbles to the construction site.

Nature-based cobble berms are typically cheaper to construct than hard protective structures but with less certainty. They can be relatively inexpensive to implement and maintain but require a monitoring program and renourishment program when damaged. Estimated costs vary widely depending on the source, transportation costs, and equipment needs. Annual maintenance costs also vary depending on location, wave exposure, and storm frequency with higher maintenance costs associated with projects where cobbles are placed in high-energy environments.

Secondary Consequences

Secondary consequences associated with cobble berms can be both positive and negative. On the positive side, cobble berms provide natural protection to assets, maintain access, and create cobble beach habitat. On the negative side, constructing a cobble berm may narrow the sandy portion of the beach, which could impact recreation, and during large storm events cause errant cobbles to be transported inland. Over time, the cost of repair would likely increase and the time between the needed repairs would narrow.

Regulatory

From a regulatory perspective, the CCC and CSLC have previously permitted cobble berms in California. However, it remains a more innovative approach and the lack of understanding of cobble transport dynamics by regulatory agencies remains a regulatory hurdle. However, because the restoration would occur above MHW, there would not likely be regulatory issues with MBNMS.

Feasibility

Cobble berm projects are likely a feasible action at site-specific low-lying locations. They would potentially help reduce wave attack at cliff-backed locations but would not protect cliff erosion caused by terrestrial erosion mechanisms.

5.3.4 Accommodation Strategies

Accommodation strategies refer to the range of adaptation strategies that employ methods that modify existing development or infrastructure, or place development in areas that decrease hazard risks and increase resiliency. On an individual project scale, accommodation strategies include actions such as elevating structures, building causeways, and flood proofing. In addition, using materials meant to increase the strength of development, refining building codes that encourage structure foundations that can more easily be relocated, or increasing the setbacks from erosion hazard areas are types of accommodation.

At a high level, accommodation strategies result in the least community disruption, as they do not change the location or spatial extent of existing assets. Apart from elevating road and bridge assets, accommodation approaches have limited impacts on tourism and recreation within the region.

On an individual project scale, accommodation strategies may include actions such as elevating structures, performing retrofits, using materials to increase the strength of development to handle additional wave impacts, building structures that can easily be moved and relocated, or using additional setback distances to account for the acceleration of erosion. On a community scale, accommodation strategies include many of the land use designations, zoning ordinances, or other measures that require the above types of actions, as well as strategies such as clustering development in less vulnerable areas or requiring mitigation actions to provide for the protection of natural areas.

5.3.4.1 Setbacks

Setbacks usually require development to be placed at a measurable distance from an identifiable location such as a cliff edge, dune crest, property boundary, or roadway. Lateral setbacks do not directly address coastal erosion, but rather accommodate erosion by allocating more space for it to occur before any development is at risk. In many jurisdictions with private ownership of the oceanfront land, increasing setbacks to account for accelerated erosion potentially delays future damages or the likelihood that coastal armoring will be required in the future. Another type of setback is a vertical setback that requires a structure to be above a certain flood elevation and may require building on higher ground or elevating existing structures. This would be applicable to lower lying areas such as Martin's Beach.

Setbacks are often implemented during initial development or redevelopment. Currently, the County's Local Coastal Program (San Mateo County 2013) requires consideration of a 50-year life span for the proposed structure and includes a minimum setback of 50 feet or a line described by the intersection of the toe of the cliff at a 20° angle. This means that for any cliff less than 140 ft, the 50 foot setback governs.

Many planning departments have setback requirements based on a calculated distance. Often an average annual erosion rate is multiplied by the expected life of the development on private property. This extrapolation of historical conditions does not account for the acceleration of erosion or deepening of flood depths that are likely to occur with sea level rise. The County could opt for an increase in setbacks that consider accelerated erosion due to sea level rise with an additional factor of safety to reduce the vulnerabilities to future development.

In constrained locations with small parcels along the coastal bluffs west of Highway 1, setbacks from the inland property boundary line may need to be relaxed to allow for future redevelopment to move away from the hazard while staying within the parcel. Parcels along the coastal bluffs west of Highway 1 are mostly zoned Planned Agricultural District/Coastal Development District (PAD/CD), with a few zoned Resource Management District/Coastal Development District (RM-CZ/CD), both of which currently require 50 foot front setbacks. The County could explore relaxing that setback to allow for development to move further away from the hazard area. Another example of this setback could also occur via micro road realignments to State Route 1 in which the road is moved landward within the existing right-of-way to accommodate another 12 to 20 feet of erosion.

Alternatively, given the predominantly public ownership along the South Coast, a setback from the cliff edge could be focused on maximizing available public space from the cliff edge to increase resiliency.

Figure 5-17. Setbacks required by the California Coastal Act accommodate cliff erosion without endangering infrastructure

Photo shows pre- and post-Coastal Act development.

Source: Coastal Records Project, Copyright © Kenneth & Gabrielle Adelman. All rights reserved.

Lifespan

The expected lifespan of an oceanfront development is typically used in the calculation of the setback. Currently, the County's Local Coastal Program (San Mateo County 2013) minimally requires at least consideration of a 50-year expected lifespan of any new structure.

The County could choose to specify an expected lifespan of any redevelopment or adopt a certain amount of sea level rise that should be considered in any development such as the current state guidance for medium–high risk aversion of 6.9 feet by 2100. The lifespan of the setback depends on the amount of time or elevation of sea level rise considered in its determination. More setback distance provides more time.

Adaptability and Certainty of Success

Setbacks have a moderate adaptive capacity as more space or elevation protects against erosion and flooding and allows the consideration of options for space allocation that have a high certainty for success. However, over time, the adaptive capacity may diminish as erosion and sea level rise continues.

Accommodation options can be implemented through planning controls, such as building codes requiring the retrofitting of existing assets through the redevelopment or new development process. Typically, this results in incremental improvements, as the rate of the redevelopment of coastal properties is relatively slow.

Financial and Economic Considerations

The cost of implementing setbacks is small with the expense usually in the form of staff and administrative time updating policies. Accommodation approaches may have substantial costs for individual property and facility owners. Exceptions may exist where the setback involves a transition between public open space and private property, where setbacks that significantly diminish the use of a property may trigger legal taking claims, although this is unlikely given the rural nature of the South Coast.

In high-energy erosional environments, particularly on bluff tops, it is unlikely that accommodation approaches will be sufficient to address the modeled level of coastal hazard exposure. The alternative to setbacks could be an engineering approach such as installing piles to a stable bedrock layer but would be limited for the bluff top properties and likely to cost much more than the value of the existing structures.

Secondary Consequences

Any secondary impacts from setbacks would be associated with monitoring and enforcement of the setbacks. In some cases, there may be habitat trade-offs between the oceanside and landward side of development. There is also a potential that homeowners may experience differences in applications of setbacks since they are applied at a major redevelopment or new development stage. Over time there could be varying setbacks from the cliff edge as the older developments sit oceanward of the newer implemented setbacks.

Regulatory

From a regulatory perspective, setbacks have been shown to be a viable and commonly used policy approach for oceanfront development in the coastal zone.

Feasibility

Setbacks are a common practice in more urban settings, and a 50-foot minimum setback may preclude development.

5.3.4.2 Elevate

Description

Elevating buildings or infrastructure (like bridges and roads) is one strategy of accommodating increased flood depths or frequency of flooding. Elevating in anticipation of sea level rise entails planning for higher flood levels and increased duration of flooding. In San Mateo County, elevating will require higher minimum elevation requirements that also consider the projection of longer and more frequent flood events. Specific elevation strategies may include raising at-risk structures, improving building code standards that require elevated base floors and foundations, or placing potentially flooded roads onto elevated road surfaces or causeways, all of which are examples of accommodation. Elevation as a principal strategy would mean elevating at-risk structures, but also all associated utilities and connective roadways. Utilities that cannot be raised may need to be flood-proofed in some way. Elevation of roadways requires substantial engineering changes for each road or driveway intersection.

Along the South Coast, the elevate approach would be most appropriate within the communities of Martin’s Beach and Pescadero. Portions of roadways along Pescadero Road and State Route 1 may also have to be elevated onto a causeway or extended bridge to accommodate both rising and longer-standing floodwaters, and to allow physical habitat processes to continue without restrictions underneath the structure.

How difficult it is to elevate a building depends on the foundation type. Slab foundations for example are not easily lifted, and some structures may have to be demolished and rebuilt. Revisions to building codes to incentivize or require elevation can also help the County implement this accommodation strategy.

Figure 5-18. Example of a raised home in Ventura County, California

Raised houses is an approach to sea level rise adaptation and very common on the Gulf of Mexico and eastern U.S. coasts.

Source: Integral Consulting Inc.

Figure 5-19. Example of a raised causeway bridge. Ten-mile bridge in Mendocino, California

Source: Craig Philpott

Lifespan and Failure Mechanisms

The lifespan of an elevation approach is project- and place-specific, depends on the increase in elevation and can likely allow several feet of sea level rise, but each project lifespan varies based on extent of the elevation, foundation engineering, and specifics of the site. Failure would likely be caused by flood elevations exceeding the lowest portion of the foundation. This is most likely to occur during high velocity wave or flood events or when debris is carried by the flows causing damages.

Adaptability and Certainty of Success

The certainty of success of elevating a structure is moderate to high but depends on whether the structure has been sufficiently elevated. If flood levels on which the elevation is based are underestimated, or more sea level rise than planned occurs, the likelihood of success will decrease. In addition, a single structure or piece of infrastructure that is elevated does not provide any flood protection benefit to other adjacent or connected structures.

Financial and Economic Considerations

The cost of elevating structures is relatively high. The costs for raising a one-story single-family home can be $140 per square foot in a flood zone, or $250 per square foot in a high-velocity wave zone (Marin C-SMART 2015). Costs are highly dependent on the building. As a general guide, buildings on continuous block foundations or piers are simpler and cheaper to elevate, while slab foundations provide substantial challenges. FEMA provides grants of up to $30,000 per structure for elevating flood-damaged structures within a special flood hazard area, and additional funding support for the elevation of properties may be available at the regional or state level (FEMA, 2022). The cost for elevating roads on causeways can exceed $570 per square foot (Marin C-SMART 2015).

Secondary Consequences

Secondary consequences associated with an elevation strategy are highly dependent on the individual project and project area. Increases in elevation may affect aesthetics and changes to community character. Elevating on the open coast, such as at Martin’s Beach, may expose building foundations to damage. Increases in road or bridge elevations may cause visual impacts, particularly where elevated properties intersect with sightlines from adjacent properties. Along the South Coast, elevation may also impact sightlines along the Coastal Trail. Elevation of roadways also requires substantial engineering changes for each road or driveway intersection.

Elevation can also promote a false sense of security in that if conditions worsen beyond what the “safe” elevation was determined to be, structures could then no longer accommodate the water levels. In addition, the false sense of security could encourage at-risk properties to stay in hazard areas or result in an increase in development.

Lastly, elevation is property or asset specific and does not provide protection on a community-wide basis, unless it is undertaken as a comprehensive community plan. Due to the cost to implement, some landowners or renters may not be willing or able to afford the elevation approach, which may disproportionately affect certain community members.

Regulatory

Any specific public transportation-related elevation would require a full California Environmental Quality Act (CEQA) environmental analysis and considerations of alternatives, and possibly a Coastal Development Permit from the County or CCC.

Feasibility

Elevation is quite feasible. Not only can it be a retrofit to existing structures, but it can also be implemented through building code updates over time. These code updates could designate higher BFEs and be factored into project planning in advance.

5.3.5 Managed Retreat

Managed retreat, also referred to as relocation, or realignment in the case of linear infrastructure like roads, are phased strategies to move existing development away from erosion or flood hazard areas and limit new development in hazard areas.

Managed relocation is not done quickly but is a comprehensively planned approach phased over time, and implemented by the gradual realignment, relocation, and eventual removal of structures and infrastructure from hazard-prone areas.

Over longer periods and higher sea levels, this “stepping back” strategy could become the most cost-effective measure in comparison to adaptation approaches that require construction, maintenance, and potential removal of erosion control structures, and are also associated with lost revenues associated with secondary impacts to coastal resources such as the loss of beach recreation revenue. Assets exposed to flooding and erosion will inevitably be impacted by hazard events in the future. Communities must decide whether to take a proactive approach that is controlled and optimized to maximize public and private benefits, or a reactive one characterized by sudden, emergency responses to extreme events like landslides and cliff collapse.

Managed retreat can take my forms, which are most effective in combination. Strategies include:

- **Acquisition and buy-out programs for existing development:** These programs allow property owners to voluntarily sell their at-risk properties to the government, typically at pre-hazard market values, to avoid future losses. Governments can then demolish structures as necessary and prevent further development on hazard-prone land. In other cases, the government may rentback the property to the original owner for a set period of time with the goal of minimizing community disruption over the short-term.

- **Transfer of development rights (TDR):** TDR programs redirect development from more hazardous areas to less hazardous areas through development incentives. For example, property owners of hazard-prone land can sell their development rights to someone wanting to develop in a less hazardous area. The property owner of the hazard-prone land thereby financially benefits from non-development (through the sale of development rights) and the developer in the less hazardous area who has purchased development rights receives extra zoning or building privileges that would otherwise not have been allowed.

- **Real estate disclosures:** State law requires property owners to provide a Natural Hazards Disclosure (NHD) statement upon selling their property. Among the six hazards required disclosed by the NHD is the 1% annual chance flood zone as mapped by FEMA. However, these zones do not capture the full extent of possible coastal flooding. Local governments may require additional hazard disclosures for real estate transactions, including additional flood scenarios. In theory, homebuyers may choose to avoid purchasing higher risk properties if properly informed of risks, thereby reducing demand for and value of at-risk properties, and supporting eventual retreat. However, risk perception and level of risk acceptance varies widely by individual, and many homebuyers may not be dissuaded by a disclosure.

- **Indemnification Agreements:** As a condition of building in a hazard area, permitting authorities may require developers or property owners to sign agreements that release the government of any liability from damages should a hazard event occur. These indemnification agreements place the cost of risk squarely on the shoulders of private property owners, as well as their private insurance companies. Indemnification may dissuade property owners from building or rebuilding in hazard zones, and therefore may be complementary to more substantive managed retreat approaches.

- **Rolling setbacks:** Rolling setbacks, or easements, are boundaries that migrate inland as the coast erodes to maintain a set distance between a property boundary and a seaward feature, such as a cliff edge or dune vegetation line. Retreat and rolling setbacks provide the accommodation space for cliffs and dunes to retreat naturally, until the point at which they reach a terminal structure (likely to be State Route 1 or associated revetments).

- **Zoning and building code changes:** Local governments may disincentivize development in hazard areas through restrictions on density and land use, as well as the establishment of risk-averse building codes that require hazard mitigation built into a structure. Requiring mitigation is an upfront added cost that may disincentivize development.

Lifespan

The lifespan of managed retreat is dependent on the inland distance of relocation, and with sufficient inland distance, this approach can ultimately reduce coastal hazard risk permanently. Retreat is likely to occur in phases and require different mechanisms to implement.

Adaptability and Certainty of Success

From a technical standpoint, a managed retreat approach is highly likely to succeed in permanently reducing or eliminating current and future risk if areas chosen for relocation are outside of projected hazard risk zones.

Financial and Economic Considerations
The cost of managed retreat depends on the value of the existing infrastructure and developments that must be relocated relative to the time and cost to acquire land, plan, environmentally review, finance, permit, and construct compared to the costs and benefits of the longer-term secondary consequences associated with choosing different adaptation approaches. Retreat may require substantial lead times for the adaptation planning process. These often have high upfront costs. The longer-term costs associated with any initial retreat investment must be weighed with the longer-term cost associated with the maintenance, potential damages, and secondary impacts associated with approaches. Governments can reduce the upfront cost, such as costs associated with relocation through staged buyout and rent-back schemes that extend the period over which the costs of realignment are spread over time.

Once assets have been relocated, there are no ongoing maintenance costs directly associated with the retreat strategy. However, decision-makers should consider costs associated with planning and monitoring of trigger events.

From a fiscal perspective, relocation of private properties can result in loss of some of the most valuable properties within the county, and hence reduce property tax revenues. The fiscal impact is dependent upon the taxable value of the properties, which may be limited by Proposition 13 restrictions.

Secondary Consequences
Managed retreat may result in social and economic impacts to community members, discussed under 'Social Equity Considerations' below. Furthermore, because managed retreat implies a removal or deemphasis of assets in a hazard zone, this approach may be coupled with a decision to invest less in other adaptation approaches in the hazard zone the community is retreating from. This may mean that remaining assets are less protected over time. However, if a managed retreat approach is phased appropriately, communities can develop plans to minimize impacts to remaining assets wherever possible.

Regulatory
From a regulatory standpoint, managed retreat strategies are likely viable; however, it depends on the specific setting and details involved. Policy changes, building code alterations, agency coordination, and public engagement will be critical to effective relocation projects. By communicating a long-term vision, establishing hazard disclosures, and providing incentives (and disincentives), it is possible to implement a managed retreat strategy over time, which realistically, is likely the most cost-effective feasible strategy over the long term.

As government entities can access debt finance at lower rates than individual property owners, public purchase schemes are likely to be cost-effective over longer planning horizons. A property purchase scheme that returns privately held coastal property to public ownership is likely to have greater public support than public funding of protective options and has the potential to increase the availability of recreation and tourism assets, thereby offsetting losses in other locations.

Feasibility

From a strictly technical standpoint, managed retreat along the South Coast is feasible. Land acquisitions could purchase some portion of private parcels in hazard areas to allow for conversion to open space or regulate coastal development from parcel boundaries fronting the coast using disclosures, zoning, and development setbacks. Some project approaches could include realignments of the State Route 1 corridor. Whether these approaches are socially and politically acceptable and feasible is a separate consideration.

Social Equity Considerations

Managed retreat discussions must be accompanied by thoughtful and inclusive conversations about impacts on equity and the long-term effects of displacement on low-income communities. Managed retreat and relocation programs may disproportionately displace low-income communities if not designed and carried out to fairly compensate and relocate communities within the same region with minimal impacts on social fabric and community functioning. Fair compensation must be defined by a community to ensure that community members can relocate within the region. This is particularly critical in the Bay Area, where it is difficult for low-income families to buy a home, even with current home equity.

Residential managed retreat and relocation strategies must consider and avoid any program characteristics that may reproduce inequities. Equitable programs should:

- Avoid targeting only homes that lack added structural mitigation measures, which are more likely to be true of low-income households, thus resulting in the relocation of low-income families only.
- Offer sufficient compensation that allows low-to-middle income community members to relocate locally or regionally.
- Consider renters as legitimate members of the community who must be financially supported through relocation.
- Clearly communicate risk and program information in culturally and linguistically appropriate ways.

Retreat strategies should consider and acknowledge that many low-income communities and communities of color, particularly Native ones, have experienced displacement across generations, and as such, these communities may understandably be cautious of relocation programs. Their histories should be validated and acknowledged, and communities must be meaningfully consulted early in the program planning process. Finally, residential retreat and relocation program planners should consider that communities have deep attachments to place, and relocation can be a painful and uprooting process. Deep community dialogue, clear communication of risks and relocation benefits, fair compensation that allows community members to remain local or regional, and emotional support for community members can help facilitate relocation and retreat strategies.

Realignment of roads like State Route 1 may be part of a retreat strategy and also have considerable equity implications, depending on how decisions are made. Potential realignment routes of State Route 1 could affect agricultural land, which would have ripple effects on the agricultural economy and farm labor jobs, which are a critical source of employment for some of the lowest income households in the region.

Planners should carefully consider the implications of road realignment to avoid reproducing inequities. Some guiding principles may include:

- Consult early with landowners and farmworkers to understand how road realignments may affect their livelihoods.
- Wherever possible, avoid realigning roads through prime agricultural land as well as agricultural land that has reliable water access.
- Coordinate with agencies and departments that provide housing and social services to ensure farmworkers are supported through any shocks to their employment status or livelihoods.

These considerations are not exhaustive and planners and practitioners that scope relocation and retreat strategies should consult early and often with communities to identify potential social consequences of their planned programs. Community-based organizations and civic groups will have local knowledge that can support early decision-making to be equitable.

5.4 ADAPTATION CRITERIA

Using County priorities, State guidance, community input collected during focus groups and community meetings, and professional judgment, the study team proposed a set of criteria to help prioritize the wide variety of potential adaptation strategies for short- and long-term adaptation approaches. These criteria help compare and contrast all of the strategies presented in section 5.3 and help synthesize the overall evaluation of adaptation alternatives. The criteria include the following:

- **Adaptation Category:** protect, accommodate, retreat / realign / relocate
- **Green vs. Gray**
- **Setting:** physical location
- **Maladaptive:** not adaptable to future conditions and/or results in potentially higher future risk
- **Feasibility:** ability to be effective in the South Coast
- **Certainty of Success:** certainty that strategy will function as intended for prescribed life span
- **Secondary Impacts:** (+ positive improvement, = no change, - negative changes)
  - Social Vulnerability/Equity Impacts
  - Beaches/Coastal Recreation
  - Public Access
  - Aesthetics
  - Habitat Ecology

- **Regulatory Viability[3]:** permittable under existing regulations
- **Lifespan:** the relative lifespan of the strategy; Short is <10 years, Medium is up to 30 years, and Long is 30+ years
- **Construction Cost:** relative construction cost
- **Maintenance Cost:** relative cost over the lifespan of the project.

The adaptation alternatives table below summarizes a range of coastal adaptation criteria to compare and evaluate a feasible range of potential adaptation strategies to help the community prioritize future adaptation decisions affecting the South Coast (Table 5-3). Public outreach and engagement efforts with key stakeholders should be used to narrow the wide range of potential adaptation strategies and locations into the most suitable interventions.

[3] This is an initial perspective. Team expertise is not in regulatory processes or legal analysis, and this interpretation should be vetted with qualified experts to evaluate the specific facts in each situation to determine the regulatory viability and legal risk.

Table 5-3. Matrix comparison of coastal adaptation alternative

Matrix Comparison of Coastal Adaptation Alternatives												
						Certainty of Success						
Strategy	**Strategy**	**Green vs Gray**	**Setting**	**Maladaptive**	**Feasibility**	**Near Term**	**Long Term**	**Beach / Coastal Recreation**	**Public Access**	**Aesthetics**	**Ecology / Habitat**	**Existing Regulatory Viability**
Criteria	***Protect, Accommodate, Relocate/Realign***	***Green, Gray***	***Upland, Cliff, Beach, Offshore***	***Y/N***	***High, Medium, Low***	***Low, Medium, High***	***Low, Medium, High***	**+ , - , =**	**+ , - , =**	**+ , - , =**	**+ , - , =**	***Y/N***
Revetments	Protect	Gray	Cliff, Beach	**Y**	High	High	Low to Medium	**-**	**=**	**-**	**-**	**Y**
Seawalls	Protect	Gray	Cliff, Beach	**Y**	Low	High	Medium	**-**	**-**	**-**	**-**	**Y**
Soil Nail Tie-Back Walls	Protect	Gray	Cliff	**Y**	Low	High	Medium	**-**	**+**	**+**	**-**	**Y**
Horizontal Flood Control Levees	Protect	Gray	Upland	**Y**	Low	High	Medium	**-**	**+**	**-**	**-**	**Y**
Artificial Reefs/Offshore Breakwaters	Protect	Gray	Offshore	**Y**	Low	Low	Low	**+**	**+**	**=**	**?**	**N**
Nourishment	Protect	Green	Beach	**N**	Low	High	Low	**+**	**+**	**+**	**+**	**N**
Sand Placement Program	Protect	Green	Beach	**N**	Low	Low to Medium	Low	**+**	**+**	**+**	**+**	**N**
Dune Restoration	Protect	Green	Beach	**N**	High	Medium	Low	**+**	**+**	**+**	**+**	**Y**
Cobble Berms	Protect	Green	Beach	**N**	High	Medium	Low	**+**	**+**	**+**	**+**	**Y**
Elevate Pescadero Creek Road (Causeway)	Accommodate	Gray	Upland	**Y**	Medium	High	Medium	**=**	**=**	**-**	**=**	**Y**
Elevate Structures	Accommodate	Gray	Upland	**Y**	High	High	Low	**-**	**-**	**-**	**-**	**Y**
Relocate Structures	Relocate	Green	Upland	**N**	High	High	High	**+**	**+**	**?**	**+**	**Y**
Micro Realignment of HWY 1	Realign	Gray	Upland	**N**	High	High	Low	**+**	**=**	**?**	**?**	**Y**
Minor Realignment of HWY 1	Realign	Gray	Upland	**N**	High	High	Medium	**+**	**=**	**?**	**+**	**Y**
Major Realignment of HWY 1 on Existing Roads	Realign	Gray	Upland	**N**	Medium	High	High	**+**	**=**	**?**	**+**	**Y**
Major New Alignment of HWY 1	Realign	Gray	Upland	**N**	Low	High	High	**+**	**=**	**?**	**+**	**Y**

(+ positive improvement, = no change, - negative changes)

5.5 QUESTIONS FOR DECISION-MAKERS

There are many challenges to adaptation planning that decision-makers must consider. Answering these questions will require a combination of community dialogue, stakeholder engagement, detailed technical evaluation, numerical modeling, economic analyses, engineering design and costing, and political will. This section is intended to provide a list of questions that need to be considered at a high level as well as more detailed considerations for cost–benefit analyses and inclusion of social equity.

5.5.1 High-Level Questions for Consideration:

- What assets or communities should be the priority for adaptive measures at this time?
- How sensitive are these assets and how much adaptive capacity do they have?
- What adaptation strategies would adequately reduce risk for the assets prioritized for protection?
- Which strategies buy decision-making time to change or scale up strategies for future levels of sea level rise and allow communities to shift strategies?
- Which strategies involve a holistic adaptation approach that considers safety, coastal resources and habitats, and community identity?
- Which strategies support the protective role of ecosystems and sustain their physical processes?
- How much sea level rise does each strategy accommodate?
- How much does each strategy cost to implement initially?
- Which strategies require increased maintenance costs over time?
- Which strategies avoid high costs and demonstrate a strong net benefit over time?
- Which strategies avoid disproportionately burdening the most vulnerable residents?
- Which strategies decrease long-term GHG emissions?

5.5.2 Economic Considerations

Adaptation requires careful consideration of the costs and benefits of each potential strategy. The following are some examples of cost–benefit questions that should be addressed:

Does the strategy result in a net benefit to public resources?

Any time public funds are spent to implement adaptation strategies, whether they are traditional “gray” or more natural living shoreline approaches, consideration of the location of the strategy and who benefits must be considered. A strategy that benefits the public, such as one that reduces travel disruptions either through protection or improvement to a public facility, may result in a net gain of public resources. The case where public funds are used to benefit private assets (e.g., armoring of single-family homes) may not be viewed by all as an equitable use of public funds.

What are the potential effects and costs related to approaches resulting in a loss or decrease in recreational opportunities?

Recreation opportunities provided by public access to the coast are available essentially for free, or by payment of a modest parking fee, and are available to residents and visitors of all income groups. Free or low-cost recreation is particularly important for socially and economically disadvantaged communities and low-income visitors. Adaptation approaches that result in beach loss or diminished accessibility have disproportionately higher impacts on low-income groups because they are less likely to be able to access substitute recreational sites or would need to spend larger portions of their income to find substitute recreational sites.

The magnitude of loss associated with changes in the existence, accessibility, or quality of a recreational site is relative to the availability of substitutes for the opportunities and features provided by the affected site. The loss of iconic or regionally important sites can have substantial impacts, experienced across a broad geographical area. In some cases, there are no substitute recreational venues with similar favorable characteristics in the region.

There are fuel and time costs associated with travel to and from a coastal recreation site, which can be used as a proxy for the recreational benefits they provide. The assumption is that the value of the recreational experience must be greater than the costs of visiting the location, and statistical methods are used to estimate the size of this benefit (e.g., the value of a beach trip). If costs increase because visitors are forced to drive further to access substitute beaches or recreation sites due to beach erosion at their preferred location, the utility or enjoyment of the recreational experience is reduced.

What are the potential effects of the adaptation strategy on agriculture?

Agriculture is the basis of the economy for the South Coast and the loss of farmland or reduction in crop production will affect farm income, and potentially lead to the loss of livelihoods for farmworkers, many of whom already struggle socioeconomically. Many growers in the Pescadero area earn significant income from farmer's markets in San Francisco and on the Bay side, and interruptions to or loss of access to State Route 1 would impact growers getting product to market. The daily and weekly trips that growers and farmworkers make to get to farms and the fuel and time costs to get their product to market should be considered. Added expenses associated with increased travel time, both for distribution and commuting, could be significant (Yuen 2021).

Decision-makers should carefully consider the impact that adaptation strategies may have on travel times either permanently or during the construction phase – as this could significantly impact access for farmworkers who commute to their jobs. A reduction in the number of farmworkers has both direct and indirect impacts, as money spent in the region has multiplier effects within the local economy. A full consideration of the potential economic impact on agriculture productivity and transport to market would require input–output analysis, using a locally specific economic impact model, survey work, and a transportation cost model.

Many farms in this area have been owned and managed by families for multiple generations, and landowners hold localized knowledge for tending and growing on this stretch of coast. These landowners should be consulted as to the potential localized impacts to their operations. The agricultural economy could be affected in multiple ways, both positive and negative, and for a more detailed analysis, a community impact analysis would be required.

Any effort to realign State Route 1 should make every attempt to avoid impacts to farmland water impoundments, which are an important source of irrigation water. A CEQA review would be required for projects that may convert land designated as Williamson Act land to non-agricultural uses.

What are the potential effects of the adaptation strategy on tourism?

Tourism is typically defined as non-business travel that includes an overnight stay. Within the South Coast, formal tourism accommodation includes facilities at Pigeon Point Light Station, the Costanoa Resort, and the Ritz-Carlton at Half Moon Bay. There are also several camping options at nearby state and county parks, including Memorial County Park with 158 campsites, as well as rental options through Airbnb, VRBO, and similar platforms.

Tourism value impacts could result from reductions in environmental quality, travel disruptions, or a combination of both factors. Given the linear nature of the study area, impacts to tourism in the South Coast area have the potential to affect tourists originating from both the northern San Francisco Bay Area peninsula and the southern Santa Cruz hubs. In addition, tourists from much farther away flock to the coast during the summer months, including an increasing number of people from the Central Valley fleeing weeks of extreme heat in excess of 100° F.

Adaptation strategies that result in diminished environmental conditions, travel disruptions, or both could have a negative impact on tourism in the South Coast. A reduction in the number of tourists has both direct and indirect impacts, as money spent in the region has multiplier effects within the local economy. A full consideration of the potential economic impact of reduced tourism visitation would require input–output analysis, using a locally-specific economic impact model, survey work, and a transportation cost model.

How does the strategy affect the transportation network, and what are the consequences of this disruption?

Projected erosion and flooding impacts would likely result in temporal and spatial disruptions to the road network in the study area, particularly in the Pescadero region. Without adaptation, this would necessitate more frequent closures and more substantial repairs, increase travel times, and also disrupt emergency services, school bus routing, and transportation of agricultural products. Realignments of the highway could improve travel by reducing disruptions and decreasing travel times, while armoring of the road could reduce tourism.

5.5.3 Social Equity Considerations

The County of San Mateo's Office of Equity defines equity as the goal of just and fair inclusion into a society in which all can participate, prosper, and reach their full potential. To achieve equity, we must create the conditions that allow all to reach their full potential.

Considerations of equity are essential for the adaptation planning process, given the disproportionate negative impacts that natural hazards and sea level rise tend to have on disadvantaged communities. Disproportionate impacts are often produced through increased exposure and less material and economic resources to prepare for, respond to, and recover from hazard events. Equitable approaches to adaptation recognize any disproportionate impacts that natural hazards and sea level rise have on certain communities and develop risk reduction strategies that target the most at-risk communities first. These communities must be consulted and given an active and meaningful role in the adaptation planning and implementation processes to ensure the safety and wellbeing of all South Coast community members.

San Mateo County has committed to understanding and devising strategies to address social inequity in all of its planning and operations, supported by a multidepartmental Core Equity Team and associated working committees. The County's 2021 Local Hazard Mitigation Plan, which addresses natural hazards and proposes mitigation strategies, was developed through several hard-to-reach community consultations and highlighted themes of equity in hazard descriptions and in proposed mitigation strategies. This unprecedented multidepartment effort incorporating equity and inclusion serves as a baseline for future improvements and place-based adjustments to better engage and serve underrepresented communities in the planning process.

In recent years, federal and state funding for mitigation and adaptation projects has been prioritized for projects that demonstrate a benefit for disadvantaged communities. For example, FEMA and the California Office of Emergency Services give priority to projects that aim to protect disadvantaged communities within their Building Resilient Infrastructure and Communities grant, Flood Mitigation Assistance grant, and Hazard Mitigation Grant Program. Many state grants, including those administered by the Strategic Growth Council and the CCC, often give preference to or require that projects benefit disadvantaged communities, as defined by the California Environmental Protection Agency.

The County's expressed commitment to equity, coupled with a windfall of unprecedented federal and state funding for hazard mitigation and climate resiliency projects that focus on disadvantaged communities, makes clear that any adaptation strategy must be designed, developed, and implemented with social equity at its forefront.

Policymakers and practitioners should engage, consult, and consider potential impacts of hazards and adaptation approaches on communities that have historically been disproportionately impacted by natural hazard events or are at increased risk of being disproportionately impacted, including:

- Black, Indigenous, and other people of color communities
- Persons with disabilities, medical, and/or access and functional needs
- Low-income and economically disadvantaged households
- Households with limited English proficiency
- Farmworkers, migrant communities, and undocumented people
- Subsistence fishermen
- Renters and agricultural leaseholders

- Older adults (age 65 or older)
- Children (under 15 years of age)

In the earliest stages of the adaptation planning process, policymakers and practitioners should engage and solicit feedback from communities and have meaningful discussions around whether the proposed planning and implementation processes will promote equitable outcomes. The Office of Sustainability's Climate Resilience team developed the following questions to guide such discussions:

1. Have communities been engaged about sea level rise and related hazards and consulted about their preferred adaptation approach?
2. Will the proposed action reduce the risk from natural hazards for the underrepresented or sensitive groups in a way that is proportional to their risk burden? How? Who is making this determination?
3. Does the proposed action benefit the identified groups and provide additional benefits to underrepresented groups beyond risk reduction? For example, will the action promote recreation opportunities, reduce travel times, promote physical exercise and walkability, or support the tourism industry? If no additional benefits have been identified, how could this action be modified so that there are additional benefits?
4. How might this action burden, negatively impact, or leave out underrepresented communities, for example through communication, transportation displacement, physical inaccessibility, impacts to transportation, impacts to livelihoods, communication, or programmatic barriers? Who is making this determination?
5. Do policymakers and practitioners have a way to evaluate and track the action's impacts on target communities to ensure the action minimizes negative impacts and maximizes positive ones?
6. If policymakers and practitioners have identified burdens, barriers, or negative impacts or opportunities to enhance the action for added community benefits, they should revisit the action to identify strategies to reduce or eliminate burdens or negative impacts; remove communication, transportation, physical or programmatic barriers; or enhance potential benefits.
7. Has a performance metric been identified for evaluating progress on this action? How will one know when this action is complete?

Meaningful community inclusion and participation is key to answering these questions and developing equitable adaptation strategies that reduce risk while avoiding perpetuating inequities. Decision-makers should partner with community-based organizations and co-scope community engagement processes and projects early in the process to ensure truly participatory adaptation.

5.5.4 Community Input on Adaptation

As part of this report's development, the Office of Sustainability, in partnership with the San Mateo Resource Conservation District and South Coast Sustainable, held community meetings in July 2021 and March of 2022 to better understand community priorities for adaptation.

Community members in attendance live in Pescadero, Martin's Beach, and other South Coast communities. This community input will guide the County forward as it maps out its adaptation strategies in the South Coast and pursues state and federal funding for project implementation.

5.5.4.1 Community Concerns about Sea Level Rise

At both the July 2021 and March 2022 community meetings, residents expressed concerns about a wide range of sea level rise-related impacts, that in some cases are already affecting their communities. These priority concerns include:

- Current and future erosion and flooding impacts to State Route 1
- Flooding impacts to Water Lane in Pescadero and surrounding agricultural lands
- Producing much needed affordable housing in Pescadero, which is complicated by its location in a floodplain
- Flooding in downtown Pescadero and impacts to homes and businesses
- Hazard impacts to the Ohlone Cemetery near Pescadero
- Challenging evacuation of people and animals and need for better preparedness/response planning
- Possible groundwater contamination, either with saltwater or contaminants released through flood events
- Need for engagement of elderly and those with disabilities to prepare and be able to evacuate during hazard events
- Reduced access to the coast as a result of erosion impacts to transportation infrastructure
- Need to reduce broader community vulnerabilities associated with poverty, insecure housing, communications, water quality, and physical access to better be able to withstand hazard event shocks

To give community members an additional medium for providing feedback beyond a meeting, a survey was embedded in the project's StoryMap where respondents could indicate their opinions on sea level rise in their community. Survey responses indicated that the most important sea level rise issues for respondents are impacts to Highway 1 and other roadways, health and human safety, and loss of cultural and historic resources. One long term resident of the coast indicated in the survey that they had considered buying a second home on the coast but had decided against it due to the projected impacts of sea level rise. Another respondent stated "*It often feels like we are on the edge of a cliff and in some ways that's a literal feeling. If we lose infrastructure to sea level rise, there are multiple places where there is no room to replace it*," referring to both the feeling of being at risk as well as the permanent loss of land that results from erosion.

5.5.4.2 Preferred Adaptation Options

- Nature-based solutions: Many community members and stakeholders that attended meetings expressed an interest in nature-based solutions for both erosion (to preclude undesired coastal armoring) and flood adaptation, which might include habitat restoration with multiple benefits.

- Adaptive agricultural practices: Community members from Pescadero expressed interest in supporting agricultural practices to build soil health and reduce impacts from flooding events.

- State Route 1 Realignment: Community members and stakeholders demonstrated interest in realigning State Route 1 away from the eroding cliffside to an extent that would prevent long-term hazard impacts and ensure continued physical accessibility to the region.

Survey respondents ranked adaptation strategies by sector, which are listed below in order ranked, with 1 being most preferred, and higher numbers being less preferred. However, it should be noted that survey respondents represent a very limited sample (9 respondents) of the broader South Coast population and may not be representative of the community as a whole. More robust public engagement must be carried out to ensure that proposed adaptation strategies are acceptable to communities, including residents who don't often participate in public meetings.

Ranked Adaptation Strategies for Homes and Businesses:

1. Relocating hazardous materials out of flood zones
2. Monitoring silt build-up and maintaining creeks to reduce flooding
3. Raising roads
4. Raising structures above flood levels
5. Exploring possibilities of relocating high-risk structures

Ranked Adaptation Strategies for State Route 1:

1. Elevating low elevation portions of State Route 1 where feasible
2. Nature-based solutions like dune restoration to mitigate erosion in the near-term
3. Realignment/relocation of State Route 1 inland to avoid erosion impacts
4. "Armoring" the coast to delay erosion along stretches of State Route 1

Ranked Adaptation Strategies for County Roads:

1. Elevate low elevation roads (e.g., Pescadero Creek Rd.) to reduce severity and duration of flooding
2. Widen roads (e.g., Stage Road in Pescadero) to support alternative routes
3. Develop new roads to serve as alternative routes during Highway 1 disruptions

Ranked Adaptation Strategies for Agriculture:

1. Participate in creek and floodplain restoration projects

2. Test and utilize agricultural practices that build soil health and stability and productivity to buffer against the deterioration and loss of farmland affected by flooding
3. Further research impacts to water quality from sea level rise and potential impacts to irrigation
4. Begin long-term planning for transition to crops that are flood- and saltwater-resistant in zones projected to be highly affected by sea level rise
5. Stormproof and elevate structures

Ranked Adaptation Strategies for Coastal Access:

1. Use nature-based systems to strengthen the shoreline
2. Research ecologically friendly ways to protect historic landmarks and cultural assets
3. Relocate parking lots out of hazard zones where possible
4. Expand pedestrian access to coastal areas

Beyond adaptation priorities, some community members communicated a need for better emergency preparedness and response, especially for residents with mobility issues and those with large animals in need of evacuation support. The community-based organizations Senior Coastsiders and Center for Independence of Individuals with Disabilities (CID) emphasized the intersection between their work to promote mobility and independence for seniors and those with disabilities and natural hazards preparedness and response. Both organizations are actively expanding their knowledge and roles in natural hazards preparedness.

5.6 BALANCING COSTS AND BENEFITS IN ADAPTATION DECISIONS

The sections above lay out a wide range of alternatives as well as a framework for considering what the tradeoffs are between selecting different strategies at a relatively high level. This section provides more details on costs and benefits specific to the South Coast. In this section, individuals, managers, and decision-makers are given site-specific values for important costs and benefits that can be used to identify more feasible adaptation approaches for each of the identified vulnerabilities over time. Table 5-4 provides a summary of the potential costs and benefits to consider. Section 5.6.1 provides a feasible range of adaptation strategies for each identified vulnerability over time. Section 5.6.2 provides ranges of adaptation costs for each strategy while Section 5.6.3 provides the value of coastal recreation for each of the park units. From these costs and benefits, decision-makers can begin evaluating the differences in relative costs and benefits between different adaptation approaches over time.

Having community-wide discussions centered on the issues described in Section 5.5 can help stakeholders understand which adaptation strategies are appropriate for the present, and when it may make social and economic sense to shift from one adaptation strategy to another. By evaluating the cost and benefits of different strategies, their impacts on equity, and their non-market recreation and habitat benefits, it is possible to start to identify a range of adaptation strategies that can be implemented over time. Table 5-4 below highlights some of the key costs and benefits to consider when evaluating various adaptation strategies. To quantify many of these values requires additional monitoring, reporting, and analysis beyond the scope of this current study.

Table 5-4. Important costs and benefits to consider when evaluating adaptation strategies

Costs	Benefits
Damages and Clean-up Costs	Avoided Damages
Construction Costs	Avoided Construction Costs
Maintenance Costs	Avoided Maintenance Costs
Loss in Recreation	Recreational Benefits
Loss in Habitat	Habitat Benefits
Loss of Revenues	Tax Revenues
Loss in Agricultural Productivity	Agricultural Revenues

One approach to identifying preferred strategies is to consider carrying out a holistic cost-benefit analysis that considers potential physical changes from various adaptation strategies on coastal recreation and habitats compared with economic impacts to upland development, recreation, habitats, and infrastructure (Revell et al. 2021). Outputs of this approach can help identify possible adaptation pathways tied to measurable triggers identifying when it is time to begin planning for the next adaptation step.

This section summarizes some quantification of important costs and benefits as well as identifies some feasible adaptation approaches for each of the identified vulnerabilities over time. The intent is to provide enough information so that decision-makers and interested stakeholders can begin to evaluate various adaptation pathways over time. This type of approach would have to be paired with careful consideration of potential social and equity impacts for all analyzed strategies.

5.6.1 Costs of Adaptation Strategies

Table 5-5. Range of costs in California for typical adaptation implementation

Strategy	Cost Ranges in California
Revetments	\$2,500–\$5,000/foot
Seawalls	\$5,000–\$10,000/foot
Soil Nail Tie-back Walls	\$15,000–\$25,000/foot
Sand Retention Groins	\$3,000–\$5,000/foot
Flood Control Levees	\$500–\$1,500/foot
Breakwaters	\$16,000/foot
Nourishment	\$5–\$30/cubic yard of sand
Dune Restoration	\$100–\$1,000/foot
Cobble Berms	\$35–\$270/ton
Redesign and Raise the Structure	\$30,000–\$40,000 per structure and \$150–\$250/square foot
Realignment of State Route 1	See Caltrans Estimates in Table 5-7
Causeway	\$350–\$550/square foot

Sources:

Beavers, R.L., A.L. Babson, and C.A. Schupp [eds.]. 2016. Coastal Adaptation Strategies Handbook. NPS 999/134090.

NOAA Office for Coastal Management and U.S. Army Corps of Engineers. 2015. Natural and Structural Measures for Shoreline Stabilization.

Caltrans. 2008. Project Study Report to Request Approval to Proceed with Formal Studies for SHOPP Project on Route 1 between Bean Hollow Road and Stage Road.

Marin County Department of Public Works

City of Pacifica Department of Public Works

County of Santa Cruz Department of Public Works

California State Parks

5.6.2 Benefits Associated with Adaptation Strategies

There is a range of non-use and indirect-use benefits associated with access to natural habitats within the study area. These values have largely been excluded from the current study, as their estimation requires detailed empirical studies over extended periods. This study provides an exploratory analysis of the recreational use value of coastal state parks within the study area. It does not attempt to value ecosystem services of the parks that do not provide use values to visitors, or broader social and health benefits of outdoor recreation.

Table 5-6 shows the estimated non-market recreation value associated with visits to State and County parks within the broader study area. The next section explores the potential impacts on the values of the business as usual/do nothing approach, and how it compares to alternative options of armoring, dune creation and realignment of State Route 1 and coastal hiking trails.

Further work on site-specific erosion modeling with and without adaptation measures could help identify both opportunities and vulnerabilities, as well as more refined future pathways and triggers. The next section provides an example of a dynamic adaptation pathway framework developed using trigger points to initiate the development and implementation of plans and actions.

Table 5-6. Non-market recreational values for state park units

Park Name	Estimated Yearly Visits	Estimated non-market value ($M)*
Año Nuevo State Park and Gazos Creek State Beach	130,000	$5.2
Bean Hollow State Beach and Pebble Beach Farm	78,000	$3.1
Cowell Ranch State Beach and Cowell-Purisima County Trail	41,000	$1.6
Pescadero Marsh Nature Preserve and Butano Farms State Park	63,000	$2.5
Pescadero State Beach	254,000	$10.2
Pomponio State Beach	103,000	$4.1
San Gregorio State Beach	132,000	$5.3
Pigeon Point Light Station State Historic Park including Pistachio Beach, Pigeon Point County Park, and Cloverdale Coastal Ranches	280,000	$11.2
Tunitas Creek County Beach	58,000	$2.3
Manhattan Beach and California Coastal Trail at Ocean Colony (City of Half Moon Bay)	150,000	$6.0
Total	**1,289,000**	**$51.6**

**Non-market value assumed to be $40 per visit (values in 2022 dollars)*

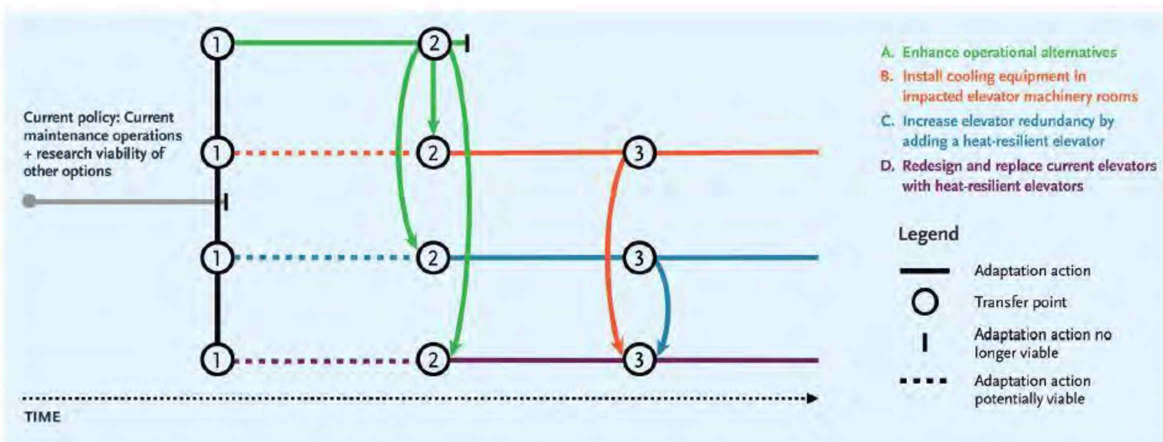
All yearly visit numbers are rounded to the nearest thousand and estimates are based on State Parks Statistical Reports, County Planning Documents, State Park General Plan Reports, Park Staff Surveys, and Conversations with Park Staff. Estimates were averaged form the years where data were available, typically 2014–2019. For smaller park areas, estimates were determined through comparisons with similar parks.

5.7 ADAPTATION APPROACHES THROUGH TIME

Adaptation to coastal erosion and sea level rise along the South Coast will likely require multiple approaches over time. Uncertainties in the timing of large storm waves at high tides, the elevation of sea level rise in the future, and projected extents of future coastal erosion require consideration of feasible adaptation strategies over both short- and long-term time scales with an adaptation pathways approach.

An adaptation pathway helps visualize some of the sequences of possible adaptation responses through time in a stepwise manner. Every alternative is designed to meet a certain performance level over a period of time, and once it reaches a tipping point where potential damages are no longer acceptable, a transition to another strategy is required. Each strategy requires lead times associated with the planning, outreach, permitting, design, and construction before it can be effective. Thus, before a tipping point of damages is realized, planners should identify possible triggers and anticipate the lead times necessary to implement a new strategy before potential damages occur. Due to the uncertainty over future physical conditions, natural variability, and changing societal values, these pathways should remain flexible (Figure 5-20).

Figure B-1. Adaptation Planning Process



Source: Los Angeles County Metropolitan Transportation Authority (Metro). Metro Climate Action and Adaptation Plan 2019, 2019 Los Angeles: author, page 38.

Note: When conditions reach a trigger (numbers), the adaptation strategy changes to one of the other options.

Figure 5-20. A simple example of an adaptation pathway from the CAPG 2020

Note: This is a simple example. Adaptation pathways are frequently much more complicated

5.7.1.1 Triggers

The moment of an adaptation tipping point or trigger helps identify when a change in path is necessary; however, not all actions can be implemented at once. As a result, trigger points are used that are hindcast from a potential tipping point, providing lead time for permitting and other considerations. The following tipping points may be considered when laying out an adaptation pathway:

- **By sea level rise elevation (or rate of sea level rise):** The South Coast is already susceptible to hazards that may occur from an El Niño event or individual storms; however, sea level rise could increase the severity and impacts of these storms. Through monitoring sea level from the nearest NOAA tide gauge at Pillar Point Harbor, triggers could be tied to a specific elevation change of sea level rise from present conditions over a 6-month period (to avoid seasonal/El Niño signals) or a rate of sea level rise increase. These triggers would allow the County to implement further actions in advance of projected sea level rise impacts.

- **By physical distance:** specify a certain distance between a defined coastal feature and an asset of interest. An example may stipulate if the distance between the oceanside of State Route 1 and the cliff edge is less than 10 feet.

- **By planning year:** specify that by a future year (e.g., 2030), a long-range study identifying appropriate strategies must be complete (e.g., transportation planning). The drawback of monitoring mechanisms based on planning years is that modeled projections of coastal hazards could occur sooner or later than that year. This is better applied to review of policies when permits expire, but the regulatory agencies appreciate knowing when the County will reevaluate its adaptation approach and often require periodic check-in.

- **By storm exposure and frequency:** monitor the frequency of exposure to wave action (e.g., how frequently does Martin's Beach get exposed to wave action or Pescadero Road at Butano Creek flood and require cleaning). To monitor the frequency of flooding, the County should track and record coastal flooding and include the date, location, type, depth, and severity. Triggers are then identified as the number of occurrences exceeded each year.

- **By damages:** identify structural damage levels that may require a reevaluation of adaptation approaches such as the damage to coastal armoring structures, erosion of a trail, fields, or private property. One approach to measuring damage would be by cost. For instance, once the County or Caltrans spends a certain amount in total or annually in maintenance, then additional steps need to be taken.

- **By net benefits:** the point identified in a detailed cost–benefit analysis where benefits for one adaptation approach exceed the cost of a previous approach. A monitoring example could be the maintenance costs of a protective adaptation over time versus the costs of a one-time relocation of the infrastructure that is being protected.

- **By insurance claims:** the County receives a list from FEMA of private properties for which federal insurance claims have been made, and the trigger could be when a certain number of claims are made in a specified amount of time. Adaptation plans that utilize triggers selected in a robust manner are important for facilitating planning, which incorporates the inherent uncertainty and risk surrounding the effects of sea level rise on coastal areas.

5.7.1.2 Monitoring

Potential triggers, once identified, need to be monitored and assessed to inform adaptation decisions, and triggers should be reevaluated and updated in the future to capture advances in sea level rise science and changing conditions. Implementing a monitoring system to identify when actions should be triggered can involve numerous stakeholders. Monitoring data can be collected by the County or State during routine maintenance activities, extracted from remote sensing data, or collected in partnership with local research institutions such as USGS or NOAA. Ideally a program that monitors the identified triggers would be integrated into routine County activities within each department so that regular data collection forms the basis for adaptation decisions.

5.8 ADAPTATION PATHWAY EXAMPLE: STATE ROUTE 1 BETWEEN BEAN HOLLOW ROAD AND SAN GREGORIO ROAD

The coastal route of State Route 1 between Bean Hollow and San Gregorio is the most vulnerable to erosion on the South Coast and is serves as critical infrastructure, providing access and commerce to the region. This section of State Route 1 runs for 8.5 miles, and many areas of this alignment are near the coast, making the road susceptible to both dune and cliff erosion. The existing approach to address threats from coastal erosion is to use riprap rock (revetments) under emergency permits to stop the erosion of the cliff and then to repair the road on the same alignment. While this has served to protect the highway from existing erosion threats, it will have limited effectiveness as a long-term strategy and could lead to increasing damages to natural resources and coastal recreation (additional details on Caltrans efforts and priority areas for this stretch can be found in section 4.3).

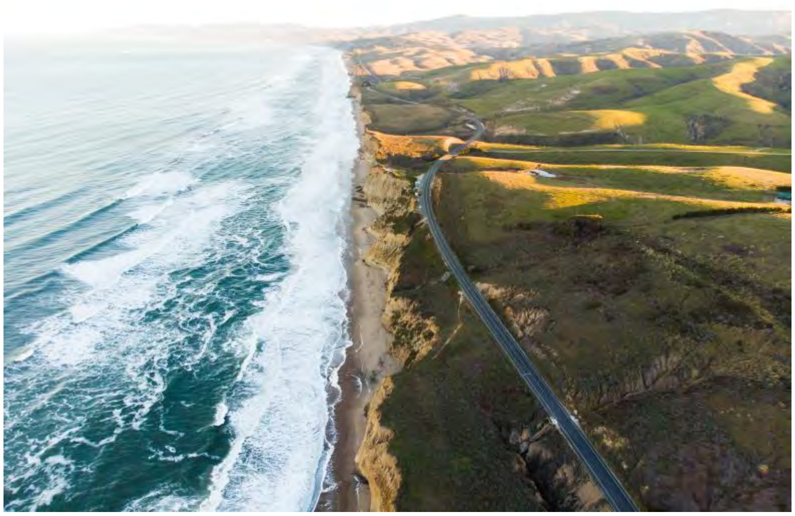


Figure 5-21. State Route 1 and high cliffs between Pescadero State Beach and San Gregorio State Beach

Source: Ethan Dow

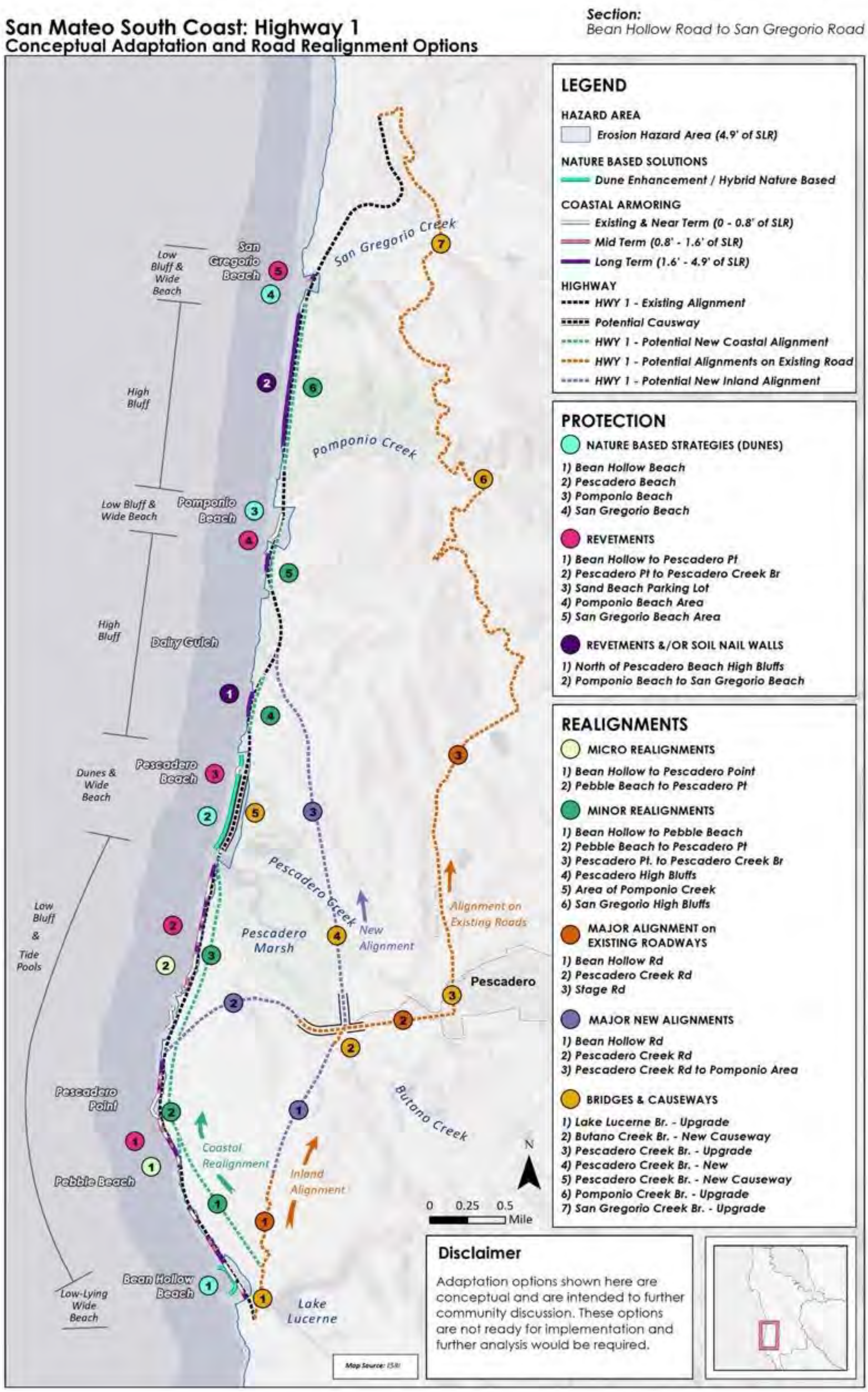
The greatest short- to medium-term threat (next 30 years) to State Route 1 in this area is coastal dune erosion at Bean Hollow Beach, Pescadero Beach, Pomponio Beach, and San Gregorio Beach as well as coastal cliff erosion near Pescadero Point. The longer-term threat (>30 years) is from erosion along the dunes near Gazos Creek Beach and the high cliffs north of Pescadero Beach (see section 4.3).

Caltrans has identified this stretch of roadway as needing additional planning and consideration and developed a Project Study Report completed in 2008 (Caltrans PID 2S210K). This plan identified different adaptation approaches for this stretch of highway, including various realignment options, and estimated some initial costs. This section attempts to take the initial work and consider how to fit the existing plan into an adaptation planning framework that considers more than just transportation, including habitat, beach access, and recreational use. Any strategy over such a long stretch of coast will require a mix of adaptation approaches, and decision-makers will need to carefully consider the relationships between multiple land uses and owners. Accounting for adaptation alternatives will be complex, and planning and implementation could take a significant amount of time.

This stretch of State Route 1 is designated as an “All American Road” by the U.S. Department of Transportation, a special classification within the national scenic byways, and the San Mateo General Plan has identified this length as a scenic roadway. Both set specific policies in order to protect views and preserve rural and coastal character. Any rerouting would involve a process of land acquisition, environmental review, and engineering studies, as well as collaboration with local communities, other stakeholders, state, county, and federal departments and permitting agencies. These considerations are beyond the scope of this work, so this study identifies them as a next step to consider how to incorporate all the adaptation planning approaches, principles, and secondary consequence considerations into developing an adaptation pathway.

5.8.1 Adaptation Pathway Options

The figures below show the complexity inherent in adaptation planning. Using results of the vulnerability assessment projecting future erosion risk to State Route 1 from cliff erosion, and realignment information provided from Caltrans 2008 (PID 2S210K), the following maps and tables have been developed. What follows includes a map of possible alternatives (Map 18), a table describing each adaptation alternative over time including projected implementation costs, (Table 5-7). Following the map and table is a description of the various actions over time and sea level rise including a discussion of the most feasible alternatives. Finally, Figure 5-22 shows a potential adaptation pathway that identifies the trade-offs between these various adaptation choices that could be considered and/or implemented over time.



Map 13. Conceptual adaptation alternative strategies for State Route 1 along the Central South San Mateo Coast

5.8.1.1 Existing Conditions—Emergency Armoring and Maintenance

The business-as-usual approach assumes some level of effort on the part of Caltrans to maintain the existing alignment in place. This may include efforts such as emergency armoring of threatened sections of roadway and repairs or replacement of failed culverts. These efforts will likely involve single-lane road closures. While this strategy has relatively low near-term costs (albeit with mounting costs over time), it involves ongoing regulatory challenges related to meeting expired permit conditions. Eventually, more severe erosion events will threaten the roadway and lead to more extensive armoring, extended lane closures, and costly emergency repairs. Expenditures for maintenance and emergency repairs will increase in both magnitude and frequency of occurrence, and the economic efficiency of making these repairs will deteriorate in comparison with alternative approaches such as realignment or protection via revetments. Over the long term, it makes longer-term economic sense to not “fill the potholes” so to speak, but rather to seek a different adaptation approach.

5.8.1.2 Short-term approaches (0-0.8 feet of sea level rise)

In the near term, it is important to begin a monitoring program of threats to the roadway, as well as begin additional technical work, and conduct meetings with key stakeholders and communities to assess support for various adaptation projects. Proactive maintenance measures such as improving and rehabilitating roadway drainage to help control runoff and reduce erosion, as well as capturing and repurposing sediment, could buy time to design and implement future planning decisions.

Protection Strategies

This stretch of State Route 1 has three distinct coastal morphologies that will likely require different protection strategies over time. Revetments are likely to protect the toe of the bluffs from wave attack and reduce erosion; however, in the long term, this will not be as effective. For the low bluffs, building and maintaining revetments will be feasible over the next 20 to 30 years, but it will come at the cost of losing space for coastal recreation, diminishing beach access, and destroying habitats.

Nature-Based Strategies

Nature-based approaches specifically for the low-lying beaches could include using cobble berms and dune restoration at areas of low-lying beaches such as Bean Hollow, Pomponio, Pescadero, and San Gregorio. Cobble berms and dune restoration would likely be effective at reducing erosion while enhancing recreation, access, and habitats.

Micro Realignments

It is also possible to build a “micro” realignment within the existing right-of-way for portions of State Route 1 approximately 10 to 20 feet inland, which would involve the removal and rehabilitation of the highway at its current location. This could occur in phases focused on high-risk erosion hot spots with the most at-risk sections to cliff erosion occurring first.

Both nature-based solutions and micro realignments working together could provide time to plan, permit, and implement longer-term solutions. Some appropriate triggers to consider for initiating mid-term planning approaches could be a number of emergency permits for revetments, or a certain distance that the highway alignment is from the cliff edge, for instance, 20 feet from shoulder to the edge.

5.8.1.3 Mid-term Approaches (0.8-1.6 feet of sea level rise)

The mid-term represents a significant fork in the adaptation pathway, where decisions made will greatly influence the longer-term adaptation costs and benefits.

Protection Strategies

The coastal morphology along this stretch of State Route 1 is characterized by beaches and dunes, low bluffs, and high bluffs. Each of the different geomorphologies will require different protection strategies over time, as the processes that drive low-lying beach and dune flooding are different from those affecting cliff erosion. In the mid-term, existing revetments on low bluffs are likely to be overtopped and require increases in armoring crest elevation, and additional lengths of protection will need to be required to protect the toe of the low bluffs from wave attack to reduce erosion. For high bluffs, however, revetments will be less effective and soil nail walls may be required. The nature-based approaches implemented in the near-term phase will require more routine maintenance to reduce erosion and wave overtopping onto the road at the low-lying beach and bluff areas.

Minor Realignment

A minor realignment would move sections of State Route 1 inland between 100 and 400 feet from the existing right-of-way. This strategy would require the purchase of land as well as the removal and rehabilitation of the highway at its current location. Minor realignment could also occur in phases, with the most at-risk section to cliff erosion, from Pescadero Point to Pescadero Creek Bridge, occurring first, and sections less at-risk at risk, such as the higher bluffs north of Pescadero Beach, occurring later. Caltrans estimated that the cost for realignment of the section from Pescadero Point to Pescadero Creek Bridge to be ~$47 million in 2022 dollars (Caltrans 2008). Minor realignment over the remaining potential vulnerable at-risk areas of this stretch could be as high as ~$70 million, for a cumulative cost total of $112 million. This strategy relies on the assumption that the Pescadero Creek Bridge crossing remains unaffected by erosion or flooding. The lead time to plan and implement this realignment is likely around 10 years (Caltrans 2021, pers. comm.).

5.8.1.4 Long-term Approaches (1.6-4.9 feet of sea level rise)

Protection Strategies

Over this time frame, previously constructed protection strategies would likely need to be rebuilt and raised in elevation and extent, essentially fortifying the coast, and doubling down on this protection approach. Armoring to this degree will prevent dune habitat from migrating inland and nature-based adaptation strategies will no longer be viable. Other secondary consequences of this approach include the loss of important habitat and recreational amenities such as beaches and tide pools, and coastal access may be made more difficult.

Minor Realignment plus Causeway

While not identified in the 2008 Caltrans Project Study Report, it may be possible to maintain the minor realignment (100 to 400 feet inland from existing alignment) with the addition of a causeway that replaces the Pescadero Creek Bridge and spans to the cliffs north of Pescadero Beach. The cost estimate for a project like this ranges between $80 million and $100 million. The causeway would allow for some recreation and habitat to be maintained at Pescadero Beach.

