AGENDA

COMMISSION ON THE ENVIRONMENT

REGULAR MEETING

WEDNESDAY, DECEMBER 6, 2017
6:00 PM
CITY COUNCIL CHAMBERS
420 CAPITOLA AVENUE, CAPITOLA, CA 95010

CALL TO ORDER AND ROLL CALL

Commissioners: Cathlin Atchison, Jacques Bertrand, Bella Hammond, Alyssa Millwood-Donahue, Kailash Mozumder, Megan Sixt, and Chair Peter Wilk

ORAL COMMUNICATIONS

The Chair may announce and set time limits at the beginning of each agenda item.
The Committee Members may not discuss Oral Communications to any significant degree, but may request issues raised be placed on a future agenda.

APPROVAL OF MINUTES – May 24, 2017 and June 20, 2017 meeting minutes

DISCUSSION

1. Coastal Climate Change Vulnerability Presentation – Ross Clark
2. Review 2018 meeting schedule

ITEMS FOR NEXT AGENDA

ADJOURNMENT to January 24, 2018

Notice: The Commission on the Environment meets on the fourth Wednesday of each month at 6:00 PM in the Community Room located at 420 Capitola Avenue, Capitola.

Agenda and Agenda Packet Materials: The Commission on the Environment Agenda is available on the City's website: *www.cityofcapitola.org/* on Friday prior to the Wednesday meeting. If you need additional information please contact the Public Works Department at (831) 475-7300.

Americans with Disabilities Act: Disability-related aids or services are available to enable persons with a disability to participate in this meeting consistent with the Federal Americans with Disabilities Act of 1990. Assisted listening devices are available for individuals with hearing impairments at the meeting in the City Council Chambers. Should you require special accommodations to participate in the meeting due to a disability, please contact the City Clerk's office at least 24-hours in advance of the meeting at 831-475-7300. In an effort to accommodate individuals with environmental sensitivities, attendees are requested to refrain from wearing perfumes and other scented products.

DRAFT MINUTES

Commission on the Environment

Regular Meeting

May 24, 2017

Peter Wilk called the meeting to order at 6:00 p.m.

CALL TO ORDER AND ROLL CALL

Commissioners Present: Jacques Bertrand, Bella Hammond (student member), Megan Sixt, and Chair Peter Wilk
Commissioners Absent: Cathlin Atchison, Alyssa Millwood-Donahue, Kailash Mozumder
City Staff Present: Steve Jesberg, Danielle Uharriet
Community Members Present: None

ORAL COMMUNICATIONS - None

APPROVAL OF MINUTES – Jacques Bertrand made a motion to approve the March 22, 2017 meeting minutes Peter Wilk seconded the motion. Motion passed 2-0, Megan Sixt abstained.

DISCUSSION

1. Work Program Updates
   a. Eco Walk/Tour

Peter Wilk will meet with Kailash Mozumder to discuss and review the sites, and stops proposed for the tour. Steve Jesberg encouraged the Commission to work quickly to define the project scope, route and to begin working on the narratives for the walk. Staff will discuss the project scope with the artist, and if interested, request a bid proposal for the Whale Tail grant application.

   b. Peery Park Habitat Restoration Project

An ivy removal work day was held on April 30th. There were four new volunteers, seven participants total, who made a clean-up of the upper flat areas of the park, removing new growth since the last event in 2016. The removal effort should continue with training volunteers on the Redtree hill area, while Staff completes and submits the 1602 consult permit to California Fish and Wildlife. Peter Wilk will contact Mr. McMenamin to schedule the next work day. Bella Hammond recommended contacting Mr. Roberts at New Brighton Middle School to request posting the event fliers on campus.

   c. McGregor Park Enhancement Project

Jacques Bertrand is compiling a detailed description of the invasive eucalyptus grove to submit to John Laird, California Secretary for Natural Resources. Mr. Bertrand suggested working jointly with State Parks to save the oak trees in the area.
Megan Sixt offered to ask State Parks who the appropriate liaison would be to assist with this effort.

   d. HERO Energy Savings/Energy Efficiency Flyer

Staff reported the City has funds available to offer grants to income eligible, senior citizens and disabled persons for energy efficiency upgrades. The Community Development Department has mailed ~3000 fliers to mobilehome owners, townhouse and condo property owners. There has been a tremendous response to the outreach effort, and now the Housing Authority is responding to interested parties, distributing applications and moving forward with the program.

   e. Central Coast Climate Collaboration (4C's)

Jacques Bertrand presented information about the steering committee nominations, summer conference, goals, participating organizations, and bylaws.