Major Realignments

Multiple major realignments could occur, and these can be classified as either alignment on existing roadways, an entirely new alignment, or some combination of both. In the 2008 Caltrans Project Study Report, Caltrans identified four major alignment alternatives. Lead times to plan, permit, and implement any of these major realignments is likely 25 years (Caltrans 2021, pers. comm.).

Alternative A: Bean Hollow Road to a New Alignment North and West of Pescadero Marsh

The alternative would realign State Route 1 from the intersection of Bean Hollow Road and State Route 1 and continue north to the intersection of State Route 1 with Pescadero Creek Road. A new westerly trending centerline would be needed to avoid agricultural ponds and a quarry. A new road centerline would be established over undeveloped grazing lands starting at the eastern boundary of Pescadero Marsh Natural Preserve. The new road would then reach State Route 1 just south of Dairy Gulch. Bean Hollow Road would need to be widened, and three bridges would be needed, over Pescadero Creek, Butano Creek, and Bean Hollow Road, with the latter being a reconstruction of the existing bridge. Caltrans estimated the cost to be ~$525 million in 2022 dollars (Caltrans 2008).

Alternative B: A New Alignment of Pescadero Creek Road to North and West of Pescadero Marsh

This alternative would be a new alignment of Pescadero Creek Road, beginning 0.9 mile south of its current intersection with State Route 1. It would be built over farmland and undeveloped land and run along the southern section of Pescadero Marsh before intersecting Pescadero Creek Road. At the intersection, improvements could be made to Pescadero Creek Road, such as an alternating fill embankment and causeway, causeway only, or reconstructed bridge, to raise road over sections that are prone to flooding. This could allow for wetland restoration opportunities by providing a space for species to migrate upslope as sea level rises. The alignment would then continue along the same new northern alignment in Alternate A above. Caltrans estimated cost is ~$442 million in 2022 dollars (Caltrans 2008).

Alignments on Existing Roads

Alternative C: Bean Hollow to San Gregorio, Largely on Existing Alignments

This alignment would start at Bean Hollow Road and continue to Pescadero Creek Road along the same route as Alternative B. It varies, however, in that it continues east on Pescadero Creek Road to Stage Road, and continues north on Stage Road, terminating ~1 mile north of San Gregorio Road to merge with State Route 1. Stage Road would need to be widened and the State would need to acquire County roads and portions of other adjacent properties. In total, this would require improvement or reconstruction of five bridges, including bridges over Bean Hollow (Lake Lucerne), Butano Creek, Pescadero Creek, Pomponio Creek, and San Gregorio Creek. Caltrans estimated cost is ~$1,151 million or ~$1.15 billion in 2022 dollars (Caltrans 2008).

Alternative D: A New Alignment of Pescadero Creek Road to Stage Road, then to San Gregorio on Existing Alignments

This alternative would start a new alignment of Pescadero Creek Road, beginning 0.9 mile south of its current intersection with State Route 1. It would be built over farmland and undeveloped land and run along the southern section of Pescadero Marsh and merge with Pescadero Creek Road. It would continue east on Pescadero Creek Road to Stage Road, and continue north on Stage Road, and continue north on Stage Road, terminating ~1 mile north of San Gregorio Road to merge with State Route 1. Stage Road would need to be widened, and the State would need to acquire County roads and potentially portions of other adjacent properties. This would require the reconstruction of four bridges, including Butano Creek, Pescadero Creek, Pomponio Creek, and San Gregorio Creek. Caltrans estimated cost is ~$1,080 million or ~$1.1 billion in 2022 dollars (Caltrans 2008).

Table 5-7. Cost comparison for adaptation alternatives for State Route 1 between Bean Hollow Beach and San Gregorio

Alternative	Description	Length	Cost Estimate (2022)
Business as Usual Assuming Ongoing Maintenance and Improvements in Infrastructure	Improve drainage, replace culverts, and maintain riprap from Bean Hollow to Pescadero Beach	8.7 miles (existing)	$3.4M (over the next 10 years)
Protection Strategies			
Nature Based Strategies			
Nature Based Strategies	Dune Creation and Enhancement at Bean Hollow, Pescadero Beach, Pomponio Beach, and San Gregorio Beach	Shoreline: 1 mile	$2M to $5M

Alternative	Description	Length	Cost Estimate (2022)
Armoring			
Armoring in the Near Term	Armoring behind low-lying beaches and parking lots, as well as at multiple low bluff segments between Bean Hollow Beach and Pescadero Beach	Riprap: 1.3 miles	$17M to $34M
Armoring in the Mid Term	Continued expansion of armoring	Riprap: 0.5 mile	$7M to $14M
Armoring in the Long Term	Continued expansion of armoring, and armoring of high bluffs between Pescadero Beach and San Gregorio Beach	Riprap: 0.8 mile Soil Nail Wall: 1 mile	$90M to $154M
Phased Realignment Strategies			
Micro Realignments (Near Term)			
Realignment within Existing Right-of-Way	Realignment within the existing right-of-way (10–20 ft) of specific road segments from Bean Hollow to Pescadero Beach	0.7 mile (new) 8.8 miles (total)	$20M to $30M
Minor Realignments (Mid to Long Term)			
Realignment near Existing Right-of-Way	Realignment 100–300 feet inland from Bean Hollow to San Gregorio	5.2 miles (new) 8.9 miles (total)	$112M
Causeway at Pescadero Beach	An extended causeway along the back of Pescadero Beach in lieu of the existing bridge and at grade roadway	0.7 miles (new)	$80M to $100M
Major Realignments (Mid to Long Term)			
Option A. Realignment around Pescadero Marsh via Bean Hollow Road to Dairy Gulch	Begin at Bean Hollow Road and continue on new roads to Dairy Gulch. Construction/reconstruction of three bridges.	4.7 miles (new) 8.6 miles (total)	$525M
Option B. Realignment around Pescadero Marsh via Pescadero Creek Road to Dairy Gulch	Begin at a realigned State Route 1 just south of Pescadero Creek Road and continue on new roads to Dairy Gulch. Construction/reconstruction of two bridges.	4.0 miles (new) 9.8 miles (total)	$442M

Alternative	Description	Length	Cost Estimate (2022)
Option C. Realignment through Pescadero via Bean Hollow Road and Stage Road	Begin at Bean Hollow Road and continue on existing roads to San Gregorio. Construction/reconstruction of five bridges.	11.3 miles (new)	$1,151M
Option D. Realignment through Pescadero via Pescadero Creek Road and Stage Road	Begin at a realigned State Route 1 just south of Pescadero Creek Road and continue on existing roads to San Gregorio. Construction/reconstruction of four bridges.	10.6 miles (new) 12.5 miles (total)	$1,080M

Sources:

Beavers, R.L., A.L. Babson, and C.A. Schupp [eds.]. 2016. Coastal Adaptation Strategies Handbook. NPS 999/134090.

NOAA Office for Coastal Management and U.S. Army Corps of Engineers. 2015. Natural and Structural Measures for Shoreline Stabilization.

Caltrans. 2008. Project Study Report to Request Approval to Proceed with Formal Studies for SHOPP Project on Route 1 between Bean Hollow Road and Stage Road.

Marin County Department of Public Works

City of Pacifica Department of Public Works

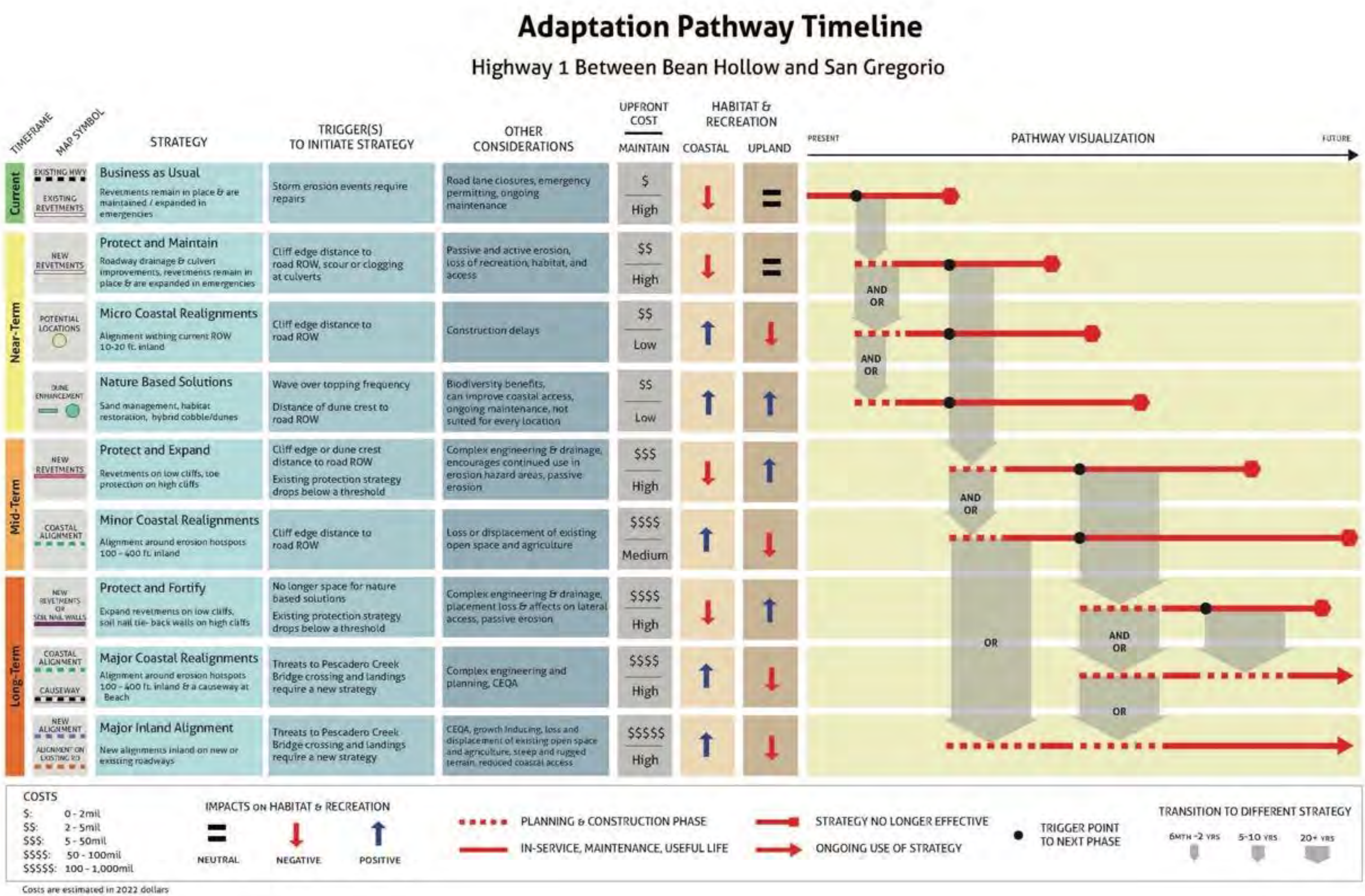


Figure 5-22. Adaptation pathway for State Route 1 along the Central South San Mateo Coast

5.8.2 Secondary Consequences of Realignments

Major or minor road realignment may have many secondary consequences, listed at a high categorical level in the list below. Impacts on social equity and agriculture should be explored carefully, since road realignment would likely reduce viable agricultural land, potentially resulting in job loss. Decision-makers would need to carefully consider new routes to avoid impacting prime agricultural land and land with water access as well as to mitigate potential job and economic losses.

Other secondary consequences may fall into the categories below. With any realignment, consultation would be required with the local community, Tribes and State Parks Tribal liaison, CCC, and other County and State agencies.

- Cultural Resources
- Noise
- Visual and Aesthetic
- GHG Emissions and Air Quality
- Community Character and Areas of Historic Significance
- Utilities
- Agriculture and Economy
- Growth-Inducing Development
- Water Quality (impacts due construction and use)
- Habitat
- Sediment Management and Coastal Processes
- Social Equity
- Public Safety and Emergency Response
- Transportation Network Functionality
- Legal
- Governance and Consideration of Regional and Local Planning.

5.8.3 Bean Hollow Example of a Cost-Benefit Analysis of Secondary Consequences for Recreation and Coastal Access

When evaluating potential adaptation strategies, several considerations and secondary consequences must be considered. This section will provide a more detailed cost–benefit framework for relationships between adaptation alternatives and recreation and coastal access. However, such a cost–benefit analysis could be focused on other sectors such as the habitat and natural environment, the social and cultural environment, commerce, etc. The economic value of damages presented in this report assume inaction. They define the potential economic impacts in the absence of any adaptation actions.

Identification of a cost-effective environmentally and socially feasible alternative will require a more site-specific investigation than is found here. This section is intended to provide a high-level evaluation of possible strategies, as well as a cost–benefit evaluation example for a specific area within this stretch.

This stretch of the South Coast is a major recreational attraction with over half a million visits a year to the state parks of Bean Hollow State Beach, Pescadero State Beach, Pescadero Marsh National Park, Pomponio State Beach, and San Gregorio State Beach. The Bean Hollow State Beach reserve incorporates the northern beach (also known as Pebble Beach), the southern Bean Hollow beach (formerly known as Arroyo de los Frijoles), and a clifftop walking trail that joins the two beaches. It is estimated to receive approximately 78,000 visits per annum, with an associated non-market recreational value of approximately $3.12 million each year. Table 5-8 provides further detail about the activities undertaken at Bean Hollow State Beach, and their associated values. The proportions assigned to each recreational activity differ from the study-wide estimates included in Table 5-8, to reflect the individual characteristics of the case study location.

Table 5-8. Non-market recreation value at Bean Hollow State Beach

Activity	Proportion of visits to Bean Hollow	Visits per year	Non-market recreation value ($M per year)
Beach recreation	35	27,300	$1.1
Fishing	10	7,800	$0.3
Hiking	40	31,200	$1.2
Tide pooling	15	11,700	$0.5
Total	**100**	**78,000**	**$3.1**

The greatest impacts projected for the case study location is flooding due to wave action, with dune and cliff erosion a secondary concern in the short-medium term but becoming more important at 1.6 feet of sea level rise and above.

Table 5-9 summarizes anticipated impacts of coastal hazards on the Bean Hollow region, and associated assumptions about the loss of recreational services associated with 4.9 feet of sea level rise. This is a hypothetical situation that is contingent on Bean Hollow being accessible. That is, it assumes that there have not already been closures of State Route 1 to the south or north of the case study area.

This section describes projected impacts under a do-nothing or business as usual approach. Table 5-9 also shows deviations from the projected impacts that would arise from armoring, dune creation or realignment of State Route 1. The rationale for the selected impact percentages is included within the relevant cells of Table 5-9.

Beach recreation at Bean Hollow beaches is already adapted to periods of flooding of the sandy beach environment due to high wave activity. Strong rip currents are common, and swimming is not recommended. As a result, most recreational activities are land-based. A 25% reduction in beach recreation has been assumed, to reflect more frequent erosion and periods of high-water levels.

With increasing sea level rise, the temporal extent of optimum conditions for tide pooling may be reduced through increasing flooding. The impact would depend on the extent to which the tidepool habitat can migrate vertically. This thought experiment assumes that with 4.9 feet of sea level rise, 100% of tide pooling opportunities are lost. Similar constraints apply to fishing from rock platforms between the two beaches. Beach fishing opportunities may offset some losses in rock fishing opportunities, so an overall loss of 10% of fishing values has been assumed.

Hiking along the clifftop trail is not subject to flood hazard, but cliff erosion may result in the separation of the trail midway between the two beaches. It is possible that hiking trail users would simply adapt to shorter trails from either end of the study area. The presence of rock outcrops at the base of the cliffs may also slow erosion in the narrowest sections. As a result, a conservative loss of 25% is estimated for hiking recreation values in the base case scenario. It is assumed that access to the hiking trail remains possible at both ends, if not from the beaches themselves then from the parking lots. Informal access and parking points also exist along the trail and provide the possibility of alternative origin and destination points.

Table 5-9. Recreation costs and benefits by strategy

Activity	Coastal hazard impacts	No Action	Armoring	Dune creation	Realignment
Beach recreation	Dune and beach erosion, flooding	25% reduction due to increased frequency of erosion and wave flooding	100% loss due to footprint and scouring effects	10% improvement due to provision of more level access points	0% loss if shoreline can retreat naturally
Fishing	Inundation of rock fishing platforms. Reduced beach width and availability for kayak launching	10% reduction due to lost rock fishing access	30% reduction due to reduced access along and across revetment or seawall	10% reduction due to lost rock fishing access	10% reduction due to lost rock fishing access
Hiking	Cliff erosion requiring trail to move inland, constrained by State Route 1	25% reduction from erosion	0% loss as cliff erosion is halted	0% loss as dune provides protection to critical erosion areas	0% loss as hiking trail can be repositioned once State Route 1 is realigned
Tide pooling	Inundation of rock platforms	25% reduction due to inundation of rock platforms	100% loss due to access constraint as outlined for fishing	25% reduction due to inundation of rock platforms	25% reduction due to inundation of rock platforms
Total loss of recreational benefits		**21.3%**	**57.5%**	**6.3%**	**8.8%**

Note: Anticipated impact (% reduction in recreation value) with 4.9 feet of sea level rise

Table 5-10 summarizes the relative economic losses from displaced recreation under each of the adaptation classes. These estimated losses are based on simple assumptions, rather than site-specific modeling and empirical economic surveys. The results represent a thought experiment, and show only the impacts for a single year, with the highest modeled sea level rise. The impacts will vary by activity and by year, with complex interactions between beach width, the available clifftop space between the coastline and State Route 1, standing water levels and wave flood levels, and accessibility of the case study site and the beaches, rock platforms, and trailheads.

Table 5-10. Relative economic losses from displaced recreation

Activity	Non-market recreation value ($M per year)	Loss of recreational value ($M per year) under Business as Usual	Loss of recreational value ($M per year) under Armoring	Loss of recreational value ($M per year) under Dune Creation	Loss of recreational value ($M per year) under Realignment
Beach recreation	1.1	0.3	1.1	-0.1	0.0
Fishing	0.3	0.0	0.1	0.0	0.0
Hiking	1.2	0.3	0.0	0.0	0.0
Tide pooling	0.5	0.1	0.5	0.1	0.1
Total	**3.1**	**0.7**	**1.7**	**0.0**	**0.1**

The thought experiment and impacts discussed in this section ignore the availability of nearby substitute locations. While it is likely that access to substitute sites will also be affected, primarily through impacts on State Route 1, it is possible that recreational losses from Bean Hollow State Beach would be transferred to other locations within the broader study area, resulting in no net loss. The location of the substitute sites, and the home location of individual visitors, would determine whether there are increased, or decreased travel and time costs associated with accessing the substitute locations.

The popularity of the beaches means that preserving and enhancing beach and recreational amenities should be considered when choosing adaptation strategies. Accomplishing this goal may be difficult as there can be competing interests, and coastal hazards are projected to impact key features of the site. For example, Arroyo de los Frijoles trail (part of the California Coastal Trail) is a popular walking trail at Bean Hollow State Beach, and the current alignment is projected to be threatened as erosion reduces land area between the bluff top and State Route 1. If State Route 1 is not relocated, competing for recreational interests may be in conflict. When evaluating alternative options for the trail, moving the trail closer to State Route 1 could make for a less enjoyable experience. However, armoring to protect the trail and State Route 1 may result in loss of the fronting beaches over time, affecting beach recreational opportunities and lateral access. When multiple alternatives that may preserve the trail are in conflict, careful cost–benefit analysis should be considered.

In addition to hiking, the benefits of the California Coastal Trail,[4] and beachgoing at the various state parks, State Route 1 also serves as an important short- and long-distance bikeway, and Pescadero is a popular biking destination. Rerouting options should consider biking-specific safety measures such as wider shoulders, signage, and striping, as well as retaining the existing right-of-way as a bikeway if an inland rerouting option is chosen for State Route 1. Recreational values associated with Bean Hollow State Beach have not been explicitly included in the analysis presented above, as they are assumed to occur primarily outside the park boundaries.

5.9 FUNDING ADAPTATION

Adaptation planning is a challenging and expensive undertaking, and the County alone cannot fund adaptation on its own. This section is intended to identify various forms of funding and financing to help the County and other stakeholders pursue financing strategies that are equitable and efficient. The San Mateo County Flood & Sea Level Rise Resiliency District, also known as OneShoreline, was established with the goal of securing and leveraging funding at the scale needed to advance multi-jurisdictional sea level rise adaptation strategies. Their work to secure and implement adaptation funding will be highly beneficial to flood-prone communities. The County may be able to partner with OneShoreline on adaptation planning next steps and federal and state grant applications.

Outside funding will require a creative approach, leveraging the area's cultural and recreational significance, and the need to maintain coastal infrastructures such as State Route 1 against increased threats from sea level rise, coastal erosion, coastal storms, and other climate hazards. Challenges include acquiring the necessary funding for adaptation strategies, communicating the need for adaptation to elected officials and staff, and gaining commitment and support from federal and state government agencies to address the realities of local adaptation challenges. The time is ripe for identifying and seeking these funds. The Biden Administration infrastructure spending and emphasis on climate resilience as well as the State of California's budget windfall are being made available for climate resilience. These two funding sources are in addition to normal funding streams available for disaster recovery and preparedness.

5.9.1 Grants and Outside Funds

Hazard Mitigation and Pre-Disaster Assistance (FEMA Programs)

The California Office of Emergency Services' Hazard Mitigation Planning Division and FEMA's Hazard Mitigation Assistance grant programs provide significant opportunities to adapt by reducing or eliminating potential losses to the County's assets through hazard mitigation planning and project grant funding. Much of the funding of specific projects must be tied to an approved Local Hazard Mitigation Plan (LHMP), which the County updates regularly. Project grants may range from hundreds of thousands to millions of dollars. Following the 2021 LHMP update, the County applied for several Hazard Mitigation Assistance (HMA) grants, including the Building Resilience Communities and Infrastructure (BRIC) and Hazard Mitigation Grant

[4] California Coastal Trail website

Program (HMGP) grants, and plans to continue pursuing this funding for ongoing risk reduction efforts.

Cultural, Community and Natural Resources Grant Program—Proposition 68

Following the passage of the California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access for All Act of 2018 (Proposition 68), $40 million has been appropriated to the California Natural Resources Agency for competitive grant funds that protect, restore, and enhance California's cultural, community, and natural resources. Funding under this program is available to local agencies and other eligible applicants for projects qualifying under several categories including resource protection, enhancement of park, water, and natural resources, and improvement of community and cultural venues or visitor centers.

California Department of Transportation Grant Program

Further grant funding through the Caltrans Sustainable Transportation Grant Program is available, including the Sustainable Communities Grants ($29.5 million awarded in 2022–2023) to encourage local and regional planning that furthers state goals, including, but not limited to, the goals and best practices cited in the Regional Transportation Plan Guidelines adopted by the California Transportation Commission.[5]

Opportunities through California State Parks' Office of Grants and Local Services Programs

The California State Parks' Office of Grants and Local Services administers grants annually for park and recreation needs. Since 2000, the office has awarded nearly $3 billion in grants for local park projects. In June 2017, $16 million in grants were awarded through the office's program from the 2002 Resources Bond Act (Proposition 40) for 25 park projects.

California Coastal Conservancy Climate Ready Grant Program

Part of the focus of this program is on coastal resource protection and community preparation for the impacts of climate change. The Coastal Conservancy funds projects covering a wide range of preparedness activities that may be applicable to the South Coast including development, and implementation of adaptation strategies and science-based scenario planning. The focus of the Grants is increasing the "availability of beaches, parks and trails for the public, protect and restore natural lands and wildlife habitat, preserve working lands, and increase community resilience to the impacts of climate change,"[6] and the South County could potentially satisfy multiple aims, garnering the project a higher priority.

5.9.2 Bond Financing

Bond financing will likely need to be funded by tax revenues, given that access to the South Coast is free and thus non-revenue generating. In the absence of a state grant, bond financing

[5] Caltrans Sustainable Transportation Planning Grants

[6] Coastal Conservancy Grants

may be an appropriate strategy for funding the large upfront expenses involved in costs associated with adaptation.

In the absence of a State grant, the County will need to determine the funding and financing of adaptation strategies for County assets. Often large capital investment projects, such as road modifications, are funded at least in part through bond financing. To repay bonds, the County will likely need to rely on tax revenues in the absence of other revenue-generating activities. With any bond financing scheme, the County must ensure sufficient future revenues. The main challenge with bond financing is ensuring there is robust underlying funding and as well as public support to gain voter approval. Two types of bonds require different funding strategies, outlined, and discussed below.

Municipal General Obligation Bonds

General obligation bonds are issued by the local government or the state. Locally issued general obligation bonds are often appropriate for adaptation projects but are subject to two-thirds voter approval because funding is tied to increased property taxes. The *ad valorem* increase in property taxes can—with supermajority approval—exceed the 1% cap set by Proposition 13. Exceeding this cap is often necessary to raise the kind of funding needed for resilience and adaptation projects. State issued general obligation bonds can be funded out of the General Fund and require only 50% voter approval. The general fund is often drawn from sales taxes and fees.

Revenue Bonds

Revenue bonds are generally not subject to voter approval, as they derive their funding from the revenue associated with a project.

5.9.3 Infrastructure and Economic Development Bank

The California Infrastructure and Economic Development Bank was created in 1994 to finance public infrastructure and private development that promote a healthy climate for jobs, contribute to a strong economy, and improve the quality of life in California communities. This bank has broad authority to issue tax-exempt and taxable revenue bonds, provide financing to public agencies, provide credit enhancements, acquire or lease facilities, and leverage state and federal funds. The bank's current programs include the Infrastructure State Revolving Fund Loan Program, California Lending for Energy and Environmental Needs Center, Small Business Finance Center, and the Bond Financing Program.

5.9.4 Taxes

Special Districts Taxes

California law supports a number of special property tax districts or property tax levies, generally applicable to new or substantially improved property. The State of California provides many options for establishing special district taxes. Many of these district taxes are oriented to improving underfinanced business districts or enabling the development of new properties. For the residential areas at Martin's Beach or around Pescadero, the County could consider the formation of a Community Facilities District (CFD). In a CFD, a property tax levy is placed upon homeowners in a defined geographic boundary so the increase in property tax would not be placed on the entire County. The funds from this tax could be used for infrastructure improvements and public services, including adaptation strategies. However, the special tax is subject to the approval of two-thirds of voters within the district. Often, CFDs are conditioned on new development approvals because of the difficulties associated with meeting this voting requirement. However, for a project with the necessary community support, such a district could be applied to existing properties.

Second Home Taxes

This could allow taxation on second homes or reduce loopholes that allow property owners to deduct the interest rates from mortgages on second homes. Under current state and federal laws, property owners can deduct the interest rates from mortgages taken out on any number of non-primary residences, a large tax break for owners of multiple homes. Along the South Coast, there are no published numbers on the number of second homes, but there are likely to be many. Currently, there is no additional tax on second homes but rather significant tax breaks in the form of write-offs for those able to afford properties. In California, legislators have pushed to eliminate the mortgage interest deduction for owners of multiple properties. Taxing or dealing with mortgage interest deductions on second homes could be justified to preserve the communities that people vacation to, and the resources that make those homes valuable. This would promote greater equity, as second homes in California are seen to provide unneeded tax benefits, rather than additional burdens on to the wealthy.

There is not currently an established practice in California for assessing second homeowners' additional taxes. However, with the predicted impacts of sea level rise on coastal resources—where many vacation homes are located—there is a growing need to consider this strategy. Furthermore, it may increase coastal access by incentivizing the conversion of these "occasional use" properties into both short-term and long-term rentals, enabling more people to visit the coast. Note, although California Assembly Bill 1905 did not pass, other bills designed to help the homeless are scheduled for Appropriation Committee hearings in the near future.

Infrastructure Financing Districts

As of September 2014, California law allows cities and other entities to create enhanced infrastructure financing districts. This allows incremental property tax revenues to be devoted to a specified purpose such as a fund for cleanup, infrastructure, parks and open space, transportation, or other things that could be applied to a variety of adaptation approaches. Historically, redevelopment agencies in the counties retained some percentage of state property and income taxes that could be applied to local infrastructure and other financing needs. However, these redevelopment agencies were dissolved during the 2008 economic recession and a valuable source of local revenues was lost. Infrastructure finance districts have been one effort to recover local funding streams. With the passage of Assembly Bill 313 and Senate Bill 628, requirements for establishing these districts have been streamlined. The intent of these bills was to fill the local funding void left by the dissolution of the redevelopment agencies. Basically, the County would establish an economic infrastructure financing district, develop a business plan with priority projects (e.g., infrastructure, adaptation), and then draw funds from changes in local tax revenues occurring as part of a redevelopment or rezone or apply for grant funds.

5.9.5 Fee Options

Impact Mitigation Fees or In Lieu Fees

Sand mitigation and public recreational impact fees or in lieu fees are another way to generate monies for adaptation measure implementation. Certain structured fees could be established to generate revenues for 1) covering the necessary planning of technical studies for, design of, and implementation of adaptation strategies, or 2) developing an emergency cleanup fund to be able to respond quickly and opportunistically following disasters. Disasters, through a different lens, are opportunities to implement changes.

There are currently two structured fees that the CCC uses to address the impacts of shoreline protection—a **Sand Mitigation Fee** and a **Public Recreation Fee**. The Sand Mitigation Fee is a fee intended to mitigate for the loss of sand supply and loss of recreational beaches in front of structures. The Public Recreation Fee addresses impacts to the loss of public recreation based upon the loss of beach area physically occupied by the coastal structure. An additional fee for ecosystem damages is under consideration by the CCC, which could assess a fee based on the cost of restoration or replacement value of the damaged habitat.

Sand Mitigation Fee: Such a fee would mitigate for actual loss of beach quality sand, which would otherwise have been deposited on the beach. For all development involving the construction of a bluff retention device, a Sand Mitigation Fee could be collected by the County to be used for sediment management purposes. The fee could be deposited in an interest-bearing account designated by the County in lieu of providing sand directly to replace the sand that would be lost due to the impacts of any protective structure. Consideration of sand volumes lost over time should factor into whether the actual sand placement is preferred or whether the volume/$ should be retained until a substantial volume can be contributed. The methodology used to determine the appropriate mitigation fee has been approved by the CCC in past cases. The funds should solely be used to implement projects, which provide sand to the County's beaches, not to fund other public operations, maintenance, or planning studies.

Public Recreation Fee: The CCC has used a methodology for calculating a statewide public recreation fee similar to their methodology for the Sand Mitigation Fee. The County could include such a methodology in the Comprehensive Land Use Plan/General Plan Update and develop administrative processes consistent with CCC guidance. The processes would include include the development of impact mitigation fees for public access and recreation, proposing a public recreation/access project in lieu of payment of Public Recreation Fees to provide a direct recreation and/or access benefit to the general public, and project prioritizations.

However, given the large stretches of the South Coast that are publicly owned by California State Parks, the in-lieu fee program may not generate significant levels of funding.

Non-local Toll for Driving Retired Portions of State Route 1

Given that State Route 1 is a vital corridor for commerce, recreation, through traffic, and local residents, implementing a toll program in its current state would be highly problematic. However, if an inland rerouting option were chosen as an adaption strategy, the existing "retired" alignment could be left in place and converted to a toll road. This could help the County both fund the maintenance necessary for the road and fund other local adaptation strategies. There are a few scenic toll roads in the United States, including the 17-Mile Drive in Pebble Beach, California ($11.25/vehicle),[7] which runs along a highly scenic coastline, and the Pike's Peak Scenic Road in Colorado ($15/person or $50/vehicle).[8] For local residents, the County could either issue an annual pass waiving the toll, or include the cost of the pass in annual taxes. However, the placement of a toll may diminish coastal access for those most impacted by road improvements, rather than the County's residents overall. The toll may, however, negatively impact coastal access for those who cannot pay and like other fees, require the approval and oversight of the CCC to ensure it is permitted.

5.9.6 Principles for Selecting a Financing Strategy

When providing a public good, any financing scheme should consider who uses the good and their ability to pay

One of the most basic principles of the public finance literature is the ability to pay principle—taxes levied on those most likely to use the (public) good and those who can afford it the most.[9] Decision-makers should thoughtfully consider this principle considering the substantial socioeconomic disparities that characterize the South Coast.

Any financing strategy should be equitable

One of the most important considerations for any tax scheme is equity. Many public finance economists favor "progressive" taxes, which tax households with higher income or wealth at a higher rate (percentage of wealth or income paid).

Any financing strategy should have community support

California has had a mixed history when it comes to taxes and tax reform. Any discussion of the strengths and weaknesses of Proposition 13 or California's tax law in general is beyond the scope of this analysis. However, any financing scheme must be approved by voters. In California, these approvals generally require a majority (50%) or supermajority (generally two-thirds of voters) to approve which can often be a barrier to raising funds. However, if the County adopts an adaptation plan with wide public support this should aid in voter approval for local finance schemes.

Any financing strategy should be robust to economic and other shocks

As with any other entity, cities and counties must rely on tax revenues to sustain their operations. A tax that is stable and predictable is preferable to a tax that varies. The most common source of fluctuations in tax revenues is the business cycle—when economic activity is strong, tax revenues are high. On the other hand, when economic activity is weak these tax revenues dwindle. Robustness is particularly important if local bonds finance any project, since creditors require payment to avoid default, and therefore prefer stability.

[7] 17-Mile Drive, Pebble Beach, California

[8] Pikes Peak Hours and Rates, Colorado Springs, Colorado

[9] Richard A. Musgrave, "Public Finance in a Democratic Society Volume III."

5.10 IMPLEMENTATION OF ADAPTATION

Different mechanisms for implementing adaptation are summarized in the California Adaptation Planning guide 2020 (Figure 5-23).

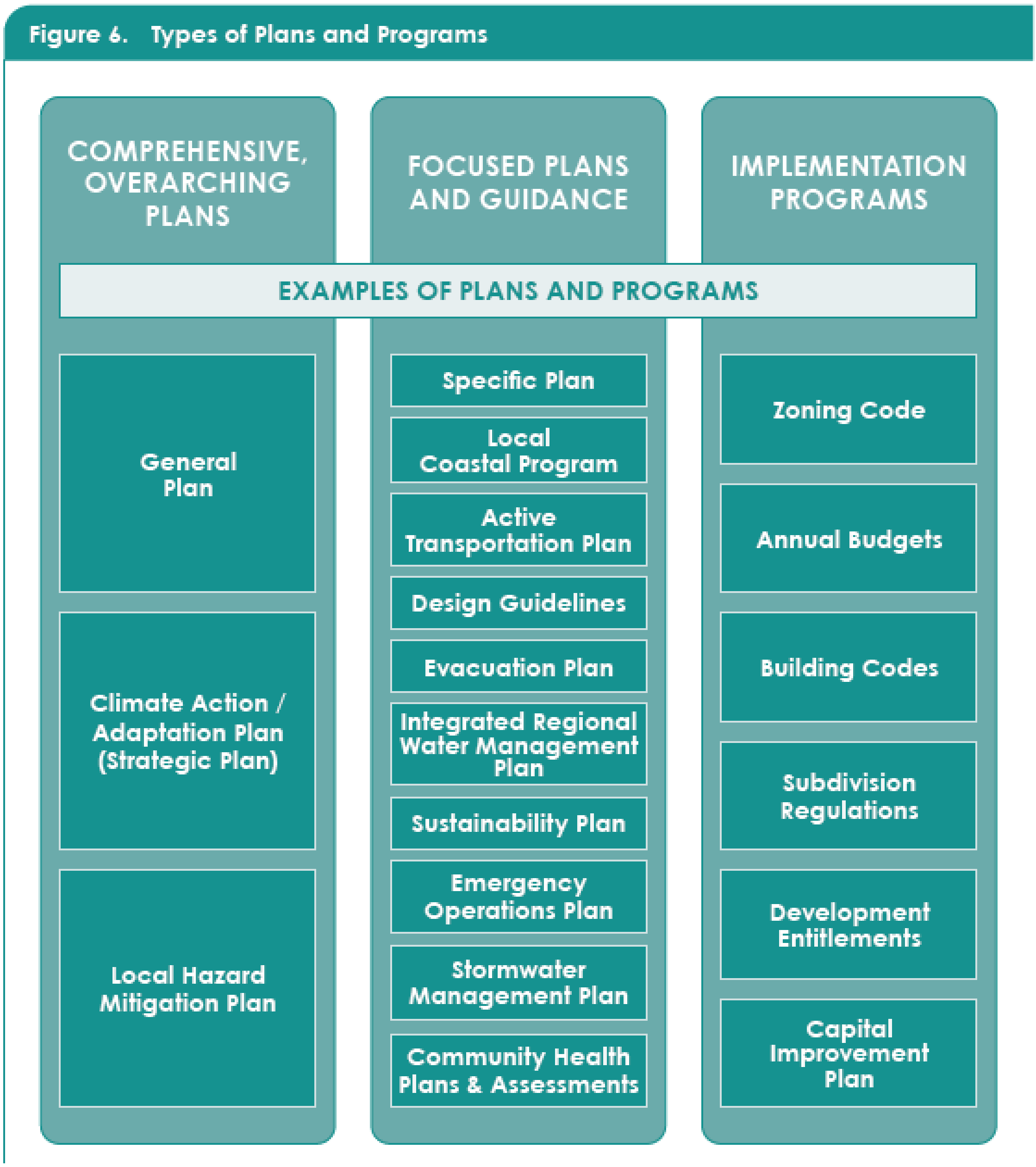


Figure 5-23. Types of plans and programs

Bean Hollow
Source: Swan Dive Media

NEXT STEPS

SEA CHANGE
SAN MATEO COUNTY

6 SUMMARY OF VULNERABILITIES AND FEASIBLE ADAPTATION STRATEGIES BY REGION

This section provides a summary of the results based on the specific measures of impacts for each sector and region over each sea level rise horizon. Given the length of the shoreline and need for specific detail, the study area is divided into three regions—North, Central, and South. The geographic extents of these regions are described below.

North: Miramontes Point in southern Half Moon Bay to the northern terminus of Pescadero State Beach, and generally extending less than a quarter of a mile inland (~563 upland acres within the combined hazard zones)

Central: Northern terminus of Pescadero State Beach to Bean Hollow Beach, and extending approximately 2 miles inland to include Butano and Pescadero Marsh areas as well as portions of the community of Pescadero (~856 upland acres in the combined hazard zones)

South: Bean Hollow Beach to the Santa Cruz/San Mateo County Line and generally extending less than a quarter of a mile inland (~630 upland acres in the combined hazard zones)

In some regions, specific areas of concern are identified and summarized in the tables below. Depending on the region, these areas are identified at either a more refined or broader scale than the north, central, and south regions.

Table 6-1. Existing vulnerabilities summary

Existing Vulnerabilities			
Sector	**Hazards**	**Exposed Assets**	**Potential Adaptation Strategies**
Land Use and Structures			
Martin's Beach	Coastal Wave Flooding and Coastal Erosion	15 cabins, including the front-row of oceanfront cabins	Armor, elevate, relocate
Pescadero, Vicinity of Water Lane	Fluvial Flooding	36 residences and businesses potentially affected	Elevate, armor (levee), repair/clean up
Cliffside Homes	Coastal Wave Flooding and Coastal Erosion	1 cliffside home near Pescadero Point potentially affected by wave flooding	Armor, elevate, relocate
Agriculture			
Northern Section	Coastal Erosion	Minor	Relocate, armor
Central Section	Fluvial Flooding	46 acres of planted fields and 29 acres of grazing and other agricultural land at four farms around Pescadero Creek Road and Water Lane	Armor (levee)
Southern Section	Coastal Erosion	Minor	Relocate, armor
Parks, Recreation, and Coastal Access			
Northern Section	All	At **Cowell Ranch Beach—**Stairway access to beach exposed to coastal wave flooding. At **Manhattan Beach—**Stairway access exposed to coastal wave flooding. The parking lot at Pomponio State Beach is potentially affected by coastal wave flooding and erosion.	Nature based, armor, relocate
Central Section	All	At **Bean Hollow State Beach**—Coastal erosion and wave flooding threatens nearly the entire portion of beach. Portions of the Arroyo de los Frijoles Trail and coastal access around to Arroyo de los Frijoles are affected. At **Pescadero State Beach**—coastal erosion and coastal wave flooding threatens nearly the entire extent of Pescadero State Beach. At **Pescadero Marsh Nature Preserve**—The majority of the marsh trials are affected by fluvial flooding including the Butano Trail, North Pond Trail, Round Hill Trail, and Sequoia Audubon Trail. Dune erosion through Pescadero Beach dunes is potentially a threat to the North Pond Habitat. The vault toilets at **Pescadero State Beach** (Pescadero State Beach) and **Bean Hollow State Beach** (Arroyo de los Frijoles)—potentially affected by storm wave flooding. The parking lots at Arroyo de los Frijoles and Pescadero State Beach are potentially affected by coastal wave flooding and erosion.	Nature based, armor, relocate
Southern Section	All	At **Año Nuevo State Park**—Coastal wave flooding is extensive at Año Nuevo Point. Dune erosion is extensive for the areas north of Franklin Point, affecting coastal access trails from Franklin Point to Gazos Beach. Erosion here is also a threat to cultural artifacts and heritage. At **Pigeon Point Light Station State Historic Park**—Coastal wave and cliff erosion impact the Pigeon Point bluffs as well as access to Pistachio Beach. The restrooms at **Pomponio State Beach**—potentially affected by storm wave flooding. The parking lot at **Gazos Creek State Beach** is potentially affected by coastal wave flooding and erosion.	Nature based, armor, relocate
County Facilities			
CAL FIRE Station	Fluvial Flooding	Fire station barracks affected by ponded flooding	Elevate, relocate
Transportation			
State Route 1	Dune Erosion and Storm Wave Flooding	¼ mile at three segments: Bean Hollow, Pescadero Beach, and Pomponio Beach	Armor, nature based, realign
County Roads	Fluvial Flooding and Storm Wave Flooding	~1 mile of Pescadero Creek Road running adjacent to the Butano Marsh and the entire ~ ½ mile of Water Lane in Pescadero are susceptible to fluvial flooding. ⅓ mile of the western facing section of Pigeon Point Road is susceptible to storm wave flooding.	Elevate (causeway), nature based
Residential Roads	Storm Wave Flooding	The entire length of Martin's Beach Road behind the rip-rap revetment is susceptible to storm wave flooding.	Elevate

Table 6-2. Near-term vulnerabilities summary

Near-Term (0.8 feet of Sea Level Rise) Vulnerabilities			
Sector	**Hazards**	**Exposed Assets**	**Potential Adaptation Strategies**
Land Use and Structures			
Martin's Beach	Coastal Wave Flooding and Coastal Erosion	Entire community is now potentially affected, including all 46 cabins (including some duplexes or triplexes).	Armor, elevate, relocate
Tunitas Creek	Coastal Erosion	6 private cliffside cabins	Armor, relocate
Pescadero—Vicinity of Water Lane	Fluvial Flooding	8 additional residential structures, for a total of 44 residences and businesses.	Armor, elevate, relocate
Cliffside Homes	Coastal Wave Flooding and Coastal Erosion	10 cliffside homes between Bolsa Point and Pescadero Point potentially affected by coastal erosion.	Armor, relocate
Agriculture			
Northern Section	Coastal Erosion	3 acres of fields at three farms, and 144 acres of grazing land and agricultural open space at multiple locations.	Armor (levee), relocate
Central Section	Fluvial Flooding	Now includes an additional 9 acres of agriculture land for 55 acres of planted fields and 30 acres of grazing and other agricultural land at 4 farms around Pescadero Creek Road and Water Lane.	Armor (levee)
Southern Section	Coastal Erosion	1 acre of fields at 1 farm and 23 acres of grazing land and agricultural open space at multiple locations.	Armor (levee), relocate
Parks, Recreation, and Coastal Access			
Northern Section	All	At the **California Coastal Trail** in Half Moon Bay, two sections of trail ~⅛ mile long are potentially affected by cliff erosion, both between 20 and 50 feet from the bluff top edge. At **Cowell Ranch State Park,** ~1 mile of trail in many sections is potentially affected by cliff erosion. At **San Gregorio State Beach,** ~⅛ of cliffside trail is potentially affected by erosion.	Armor, relocate
Central Section	All	At **Bean Hollow State Beach,** an additional ½ mile of the Arroyo de los Frijoles Trail is affected. The access stairways at Pebble Beach are also affected. At **Pescadero State Beach,** coastal erosion threatens 0.4 mile of bluff top hiking trails. The parking lot at Pebble beach is potentially affected by coastal wave flooding and erosion. The cliffside parking lots at **Pescadero State Beach**, Rockside, and the South lot, are potentially affected by erosion.	Armor, nature based (dunes), relocate
Southern Section	All	At **Año Nuevo State Park,** coastal wave flooding and dune erosion remain extensive at Año Nuevo Point and Franklin Point, and ~2 miles of trail are now affected. At **Pigeon Point Light Station State Historic Park,** cliff erosion begins to threaten the light station. Small sections of trail and coastal vistas are affected at **Cloverdale Coastal Ranches** (POST) and the **Pigeon Point County Park**. The parking lot at Pigeon Point is potentially affected by coastal wave flooding and coastal erosion.	Armor, relocate
County Facilities			
CAL FIRE Station	Fluvial Flooding	Fire station apparatus building is now susceptible to ponded flooding.	Elevate, relocate
Transportation			
State Route 1	Dune Erosion and Storm Wave Flooding	¼ mile of State Route 1 is now susceptible to erosion, including expanded stretches of those areas mentioned before: Bean Hollow, Pescadero Beach, and Pomponio Beach, and a new area near the County Line at Wilson Gulch.	Armor, nature based (dunes), relocate (micro)
County Roads	Fluvial Flooding and Storm Wave Flooding	Pescadero Creek Road and Water Lane remain susceptible to fluvial flooding. Pigeon Point Road remains susceptible to wave flooding, and small portions are vulnerable to cliff erosion.	Elevate
Residential Roads	Storm Wave Flooding	Martin's Beach Road remains vulnerable to storm wave flooding and erosion.	Elevate

Table 6-3. Mid-term vulnerabilities summary

Mid-Term (1.6 feet of Sea Level Rise) Vulnerabilities			
Sector	**Hazards**	**Exposed Assets**	**Potential Adaptation Strategies**
Land Use and Structures			
Ritz-Carlton Hotel and Half Moon Bay Golf Links	Coastal Erosion	Small portions of the golf course and landscaped grounds are threatened by cliff erosion.	Armor, relocate
Martin's Beach	Coastal Wave Flooding and Coastal Erosion	Threats from coastal wave flooding and coastal erosion escalate.	Armor, nature based (dunes), relocate
Pescadero—Vicinity of Water Lane	Fluvial Flooding	1 additional residential structure, for a total of 45 residences and businesses.	Armor (levee), elevate, relocate
Cliffside Homes	Coastal Wave Flooding and Coastal Erosion	7 cliffside homes between Bolsa Pt and Pescadero Point, this now represents just over ½ of all homes on this stretch.	Armor, relocate
Gazos Creek	Coastal Wave Flooding and Fluvial Flooding	The Gazos Creek Alliance gas station is potentially affected.	Armor, nature based (dunes), elevate, relocate
Agriculture			
Northern Section	Coastal Erosion	Now includes 7 total acres of fields at three farms threatened by cliff erosion, and 172 total acres of grazing land and agricultural open space at multiple locations.	Armor, relocate
Central Section	Fluvial Flooding	Now includes an additional 12 acres to make 62 acres of planted fields and 30 acres of grazing and other agricultural land at four farms around Pescadero Creek Road and Water Lane.	Amor (levee), relocate
Southern Section	Coastal Erosion	Now includes 3 acres of fields at 1 farm and 39 acres of grazing land and agricultural open space.	Armor, relocate
Parks, Recreation, and Coastal Access			
Northern Section	All	At the **California Coastal Trail** in Half Moon Bay, ½ mile of trail is now affected including major stretches from Miramontes Point to Cañada Verde Creek. At **Cowell Ranch State Park,** ~2 miles of trail are now potentially affected by cliff erosion. At **San Gregorio State Beach** and **Pomponio State Beach,** short sections of cliffside trail remain potentially affected by erosion.	Armor, relocate
Central Section	All	At **Bean Hollow State Beach,** an additional 0.8 mile of the Arroyo de los Frijoles Trail is now affected. At **Pescadero State Beach,** coastal erosion now threatens ½ mile of bluff top hiking trails. Two vault toilets at **Pescadero State Beach** are potentially affected by cliff erosion. The north cliffside lot is potentially affected by erosion.	Armor, nature based, relocate
Southern Section	All	At **Año Nuevo State Park and Nature Reserve,** ~3 miles of trail are now affected, this includes the Año Nuevo Point Trail, New Year's Creek Trail, the Equal Access Boardwalk, and Cove Beach Trail in the State Park (southern section), and Atkinson Bluff Trail and Service Road, Franklin Point Trail, Gazos Creek Trail, and South Whitehouse Creek Trail in the State Reserve (northern section). At **Pigeon Point Light Station State Historic Park,** access roads to the Light Station begin to be threatened by coastal erosion. 0.5 mile of trail and coastal vistas is now affected at both Cloverdale Coastal Ranches (POST) and the Pigeon Point County Park. The two off-street parking areas at Pigeon Point (not on State Parks land) are potentially affected by erosion.	Armor, relocate
County Facilities			
CAL FIRE Station	Fluvial Flooding	Both fire station buildings remain susceptible to ponded flooding.	Elevate, relocate
Transportation			
State Route 1	Dune Erosion and Storm Wave Flooding	The length of susceptible roadway increases by ~1 mile, making approximately 1.5 miles total. This includes all sections previously mentioned: Bean Hollow, Pescadero Beach, Pomponio Beach, County line, with the County line area extending most significantly to 1/3 mile, and Pescadero State Beach also extending significantly to 1/4 mile. Areas where State Route 1 is in close proximity to the cliff are now susceptible to dune erosion, such as the areas around Pescadero Point.	Armor, nature based, realign (minor or major)

Mid-Term (1.6 feet of Sea Level Rise) Vulnerabilities			
Sector	**Hazards**	**Exposed Assets**	**Potential Adaptation Strategies**
County Roads	Fluvial Flooding and Storm Wave Flooding	Pescadero Creek Road and Water Lane remain susceptible to fluvial flooding. Pigeon Point Road remains susceptible to wave flooding, and small portions are vulnerable to cliff erosion. Access to and from the lighthouse from State Route 1 is now vulnerable to cliff erosion.	Elevate, relocate
Residential Roads	Storm Wave Flooding	Martin's Beach Road remains vulnerable to storm wave flooding and erosion.	Armor, elevate, relocate

Table 6-4. Long-term vulnerabilities summary

Long-Term (4.9 feet of Sea Level Rise) Vulnerabilities			
Sector	**Hazards**	**Exposed Assets**	**Potential Adaptation Strategies**
Land Use and Structures			
Ritz-Carlton Hotel and Half Moon Bay Golf Links	Coastal Erosion	The hotel structure becomes potentially affected.	Armor, relocate
FS WebSDR HF Radio Receiving Site	Coastal Erosion	Radio tower area potentially affected.	Armor, relocate
Martin's Beach	Coastal Wave Flooding and Coastal Erosion	The potential for more serious consequences from coastal wave flooding and coastal erosion escalate.	Armor, relocate
Pescadero—Vicinity of Water Lane	Fluvial Flooding	An additional 8 primary residential structures, for a total of 53 residences and businesses.	Armor (levee), elevate, relocate
Cliffside Homes	Coastal Wave Flooding and Coastal Erosion	19 of the 22 homes on this stretch are now vulnerable to erosion and coastal wave flooding.	Armor, relocate
Gazos Creek	Coastal Wave Flooding and Fluvial Flooding	In addition to the gas station, the State Route 1 Brewery restaurant and one residence off of Gazos Creek Road are now potentially affected.	Armor, elevate, relocate
Agriculture			
Northern Section	Coastal Erosion	Now includes 20 total acres of fields at 3 farms threatened by cliff erosion, and 256 total acres of grazing land and agricultural open space at multiple locations.	Armor, relocate
Central Section	Fluvial Flooding	Now includes an additional 35 acres for 91 acres of planted fields and 36 acres of grazing and other agricultural land at 4 farms around Pescadero Creek Road and Water Lane.	Armor (levee), relocate
Southern Section	Coastal Erosion	Now includes 9 acres of fields at 2 farms and 96 acres of grazing land and agricultural open space.	Armor, relocate
Parks, Recreation, and Coastal Access			
Northern Section	All	At the **California Coastal Trail** in Half Moon Bay, 0.7 mile of trail is now affected including nearly the entire stretch from Miramontes Point to Cañada Verde Creek. At **Cowell Ranch State Park,** 2.9 miles of trail is now potentially affected by cliff erosion, including nearly the entire bluff top stretch of trail. At **San Gregorio State Beach** and **Pomponio State Beach,** nearly all of the cliffside trails are potentially affected by erosion.	Armor, relocate
Central Section	All	At **Bean Hollow State Beach,** a total of ~1 mile of the Arroyo de los Frijoles Trail is affected, nearly the entire stretch. At **Pescadero State Beach,** coastal erosion now threatens 0.7 mile of bluff top hiking trails. The restroom at Pebble Beach is potentially affected by erosion.	Armor, relocate
Southern Section	All	At **Año Nuevo State Park and Nature Reserve,** ~4.5 miles of trail are affected, including the Año Nuevo Point Trail, New Year's Creek Trail, the Equal Access Boardwalk, and Cove Beach Trail in the State Park (southern section), and Atkinson Bluff Trail and Service Road, Franklin Point Trail, Gazos Creek Trail, and South Whitehouse Creek Trail in the State Reserve (northern section). At **Pigeon Point Light Station State Historic Park,** access roads to the Light Station continue to be threatened by coastal erosion. 0.8 mile of trail and coastal vistas is now affected at Cloverdale Coastal Ranches (POST) and the Pigeon Point County Park.	Armor, relocate
County Facilities			
Cal Fire Station	Fluvial Flooding	Both fire station buildings remain susceptible to ponded flooding.	Relocate

Long-Term (4.9 feet of Sea Level Rise) Vulnerabilities			
Sector	**Hazards**	**Exposed Assets**	**Potential Adaptation Strategies**
Pescadero Corporation Yard	Fluvial Flooding	Portions of the County Yard are susceptible to ponded flooding.	Elevate, relocate
Transportation			
State Route 1	Dune Erosion and Storm Wave Flooding	2.9 additional miles of State Route 1 are vulnerable, making 4.5 total miles. All sections mentioned before, including Bean Hollow, Pescadero Beach, County Line, Pescadero Point to Pescadero Bridge. Areas between Bean Hollow and Pescadero point increase significantly. New stretches of road are threatened, including around Gazos Creek, sections near the Pigeon Point viewpoint and at Yankee Jim Gulch, a section between the San Gregorio Beach parking area and the bridge, and a section near Tunitas Creek just north of Tunitas Creek Road.	Armor, realign
County Roads	Fluvial Flooding and Storm Wave Flooding	Pescadero Creek Road and Water Lane remain susceptible to fluvial flooding. Nearly the entire length of Pigeon Point Road is vulnerable to cliff erosion.	Elevate, realign
Residential Roads	Storm Wave Flooding	Martin’s Beach Road remains vulnerable to storm wave flooding and erosion.	Armor, relocate

7 NEXT STEPS

1. Develop Project Concepts and Adaptation Plans

Based on this vulnerability assessment's identification of highly exposed assets, combined with public feedback on areas of highest concern, the County will explore adaptation projects that reduce risk in the areas of highest exposure and vulnerability. Project scoping and development will require ongoing engagement with the Association of Ramaytush Ohlone, local communities, and public agencies. For coastal adaptation projects that impact state-managed assets, such as State Route 1 or state parks, it will be necessary to coordinate closely with State Parks and Caltrans.

2. Acquire Funding to Implement Projects

After identifying priority adaptation projects for the South Coast, the County should identify and apply for grants that are a good fit for each project, considering grant period and conditions, reporting requirements, and any local cost share.

In recent years, there has been an unprecedented amount of state and federal climate resilience funding available for adaptation implementation in San Mateo County. FEMA's Hazard Mitigation Assistance Program which includes the Building Resilient Infrastructure and Communities grant, Flood Mitigation Assistance program, and Hazard Mitigation Grant Program offer billions of dollars of funding at the national level for hazard mitigation projects. Other federal agencies that provide funding relevant to resilience and adaptation include the Department of Housing and Urban Development which runs a hazard mitigation-specific community development block grant program, the Environmental Protection Agency, the Department of Energy, and for Tribes, the Department of the Interior. A comprehensive list of active federal grants is available at Grants.gov.

State funding sources for adaptation implementation include the Coastal Conservancy, the Ocean Protection Council, the Strategic Growth Council, the Department of Conservation, and the Department of Water Resources, among others. A comprehensive list of active state grants is available at the California Grants Portal.

3. Continue Community Engagement, Outreach and Education around Sea Level Rise

Community outreach and engagement should occur early and often during adaptation project development and implementation. However, it is also important to keep communities engaged on coastal hazards consistently, and not just on a project basis. The County could consider expanding existing environmental education program models, such as the Youth Exploring Sea Level Rise Science (YESS) program, to include the wider community so that there is ample opportunity for adults to stay engaged on risks related to sea level rise and other natural hazards and get involved in adaptation initiatives.

4. Update Policies to Facilitate Adaptation and Resilience

Existing policies should be reviewed and updated to ensure that the County's policy frameworks are consistent with adaptation goals and that they facilitate risk reduction projects. The County has several planning documents that establish policies applicable to sea level rise hazards, including the Safety Element of the General Plan, which is set to be updated in 2023, and the Local Coastal Program, which will be updated following the Safety Element update to incorporate sea level rise and ensure consistency across the two documents. The Local Hazard

Mitigation Plan (LHMP) is another opportunity to establish hazard mitigation goals and projects that are consistent with those goals and other county policies. The next full LHMP update will begin in 2025 for submission to FEMA by 2026. Aside from countywide policy development, there is opportunity to develop or update local land use policies through town planning processes in unincorporated areas like Pescadero.

5. Conduct or Support Additional Studies and Research

This study identified several data gaps that hinder a full understanding of the complex impacts that sea level rise will have on South Coast communities. Future studies, whether carried out by the County or other stakeholders, could address the following:

- Compound flooding: The County has started the evaluation of future compound flood hazards from the combination of fluvial runoff altered by climate change and sea level rise. Initially this was included in this report but discrepancies in the compound flood modeling as well as misalignment with the sea level rise scenarios evaluated here raised questions as to the validity of the modeling results. As a result, this was removed from this report and the modeling was passed to Stanford University for refinement. Results of the updated modeling should be included in an update to this vulnerability assessment.
- Groundwater modeling: Given the importance of the limited groundwater supplies to agriculture and water supply, more robust modeling of this resource under future climate scenarios is warranted.
- Addition of Groundwater and Wastewater into a Vulnerability Assessment: Early in this vulnerability assessment, the project team identified a lack of data regarding the water supply wells (agricultural and drinking water), as well as septic systems. These sectors were not included in the vulnerability assessment and were identified by the community and Agricultural Commission as necessary.
- Agricultural valuation: A more in-depth examination of the economics of the agricultural sector from all climate change-related hazards (not only sea level rise) is needed. This should include consideration of a wider variety of climate variables (temperature, precipitation, wildfire, etc.) as well as potential changes in crops, and consideration of other aspects of bringing the crops to market should be evaluated.

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9 APPENDIX A. PLANNING BACKGROUND

Sea level rise and climate resiliency planning has become a forefront issue for coastal communities and is at the top of many coastal decision-makers priority list in California. This appendix discusses the State regulatory framework that prompts and guides many of the regional studies, as well as many of the local and regional initiatives that are relevant to the San Mateo County South Coast.

Relevant Work at the State, Regional, and Local Level

State Level

California State Parks Sea Level Rise Adaptation Strategy (2021)

In 2021, an internal and multidisciplinary working group from State Parks developed this Sea Level Rise Adaptation Strategy to provide the framework and the decision support tools needed to improve the resilience of coastal units of the State Park System. This strategy lays out a comprehensive roadmap to build a rapid and agile response to sea level rise. Some of the actions identified in the strategy are already being implemented, while others will be prioritized over the upcoming years, pending funding availability, partnerships, and additional organizational capacity.

The Nature Conservancy and Coastal Conservancy's Conserving California's Coastal Habitats (2018)

This assessment quantifies and maps the vulnerability of California's coastal habitats, imperiled species, and conservation lands to sea level rise, as well as opportunities for conservation strategies to maintain coastal habitat area in the face of sea level rise. This assessment is intended to help decision-makers and California's communities better understand what is at risk from sea level rise, where California's coastal resources are most vulnerable, and what we can do to ensure that California's future coast will be as well conserved, diverse, accessible, and valuable as it is today. Portions of this vulnerability assessment related to habitats on the South San Mateo County Coast relied on this Conserving California's Coastal Habitats document.

Assembly Bill 691 (2013)

California Assembly Bill 691 is a first of its kind effort to collectively address risk and exposure to sea level rise at some of California's highest revenue generating granted public trust lands such as ports, harbors, and public piers. Overseen by the State Lands Commission, many of these granted lands serve as gateways to the sea that support national defense, commerce, fishing, recreation, and entire coastal economies. Passed in 2013, the legislation required all trustees of granted lands that generate more than $250,000 annually to prioritize sea level rise adaptation and to prepare a report outlining vulnerabilities and how impacts will be addressed. San Mateo County was responsible for preparing three AB691 assessments. One land grant, a subtidal stretch from Pescadero Creek to Bean Hollow Beach, is in the South Coast area. Reports were due on July 1, 2019, based on four general guiding criteria:

1. Inventory vulnerable natural and built resources and facilities.

2. Provide maps of projected impacts for 2030, 2050 and 2100.

3. Estimate the financial costs of sea level rise.

4. Provide a description of proposed adaptation measures to protect and preserve impacted resources and structures.

County Level

The County's sea level rise planning is set within the broader work by federal, state, and regional regulations and strategies.

Sea Change San Mateo County (2015 and ongoing)

Launched by San Mateo County's Office of Sustainability and the County's Board of Supervisors in 2015, Sea Change SMC is the County's guiding initiative for regional sea level rise planning and collaboration. The first task outlined under Sea Change SMC included the commencement of the San Mateo County Sea Level Rise Vulnerability Assessment. The assessment, which was supported and funded by the County and the California State Coastal Conservancy, began in 2015 and covers the entire County except the area south of Half Moon Bay. This south San Mateo County coast vulnerability assessment completes the sea level rise vulnerability study and addresses the areas not yet covered by the Sea Change initiative.

The goals of this effort were to assess vulnerability, identify impacts of flooding and erosion on people, places, and critical infrastructure, and provide a menu of actionable solutions to protect people and places. Task 2 under Sea Change SMC is to initiate a community engagement process to build support for cross-jurisdictional collaboration, which this now completed County-wide vulnerability assessment will help facilitate and guide adaptation planning.

Local Hazard Mitigation Plan (2021)

The County Office of Emergency Services completed an update to the 2016 Multijurisdictional Local Hazard Mitigation Plan, which is currently in draft form. Local hazard mitigation planning requires a large regional and cross-jurisdictional effort to plan for the reduction of risk from natural and man-made disasters. The County of San Mateo Office of Emergency Services is leading the Local Hazard Mitigation Plan update, in coordination with County departments, all 20 cities, and regional special districts. The process will be informed by a steering committee and robust public engagement.

The Local Hazard Mitigation Plan assesses hazard vulnerabilities and identifies mitigation actions that jurisdictions will pursue to reduce the level of injury, property damage, and community disruption that might otherwise result from such events. The plan addresses natural and human-caused hazards, including flooding, drought, wildfire, landslides, severe weather, terrorism, cyber threats, pandemic, and the impact of climate change on hazards, as well as other hazards. Adoption of the plan helps the County and its partners remain eligible for various types of pre- and post-disaster community assistance, such as grants, from the FEMA and the State government.

Connect the Coastside Plan (2021)

Connect the Coastside is a community-based transportation plan to help improve mobility and safety for coastside residents and visitors. It identifies programs and improvements for the State Route 1 and Highway 92 corridors to improve mobility and accommodate the Midcoast's future transportation needs. A key purpose of the plan is to define priority projects that will then be eligible to apply for funding.

The Connect the Coastside project has involved a broad public outreach program to ensure that the final plan reflects the unique character and vision of residents and businesses and aligns with broadly held community values. This plan will require ongoing community engagement to refine the infrastructure proposals into detailed designs and to advocate for funding necessary to construct these improvements.

Caltrans District 4 Vulnerability Assessment (2018)

Caltrans completed district-level vulnerability assessments for climate change impacts to agency assets in 2018-2019. This technical report provides background information, methodology, and findings of projected climate change impacts to Caltrans assets and guided the development of the Caltrans Adaptation Priorities document for District 4 that was released in 2020.

Caltrans Adaptation Priorities—District 4 (2020)

The purpose of this report is to prioritize the order in which assets found to be exposed to climate hazards will undergo detailed asset-level climate assessments. Because there are many potentially exposed assets in the district, detailed assessments will need to be done sequentially according to their priority level. The prioritization considers, amongst other things, the timing of the climate impacts, their severity and extensiveness, the condition of each asset (a measure of the sensitivity of the asset to damage), the number of system users affected, and the level of network redundancy in the area. Prioritization scores are regenerated for each potentially exposed asset based on these factors and used to rank them. Though it is likely that climate change will cause a wide array of hazards that will impact many physical asset categories, this report is focused on bridges, large culverts, small culverts, and roadways.

San Mateo Crop Reports (2019)

San Mateo County is required to present annual crop reports pursuant to Section 2279 of the California Food and Agricultural Code. The 2019 report found that the total estimated gross value of San Mateo County agricultural production in 2019 was $130,342,000, a decrease of 12.6% from 2018. This figure does not consider other inputs such as labor, packaging, transportation, and other production costs that drive the economy in the study area. While this figure represents county-wide agricultural production value, most County agricultural operations take place in the region covered by this vulnerability assessment.

SMC Parks Dept. Visitor Use/Non-Use Study (2016)

This study filled an important data gap assessing the attitudes, experiences, use patterns, and preferences regarding park visitation among San Mateo County residents. Up until the time of this study in 2016, research to inform the management and delivery of parks and recreation opportunities across both public and private sectors has been limited.

This study utilized both qualitative and quantitative methods including focus groups, onsite visitor intercept surveys, and follow-up surveys. Data collected from this study has the potential to improve park services, guide future decision making and planning, and was valuable to informing vulnerabilities related to recreation in this assessment. By deepening the understanding of current park users as well as the barriers/constraints experienced by underrepresented groups, San Mateo County Parks holds the power to expand recreational services that meet the needs of its residents, thereby improving community health, wellness, overall quality of life.

California Coastal Trail Planning (2003 and ongoing)
Led by the Coastal Conservancy, the vision for the California Coastal Trail is a continuous interconnected public trail system along the California coastline. It is designed to foster appreciation and stewardship of the scenic and natural resources of the coast and serves to implement aspects of Coastal Act policies promoting non-motorized transportation. The Trail system is to be located on a variety of terrains, including the beach, bluff edge, hillsides providing scenic vantage points, and within the highway right-of-way. It may take many forms, including informal footpaths, paved sidewalks, and separated bicycle paths. When no other alternative exists, it sometimes connects along the shoulder of the road.

San Mateo County has joined an exciting partnership of the Coastside Land Trust, California Coastal Conservancy, Peninsula Open Space Trust, and City of Half Moon Bay to complete a significant gap in the California Coastal Trail along the bluff tops south of Poplar Beach in Half Moon Bay between the Wavecrest Property and Redondo Beach.

Climate Action Planning (ongoing)
The County has two climate action plans currently in place, a Government Operations Climate Action Plan and a Community Climate Action Plan. The County's Office of Sustainability is responsible for updating and implementing both plans, ensuring that the County meets its greenhouse gas (GHG) emissions reduction commitments as required by Assembly Bill 32 of 2006.

The San Mateo County Government Operations Climate Action Plan guides County efforts to continue to reduce GHG emissions. On January 26, 2021, the San Mateo County Board of Supervisors adopted the Government Operations Climate Action Plan (GOCAP), a comprehensive strategy to address the climate crisis making significant reductions to GHG emissions to achieve carbon neutrality by 2035. The passage of the GOCAP establishes the County of San Mateo as a regional climate leader with the strongest climate action plan for government operations among the Bay Area counties. San Mateo County communities are already experiencing the impacts of climate change including rising temperatures, wildfires and hazardous air quality, extreme storms, sea level rise, and coastal erosion. Children, older adults, those with medical conditions, communities of color, and residents with unstable economic or housing situations most acutely feel these climate impacts.

In 2013, the County's Planning and Building Department completed the Community Climate Action Plan (also known as the Energy Efficiency Climate Action Plan). This Plan includes a GHG inventory of all the emissions that resulted from the unincorporated areas and a list of various proposed measures to reduce these emissions. The Office of Sustainability recently updated the Community Climate Action Plan and was adopted by the San Mateo County Board of Supervisors in October 2022.

Local Level

Tunitas Creek Beach Preferred Plan/Beach Improvement Project (2021)
Tunitas Creek Beach is slated to become San Mateo County's newest park. This project aims to work with the community to create adequate parking facilities, restrooms, trail access to the

beach, ranger facilities, and an overlook area based on community values and visitor feedback. This study indicated that priorities for refining the project plan are centered on preservation and restoration, ease of access, public restrooms, and security, while concerns of overdevelopment and crowding were expressed.

Butano Creek Chanel Stabilization and Habitat Enhancement at Cloverdale Road Bridge, (estimated completion September 2021)

Over time, erosion has caused the streambed of Butano Creek to lower at the Cloverdale Road Bridge in Pescadero. This puts the piers of the bridge at risk of becoming exposed and has destabilized the surrounding creek banks, which are depositing sediment into the water and negatively impacting water quality. The San Mateo Resource Conservation District (RCD) and San Mateo County Department of Public Works (DPW) are working in partnership to address these erosion-related impacts near the Cloverdale Road Bridge.

This project will ensure that slopes and channel banks surrounding the piers are stable and secure while also greatly improving habitat for wildlife that count on local creeks. RCD and DPW are also working to store sediment in the stream in this area that would otherwise wind up downstream. This will help to reduce flooding downstream and increase the longevity of the Butano Creek Reconnection Project that was completed in 2019.

Butano Channel Reconnection Project (2019)

Historic land use in the Butano Creek watershed, including logging and channelizing creeks, road construction, agriculture, and development (including a town in the floodplain) dramatically increased the volume of sediment entering the marsh. Routine dredging in the marsh and along Butano Creek historically conducted by local farmers ended when the State of California acquired the marsh and lagoon in 1974 as a nature preserve, along with environmental regulations, notably the Endangered Species Act (1973), Clean Water Act (1977), and California Coastal Act (1976).

Lower Butano Creek, where it runs through the marsh, has completely filled in with sediment. This blocks threatened steelhead trout and endangered coho salmon from the entire Butano watershed for spawning, rearing their young, and finding critical refuge during storms and droughts. In addition, annual mass deaths of steelhead in the marsh from poor water quality have garnered significant media attention, even as far away as the Washington Post. Chronic flooding of the main road into Pescadero cuts the community off from emergency services and the primary access to State Route 1. Where there used to be 14 feet of clearance under the bridge, now a sediment filled channel exacerbates flooding and road closures. In addition to safety and emergency response, this severely impairs commercial activity in town. Even the perception that the road may be closed deters people from coming to town, resulting in economic impacts.

The RCD has been working for years to find solutions to these problems, engaging engineers, scientists, community members, and representatives from several different agencies. In 2017, the RCD was awarded funding to reestablish 8,000 feet of the historical creek channel, remove 45,000 cubic yards of sediment, and reuse the dredge material to fill historic human-made pits to restore 28 acres of degraded marsh.

Pescadero Hydrologic Analysis (2020)

This report presents the results of the hydrologic analysis conducted to estimate synthetic unimpaired and impaired flows entering the estuary. The hydrographs presented in this report were developed based on several data sources including U.S. Geological Survey and private gages' mean daily discharge records, water rights data, land-use-based water demand data, irrigation efficiency data, and monthly evapotranspiration rates. Based on the methods described below, mean daily discharge records were developed for a 67-year period (1952–2019). This report describes the results of the analysis and provides information on the potential biological responses associated with the differences between the unimpaired and impaired flows calculated.

Groundwater Studies (2018)

The Office of Sustainability and the Environmental Health Services division of San Mateo County Health jointly completed a groundwater basin assessment of the San Mateo Plain Subbasin to assess the groundwater resources and current condition of the subbasin and to identify potential groundwater management strategies. The project was funded by Measure K (formerly Measure A), a county-wide half-cent general sales tax passed by voters, and the Office of Sustainability.

Work on the assessment commenced in April 2016; the assessment was completed in August 2018. The development of the groundwater basin assessment was a collaborative process, and the San Mateo County Office of Sustainability now hosts a webpage specifically focused on the data and findings of this project.

City of Half Moon Bay Sea Level Rise Vulnerability Assessment (2016)

Half Moon Bay's Local Coastal Program was adopted in 1993, and this project was an effort to ensure that it reflects current conditions, information, and community priorities in line with the City's General Plan. This document assesses the City of Half Moon Bay's vulnerability to sea level rise. Information in this document has informed the development of sea level rise adaptation policies related to land use, habitat conservation, recreation and coastal access, and hazards.

Solutions to Flooding on Pescadero Creek Road (cbec eco engineering, Stillwater Sciences, 2014)

This report was prepared for the San Mateo Resource Conservation District to identify feasible long-term solutions to reduce the flooding of Pescadero Creek Road by Butano Creek. The goal of this project is to maximize opportunities that enhance or restore wetland and floodplain habitats, fish passage, as well as create more natural sediment dynamics upstream, downstream and near the road to reduce the frequency and extent of future management interventions.

Caltrans Concept and State Road 1 Relocation Planning, Pescadero to San Gregorio rerouting (2008)

Prompted by a 2003 erosion event that threatened a recently realigned stretch of State Route 1 near Pescadero, the California Department of Transportation (Caltrans) was required by the Coastal Commission to study alternative highway realignment solutions that would avoid erosion hazards. The study evaluated five rerouting alternatives as well as no-build and minimum-build alternatives. The rerouting alternatives studied range from a parallel realignment of State Route 1 250 feet east of its current location to more involved realignments that travel further inland, such as beginning at the intersection with Bean Hollow Road connecting with Stage Road in Pescadero and reaching a terminus at San Gregorio Road. The range of costs (in 2008 dollars) was $1.7 million for the minimum build alternative to $607 million to reroute form Bean Hollow Road to San Gregorio Road. Each alternative involved a preliminary environmental impact assessment looking at a range of potential impacts such as community, cultural, visual, and biological resources.

Pigeon Point Light Station State Historic Park General Plan (California State Parks, ESA Consulting, 2017)

Sets up a general plan for the park and addresses key issues for the park including balancing growth and park character, parking, and infrastructure, protecting habitat, bluff erosion and sea level rise, and other regional and cultural resource interests.

10 APPENDIX B. PHYSICAL SETTING

1.1 PHYSICAL SETTING

1.1.1 Climate

San Mateo County has a coastal Mediterranean climate defined by cool, wet winters and warm, dry summers. The average rainfall in the study area over the historical record is approximately 23–28 inches per year with the highest amounts of rain falling in February. Although the warmest month is September, with an average maximum temperature of 72°F, summer temperatures in the region are frequently impacted by high winds and dense fog, resulting in rapid cooling.

California's Fourth Climate Change Assessment, completed in 2018, identified multiple climate variables that are impacting San Mateo County, and existing conditions are changing rapidly. While this vulnerability assessment is focused only on sea level rise impacts, it is important to acknowledge the impact that other climatic variables, such as temperature and precipitation, will have on the region.

Overall, the San Francisco Bay Area average annual maximum temperature increased by 1.7°F (0.95°C) from 1950 to 2005, and, even with substantial global efforts to reduce GHG emissions in the coming decades, the Bay Area will likely see a significant increase in temperature by mid-century (State of California 2018). By the end of the century, the emissions reduction scenario that occurs could make a major difference in how much Bay Area temperatures rise. For example, the medium emissions pathway represents almost a 2°F reduction from the high emissions pathway by end of the century (Table 1-1). Warming near the coast will be affected by changes in fog and sea breeze, but the influence of climate change on these highly localized features of the San Mateo County climate is poorly understood at this time (State of California 2018). Some studies suggest that eastern Pacific summertime fog declined substantially over the twentieth century (Johnstone and Dawson 2010), and the influence of climate change on historical and future changes in fog prevalence remains an unresolved issue. Regardless, increased surface temperatures have increased summertime cooling costs for residents of San Mateo County, especially at night when onshore winds diminish (Gershunov and Guirguis 2012).

California's precipitation is the most episodic in the nation (Dettinger et al. 2011), and precipitation in the San Mateo County area will continue to exhibit high year-to-year variability, with very wet and very dry years. Recently, the 2012–2016 California drought led to the most severe moisture deficits in the last 1,200 years and a 1-in-500 year low in Sierra snowpack. Importantly, paleoclimatic records show that mega-droughts spanning multiple decades have occurred in California's past.

Table 1-1. Historical and projected future temperature and precipitation ranges for the South San Mateo Coastal Area

Climate Indicator		Baseline (1961–1990)	Mid-Century (2035–2069)		End-Century (2070–2099)	
		Observed	Medium Emissions (RCP 4.5)	High Emissions (RCP 8.5)	Medium Emissions (RCP 4.5)	High Emissions (RCP 8.5)
Temperature *(°F)*	Average	65.1				
	Change		68	68.8	69.1	71.8
	Range		66.4–69.5	67.1–70.5	67.2–71.5	69.2–75.6
Precipitation *(inches)*	Average	27.7				
	Change		28.7	29.3	29.5	30.5
	Range		25.1–36.9	23.8–37.1	24.5–35.8	21.5–40.4

Source: Cal-Adapt
RCP = relative concentration pathway
*Four models have been selected by California's Climate Action Team as priority models for research contributing to California's Fourth Climate Change Assessment (**Pierce et al. 2018**).*

There are two emerging perspectives on how climate change is affecting precipitation in California. On one hand, any changes in annual mean precipitation that occur are currently expected to be relatively small compared to the range of natural variability experienced in the region (USGCRP 2017). On the other hand, atmospheric and climate models both indicate that the largest individual storms are becoming more intense with climate change (Pall et al. 2017; Prein et al. 2017; Risser and Wehner 2017), and there is some evidence that this might also be accompanied by more frequent extremely dry periods, as well as more frequent "whiplash" events that swing from extremely dry to extremely wet conditions in California (Swain et al. 2018), further enhancing variability in a system already characterized by "booms and busts." Either way, the Bay Area's largest winter storms will likely become more intense, and potentially more damaging, in the coming decades. Future temperature increases, regardless of whether total precipitation goes up or down, will likely cause longer and deeper California droughts, posing major problems for water supplies, natural ecosystems, and agriculture.

1.1.2 Geology and Geomorphology

Mountains

The coast of South San Mateo County is separated from the San Francisco Peninsula by Montara Mountain, which forms the northern spur of the Santa Cruz Mountains, part of the California Coast Ranges. The Coast Ranges are a series of northwest- to southeast-oriented ranges separated by parallel valleys. The ranges and valleys are the results of tectonic activity in the form of oblique movement between the Pacific Plate and the North American Plate. Geologically, the Coastal Ranges are young (3–4 million years), and still active today (see Map 1).

Marine Terraces

Marine terraces are the dominant geomorphology along the South San Mateo County coastline and are evidence of the tectonically active nature of the region. Marine terraces are relatively flat-topped features with steep ocean-fronting slopes created by the rise and fall of sea levels over millennia combined with uplift associated with movements on active fault systems. When sea levels rise, waves carve a planar surface that is subsequently uplifted. Lithologically, marine terraces comprise soft, poorly consolidated sand and gravel at the top and a more indurated, thus stronger, lithologic unit at the base. The lithology of the basal unit controls the localized geomorphology that ranges from low relief steep slopes with narrow fronting beaches to vertical cliffs with no or little beach and wave-cut notches and sea caves.

Creeks and Stream

Numerous streams and creeks interrupt the seacliff and marine terraces throughout the study area coastline. The largest ones include Gazos Creek, Pescadero Creek, San Gregorio Creek, and Tunitas Creek. Beaches and barrier spits form at many of the larger creek mouths, and result in the formation of lagoons that are adjacent to the ocean but separated by the barrier spits that frequently breach during winter storms.

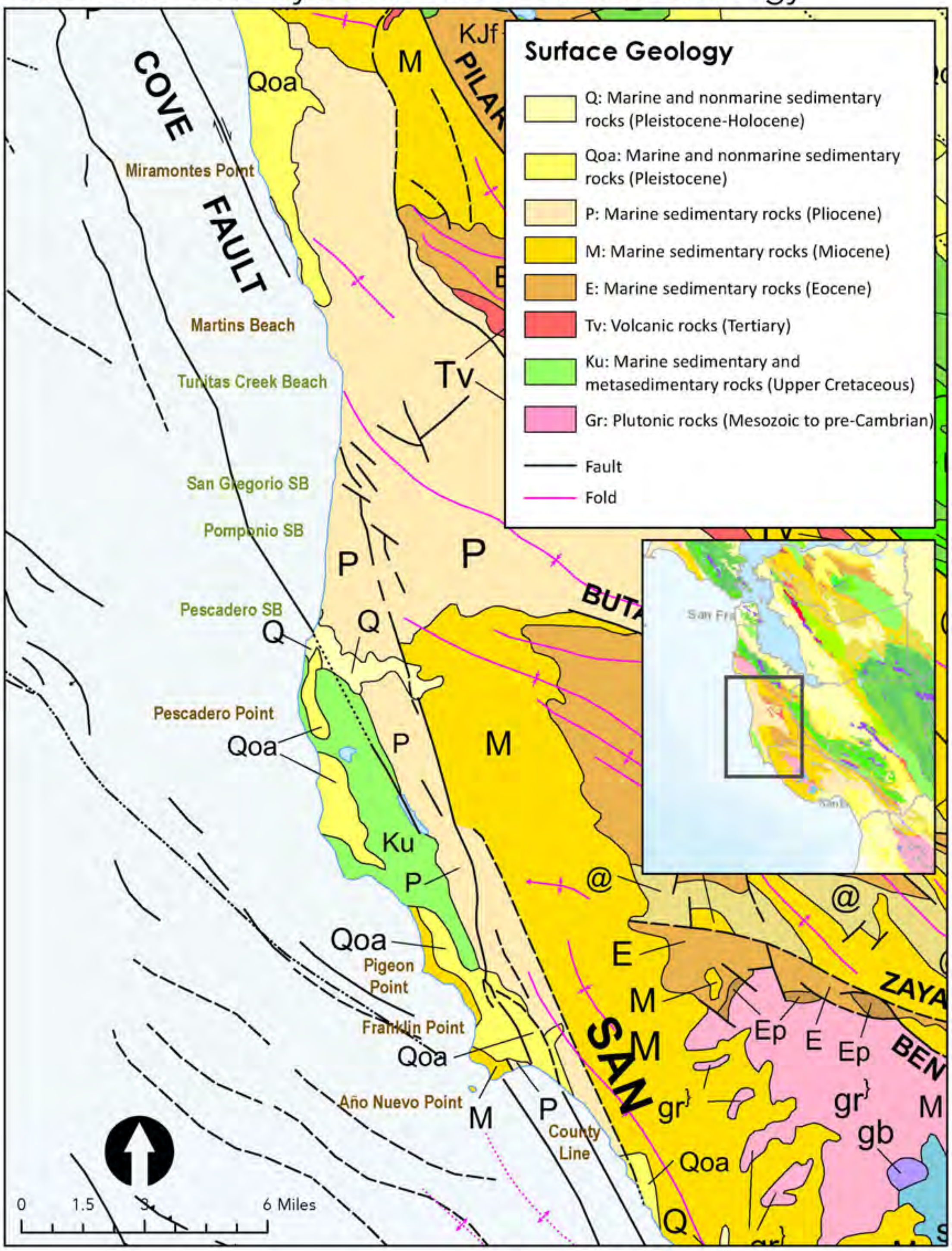
Dune and Cliffs

The coastal character of the South San Mateo Coast is variable, with bluffs being the predominant back beach feature at 89%, and 11% of the coast backed by sandy dunes. The bluffs also vary substantially in elevation with most bluff tops ranging in height from 40 to 100 feet, with the highest bluffs reaching up to 280 feet in the area just north of San Gregorio Beach between San Gregorio Creek and Tunitas Creek (Figure 1-1).

Geology of the Area North of Pescadero State Beach

North of Pescadero State Beach, the geology is dominated by marine terrace deposits overlying various members of the Purisima Formation that can range from fine- to coarse-grained sandstones to fine-grained siltstones and mudstones. The variable material strength of the Purisima Formation, along with locations of faults, joints, and fracture systems that change along the coast, influences the geomorphology, including the height and slope of the seacliffs. The seacliffs vary dramatically in height along this portion of the study area and range from 30 feet to more than 150 feet.

San Mateo County South Coast Surface Geology



Map 1. Geology of the San Francisco peninsula with general locations of major faults.
Source: California Geologic Survey

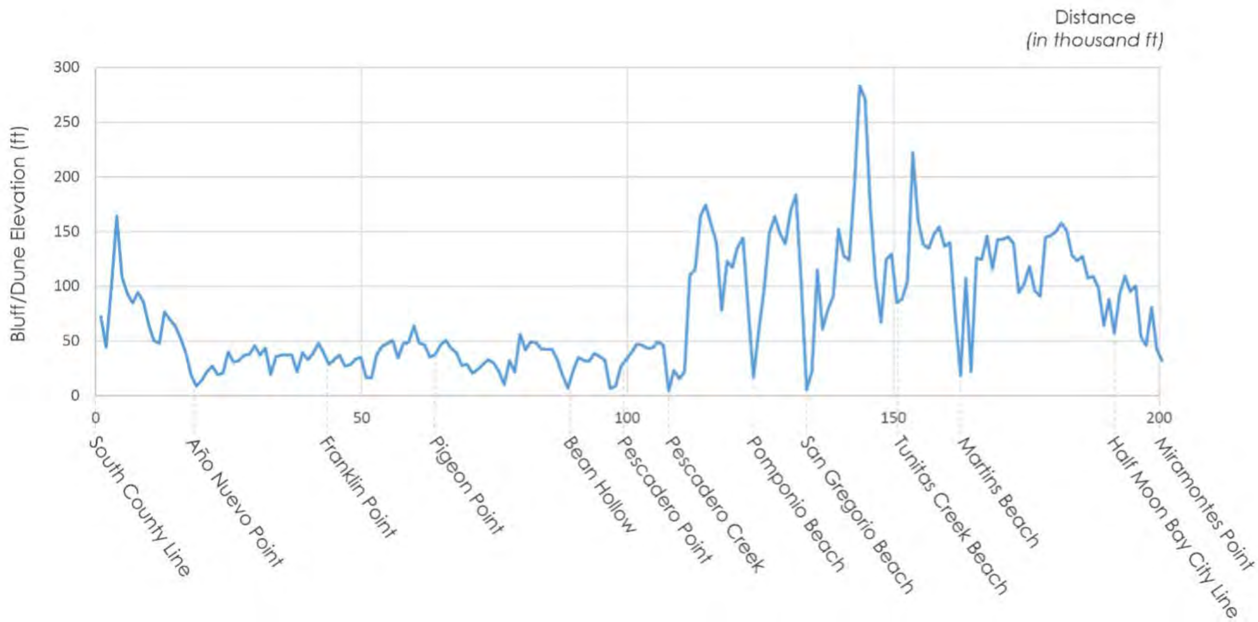


Figure 1-1. Bluff and dune elevations of the study area.

The areas less than 30 feet tend to be either sand dunes or creek mouths and are susceptible to both erosion and flooding, while areas higher than 30 feet are most susceptible to erosion.

Geology of the Area South of Pescadero State Beach

South of Pescadero State Beach to just north of Point Año Nuevo, the landscape is lower relief than to the north, with low marine terraces of the Pigeon Point Formation overlain with intermittent deposits of marine terrace deposits. The Pigeon Point Formation is variable and contains coarser sandstones and conglomerates as well as mudstones and siltstones. The seacliffs along this stretch of coast generally range in height from approximately 10 to 30 feet.

Point Año Nuevo, which is part of Año Nuevo State Park, was formed in the Monterey Formation, a thinly layered mudstone that is overlain by a large field of active sand dunes. Just offshore of Point Año Nuevo lies Año Nuevo Island, once connected to the mainland by a tombolo of sand as noted by explorer Sebastian Vizcaino in 1603 (Patsch and Griggs 2007).

1.1.3 Littoral Cell and Sediment Budget

A littoral cell is an area of coastline that contains the complete cycle of sedimentation, including sources, transport pathways, and sinks. The presence of sand on any beach depends on the transport of sand within the littoral cell and human activities, especially those that are shore perpendicular such as the jetties at Pillar Point Harbor, can disrupt the flow of sand in a littoral cell. In the part of the Santa Cruz littoral cell that extends from Pillar Point to Moss Landing, it is estimated that 80% of the sediment budget comes from rivers and 20% from bluff erosion (Patsch and Griggs 2007). As with much of coastal California, the net transport of sand is generally from north to south.

1.2 COASTAL PROCESSES AND HAZARDS

The seasonal coastal processes of tides, waves, longshore currents, and winds move sediment and shape the coastline of San Mateo County. Coastal erosion is a natural process that occurs from a combination of sea level rise and coastal storms. Natural processes, if allowed to occur unimpaired by human activities, move sediment and shape the landscape (morphology), creating habitats over millennia. Beaches form from the deposition of sand from alongshore sand transport and erosion of the backshore features (bluffs and dunes) during storm events. The daily tidal and wave action reworks the sand to constantly reshape important recreational areas and habitats.

Coastal change is dependent on sediment supply, coastal processes such as waves, tides, and currents, and human activities. If sediment supply exceeds sediment removal, the coast will prograde seaward; if there is more sediment removed than supplied, the coast will erode. These processes occur over a range of time and spatial scales. Long-term changes are caused more by changes in sediment supply and sea level rise, whereas short-term change occurs in response to events such as large storms or tsunamis.

San Mateo County beaches experience seasonal cycles during which winter storms may remove significant amounts of sand, creating steep, narrow beaches, and in the summer, gentle waves return the sand, widening beaches and creating gentle slopes. As a result of the seasonal cycles, beaches are the widest in mid-fall and narrowest in early spring. Because there are so many factors involved in coastal change, including human activity, sea level rise, seasonal fluctuations, and climate change, sand movement will not be consistent year after year in the same location.

1.2.1 Coastal Processes

Coastal processes are generally caused by tides and waves that move sediment and erode the coast. These natural physical processes only become hazardous when development and infrastructure are built in the way of these natural processes. Coastal erosion, another coastal process, typically occurs during coincident high tides and high wave events. Further discussion of specific coastal hazards and how they were projected into the future is included in Section 4, “Methodology and Approach.”

1.2.1.1 Tides

The Half Moon Bay tide gauge at Pillar Point (NOAA Station 9414131) was used to identify the elevations of mean high water (MHW is a value of 4.99 feet North American Vertical Datum [NAVD88]) and mean low water (MLW is a value 0.04 feet NAVD88). The tidal datums are shown in Table 1-2. Rising MHW tide levels and tidal levels used in erosion estimates as described below were used to map projections of tidal flooding along the coast.

Table 1-2. Tidal datums for Pillar Point Harbor

Datums for Pillar Point Harbor, California (9414131)		
Datum	**Value in Feet**	**Description**
MHHW	5.6	Mean Higher-High Water
MHW	4.95	Mean High Water
MTL	3.03	Mean Tide Level
MSL	2.99	Mean Sea Level
MLW	1.11	Mean Low Water
MLLW	0	Mean Lower-Low Water
NAVD88	–0.04	North American Vertical Datum of 1988

Epoch: 1983–2001

Tides in San Mateo County are mixed, predominantly semidiurnal, and are composed of two low and two high water levels of unequal heights per 24.8-hour tidal cycle. Typically, the largest tide ranges in a year occur in late December to early January when the moon and sun are in alignment and closest in their orbits to the earth. These astronomical high tides are known as "king tides" (Figure 1-2), and often result in coastal flooding unrelated to storm events.

Figure 1-2. Overhead view of Bean Hollow State Beach during a high tide and high swell event
Source: Swan Dive Media

Maximum water levels occur as a result of astronomical tides, wind surge, wave setup, density anomalies, long waves (including tsunamis), and El Niño and Pacific decadal oscillation events. On longer time scales, the tides will reach higher elevations as sea level rise rates accelerate.

1.2.1.2 Wave Climate

The waves that approach the South San Mateo Coast are characterized by three dominant types, broken down by their wave source and direction. The northern hemisphere waves typically are generated by cyclones in the north Pacific during the winter and bring the largest waves (up to 25 feet). The southern hemisphere waves are generated in the Southern Ocean during the summer months and produce smaller waves with longer wave periods (greater than 20 seconds). Local wind waves are generated throughout the year either because of storms coming ashore during the winter, or strong sea breezes in the spring and summer. The shoreline varies in orientation along the coast, trending north–northwest to the north–northeast, and therefore may be affected differently by the angles of wave approach. Given the various shoreline orientations and wave directions, it is unlikely that any single large wave event would simultaneously cause extensive damage along the entire coast.

1.2.1.3 Longshore Currents

Because the largest waves approach the San Mateo County open coastline from the northwest, the dominant direction of longshore currents, and thus alongshore sediment transport, is from the north to the south. Less frequently, there are reversals in the sediment transport direction due to large storm waves during El Niño years that tend to come from the southwest.

1.2.1.4 Winds

The winds experience mild seasonal variations along the San Mateo Coast, with the windier part of the year from February to July with average wind speeds of approximately 9 miles per hour. The calmer wind window extends from July to February with an average speed of 7 miles per hour. The direction of the winds also shifts seasonally, coming dominantly from the west from February to November and from the north the rest of the year (Figure 1-3).

1.2.1.5 Tsunamis

Tsunamis are ocean waves with extremely long wave periods that can be generated by earthquakes, landslides, or volcanic eruptions. There are different sources of tsunamis—those that come from distant sources (farfield) and those that come from movement on local faults or submarine landslides (nearfield). There are no known recorded deaths from tsunamis in San Mateo County, but there is documentation of tsunami-caused wave impact from farfield events in 1946, 1960, and 1964, associated with earthquakes in Alaska and the Aleutian Islands.

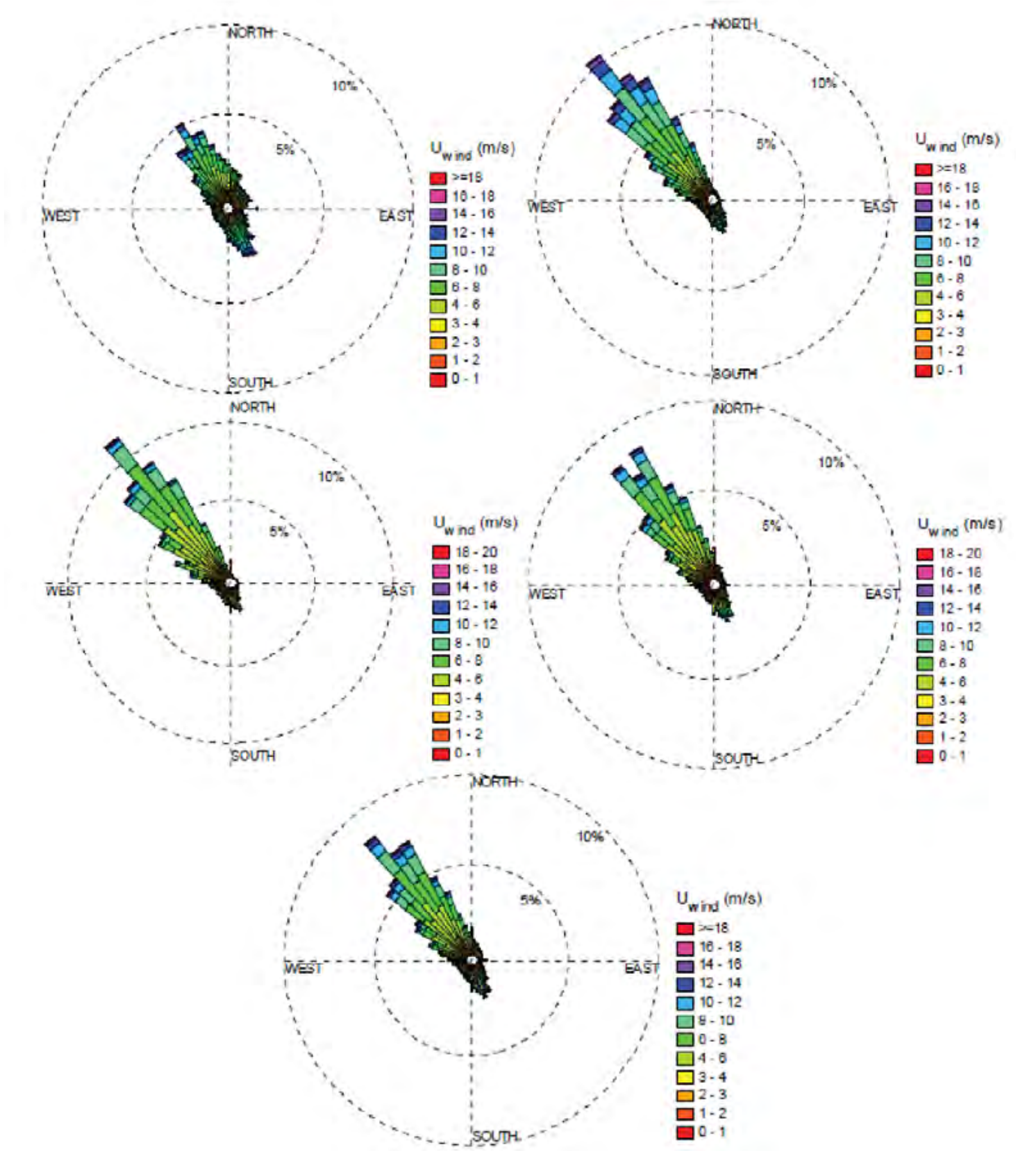


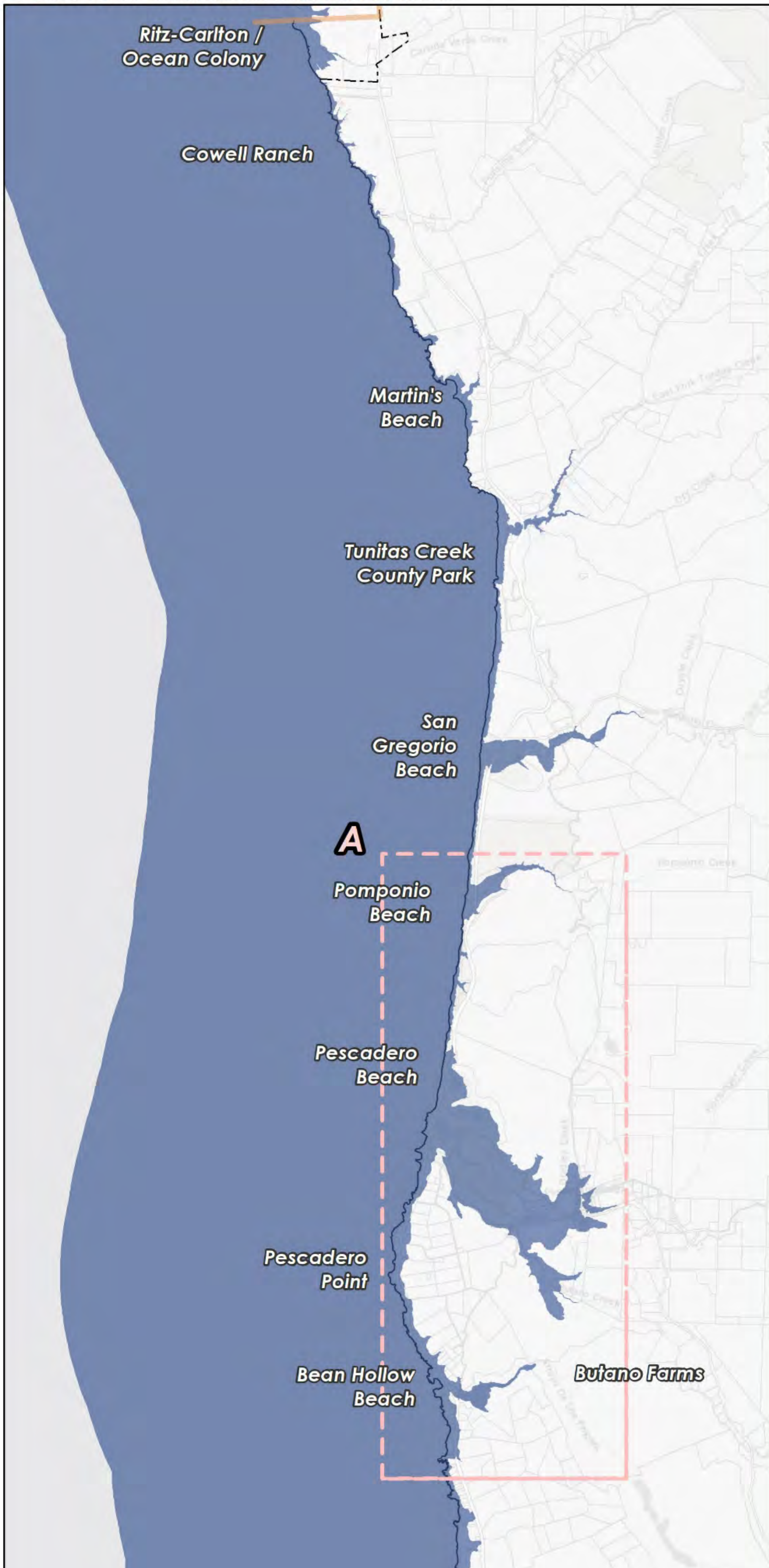
Figure 1-3. Wind rose of the annual and seasonal directional wind speed in the South Coast (m/s). Winter (top-left), spring (top-right), summer (middle-left), fall (middle-right), annual (bottom)

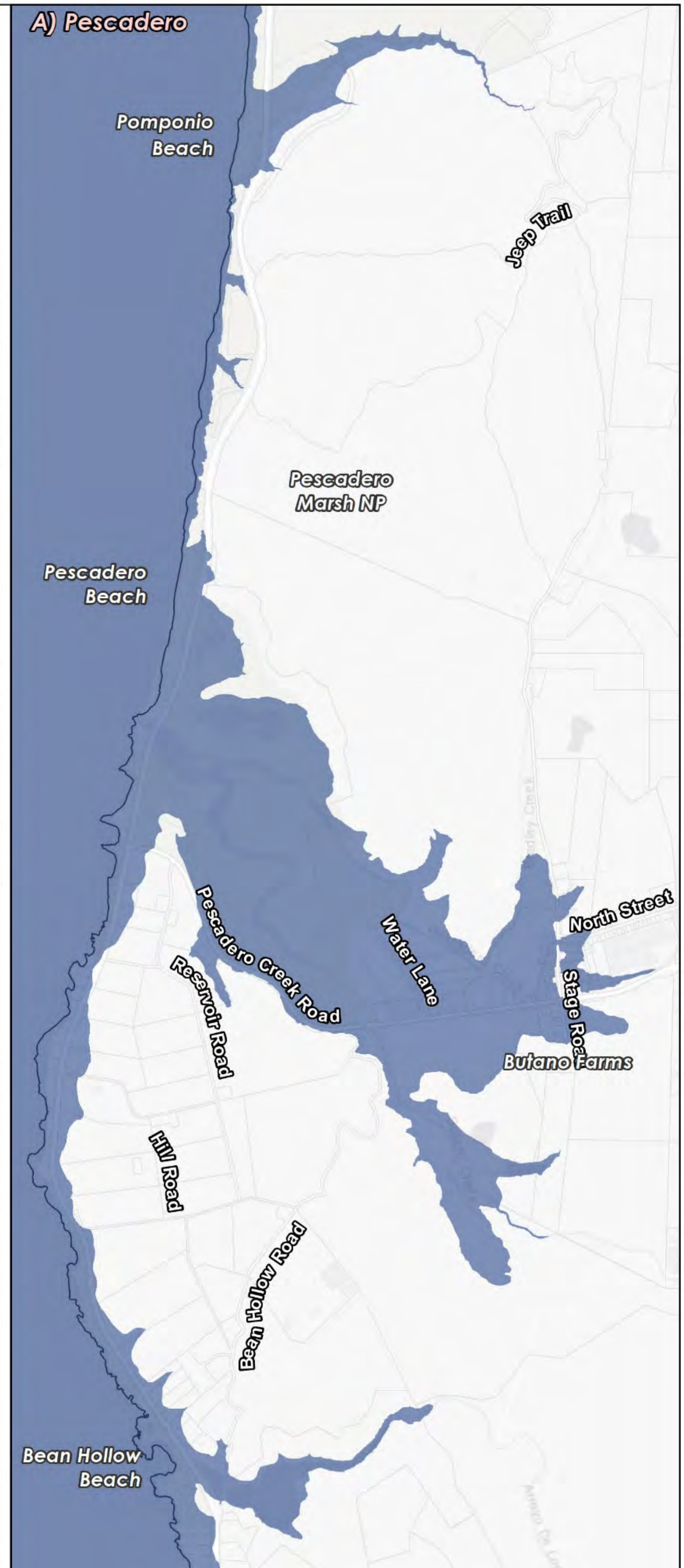
Source: USACE, North Half Moon Bay Shoreline Improvement Project, 2015

Section:
San Mateo County South Coast

San Mateo South Coast: Tsunami Hazard Area

CGS 2021 Tsunami Hazard Area





1.2.2 Existing and Historical Coastal Hazard Impacts

Historically, severe El Niño winter storms have caused significant coastal erosion throughout the study area, most notably on State Route 1 near the intersection with Pescadero Creek Road. Due to continuing threats from erosion, sections of this road were realigned to the limits of the Caltrans right-of-way in 2002. Months later, in the winter of 2003, storms led to erosion by up to 13 feet near the newly aligned roadway, forcing Caltrans into emergency response mode. In the summer and fall of 2003, 390 linear feet of rock (riprap) over three sections were placed to protect State Route 1 from continued coastal erosion. Later, in 2013, more rock along with geotextile filter fabric was added connecting the two smaller 50-foot revetments into one larger section (Figure 1-4).

Pescadero State Beach Historical Armoring Progression

	**1979**—No armoring, note the dry sand beach visible despite the large wave conditions.
	**2003**—Winter storms lead to erosion, and emergency riprap is placed with cobbles and gravels usually covered with sand now visible

	**2019**—Two sections expanded and connected into one larger riprap structure. Note the encroachment of riprap on the dry sand beach and lateral beach access on the left of the image.
	**2021**—Current Conditions (low tide, October 2021). The lack of footprints and signs of kelp or driftwood indicate that the waves routinely interact with the revetment.

Figure 1-4. Pescadero State Beach armoring progression showing how emergency permitted revetments have expanded and are reducing the width of the recreational beach.

Source: 1979, 2003, 2019—Coastal Records Project. 2021—Integral Consulting Inc.

Caltrans estimated that the long-term average annual erosion rate for this stretch of coast is between 3 and 5 feet per year (Caltrans 2018). With sea level rise, the rate of erosion can be expected to accelerate. Caltrans, as part of its road maintenance work, is acutely aware of the fact that erosion along State Route 1 is a recurring and growing issue that will need to be addressed.

1.2.2.1 Existing Estuary Flooding Hazards

Historical flooding of the town of Pescadero is well documented and related to Butano Creek frequently exceeding its channel capacity, even during low magnitude events (Figure 1-7). For more than 25 years, Pescadero Creek Road has been blocked almost annually by flooding of

Butano Creek, jeopardizing public safety and impeding access by public safety officers and medical responders into and out of the Pescadero community. When the bridge over Butano Creek was first built in 1961, the river bottom below the underside of the bridge had approximately 11 feet of clearance. Clearance under the bridge had been reduced significantly before the dredging of Butano Creek during the summer of 2019. A survey in 2001 found only about 2 feet of clearance in some sections between the underside of the bridge and the creek bottom (San Mateo County Superior Court 2011). This sediment accumulation has increased the frequency of flooding and can impair fish passage and other critical ecosystem services, creating dangerous conditions that inhibit emergency services access and isolate Pescadero. The responsibility for Pescadero Creek Road and its maintenance belongs to San Mateo County Public Works, which is also responsible for a 30-foot right-of-way on either side of the road.

The San Mateo County Board of Supervisors passed a resolution in 2018 contributing $1 million toward a dredging effort at Butano Creek, which also received state and federal funding. The San Mateo Resource Conservation District (RCD) and State Parks led the project with a goal of reducing the extent, duration, and frequency of flooding. The project has restored more than a mile of the historical creek channel and removed approximately 65,000 cubic yards of sediment. This material was deposited into relic agricultural channels and ditches in the Butano Marsh. As of early 2022, the restoration project performed very well in large rain events. There was still some flooding of the road, but the flooding was of a very short duration, hours rather than weeks (Robins 2022, pers. comm.). It is expected that silt deposition, vegetation overgrowth, and debris collection will likely require periodic clearing and cleanup efforts in future years.

Figure 1-5. Dredging of the Butano Channel at Pescadero Creek Road, 2020
Source: Jordan Plotsky

Figure 1-6. Flooding in the town of Pescadero, 2017
Source: San Mateo RCD

Figure 1-7. Flood conditions at the Butano Creek Bridge, 2017
Source: San Mateo RCD

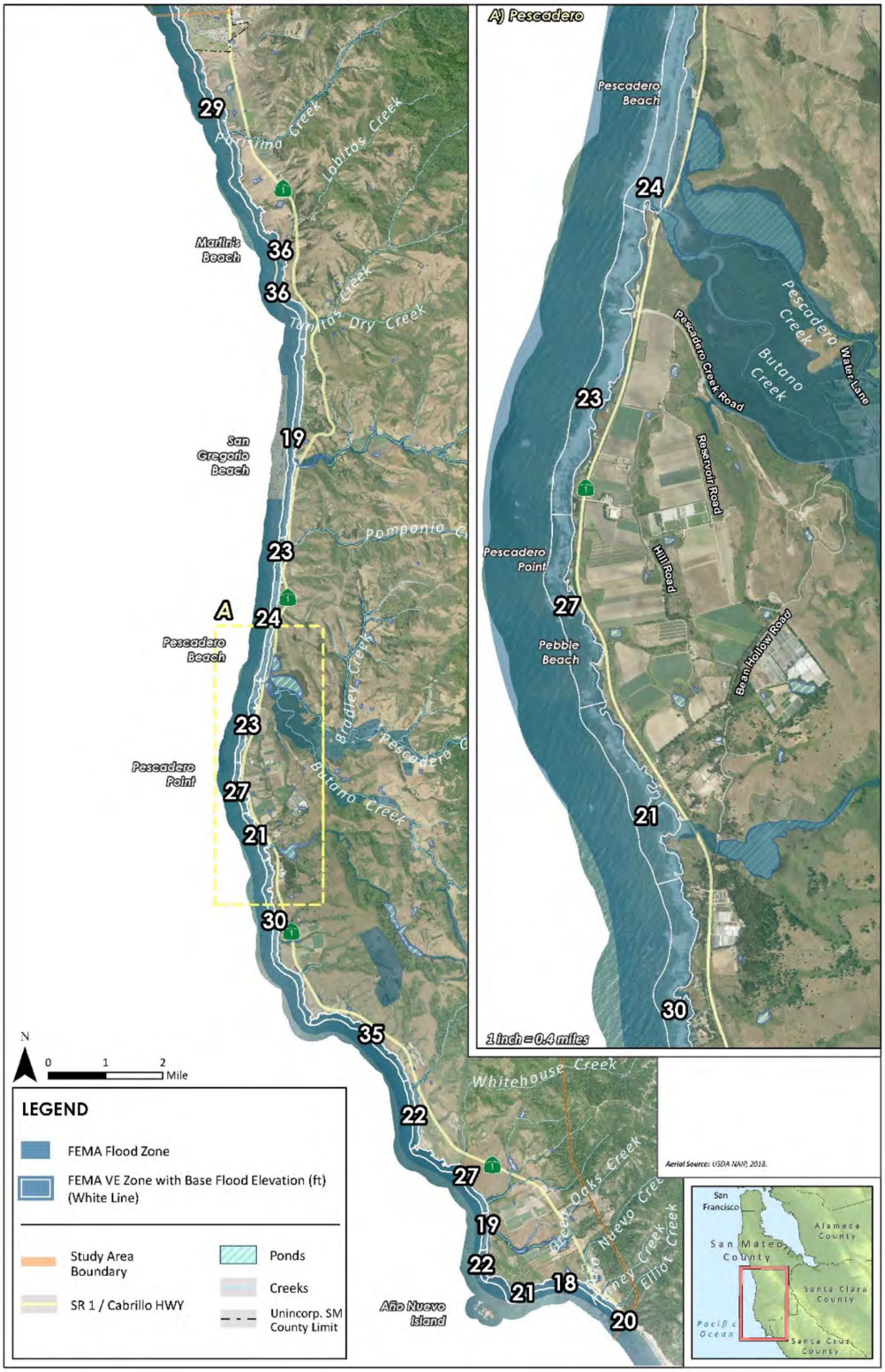
1.2.2.2 Existing Storm Wave Flooding Hazards

The community of Martin's Beach has a history of experiencing storm-wave flooding. The community is currently protected from storm wave flooding by a 963-foot-long riprap revetment and 200-foot-long retaining wall along the shoreline. The revetment was constructed under an emergency permit from the CCC and approval was explicitly meant to be temporary. Many portions of this seawall have been undermined and eroded and during storm events the roadway behind this wall and the front row of homes are flooded (Figure 1-8). According to a resident account, historically, the previous owners would import fill to widen the road every summer, which would subsequently be washed out in winter storms and winter repairs would be made as needed.

Figure 1-8. Storm wave flooding at Martin's Beach, January 2021
Source: David Taylor

Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) delineate coastal flood hazards as part of the National Flood Insurance Program. This program requires a highly specific technical analysis of watershed characteristics, topography, channel morphology, hydrology, and hydraulic modeling to map the extent of existing wave run-up-related flood hazards. These maps represent the existing 100-year and 500-year FEMA flood events (1% and 0.2% annual chance of flooding, respectively) and determine the flood extents and flood elevations across the landscape (Map 3). FEMA flood maps are based on existing flood hazards and do not account for coastal processes, sea level rise, or climate change.

San Mateo South Coast: FEMA Flood Zone with Storm Wave Flooding Extent



Map 3. FEMA flood zone with storm wave flood extent and BFEs (feet), which are represented by the bolded numbers.

1.2.3 Coastal Armoring Locations

Given the rural character of the South San Mateo Coast, very little of the overall coast is armored. An inventory of existing coastal armoring conditions shows 19 different structures that cover 3,171 feet (0.6 mile) of shoreline. The highest concentration of coastal armoring occurs between Bean Hollow and the Pescadero Creek Bridge, protecting both the coastal homes in this region and State Route 1 (Map 7). A table of the coastal armoring conditions in the South County is listed below.

Table 1-3. Coastal armoring types and conditions

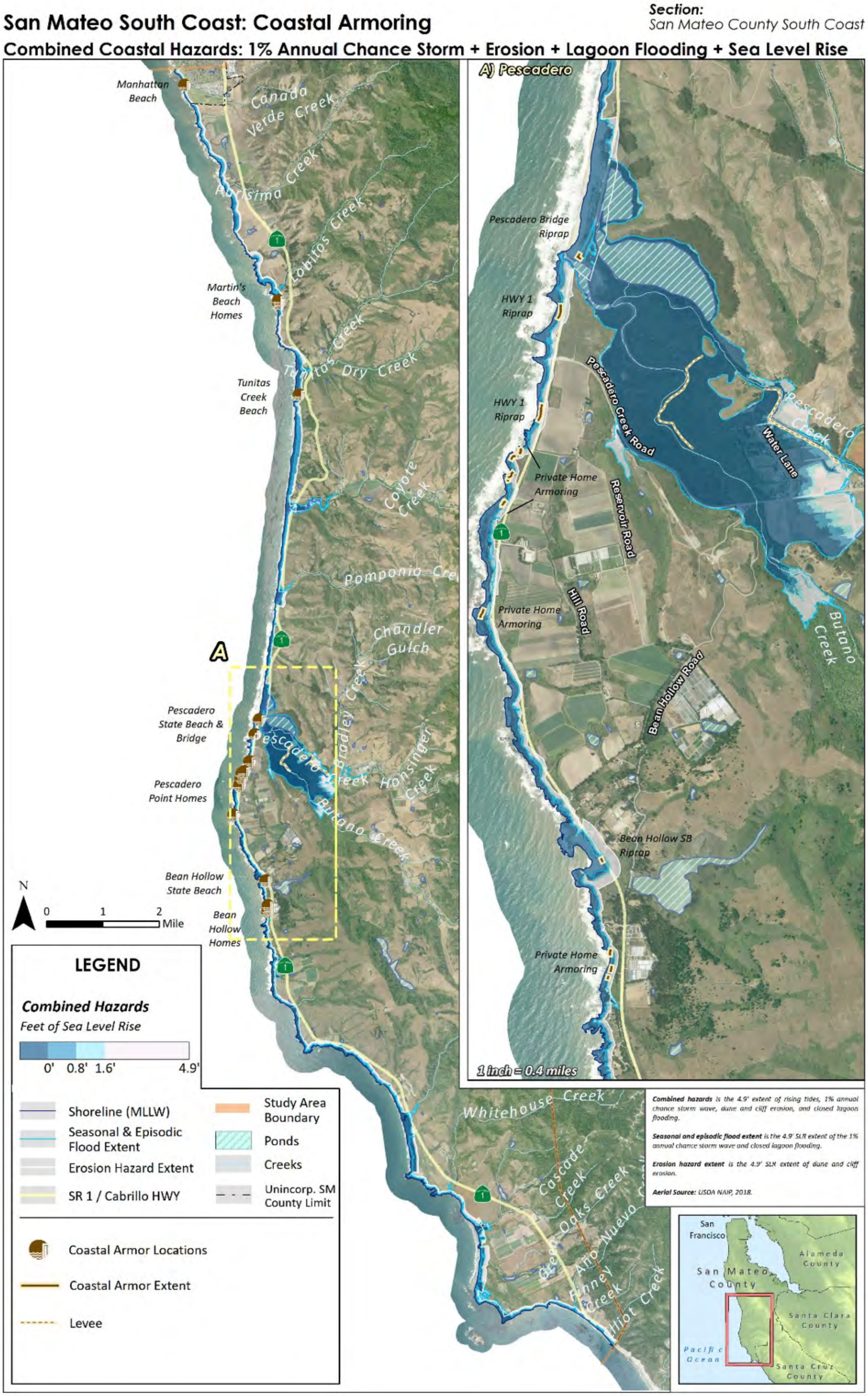
Coastal Armor Type and Condition					
	Private Structures			Public Structures	
	Condition		Private Total	Public Total	
Structure Type	Deteriorating Condition	Good Condition		Good Condition	Grand Total
Gabions		62	62		62
Riprap		1,141	1,141	945	2,086
Seawalls	482	459	941	82	1,024
Grand Total	**482**	**1,662**	**2,144**	**1,027**	**3,171**

Source: CCC coastal structures database (2016) digitized to a standard back shoreline and archived in the Coastal Records Database. Actual locations were rectified using high resolution aerial photos (2018).

Some riprap structures were placed under temporary emergency permits and are intended to be removed in the future. All gabions here are temporary structures.

Concrete walls can be of multiple types including concrete sandbag walls.

Note: ~160 linear feet of concrete and steel piers fronting the Ritz-Carlton were removed in 2018, and ~200 feet of riprap fronting the Ritz-Carlton and 18th hole of the HMB Golf Links Old Course was also removed in 2007.



Map 4. Coastal armoring locations

1.3 HABITATS

The South Coast region is home to a wide variety of terrestrial and aquatic habitats. The Monterey Bay National Marine Sanctuary (adjacent to the South Coast shoreline) encompasses several managed areas and protected habitats. These areas are host to a wide variety of species, including more than 20 cetacean species (whales and dolphins), six species of pinnipeds (seals and sea lions), otters, birds, fish, and many others. On land, the study area encompasses a variety of habitat types that range from low rocky intertidal areas at the coastal edge to upland coastal prairie, scrub, and chaparral. Table 1-4 details the range of land cover and habitat types found in the study area.

Table 1-4. Land cover and habitat types within the study area for which data is available

Land Cover	Acres	Percentage of Total
Agriculture	240	9.9%
Uplands: Coastal Prairie, Coastal Scrub, Chaparral	696	28.9%
Lowlands: Marsh, Tidal Flat, Aquatic, Riverine, etc.	370	15.3%
Upland Forest & Riparian Forest	225	9.3%
Back Beach Dunes and Cliffs	206	8.5%
Foreshore and Backshore Beach	458	19.0%
Rocky Intertidal	106	4.4%
Developed	111	4.6%
Grand Total	**2,413**	**100.0%**

Developed: Includes structures and roadways.

Agriculture: Includes planted fields, grazing lands, and dedicated open space. These areas may represent an overestimate of actual agricultural land.

The combined hazard area is defined as the maximum extent of coastal hazards with 4.9 feet of sea level rise.

Major Habitat Groupings and Species

The following special status and federally listed species are located within the South Coast area: black abalone, tidewater goby, red-legged flog, steelhead, Coho salmon, Steller sea lion, marbled murrelet, and western snowy plover. One charismatic species on the South Coast is the northern elephant seal, which, despite nearly being hunted almost to extinction by the turn-of-the-20th century, has made a remarkable comeback. A seal was first reported on Año Nuevo Island in 1955, and the first birth was recorded in 1961 (California State Parks 2021).

Rocky Intertidal Zones provide habitat areas between the lowest and highest tidal water levels as well as areas that are wet by the spray of breaking waves. These areas support many species of plants, invertebrates, and fish.

Figure 1-9. Rocky intertidal habitat
Source: Ana Miscolta-Cameron

Bar Built Estuaries, Creeks, Sloughs, Lagoons, and Ponds are highly species-rich and diverse areas for many life stages of fish, shellfish, and other organisms. Areas are critical for tidewater goby and salmonids. Pescadero and Butano creeks and marsh are spawning and rearing grounds for threatened steelhead trout and endangered Coho salmon, and they provide critical refuge during storms and droughts. Sheltered ponds and streams, especially those with overhanging willows, are ideal habitats for the federally listed California red-legged frog.

Figure 1-10. California red-legged frog
Source: Santa Cruz Public Libraries

Sandy Beaches, Coastal Dunes, and Strands provide habitat for invertebrates, as well as forage, resting, and nesting grounds for shorebirds such as the western snowy plover, sanderlings, and willets. Coastal dunes and beaches are also used as breeding grounds and haul outs for numerous pinnipeds.

Figure 1-11. Western snowy plover
Source: Audubon California

Bluffs and Cliffs can provide nesting habitats for birds such as the common murre and pigeon guillemot.

Coastal Prairie is a species-rich grassland community adapted to high winds, salt spray, fire, and grazing disturbances. Coastal prairie terraces are often used for grazing agriculture, but it is also home to rare plant communities and listed species such as the San Francisco garter snake.

Figure 1-12. San Francisco garter snake
Source: Center for Biological Diversity

Pescadero Marsh provides habitat for than 200 species of shorebirds, waterfowl, raptors, and migrant birds. It is situated directly on the Pacific Flyway and serves as an important stop-over point for migrant shorebirds, a wintering ground for numerous waterfowl, and a breeding ground for a variety of marsh birds. Species of concern that occur here include federally and state-listed red-legged frog and San Francisco Gartner snake as well as tidewater goby. The marsh is a steelhead spawning stream and also supports Coho salmon. As the only sizable marsh on the California coast between San Francisco Bay and Santa Cruz County, it is a rare and valuable resource (Figure 1-13).

Figure 1-13. Mouth of Pescadero Lagoon, North Pond, and Pescadero State Beach, 2021.
Source: Swan Dive Media

11 APPENDIX C. SECTOR PROFILES AND RESOURCE SECTOR MAPS

Resource Sectors

The resource and infrastructure sectors evaluated and mapped in the assessment include:

- Land Use and Structures
- Agriculture
- Roads and Parking
- Parks, Recreation, and Coastal Access
- Significant Facilities

How to Interpret the Sector Maps

Each sector map illustrates the sea level rise elevation at which assets become exposed to coastal hazards. The following maps show results of detailed spatial analysis that intersect the projected extents of existing and future coastal hazards with the locations of assets, resources, and infrastructures. Assets are color-coded based on the elevation of sea level rise that first leads to potential damages.

The sector maps are divided into three geographic sections and are designed to maximize readability on an 11x 17 in. printed page. Users who want to examine details of the maps more closely (beyond zooming in on these PDF maps), may view a story map of the causative hazards at the San Mateo County GIS website.

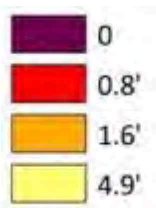
Combined Hazards

"Combined hazards" in this analysis signify the furthest spatial extent of all coastal hazards considered in this assessment. The combined coastal hazard area is based on the best available scientific projections of coastal hazards at four sea level rise intervals and is represented on a scale from dark (delft blue) to light (snow white).

The storm wave hazard extent represents the projected impacts caused by a 1% annual chance event. The erosion extent is more complicated and is based on other local factors and statistical probabilities. The estuary flood extent has no projected probability but can be considered an extreme event. Taken together, the full hazard extents mapped in the combined hazard layer for each sea level rise scenario is highly unlikely to occur everywhere, as this represents the potential for extreme events across multiple areas, different physical processes, varying shoreline orientations, changing wave directions, and other local geomorphic factors. All projected hazard extents assume that no adaptation has been implemented—in other words, they are worst-case scenarios projected to occur if nothing is done to plan for sea level rise in the future.

Potentially Impacted Features and Areas

For each sector, the combined hazards are intersected with the locations of assets to identify when the first instance of exposure occurs. All potentially affected assets are coded using a color scheme identifying if they are projected to be exposed now, or at some point in the future, ranging from purple, red, orange, to yellow.



Each color-coded feature corresponds to the sea level rise elevation that affects each asset. To identify which hazard is exposing a particular asset, readers are encouraged to visit the San Mateo County GIS website or refer to the location-specific maps and sector summaries in this report.

Exposure and Risks to Agriculture from Coastal Hazards and Sea Level Rise on the South Coast of San Mateo County

Overview

Fields above the coastal bluffs near Half Moon Bay

Background: The South San Mateo Coast has a couple dozen working farms and several ranches leased for grazing. Agriculture is the basis of the economy for the South County and the loss of farmland or reduction in crop production will affect farm income, and potentially lead to the loss of livelihoods for farmworkers. Many growers in the Pescadero area earn significant income from farmer's markets in San Francisco and on the Bay side.

Hazard Overview: The best available projections of coastal hazards identify ten farms at risk of coastal erosion, estuary flooding and wave flooding. With **4.9 feet of sea level rise (SLR),** approximately **551 acres of agricultural land** across ten farms will be exposed to coastal hazards**.** This includes **120 acres of planted fields**, **387 acres of grazing land** and **44 acres** of developed agricultural land. Thirty acres of planted fields dedicated to growing Brussel sprouts, leeks, and beans, are adjacent to coastal bluffs and susceptible to erosion. In the flood-prone low-lying areas east of Pescadero Marsh, around 90 acres of planted fields grow herbs, pumpkins, and squash.

Methodology

To evaluate the impacts of coastal hazards and SLR on agriculture, this study considered the following measures:

• ***Acreage of land exposed*** from the Farmland Mapping and Monitoring Program • ***Economic damages to land*** is based on assessed value (in $ 2019)

Assumptions: The analysis identifies agricultural land acreages affected by coastal hazards, and the tax-assessed value of this land, after adjusting for tax exemptions. This study collected information about the production value and net profitability of agricultural land in the study area, but this data was not available at a fine enough level to estimate the productive losses for individual land parcels due to inundation. Land values for agricultural properties reflect potential future production values and are incorporated into the economic impact estimates.

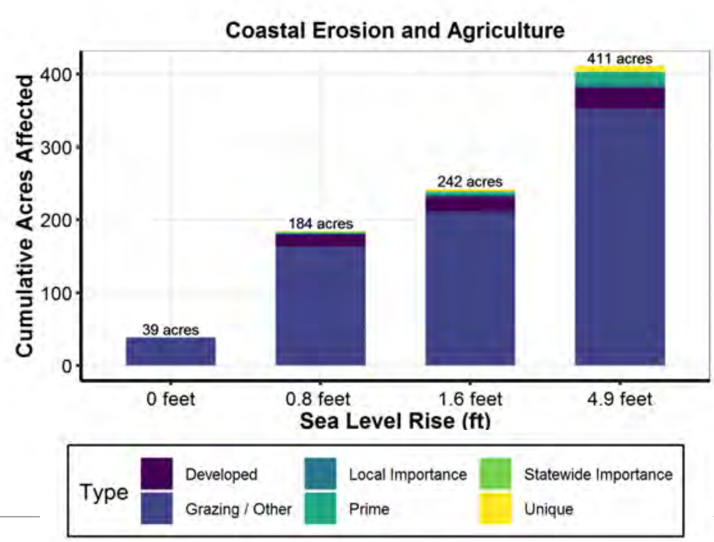
Note: Wave flooding impacts on agricultural assets were assessed, but impacts are minor. A single farmstead building at the south of Martin's Beach is currently susceptible to wave flooding impacts, causing minor damage estimated at around $3K. This building is projected to be affected by cliff erosion at ***0.8 feet***, so no additional wave flooding impacts are projected due to SLR.

Note: Climate changes to temperature, precipitation, and extreme heat will likely impact agriculture more significantly than SLR but were beyond the scope of this study. Other challenges, such as access to labor, distribution, and changes in market forces were also not included.

Coastal Erosion

Coastal erosion occurs along cliffs and low-lying dune-backed beaches causing permanent loss of land and structural damages. Coastal erosion to both cliffs and dunes poses the highest potential risk to agriculture due to permanent loss of land.

With 0.8 feet to 4.9 feet of SLR, agricultural lands will become increasingly susceptible to erosion. By ***4.9 feet***, 411 acres of agricultural land may be affected by erosion, the majority of which is clifftop grazing land. Currently, 39 acres of grazing land are susceptible to coastal erosion, with 163 acres affected at ***0.8 feet***, 211 acres at ***1.6 feet,*** and 352 acres affected at ***4.9 feet.***



Erosion does not currently affect areas with planted fields. With SLR, these areas are projected to be affected by erosion, including 4 acres at ***0.8 feet***, 6.5 acres at ***1.6 feet***, and 19.3 acres at ***4.9 feet***, for a cumulative total of ~30 acres. Planted fields near the Half Moon Bay City line, and the Santa Cruz County Line, are most at-risk of cliff erosion.

ECONOMIC IMPACT:
Currently, $1.4M of agricultural assets are susceptible to coastal erosion. Erosion damage is projected to increase to $3.2M by ***0.8 feet***, and to $4.0 million by ***1.6 feet***. Cliff erosion accounts for around 95-96% of erosion damage to this point. At *4.9 feet*, dune erosion damages increase sharply to $583K (9%). Total erosion damage at ***4.9 feet*** is projected to be $6.6M.

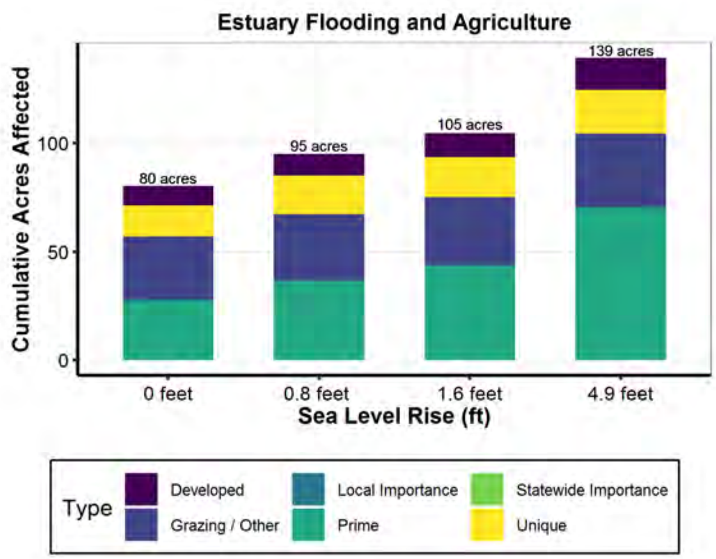
Estuary Flooding - Closed Lagoon Flooding

Closed estuary flooding occurs when beaches form seasonally at creek mouths and water levels exceed carrying capacity. SLR is likely to expand existing estuary flooding extents and depths. More frequent or severe estuary flooding events may result in damages and disruptions to agricultural activities. Increased saltwater deposits to agricultural soils will affect soil chemistry and may require farmers to shift from higher-value crops to lower value ones, or even abandon fields.