2. Other Items
   a. Recycle/Repair/Fix It Event – July 29, 2017

Jacques Bertrand suggested the Commission promote the event and consider participating. He requested fliers be available at the public counter.

   b. Fishing Line Disposal Units

Megan Sixt offered to contact Surfrider Foundation to obtain the specifications of the fishing line disposal units, such as the size, signage, number of units suggested for placement, who is responsible for emptying and maintains the units. Staff requested a photo of the unit and signage, similar to the photo in the agenda packet. The information should be transmitted to staff who will schedule the item for a future City Council agenda to approve the units and the locations for placement.
Jacques Bertrand made a motion for Megan make the presentation to the City Council. The motion was seconded by Peter Wilk. The motion passed 3-0.

ITEMS FOR NEXT AGENDA - None

ADJOURNMENT to Workshop on June 28, 2017

Approved at the meeting of July 26, 2017

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Danielle Uharriet
Environmental Projects Manager

DRAFT MINUTES

Commission on the Environment

Special Meeting

June 20, 2017

Peter Wilk called the meeting to order at 5:30 p.m.

CALL TO ORDER AND ROLL CALL
Commissioners Present: Cathlin Atchison, Jacques Bertrand, Kailash Mozumder, and Chair Peter Wilk
Commissioners Absent: Megan Sixt
City Staff Present: Steve Jesberg, Danielle Uharriet
Community Members Present: None

DISCUSSION

1. Consider Recommendations to the City Council on the Climate Mayors and Paris Agreement.

Staff distributed a revised copy of the City Council agenda report, including the draft resolution.

Following a lengthy discussion regarding the pros and cons of a local agency making a statement regarding a national political issue, Cathlin Atchison made a motion to recommend to the City Council that they direct the Mayor to join the Climate Mayors and approve a related resolution in support of the Paris Agreement as recommended by the Climate Mayors network. The motion was seconded by Kailash Mozumder. The motion passed 3-0, Jacques Bertrand abstained.

ADJOURNMENT to Workshop on June 28, 2017

Approved at the meeting of July 26, 2017

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Danielle Uharriet
Environmental Projects Manager

CAPITOLA CITY COUNCIL AGENDA REPORT

MEETING OF OCTOBER 12, 2017

FROM: Community Development

SUBJECT: Coastal Climate Change Vulnerability Report

RECOMMENDED ACTION: Accept report.

BACKGROUND: The County of Monterey was awarded a $150,000 grant from the California Coastal Conservancy Ocean Protection Council in November 2013 to study regional sea level rise vulnerability and evaluate potential adaptation responses. The City of Capitola and the County of Santa Cruz partnered on the study along with the Central Coast Wetlands Group, Center for Ocean Solutions, Nature Capital Project, and the Nature Conservancy.

The grant-funded study was concluded in June 2017. Findings and results for Capitola are presented in a Coastal Climate Change Vulnerability Report for Capitola (Attachment 1).

DISCUSSION: The City of Capitola has taken a number of actions over the past several years to better understand and address the effects of climate change, including preparation of a Sea Level Rise Assessment (2012), an updated Local Hazard Mitigation Plan (2012), a baseline greenhouse gas inventory (2013), the General Plan Update (2014), and adoption of the City's first Climate Action Plan (2015). The attached Coastal Climate Change Vulnerability Report builds upon these previous efforts and provides additional hazard-specific forecasts for the long-term impacts of sea level rise. The information in the report is intended to facilitate future City efforts develop sea level rise adaptation strategies.

The study evaluated the anticipated effects of sea level rise on critical coastal infrastructure and public and private improvements over three time horizons: 2030, 2060, and 2100. The study considered effects resulting from different types of coastal hazards, including rising tides, storm flooding, river flooding, and erosion. The study also provides estimates of the economic value of vulnerable infrastructure and improvements and offers possible adaptation strategies the City may consider in future planning efforts.

Sea level rise projections used in the report were based on the results of a 2012 National Research Council study. Unlike past efforts, this study also evaluated the effects of Soquel Creek flooding in conjunction with the effects of sea level rise. The study also distinguishes the potential impacts and time horizons of each type of coastal hazard to help the City identify appropriate adaptation strategies. For example, flooding from rising tides is a brief event that results in temporary impacts which can often be repaired. Conversely, bluff failure resulting from coastal erosion results in permanent impacts that require more proactive adaptation measures to effectively mitigate.