The low-lying agricultural area east of Pescadero is currently at-risk to closed estuary flooding, and SLR will exacerbate these types of flooding events. Ninety acres of planted fields are at-risk of estuary flooding by ***4.9 feet***. Of these ninety acres, 41.8 acres are ***currently*** at-risk, 4.6 acres will be at-risk with ***0.8 feet***, and 62.2 acres at ***1.6 feet***.

ECONOMIC IMPACT:

Currently, $128K of agricultural buildings are exposed to estuary flooding. At ***0.8 feet*** the value increases to $329K, and by ***1.6 feet*** the value increases to $610K. By ***4.9 feet*** this figure increases to $1.1M, which represents around 14% of total coastal hazard damages to agricultural assets.



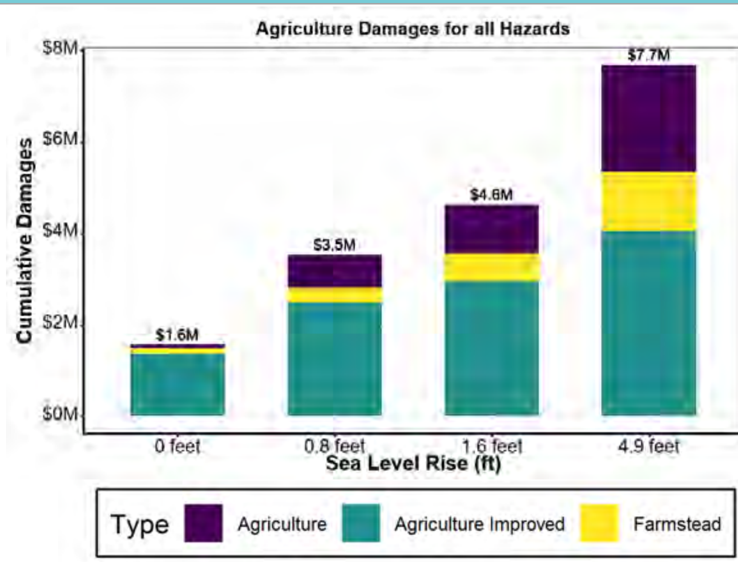
All Hazards - Economics

This economic analysis only focuses on direct impacts from future sea level rise and coastal hazards and is not a comprehensive economic loss assessment.

ECONOMIC IMPACTS:

By ***4.9 feet***, approximately $7.7M worth of agricultural lands and buildings are vulnerable to all hazards. Agricultural lands lost to erosion are the dominant concern from an asset value perspective, comprising about 86% of losses. Note that this study did not value flood-related impacts on land.

Of the estimated agricultural land damages due to erosion, two-thirds of the impacted lands are classified as generic "*Agriculture*" lands, which do not have structures on the parcel. One-third of the impacted lands are classified as "*Agriculture Improved*" lands that have structures such as dwelling units.



Potential Adaptation Strategies

Range of Strategies:

Protect – Constructing levees and coastal armoring to reduce hazard exposure is a "gray" or engineering protection approach, traditionally implemented along coastlines and waterways to stop erosion and reduce flooding. A "green" protection approach would be to nourish beaches, augment sand dunes or contour horizontal levees to protect against future coastal and estuary flood hazards.

Accommodate - Elevating or increasing setbacks for agricultural-related development, including farmhouses and barns, is a method of accommodation. Floodplain easements can compensate farmers for allowing physical flood processes to occur. Seasonal rotation of crops and grazing lands could allow for use of most agricultural lands.

Managed Retreat – This approach includes policy and/or regulatory options (e.g., transfer of development and easements) as well as the purchase of at-risk properties. Options may be limited based on the suitability of land and water rights. Fence and road realignments around bluff top grazing lands could likely avoid most impacts.

Secondary Impacts: Protection options could cause impacts to other sectors such as beach recreation or habitats and possibly diminish sediment supply and soil quality from episodic flooding over time. Retreat strategies may result in secondary impacts due to the loss of agricultural land, and potentially increase exposure to saltwater with a subsequent decline in soil quality.

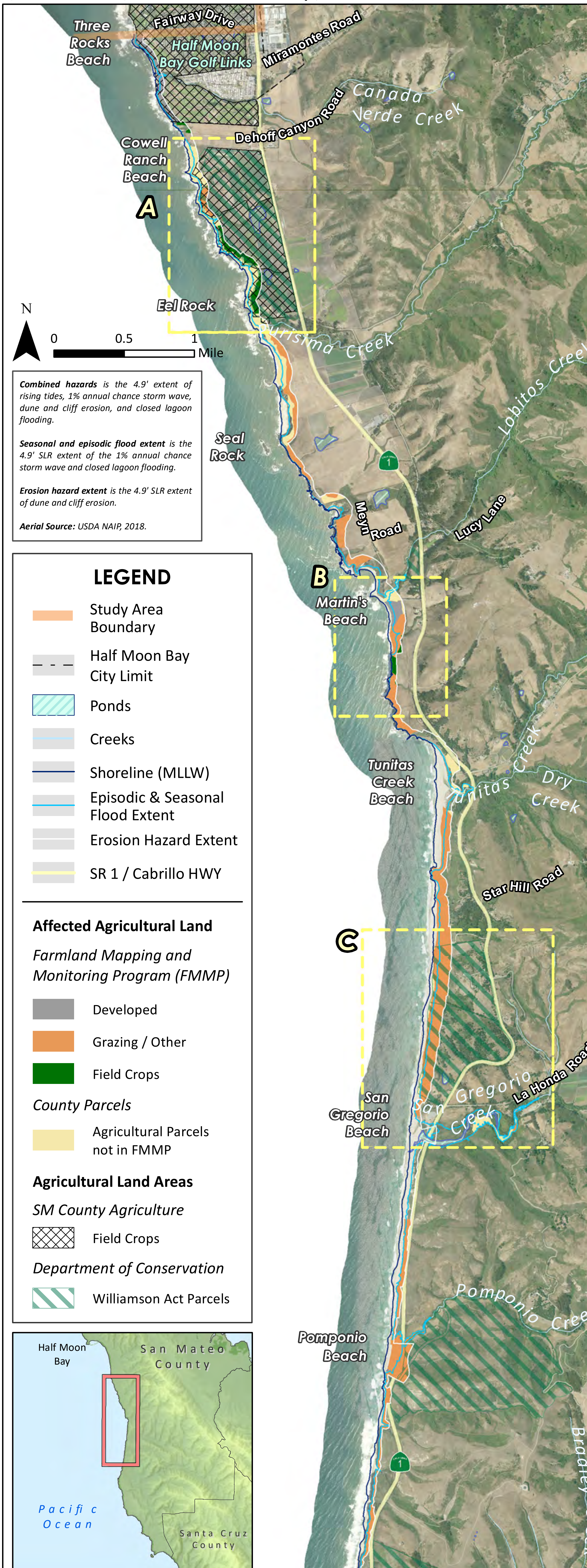
Findings and Strategy Options

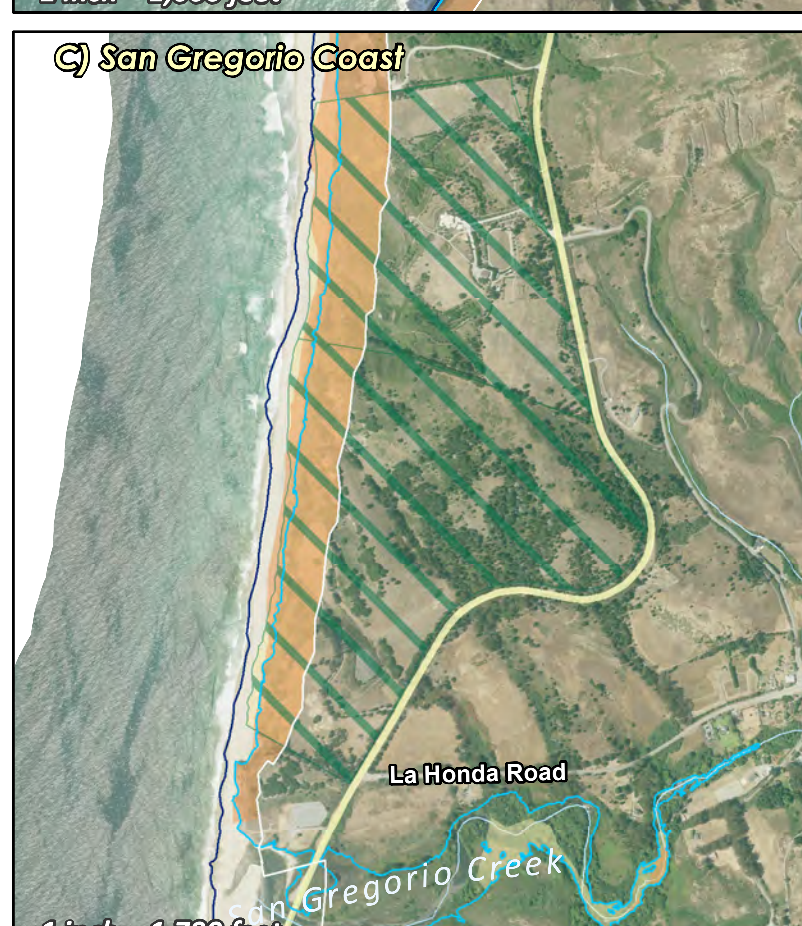
Future Challenges	Strategy Options
• Agriculture faces challenges beyond those discussed in this document, including other climate change impacts, economic pressures, and logistics. • Climatic challenges include a potential increase in seasonal temperatures, changes in the fog regime, increase in the variability and intensity of precipitation, threats related to wildfire, changes to surface water quantity and quality, and changes to groundwater (not analyzed in this study). • Economic challenges include rising property values and property taxes, the rising cost of living, lack of affordable housing, and limited local labor force. • Logistical challenges may include a lack of agricultural processing, packing, and shipping facilities nearby and potential impacts to Highway 1. • Crop value damages caused currently by closed estuary Flooding may increase. In the future, a loss in land value and production due to erosion.	**Policy** • Expand the floodplain easement program. • Expand the LCA program with a focus on locations not projected to be impacted by coastal hazards. • Reduce permitting and monitoring burdens **Projects and Monitoring** • Conduct detailed analysis of climate change on specific crops and agricultural lands. • Potentially require any abandonment or retreat strategies to remove derelict or threatened structures. • Evaluate the effect of saltwater intrusion into groundwater basins and rising salinity in the irrigation water supply. • Monitor frequency, duration and depth of flooding and soil salinity at low-lying areas around the County.

San Mateo South Coast: Agriculture

Section:
Ocean Colony to Pescadero Beach

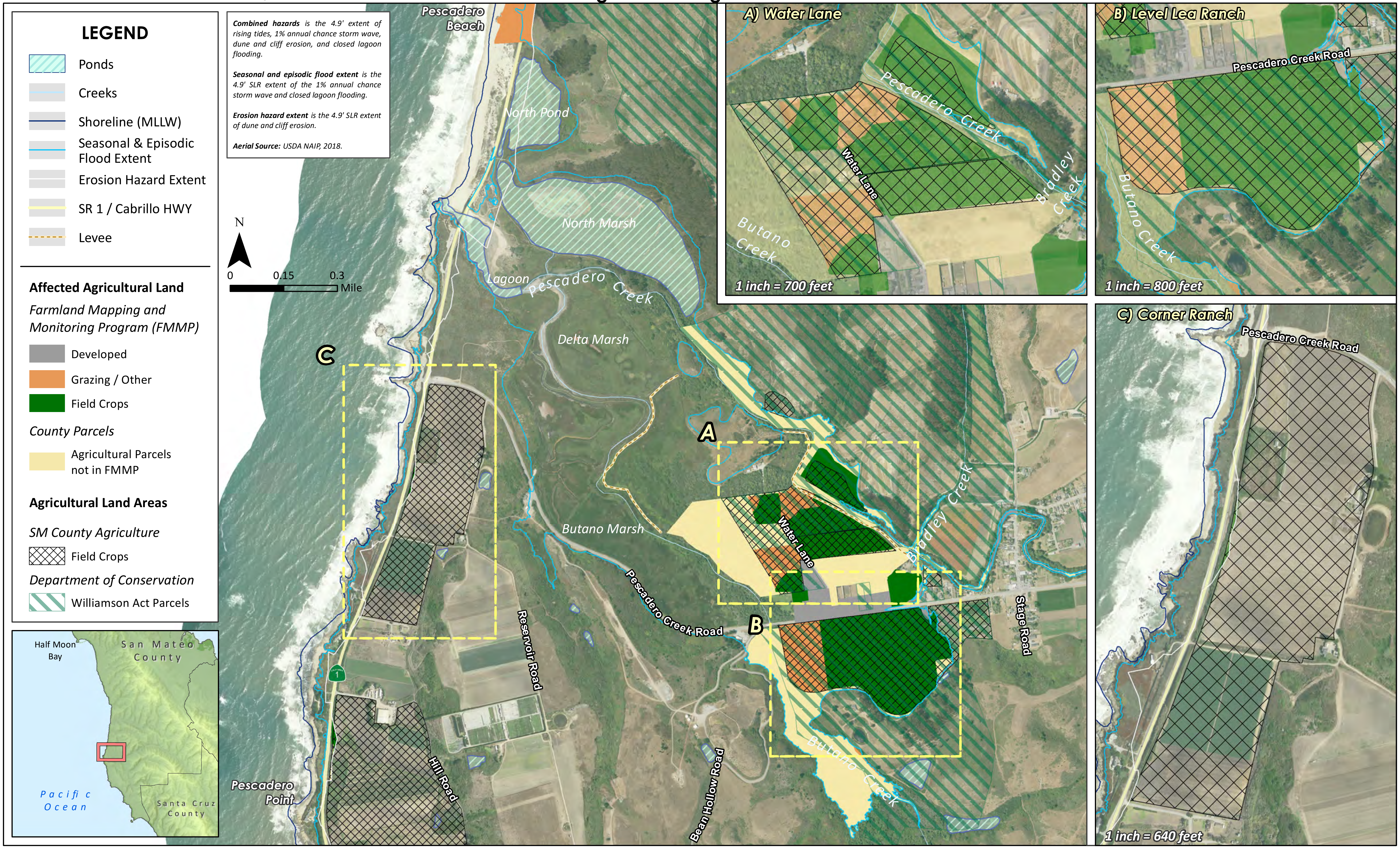
Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise





San Mateo South Coast: Agriculture

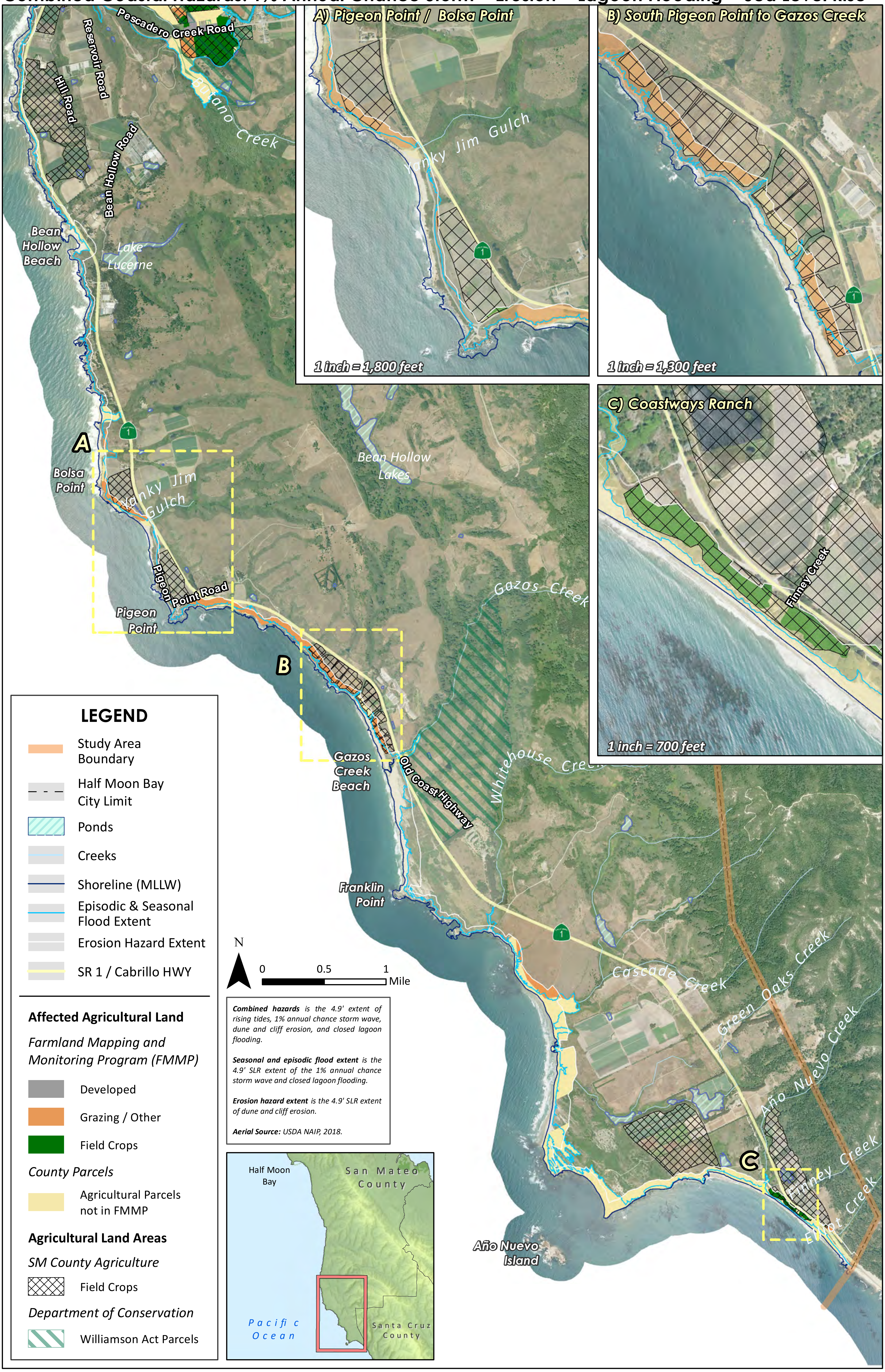
Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



San Mateo South Coast: Sector

Section:
Pescadero Point to South County Line

Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



Risks to Land and Buildings from Coastal Hazards and Sea Level Rise on the South Coast of San Mateo County

Overview

Background: The South San Mateo Coast is relatively rural, with land uses dominated by open space, rural residential and agriculture. The public right of ways associated with Highway 1 provides critical access, services, and revenues.

The community of Martin's Beach is currently vulnerable to storm wave flooding.

Hazard Overview: This research predicts that about **2,288 acres** of land in the study area will be exposed to one or more coastal hazards with ***4.9' of sea level rise (SLR)***. About half of these projected lands at risk are considered open space, primarily owned by California State Parks (1,096 acres) and the Peninsula Open Space Trust (110 acres). Private ownership comprises around 630 acres, which includes 22 acres of commercial land. Public right-of-ways, primarily managed by Caltrans, occupy 428 acres. Located in this projected hazardous area are **123 primary buildings** (houses, farmsteads, and commercial facilities, not outbuildings such as sheds and garages), including a **fire station, gas station,** and the **Pigeon Point Lighthouse** (described in a separate Significant Facilities Sector Profile), **and 109 residences**. Of these residences, close to half are in Martin's Beach and near Tunitas Creek, with the remaining buildings located in Pescadero, near Water Lane and Pescadero Creek Road, and along the cliffs between Bolsa Point and Pescadero Point (See maps).

Methodology

To evaluate the impacts of coastal hazards and sea level rise on land use, the following measures of impact were considered:

• Acreage of land affected • # of primary buildings • Erosion damages to land and buildings •Flood damage to buildings, if not previously eroded

This study evaluated exposure of land and buildings to coastal hazards (coastal wave flooding, coastal erosion, and estuary flooding) using geospatial analysis of the County Assessor's parcel data and assessed values, along with projected coastal hazard data and SLR elevation scenarios. For properties without reliable assessable tax values, researchers imputed a reasonable price for the land and structure. The economic analysis calculated hazard-induced damages to lands based on the percentage of acreage eroded and evaluated structural damages to buildings based on depth damage curves to estimate cleanup and replacement costs associated with flooding. Total loss of building value was assumed when the footprint of a building was eroded (for more detailed methods, please see section 3 of the South Coast SLR VA Assessment). Flooding damage to land was not estimated, as it depends on land use, vegetation type, duration, timing, and depth of inundation.

Note: Assets may be affected by multiple coastal hazards, at different points in time. Damage estimates are reported by hazard and cannot be added together to arrive at the sum of hazard totals. Primary and accessory building damages are included in economic impacts, however, only numbers of primary buildings are reported in the tables below.

Coastal Wave Flooding

Coastal wave flooding is the inundation of land and buildings due to wave runup and storm surge. Coastal wave flooding fron a 1% annual chance storm (100-year event), results in temporary flood damages to buildings and their contents. Notably, as wave flooding increases in depth and velocity, this increases coastal erosion, with impacts from flood clean-up to permanent damage or loss.

Potential wave flooding impacts with up to 4.9' of sea level rise:

Under ***existing*** conditions, around 739 acres of the study area are projected to be at-risk of wave flooding, exposing 16 buildings, primarily in the Martin's Beach Area. Most of the land susceptible to wave flooding is categorized as beach, open space, and agricultural grazing land. With ***0.8' and 1.6'***, more land becomes exposed to coastal wave flooding, but no further buildings are exposed. With **4.9'**, a total of 855 acres of land and two additional buildings are exposed near Bean Hollow State Beach, for a total of 18 primary buildings exposed to coastal wave flooding.

ECONOMIC IMPACT: Under existing conditions, approximately $1.0M of buildings at Martin's Beach are exposed to coastal wave flooding. This increases only slightly with additional SLR. With **4.9'**, this study predicts

SLR	Acres	Number of Primary Buildings	Damages To Buildings Noncumulative, (Cumulative) $M
0 feet (existing)	739	16	$1.006
0.8 feet	27 (766)	0 (16)	$0.005 (1.012)
1.6 feet	17 (783)	0 (16)	$0.005 (1.017)
4.9 feet	72 (855)	2* (18)	$0.005 (1.022)
Total	**855**	**18**	**$1.022**

******Buildings near Bean Hollow are also subject to cliff erosion in earlier horizons, so they do not result in additional flood damages.*

$1.02M in potential damages, with most costs associated with flood cleanup of residential buildings at Martin's Beach, and $130K of costs associated with park bathroom clean up.

Coastal Erosion

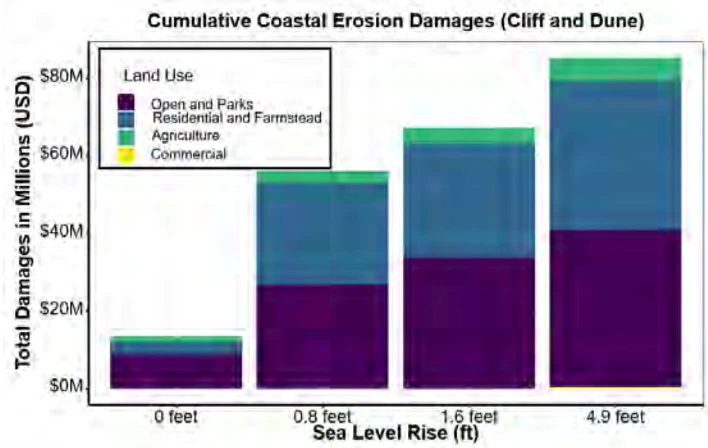
Coastal erosion occurs along cliffs and low-lying dune-backed beaches causing permanent loss of land and structural damages. Cliff erosion poses the greatest potential risk to land values and buildings.

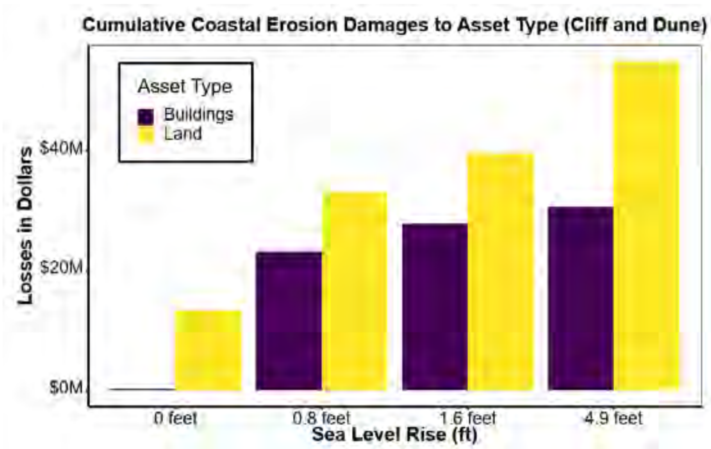
SLR	Acres Cliff/Dune/ **Total** (cumulative total)	Number of Primary Buildings Cliff/Dune/ **Total** (cumulative total)	Erosion Damages to Land / Buildings Noncumulative, (cumulative) ($M)
0 feet (existing)	97 / 440 / **537**	0 / 1 / **1**	$13.2/ 0.2 ($13.2/ 0.2)
0.8 feet	342 / 136 / **478** (1,015)	66 / 1 / **67** (68)	$19.8/ 22.9 ($33.0/ 23.1)
1.6 feet	144 / 26 / **170** (1,185)	10 / 1 / **11** (79)	$6.5/ 4.6 ($39.4/27.7)
4.9 feet	334 / 96 / **430** (1,615)	5 / 2 / **7** (86)	$15.4/ 2.8 ($54.8/ 30.5)
Total	917 **/** 698 **/ 1,615**	81 **/** 5 **/ 86**	**$85.3**

Under ***existing*** conditions, 537 acres of primarily open space land is at-risk of erosion with only one building, currently marked for demolition, projected to be susceptible to dune erosion at Tunitas Beach. With ***0.8 feet***, 1015 acres and 68 buildings are projected to be susceptible to erosion, primarily at Martin's Beach. With ***1.6 feet***, **1**,185 acres of land and 79 buildings are projected to be eroded, primarily between Bolsa Point and Pescadero Point west of Highway 1. The commercial land near Gazos Creek is also projected to become exposed to coastal erosion. With ***4.9 feet***, a total of 1,615 acres and 86 buildings are projected to be susceptible to coastal erosion. Approximately 87% of this land is in open space and natural areas (1,321 acres), but the more valuable residential property means that much of the economic damage is to residential properties. Most erosion impacts are due to cliff erosion affecting agricultural, residential and farmstead, and open space lands.

ECONOMIC IMPACT: This study estimates around $85.3M in erosion damages to lands and buildings, due primarily to impacts on residential and commercial lands, not structures.

ECONOMIC IMPACTS:





Damages to lands climb steadily with higher SLR elevations from $13.2M currently to $33.0M at ***0.8 feet***, and $39.4 million by ***1.6 feet***, reaching $54.8 million at ***4.9 feet***. At ***0.8 feet*** the buildings at Martin's Beach and near Bean Hollow State Beach may be impacted, few additional buildings become exposed across higher SLR elevations due to the rural nature of the coast and larger setbacks in most other locations.

Estuary Flooding - Closed Lagoon Flooding

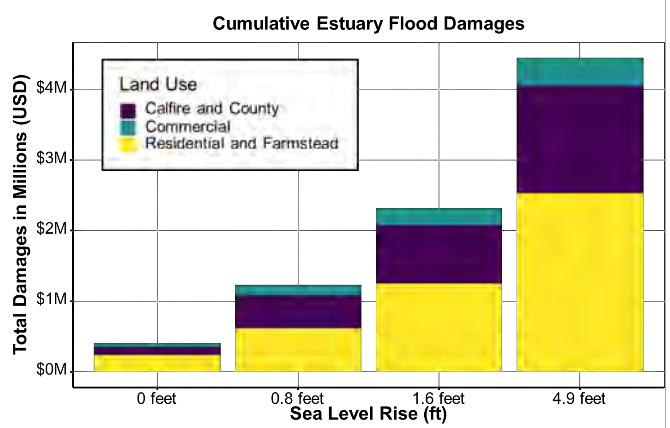
Closed estuary flooding occurs when beaches form seasonally at creek mouths, causing ponding and elevated water levels. Flooding can reach beach elevation if watershed discharge and wave overtopping inputs are sufficient. SLR is likely to expand existing estuary flooding extents and depths. Areas most at-risk of estuary flooding impacts include Gazos Creek, Pescadero / Butano Creeks, and San Gregorio Creek.

Estuary flooding ***with 4.9 feet*** may affect the following:
Land Area: Estuary flooding is projected to impact 412 total acres of land above the normal extent of tidal and riverine flooding (non-regularly flooded), including 256 acres of natural area, 35 acres of developed land, and 120 acres of land used for agriculture.

Buildings: Estuary flooding is projected to impact 39 primary buildings, the majority of which are located around Water Ln and Pescadero Creek Rd, with 33 residential buildings, 2 commercial buildings, and the CAL FIRE Station. Near Gazos Creek, another three primary buildings are exposed to estuary flooding, including a gas station and a restaurant.

ECONOMIC IMPACT:
Buildings (without adaptation) at **4.9 feet:**
There is a projected $4.5M in damages from Estuary Lagoon Flooding primarily affecting residential and farmstead buildings. The CAL FIRE station already experiences flood impacts, which will increase in severity and affect additional buildings with increasing SLR.

SLR	Acres (cumulative)	Number of Primary Buildings (cumulative)	Damages To Buildings Noncumulative, (Cumulative) ($M)
0 (existing)	255	25	$0.40 (0.40)
0.8 feet	31 (286)	2 (27)	$0.83 (1.23)
1.6 feet	25 (311)	2 (29)	$1.08 (2.32)
4.9 feet	101 (412)	10 (39)	$2.13 (4.45)
Total	**412**	**39**	**$4.45M**



Potential Adaptation Strategies

<u>**Range of Strategies:**</u> Includes "No Action" and cleanup, as well as protect, accommodate and managed retreat strategies.

Protect – Constructing coastal armoring to reduce erosion vulnerabilities or raising levee elevation is the "gray" protection approach. A "green" protection approach be to augment dunes or restore wetlands to protect against future coastal hazards.

Accommodate – This approach includes elevating buildings and increasing setbacks. Elevating structures is expensive if completed as a retrofit, however, changing the building code could guide structural elevation over time, with the bulk of the cost placed on developers and private property owners redeveloping their properties. Identification of properties to elevate or relocate using FEMA or other maps could be included in the LHMP as a mitigation action, facilitating federal funding opportunities.

Managed Retreat – This approach includes policy and/or regulatory options (e.g., transfer of development, repetitive loss, and rolling easements) as well as the voluntary purchase of susceptible properties, potentially with a lease back option.

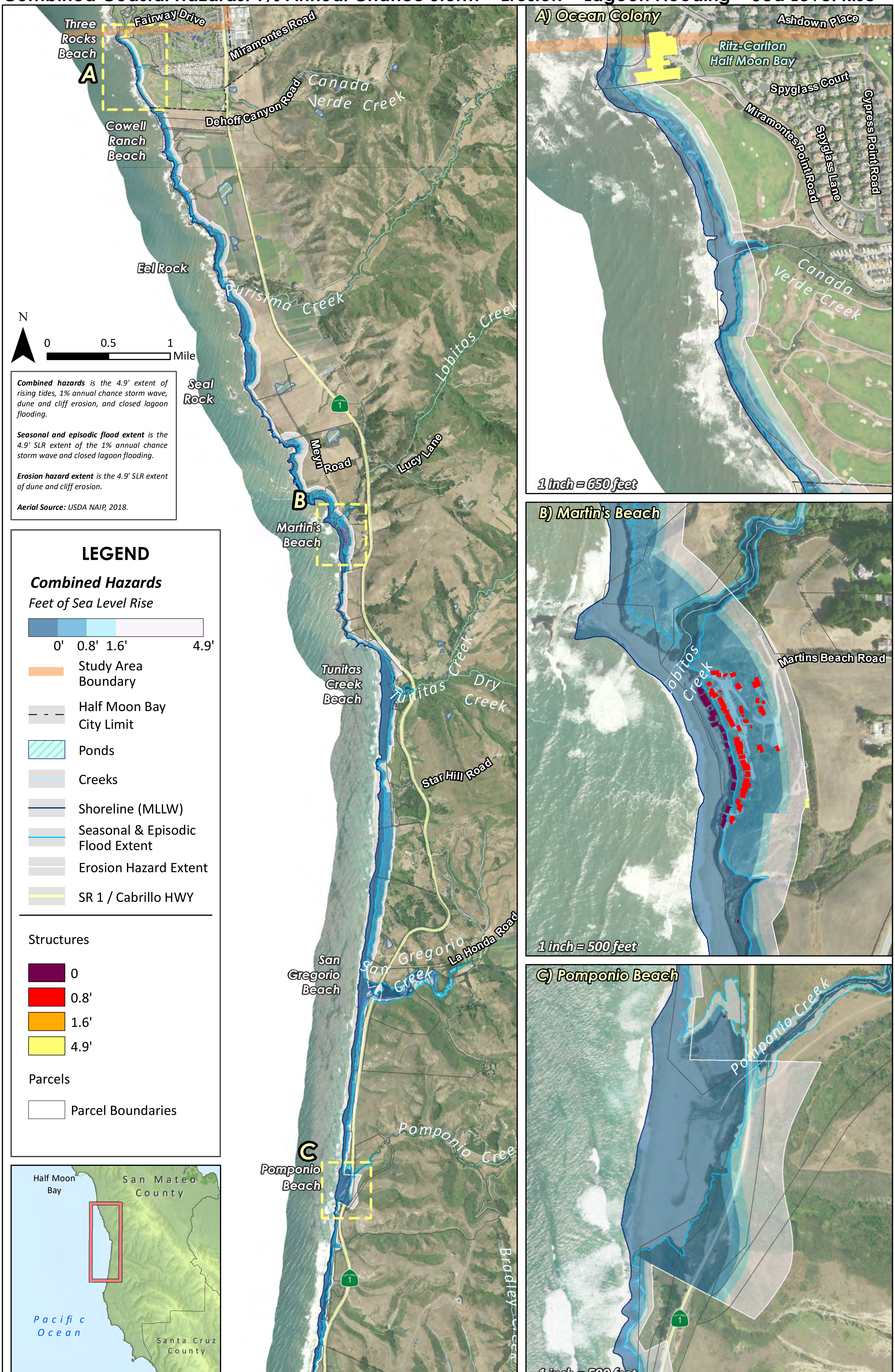
<u>**Secondary Impacts:**</u> Retreat strategies have secondary impacts due to the loss of buildings, property, and potential resulting impacts on the tax base revenues to the County. Gray protection, traditionally a favored approach, would result in a loss of beaches and wetlands over time. Green protection strategies may benefit beaches and homes by maintaining recreational uses but may not be suitable for addressing erosion along high-energy cliff backed shorelines.

Findings and Strategy Options	
Summary	**Strategy Options**
Impacts: ***Currently***, 16 buildings in the front line of homes in the community of Martin's beach are vulnerable to storm wave flooding from a 1% annual storm wave event, and 25 primary buildings in the community of Pescadero are vulnerable to closed estuary flooding. ***With 0.8 feet***, the entire community of Martin's Beach and 10 cliffside homes are potentially vulnerable to coastal erosion. ***With 1.6 feet***, portions of the Half Moon Bay Golf Course and seven additional cliffside homes may be vulnerable to erosion and the commercial buildings near Gazos Creek become vulnerable to estuary flooding. ***With 4.9 feet,*** damages to land and buildings associated with erosion escalate steadily, with the Ritz-Carlton Hotel potentially vulnerable to erosion. *Note that the value of damage to the Ritz Carlton Hotel building is not included in summary figures in this sector profile.* **ECONOMIC IMPACTS:** • **Coastal erosion** is the hazard of highest concern, accounting for $85.3M (94%) of the total vulnerability damages of $90.8M from all coastal hazards, with most economic impacts in the Martin's Beach and Pescadero Point areas. In terms of the spatial extent of coastal hazards, 87% of all the eroded lands occur to open space and natural areas in publicly owned lands indicating that managed retreat may be the most cost-effective long-term adaptation strategy for these lands. • **Cliff erosion** poses the highest economic risk to land uses, $74.6M projected ***with 4.9 feet*** without adaptation. • **Dune erosion** threatens an additional $10.7M of land and buildings **at *4.9 feet***. • **Martin's Beach** is the most vulnerable residential area, currently exposed to wave flooding and likely subject to coastal erosion in the near future. • **Closed Lagoon flooding** currently poses risk to the community of Pescadero and is likely to escalate in frequency, depth, and duration in the future. **Trigger points:** The largest near-term risks related to sea level rise is from erosion damages to land and buildings located close to the beach and clifftop edge. This highlights the opportunity to address risks before the ***0.8 feet*** threshold, with a look ahead to the more drastic costs at ***4.9 feet,*** when the Ritz-Carlton Hotel is potentially affected.	**Policy:** • The properties most at risk to flooding and coastal erosion are the only ones at risk in the future. A simple adaptation approach could be to not allow redevelopment in the same footprint. **Projects:** • Develop a vision or managed retreat plan for Martin's Beach. • Consider requiring any abandonment to remove derelict or threatened buildings. • Work with State Parks to develop dune, sediment, and lagoon mouth management plans. **Monitoring:** • Monitor frequency, duration, and depth of flood impacts. Especially for low-lying areas of Pescadero and Martin's Beach. • Monitor cliff retreat at Martin's Beach, Tunitas Creek, and Pescadero Point and key areas of concern along the Highway 1 corridor.

San Mateo South Coast: Land Use Parcels and Structures

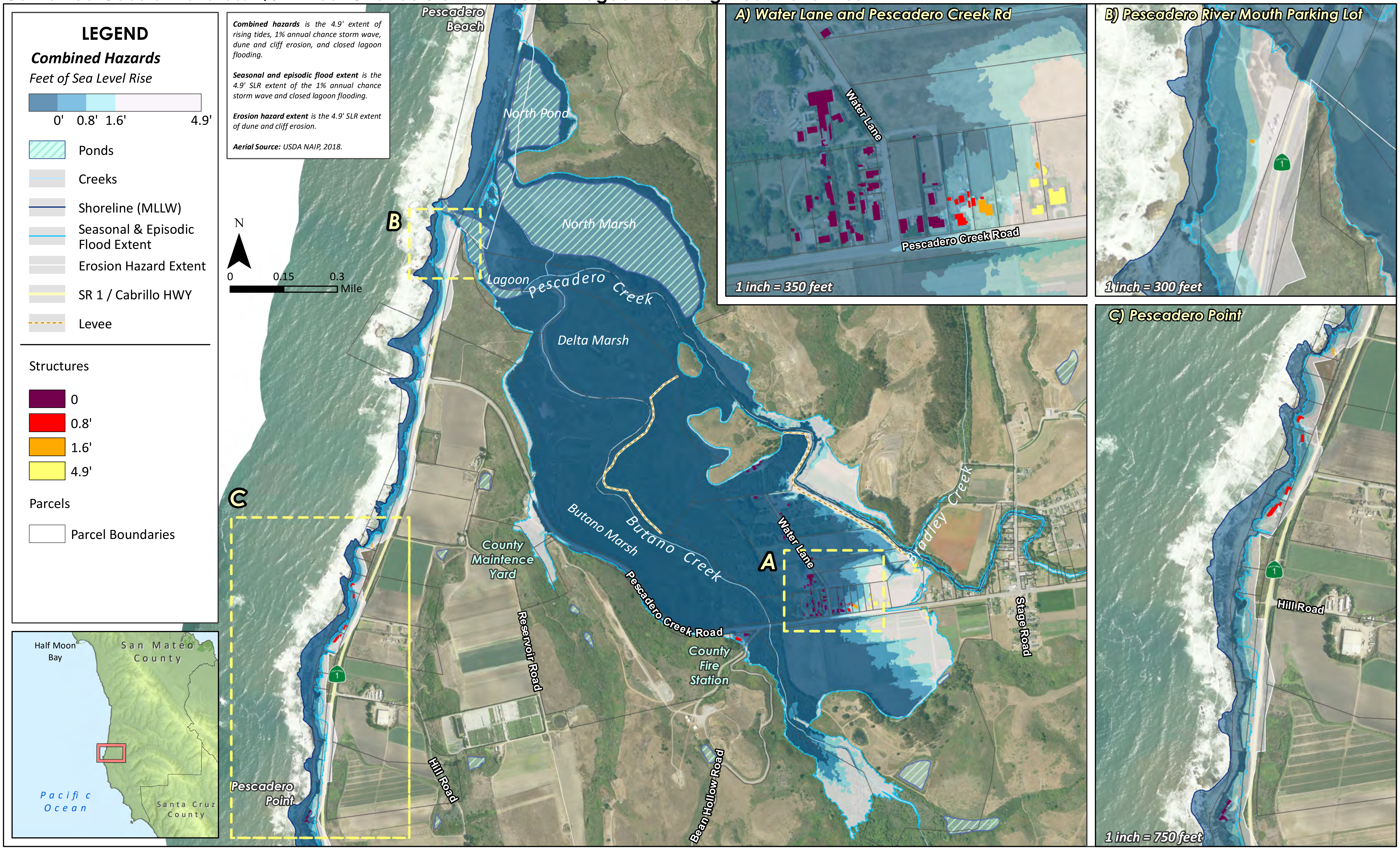
Section:
Ocean Colony to Pescadero Beach

Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



San Mateo South Coast: Land Use Parcels and Structures

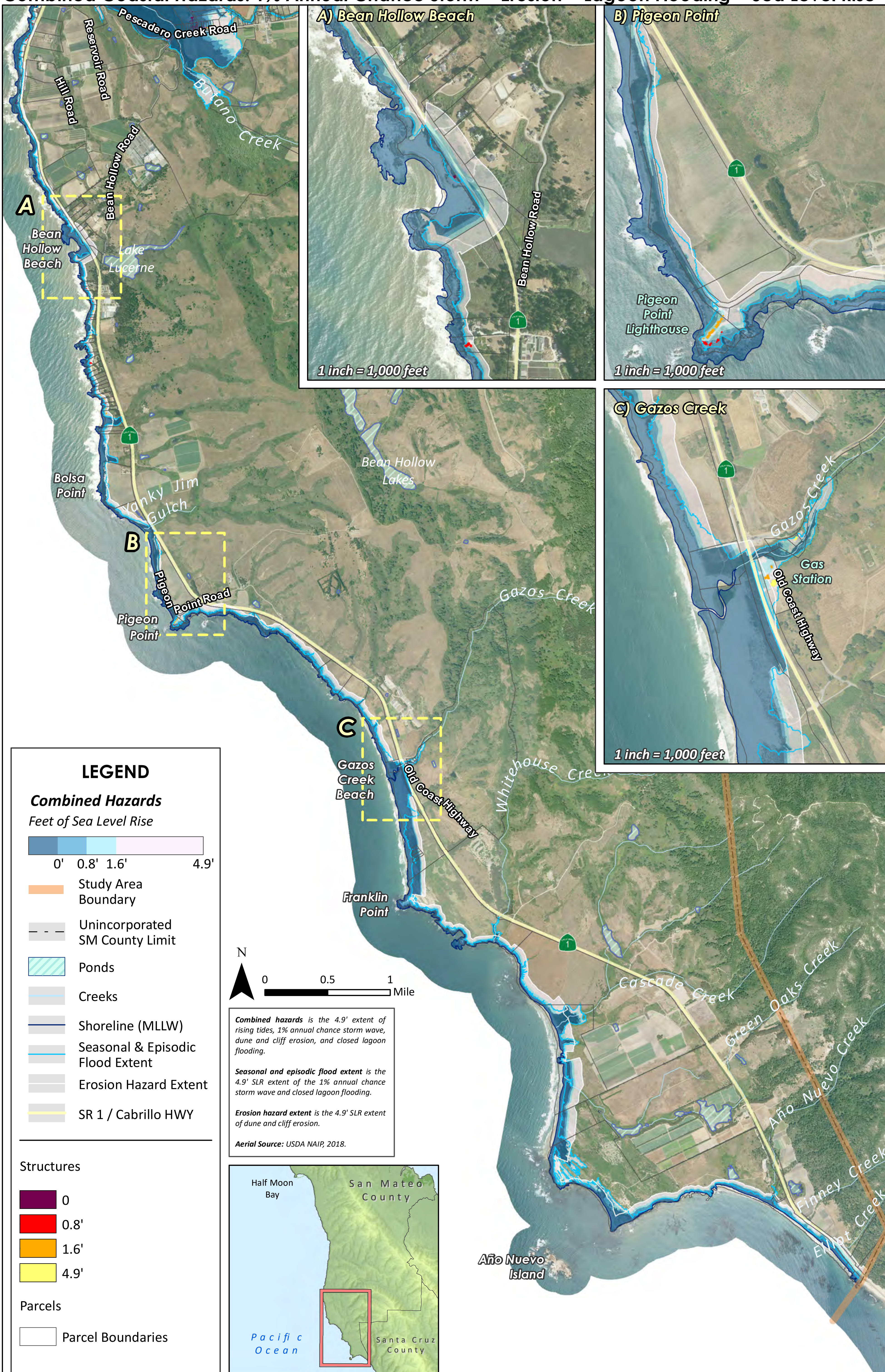
Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



San Mateo South Coast: Land Use Parcels and Structures

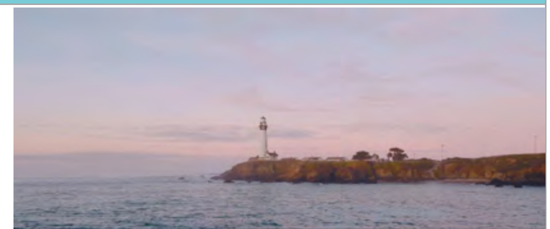
Section:
Pescadero Point to South County Line

Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



Exposure and Risks to Parks, Recreation, and Coastal Access from Coastal Hazards and Sea Level Rise on the South Coast of San Mateo County

Overview



Lighthouse at Pigeon Point Light Station State Historic Park

Background: There are ten distinct park areas that receive around 1.2 million annual visits. California State Parks owns and manages 89% of the total parks land area and is the single largest owner of coastal property along the South Coast. The greatest number of visits are to Pigeon Point Light Station State Historic Park (SHP), Pescadero State Beach, Año Nuevo State Park, and the California Coastal Trail in Southern Half Moon Bay.

Hazards Overview: The best available scientific projections of coastal hazards with **4.9 feet of sea level rise (SLR)** show approximately **1,230 acres of parks and protected open space** areas affected by coastal hazards. The following recreational amenities may be impacted: around **16 miles of trails, 41 coastal access points**, **and nine public parking lots** as well as numerous roadside parking areas, **seven public restrooms**, and the facilities at Pigeon Point Lighthouse.

Cultural Resources: Coastal San Mateo County is rich in cultural history, with numerous sites with midden soils, cultural artifacts, and other evidence of past human occupation. Important cultural resources include remnants of tools and weapons made from Monterey Chert, a primary geological resource sourced from Año Nuevo. Following Spanish colonization, cultural remnants from historic-era activities were found, including those used in agriculture, commerce, and whaling. Some prominent culturally significant areas include The Pigeon Point Light Station, Historic Año Nuevo Island Light Station, and Franklin Point Historic Shipwreck Cemetery. Due to the significance and sensitivity of these resources, they cannot be quantified and mapped.

Total Estimated Nonmarket Value: In addition to the estimated value of the land and buildings, these facilities provide substantial benefits to recreational users and tourists not captured in existing markets. Parks in the study area cumulatively provide an additional use value estimated at $51.6M, based on a $40 value per visit (derived from academic studies specific to California parks). Recreation types are estimated based on San Mateo County Coastal Recreation Surveys.

Yearly Park Visits	Recreation Type	Percentage of Visits	Estimated number of visits per activity	Estimated Annual Aggregate Recreational Use Benefits ($millions/year) at $40/visit
1,289,000	Beach Recreation	30%	386,700	$15.5M
	Surfing	10%	128,900	$5.2M
	Kayaking	5%	64,450	$2.6M
	Fishing	15%	193,350	$7.7M
	Hiking	30%	386,700	$15.5M
	Tide-Pooling	10%	128,900	$5.2M
	Total	**100%**		**$51.6M**

Methodology

To evaluate the impacts of coastal hazards and SLR on parks, recreation, and access, the following measures of impact were considered:

• Acreage of land exposed • Miles of Trail exposed • Number of coastal access locations exposed • Number of structures exposed • Potential losses in visitation • Economic losses to land and buildings (in 2019 dollars)

Assumptions: Economic analysis of these resources relies on published reports and conversations with California State Parks, as well as the San Mateo County Parks Visitor study report, which details information on recreational use. Replacement costs of trail due to erosion is assumed to be $4 per foot. Park bathrooms were estimated at $20K per facility. The value of an acre of parkland is estimated at $40K, based on historical sales prices for parcels incorporated into parkland. **Note:** Habitat and cultural resources are not detailed here. Also, some sections of trail may be affected by numerous hazards, so cumulative totals may not be the same as all individual hazard totals combined.

Existing Exposures		
Coastal Erosion • Parkland—273 acres • Trails—0.8 miles • Coastal Access Trails—0.4 miles • Restrooms—1	**Coastal Wave Flooding** • Parkland—378 acres • Trails—1.6 miles • Coastal Access Trails—0.6 miles • Restrooms—2	**Estuary Flooding** • Parkland—489 acres • Trails—2.1 miles

Parkland: Parks and open spaces have large acreages of low-lying beaches, dunes, and marsh areas that regularly experience seasonal and episodic flooding. As a result, existing vulnerabilities are high. **Currently, 911 acres** are vulnerable to wave flooding, estuary flooding, and coastal erosion, the majority of which regularly experiences flooding. Pescadero Marsh NR and Año Nuevo SP comprise 69% of the parklands inside the projected coastal hazard areas. Of greatest concern, however, are pocket beaches and beaches confined by Highway 1, such as those at Bean Hollow SP, Pescadero SB, and Pomponio SB, all currently susceptible to dune erosion.

Trails: A total of 4.2 miles of trail is currently exposed to coastal hazards, with some sections exposed to multiple hazards. At Pescadero Marsh NP, coastal hazards, particularly estuary flooding, are projected to impact 2.1 miles of trail. At Año Nuevo SP, coastal erosion and wave flooding are projected to affect 0.8 miles of trail length, primarily beach accessways and dune trails around Franklin Point, Año Nuevo Point, and Gazos Creek Beach. Wave flooding and coastal erosion are also projected to impact the coastal stairways at Pebble Beach, Manhattan Beach, Cowell Ranch Beach, and Pescadero Beach at Rockside.

Restrooms: Coastal wave flooding and coastal erosion are projected to affect three restrooms in the parking lots at Bean Hollow SB, Pescadero SB Lot North (Sand Beach), and Pomponio SB. These low-lying restrooms represent approximately $60K in estimated damages and replacement costs.

ECONOMIC IMPACTS:

- Property Values of Parks: $8.8M currently at risk, based on the imputed value of land and buildings
- Trails: $17K currently at risk due to erosion
- Park Bathrooms: $60K currently at risk to storm wave and dune erosion.

Projected Exposures

0.8 feet of sea level rise

Coastal Erosion • Parkland—215 acres • Trails—4.5 miles • Coastal Access Trails—0.5 miles • Structures—4 (including PP Lighthouse)	**Coastal Wave Flooding** • Parkland—20 acres • Trails—0.5 miles • Coastal Access Trails—<0.1 miles	**Estuary Flooding** • Parkland—9 acres • Trails—<0.1 miles

Parkland: Cliff erosion is the greatest hazard of concern for parklands, projected to impact 198 acres total, with 72 acres at Año Nuevo SP, and between 10-20 acres each at Cowell Ranch SP, Cloverdale Coastal Ranches, San Gregorio SB, Pigeon Point SHP, Bean Hollow SB, Pescadero SB, and Pomponio SB.

Trails: Cliff and dune erosion are projected to impact 4.5 miles of trail. The most affected sections of trail are Año Nuevo Point Trail, Atkinson Bluff Trail, and Franklin Point Trail at Año Nuevo SP with a combined 1.2 miles affected, the connected Cowell-Purisima Coastal Trail at Cowell Ranch SP and California Coastal Trail near the HMB City Limits with 1.2 miles affected, and the Arroyo de los Frijoles Trail at Bean Hollow SB with 0.5 miles affected.

Structures: Cliff erosion is projected to affect the Pigeon Point Lighthouse (California Register of Historic Places), Keepers Store and Interpretive Center (Historic American Buildings Survey), and other buildings at the Pigeon Point SHP.

ECONOMIC IMPACTS:

- Property Values of Parks: $18.0M of new assets at risk ($26.9M total), based on the imputed value of land and buildings
- Trails: $94K of new trails at risk ($112K total) due to erosion
- Park Bathrooms: No additional exposure ($60K remains at risk)

1.6 feet of sea level rise

Coastal Erosion • Parkland—93 acres • Trails—3.9 miles • Coastal Access Trails—0.2 miles • Structures—3 (including the PP Lighthouse Hostel buildings) • Restrooms—3	**Coastal Wave Flooding** • Parkland—12 acres • Trails—0.3 miles • Coastal Access Trails—<0.1 miles • Restrooms—2	**Estuary Flooding** • Parkland—8 acres • Trails—<0.1 miles

Parkland: Cliff erosion affects a total of around 78 acres with 38 acres at Año Nuevo SP, 12 acres at Cloverdale Ranches, and 8 acres at Pigeon Point SHP.

Trails: Cliff and dune erosion are projected to impact 3.7 miles of trail. The most affected sections will continue to be the Año Nuevo Point Trail, Atkinson Bluff Trail, and Franklin Point Trail at Año Nuevo SP, the Cowell-Purisima Coastal Trail at Cowell Ranch SP, and California Coastal Trail in the Half Moon Bay City Limits, and the Arroyo de los Frijoles Trail at Bean Hollow SB.

Structures: Cliff erosion is projected to impact the Pigeon Point Hostel.

Restrooms: Cliff erosion is projected to impact three additional restrooms: one at Pigeon Point SHP, and two at Pescadero SB.

ECONOMIC IMPACTS:

- Property Values of Parks: $7.0M of new assets at risk ($33.9M total) at risk
- Trails: $83K of new trails at risk ($194K total) due to erosion
- Park Bathrooms: $60K of new facilities at risk ($120K total)

4.9 feet of sea level rise

Coastal Erosion	Coastal Wave Flooding	Estuary Flooding
• Parkland—209 acres (790 acres total) • Trails—4.2 miles (13.4 miles total) • Coastal Access Trails—0.2 miles (1.3 miles total) • Restrooms—1 (7 total)	• Parkland—53 acres (463 acres total) • Trails—0.8 miles (3.2 miles total) • Coastal Access Trails—0.1 miles (1 mile total)	• Parkland—35 acres (541 acres total) • Trails—0.1 miles (2.2 miles total)

Parkland: Cliff erosion is projected to be the greatest hazard of concern for parklands ***with 4.9 feet*** impacting 147 acres total. The most affected are Año Nuevo SP and Cloverdale Coastal Ranches, impacting 80 and 26 acres, respectively.

Trails: Combined hazards are projected to impact 3.8 miles of trail. Storm wave flooding is projected to impact 0.2 miles of trail at the dune hiking areas of Año Nuevo SP. Cliff and dune erosion threaten 1.6 miles at Año Nuevo SP, as well as roughly a quarter of a mile of trail at Bean Hollow SB, Pescadero Marsh NP, Pescadero SB, and Pomponio SB.

Restrooms: Cliff erosion is projected to impact one additional restroom at the Pebble Beach Parking Lot.

ECONOMIC IMPACTS:

- Property Values of Parks: $6.8M of new assets at risk ($40.7M total)
- Trails: $90K of new trails at risk ($284K total) due to erosion
- Park Bathrooms: $20K of new facilities at risk ($140K total)

Potential Adaptation Strategies

Range of Strategies: Includes “No Action” and cleanup, as well as protect, accommodate and managed retreat strategies

Protect—Consider green protection measures such as augmentation of dunes and cobble beach nourishment. In some cases, access stairs may be upgraded to a concrete structure to provide vertical access and provide some protection.

Accommodate—Elevate the grade of trails to accommodate future coastal flood levels in low-lying areas and identify alternative alignments along erosion exposed areas.

Managed Retreat—Remove or relocate trails and coastal access ways away from areas vulnerable to coastal hazards.

Trade-offs: Green protection measures may benefit lateral access by maintaining sandy and intertidal beaches for recreational uses, but require regular maintenance, particularly with higher levels of SLR. Gray protection measures would effectively protect coastal access and trails but would likely lead to loss of beaches and public access over time.

Strategy Options

Policy:

- Coordinate with State Parks and regional partners on shoreline management to maintain beach access.
- Coordinate with the County and State, and local to create sustainable funding mechanisms.
- Develop a long-range plan for the California Coastal Trail.

Projects:

- Relocate portions of trails exposed to erosion.
- Perform regular dune or cobble restoration.
- Plan acquisition of missing component of California Coastal Trail near Cowell Ranch.

Monitoring:

- Monitor depth, extent, and frequency of flooding.

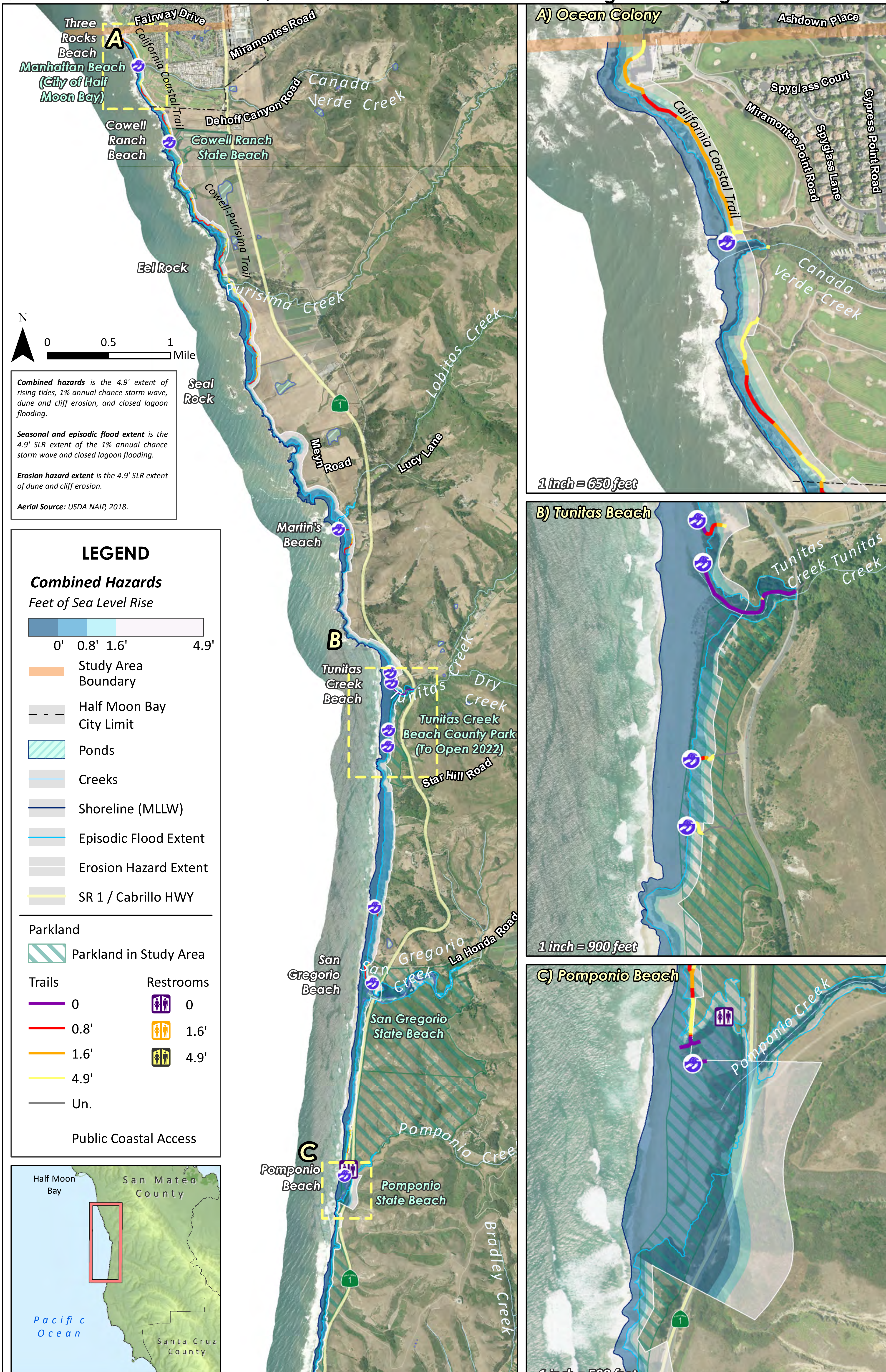
Data Needs:

- Planned future alignment of the California Coastal Trail.
- Planned future trails and amenities at Tunitas Creek County Park.

San Mateo South Coast: Parks and Coastal Access

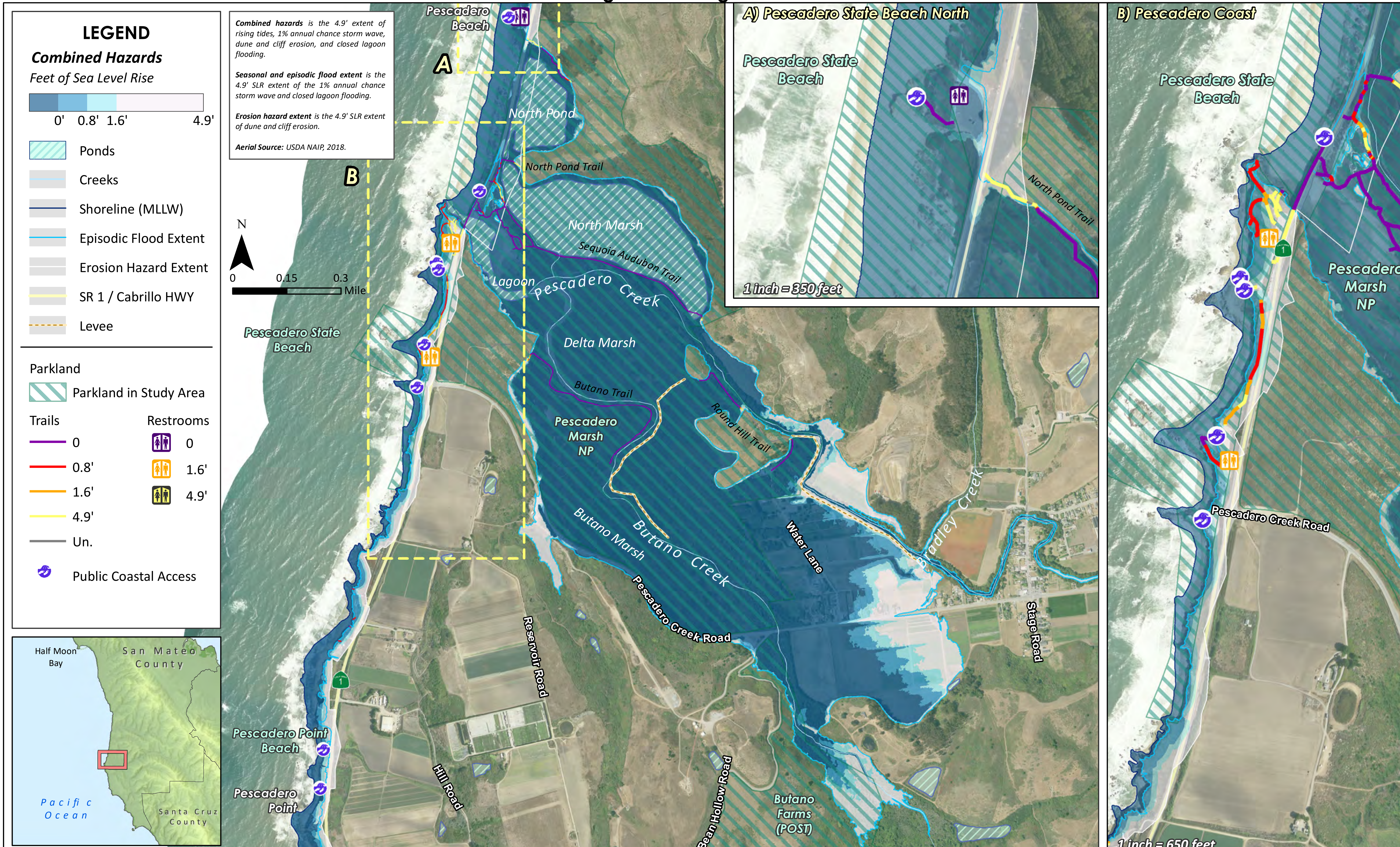
Section:
Ocean Colony to Pescadero Beach

Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



San Mateo South Coast: Parks and Coastal Access

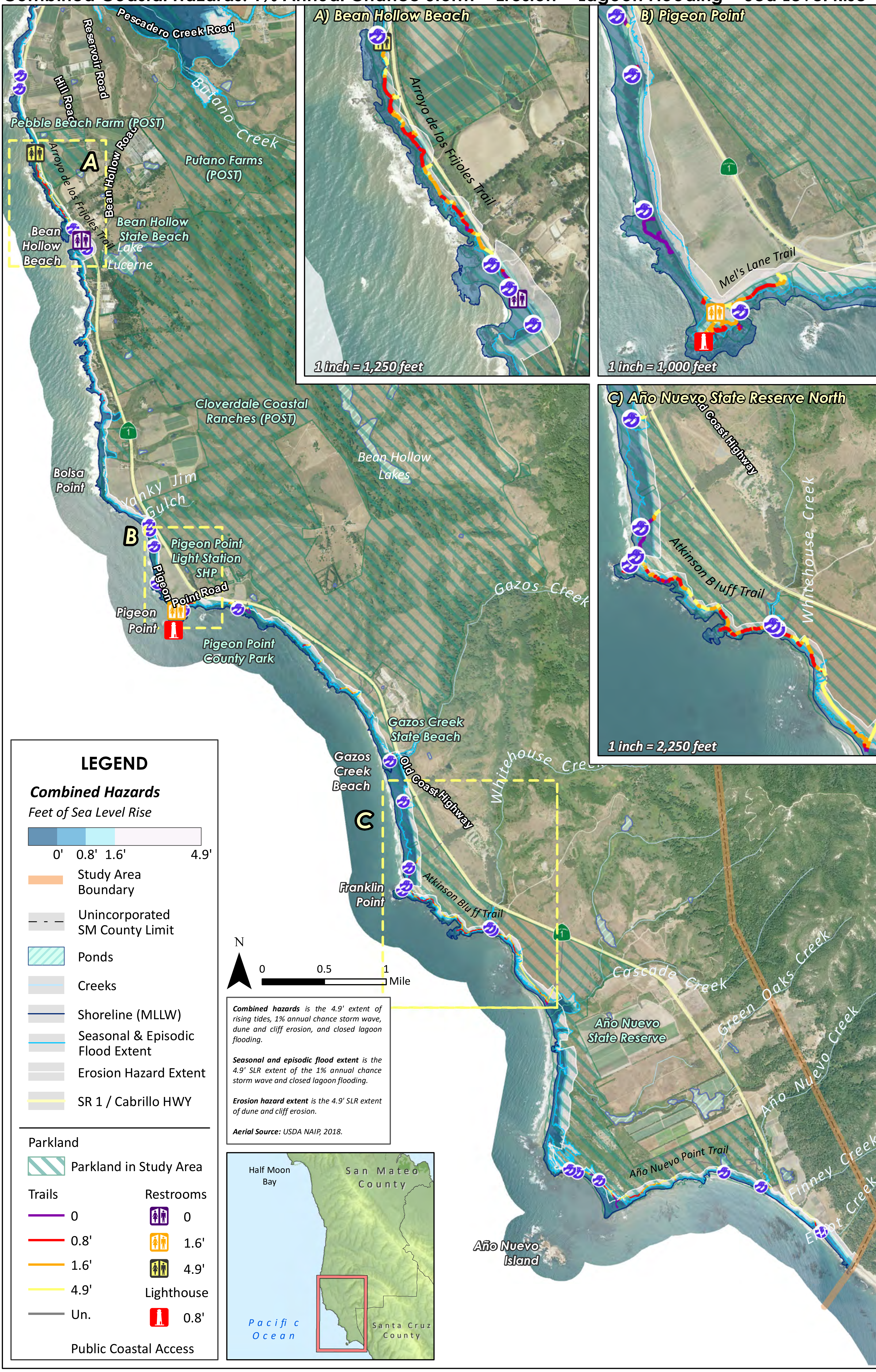
Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



San Mateo South Coast: Parks and Coastal Access

Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise

Section:
Pescadero Point to South County Line



Exposure and Risks to Significant Facilities and Resources from Coastal Hazards and Sea Level Rise on the South Coast of San Mateo County

Overview

This study identified several significant facilities important to the County and coastal communities, including the Gazos Creek Alliance Gas Station, the Pigeon Point Lighthouse Station, CAL FIRE Station 59, the Pescadero Corporation Yard, and the Ritz-Carlton Half Moon Bay Hotel and Half Moon Bay Golf Links. These facilities are identified as significant because they either provide essential public services, have significant asset value, or both. Note that septic, water supply, and utilities are not included in this analysis due to a lack of data. Indirect economic costs such as potential job losses are not included as well.

Methodology

This study evaluated exposure of significant facilities exposure to coastal wave flooding, coastal erosion and estuary flooding using geospatial analysis of the County Assessor's parcel data and assessed values, along with projected coastal hazard data and SLR elevation scenarios. For properties without reliable assessable tax values, researchers imputed a reasonable price for the land and structure. The economic impact associated with hazard exposure to significant facilities are based on the following:

Value = Recorded Net Asset Value, Sale Value, or Best Estimate of Replacement Cost

Mitigation or Remediation Associated Costs = Cleanup Costs or Relocation Costs

Assumptions: This study relies on the Environmental Protection Agency (EPA) for potential associated costs to fuel storage tanks that could be affected by flooding. Replacing an exposed storage tank is estimated to cost $125K. If the tank is ruptured and contamination spreads, remediation estimates range from $5K to $2M. If estuary flooding affects these tanks, both replacement and remediation may be necessary.

Gazos Creek Alliance Gas Station and Highway 1 Brewing Company

Ownership: Private

Regulatory: State—Storage Tank

Buildings: 3 (7,515 sq. ft.)

Property: 2.9 acres

Elevation of Buildings: 15.2 to 18.6 feet NAVD88

Sensitivity: HIGH

Adaptive Capacity: MED

Consequences: MED

Summary of Asset: This gas station serves as the only fueling location between Half Moon Bay (23 miles north) and Santa Cruz (25 miles south) with pumps open 24/7, making it a critical point for emergency refueling. The facility includes a gas station, restaurant, and RV parking. The property has underground gas storage tanks that have the potential to cause environmental contamination if exposed to coastal hazards.

Hazards Exposure: Wave Flooding, Closed Lagoon Flooding, Dune Erosion (currently protected by Highway 1).
1.6 feet of SLR: Closed Lagoon Flooding is projected to impact the two main entrances and gas pumps.
4.9 feet: Dune Erosion is projected to affect the property. Closed Lagoon Flooding is projected to affect the two primary structures on site.

Narrative: With 1.6 feet, entrances and the gas station lie at ~15 to 18 feet elevation are projected to be susceptible to closed lagoon flooding from Gazos Creek. The site is also projected to be exposed to wave flooding if waves overtop Highway 1, or if dune erosion passes Highway 1.

ECONOMIC FACTORS:

- Assessors Value: $19.8M (SMC Assessors, year of last sale 1985)
- Underground storage tank relocation cost: $125K
- Potential underground storage tank cleanup costs: Range: $5K – $2M. Average: $275K

Challenges and Opportunities: Stakeholders may consider the **r**elocation of the facility to the southern portion of the parcel, which is higher in elevation (20'+), away from the coastal hazard zone, and has available space. Highway 1 provides some protection from storm wave flooding and dune erosion progression.

Pigeon Point Light Station State Historic Park

Ownership: State Parks

Management: State Parks, U.S. Coast Guard, Hostelling International

Buildings: 8 (13,500 sq. ft.)

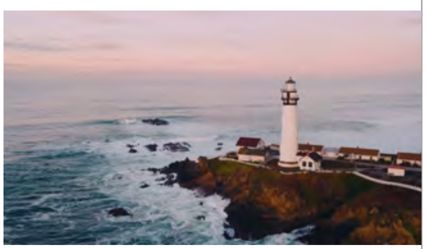
Property: 4.7 acres (22.6 acres for the entire State Park)

Min. Distance from Bluff Top Edge: ~10 feet

Sensitivity: HIGH

Adaptive Capacity: LOW

Consequences: MED



Summary of Asset: Built in 1871, the Pigeon Point Light Station remains an active Coast Guard navigation aid. The State Historic Park includes the Light Station, Interpretive Center, Hostel, restrooms, and other State Park-related facilities. It is also listed on the National Register of Historic Places and designated a California Historical Landmark. Adjacent to the Light Station is a hostel that serves 12,000 to 14,000 guests per year and is a non-profit with a mission to provide student education programs and accessible travel. The hostel is a popular stop-off for bikers along Highway 1.

Hazard Exposure: Cliff Erosion
0.8 feet: Cliff erosion could impact four structures, including the lighthouse station and interpretive center.
1.6 feet: Cliff erosion may impact four additional structures, including the Hostel buildings.

Note: Site-specific modeling to refine cliff erosion hazards is recommended.

Narrative: California State Parks published a General Plan in 2017 that includes a site-specific assessment of erosion hazards with bluff setback requirements. In this study, the Light Station and all other State Park buildings are within the erosion hazard zone between **2050** and **2100**. Currently, active bluff erosion is occurring due to rainfall-runoff and poor site drainage, as well as by wave uprush that directly impacts the bluff. As sea levels rise, wave uprush on the bluff will lead to accelerated erosion rates and retreat of the bluff top edge.

ECONOMIC FACTORS:

- In 2021, California State Parks received a grant to fully restore the Lighthouse in its current location: $18.9M
- Estimates from the 2017 General Plan gave a potential replacement cost to relocate and reconstruct all buildings: $8.5M with the Hostel comprising $3.4M of this value).

Challenges and Opportunities:
California State Parks recently received a grant to complete an $18.9M restoration, emphasizing community interest in preserving the structure.

Armoring options may be challenging due to the exposure of the site to intense coastal storms, and protection of the entire promontory would require a very long and highly engineered structure. The site is also an ecological and educational resource, and armoring would impact the intertidal zone and have impacts on aesthetics.

CAL FIRE San Mateo Santa Cruz Unit—Station 59

Ownership: County of San Mateo

Management: County of San Mateo, CAL FIRE

Regulatory: State—Storage Tank, EPA—EIS

Buildings: 2 (6,645 sq. ft.)

Property: 1.1 acres

Elevation of Buildings: 4.3 to 5.1 feet NAVD88

Sensitivity: HIGH

Adaptive Capacity: MED

Consequences: HIGH

Summary of Asset: The CAL FIRE Station provides essential services for the health and safety of the region and includes a barracks and an apparatus building for vehicles and equipment. Built in the 1960s, the buildings have several structural issues. In 2013, funds were approved to construct a new facility, and as of June 2021, a project to build a replacement fire station adjacent to the Pescadero High School is in preliminary design. The existing facility on Pescadero Creek Rd would be retained to provide easier emergency access to Highway 1, but would be affected by periodic inundation.

Narrative: The barracks building already experiences flooding from Butano Creek, causing plumbing backups and mold damage. Interruption or loss of emergency services, which are existing problems in the community, may be exacerbated by future SLR scenarios, and have high consequences for public safety.

Hazard Exposure: Closed Lagoon and Fluvial flooding (not included in this analysis)

Current: Fire Station barracks and location may have obstructed access toward Pescadero
0.8 feet: Fire Station apparatus building becomes exposed

ECONOMIC FACTORS:

- Approximate Property Replacement Value: **$8M**
- Above ground storage tank relocation cost: **$125K**
- Potential storage tank leak cleanup costs: **$5K to $2M. Average: $275K**

Challenges and Opportunities: The County is currently planning to relocate the fire station and renovate the existing apparatus building by raising the ground floor. Plans should consider flood- proofing strategies and connectivity of critical facilities and site access.

Pescadero Corporation Yard

Ownership: County of San Mateo

Regulatory: State – Fueling Station

Buildings: 2 (3,460 sq. ft. total)

Property: 22.4 acres

Elevation of Yard: 6.8 to 8.2 feet NAVD88

Sensitivity: HIGH

Adaptive Capacity: MED

Consequences: MED

Summary of Asset: Serves as the County fleet and maintenance facility for the region and has a fueling station on the premises. Based on the 1853 topographic survey of the marsh, this low-lying area connected with the marsh on the north side of Pescadero Creek Road.

Narrative: Structures on site are not directly affected, however, **by 4.9 feet** ingress and egress may be affected by estuary-related flooding along Pescadero Creek Road. If the yard floods, vehicles will no longer be able to access the site. An above-ground fuel tank is also located on site.

Hazard Exposure: Closed Lagoon Flooding
Current to 1.6 feet: Obstructed access on Pescadero Creek Rd toward Pescadero
4.9 feet: Site access, site yard, fuel pump, and parking area potentially flooded.

ECONOMIC FACTORS:

- Aboveground fuel tank relocation cost: **$125K**
- Potential fuel tank cleanup costs: **$5K to $2M. Average: $275K**

Challenges and Opportunities: The County may have the opportunity to relocate the yard to a higher-ground site on adjacent properties to the south. The properties are County-owned and have access to Bean Hollow Road but would require site improvements. Areas to the north and west are steep upland areas that limit redevelopment opportunities.

Ritz-Carlton Hotel Half Moon Bay and Half Moon Bay Golf Links

Ownership: Private

Buildings: 1 (70,890 base floor sq. ft., 298,264 gross sq. ft., *parking structure not included*)

Property: 10.8 acres (~270 acres when including golf courses and hotel)

Min. Distance from Bluff Top Edge: ~130 feet

Sensitivity: HIGH

Adaptive Capacity of Hotel: LOW

Adaptive Capacity of Golf Course: HIGH

Consequences: HIGH

Summary of Asset: The hotel is located at Miramontes Point in Half Moon Bay and was constructed in 2001. The six-story building contains 271 rooms, restaurants, spas, and other amenities. It is the only oceanfront hotel in Half Moon Bay with two golf courses nearby. The facility and related activities provide significant contributions to the City of Half Moon Bay's employment and tax base and draw tourists from afar.

Narrative: A geotechnical investigation from 2002 identified an average erosion rate of 0.75 feet per year. between 1963 and 2000. As sea levels rise, erosion rates will accelerate the retreat of the cliff edge. Topography data from 2018 showed the hotel's most cliffside location at 130 feet from the bluff edge. This seaward section of the hotel may be susceptible to erosion in the future.

Hazard Exposure: Cliff erosion
0.8 feet: 18th green at both the old and new golf courses are affected
1.6 feet: Portions of the Coastal Trail and golf course, and ocean lawn grounds affected
4.9 feet: The forward, ocean-fronting wing, of the hotel may be exposed to coastal erosion. This wing includes the Miramontes, Montara, and El Granada Dining and Meeting Rooms, as well as rooms on the floors above.

ECONOMIC FACTORS:

Total Value: $ 244M (Source: SMC Assessors)

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- Estimated Annual Transient Occupancy Tax: $5.7M
- Estimated Half Moon Bay Tax Contribution: $2.4M*
- Estimated Total Property Tax Contribution: $8.1M
- Assessed Property Value of entire Hotel and Golf Course Properties Combined: $244M

*The Transient Occupancy Tax assumes a 50% occupancy rate and a $1,000 median room rate. Does not include revenues derived from the golf course and other indirect employment benefits.

Challenges and Opportunities: Erosion of the bluff could be accommodated with some reconfiguration of the course and realignment of the adjacent California Coastal Trail.

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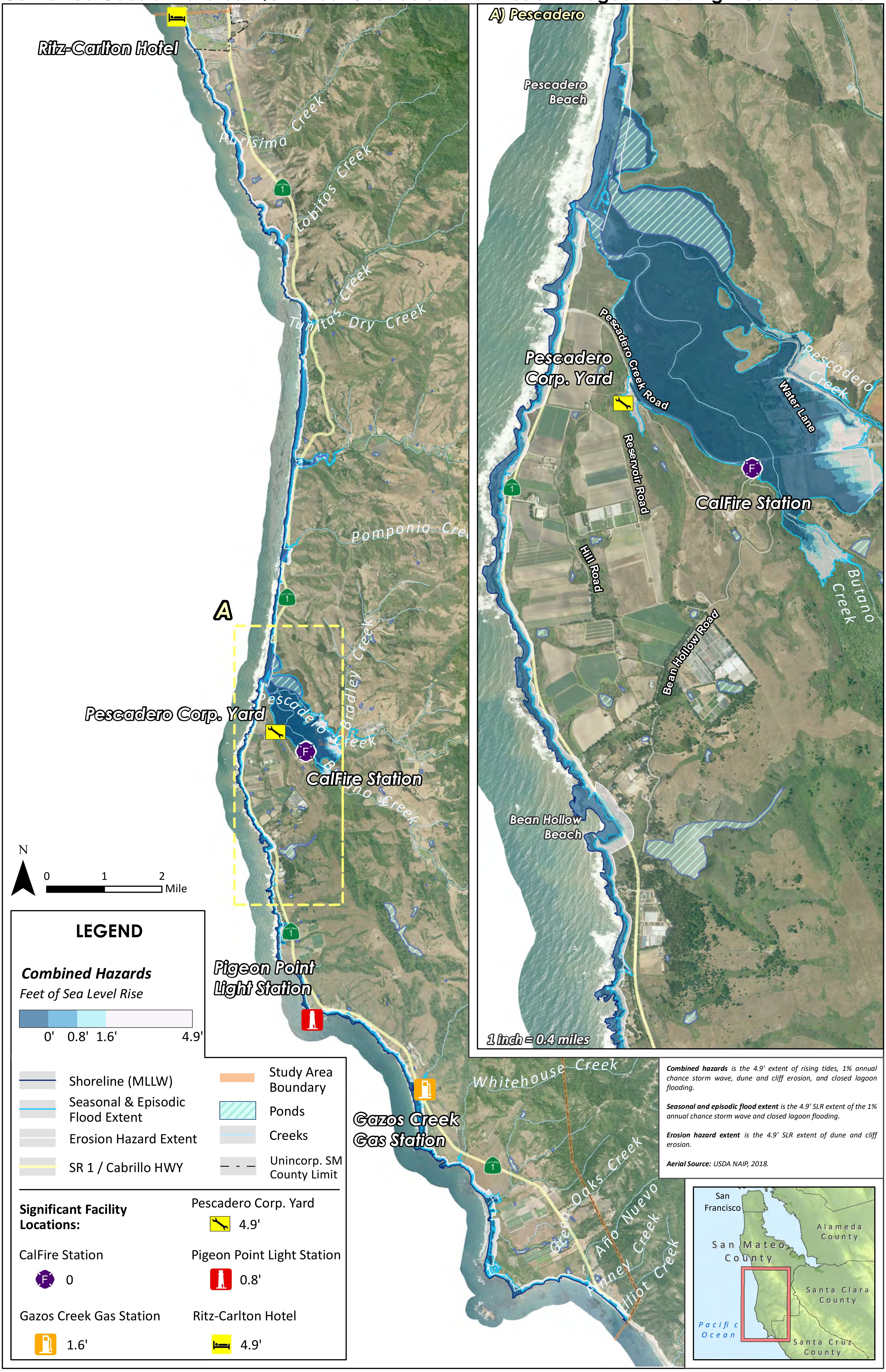
San Mateo South Coast: Significant Facilities

Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



LEGEND

Combined Hazards

Feet of Sea Level Rise

0' 0.8' 1.6' 4.9'

Shoreline (MLLW)
Seasonal & Episodic Flood Extent
Erosion Hazard Extent
SR 1 / Cabrillo HWY
Study Area Boundary
Ponds
Creeks
Unincorp. SM County Limit

Significant Facility Locations:

Pescadero Corp. Yard 4.9'

CalFire Station 0

Pigeon Point Light Station 0.8'

Gazos Creek Gas Station 1.6'

Ritz-Carlton Hotel 4.9'

Combined hazards *is the 4.9' extent of rising tides, 1% annual chance storm wave, dune and cliff erosion, and closed lagoon flooding.*

Seasonal and episodic flood extent *is the 4.9' SLR extent of the 1% annual chance storm wave and closed lagoon flooding.*

Erosion hazard extent *is the 4.9' SLR extent of dune and cliff erosion.*

Aerial Source: *USDA NAIP, 2018.*

Exposure and Risks to Roads and Parking from Coastal Hazards and Sea Level Rise on the South Coast of San Mateo County

Overview

Highway 1 at Pescadero Creek Rd

Existing Conditions: Highway 1 is the primary transportation corridor connecting the South San Mateo Coast. This 24.6 mile stretch of highway sees an annual average daily traffic count of 4,150 at the Santa Cruz County Line in the south, and 12,600 at Miramontes Point Road in the North. Most public parking areas along the coast are located in official State Parks lots and in informal roadside parking areas. Eleven formal State Park lots hold 438 parking spaces. Existing erosion on Highway 1 has led to the placement of three sections of armoring near Pescadero State Beach (SB), constructed through emergency permits.

Hazards Overview: The best available scientific projections with **4.9 feet of sea level rise (SLR)** show approximately **11.4 miles of total roadway** projected to be affected by coastal hazards. Erosion is projected to affect approximately **4.5 miles** of Highway 1. Estuary flooding is projected to affect **1.2 miles** of Pescadero Creek Rd, the most impacted **County Road**. Smaller local roads and driveways are also affected, mainly where they meet Highway 1. Coastal erosion and coastal wave flooding are projected to impact **eleven parking lots** maintained by State Parks.

Methodology

To evaluate the impacts of coastal hazards and SLR on roads and parking, the following measures of impact were considered:

• Length of Road Exposed by Type • Number and Square Feet of Parking Lots Exposed

Assumptions: Parking lot relocation has been calculated by multiplying the square feet of parking area affected by all hazards with a replacement cost, assumed to be $5/sqft. Physical Road Costs due to threats from coastal erosion were calculated as $500/foot for Highway 1 and $280/foot for non-Highway roads. This assumes that there is adequate space within the right-of-way or in nearby areas for replacement, and does not consider costs of permitting and removal. Revetment Placement was calculated as the linear feet of potentially affected Highway 1 sections by $2,577/foot (Source: Caltrans 2007). The indirect economic damages resulting from hazards, such as service disruption and economic shutdowns due to flooding of Pescadero Creek Road, are not estimated here.

Note: Direct paving costs are a fraction of potential physical road costs, and ignore indirect costs such as travel time disruptions. These costs will be further evaluated in a detailed adaptation section of the San Mateo South Coast SLR VA and Adaptation report.

Existing Exposures

Coastal Erosion

- All Roads: 0.46 mile
- Highway 1: 0.35 mile
- Parking: 0.5 acres / around 55 spaces

Estuary Flooding

- All Roads: 2.09 miles
- Pescadero Creek Rd: 0.9 mile

Coastal Wave Flooding

- Parking: 1.2 acres / around 119 spaces

Roads: Currently the most at-risk roads are within the floodplains of Pescadero and Butano Creeks. Estuary-related flooding in these areas is projected to affect 0.9 miles of Pescadero Creek Rd, 0.47 miles of Water Lane, and 0.25 miles of Highway 1 around Pescadero North Marsh.

Parking: Coastal wave and dune erosion are projected to impact four beach access parking lots, including Bean Hollow, Gazos Creek SB, Pescadero Sand Beach, and Pomponio SB, as well as informal parking spaces along Highway 1 around Bean Hollow.

Culverts: State-owned culverts at Gazos Creek, Yankee Jim Gulch, and Arroyo de los Frijoles at Bean Hollow SB. County-owned culverts around Pescadero Creek Road are subject to estuary flooding.

ECONOMIC IMPACT:

- Parking Relocation and Repaving Cost: **$310K**
- Physical Road Costs: **$1.1M**

Projected Exposures

0.8 feet of sea level rise

Coastal Erosion

- All Roads: 1.27 miles (1.73 total)
- Highway 1: 0.8 miles (1.32 total)
- Parking: 0.6 acres / around 60 spaces (1.1 acres / ~115 spaces total)

Estuary Flooding

- All Roads: 0.22 miles (2.32 total)
- Pescadero Creek Rd: 0.08 mile (0.98 miles total)

Coastal Wave Flooding

- Parking: <.1 acres / around 7 spaces (1.2 acres / 126 spaces total)

Roads:
Cliff erosion is projected to affect sections of Highway 1 near the southern County Line (~300 feet), Bean Hollow (~130 feet), Pescadero SB near the northern armored section (~40 feet).
Dune fronted: Bean Hollow at Arroyo de los Frijoles (~1,100 feet), Pescadero SB at Sand Beach (~2,300 feet), near Pomponio SB (~830 feet).

Parking: Coastal erosion and wave flooding are projected to affect four parking lots, including Pebble Beach at Bean Hollow SB and Pigeon Point, with cliff erosion projected to impact two cliff-fronted lots at Pescadero SB (Rockside and Creek Mouth, South Lot). Coastal erosion and storm wave flooding are projected to impact the informal street-side parking spaces along Pigeon Point Road from the Light Station to Pistachio Beach.

ECONOMIC IMPACT:

- Parking Relocation and Repaving Cost: **$100K ($420K total)**
- Physical Road Costs: **$2.1M ($3.3M total)**

1.6 feet of sea level rise

Coastal Erosion

- All Roads: 1.81 miles (3.54 total)
- Highway 1: 0.97 mile (1.58 total)
- Parking: 1 acre / around 100 spaces (1.1 acres / around 215 spaces total)

Estuary Flooding

- All Roads: 0.16 mile (2.48 total)
- Pescadero Creek Rd: 0.04 mile (1.02 total)

Coastal Wave Flooding

- Parking: <.1 acres / around 4 spaces (1.2 acres / 130 spaces total)

Roads:
Cliff erosion is projected to affect sections of Highway 1 near the southern County Line (~1,960 feet), five distinct sections between Bean Hollow and Pescadero Pointt (~1,000 feet), and six distinct sections between Pescadero Pointt and Pescadero Bridge (including all 3 currently armored sections) (~1,300 feet).
Dune erosion is projected to affect sections of Highway 1 at Bean Hollow (~1,300 feet), Pescadero SB at Sand Beach (~2,500 feet), and near Pomponio (~1,300 feet).

Parking: Cliff Erosion is projected to affect the North Lot at the Pescadero Creek Mouth.

ECONOMIC IMPACT:

- Parking Relocation and Repaving Cost: **$170K ($590K)**
- Physical Road Costs: **$3.8M ($7M total)**

4.9 feet of sea level rise

Coastal Erosion

- 4.94 miles (8.48 miles total)
- Highway 1: 2.93 miles (4.5 total)
- Parking: 1.6 acres / ~164 spaces (3.1 acres / around 379 spaces total)

Estuary Flooding

- All Roads: 0.75 miles (3.23 total)
- Pescadero Creek Rd: 0.13 mile (1.15 total)

Coastal Wave Flooding

Roads: Erosion affects the following sections of Highway 1:
Cliff erosion is projected to affect sections of Highway 1, including two sections at County Line (~2,900 feet), Pigeon Point Viewpoint (~800 feet), Yankee Jim Gulch (~200 feet), three sections between Bean Hollow and Pescadero Point (~3,600 feet), seven sections between Pescadero Pt and Pescadero Bridge (~6,500 feet), three small sections near northern Pescadero SB, near Pomponio SB (~630 feet), three sections between Pomponio SB and San Gregorio SB (~1,300 feet), and at Tunitas Creek (~1,300 feet).
Dune erosion is projected to affect sections of Highway 1 at Gazos Creek (~1,300 feet), Bean Hollow (~1,500 feet), Pescadero SB at Sand Beach (~3,500 feet), Pomponio (~1,300 feet), and San Gregorio (~400 feet).

Parking: Two informal off-street parking lots at Pigeon Point are projected to be affected by cliff erosion.

ECONOMIC IMPACT:

- Parking Relocation and Repaving Cost: **$320K ($910K)**
- Physical Road Cost: **$10.7M ($17.7M total)**

- Parking: 0.1 acres / around 13 spaces (1.2 acres / 143 spaces total)

Potential Adaptation Strategies

Range of Strategies: Includes "No Action" and cleanup, as well as protect, accommodate, and managed retreat strategies

Protect - ***(Gray)*** Construct and maintain coastal armoring along Highway 1 and parking lot segments along Highway 1 to stop erosion.

Highway 1	Existing	0.8 feet	1.6 feet	4.9 feet	Totals
Est. Costs	$4.8M	$3.3M	$13.3M	$39.8M	$61.3M

Note: Table includes road costs plus revetment costs

(Green) Natural dune restoration or nourishment along low lying road areas can reduce erosion and flood risk

Accommodate—Elevate roads to accommodate flooding along Pescadero Creek Road either by building a causeway, or incrementally elevating the road surface during routine repaving by adding two to three inches of asphalt.

Managed Retreat—Realign sections or all of Highway 1 or remove roads from the hazardous areas as per Caltrans realignment study

Secondary Impacts: ***Retreat*** strategies may negatively impact traffic and other resources of the County, depending on the realignment. ***Accommodation*** strategies may create additional stormwater drainage issues. Green ***protection*** strategies could provide some room for habitat transgression for roads adjacent to wetlands. Gray ***protection*** strategies could negatively impact beach and dune habitat transgression as well as escalate maintenance costs.

Findings and Strategy Options

Summary

Impacts: ***Currently,*** the most vulnerable stretches of County roads are due to flooding along Pescadero Creek Road and Water Lane. Low-lying sections of Highway 1 near Pescadero SB North Marsh and Gazos Creek are also potentially affected by a combination of storm-wave and estuary-related flooding. Low-lying sections of Highway 1 are threatened by dune erosion. ***With 0.8 feet of SLR***, threats from potential dune erosion accelerate at Bean Hollow, Sand Beach, and Pomponio SB. ***With 1.6 feet***, threats from cliff erosion escalate near the County Line, and along 11 distinct sections between Bean Hollow and Pescadero Bridge. ***With 4.9 feet,*** significant stretches of Highway 1 are potentially threatened by dune and cliff erosion, and many smaller sections merge into much larger sections of threatened roadway. Approximately 4.5 miles of Highway 1 are potentially affected.

Strategy Options

- Work with Caltrans on Highway 1 to ensure that regional connections remain intact.
- Work with State Parks to identify future beach access parking so that there is no net loss of coastal access.
- Update the transportation planning documents to identify preferred adaptation strategies to reduce impacts.
- Construction of a raised roadway and or causeway across the flood-prone portions of Pescadero Creek Rd.
- Channel dredging or elevated bridge along Butano Creek to reduce flooding at the bridge crossing.
- All solutions above should consider habitat connectivity and impacts to coastal, upland, and marsh habitats.

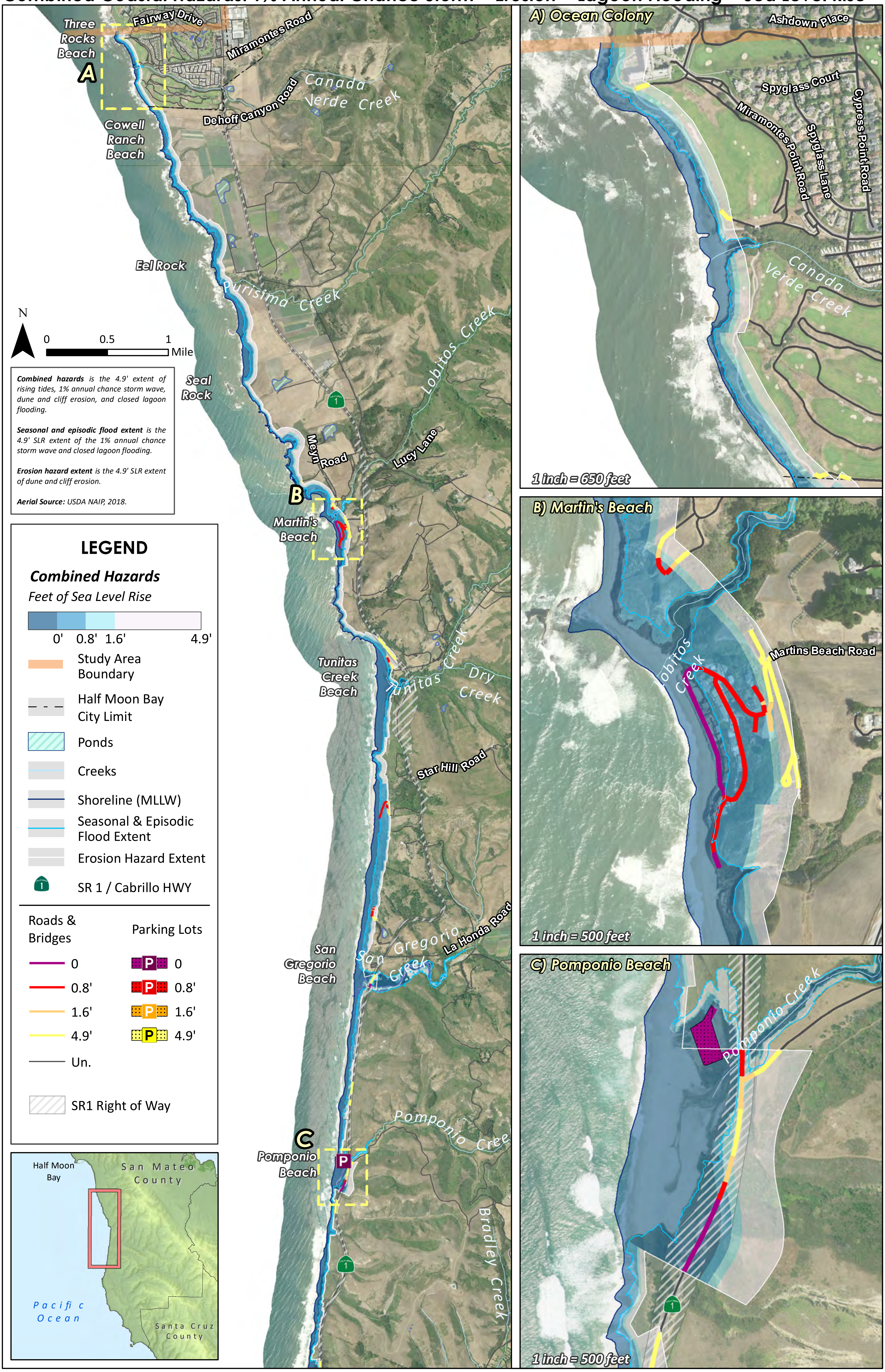
Monitoring:

- Monitor depth, extent, and frequency of road flooding along frequently impacted areas.
- Monitor erosion rates along vulnerable stretches of coast.

San Mateo South Coast: Transportation

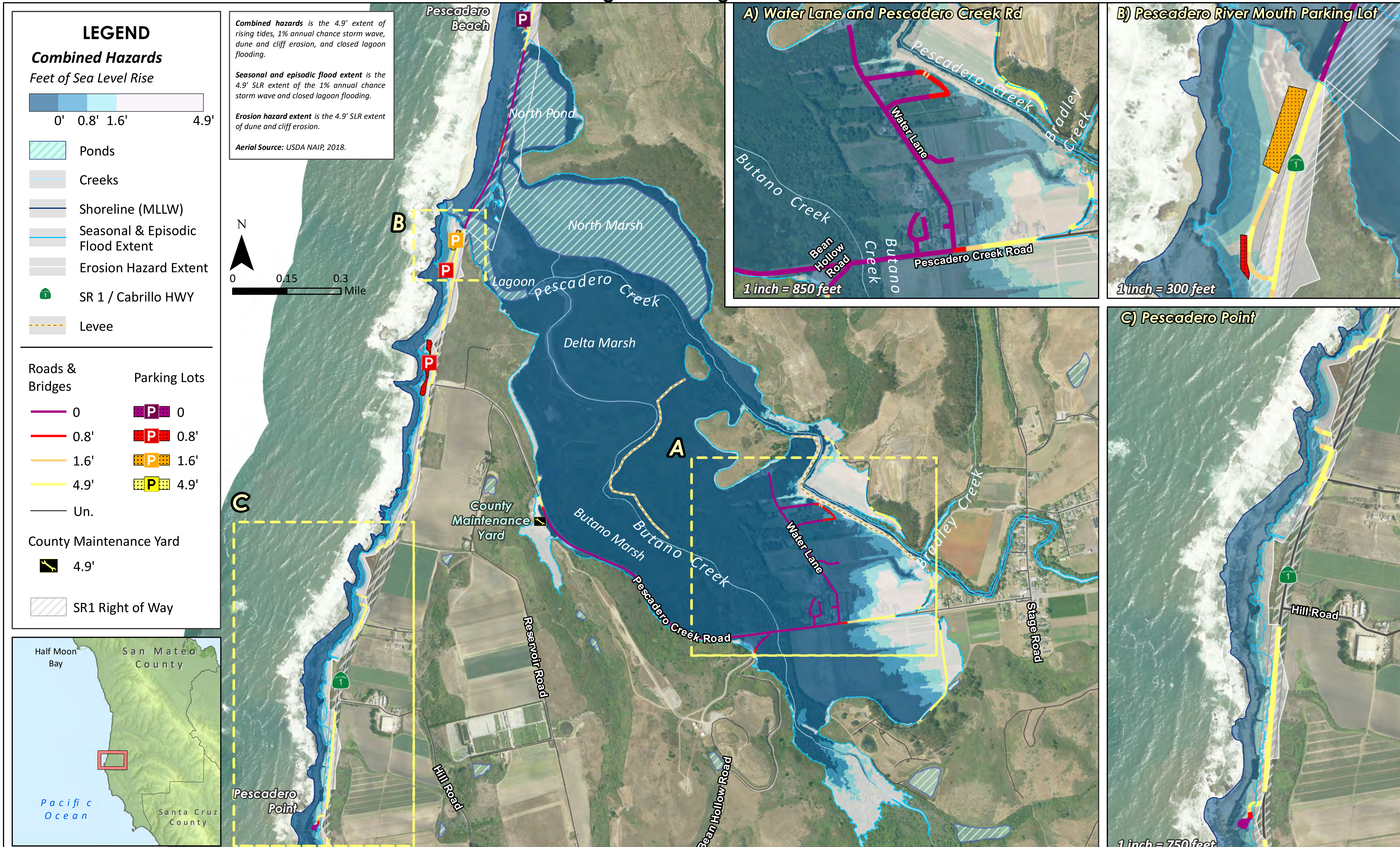
Section:
Ocean Colony to Pescadero Beach

Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



San Mateo South Coast: Transportation

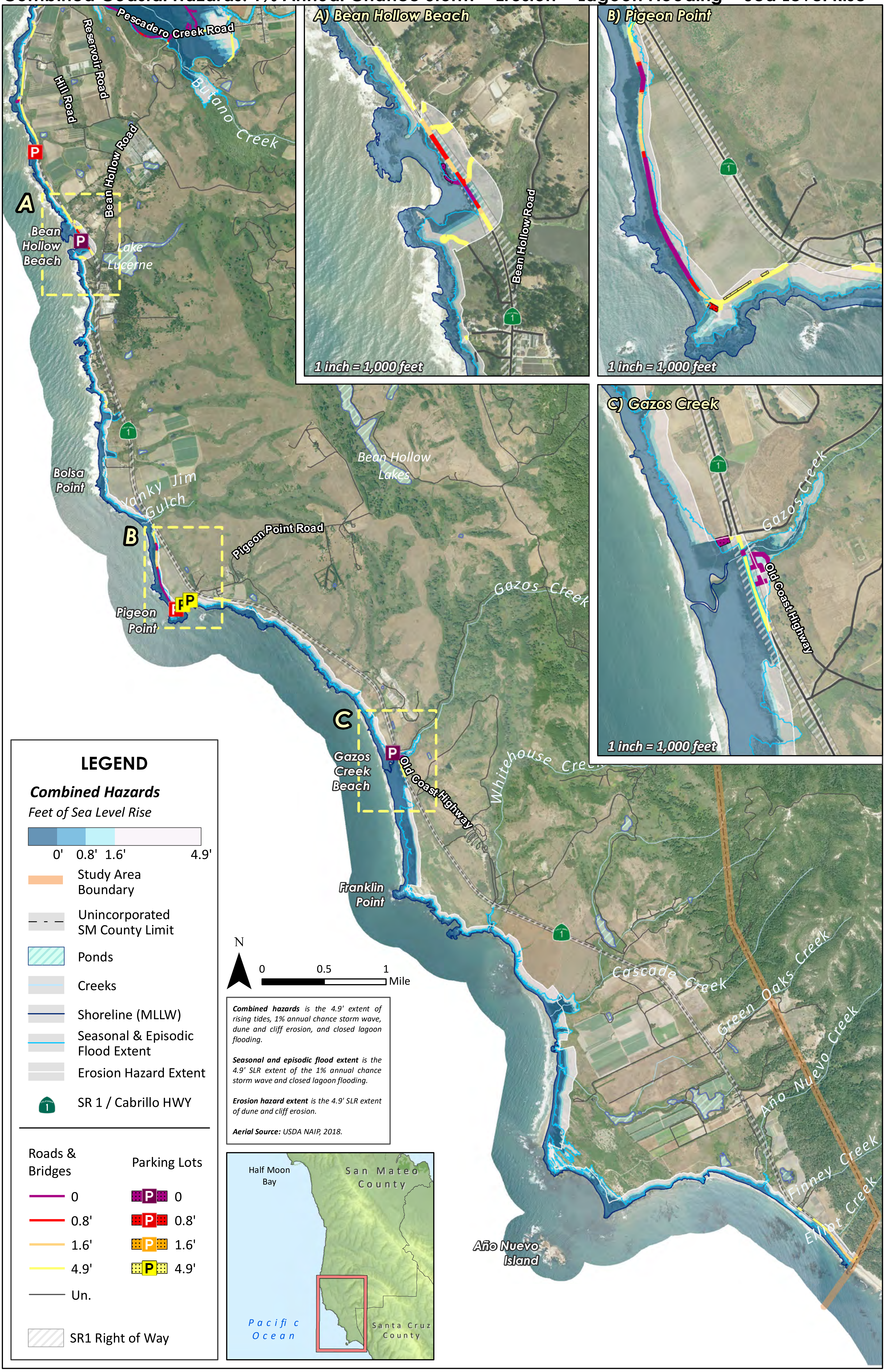
Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



San Mateo South Coast: Transportation

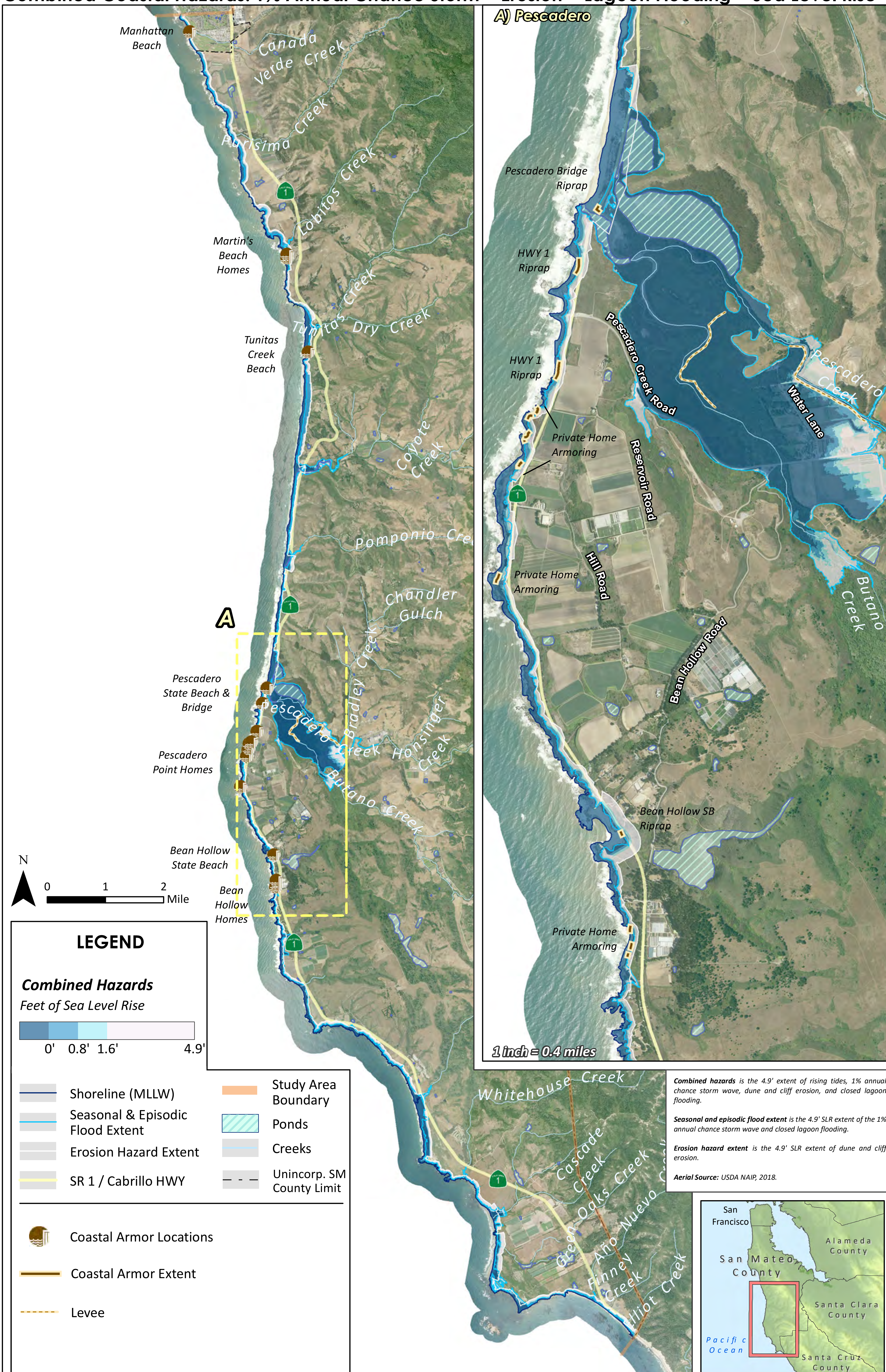
Section:
Pescadero Point to South County Line

Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



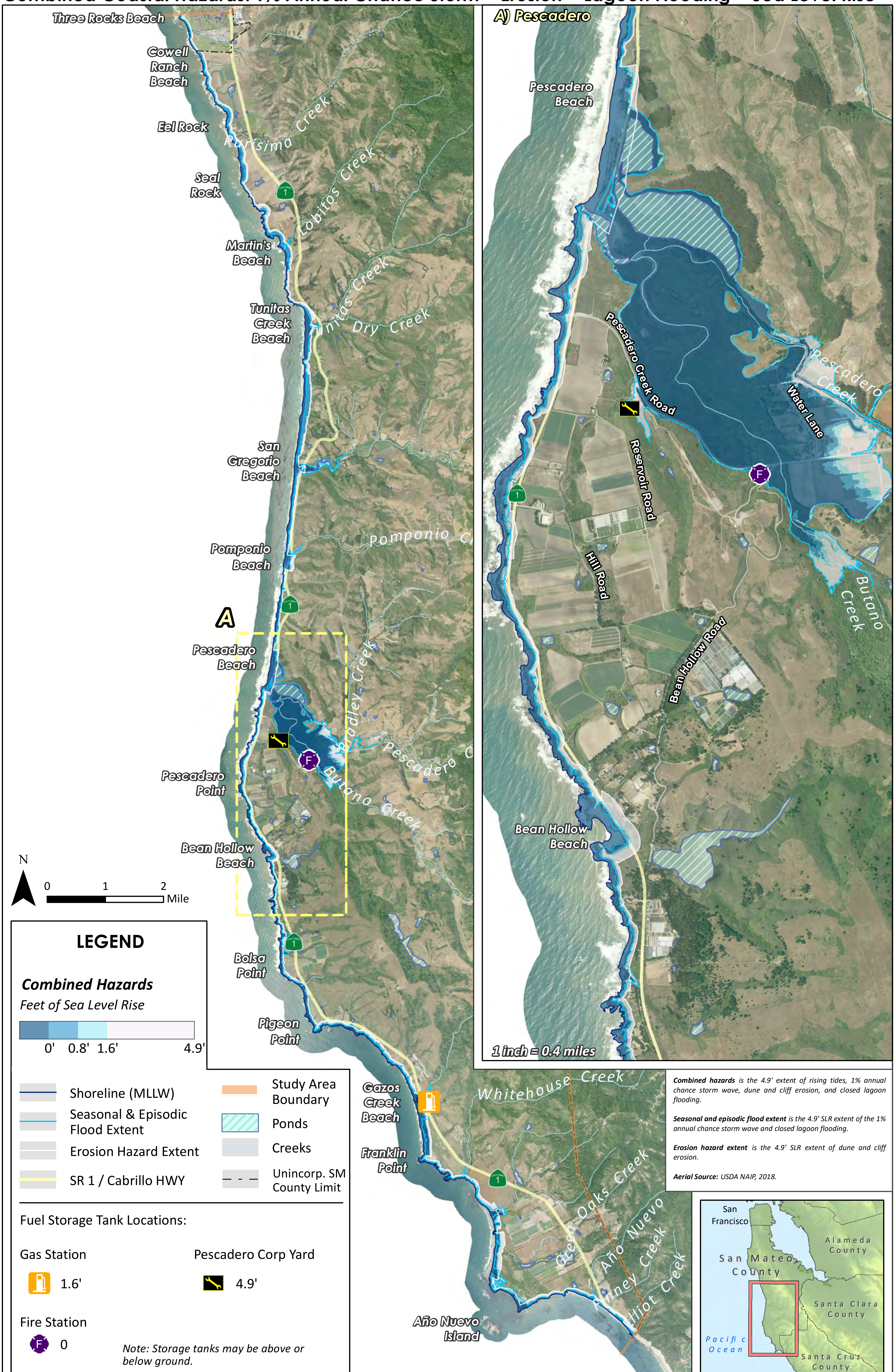
San Mateo South Coast: Coastal Armoring

Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



San Mateo South Coast: Hazardous Materials

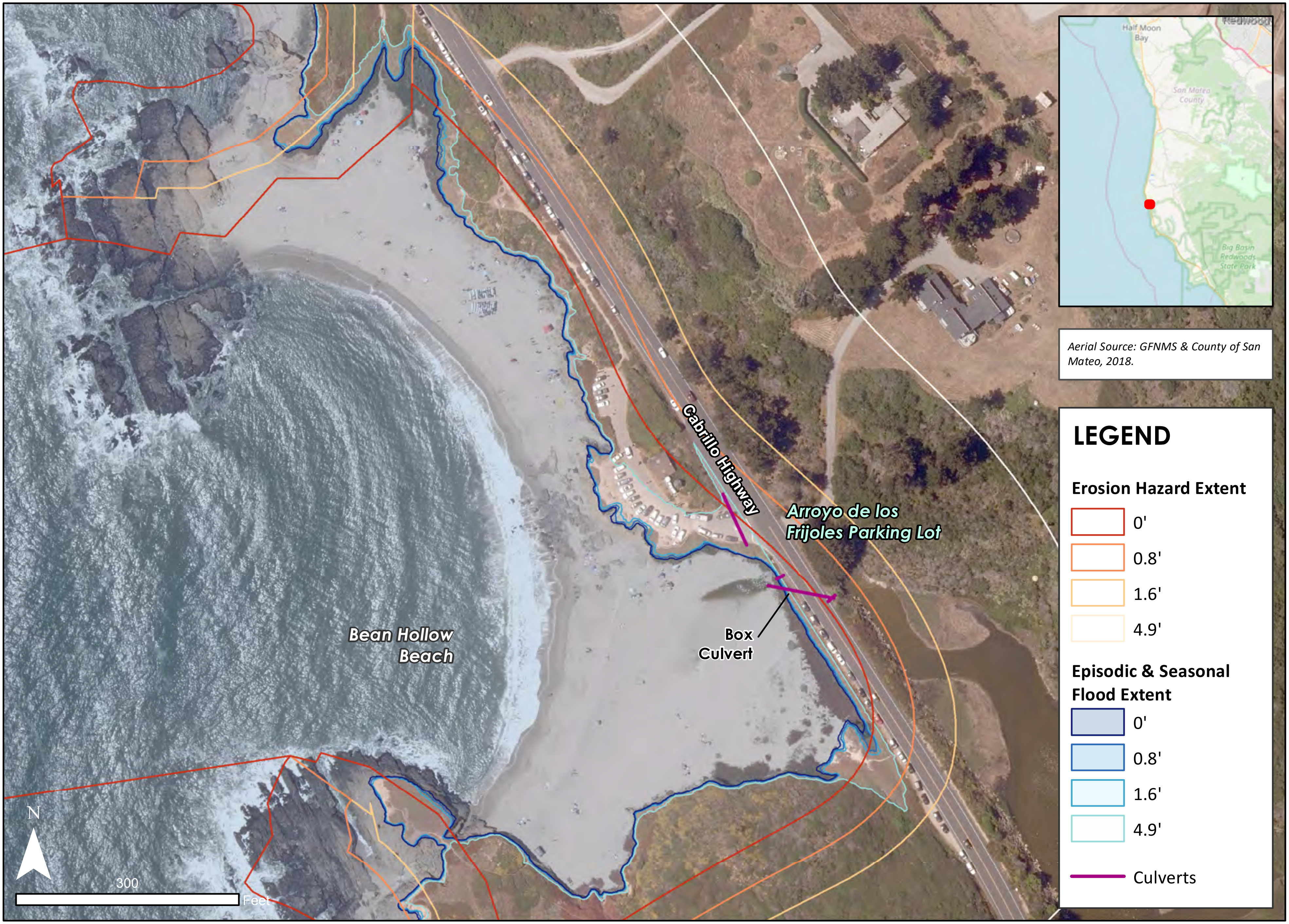
Combined Coastal Hazards: 1% Annual Chance Storm + Erosion + Lagoon Flooding + Sea Level Rise



12 APPENDIX D. MAPS OF SPECIFIC VULNERABLE AREAS

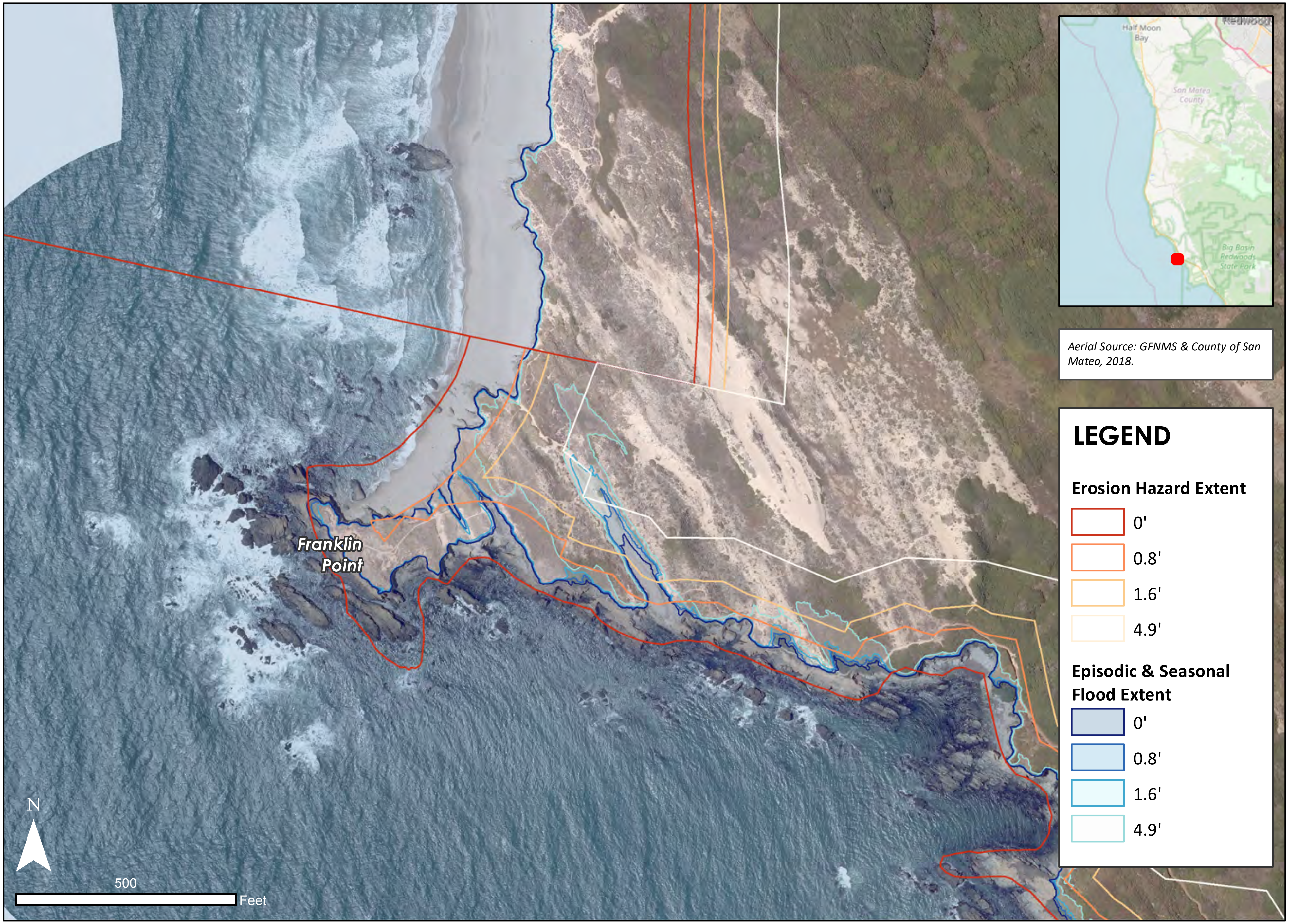
Año Nuevo Point

Bean Hollow



Cabrillo Highway
Arroyo de los Frijoles Parking Lot
Box Culvert
Bean Hollow Beach
N
300
Feet
Half Moon Bay
San Mateo County
Big Basin Redwoods State Park
Aerial Source: GFNMS & County of San Mateo, 2018.
LEGEND
Erosion Hazard Extent
0'
0.8'
1.6'
4.9'
Episodic & Seasonal Flood Extent
0'
0.8'
1.6'
4.9'
Culverts

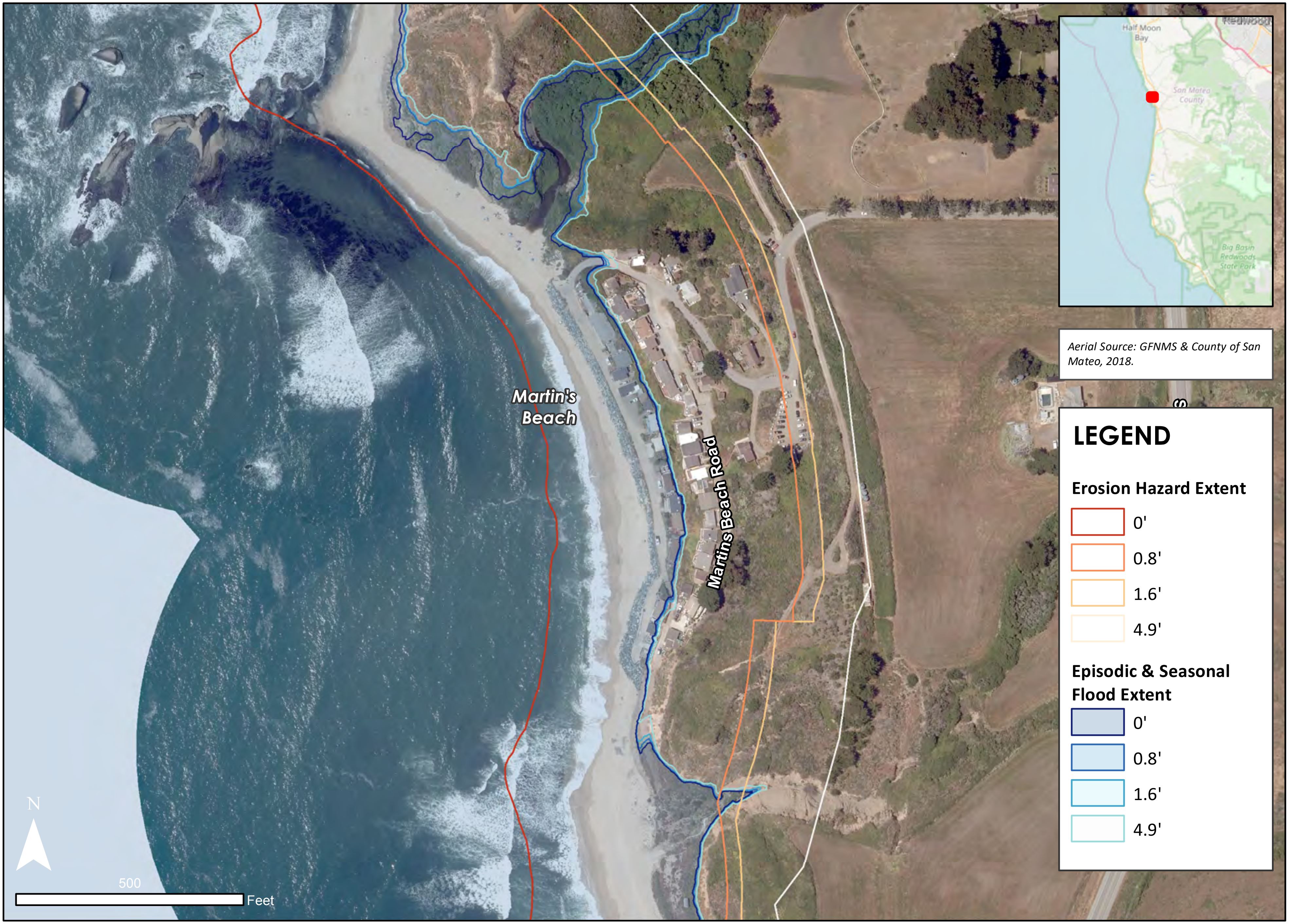
Franklin Point



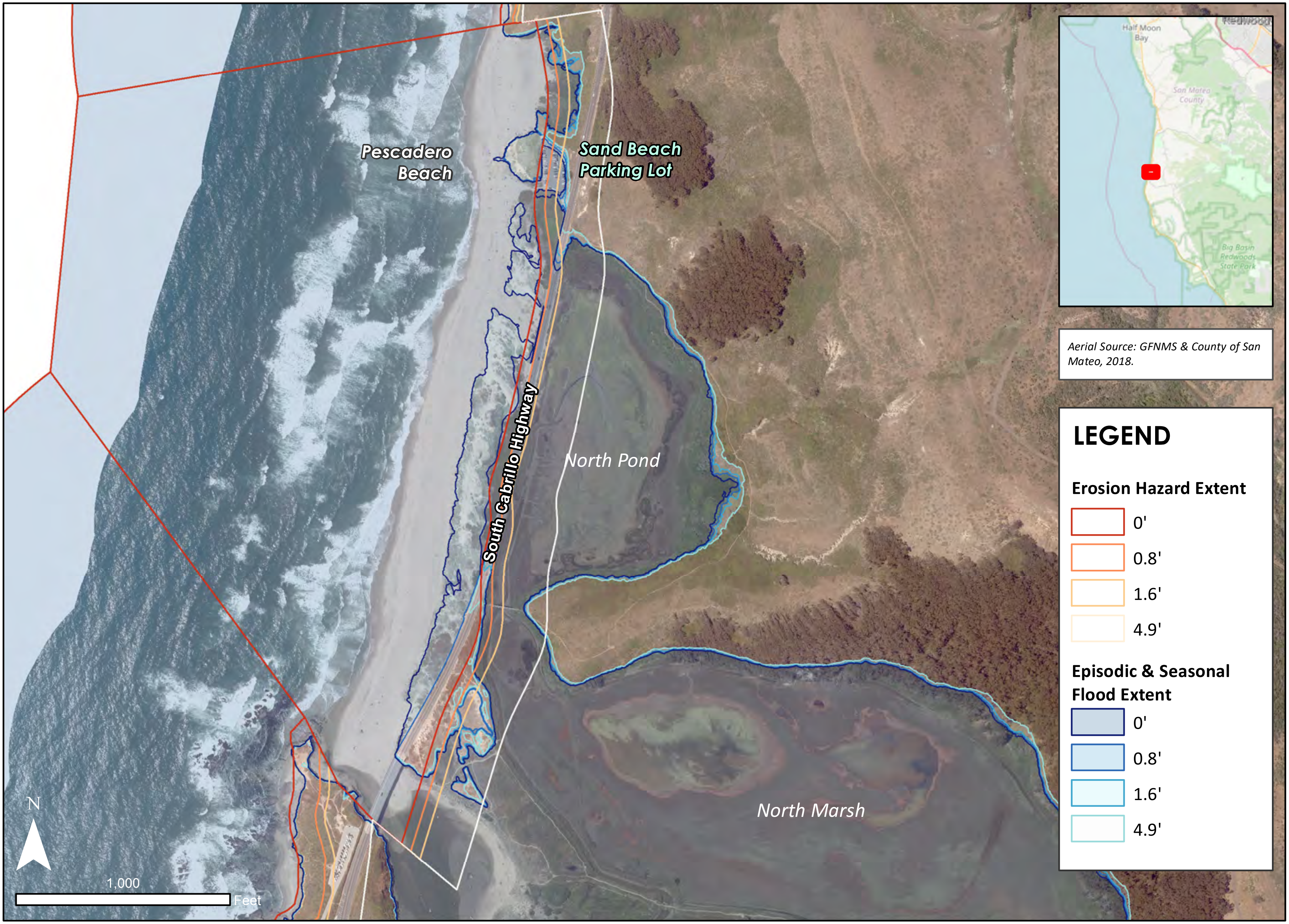
Gazos Creek

Gazo's Creek
Parking Lot
Cabrillo Highway
Gazos Creek
Alliance Gas Station
Old Coast Highway
HWY 1
Brewing Co.
N
300
Feet
Half Moon Bay
San Mateo County
Big Basin Redwoods State Park
Aerial Source: GFNMS & County of San Mateo, 2018.
LEGEND
Erosion Hazard Extent
0'
0.8'
1.6'
4.9'
Episodic & Seasonal Flood Extent
0'
0.8'
1.6'
4.9'

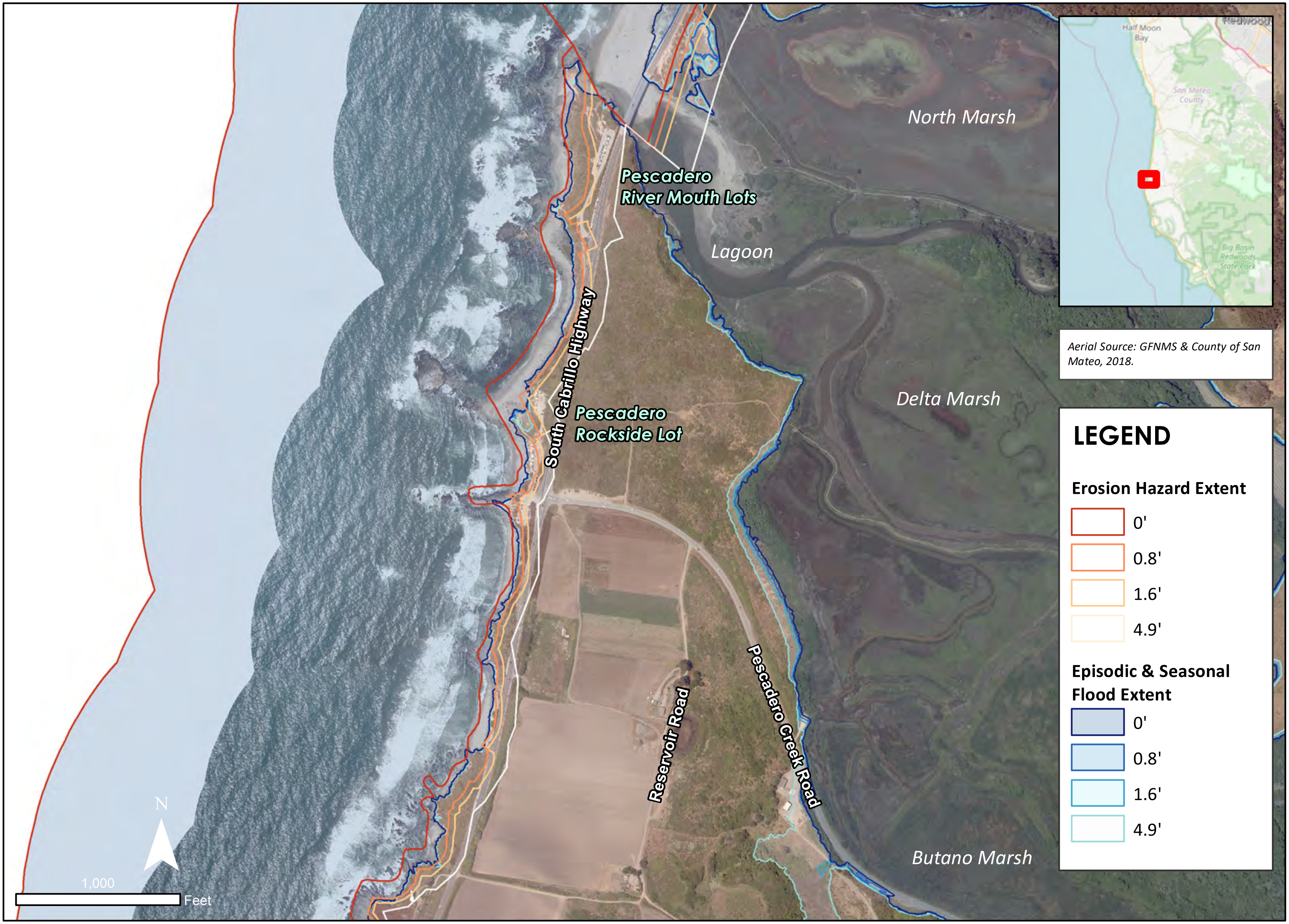
Martin's Beach



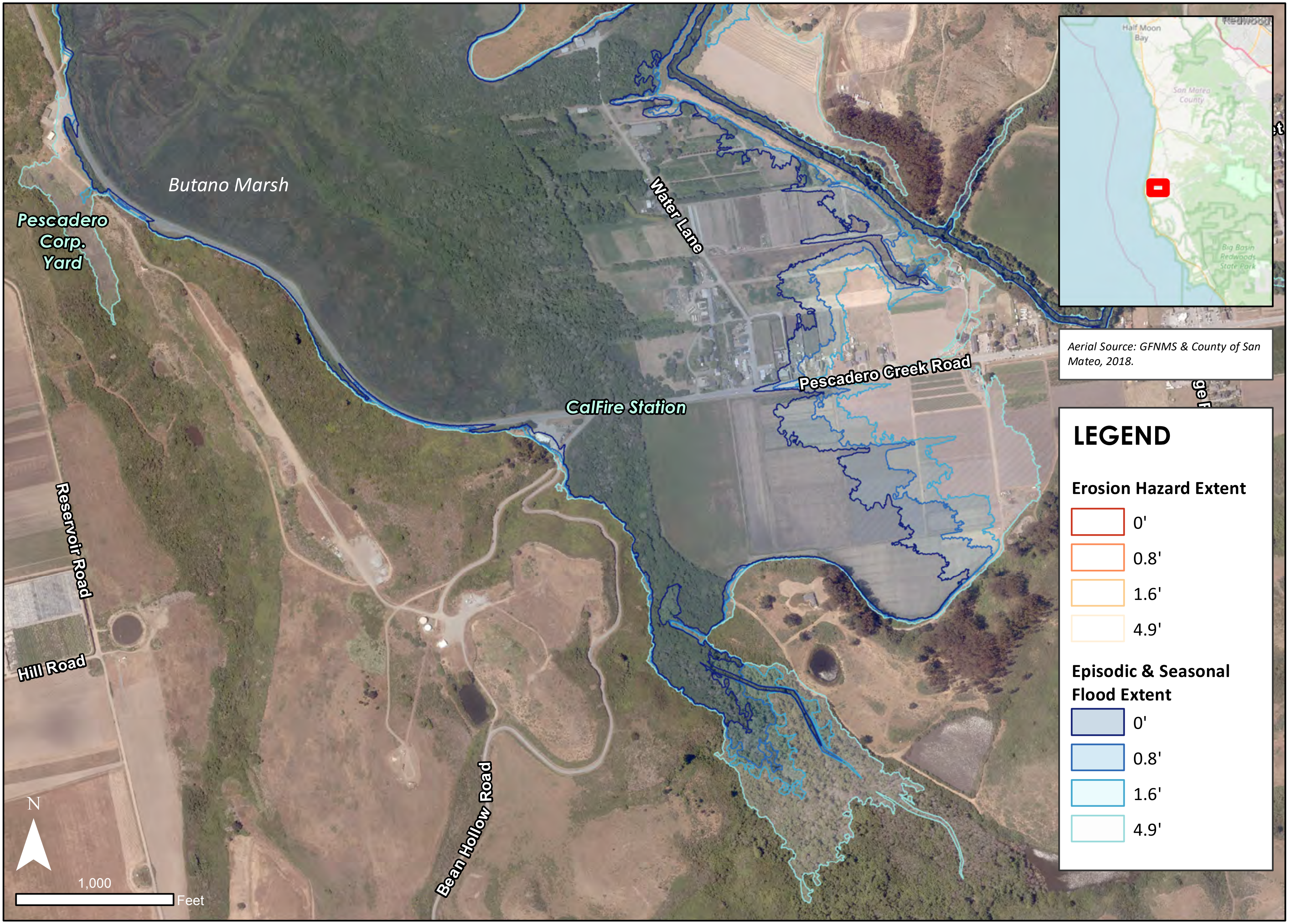
Pescadero Beach



Pescadero Cliffs



Pescadero Creek Rd and Water Ln



Pigeon Point

Pomponio Beach

Ocean Colony / Ritz-Carlton Half Moon Bay

Tunitas Creek

13 APPENDIX E. PESCADERO MARSH HABITAT MIGRATION WITH SEA LEVEL RISE

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To:	Jim Robins, Central Coast Wetlands Group at MLML, County of San Mateo
From:	David Revell, Ph.D., and Central Coast Wetlands Group at MLML
Date:	12/1/2021
Subject:	Pescadero Marsh Habitat Evolution with Sea Level Rise Study
Project No.:	C3085 & C3287

1.1 PESCADERO MARSH HABITAT EVOLUTION WITH SEA LEVEL RISE STUDY

1.1.1 Purpose

The purpose of this study is to attempt to quantify the habitat evolution associated with sea level rise for Pescadero Marsh based on changes in the projected duration of inundation and site-specific species data. It is intended that this study inform future research efforts into habitat evolution and climate change for Pescadero Marsh, and to serve as a framework for other bar-built estuaries across the state.