Key findings of the study include:

- The number of properties and improvements vulnerable to coastal hazards in 2030 is similar, but slightly higher than current conditions.
- The number of vulnerable properties and improvements increases significantly by 2060.
- By 2060, all 12 of the City's public coastal access ways may be compromised.
- By 2060, projected flood water depths along the Soquel Creek pathway are estimated to be as much as 8 feet.
- Cliff Drive will be vulnerable to bluff failure by 2060 if armoring is not replaced.
- By 2100, most of the beach may be lost if Esplanade businesses remain in their current locations.
- As many as 221 properties may be threatened by bluff failure by 2100 if armoring is not replaced or introduced.
- By 2100, much of the Village may be periodically flooded during winter storms and high river discharges.
- By 2100, over $395 million of properties, transportation, and utility infrastructure will be at risk from coastal hazards.

The number of properties and improvements vulnerable to coastal hazards increases over time as sea levels continue to rise and existing coastal armoring fails. For the purposes of the study, it was assumed that all existing coastal armoring (sea walls, revetments, rip rap, jetties, etc.) would no longer be present by 2060.

The following three tables provide a summary of assets vulnerable to coastal hazards (Table 1), critical public facilities vulnerable to coastal hazards (Table 2), and the projected valuation of properties and infrastructure at risk from various coastal hazards (Table 3).

TABLE 1: Assets Vulnerable to Cumulative Coastal Hazards by Time Horizon

Asset	2010	2030 (with armor)	2060 (no armor)	2100 (no armor)
Buildings	206	219	295	370
Roads	6,473 feet	7,012 feet	13,316 feet	17,138 feet
Rail	422 feet	422 feet	2,076 feet	3,261 feet
Stormwater Pipes	8,039 feet	8,686 feet	11,864 feet	11,992 feet
Sewer Pipes	12,636 feet	13,452 feet	19,819 feet	23,901 feet
Water Mains	12,857 feet	13,774 feet	19,360 feet	23,339 feet

TABLE 2: Critical Public Facilities Vulnerable to Coastal Hazards by Time Horizon

Facility	Coastal Hazard Type	Projected Impact Year
City Hall/Police Station	River Flooding	2030
Fire Station	River Flooding	2030

	Storm Flooding	2060
Capitola Wharf	Storm Flooding Erosion	2030 2060
Capitola Beach	Erosion River Flooding Storm Flooding	2030 2030 2060
Cliff Drive and Stockton Bridge	Erosion	2060
Esplanade	Storm Flooding River Flooding Erosion	2010 2030 2060
Prospect Avenue	Erosion	2100

TABLE 3: Total Value of Capitola Properties and Infrastructure at Risk

Asset	2010	2030 (with armor)	2060 (no armor)	2100 (no armor)
Property Losses	$185,850,000	$200,150,000	$275,040,000	$344,210,000
Transportation	$1,930,600	$2,081,520	$4,309,760	$5,711,720
Utility Infrastructure	$24,153,996	$24,852,462	$38,313,598	$45,824,072
Total	$211,934,596	$227,083,982	$317,663,358	$395,745,792

Next Steps

Staff recommends the City Council accept the report. No immediate action is currently proposed; however, it is anticipated that the study and its findings will serve as a foundation for future adaptation planning and preparation.

FISCAL IMPACT: None.

ATTACHMENTS:

1. Capitola Coastal Climate Change Vulnerability Report

Report Prepared By: Rich Grunow
Community Development Director

Coastal Climate Change Vulnerability Report
October 12, 2017

Reviewed and Forwarded by:

Jamie Goldstein, City Manager 10/6/2017

City of Capitola
Coastal Climate Change Vulnerability Report

Image: L. Engelking

JUNE 2017

CENTRAL COAST WETLANDS GROUP

MOSS LANDING MARINE LABS | 8272 MOSS LANDING RD, MOSS LANDING, CA

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Prepared by

Central Coast Wetlands Group at Moss Landing Marine Laboratories

Technical assistance provided by

ESA

Revell Coastal

The Nature Conservancy

Center for Ocean Solutions, Stanford University

Prepared for

City of Capitola

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CCWG
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Summary of Findings

This hazard evaluation is intended to provide a predictive chronology of future risks to benefit local coastal planning and foster discussions with state regulatory and funding agencies. Estimates of the extent of assets at risk of various climate hazards were made using best available regional data. This approach allows planners to understand the full range of possible impacts that can be reasonably expected based on the best available science, and build an understanding of the overall risk posed by potential future sea level rise. The hazard maps provide projected hazard zones for each climate scenario for each of the three planning horizons. For clarity, this report focuses the hazard analysis on a subset of those scenarios, recommended by local and state experts.