1.1.1.1 Disclaimer

This study is an attempt at a new approach to mapping habitat evolution with sea level rise. There are many additional considerations related to habitat evolution that were not considered in this study, such as changes in salinity, temperature, precipitation, disturbance regime, and species interactions etc. All of these additional factors are beyond the scope of this work. However, it is hoped that the team of Integral/Central Coast Wetlands Group at MLML/Alnus Ecological/RCD can use these initial results to pursue additional funding to build a more robust habitat evolution model in the future.

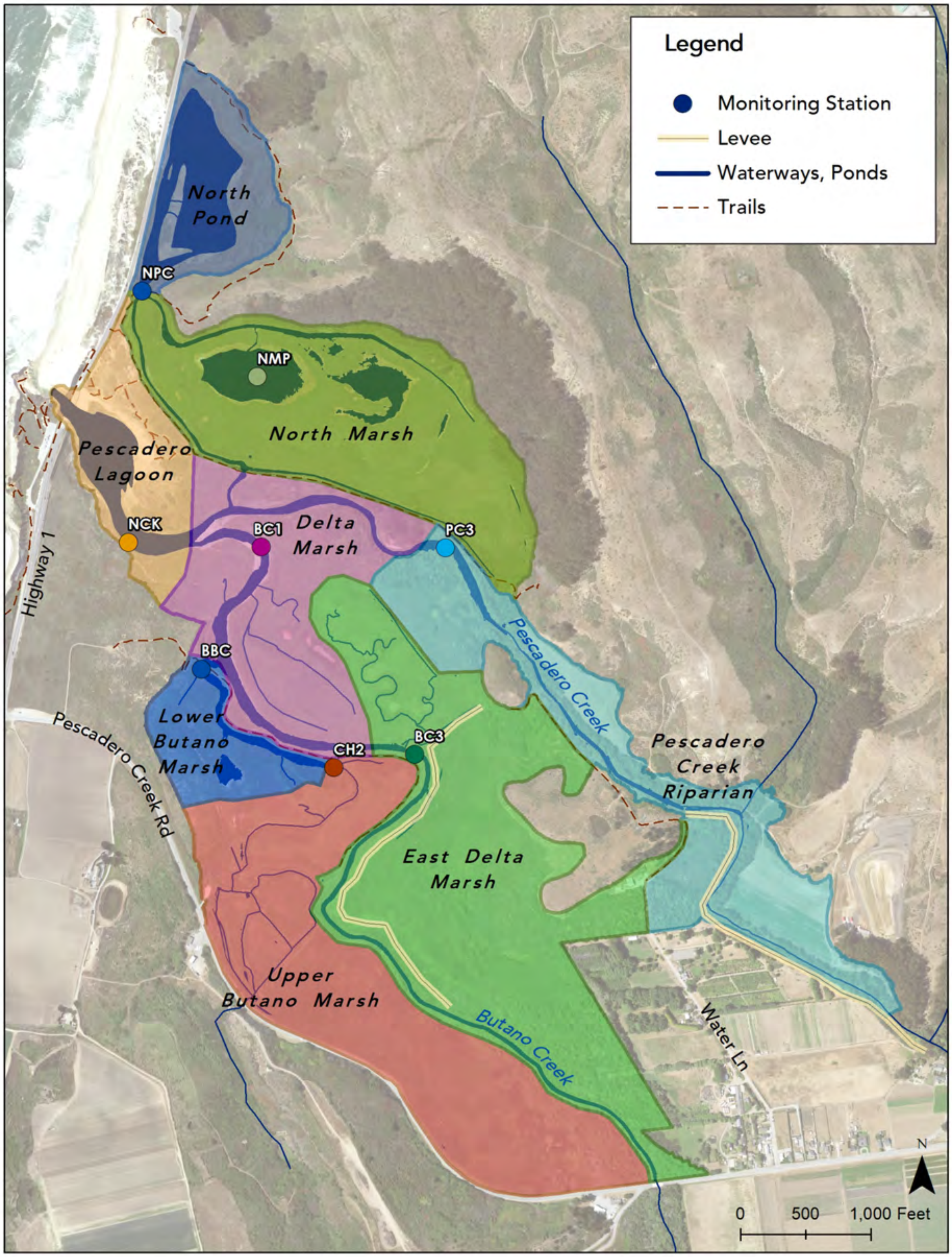


Figure 1. Pescadero Marsh Study Area. Water level gauge locations and their associated zones of influence are indicated by their color.

1.1.2 Introduction

Within San Mateo County, Pescadero Marsh is the most studied and well-defined wetland system. The Pescadero Marsh is a bar built estuary with both saltwater and freshwater marsh habitats, subject to a range of tides when open, wave overtopping events when closed, and receives freshwater flows from Pescadero and Butano Creeks throughout the year.

Bar built estuaries are complicated ecosystems that are a function of physical fluvial and coastal processes which control the behavior of the mouth at the barrier beach. Marsh habitats and marsh plain inundation is often driven by a unique interaction of mouth dynamics and muted tidal mixing making most open estuarine inundation models less applicable. Existing habitats are correlated with the duration of inundation and extents of salinity in the lagoon rather than a simple relation of marsh elevation relative to the tide range.

Furthermore, because of the local proximity to sediment from river transport and extreme flooding conditions during winter storms, these models likely underestimate the resiliency of these systems to sea level rise (Clark and O'Connor 2019). Future drivers of change include sea level rise, marsh accretion/flooding, and estuarine mouth closure/wave overtopping dynamics. Together, these effects alter the hypsometry, or the measurement of land elevation relative to the tide, of each of the coastal wetland systems on the Central Coast. Changes in hypsometry and estuary inundation frequency and depth can alter the distributions of wetland plant communities and habitats.

One recognized limitation of existing modeling efforts is the lack of system-specific estimates of sediment accretion and hydrologic connectivity/mouth dynamics for bar built estuaries. This study has compiled existing data to localize projections of sea level rise-driven habitat evolution within Pescadero Marsh. Given the limited funding of this study, some simplifying assumptions were made that can be improved upon which are identified below.

1.1.3 Pescadero Marsh Habitat Study Methodology

Data Sources

To conduct this study, Integral Consulting relied on the following data and information:

- Water level sensor data from CA State Parks (2016-2017 and 2020-2021)
- Habitat mapping from CA State Parks (updated in 2018), based on the National Wetlands Inventory (USFWS)
- Detailed topo/bathy DEM provided by UC Davis (updated post-Butano restoration in 2020)

- California Central Coast vegetation inundation information from Central Coast Wetlands Group at MLML (CCWG)

Methods

1) Generate water level exceedance curves with sea level rise scenarios for each water level gauge

Using the available State Parks water level data, exceedance curves representing the duration of water levels over several years at different parts of the marsh plain were developed. For each of these curves, the sea level rise scenarios used in the San Mateo County Sea Change Assessment were applied (0.8 feet, 1.6 feet, and 4.9 feet). These sea level rise rates correspond to the medium-high risk aversion scenario from the current State guidance.

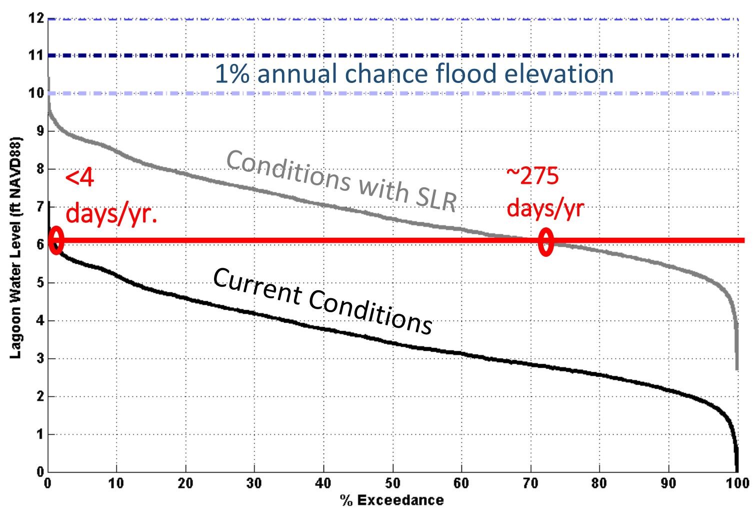


Figure 2. Example of an Exceedance Curve with Sea Level Rise

2) Identify distinct zones (or areas of influence) associated with each water level monitoring station

Marsh zones were delineated based on firsthand knowledge of the marsh, and breaks were drawn along physical features such as levees whenever possible. When such features were not present, higher elevation areas represented by natural changes in the grade were used. An attempt was made to keep all sub drainage basins intact (Figure 1. Pescadero Marsh Study Area. Water level gauge locations and their associated zones of influence are indicated by their color).

3) Develop filled contours for the entire marsh

Using the 2020 Pescadero Marsh DEM, filled contours were generated at every 0.2 feet (this was the highest level of granularity achievable using the digital elevation source and software available). These elevation zones were used to build habitat areas for existing and future conditions.

4) **Associate vegetation inundation percentages to general habitat classifications** Relying on the work by CCWG, general habitat classes were associated with vegetation inundation percentages for Pescadero Marsh. These classes included: estuarine/riverine, sand/mudflat/alkali flat, low marsh, mid marsh, high marsh, episodically flooded, and uplands. These groups are generally based on vegetation tolerance to salinity and duration of inundation (Figure 4. Vegetation Inundation Percentage Ranges for California Central Coast Marsh Species). Note that due to the variation that occurs within the marsh there may be some misrepresentation of habitat groupings for specific marsh zones. Further study and field verification could be used to better improve these classifications for each marsh zone.

5) **Apply habitat classifications to inundation percentages for each marsh zone** Our previous studies suggest that plant species occur along a gradient relative to percentage inundation duration and this range of inundation suitability likely varies among years and marsh locations. For this study, species were grouped into inundation habitat classes with defined breakpoints in inundation periodicity used to demarcate various marsh zones (Figure 3. Example of Habitat Classification Applied to an Exceedance Curve). The relationship between habitat zones and inundation percentages was verified using geospatial data from CA State Parks. Each zone used custom breakpoints, and these can be found in tables 2 - 9. These custom breaks were used as station locations were not always representative of water levels throughout the station's area of influence or marsh zone. Considerations were made where elevation gradients were more highly variable between upstream and downstream areas of the zone, or where physical characteristics such as levees or proximity to fresh and saltwater inputs influence water flow.

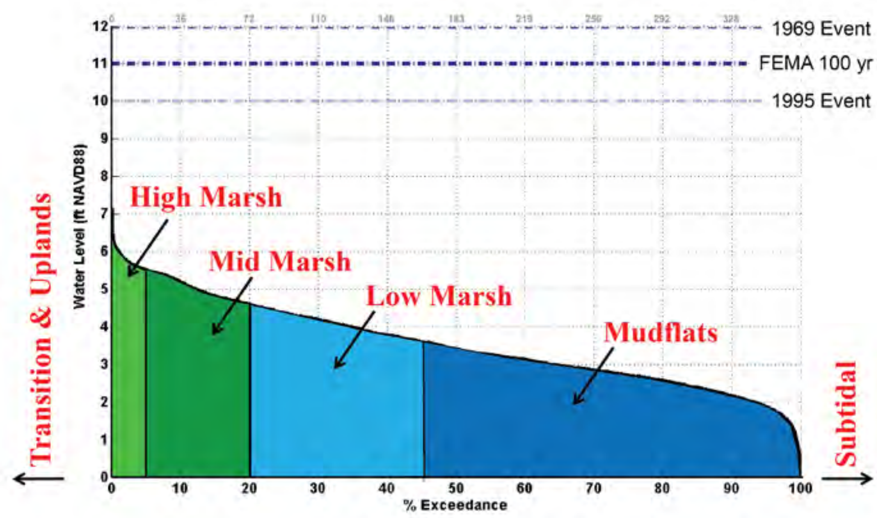


Figure 3. Example of Habitat Classification Applied to a Standard Estuarine Exceedance Curve

6) **Habitat migration with sea level rise was calculated for scenarios of both with and without sediment accretion.**
   The relationships between habitat classifications and inundation percentage were assumed to stay consistent with sea level rise. A consistent accretion rate of 5mm/yr. was assumed, and the deposition across the marsh plain was assumed to be even. This rate was determined based on professional judgment by CCWG, and relies on a report by the Pescadero Lagoon Science Panel by John Largier et. al. in 2015. It was reported that in topographic surveys between 1987 and 2011, the East Butano Marsh accreted between 0.5 ft and 1.3 ft, and the North Pond has accreted ~1ft on average, while no accretion was observed in North Marsh. Taking these accretion rates in aggregate, a rate of 5 mm was assumed.

7) **Habitat acres by sea level horizon for both with and without accretion was exported to tables.**
   This information can be found later in this report. Aggregated statistics for the entire marsh can be found in Figures 7 – 9. Figures and tables for habitat migration for individual marsh zones be found in Figures 10 – 23 and Tables 2 – 9.

Potential Model Refinements

- An interpolation method (ex. Kriging) could be used to develop a raster surface that represents the percentage of inundation associated with each habitat range at each raster cell. Some assumptions may have to be used for sections of the marsh where monitoring stations are sparse or non-existent. This raster surface would form the base layer for existing and future habitat evolution.

- Improved fieldwork and verification of plant species could significantly improve the assumptions of marsh conditions including the relationships between habitat and hypsometry. Training data could be then used as input in neural network analysis.

- Establishing sedimentation rate markers on various areas of the marsh plain will help to improve accretion rate estimates over time, improving modeling outputs.

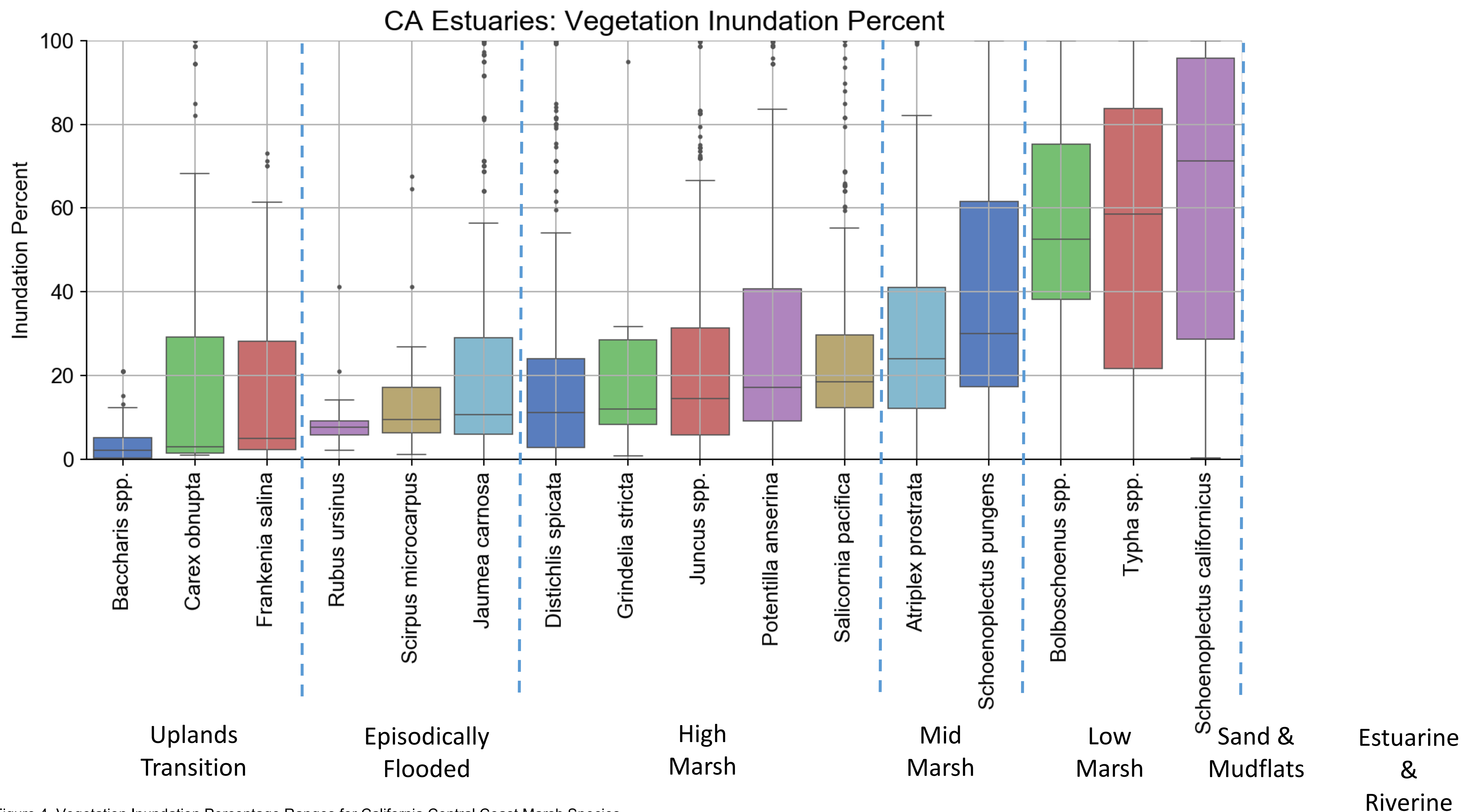
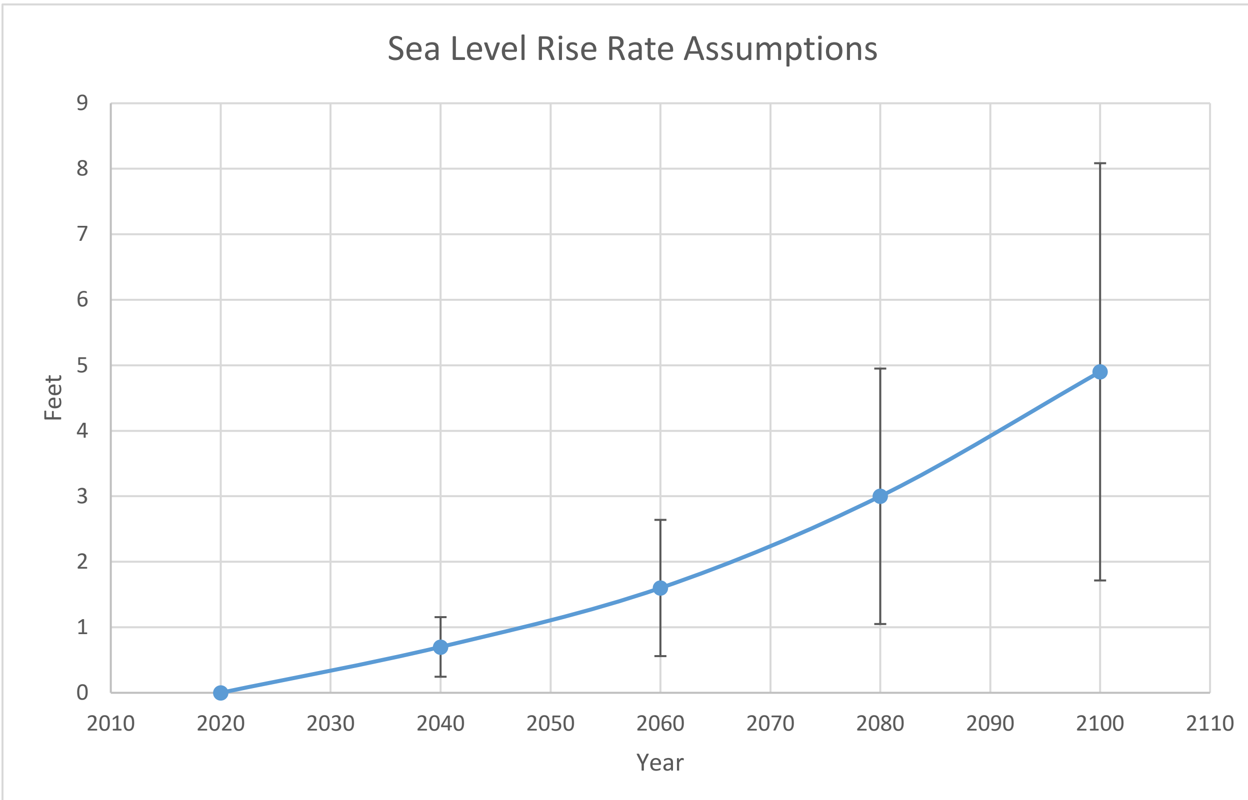


Figure 4. Vegetation Inundation Percentage Ranges for California Central Coast Marsh Species



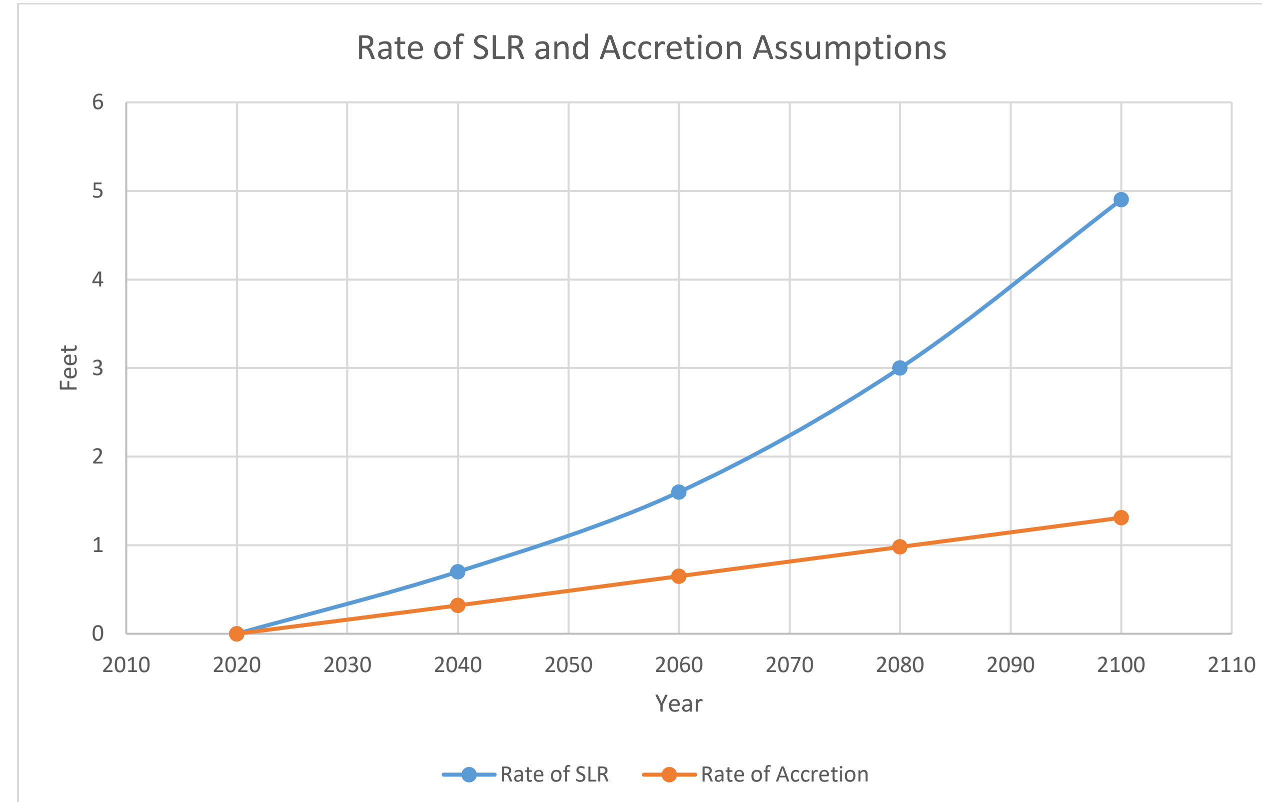


Figure 5. Sea Level Rise Assumptions

Source: OPC, 2018. Based on the sea level rise assumption used in the San Mateo County Sea Change Assessment

Whiskers are representative of the approximate extreme high and low bounds for sea level rise for the region

Figure 6. Rate of Sea Level Rise Compared to the Assumed Rate of Sediment Accretion

Accretion rate = 5mm a year

Year	SLR (ft.)	Accretion Elevation Gain (ft.)	Difference (ft.)
2020	**0**	**0**	**0**
2040	**0.8**	**0.33**	**0.47**
2060	**1.6**	**0.66**	**0.94**
2080	3	0.98	2.02
2100	4.9	1.31	3.59

Table 1. Sea Level Rise and Accretion Elevation Gains by Year Assumptions

Accretion rate = 5mm a year

Bold = Sea Level Rise Elevations used in the Study

1.1.4 Entire Pescadero Marsh Habitat Evolution with Sea Level Rise Results

Habitat Evolution Tables

Figure 7. Pescadero Marsh Habitat Evolution with Sea Level Rise (SLR in feet)

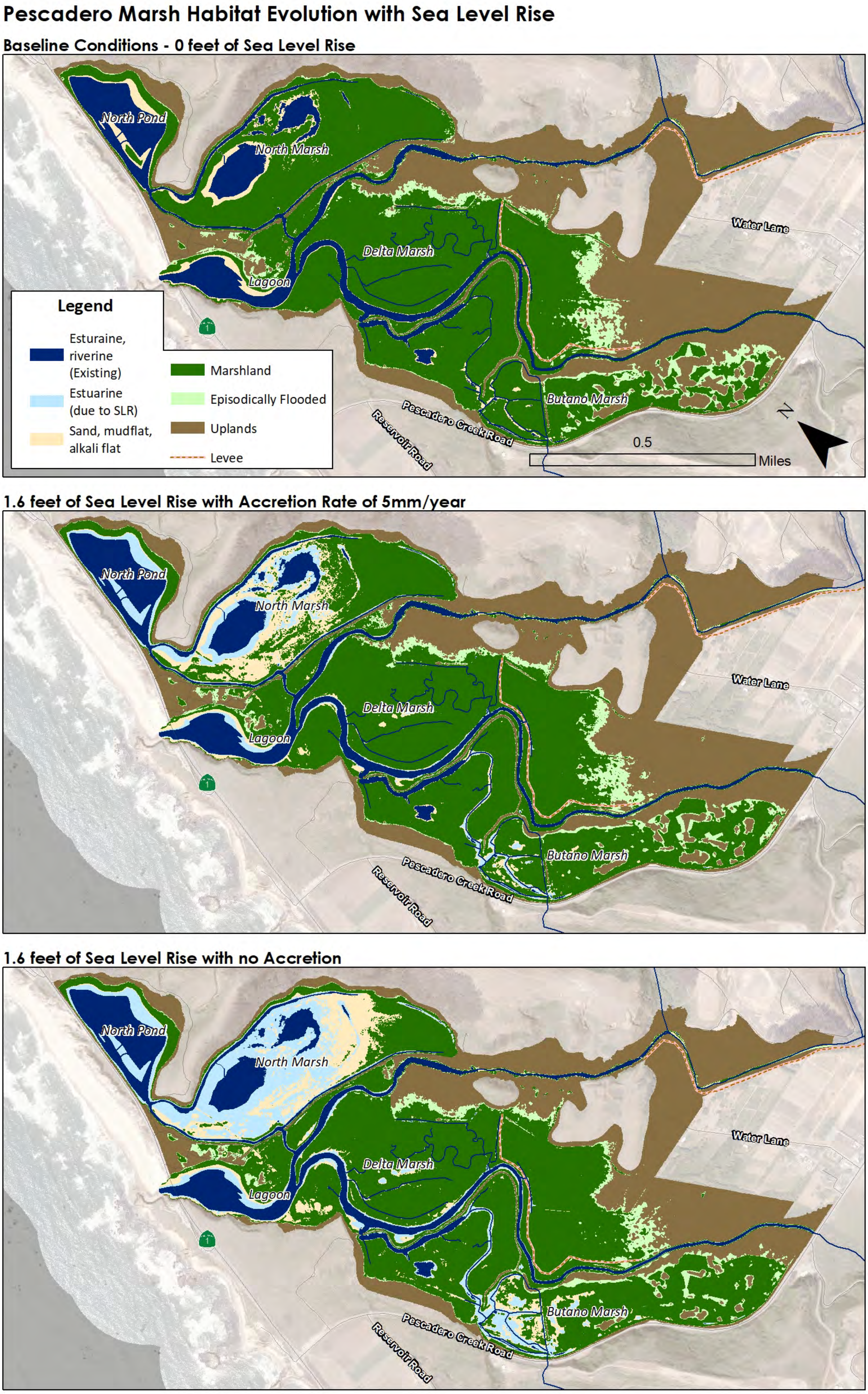


Figure 8. Pescadero Marsh Habitat Evolution with Sea Level Rise, Near Term

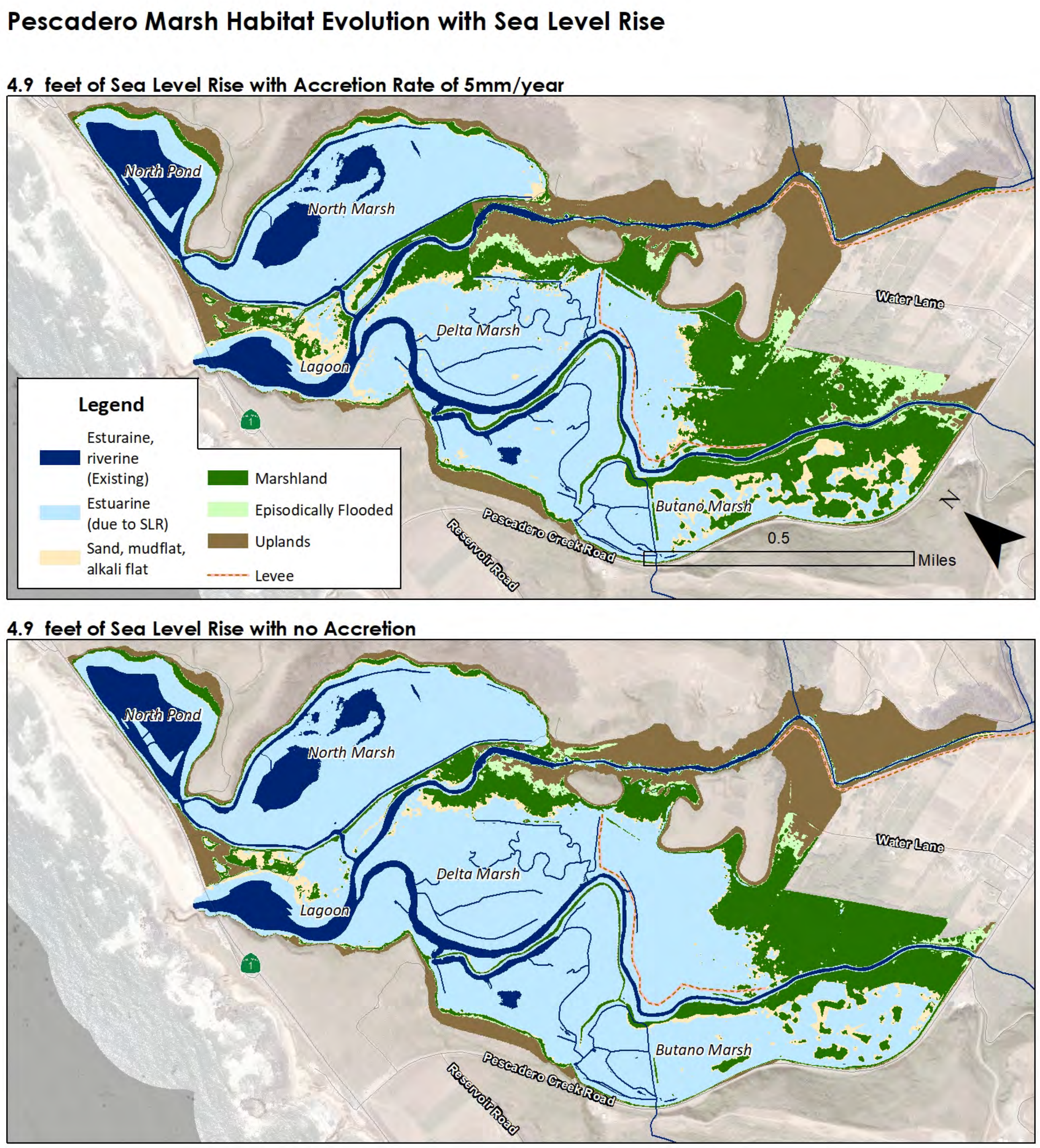


Figure 9. Pescadero Marsh Habitat Evolution with Sea Level Rise, Long Term

1.1.5 Individual Zones Habitat Evolution with Sea Level Rise Results

1.1.5.1 NPC – North Pond

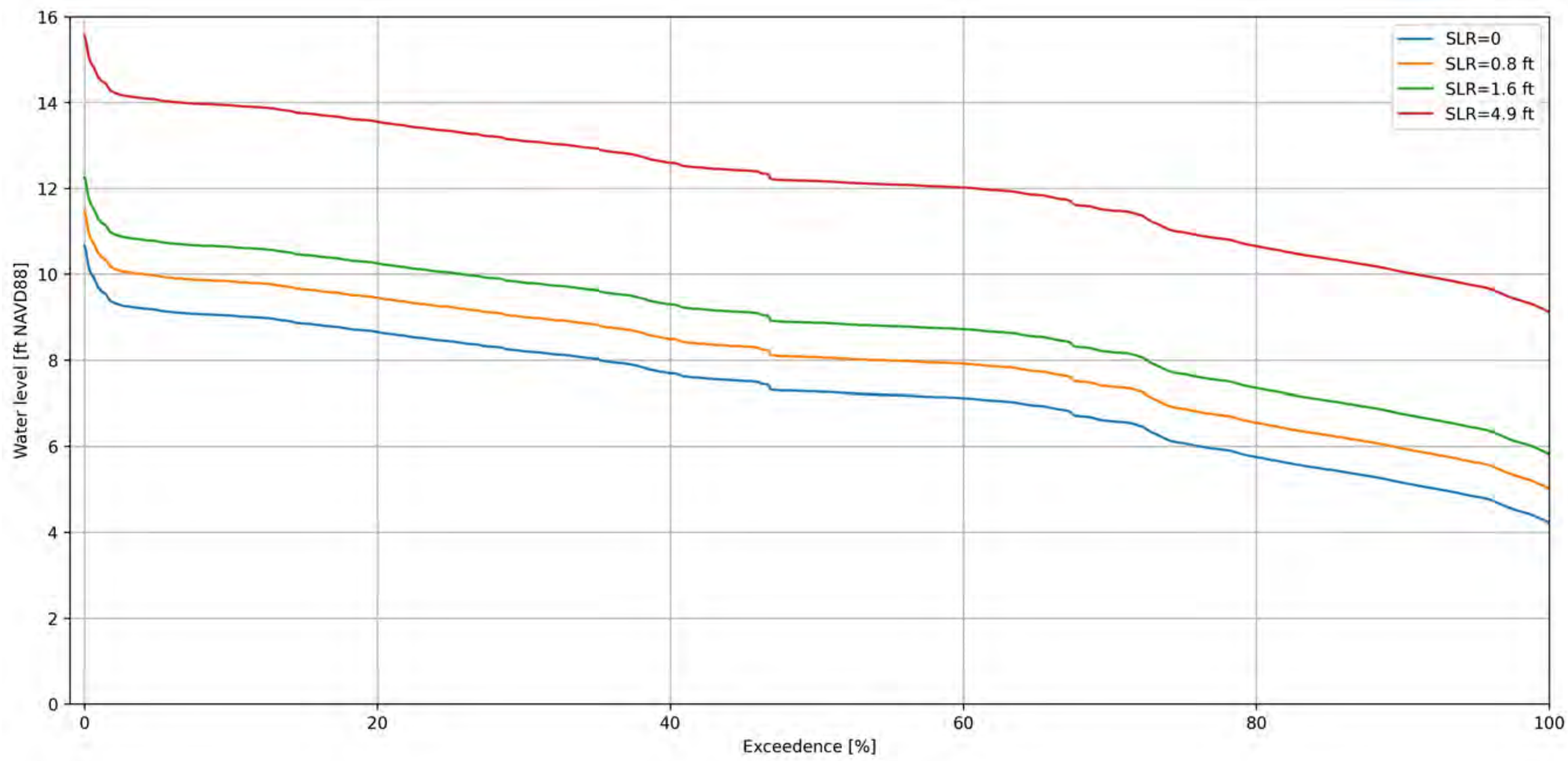


Figure 10. North Pond (NPC) Exceedance Curves. 2020-2021.

Habitat Type	**Inundation Percentage**	**Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon**			
		0	0.8’	1.6’	4.9’
Episodically flooded	2 - 7	9.34	10.14	10.94	14.24
High marsh	7 - 12	9.09	9.88	10.69	13.98
Mid marsh	12 - 24	8.99	9.78	10.59	13.89
Low marsh	24 - 86	8.47	9.26	10.07	13.37
Sand, mudflat, alkali flat	86 - 92	5.41	6.21	7.01	10.31
Estuarine, riverine	92 - 100	5.04	5.83	6.64	9.94

Table 2. North Pond (NPC) Habitat Areas by Inundation Percentage and Elevation by Sea Level Rise

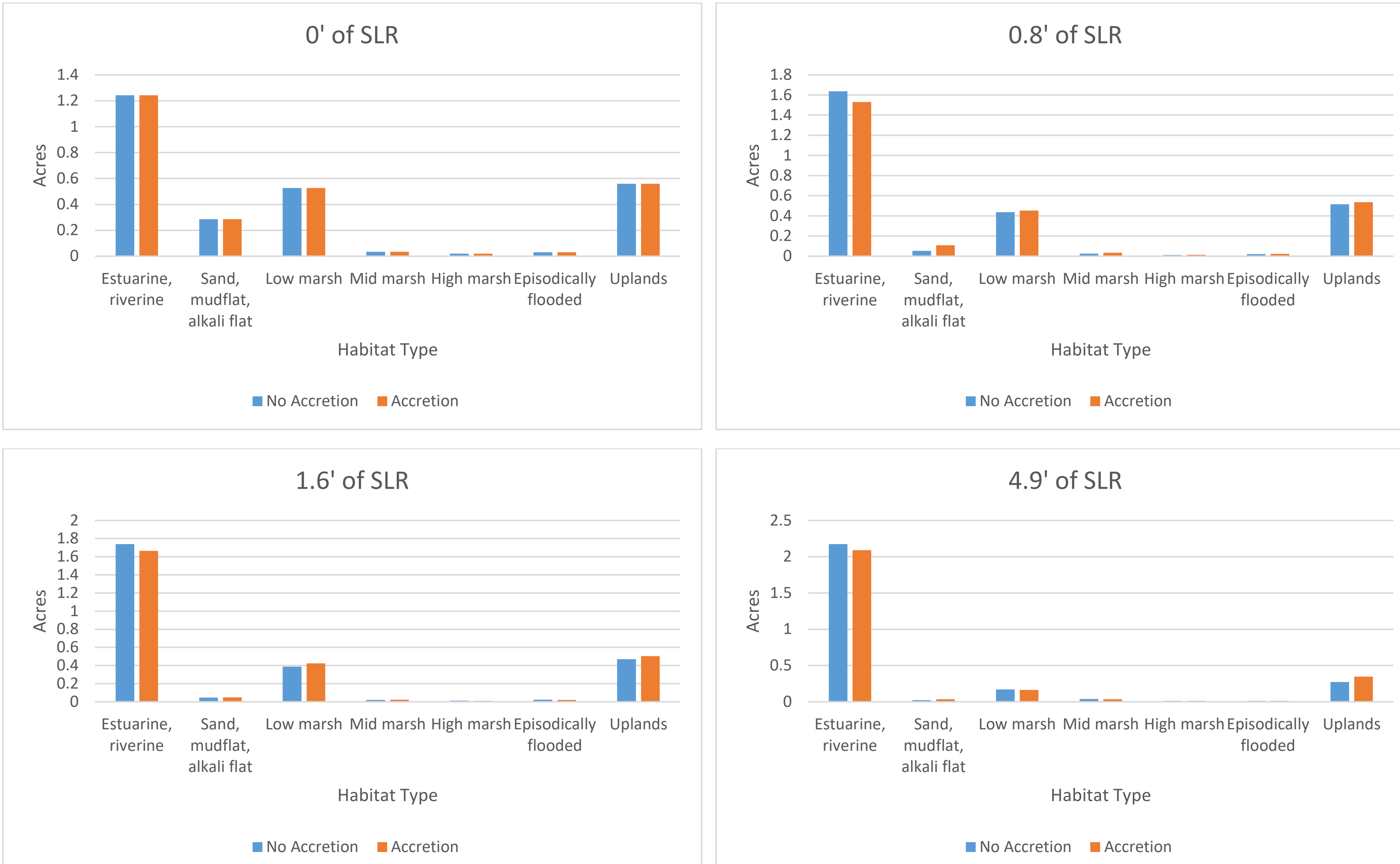


Figure 11. North Pond (NPC) Habitat Evolution with Sea Level Rise

1.1.5.2 NMP – North Marsh

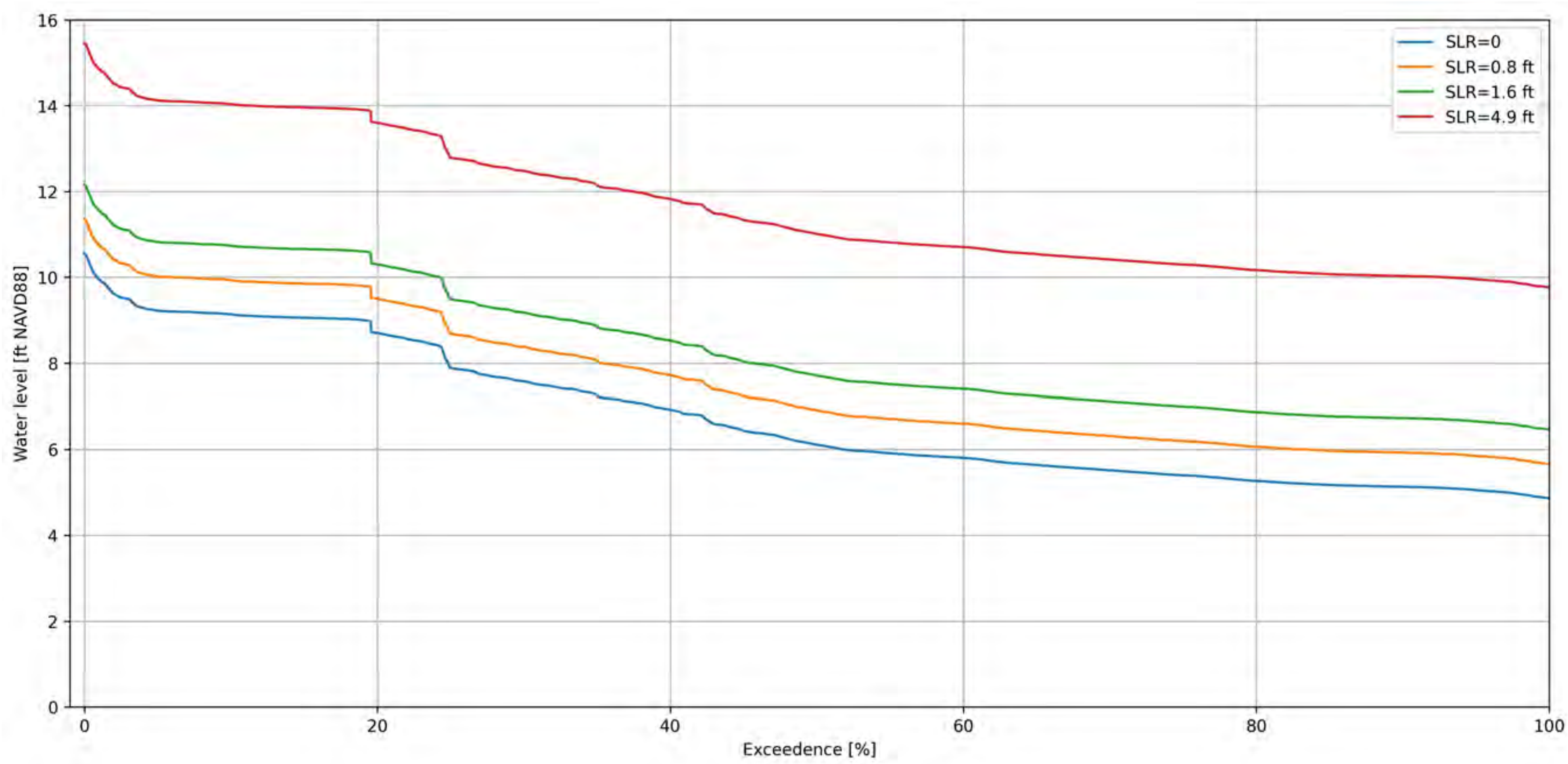


Figure 12. North Marsh (NMP) Exceedance Curves. 2020-2021.

Habitat Type	Inundation Percentage	Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon			
		0	0.8’	1.6’	4.9’
Episodically flooded	2- 7	9.62	10.41	11.22	14.51
High marsh	7- 12	9.19	9.99	10.79	14.09
Mid marsh	12 - 24	9.09	9.89	10.69	13.99
Low marsh	24 - 60	8.42	9.22	10.02	13.32
Sand, mudflat, alkali flat	60 - 86	5.80	6.60	7.40	10.70
Estuarine, riverine	86 - 100	5.16	5.96	6.76	10.06

Table 3. North Marsh (NMP) Habitat Areas by Inundation Percentage and Elevation by Sea Level Rise

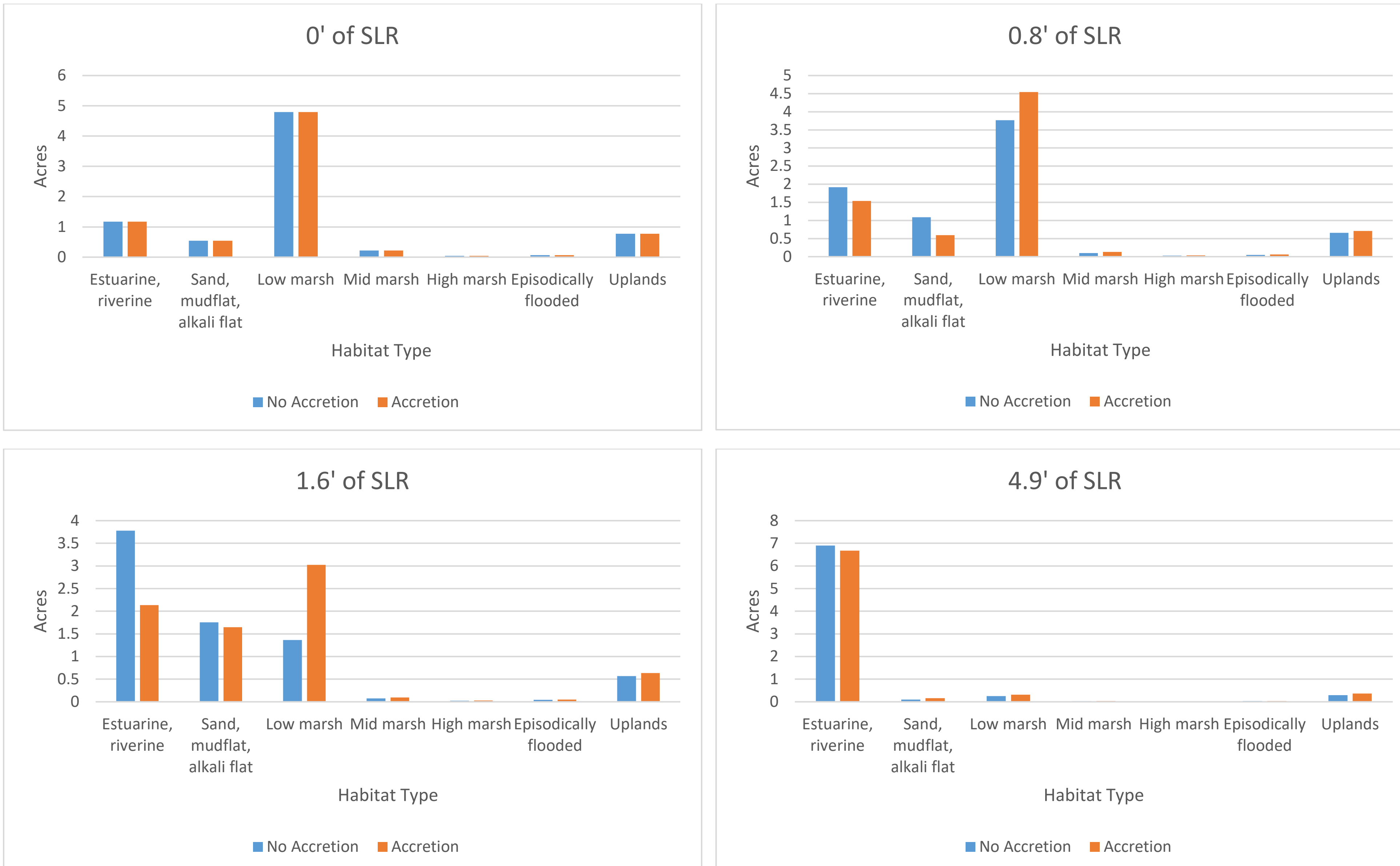


Figure 13. North Marsh (NMP) Habitat Evolution with Sea Level Rise

1.1.5.3 BC1 – Delta Marsh

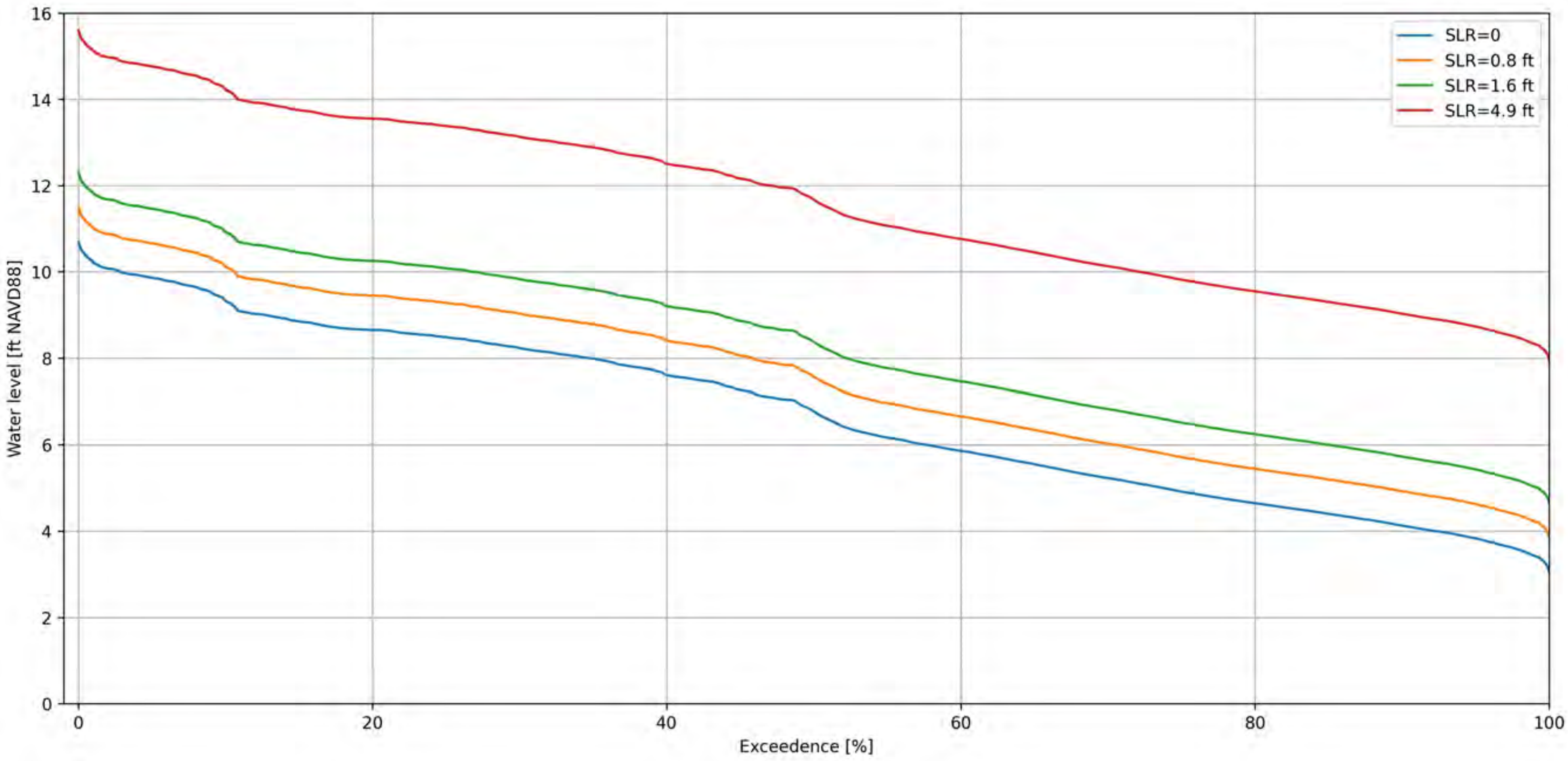


Figure 14. Delta Marsh (BC1) Exceedance Curves. 2016-2017.

Habitat Type	Inundation Percentage	Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon			
		0	0.8’	1.6’	4.9’
Episodically flooded	5 - 10	9.86	10.47	11.27	14.57
High marsh	10 - 20	9.33	9.95	10.75	14.05
Mid marsh	20 - 45	8.65	9.27	10.07	13.37
Low marsh	45 - 75	7.26	7.88	8.68	11.98
Sand, mudflat, alkali flat	75 - 86	4.92	5.54	6.34	9.64
Estuarine, riverine	86 - 100	4.36	4.97	5.77	9.07

Table 4. Delta Marsh (BC1) Habitat Areas by Inundation Percentage and Elevation by Sea Level Rise

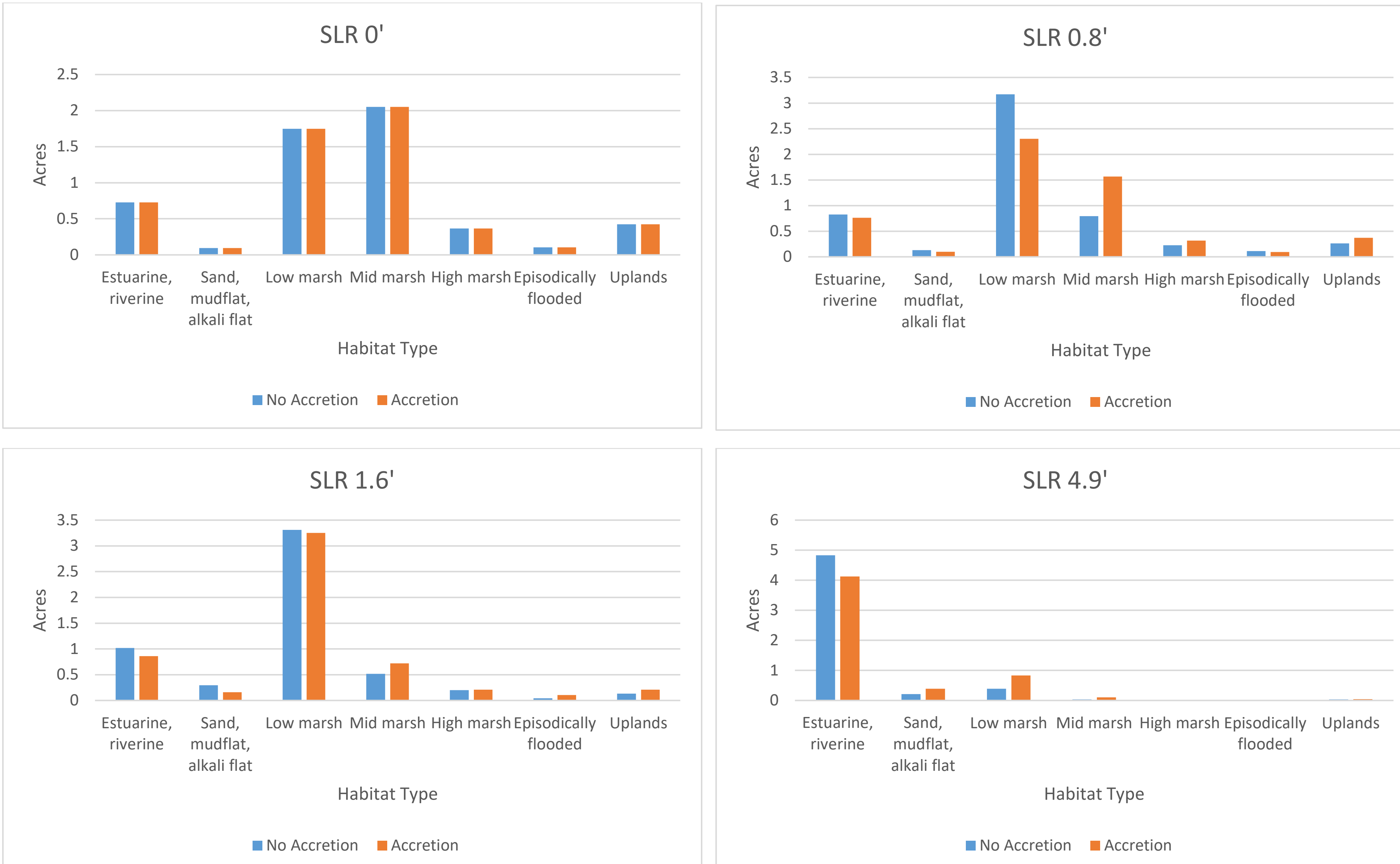


Figure 15. Delta Marsh (BC1) Habitat Evolution with Sea Level Rise

1.1.5.4 NCK – Pescadero Lagoon

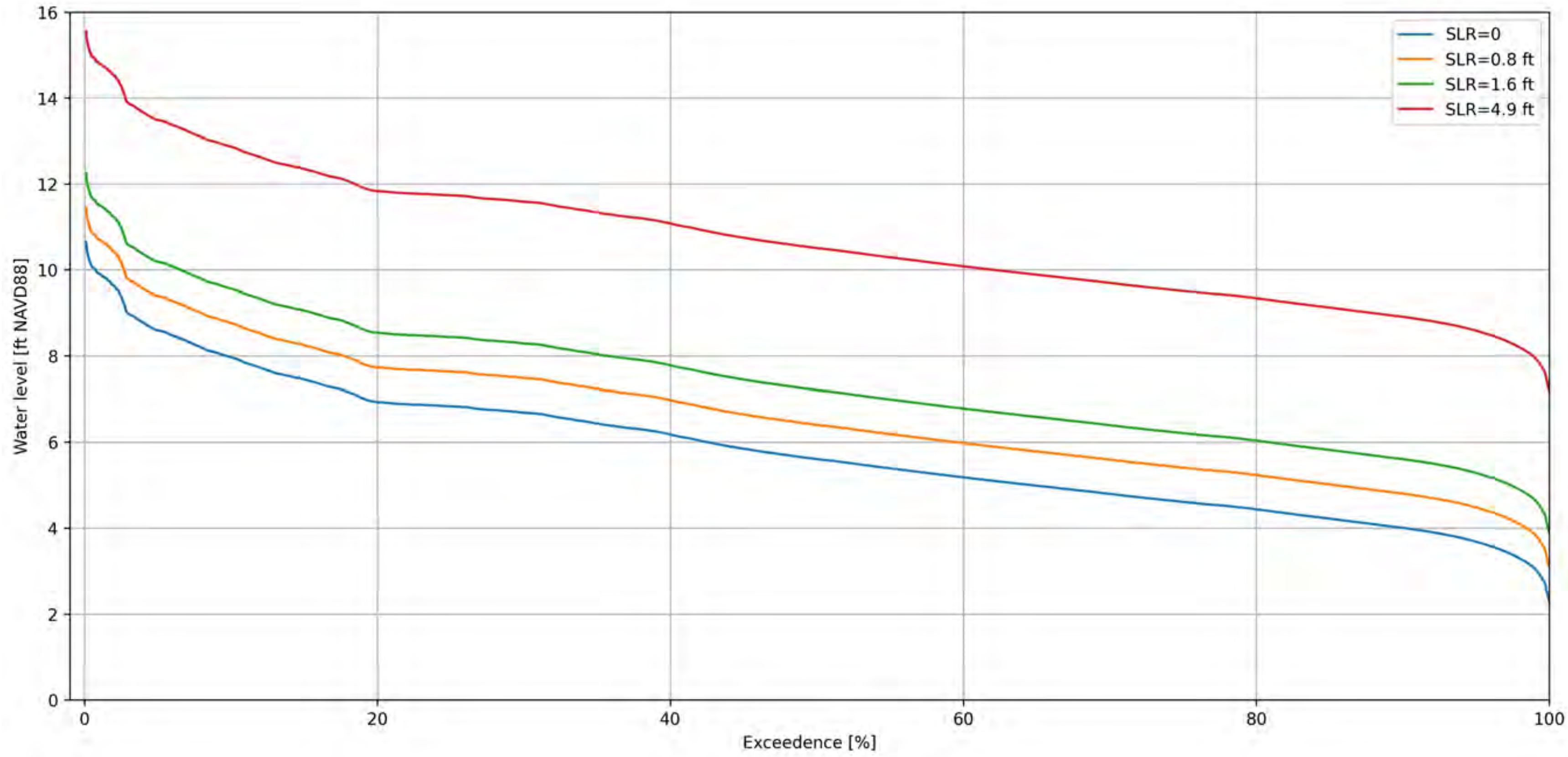


Figure 16. Pescadero Lagoon (NCK) Exceedance Curve. 2016-2017.

Habitat Type	Inundation Percentage	Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon			
		0	0.8’	1.6’	4.9’
Episodically flooded	2 - 5	9.60	10.40	11.20	14.50
High marsh (sand dune)	5 - 10	8.58	9.38	10.18	13.48
Mid marsh (sand dune)	10 - 20	7.95	8.75	9.55	12.85
Low marsh (sand dune)	20 - 45	6.93	7.73	8.53	11.83
Sand, mudflat, alkali flat (sand)	45 - 86	5.84	6.64	7.44	10.74
Estuarine, riverine	86 - 100	4.17	4.97	5.77	9.07

Table 5. Pescadero Lagoon (NCK) Habitat Areas by Inundation Percentage and Elevation by Sea Level Rise

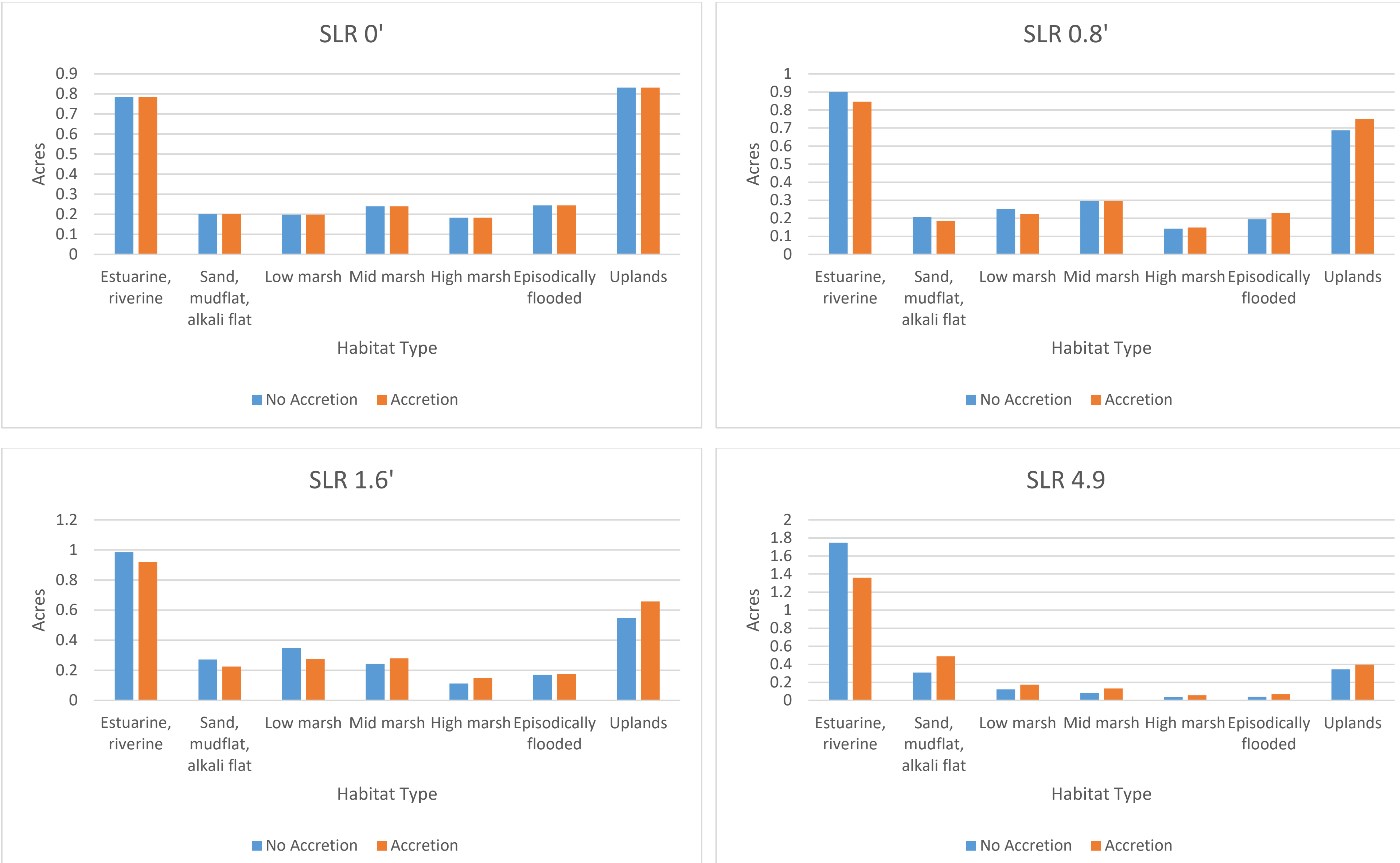


Figure 17. Pescadero Lagoon (NCK) Habitat Evolution with Sea Level Rise

1.1.5.5 BBC – North Butano Marsh

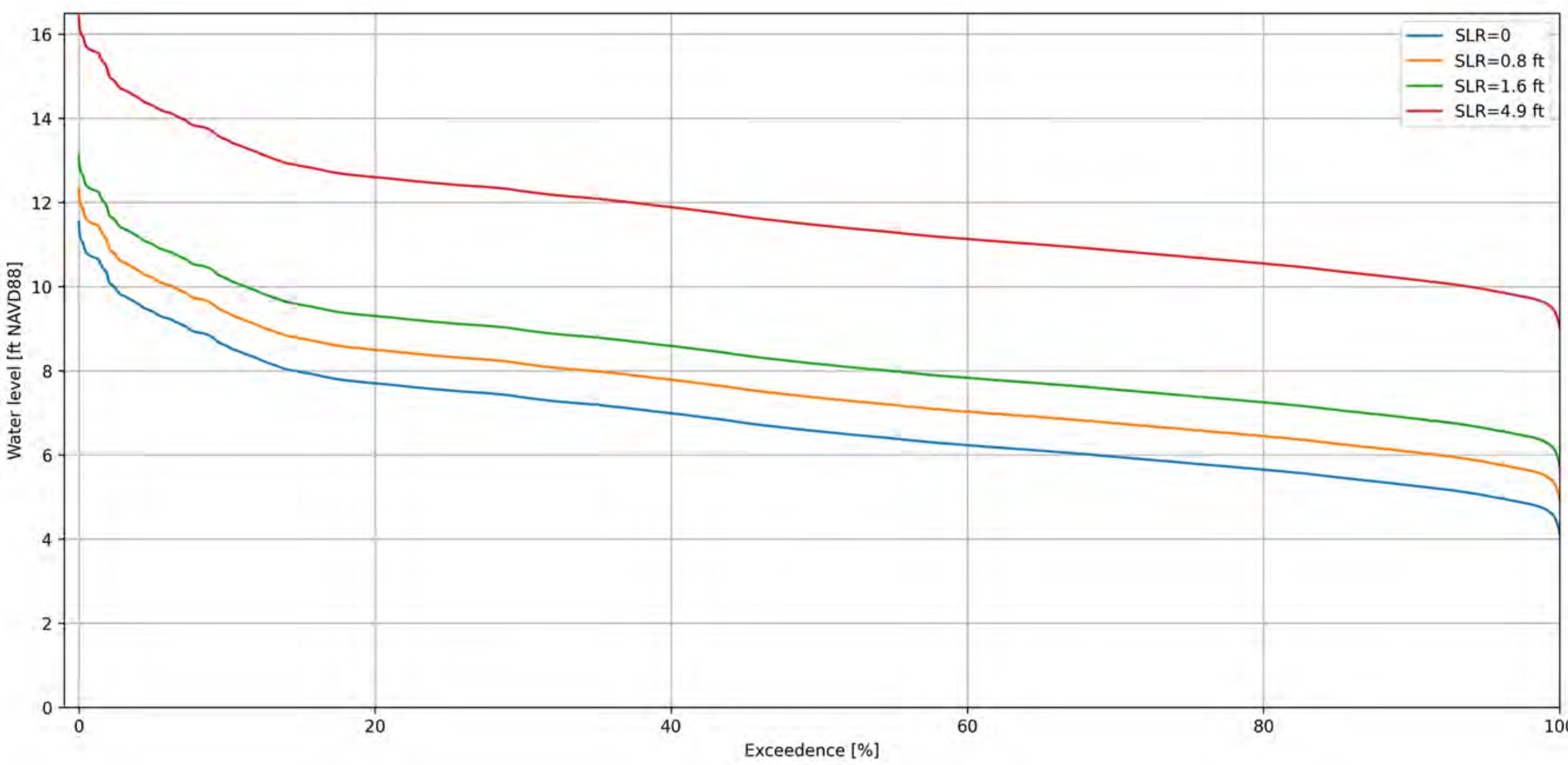


Figure 18. North Butano Marsh (BBC) Exceedance Curve. 2016-2017.

Habitat Type	Inundation Percentage	Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon			
		0	0.8’	1.6’	4.9’
Episodically flooded	5 - 10	9.41	9.41	9.74	13.04
High marsh	10 - 20	8.59	8.59	8.93	12.23
Mid marsh	20 - 45	7.70	7.70	8.04	11.34
Low marsh	45 - 75	6.76	6.76	7.10	10.40
Sand, mudflat, alkali flat	75 - 86	5.81	5.81	6.14	9.44
Estuarine, riverine	86 - 100	5.43	5.43	5.77	9.07

Table 6. North Butano Marsh (BBC) Habitat Areas by Inundation Percentage and Elevation by Sea Level Rise

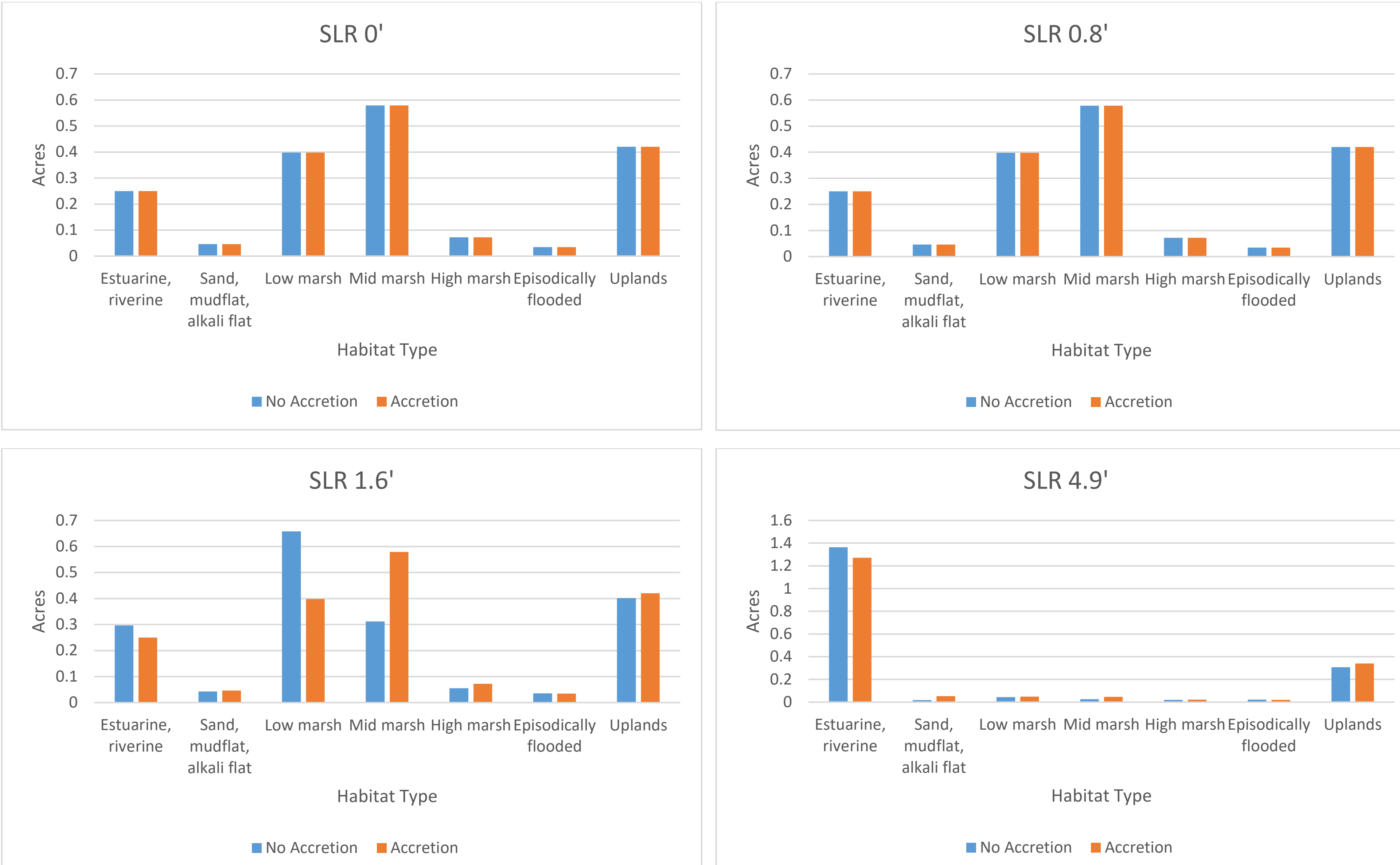


Figure 19. North Butano Marsh (BBC) Habitat Evolution with Sea Level Rise

1.1.5.6 CH2 – Middle and East Butano Marsh

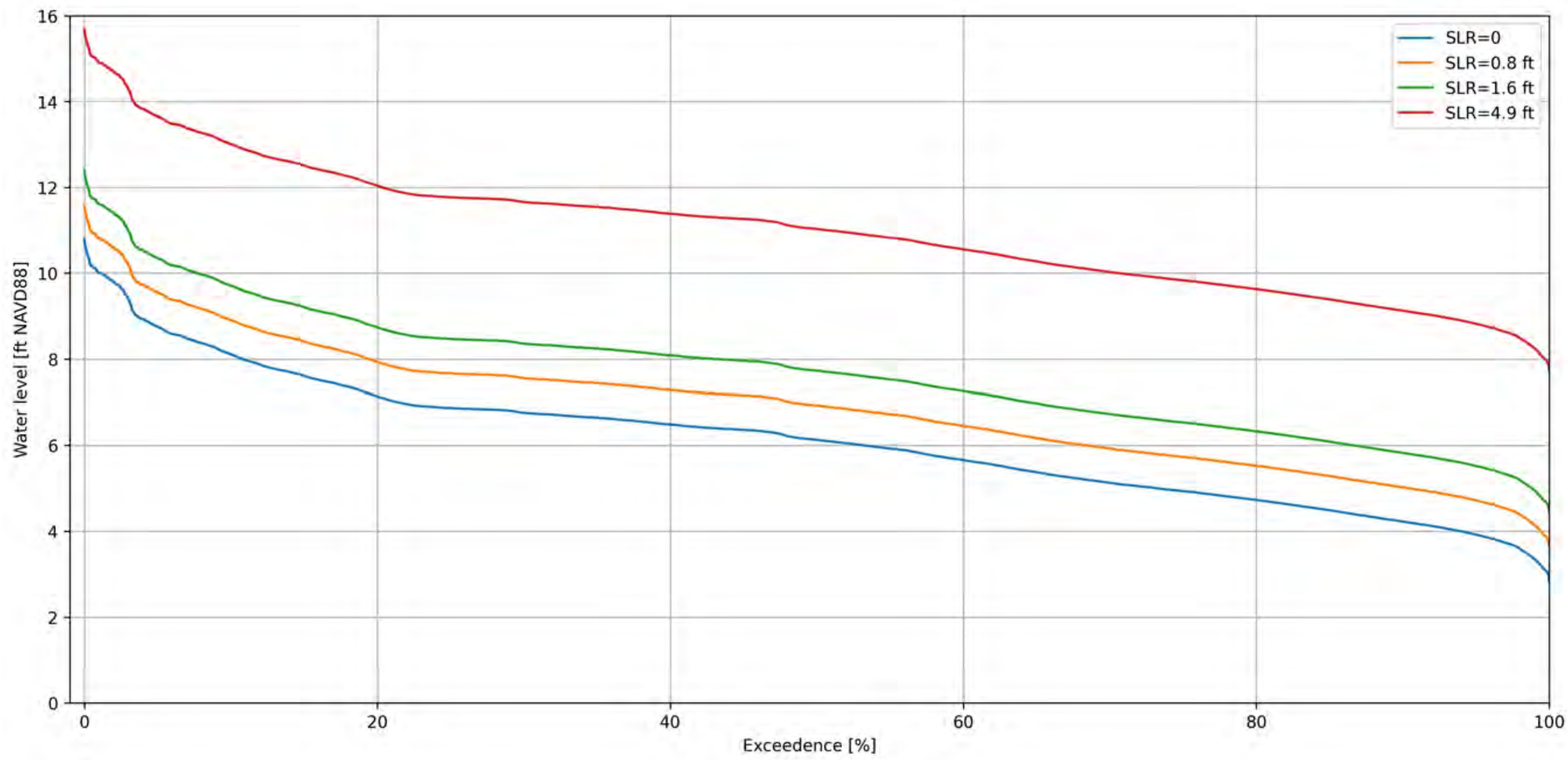


Figure 20. Middle and East Butano Marsh (CH2) Exceedance Curve. 2016-2017.

Habitat Type	**Inundation Percentage**	**Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon**			
		0	0.8’	1.6’	4.9’
Episodically flooded	5 - 10	8.75	9.28	10.08	13.38
High marsh	10 - 20	8.11	8.64	9.44	12.74
Mid marsh	20 - 45	7.14	7.67	8.47	11.77
Low marsh	45 - 75	6.36	6.90	7.70	11.00
Sand, mudflat, alkali flat	75 - 86	4.93	5.47	6.27	9.57
Estuarine, riverine	86 - 100	4.44	4.97	5.77	9.07

Table 7. Middle and East Butano Marsh (CH2) Habitat Areas by Inundation Percentage and Elevation by Sea Level Rise

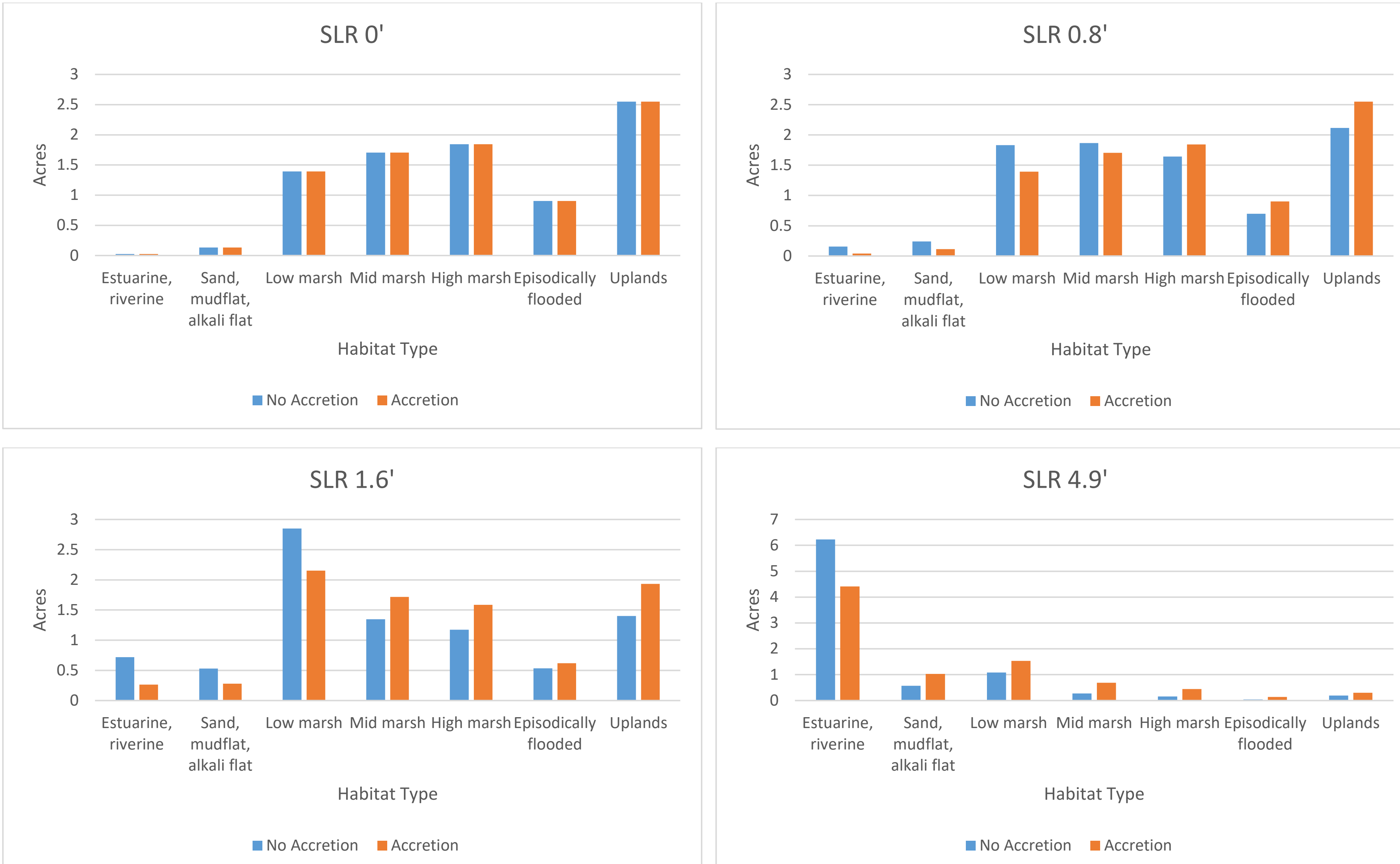


Figure 21. Middle and East Butano Marsh (CH2) Habitat Evolution with Sea Level Rise

1.1.5.7 BC3 – East Delta Marsh

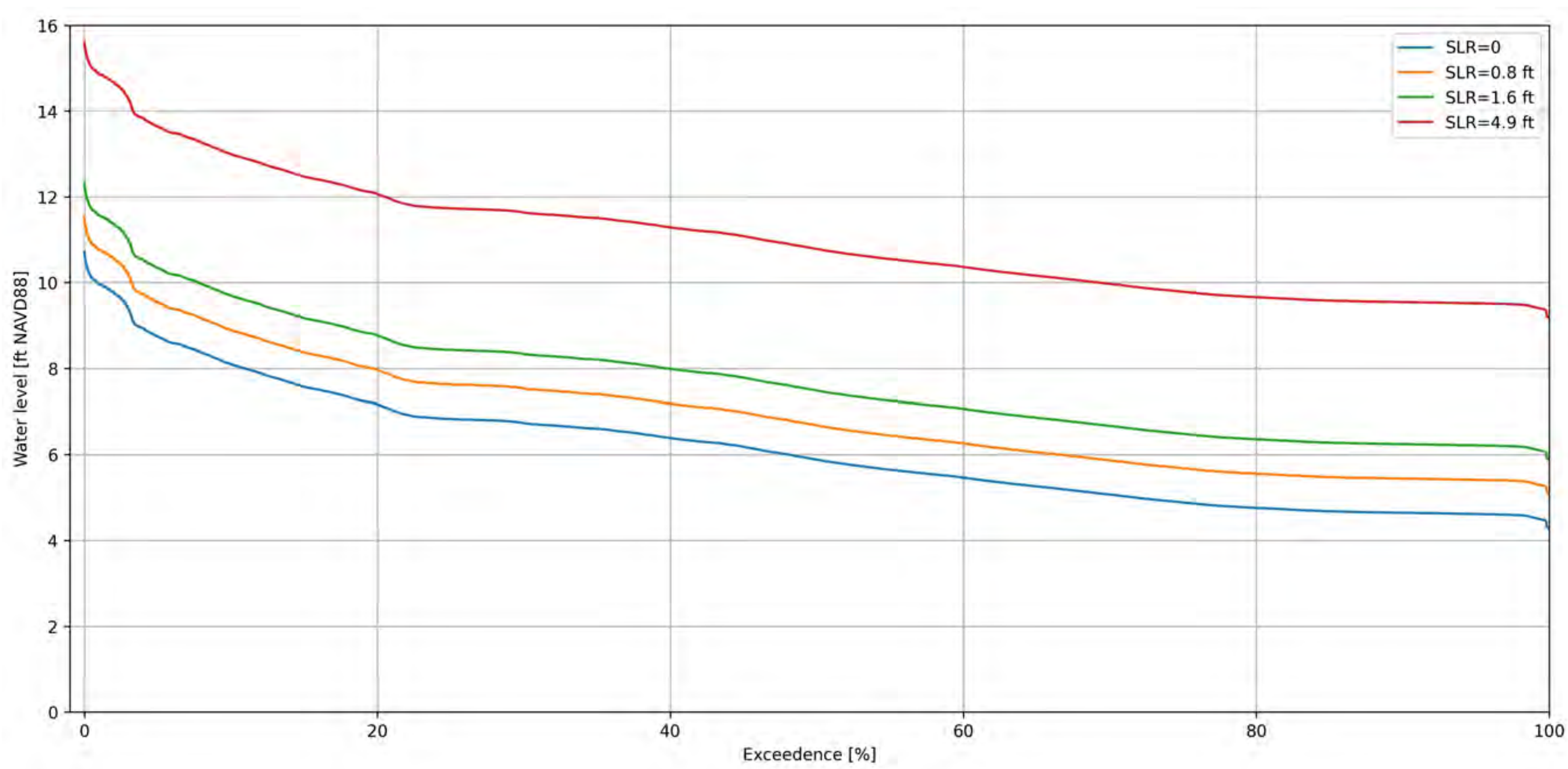


Figure 22. East Delta Marsh (BC3) Exceedance Curve. 2016-2017.

Habitat Type	Inundation Percentage	Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon			
		0	0.8′	1.6′	4.9′
Episodically flooded	5 - 10	8.74	9.04	9.84	13.14
High marsh	10 - 20	8.10	8.40	9.20	12.50
Mid marsh	20 - 45	7.17	7.47	8.27	11.57
Low marsh	45 - 75	6.18	6.48	7.28	10.58
Sand, mudflat, alkali flat	75 - 86	4.89	5.19	5.99	9.29
Estuarine, riverine	86 - 100	4.67	4.97	5.77	9.07

Table 8. East Delta Marsh (BC3) Habitat Areas by Inundation Percentage and Elevation by Sea Level Rise

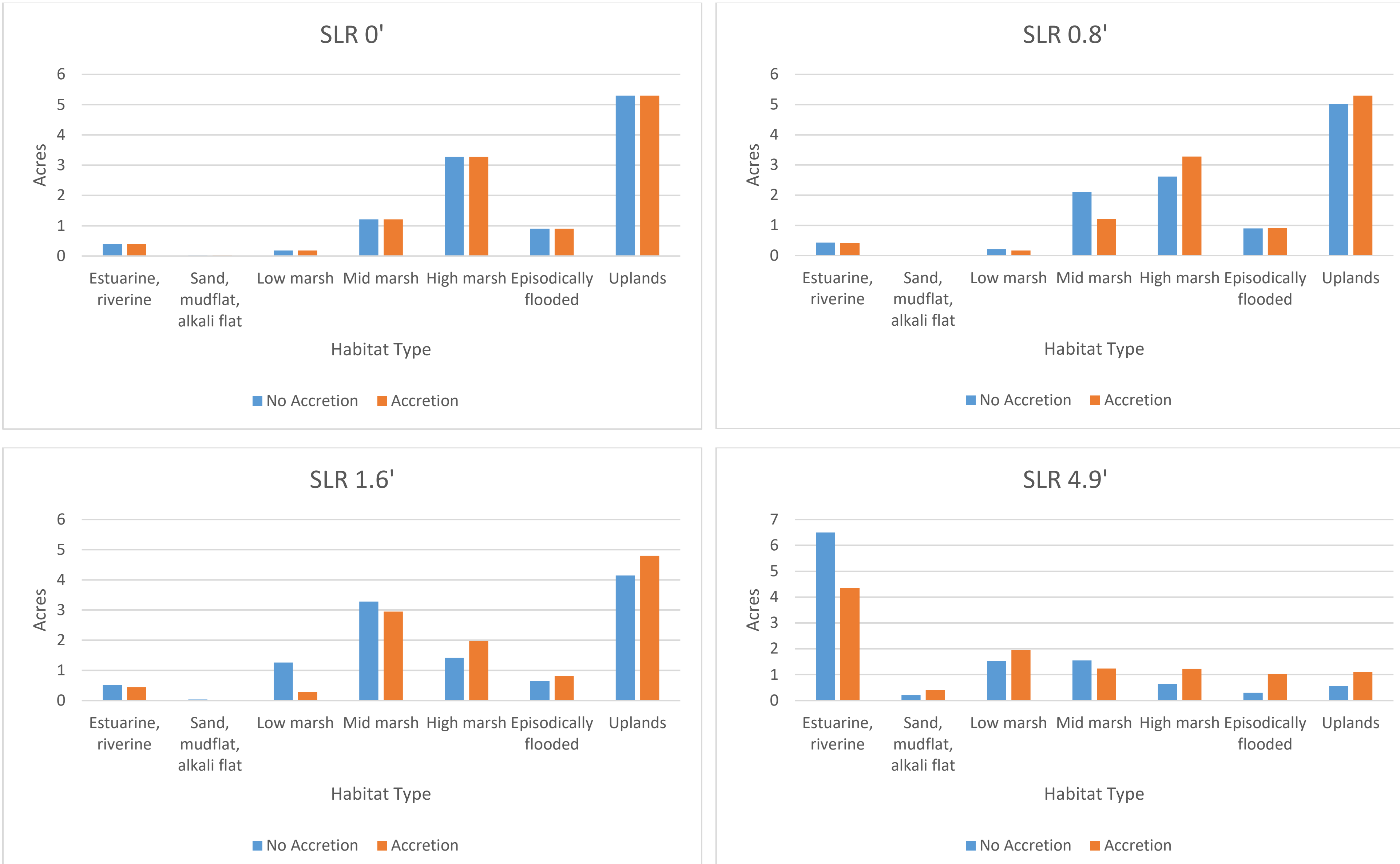


Figure 23. East Delta Marsh (BC3) Habitat Evolution with Sea Level Rise

1.1.5.8 PC3 – Pescadero Creek Riparian

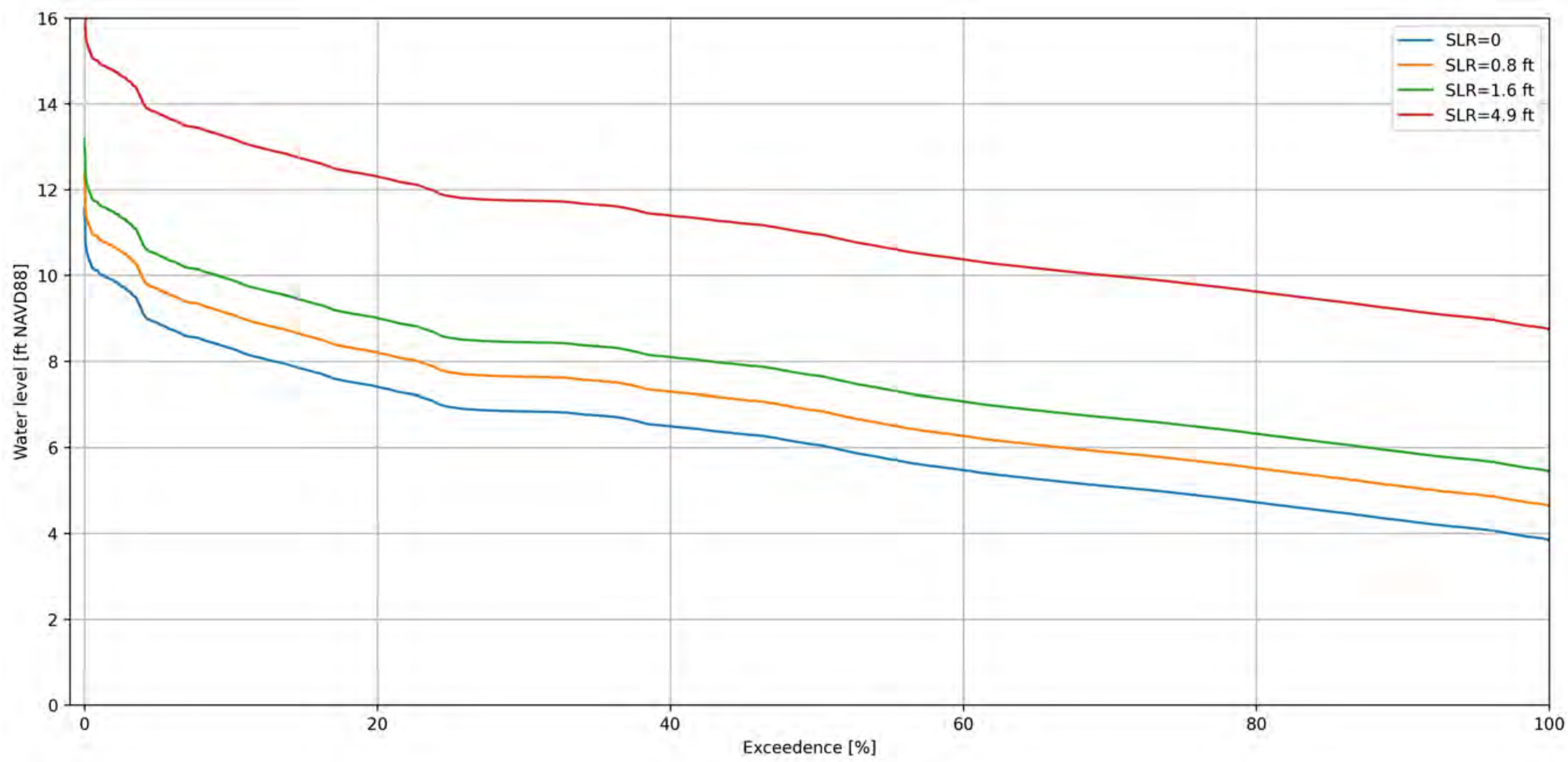


Figure 24. Pescadero Creek Riparian Area (PC3) Exceedance Curve. 2016-2017.

Habitat Type	**Inundation Percentage**	**Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon**			
		0	0.8′	1.6′	4.9′
Episodically flooded	3 - 5	9.63	9.63	9.63	11.65
High marsh	5 - 7	8.89	8.89	8.89	10.90
Mid marsh	7 - 10	8.58	8.58	8.58	10.60
Low marsh	10 - 20	8.30	8.30	8.30	10.32
Sand, mudflat, alkali flat	20 - 24	7.41	7.41	7.41	9.42
Estuarine, riverine	24 – 100*	7.05	7.05	7.05	9.07

Table 9. Pescadero Creek Riparian Area (PC3) Habitat Areas by Inundation Percentage and Elevation by Sea Level Rise

**Due to the large change in grade and the relatively low placement of the station in this zone, a much larger inundation percentage was used to capture the riverine habitat throughout this zone. Due to the relatively steep riverbanks in this section, this change still produced a riverine habitat zone that approximated actual conditions within a relatively close spatial range.*

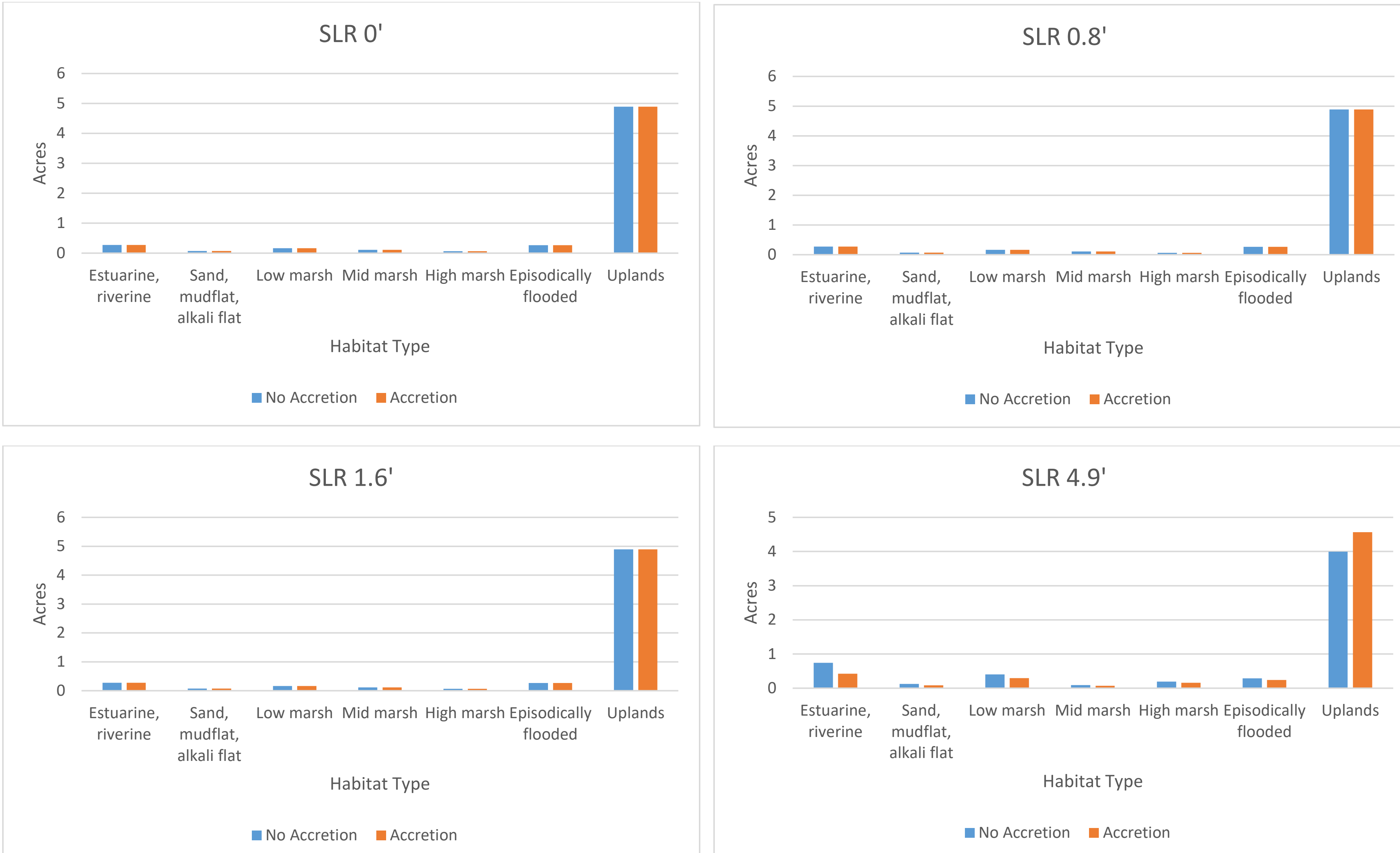


Figure 25. Pescadero Creek Riparian Area (PC3) Habitat Evolution with Sea Level Rise

1.1.6 Conclusions

As the Pescadero Marsh is largely dependent on varying water levels that change across the different parts of the marsh both seasonally and intra-annually, it is anticipated that the increase in sea level rise and depths and duration of water levels will be a large driver of ecological changes to the system. The topography of the area is characterized by a relatively flat marsh plain surrounded by steep slopes. This topography confines the suitable areas that marsh habitat can expand or migrate to in the future, both landward and upslope. Assuming an accelerated pace of sea level rise into the future, the zones of suitability for marsh habitat will increasingly become confined, with a substantial shift of marsh habitats toward subtidal habitats accelerating significantly after 1.6 feet of sea level rise. In the near term, rising sea levels may mean areas suitable for low and mid marsh habitat could expand, and areas of high marsh and edge-marsh uplands may become more confined. Over the long term, however, areas suitable for marsh expansion will decrease and the habitat zones between subtidal / estuary areas and uplands will narrow.

The assumption of a sediment accretion rate of 5/mm a year does provide some resilience to the system and provides an offset to marshland habitat loss in the near term (up until 1.6' of SLR), however, in the long term as the rate of sea level rise accelerates at a faster pace than the rate of accretion, this accretion benefit is reduced. It is important to note that sediment generally is deposited in large episodic events, particularly during those that occur in the early fall period. There is also likely to be variable accretion (in both space and time) across the marsh plain due to proximity to sediment sources and the occurrence of fluvial flood events. This variability, as well as potential changes due to sea level rise and climate change, have not been considered in this study. Future work should consider potentially establishing sediment elevation tables or markers which will allow us to determine the relative rates of accretion across the marsh.

Potential Strategies

Sediment is nature's adaptation resource and the supply and transport of sediment throughout the marsh has been disrupted due to human activities such as forestry in the watershed, and levee and road construction.

Some examples that could also affect the future health of the Pescadero Marsh include altering the marsh levees to allow for more sediment deposition in the marsh plains as well as to reduce flow velocities during flood events. In addition, reducing the tidal connectivity between some of the marshes and lagoon could reduce ebb-tidal scour within the tidal channels and promote sediment retention in the system.

Highway 1 has fixed the position of the sand spit near the North Pond and is limiting sediment exchange between the marsh and open coast. Currently, wind-blown sand that lands on Highway 1 is cleaned and transported downcoast to Pescadero State Beach across from Pescadero Road. This wind-blown sand would naturally be deposited in the North Pond likely slowly filling it and reducing the natural tidal prism in the lagoon and reducing ebb-tidal scour. Strategic placement of sand from highway cleaning may be beneficial to the system over time.

14 APPENDIX F. VULNERABILITY ASSESSMENT TABLE OF RESULTS

SECTOR																				
METRIC																	Parcels			
TYPE	Agriculture																			
SUB-TYPE	Agriculture			Agriculture Improved			Cal Fire / County Fire Department			Commercial			Community			County			Golf	
UNITS	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)
Total in Zone																				
Cumulative																				
Erosion - Cliff																				
0	38	9	9	34	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	160	20	11	109	13	8	0	0	0	0	0	0	0	0	0	0	0	0	8	2
50	211	31	11	128	21	8	0	0	0	0	0	0	0	0	0	0	0	0	11	4
150	324	49	18	179	34	13	0	0	0	0	0	0	0	0	0	0	0	0	18	6
Erosion - Dune																				
0	27	3	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	33	6	3	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	38	9	3	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150	66	14	5	2	4	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Fluvial Backwater																				
0	31	6	6	100	11	11	1	1	1	1	4	4	0	2	2	0	1	1	0	0
25	34	10	6	116	22	13	1	2	1	1	7	4	0	4	2	0	2	1	0	0
50	36	14	6	131	33	13	1	3	1	2	10	4	0	6	2	0	3	1	0	0
150	39	20	8	190	47	16	1	4	1	3	14	5	0	9	3	4	4	1	0	0
Tidal																				
0	64	9	9	15	2	2	0	0	0	0	0	0	0	0	0	0	0	0	1	1
25	69	18	9	16	4	2	0	0	0	0	0	0	0	0	0	0	0	0	1	2
50	74	27	9	16	7	3	0	0	0	0	0	0	0	0	0	0	0	0	1	3
150	91	36	9	22	16	9	0	0	0	0	1	1	0	0	0	0	0	0	1	5
Wave																				
0	155	10	10	47	9	9	0	0	0	0	0	0	0	0	0	0	0	0	4	2
25	164	21	11	49	18	9	0	0	0	0	0	0	0	0	0	0	0	0	4	4
50	172	32	11	51	27	9	0	0	0	0	0	0	0	0	0	0	0	0	4	6
150	205	43	11	56	36	9	0	0	0	0	0	0	0	0	0	0	0	0	4	8
Combined																				
0	197	16	16	150	20	20	1	1	1	1	4	4	0	2	2	0	1	1	4	2
25	266	32	18	233	40	22	1	2	1	1	7	4	0	4	2	0	2	1	8	4
50	319	48	18	266	60	22	1	3	1	2	10	4	0	6	2	0	3	1	11	6
150	461	73	27	376	87	29	1	4	1	3	14	5	0	9	3	4	4	1	18	8
Non-Cumulative																				
Erosion - Cliff																				
0	38.50	9	9	34.47	5	5														
25	121.20	11	2	74.65	8	3													7.83	2
50	51.10	11		19.02	8														3.21	2
150	112.83	18	7	51.31	13	5													6.73	2
Erosion - Dune																				
0	27.34	3	3	0.59	1	1														
25	5.29	3		0.17	1															
50	5.38	3		0.65	1															
150	28.18	5	2	0.98	1					0.62	1	1								
Fluvial Backwater																				
0	30.94	6	6	99.62	11	11	0.59	1	1	0.80	4	4	0.07	2	2	0.26	1	1		
25	2.75	4		16.86	11	2	0.27	1		0.05	3		0.01	2		0.03	1			
50	2.68	4		14.27	11		0.07	1		0.66	3		0.01	2		0.11	1			
150	2.95	6	2	59.40	14	3	0.05	1		1.46	4	1	0.02	3	1	3.15	1			
Tidal																				
0	63.97	9	9	14.77	2	2													0.52	1
25	5.38	9		0.78	2														0.06	1
50	4.97	9		0.78	3	1													0.08	1
150	16.46	9		5.19	9	6				0.05	1	1							0.78	2
Wave																				
0	154.62	10	10	47.13	9	9													4.10	2
25	9.43	11	1	2.04	9														0.04	2
50	7.51	11		1.65	9														0.04	2
150	33.00	11		5.17	9														0.19	2
Combined																				
0	197.08	16	16	149.89	20	20	0.59	1	1	0.80	4	4	0.07	2	2	0.26	1	1	4.10	2
25	69.19	16	2	83.35	20	2	0.27	1		0.05	3		0.01	2		0.03	1		4.13	2
50	52.57	16		33.22	20		0.07	1		0.66	3		0.01	2		0.11	1		3.12	2
150	142.42	25	9	109.82	27	7	0.05	1		1.52	4	1	0.02	3	1	3.15	1		6.61	2

Visitor Services				Open Space and Recreation			Residential			**Total**			Cal Fire / County Fire Department		Commercial				Farmstead
	Hotel														Commercial (primary)		Commercial (storage)		
count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	sq ft	count (unique)	sq ft	count (unique)	sq ft	count (unique)	sq ft
0	0	0	0	70	42	42	8	21	21	151	77	77	0.00	0	0.00	0	0.00	0	0.00
2	0	1	1	203	92	50	37	48	27	516	176	99	0.00	0	0.00	0	0.00	0	0.00
2	0	2	1	249	145	56	49	74	27	648	277	105	0.00	0	0.00	0	0.00	0	0.00
2	1	3	1	334	198	59	75	106	33	931	396	126	0.00	0	0.00	0	0.00	0	900.00
0	0	0	0	133	16	16	3	2	2	165	22	22	0.00	0	0.00	0	0.00	0	0.00
0	0	0	0	145	30	17	3	4	2	181	42	23	0.00	0	0.00	0	0.00	0	0.00
0	0	0	0	155	45	19	3	7	3	198	64	26	0.00	0	0.00	0	0.00	0	0.00
0	0	0	0	197	61	21	9	13	6	275	93	34	0.00	0	6817.99	2	0.00	0	0.00
0	0	1	1	471	29	29	16	28	28	619	83	83	2903.50	1	2971.51	2	0.00	0	12815.23
0	0	2	1	476	54	30	21	52	30	649	155	88	6645.50	2	2971.51	2	0.00	0	12815.23
0	0	3	1	481	79	30	23	75	30	674	226	88	6645.50	2	5296.51	3	697.50	1	12815.23
0	0	4	1	503	110	36	32	101	35	772	313	106	6645.50	2	9789.51	4	697.50	1	15874.72
1	0	0	0	101	46	46	4	23	23	185	81	81	0.00	0	0.00	0	0.00	0	0.00
1	0	0	0	119	95	49	5	46	23	210	165	84	0.00	0	0.00	0	0.00	0	0.00
1	0	0	0	141	147	52	6	69	23	239	253	88	0.00	0	0.00	0	0.00	0	0.00
2	0	0	0	353	203	56	12	96	27	478	357	104	0.00	0	0.00	0	0.00	0	0.00
2	0	0	0	245	54	54	22	25	25	472	100	100	0.00	0	0.00	0	0.00	0	0.00
2	0	0	0	256	108	54	22	50	25	496	201	101	0.00	0	0.00	0	0.00	0	0.00
2	0	0	0	263	162	54	23	75	25	512	302	101	0.00	0	0.00	0	0.00	0	0.00
2	0	0	0	290	216	54	26	100	25	581	403	101	0.00	0	0.00	0	0.00	0	0.00
2	0	1	1	731	76	76	40	54	54	1,123	177	177	2903.50	1	2971.51	2	0.00	0	12815.23
2	0	3	2	811	153	81	63	107	59	1,384	354	192	6645.50	2	2971.51	2	0.00	0	12815.23
2	0	5	2	862	234	87	77	160	60	1,539	535	199	6645.50	2	5296.51	3	697.50	1	12815.23
2	1	7	2	988	318	94	118	224	73	1,970	748	237	6645.50	2	9789.51	4	697.50	1	16774.72
				70.50	42	42	7.80	21	21	151.26	77	77							
2	0.07	1	1	132.33	50	8	28.92	27	6	364.99	99	22							
	0.20	1		45.73	53	6	12.16	26		131.43	101	6							
	0.94	1		85.38	53	3	26.31	32	6	283.49	119	21							900
				133.42	16	16	3.16	2	2	164.51	22	22							
				11.26	14	1	0.06	2		16.77	20	1							
				10.36	15	2	0.09	3	1	16.49	22	3							
				42.18	16	2	5.32	6	3	77.28	29	8			6,818	2			
	0.09	1	1	470.65	29	29	16.12	28	28	619.14	83	83	2,904	1	2,972	2			12,815
	0.01	1		5.59	25	1	4.60	24	2	30.17	72	5	3,742	1					
	0.01	1		4.51	25		2.21	23		24.53	71	0			2,325	1	697	1	
	0.05	1		21.78	31	6	9.46	26	5	98.32	87	18			4,493	1			3,059
1				101.10	46	46	4.35	23	23	184.70	81	81							
				17.82	49	3	0.87	23		24.92	84	3							
				22.26	52	3	0.89	23		28.97	88	4							
1				211.89	56	4	5.40	27	4	239.76	104	16							
2				244.70	54	54	21.56	25	25	472.11	100	100							
				11.62	54		0.87	25		23.99	101	1							
				6.55	54		0.59	25		16.35	101	0							
				27.33	54		2.53	25		68.22	101	0							
2	0.09	1	1	730.76	76	76	39.83	54	54	1123.47	177	177	2,904	1	2,972	2			12,815
	0.08	2	1	80.46	77	5	23.25	53	5	260.83	177	15	3,742	1					
	0.22	2		51.14	81	6	13.99	53	1	155.12	181	7			2,325	1	697	1	
	0.99	2		125.34	84	7	41.06	64	13	430.97	213	38			4,493	1			3,959

Land use

Structures (areas by entire structure)

Farmstead			Hotel		Parks				Residential								Total		Developed
l (primary)	Farmstead (sheds, barns, etc)				Parks (primary)		Parks (bathrooms)		Residential, Single		Residential, Single (garages)		Residential, Multiple		Residential, Multiple (garages)				
count (unique)	sq ft	count (unique)	sq ft	count (unique)	sq ft	count (unique)	sq ft	count (unique)	sq ft	count (unique)	sq ft	count (unique)	sq ft	count (unique)	sq ft	count (unique)	sq ft (all)	count (unique, all)	acres
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
0	211.71	1	0.00	0	4443.00	4	0.00	0	30838.92	10	0.00	0	56343.02	52	3130.53	8	94967.18	75	16.59
0	211.71	1	0.00	0	13188.49	7	744.70	3	44597.87	17	0.00	0	56343.02	52	3130.53	8	118216.33	88	20.78
1	211.71	1	70889.69	1	13188.49	7	858.03	4	54930.45	20	2592.50	4	56343.02	52	3274.25	9	203188.15	99	28.86
0	0.00	0	0.00	0	0.00	0	873.99	1	4793.48	1	0.00	0	0.00	0	0.00	0	5667.47	2	0.00
0	0.00	0	0.00	0	0.00	0	953.75	2	4793.48	1	0.00	0	225.70	1	0.00	0	5972.92	4	0.00
0	0.00	0	0.00	0	0.00	0	953.75	2	4793.48	1	0.00	0	427.28	2	0.00	0	6174.50	5	0.00
0	0.00	0	0.00	0	0.00	0	953.75	2	4793.48	1	0.00	0	427.28	2	0.00	0	12992.49	7	0.00
9	22206.35	16	0.00	0	0.00	0	0.00	0	18133.97	13	6735.01	12	0.00	0	0.00	0	65765.57	53	8.93
9	22206.35	16	0.00	0	0.00	0	0.00	0	19941.46	14	9112.51	19	0.00	0	0.00	0	73692.56	62	9.98
9	22606.35	17	0.00	0	0.00	0	0.00	0	22738.97	15	9553.52	20	0.00	0	0.00	0	80353.57	67	11.15
11	25667.86	20	0.00	0	0.00	0	0.00	0	38377.97	22	10353.51	22	0.00	0	0.00	0	107406.56	82	14.80
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
0	211.71	1	0.00	0	0.00	0	199.11	2	5044.52	1	0.00	0	16604.49	15	224.81	1	22284.64	20	7.12
0	211.71	1	0.00	0	0.00	0	199.11	2	5044.52	1	0.00	0	16604.49	15	224.81	1	22284.64	20	7.21
0	211.71	1	0.00	0	0.00	0	199.11	2	5044.52	1	0.00	0	16604.49	15	224.81	1	22284.64	20	7.30
0	211.71	1	0.00	0	0.00	0	199.11	2	7747.52	2	0.00	0	18618.49	16	224.81	1	27001.64	22	7.66
9	22418.06	17	0.00	0	0.00	0	1073.11	3	27971.97	15	6735.01	12	16604.49	15	224.81	1	93717.69	75	16.05
9	22418.06	17	0.00	0	4443.00	4	1073.11	3	55573.86	25	9112.51	19	56568.71	53	3130.53	8	174752.02	142	26.97
9	22818.06	18	0.00	0	13188.49	7	1817.80	6	72130.31	33	9553.52	20	56770.30	54	3130.53	8	204863.75	161	32.24
12	25879.57	21	70889.69	1	13188.49	7	1931.13	7	98101.90	43	12946.01	26	56770.30	54	3274.25	9	316888.56	187	43.86
																	0	0	
	212	1			4,443	4			30,839	10			56,343	52	3,131	8	94,967	75	16.59
					8,745	3	745	3	13,759	7							23,249	13	4.19
1			70,890	1			113	1	10,333	3	2,593	4			144	1	84,972	11	8.08
							874	1	4,793	1							5,667	2	
							80	1					226	1			305	2	
													202	1			202	1	
																	6,818	2	
9	22,206	16							18,134	13	6,735	12					65,766	53	8.93
									1,807	1	2,378	7					7,927	9	1.05
	400	1							2,798	1	441	1					6,661	5	1.17
2	3,062	3							15,639	7	800	2					27,053	15	3.66
																	0	0	
																	0	0	
																	0	0	
																	0	0	
	212	1					199	2	5,045	1			16,604	15	225	1	22,285	20	7.12
																	0	0	0.09
																	0	0	0.09
									2,703	1			2,014	1			4,717	2	0.36
9	22,418	17					1,073	3	27,972	15	6,735	12	16,604	15	225	1	93,718	75	16.05
					4,443	4			27,602	10	2,378	7	39,964	38	2,906	7	81,034	67	10.92
	400	1			8,745	3	745	3	16,556	8	441	1	202	1			30,112	19	5.27
3	3,062	3	70,890	1			113	1	25,972	10	3,392	6			144	1	112,025	26	11.61

Agriculture														Pa						
FMMP					Fields (ag. commission)			Prime Soils			Williamson Act			State Parks			County Parks			
Grazing / Other	Local Importance	Prime	Statewide Importance	Unique																
acres	acres	acres	acres	acres	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	acres	count (each)	count (unique)	
23.81	0.00	0.00	0.00	0.00	0.09	4	4	1.41	7	7	12.06	2	2	86.42	10	10	3.22	2	2	
145.41	1.10	1.42	0.00	1.56	27.53	20	16	23.59	31	24	59.95	5	3	256.70	20	10	13.92	4	2	
189.43	2.26	4.79	0.00	3.53	48.43	36	16	49.85	59	28	69.86	8	3	317.87	30	10	18.55	6	2	
318.40	5.19	16.08	0.21	8.45	100.51	58	22	127.93	92	33	96.54	13	5	429.06	41	11	28.36	8	2	
14.97	0.00	0.00	0.00	0.00	0.00	0	0	0.03	1	1	0.00	2	2	166.33	8	8	3.16	1	1	
18.05	0.00	0.00	0.00	0.00	0.00	0	0	0.03	1	1	0.46	4	2	182.97	16	8	3.22	2	1	
21.24	0.00	0.00	0.00	0.00	0.00	0	0	0.42	4	3	0.75	6	2	198.00	24	8	3.30	3	1	
34.28	0.00	0.00	0.00	0.00	0.00	0	0	6.69	10	6	12.42	10	4	259.96	32	8	3.56	4	1	
29.43	0.00	27.69	0.00	14.12	71.94	3	3	117.90	24	24	88.90	13	13	481.53	6	6	0.00	0	0	
30.32	0.00	36.77	0.00	17.89	84.83	6	3	140.31	48	24	103.20	27	14	488.21	12	6	0.00	0	0	
31.18	0.00	43.91	0.00	18.31	91.75	10	4	158.03	72	24	115.43	41	14	494.25	18	6	0.00	0	0	
34.36	0.00	70.15	0.00	20.11	113.68	14	5	218.79	99	27	160.13	57	16	520.27	24	6	0.00	0	0	
0.00	0.00	0.00	0.00	0.00	0.52	1	1	0.13	4	4	0.00	0	0	150.95	11	11	1.62	1	1	
0.00	0.00	0.00	0.00	0.00	0.58	2	1	1.95	12	8	0.00	0	0	172.89	22	11	1.97	2	1	
0.00	0.00	0.00	0.00	0.00	0.66	3	1	2.41	22	10	0.02	1	1	198.32	33	11	2.27	3	1	
0.00	0.00	0.00	0.00	0.00	1.44	4	1	4.95	37	15	1.40	4	3	425.18	44	11	3.05	5	2	
55.50	0.03	0.00	0.00	0.00	4.59	5	5	20.42	26	26	12.73	3	3	350.38	10	10	10.24	2	2	
58.95	0.04	0.00	0.00	0.00	4.68	11	6	22.71	52	26	13.86	7	4	368.81	20	10	10.67	4	2	
62.72	0.04	0.00	0.00	0.00	4.78	17	6	25.09	78	26	14.64	11	4	379.48	30	10	11.05	6	2	
76.79	0.04	0.00	0.00	0.00	6.48	27	10	33.84	106	28	16.32	15	4	426.27	40	10	12.64	8	2	
87.30	0.03	27.69	0.00	14.12	76.58	11	11	138.74	47	47	103.30	16	16	871.81	11	11	11.73	2	2	
196.11	1.10	38.18	0.00	19.45	112.97	30	19	181.25	98	54	163.88	34	19	966.12	22	11	19.45	4	2	
241.98	2.26	48.70	0.00	21.84	140.64	50	20	223.94	153	58	186.36	52	19	1034.21	33	11	23.79	6	2	
386.66	5.19	86.23	0.21	28.56	214.47	76	27	366.55	217	67	269.39	74	23	1209.35	44	11	33.60	8	2	
23.81					0.09	4	4	1.41	7	7	12.06	2	2	86.42	10	10	3.22	2	2	
121.60	1.10	1.42		1.56	27.44	16	12	22.18	24	17	47.90	3	1	170.27	10		10.69	2		
44.02	1.16	3.38		1.97	20.89	16		26.25	28	4	9.91	3	0	61.17	10		4.63	2		
128.97	2.94	11.28	0.21	4.92	52.09	22	6	78.09	33	5	26.67	5	2	111.19	11	1	9.81	2		
14.97					0.00			0.03	1	1	0.00	2	2	166.33	8	8	3.16	1	1	
3.09					0.00						0.46	2	0	16.64	8		0.06	1		
3.19					0.00			0.39	3	2	0.29	2	0	15.03	8		0.09	1		
13.04					0.00			6.27	6	3	11.67	4	2	61.96	8		0.26	1		
29.43		27.69		14.12	71.94	3	3	117.90	24	24	88.90	13	13	481.53	6	6				
0.89		9.08		3.76	12.88	3		22.41	24	0	14.31	14	1	6.67	6					
0.86		7.14		0.43	6.93	4	1	17.72	24	0	12.23	14	0	6.04	6					
3.18		26.24		1.80	21.92	4	1	60.76	27	3	44.70	16	2	26.02	6					
					0.52	1	1	0.13	4	4				150.95	11	11	1.62	1	1	
					0.06	1		1.82	8	4				21.94	11		0.35	1		
					0.08	1		0.46	10	2	0.02	1	1	25.42	11		0.30	1		
					0.78	1		2.54	15	5	1.38	3	2	226.86	11		0.78	2	1	
55.50	0.03				4.59	5	5	20.42	26	26	12.73	3	3	350.38	10	10	10.24	2	2	
3.45	0.00				0.09	6	1	2.29	26	0	1.13	4	1	18.43	10		0.43	2		
3.77	0.00				0.09	6		2.37	26	0	0.78	4	0	10.67	10		0.38	2		
14.07	0.00				1.70	10	4	8.75	28	2	1.68	4	0	46.78	10		1.60	2		
87.30	0.03	27.69		14.12	76.58	11	11	138.74	47	47	103.30	16	16	871.81	11	11	11.73	2	2	
108.81	1.07	10.50		5.33	36.38	19	8	42.51	51	7	60.58	18	3	94.31	11		7.73	2		
45.87	1.16	10.52		2.39	27.67	20	1	42.69	55	4	22.48	18		68.09	11		4.34	2		
144.69	2.94	37.53	0.21	6.72	73.84	26	7	142.60	64	9	83.02	22	4	175.14	11		9.81	2		

rks						Transportation																							
						Roads																							
						SR 1 (bridges filtered for surface flooding, not erosion, combined is not filtered. wave ends at SR1)								Other Roads (bridges filtered for surface flooding, not erosion, combined is filtered)															
POST			Total Park			SR1 Cohesive Sections (unique, erosion only, bridges counted separately)	SR1 Bridges (unique, erosion only)	SR1 - Length		SR1 - Area		SR1 - ROW		Residential Driveway		Secondary Road		Service Road		Track (off road)		**Total** (SR1, Res, Sec, Ser, Ter, Track)	**Parking Lots** (public, lots no shoulder parking)			**Culverts**		Trail	
acres	count (each)	count (unique)	acres	count (each)	count (unique)	count	count	ft	miles	sq ft	acres	sq ft	acres	ft	miles	ft	miles	ft	miles	ft	miles	miles	sq ft (each)	acres (each)	count (unique)	ft (each)	count (unique)	ft	miles
13.66	1	1	103.31	13	13	0.00	0.00	0.00	0.00	0.00	0.00	6139.87	0.14	0.00	0.00	0.00	0.00	0.00	0.00	67.03	0.01	0.01	0.00	0.00	0	0.00	0	465.46	0.09
30.90	2	1	301.52	26	13	22.00	0.00	33.54	0.01	7417.92	0.17	459167.71	10.54	2578.59	0.49	0.00	0.00	1061.46	0.20	1632.04	0.31	1.00	13596.81	0.31	4	101.55	4	23170.86	4.39
42.71	3	1	379.13	39	13	22.00	0.00	2999.90	0.57	115264.56	2.65	951550.82	21.84	4958.70	0.94	0.00	0.00	2006.03	0.38	2236.05	0.42	2.31	42627.32	0.98	5	290.92	7	43493.83	8.24
68.48	5	2	525.91	54	15	22.00	1.00	15262.20	2.89	604984.78	13.89	2877161.36	66.05	9377.19	1.78	0.00	0.00	3994.62	0.76	4383.49	0.83	6.25	105562.23	2.42	7	1768.65	24	64298.31	12.18
0.00	0	0	169.49	9	9	6.00	1.00	1872.13	0.35	73936.02	1.70	295535.27	6.78	0.00	0.00	0.00	0.00	512.30	0.10	0.00	0.00	0.45	22993.50	0.53	4	235.94	5	3919.01	0.74
0.00	0	0	186.19	18	9	6.00	1.00	3130.29	0.59	131514.70	3.02	537579.28	12.34	45.01	0.01	0.00	0.00	688.62	0.13	0.00	0.00	0.73	34507.77	0.79	4	295.52	6	4760.10	0.90
0.00	0	0	201.31	27	9	6.00	2.00	5309.58	1.01	212757.49	4.88	832201.05	19.10	142.94	0.03	0.00	0.00	968.09	0.18	85.95	0.02	1.23	47760.92	1.10	4	345.03	7	5089.25	0.96
0.00	0	0	263.52	36	9	6.00	3.00	8518.33	1.61	341216.32	7.83	1527335.28	35.06	1114.30	0.21	0.00	0.00	1848.26	0.35	295.75	0.06	2.23	53790.40	1.23	4	601.82	11	6702.55	1.27
7.95	1	1	489.48	7	7	0.00	0.00	1298.39	0.25	51438.55	1.18	399425.63	9.17	4996.44	0.95	4756.43	0.90	7.81	0.00	0.00	0.00	2.09	0.00	0.00	0	0.00	0	11267.36	2.13
10.31	2	1	498.52	14	7	0.00	0.00	1407.49	0.27	55821.95	1.28	428383.20	9.83	5623.00	1.06	5197.55	0.98	18.52	0.00	0.00	0.00	2.32	0.00	0.00	0	0.00	0	11513.98	2.18
12.31	3	1	506.56	21	7	0.00	0.00	1506.77	0.29	59891.95	1.37	471208.14	10.82	5872.33	1.11	5390.87	1.02	301.94	0.06	0.00	0.00	2.48	0.00	0.00	0	0.00	0	11767.01	2.23
21.58	4	1	541.85	28	7	0.00	0.00	1823.22	0.35	72013.13	1.65	618207.87	14.19	7520.12	1.42	6067.88	1.15	1661.16	0.31	0.00	0.00	3.23	0.00	0.00	0	1.56	1	12456.76	2.36
2.83	1	1	155.40	13	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0	207.77	0.04
3.68	2	1	178.54	26	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0	221.37	0.04
4.69	3	1	205.28	39	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0	275.46	0.05
8.44	4	1	436.67	53	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	5.93	1	3694.55	0.70
17.36	1	1	377.98	13	13	0.00	0.00	0.00	0.00	0.00	0.00	394419.49	9.05	2851.84	0.54	0.00	0.00	1264.03	0.24	141.74	0.03	0.81	50264.69	1.15	2	165.23	4	8337.15	1.58
18.07	2	1	397.55	26	13	0.00	0.00	0.00	0.00	0.00	0.00	436745.49	10.03	3148.71	0.60	0.00	0.00	1296.53	0.25	152.49	0.03	0.87	52864.89	1.21	2	169.61	4	10126.68	1.92
18.90	3	1	409.42	39	13	0.00	0.00	0.00	0.00	0.00	0.00	464105.36	10.65	4034.82	0.76	0.00	0.00	1323.87	0.25	163.82	0.03	1.05	54388.71	1.25	2	174.58	4	11486.63	2.18
23.28	4	1	462.19	52	13	0.00	0.00	0.00	0.00	0.00	0.00	586035.06	13.45	4735.13	0.90	0.00	0.00	1512.89	0.29	222.22	0.04	1.23	59768.47	1.37	6	263.04	6	15786.85	2.99
28.41	2	2	911.94	15	15	6.00	1.00	2842.94	0.65	135303.79	3.11	940898.68	21.60	8279.11	1.57	4756.43	0.92	1834.05	0.35	165.71	0.03	3.51	63289.82	1.45	4	379.65	7	22257.75	4.22
42.35	4	2	1027.93	30	15	28.00	1.00	4022.96	0.87	189976.20	4.36	1534535.39	35.23	10908.40	2.07	5197.55	1.00	3019.84	0.57	1632.04	0.31	4.82	83876.36	1.93	8	542.25	12	44324.44	8.39
55.78	6	2	1113.77	45	15	28.00	2.00	7847.08	1.60	333666.08	7.66	2195185.87	50.39	12673.11	2.40	5390.87	1.04	4099.69	0.78	2322.01	0.44	6.25	117507.52	2.70	9	760.01	15	64143.85	12.15
90.64	9	3	1333.59	61	16	28.00	4.00	23085.63	4.50	946316.65	21.72	4587693.20	105.32	17963.95	3.40	6067.88	1.17	7659.05	1.45	4679.24	0.89	11.41	181608.18	4.17	11	2376.49	35	84347.36	15.97
13.66	1	1	103.31	13	13							6,140	0.14							67	0.01	0.01						465	0.09
17.24	1		198.21	13	0	22		34	0.01	7,418	0.17	453,028	10.40	2,579	0.49			1,061	0.20	1,565	0.30	0.99	13,597	0.31	4	102	4	22,705	4.30
11.81	1		77.61	13	0			2,966	0.56	107,847	2.48	492,383	11.30	2,380	0.45			945	0.18	604	0.11	1.31	29,031	0.67	1	189	3	20,323	3.85
25.77	2	1	146.78	15	2		1	12,262	2.32	489,720	11.24	1,925,611	44.21	4,418	0.84			1,989	0.38	2,147	0.41	3.94	62,935	1.44	2	1478	17	20,804	3.94
			169.49	9	9	6	1	1,872	0.35	73,936	1.70	295,535	6.78					512	0.10			0.45	22,994	0.53	4	236	5	3,919	0.74
			16.70	9	0			1,258	0.24	57,579	1.32	242,044	5.56	45	0.01			176	0.03			0.28	11,514	0.26		60	1	841	0.16
			15.12	9	0		1	2,179	0.41	81,243	1.87	294,622	6.76	98	0.02			279	0.05	86	0.02	0.50	13,253	0.30		50	1	329	0.06
			62.21	9	0		1	3,209	0.61	128,459	2.95	695,134	15.96	971	0.18			880	0.17	210	0.04	1.00	6,029	0.14		257	4	1,613	0.31
7.95	1	1	489.48	7	7			1,298	0.25	51,439	1.18	399,426	9.17	4,996	0.95	4,756	0.90	8	0.00			2.09						11,267	2.13
2.37	1		9.04	7	0			109	0.02	4,383	0.10	28,958	0.66	627	0.12	441	0.08	11	0.00			0.22						247	0.05
2.00	1		8.05	7	0			99	0.02	4,070	0.09	42,825	0.98	249	0.05	193	0.04	283	0.05			0.16						253	0.05
9.27	1		35.29	7	0			316	0.06	12,121	0.28	147,000	3.37	1,648	0.31	677	0.13	1,359	0.26			0.76				2	1	690	0.13
2.83	1	1	155.40	13	13																	0.00						208	0.04
0.85	1		23.14	13	0																	0.00						14	0.00
1.01	1		26.74	13	0																	0.00						54	0.01
3.75	1		231.38	14	1																	0.00				6	1	3,419	0.65
17.36	1	1	377.98	13	13							394,419	9.05	2,852	0.54			1,264	0.24	142	0.03	0.81	50,265	1.15	2	165	4	8,337	1.58
0.71	1		19.56	13	0							42,326	0.97	297	0.06			33	0.01	11	0.00	0.06	2,600	0.06		4		1,790	0.34
0.83	1		11.88	13	0							27,360	0.63	886	0.17			27	0.01	11	0.00	0.18	1,524	0.03		5		1,360	0.26
4.39	1		52.77	13	0							121,930	2.80	700	0.13			189	0.04	58	0.01	0.18	5379.7594	0.12	4	88	2	4,300	0.81
28.41	2	2	911.94	15	15	6	1	2,843	0.65	135,304	3.11	940,899	21.60	8,279	1.57	4,756	0.92	1,834	0.35	166	0.03	3.51	63,290	1.45	4	380	7	22,258	4.22
13.95	2		115.98	15	0	22		1,180	0.22	54,672	1.26	593,637	13.63	2,629	0.50	441	0.08	1,186	0.22	1,466	0.28	1.31	20,587	0.47	4	163	5	22,067	4.18
13.42	2		85.85	15	0		1	3,824	0.73	143,690	3.30	660,650	15.17	1,765	0.33	193	0.04	1,080	0.20	690	0.13	1.43	33,631	0.77	1	218	3	19,819	3.75
34.87	3	1	219.82	16	1		2	15,239	3	612,651	14	2,392,507	54.92	5,291	1	677	0	3,559	1	2,357	0	5.16	64100.665	1.47	2	1616	20	20,204	3.83

Recreation Trail				Coastal Armor			Hazardous Facilities (UST & EIS at Calfire Station, UST at Gas Station, gas pump at County Corp Yard) (note: nothing active in geotracker, 4 closed cleanups)	Habitat																								
Trail																																
Vertical Access (public)		Vertical Access (private)						Agricultural Wetlands	Agriculture	Annual Grassland	Aquatic Bed	Barren	Chaparral	Coastal Dune	Coastal Scrub	Developed	Freshwater Marsh	Inland Shore	Irregularly-Flooded Estuarine Marsh	Lakes / Ponds	Mixed Evergreen Forests and Woodlands	Non-Native Tree	Oak Forests and Woodlands	Prime Agriculture	Rare Coastal Conifer Forest and Woodlands	Rare Oak Forests and Woodlands	Rare Vegetated Dune	Regularly-flooded Estuarine Marsh	Riparian Forest and Shrub	Riverine	Rocky Intertidal	Seasonal Freshwater Marsh
ft (each)	count (unique)	ft (each)	count (unique)	ft (each)	ft (unique)	count (unique)	count	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres	acres
218.42	5	12.70	1	200.94	277.69	2	0	0.00	3.14	2.17	0.15	3.19	0.64	1.24	3.13	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	2.94	0.00	0.11	0.07	78.14	0.00
2907.86	26	578.21	12	3073.40	3136.24	17	0	0.00	27.83	73.37	0.21	57.34	44.15	11.50	72.78	22.19	0.00	0.13	0.00	0.00	0.00	4.49	0.45	2.03	4.01	0.00	16.91	0.00	4.83	0.78	103.63	0.10
4106.26	28	791.28	15	3136.24	3136.24	17	0	0.00	45.02	111.87	0.21	66.55	51.16	16.35	102.65	33.55	0.01	0.31	0.00	0.00	0.00	6.55	1.19	7.32	6.50	0.00	25.68	0.00	10.86	1.22	104.27	0.12
5220.01	31	1066.15	15	3136.24	3136.24	17	0	0.02	83.62	203.51	0.21	81.26	67.48	24.23	167.98	64.00	0.03	0.35	0.00	0.13	0.00	13.39	2.35	29.29	15.28	0.00	41.08	0.00	24.97	2.00	104.94	0.15
1672.54	9	0.00	0	0.00	195.31	2	0	0.00	2.67	1.55	0.00	18.91	2.78	8.59	29.34	2.95	0.00	0.00	0.00	0.09	0.00	2.29	0.00	0.00	0.31	0.00	14.98	0.00	2.57	0.92	1.00	0.14
1804.12	9	0.00	0	0.00	195.31	2	0	0.00	2.88	2.63	0.00	20.23	4.62	9.65	38.76	5.37	0.00	0.00	0.02	0.40	0.00	2.48	0.00	0.00	0.58	0.00	16.20	0.00	3.59	1.14	1.00	0.37
1844.52	9	0.00	0	0.00	195.31	2	0	0.00	3.08	3.92	0.00	21.21	6.33	9.65	48.83	8.73	0.00	0.00	0.17	1.29	0.00	3.17	0.00	0.00	0.85	0.00	17.12	0.22	4.80	1.29	1.00	0.40
2012.00	9	0.00	0	0.00	195.31	2	0	0.00	4.36	7.36	0.00	22.81	10.96	9.65	93.61	16.45	0.00	0.00	1.43	9.75	0.00	4.62	0.00	0.00	5.31	0.00	19.04	1.33	11.52	2.03	1.00	0.59
38.23	1	0.00	0	0.00	99.97	1	1	0.00	48.02	24.47	0.00	2.20	34.35	0.89	29.79	24.30	0.00	0.00	101.77	41.43	0.58	6.66	0.00	25.73	0.00	6.32	1.03	19.90	50.45	11.66	0.00	1.23
58.49	1	0.00	0	0.00	99.97	1	1	0.00	53.83	29.30	0.00	2.41	35.91	0.97	30.95	25.60	0.00	0.00	102.05	41.46	0.78	6.92	0.00	33.38	0.00	6.35	1.23	19.99	57.92	11.91	0.00	1.26
78.23	2	0.00	0	0.00	99.97	1	2	0.00	57.38	32.05	0.00	2.59	37.14	1.03	32.15	27.48	0.00	0.00	102.27	41.48	0.86	7.16	0.00	39.32	0.00	6.39	1.42	20.05	65.94	12.13	0.00	1.29
213.82	3	0.00	0	0.00	99.97	1	3	0.00	64.25	51.97	0.00	4.03	43.73	1.36	38.56	34.99	0.00	0.00	102.56	41.59	1.44	8.10	0.00	56.17	0.00	6.49	4.49	20.52	96.43	13.21	0.00	1.41
0.00	0	0.00	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0	0.00	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0	0.00	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
166.28	4	0.00	0	0.00	77.30	3	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3352.70	34	260.86	14	0.00	2955.23	18	0	0.00	12.82	26.33	0.20	36.91	6.57	15.69	38.02	4.72	0.07	0.00	0.00	0.00	0.00	3.30	0.00	0.17	0.17	14.65	0.00	0.30	21.20	1.59	102.93	0.34
3542.09	35	277.70	14	0.00	2955.23	18	0	0.00	14.48	28.88	0.20	37.95	7.36	25.14	42.91	5.21	0.07	0.00	0.00	0.00	0.00	3.50	0.00	0.27	0.17	15.65	0.00	0.37	23.40	1.78	103.10	0.53
3858.12	36	294.23	14	0.00	2955.23	18	0	0.00	16.19	30.52	0.20	38.92	8.57	27.47	46.18	5.86	0.07	0.00	0.00	0.00	0.00	3.73	0.00	0.48	0.18	17.36	0.00	0.42	25.30	1.96	103.24	0.59
4510.06	38	385.94	15	0.00	2955.23	18	0	0.00	25.89	38.88	0.20	42.43	10.63	33.92	64.27	7.10	0.08	0.35	0.00	0.00	0.00	4.55	0.00	1.83	0.22	23.94	0.00	0.55	33.46	2.47	103.83	1.62
3998.88	37	260.86	14	2896.15	3331.56	19	1	0.00	63.51	51.58	0.21	47.93	42.55	22.28	94.28	31.26	0.07	0.00	101.86	41.51	0.58	11.05	0.00	25.90	0.57	6.32	25.23	20.17	73.32	13.71	103.87	1.63
5947.42	40	694.04	14	3331.56	3331.56	19	1	0.00	89.80	112.46	0.21	82.11	85.95	27.64	160.24	54.21	0.07	0.13	102.15	41.62	0.78	15.39	0.45	35.67	4.59	6.35	36.14	20.32	86.26	14.72	105.65	1.94
6654.10	40	819.27	14	3331.56	3331.56	19	2	0.00	109.14	152.17	0.21	91.06	95.00	32.13	197.92	68.39	0.07	0.31	102.51	41.63	0.86	18.47	1.19	46.97	7.36	6.39	44.69	20.61	100.01	15.43	105.76	2.03
7646.53	41	1066.15	15	3331.56	3331.56	19	3	0.02	154.26	263.11	0.21	105.26	122.04	40.54	311.24	110.89	0.08	0.35	103.49	41.82	1.44	28.06	2.35	85.77	20.59	6.49	60.14	21.43	148.79	17.81	105.94	3.24

218	5	13	1	201	278	2			3.14	2.17	0.15	3.19	0.64	1.24	3.13	0.74									0.14		2.94		0.11	0.07	78.14	0.00
2,689	21	566	11	2,872	2,859	15			24.69	71.20	0.05	54.15	43.51	10.26	69.65	21.45		0.13				4.49	0.45	2.03	3.87		13.97		4.72	0.71	25.48	0.10
1,198	2	213	3	63					17.19	38.50		9.21	7.01	4.85	29.88	11.36	0.01	0.18				2.06	0.75	5.30	2.50		8.77		6.03	0.44	0.65	0.02
1,114	3	275						0.02	38.60	91.63		14.71	16.31	7.88	65.32	30.45	0.02	0.04		0.13		6.84	1.16	21.97	8.78		15.40		14.11	0.78	0.67	0.03
1,673	9				195	2			2.67	1.55		18.91	2.78	8.59	29.34	2.95				0.09		2.29			0.31		14.98		2.57	0.92	1.00	0.14
132									0.21	1.09		1.32	1.84	1.06	9.42	2.42			0.02	0.32		0.19			0.27		1.22	0.00	1.03	0.22		0.23
40									0.20	1.29		0.98	1.71	0.01	10.08	3.36			0.15	0.89		0.69			0.27		0.92	0.22	1.20	0.15		0.03
167									1.28	3.44		1.60	4.63		44.78	7.72			1.26	8.45		1.46			4.46		1.92	1.11	6.72	0.74		0.19
38	1				100	1	1		48.02	24.47		2.20	34.35	0.89	29.79	24.30			101.77	41.43	0.58	6.66		25.73		6.32	1.03	19.90	50.45	11.66		1.23
20									5.81	4.84		0.21	1.56	0.08	1.17	1.30			0.27	0.03	0.20	0.26		7.65		0.03	0.20	0.09	7.46	0.25		0.03
20	1						1		3.55	2.75		0.18	1.23	0.06	1.19	1.88			0.22	0.03	0.09	0.25		5.94		0.04	0.19	0.07	8.02	0.22		0.03
136	1						1		6.87	19.92		1.45	6.59	0.33	6.41	7.51			0.29	0.10	0.58	0.93		16.86		0.10	3.07	0.46	30.49	1.08		0.13
166	4				77	3																										
3,353	34	261	14		2,955	18			12.82	26.33	0.20	36.91	6.57	15.69	38.02	4.72	0.07					3.30		0.17	0.17	14.65		0.30	21.20	1.59	102.93	0.34
189	1	17							1.67	2.55	0.00	1.04	0.79	9.45	4.89	0.49	0.00			0.00		0.20		0.10	0.01	1.00		0.07	2.21	0.19	0.18	0.19
316	1	17							1.71	1.64	0.00	0.97	1.20	2.33	3.27	0.65	0.00	0.00				0.22		0.21	0.01	1.71		0.06	1.90	0.18	0.14	0.06
652	2	92	1						9.69	8.35	0.00	3.51	2.06	6.45	18.08	1.24	0.01	0.35				0.82		1.35	0.04	6.58		0.13	8.16	0.51	0.59	1.03
3,999	37	261	14	2,896	3,332	19	1		63.51	51.58	0.21	47.93	42.55	22.28	94.28	31.26	0.07		101.86	41.51	0.58	11.05		25.90	0.57	6.32	25.23	20.17	73.32	13.71	103.87	1.63
1,949	3	433		435					26.30	60.88		34.18	43.39	5.36	65.96	22.94	0.00	0.13	0.29	0.11	0.20	4.34	0.45	9.77	4.02	0.03	10.91	0.15	12.94	1.00	1.77	0.31
707		125					1		19.34	39.71		8.95	9.06	4.49	37.69	14.18	0.00	0.18	0.36	0.01	0.09	3.09	0.75	11.30	2.77	0.04	8.55	0.29	13.75	0.71	0.11	0.09
992	1	247	1				1	0.02	45.12	110.94		14.19	27.04	8.41	113.31	42.50	0.01	0.04	0.98	0.18	0.58	9.59	1.16	38.81	13.24	0.10	15.45	0.82	48.78	2.38	0.18	1.21

Swash Beach	Tidal Flat and Salt Panne	Tidal Freshwater Forested/Shrub	Tidal Freshwater Marsh	Upper Beach	**Total**
acres	acres	acres	acres	acres	acres
109.92	2.09	0.00	0.00	129.40	337.24
131.02	2.96	0.00	0.00	222.03	802.74
131.11	2.97	0.00	0.00	225.60	951.10
131.11	3.05	0.00	0.00	227.61	1288.04
32.54	12.34	0.00	0.00	66.22	200.18
32.54	13.47	0.00	0.00	66.36	222.30
32.54	14.35	0.12	0.00	66.36	245.45
32.54	17.77	0.53	0.00	66.36	339.03
0.00	49.15	17.22	123.72	5.82	626.68
0.00	49.28	17.30	123.74	5.89	658.41
0.00	49.43	17.37	123.76	5.95	684.63
0.00	49.62	17.41	123.86	6.06	788.26
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
163.64	16.98	0.00	0.00	272.38	738.97
163.65	16.99	0.00	0.00	274.25	765.87
163.65	17.00	0.00	0.00	275.29	783.20
163.65	17.03	0.00	0.00	278.43	855.33
163.65	57.32	17.22	123.72	278.57	1419.86
163.65	57.36	17.30	123.74	292.73	1739.60
163.65	57.43	17.37	123.76	293.61	1916.13
163.65	58.41	17.41	123.86	294.22	2412.91

109.92	2.09			129.40	337.24
21.10	0.87			92.63	465.51
0.09	0.00			3.57	148.36
	0.08			2.01	336.94
32.54	12.34			66.22	200.18
	1.13			0.13	22.13
	0.88	0.12			23.15
	3.42	0.41			93.58
	49.15	17.22	123.72	5.82	626.68
	0.13	0.09	0.02	0.07	31.73
	0.15	0.06	0.02	0.06	26.23
	0.19	0.05	0.10	0.11	103.62
163.64	16.98			272.38	738.97
0.00	0.01			1.88	26.90
0.00	0.01			1.04	17.33
0.00	0.03			3.14	72.13
163.65	57.32	17.22	123.72	278.57	1,419.86
0.00	0.04	0.09	0.02	14.16	319.74
	0.07	0.06	0.02	0.88	176.53
	0.98	0.05	0.10	0.61	496.78

15 APPENDIX G. MODEL COMPARISON MEMOS

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May 26, 2022 Project No. C3085

To: OOS, San Mateo County

From: David Revell, Ph.D., Matthew Jamieson

Subject: **San Mateo South Coast VA Coastal Hazard Model Comparison and Justification**

Dune Erosion

Hazard Model Incorporated into the Study

- Integral Consulting Dune Erosion (2021)

Other Hazard Models Considered

- Pacific Institute Coastal Erosion (2008),
- CoSMoS COAST (2015),
- CoSMoS Long Term Shoreline Change (preliminary dataset 2020).

Justification for the Model Choice

None of the three available models were considered good candidates for the vulnerability assessment study.

The model resolution of the Pacific Institute work was considered overly coarse and conservative for some of the locations of interest for the South County Coast (e.g., Bean Hollow Beach) and unfit for this scale of analysis. The model was seen as an extreme case since it assumes that the dune will erode based on the maximum total water level elevation without consideration of the duration of the storm event. The model did not consider changes in geology or landform once the dune is completely eroded, nor did it consider when dune erosion would encounter concrete such as Highway 1.

The CoSMoS COAST model suffers from linear interpolation issues related to connecting coarse resolution transects (~100m) and does not provide spatially explicit results along an irregular coast. As a result, the results do not have adequate resolution to match the shoreline.

The CoSMoS Long Term Shoreline Change model (preliminary dataset) had much-improved transect spacing from the previous CoSMoS COAST model (~20 m vs ~100 m), however, it had numerous issues related to poor bluff-top and dune-crest feature delineation. The major issues were: that features were located either too far upslope or downslope from the known dune crest, and false detections occurred along the offshore rock, coastal promontories, and small drainage areas. Dramatic swings in erosion extents were found (<100 m between horizons), especially in dune-backed beaches and drainages. Finally, no existing conditions (or baseline) feature for dune-crest edge features were available.

Cliff Erosion

Hazard Model Incorporated into the Study

- Pacific Institute Coastal Erosion (2008)

Hazard Models Considered

- Pacific Institute Coastal Erosion (2008),
- CoSMoS COAST (2015),
- CoSMoS Long Term Shoreline Change (preliminary dataset 2020).

Justification for the Model Choice

This Pacific Institute Coastal Erosion model (2008) was spatially explicit and consistent with the models used in the related SeaChange San Mateo Report (2018) for the rest of the open Pacific Ocean coastline in the County. It was acknowledged to be conservative but did consider the geology and geomorphology of the coast and model results provided an existing and projected future coastal erosion hazard zone.

The CoSMoS Long Term Shoreline Change Cliffs model (preliminary dataset 2020) had much-improved transect spacing from the previous CoSMoS model (~20 m vs ~100 m), however, it had numerous issues related to poor bluff-top feature delineation. The major issues were: that features were located either too far upslope or downslope from the known bluff-top, and false detections occurred along the offshore rock, coastal promontories, and small drainage areas. In addition, no existing hazard conditions (or baseline) were mapped for cliff-backed shoreline segments, and across future horizons, locations of positive shoreline change (accretion of the bluff top) were found. Finally, the connection of transect results along areas with an irregular-shaped coastline created some poor representation of erosion that was considered overly coarse.

Coastal Wave Flooding

Hazard Model Incorporated into the Study

- Integral Consulting Coastal Wave Flooding (2020).

Hazard Models Considered

- CoSMoS Wave Flooding (2015).

Justification for the Model Choice

Overall, the CoSMoS storm wave flooding model did a decent job in replicating existing storm wave events along the narrow beaches in south San Mateo County when compared to the FEMA flood maps. However, in wider beach areas, such as Pescadero, there were numerous locations where even in a 100-year wave event, with sea level rise, the beach was not projected to flood. In areas adjacent to creek mouths and bar built estuaries, the extent of wave flooding was considered to be too far inland.

After a detailed review of all available CoSMoS technical documentation of the Central Coast CoSMoS wave run up results, it was determined that the wave run up also included a potential fluvial (watershed) flow event. These coastal confluence flood results of both the wave run up and the fluvial flow was mapped together and thus it was difficult to know what influence a fluvial event had on the wave flooding hazard extent.

In most low-lying areas (e.g. Pescadero), the coastal confluence flooding was determined to be a ~5 to 10-year return period fluvial event. Thus, the fluvial flooding component was significantly less than projected FEMA fluvial flood extents and thus confusing to interpret and communicate to non-technical stakeholders. Ultimately, the underprediction along wide sandy beaches and the inability to separate the two different physical processes (wave run up and coastal confluence) was deemed to make the data unusable.

To resolve these issues, Integral Consulting mapped the existing 1% annual chance coastal wave flood using FEMA's regulatory BFE elevations and elevated those based on the sea level rise horizons. Results were mapped on the 2018 high-resolution County topographic LIDAR data set. With this method, the team was able to parse out the areas under influence of coastal wave flooding from fluvial influence.

Rising Tides

Rising tides were mapped on the same 2018 Countywide digital elevation model as the coastal storm wave-flooding model (Integral, 2020) to keep consistency between models. Results were comparable to the CoSMoS model average conditions (daily/background conditions with spring tide), however, they were mapped at a higher resolution.

Coastal Confluence

Hazard Model Incorporated into the Study

- None

Hazard Models Considered

- GEI Consultants Fluvial Flood and Coastal Confluence Model (2021).

Justification for not Choosing this Model

The County of San Mateo commissioned a study by GEI Consultants to evaluate future fluvial and coastal confluence flood hazards across the County at a high spatial resolution and projected into the future for 2030 and 2070. As a separate study, this model relied on different sea level rise elevations and time horizons than were chosen for the San Mateo South Coast Vulnerability Assessment.

The GEI model approach ran forecasted precipitation time series data through a variable infiltration capacity (VIC) model to simulate future hydrologic conditions and changes for 2030 and 2070. After a preliminary review by Integral Consulting and several conversations with GEI, it was identified that the flood risk between 2030 and 2070 ***decreased*** in many areas of the lower Pescadero watershed.

After the study team's preliminary review, a team from Stanford, under a separate agreement with the County, reviewed the model and found significant problems in this model based on substantial differences in flood extents based on the time steps assumed in the model. Ultimately, given the discrepancies, the County instructed Integral Consulting not to include this hazard in the vulnerability assessment.

Closed Lagoon Flooding

Hazard Model Incorporated into the Study

- Integral Consulting Closed Lagoon Flooding (2021).

Hazard Models Considered

- CoSMoS Groundwater (2020).

The CoSMoS Groundwater model (2020) was considered for the assessment, but upon review of the draft results, draft technical methods report, and discussions with the USGS modeling team, it was determined that the groundwater model did not consider the seasonal changes in the bar built estuary conditions and thus was inapplicable for this assessment.

As a result, Integral developed a geomorphic approach to estimating this flooding based on the closed sand bar berm crest elevations and assumed that wave overtopping and watershed discharge would be sufficient to fill these estuaries. As sea levels rise, the assumption was made that there would be enough sediment in the littoral (beach) system that the beach berm crest elevations would rise with sea level rise, and closed lagoon flooding extents would expand.

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MEMORANDUM

Date: 8/22/2019

To: San Mateo County

From: David Revell, PhD, Craig Jones, PhD

Subject: Coastal Hazard Model Comparison

Purpose

The purpose of this technical memorandum is to provide a summary review of comparisons of the available coastal hazard models in South San Mateo County and to recommend the most appropriate model for each type of coastal hazard to use to project future conditions required for the South San Mateo County Vulnerability Assessment and Adaptation Plan. For this project, spatially explicit projections of future coastal hazard extents are required as well as supporting technical documentation that allows for interpretation of model results.

The South San Mateo County work is evaluating the suite of coastal processes driving coastal evolution and creating coastal hazards. The hazards being considered for inclusion in the vulnerability assessment include:

- Coastal Erosion (Cliff and Dune)
- Coastal Wave Flooding from a 100 year wave run up event
- Coastal Confluence (fluvial flooding exacerbated by Sea Level Rise)
- Changes in groundwater

Available Models

The descriptions below are summaries of the models and interested readers should consult the references and documentation associated with the various models for additional details.

FEMA

The Federal Emergency Management Agency (FEMA) as part of their Congressional mandate, maps a regulatory Flood Insurance Rate Map (FIRM) used to determine flood insurance premiums. The flood mapping follows federal guidelines to delineate potential flood impacts from a 1% annual chance storm event[1](FEMA 2005). The flood mapping comes from two primary sources, wave runup and fluvial flooding. The wave runup mapping is determined by the combination of high tides and maximum wave run up elevations (aka total water level). The wave run up is calculated 3 different ways considering the type of backshore (e.g. armored, sandy beach, or cliff) and the highest run up elevation is mapped. The mapped hazard zones are delineated as a high wave velocity (V or VE) zone or a ponded water (A) zone. The entire Pacific Coast FIRMS were recently remapped following updated federal guidelines for the Pacific Coast. It is important to note that sea level rise and coastal erosion were not factored into this coastal regulatory map update and so the FEMA

[1] FEMA used to call this the 100 year storm, but now refers to these events as the 1% annual chance storm because it has a 1% probability of occurring in any given year and the occurrence of an event one year does not affect the probability of a similar magnitude storm occurring the next year.

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model is primarily used as a basis for comparison with other models to evaluate their performance under an existing condition 1% annual chance wave event.

Fluvial flooding also representing a 1% annual chance storm based on fluvial discharge calculated statistically based on available stream gauge data. The fluvial mapping follows a different set of guidelines using a cross sectional HEC-RAS model. This HEC-RAS model is sensitive to stream bed elevation and to bottom (tailwater) elevations. The fluvial flood hazards are mapped as A or AE for the 1% flood extent and as X for the 0.2% annual chance storm (~500 year return period). The mapping accuracy requires a certain size of the drainage to be included in the FIRM fluvial flood hazard mapping. As a result, many of the small drainages in South San Mateo County are not currently mapped by FEMA. It is important to note that sea level rise and climate change which would affect bottom tailwater elevations and fluvial discharge based on changes in precipitation were not factored into these regulatory maps and so the FEMA model is primarily used as a basis for comparison with the DWR funded County model to evaluate its performance under an existing condition 1% annual chance fluvial event.

COSMOS

The Coastal Storm Modeling System (CoSMoS) developed by the USGS is a numerical and probabilistic modeling framework developed to account for the impacts of climate change accelerated sea level rise during the 21st century. The model includes sea level rise and plausible storm scenarios (i.e, 0, 20, 100 year events), for a variety of coastal settings and hazards. The model is driven by a state of the art downscaled climate model that drives a series of nested wave models to provide a local forecast of future wave conditions and total water levels that has been well calibrated with availabe tide and wave buoy observations across California (Barnard et al., 2014; Erikson et al 20XX, Barnard et al., 2009).

The COSMOS model has multiple modules to account for different types of coastal processes and hazards. Model results are projected into the future at 0.25 m increments of sea level rise and available for view online at Our Coast Our Future (WEBSITE) with more detailed data available for download at the USGS Science Base (WEBSITE). The individual modules methodologies are summarized below and compared with comparable modeling results under the relevant hazard sections include:

- Cliff Erosion
- Shoreline Change
- (COAST) Wave Run up
- Coastal Confluence
- Groundwater

Pacific Institute

In 2008, as part of the 2nd California Climate Assessment, the Pacific Institute conducted the first statewide vulnerability assessment to coastal erosion and coastal flooding hazards accelerated by sea level rise in California. Underlying this analysis was the development of coastal dune and cliff erosion models which followed the FEMA coastal hazard guidelines (2005) but incorporated both sea level rise and coastal erosion in projected future hazard extents (PWA 2009, Revell et al 2011). The erosion response models were driven by downscaled climate models of sea level rise (Cayan 2009) with waves transformed along the coast by Scripps to provide local nearshore projections of wave run up and tides (Bromirski et al 2009, O'Reilly 1998).

The backbone of the hazard models was a backshore representation of the entire coast of California divided into 500m segments based on similar geology, backshore type (dune, cliff, or inlet), and geomorphic characteristics interpreted

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from topographic LIDAR at a 100 m spacing (Revell et al 2011). The Pacific Institute evaluated projected changes to three coastal hazards including wave flooding, cliff and dune erosion. The individual hazard model methodologies are summarized below and compared with comparable modeling results under the relevant hazard sections.

Specific Coastal Hazard Model Comparisons

The model comparison consists of a summary description of the individual hazard models followed by a direct spatial comparison of projected hazard zones for similar sea level rise estimates from each model. The final section of this technical memo makes recommendations on the best model to use in evaluating vulnerabilities associated with each coastal hazard for the South San Mateo County Vulnerability and Adaptation Planning Project.

For consistency in the comparisons where appropriate, similar sea level rise elevations were compared from each model (Table 1.) Specific comparisons between available models projecting different coastal hazards are identified below.

Table 1. Elevations of sea level rise used in the model comparison

Approximate Time	Pacific Institute	COSMOS elevation
2025	8 inches	8.8 inches (0.25 m)
2050	16 inches	19.7 inches (0.50 m)
2100	55 inches	59 inches (1.50m)

Coastal Erosion

Cliff Erosion compares the COSMOS Cliff and Pacific Institute Cliff erosion models

Dune Erosion compares the COSMOS Coast shoreline change and the Pacific Institute Dune Erosion models

Coastal Wave Flooding compares the existing FEMA FIRM VE Zone (1% annual chance wave event) and COSMOS storm wave run up from a 100 year wave event without sea level rise

Coastal Confluence compares FEMA FIRM A and X zones (1% annual chance fluvial flood event) and the DWR funded County modeling (2019)[2] (footnote COSMOS includes but doesn't delineate or look at 100 year river flow

Groundwater modeling is not currently available from any source although COSMOS is developing a module which is in draft form. Presently, however the model based on draft results and webinar does not include the effect of bar built estuaries which complicate groundwater dynamics seasonally across each of the south San Mateo County drainages.

Cliff Erosion

COSMOS Cliff Erosion Method

The Coastal Storm Modeling System (CoSMoS) is a numerical and probabilistic modeling framework developed to account for the impacts of climate change accelerated sea level rise during the 21st century. The model includes sea level rise and plausible storm scenarios, on a variety of coastal settings, in particular for cliffed, active-margin settings like California (Barnard et al., 2014; Barnard et al., 2009). The COSMOS cliffs is part of the overall COSMOS hazard framework which is described in detail in Limber et al 2015. For more details please see this paper and references within.

[2] Note that COSMOS also considers coastal confluence but that model projects fluvial flood hazards associated with the most likely fluvial discharge event associated with the 100-year wave event. Typically this is around a 5 to 10 year recurrence interval which is not suitable for the vulnerability assessment due to the underprediction of flood hazard extents as mapped by FEMA FIRM maps.

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The Cliff erosion specific projections are based on an ensemble of 4 individual cliff erosion models:

- Equilibrium SCAPE model - Walkden and Hall (2005, 2011) and Walkden and Dickson (2008)
- Non-equilibrium SCAPE model -
- Trenhaile 2011
- Bruun-type model –Young et al 2014

The primary input parameters included an end point historic erosion rate calculated between the 1970s and 1998 obtained from the National Shoreline Assessment of Cliff Changes (Hapke and Reid 2007) and driven by the projected future wave forcing obtained from the COSMOS wave downscaling modeling transformed to the local nearshore zone. Erosion hazards were calculated along 500 foot alongshore spacing transects for each of the 4 models in cliff-backed areas. Existing erosion was not mapped. The mapped coastal cliff erosion hazard extents represent future projections of the cliff edge location. To develop a polygon hazard zone (needed for this vulnerability assessment), the mean erosion distance calculated by the 4 models was buffered using one standard deviation. Cliff erosion extents for areas between the 500 ft spaced cliff transect calculations were linearly interpolated.

The CoSMoS Cliff model included both a “hold the line” management assumption (not allowing erosion to continue through existing armoring or development (including roads) and a “let it go” management assumption which allowed erosion to continue into development. For purposes of this comparison the “let it go” management assumption was evaluated. It is unclear how mapped model outputs were reviewed.

Pacific Institute Cliff Erosion Method

The Pacific Institute modeling of cliff erosion was also based on the historic erosion rates calculated by the National Shoreline Assessment of Cliff Changes (Hapke and Reid 2007). The model filtered these historic erosion rates by excluding those that intersected existing coastal armoring and then averaged the erosion rates along 500m segments of coast with similar geology. To account for the alongshore variability and include an additional factor of safety, two standard deviations of the historic erosion rates within each geologic unit were multiplied by the years elapsed by each planning horizon and accelerated based on the percent increase in the hours of wave attack at the toe of the cliff (Revell et al 2011, PWA 2009).

The mapping was based on similar 500m segments with the projections of future erosion hazards buffered from the initial 1998 cliff edge extracted from topographic lidar. Draft results of the model were presented and reviewed by experts in cliff erosion including several USGS scientists. The Pacific Institute model projected erosion hazards assuming no existing armoring (assuming that was a future adaptation decision). This Pacific Institute Cliff Erosion Model was used in the related SeaChange vulnerability assessment used in the rest of the San Mateo County Coast.

Cliff Erosion Comparison

Upon visual inspection there were vast differences in the mapped projected extents of cliff erosion hazards along south San Mateo County. Figure 1 provides a representative comparison of the COSMOS and Pacific Institute Cliff erosion projections. Generally, several differences are notable.

1. Pacific Institute typically predicts larger cliff erosion extents than COSMOS Cliffs. This is likely due to the use of 2 standard deviations around the geologically related historic erosion rates.
2. COSMOS does not provide spatially explicit mapping of the cliff erosion results. This is likely due to the linear interpolation between 500 feet spaced calculation points. The result is that in some cases the COSMOS cliff

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hazard zone is mapped across a beach and in other locations it cuts across headlands or promontories that may be associated with differences in geology, local rock hardness or other physical characteristics.

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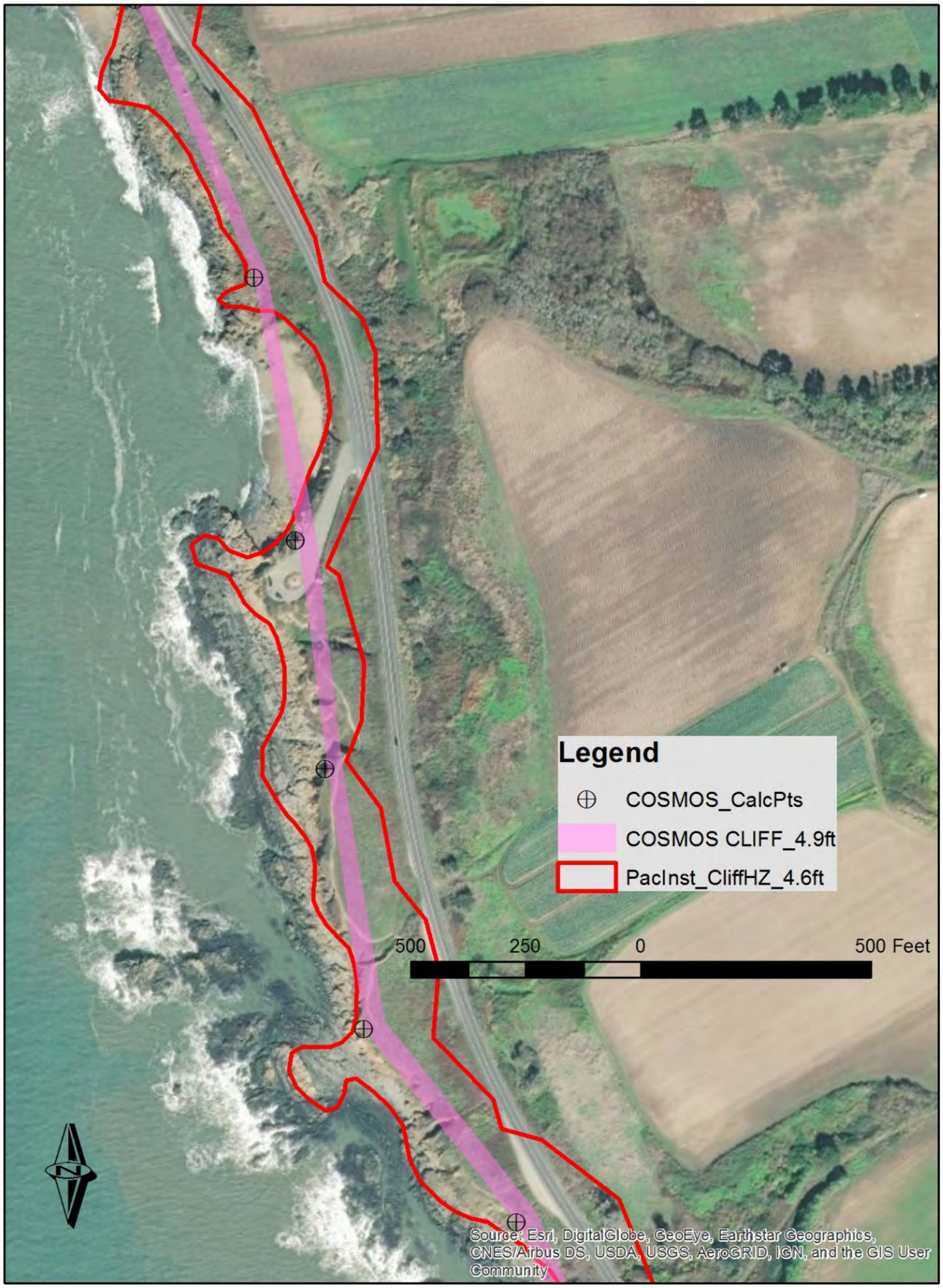

Figure 1. Representative comparison of Pacific Institute cliff erosion projections (in red) and COSMOS cliff erosion projections (in pink). The black circles outlined circles show the COSMOS calculation points.

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Dune Erosion

COSMOS COAST

COSMOS COAST is a shoreline change model that projects future position of a MHW shoreline based on a data assimilation of historic shoreline positions (Vitousek et al 2015). The model is based on trends of MHW shoreline change calculated at 100 m spaced alongshore transects. The projections of MHW shoreline position are not representative of actual dune erosion as dunes lie geomorphically at the back of the beach and the MHW shoreline is often at the ocean's edge or exceeded with even moderate amounts of wave run up.

For south San Mateo County it is unclear exactly which historic shoreline position data was included in the data assimilation but most likely it is based on a time series of perhaps 5 to 7 shorelines extracted from publicly available topographic lidar that date back to 1997. The COAST model also interpolates linearly between transects.

Pacific Institute

The Pacific Institute dune erosion model projects dune erosion hazards based on a geometric model of dune erosion (Komar et al 1998) and consistent with the FEMA guidelines for mapping of coastal hazards (FEMA 2005). The model projects future dune erosion based on the exceedance of total water elevations above the elevation of the toe of the dune (Revell et al 2011). The hazard zone represents future dune crest location and is mapped based on a translation of the foreshore beach slope and thus is sensitive to measurements of beach slope, toe elevation and total water level projections. The model could be considered a worst-case approach since it assumes that the dune will erode based on the maximum total water level elevation without consideration of the duration of the storm event.

Comparison

It is duly noted that this comparison is not a direct comparison of dune erosion since the models project the position of different reference features – COAST – MHW shoreline and Pacific Institute – dune crest. An example result of the dune erosion comparison can be seen in Figure 2. From the visual comparisons several observations were made.

1. The COAST model suffers from the same linear interpolation issue as the COSMOS Cliff mapping that do not provide spatially explicit results along an irregular coast such as that found in South San Mateo County. In some cases the results do not even match the shoreline.
2. It appears that the COAST model does not interact with the Cliff model as often the shoreline position is projected to be inland of the cliff erosion hazard zone.
3. The Pacific Institute erosion projects are high and do not consider changes in geology or landform once the dune is completely eroded.

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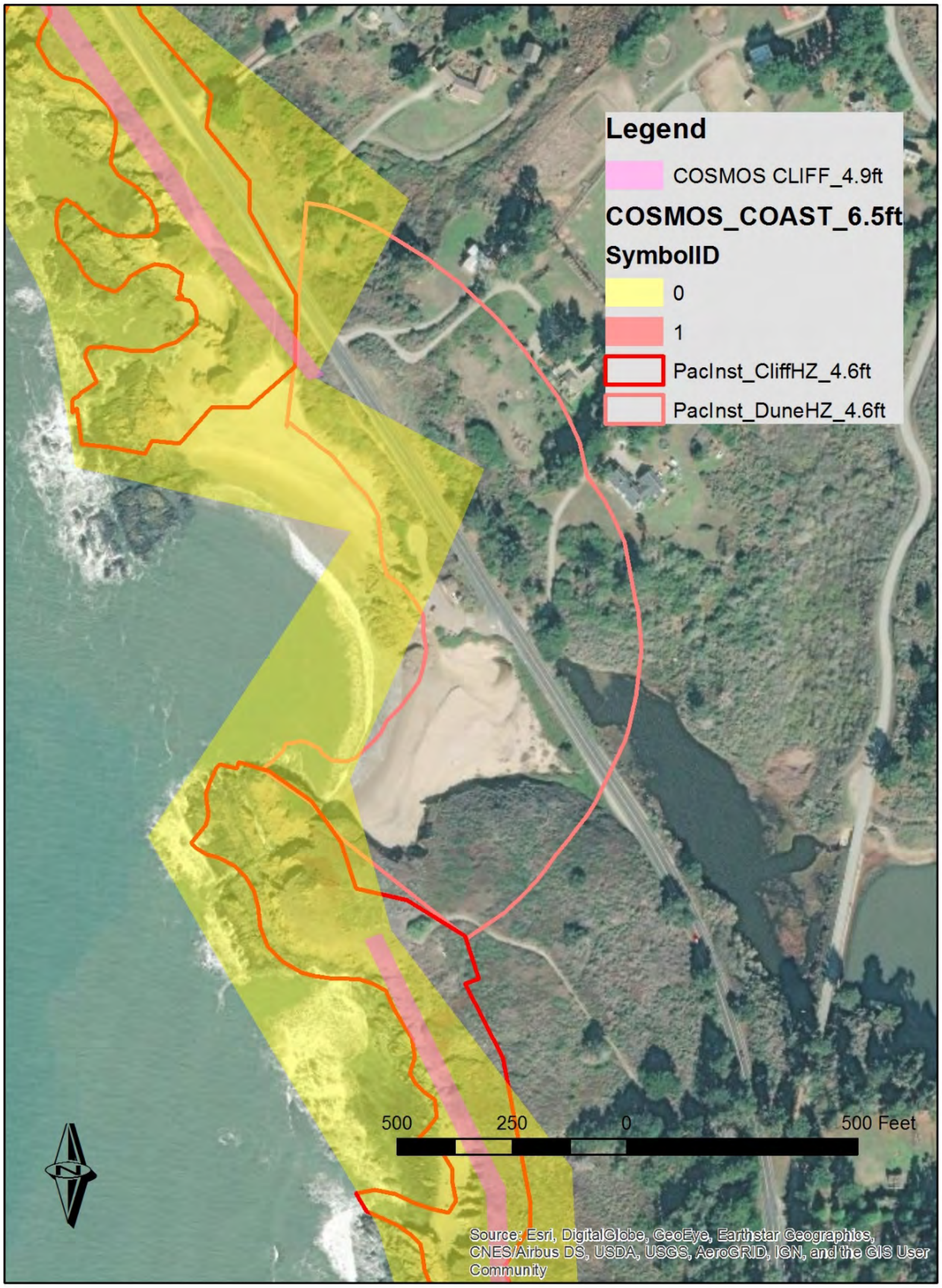

Figure 2. Comparison between COSMOS COAST MHW shoreline changes (in yellow) and Pacific Institute Dune erosion projections (outlined in pink) at Bean Hollow State Park. Also shown are the COSMOS (in pink) and Pacific Institute Cliff projections (outlined in red). Note that the COSMOS COAST results are for a higher level of sea level rise and a different reference feature (shoreline versus dune crest and thus not directly comparable).

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Coastal Wave Flooding

COSMOS Wave

The COSMOS wave flooding hazards use an XBeach model on 100 meter spaced transects to calculate the extent of run up and storm induced erosion based on a specific time series of a storm. The mapping of flood hazards is based not on the maximum wave run up elevation and extent but rather on the elevation of the most likely flooding defined as a duration between 1 and 3 minutes of flooding during the storm event. This is often referred to as the dynamic wave set up elevation and is virtually impossible to observe or measure in the field. For the comparison the COSMOS Wave flooding for existing conditions and a 100 year wave event was used.

In addition to coastal wave induced flooding, the COSMOS storm wave flooding includes flood results from coastal confluence fluvial modeling associated with a precipitation event that is statistically most likely to occur at the same time as the 100 year wave event. Without specific technical documentation of the results from the Central Coast COSMOS results, it is difficult to know what the level of fluvial event is associated with this large wave run up event. From experiences in southern California, the fluvial event is usually around a 5 to 10 year recurrence interval. Thus, in some low lying areas (e.g. Pescadero),the combination of both the coastal confluence aspects (~5 to 10 year return period fluvial event), with the wave induced flooding complicates the interpretation of wave flood hazards as it is impossible to separate the two different physical processes in the current data format (Figure 3).

FEMA VE Zone

As described above, this federal regulatory flood map illustrates the projected location of high velocity wave run up flooding and the total water elevation (tides + wave run up) associated with the 1% annual chance storm event (FEMA 2005). However, the FEMA mapping does not include coastal storm erosion or sea level rise so the comparison is limited to existing conditions and a 1% annual chance storm condition.

Comparison

Overall, the COSMOS storm wave flooding does a good job in replicating the FEMA VE zone along the relatively narrow beaches in south San Mateo County. There are some exceptions in wider beach areas were even under a 100 year wave event the beach is not projected to flood. The largest deviation between the FEMA VE zone and the COSMOS Wave flooding is provided in Figure 3 and occurs along the beach north of the Pescadero Marsh entrance (Figure 3).

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Figure 3. Comparison of the COSMOS Wave and Coastal Confluence for a 100 year event and no sea level rise (in blue) with the FEMA VE Zone representing the 1% annual chance wave run up extent (blue/white hatching). Note that COSMOS Wave maps a likely flooding extent defined by a duration exceeding 90 seconds. Note the flood extents in the mouth of Pescadero Marsh resulting from the inclusion of the coastal confluence flooding.

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Coastal Confluence[3]

Coastal confluence flooding is a result of fluvial flooding occurring during elevated sea level or tailwater elevations that can slow fluvial discharge and back up flood waters causing greater extents and depths beyond normally anticipated flood levels. This climate induced phenomenon is not currently included in any FEMA regulatory flood mapping.

Department of Water Resources model

The California Department of Water Resources (DWR) developed statewide climate models and projection datasets to depict future precipitation, temperature and sea level conditions for California projected at years 2030 and 2070. The County of San Mateo commissioned a study by GEI to apply this data set to evaluating future fluvial and coastal confluence flood hazards across the County at a high spatial resolution. The model approach runs forecasted precipitation time series data through a Variable Infiltration Capacity (VIC) model to simulate future hydrologic conditions and changes at 2030 and 2070. Using these projections, a flood frequency analysis was conducted and used to calculate future 20 and 100 year rainfall intensities. Results of the future precipitation are turned into discharge and flood extents modeled using a 2D Hec-RAS model. Sea level rise was included using the medium-high sea level rise projections from the California Ocean Protection Council (2018). These projections indicated sea level rise of **0.8** feet by 2030 and **3.5** feet by 2070. Water level elevations at the ocean were provided from COSMOS for the corresponding sea level rise changes and incorporated as bottom boundary conditions in the HEC-RAS model. DWR data product also provides depth of flooding in 3 risk categories Low (1.5 – 3 feet), Medium (3-6 feet), and High (> 6 feet).

FEMA FIRM model

The FEMA regulatory FIRM map for existing 1% and 0.2 % annual chance fluvial flood events were used in the comparison of existing conditions.

Comparison

Comparison with the existing FEMA A Zones and X zones (0.2% annual chance), show that the DWR model resolved much more detailed modeling across the landscape at a much higher resolution. The higher resolution modeling shows many more of the smaller drainages across the south San Mateo coast. The improved DWR resolution shows the effects of culverts under Highway 1 causing backup upstream of the highway. In low lying areas such as Pescadero Marsh the confluence modeling shows expansion of the coastal confluence flood hazard zones outside of the designated FEMA flood hazard zones.

Groundwater

Groundwater modeling is not currently available from any source although COSMOS is developing a module which is in draft form. As presented in the July webinar to the County however the groundwater model based on draft results and webinar does not include the effect of bar built estuaries which complicate groundwater dynamics seasonally across each of the south San Mateo County estuaries and drainages.

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[3] Note that COSMOS also considers coastal confluence but that model projects fluvial flood hazards associated with the most likely fluvial discharge event associated with the 100-year wave event. Typically, this is around a 5 to 10 year recurrence interval which is not suitable for the vulnerability assessment due to the underprediction of flood hazard extents as mapped by FEMA FIRM maps.

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Recommendations

Coastal Erosion

Cliff Erosion The Team recommends the use of the Pacific Institute cliff erosion data to provide better spatial representation of hazards and be consistent with previous vulnerability assessments conducted in the County.

Dune Erosion The Team recommends the use of the Pacific Institute Dune Erosion data as it is the only available model which explicitly maps dune erosion and is consistent with previous vulnerability assessments conducted in the County.

Coastal Wave Flooding The Team recommends the use of the COSMOS Wave flooding results, however some consideration must be given to separating out the wave flood hazards. Two potential options to accomplish this:

1. The County request the USGS to separate out the coastal confluence component from the wave induced flooding, or
2. the Team will have to develop a method to clip portions of the confluence hazards perhaps by using the limit of the FEMA VE zone or some other method TBD.

Coastal Confluence The Team recommends the use of the DWR coastal confluence flood model results for all sectors assets and infrastructure lower than 20 feet in elevation. Given the high resolution detail in the modeling outputs that closely match the existing FEMA FIRM maps, and the flood depth attribute data useful for supporting the economic damage assessment of coastal confluence flood hazards, the Team recommends the use of the DWR data as is.

Groundwater The Team recommends a wait and see approach. Should the CoSMoS groundwater results become available with appropriate technical documentation then it may be possible to evaluate the result using some low lying hydraulically unconnected flood model data, or potentially a bathtub elevation model for the bar built estuaries based on the governing beach berm crest elevations.

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MEMORANDUM

To:	Hilary Papendick, San Mateo County
From:	Craig Jones, David Revell, and Matthew Jamieson, Integral Consulting
Date:	6/28/2021
Subject:	Methodology for projecting dune erosion extents for sea-level rise scenarios for the South San Mateo County Coast

BACKGROUND AND PURPOSE

The determination of beach and dune response under sea-level rise is a critical component in mapping the hazards of the South San Mateo County coast. While previous efforts regarding mapping are available from the Pacific Institute (PI) and the USGS COSMOS modeling, the resolution of the assessments and/or transect locations are at a larger resolution than some of the features of interest for the south county coast (e.g. Bean Hollow Beach). Following various coastal hazard erosion model comparisons and substantial delays in the project schedule waiting for COSMOS data, a lack of site specific dune erosion projections were identified as a critical data gap. Integral working with the County Office of Sustainability identified that revised coastal dune erosion hazard modeling and mapping was required. This memo documents the methods used to calculate potential dune erosion extents consistent with the sea level rise scenarios identified for the South San Mateo County Sea Level Rise Vulnerability and Adaptation Assessment.

METHODOLOGY

Given the data gaps, a hybrid approach was developed that utilized peer reviewed coastal erosion and sea-level rise response calculations. These methods were refined from the original Pacific Institute dune erosion modeling (Revell et al 2011) and dune erosion methods considered in the U.S. Army Corps of Engineers Coastal Engineering Manual (2006) and revised FEMA Pacific Coast Flood Guidelines (FEMA 2018).

Both of these methods considered two contributions to erosion affecting a sandy shoreline episodic storm and long-term sea level rise erosion. Episodic erosion is storm-induced erosion resulting from short duration, high intensity storm events. Shoreline profile changes during storms often result in significant erosion, retreat, or removal of backshore dunes and may result in greater landward propagation of waves and flooding. Chronic erosion is associated with slow, long-term processes such as gradual shoreline change associated with: (1) sea-level rise, (2) land subsidence, (3) changes in sediment supply due to watershed modifications, coastal structures, development, and (4) decadal adjustments in rainfall, runoff, and wave climate associated with global warming. The FEMA guidance for episodic erosion is based on well-accepted coastal engineering and science and is appropriate for use in hazards determination. Chronic erosion due to sea-level rise, which is not addressed directly by FEMA, can be further considered using standard coastal engineering methods outlined in the U.S. Army Corps of Engineers Coastal Engineering Manual (2006). The Pacific Institute method combined both of these methods into projecting dune erosion hazards with sea level rise (Revell et al 2011). Overall, there is widespread use and validation of these methods in the peer-reviewed literature providing confidence in the use of the hybrid approach outlined below for the South County coast.

BEACH TRANSECTS

The sandy shorelines along the South County coast can be generally described by a typical dune backed beach profile (Figure 1). The summer condition builds a higher elevation berm along the shoreline while the most likely winter profile (MLWP) during non-storm condition has sand moved to offshore depositional bars during higher average wave conditions. The MLWP for any given mean sea-level stage is the baseline for determining the episodic erosion during a storm event.

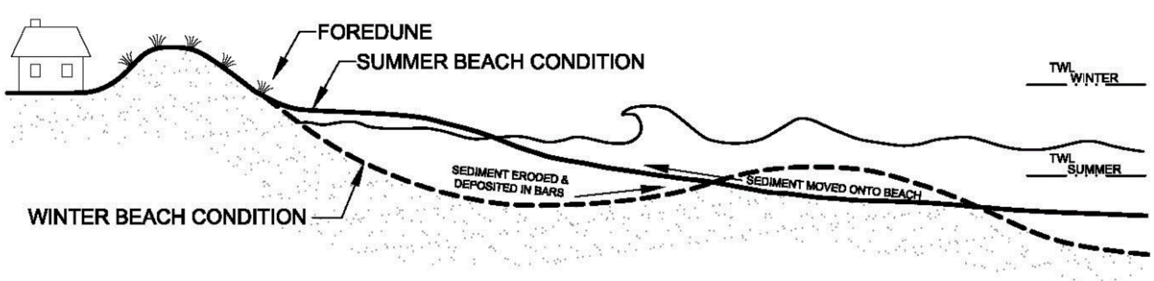

Figure 1. Typical sandy dune backed beach profile for summer and winter conditions (adapted from Griggs, 1985).

Typically, erosion assessments are conducted for transects as shown in Figure 1. The erosion along individual transects at the appropriate scale can be used to reconstruct the eroded shoreline conditions. The challenge for assessment is determining the scale of extraction. As well documented in the coastal literature, shoreline erosion during storm events is highly variable on scales on the order of hundreds of meters along shore. The scale of transect across shore for erosion analysis necessarily must capture these variations at transect scales of less than 100s of meters.

EROSION CALCULATION

Erosion is a complex and variable process controlled by site conditions (e.g., grain size, profile) and storm conditions (e.g., wave heights, water levels). While highly resolved mechanistic models are available to asses coastal erosion, these models require intensive resources to deploy and some times do not offer an increased level of confidence or certainty for long-term sea-level rise scenarios. Geometric erosion models commonly applied in coastal engineering applications offer a consistent, objective, and simplified approach to performing storm-induced and sea-level rise erosion on sandy coasts (CEM 2008; Revell et al 2011; FEMA 2018).

For episodic erosion, a geometric model was developed by Komar et al. (1999) to estimate dune erosion. The model was further modified by McDougal and MacArthur (2004) to provide estimates of beach profile recession due to large storm events and has been validated in numerous peer-reviewed applications (Revell et a 2011; FEMA 2018). Erosion is calculated due to changes in the total water level and beach slope which can readily be determined from previous COSMOS and FEMA work as well as the transects extracted as part of this effort. The underlying assumption for the application along the South Coast is that the transects are representative of the MLWP and that erosion during a large wave event and water-level changes are consistent with the behavior of a typical sandy coast.

The shoreline profile is defined by the beach face slope, *m*, the beach-dune juncture elevation, E_j, and cross-shore location of the beach-dune juncture, y_j as shown in Figure 2. The juncture elevation occurs at the total water level (TWL), the sum of the stillwater level (SWL), wave setup, and runup. The sum of the astronomical tide, coastal processes due to El Niño, surge, setup, and runup is obtained from the updated FEMA regulatory flood maps.

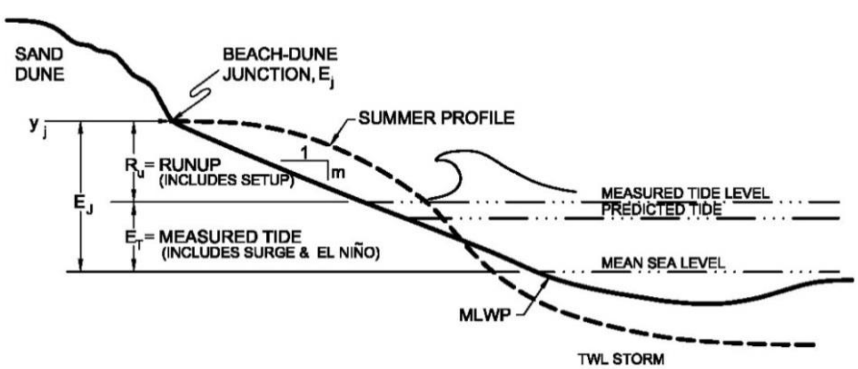

Figure 2. Definition of terms in the geometric erosion modeling (FEMA 2018).

Summary of the Erosion Calculation

The first step for determining eroded beach profiles is to estimate the MLWP for each transect (shore profile). The profile is characterized by the beach face slope in the swash zone, m and the beach-dune juncture elevation and cross-shore location, E_j and y_j MLWP as shown in Figure 2. The juncture elevation in is taken to occur at the maximum extent of the still water plus the total runup. The TWL includes all processes that influence the water surface elevation such as the astronomical tide, surge, and El Niño. The juncture elevation is estimated for the typical winter wave conditions as:

$$E_j = (R + E_T)$$

where the runup includes the setup and the tide includes surge and El Niño. These values were computed using a Python computer program designed to assess each profile and extract the relevant parameters. The recession/erosion in the FEMA (2018) model due to E_{jStorm} is calculated as the erosion into the MLWP. The maximum potential recession is given by:

$$R_{Storm} = \frac{E_{jStorm} - E_{jMLWP}}{m}$$

where E_{jStorm} and E_{jMLWP} correspond to beach-dune elevations evaluated at the storm conditions for the MLWP.

To accommodate sea-level rise, the cross-shore location of the juncture point, y_j changes with each sea-level rise scenario. The y_j is adjusted for each sea-level rise scenario and includes the recession of the MLWP due to sea-level rise (see below). A summary of the steps for determining storm-induced beach profile changes for the sandy beaches of the South Coast using the geometric erosion modeling are as follows.

Develop Data:

1. Obtain wave and water-level data necessary to define the waves and water levels for the largest storms. (Sources: FEMA, COSMOS)

2. Determine existing sandy shoreline location and conditions.

3. Obtain beach profile data from available topographic LIDAR required to establish the MLWP for transects along each sandy reach of coast.

4. Obtain historical beach profile data required to qualitatively evaluate local hot spot erosion and use the data to inform addition of transects for evaluation.

Determine Erosion During Storm Event:

1. Determine TWL as required to calculate the potential recession (erosion) for the storm, R_{storm} (defined below)

2. Determine storm duration recession reduction factor for the storm

3. Save erosion conditions corresponding to the largest annual TWL storm event

Sea-level Rise Considerations

A common method for determining sandy shoreline adaptation to sea-level is to use the Bruun. The assumption in the Bruun Rule is that a sandy shoreline is not a fixed geologic structure, but is the result of the coastal response to recent hydrodynamic conditions. Bruun proposed that the slope of the equilibrium profile Z_{eq} would remain a fixed response to those conditions. Therefore, the profile moves to keep the same position with respect to a changing sea-level.

The equilibrium profile is derived from a large number of beach profiles of the Californian and the US Atlantic and Gulf coasts. Bruun (1962) and Dean and Mauremeyer (1983) derived an equilibrium profile (often called the Bruun profile) of the form:

$$h(x) = A x^{2/3}$$

where h is the water depth, x the cross-shore distance, and A is a coefficient depending on the sediment settling velocity w [m/s], $A \approx 0.5w^{0.44}$. For the South Coast we assume that the fall velocity is typically medium sand across the profiles which aligns with site observations. By using the equilibrium profile under each sea-level rise scenario, the new MLWP can be imposed for the episodic erosion calculation. The combination of sea-level rise and episodic erosion are used to compute the total shoreline change under each scenario for each transect.

SUMMARY

The determination of beach and dune response under sea-level rise scenarios is a critical component in mapping the hazards of the South San Mateo County coast. The hybrid approach developed and outlined herein utilizes standard coastal erosion and sea-level rise response calculations informed with the previous Pacific Institute, COSMOS and FEMA assessments provides the optimal method for the determination of the response of the South Coast sandy shorelines to sea-level rise.

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