Key findings for the City of Capitola include:

- Infrastructure closest to the beach will continue to be impacted by the force of waves, the deposition of sand, kelp and other flotsam, and by floodwaters that do not drain between waves.
- Infrastructure further inland is most vulnerable to flooding by a combination of ocean and riverine sources.
- Infrastructure identified as vulnerable to coastal flooding by 2030 is similar to that which is currently vulnerable.
- Total property values at risk from the combined hazards of coastal climate change for 2030 were estimated at $200 million.
- Property value at risk may increase to $275 million dollars by 2060. That value is reduced by approximately $50 million dollars if current coastal armoring is replaced or upgraded.
- By 2060 use of all 12 public access ways may be restricted due to various coastal climate vulnerabilities.
- Projected flood water depths along the river walkway are estimated to be as much as 8 feet by 2060.
- Cliff Drive remains a key western access road into the downtown area and is vulnerable to cliff erosion by 2060 if coastal armoring is not replaced.
- By 2100 most of the beach may be lost due to higher sea levels and beach erosion if back beach structures are rebuilt in their current locations.

- As many as 221 properties are within the 2100 bluff erosion zone if protective structures are not maintained or replaced.
- By 2100 SLR and Fluvial models used in this analysis project that much of the downtown area may be periodically flooded during winter storms and high river discharges.
- By 2100 tidal inundation within portions of the downtown area may become a serious challenge, risking 23 residential and 23 commercial buildings to monthly flooding.
- By 2100, portions of Capitola may be too difficult and costly to protect from the combined hazards of Coastal Climate Change.

This study confirms that coastal flooding will remain a primary risk to low-lying areas of Capitola Village. This study also suggests that river flooding may be of greater risk to the community than previously realized and significant investments will be required to protect all public and private infrastructure from future erosion risks. Establishing strategic managed retreat policies early will likely best enable the long-term implementation of these policies and ensure long term sustainability for the community.

1. Introduction

1.1 Project Goals

This report was funded by The Ocean Protection Council through the Local Coastal Program Sea Level Rise Adaptation Grant Program. This grant program is focused on updating Local Coastal Programs (LCPs), and other plans authorized under the Coastal Act[1] such as Port Master Plans, Long Range Development Plans and Public Works Plans (other Coastal Act authorized plans) to address sea-level rise and climate change impacts, recognizing them as fundamental planning documents for the California coast.

This project will achieve three key objectives to further regional planning for the inevitable impacts associated with sea-level rise (SLR) and the confounding effects of SLR on fluvial processes within the City of Capitola. This project will:

1. Identify what critical coastal infrastructure may be compromised due to SLR and estimate when those risks may occur;
2. Identify how fluvial processes may increase flooding risk to coastal communities in the face of rising seas; and
3. Define appropriate response strategies for these risks and discuss with regional partners the programmatic and policy options that can be adopted within Local Hazard Mitigation Plan and LCP updates.

This report is intended to provide greater detail on the risks to the city from coastal climate change during three future time horizons (2030, 2060 and 2100). Risks to properties were identified using the ESA PWA Monterey Bay Sea Level Rise Vulnerability Study[2] layers developed in 2014 using funding from the California Coastal Conservancy.

The City of Capitola adopted a Hazard Mitigation Plan in May 2013.[3] This plan "identifies critical facilities that are vital to the city's and other local agencies' response during a natural disaster, particularly those that are currently vulnerable or at risk, assesses vulnerability to a variety of natural disasters

[1] State of California. California Coastal Act of 1976. http://www.coastal.ca.gov/coastact.pdf

[2] ESA PWA. 2014. Monterey Bay Sea Level Rise Vulnerability Study: Technical Methods Report Monterey Bay Sea Level Rise Vulnerability Study. Prepared for The Monterey Bay Sanctuary Foundation, ESA PWA project number D211906.00, June 16, 2014

[3] RBF and Dewberry. 2013. City of Capitola Local Hazard Mitigation Plan. Prepared for the City of Capitola.

(earthquake, flood, coastal erosion, etc.), and identifies needed mitigation actions." Sea level rise is noted as a significant hazard to the city. The plan also sets goals to protect the city from sea level rise. Potential actions listed include integrating the results of this City of Capitola Coastal Hazards Vulnerability Report into the Local Hazard Mitigation Plan risk assessment and incorporating climate change risks and climate adaptation options into the general plan.

1.2 Study Area

The planning area for Capitola's Local Coastal Program encompasses the Coastal Zone within the City of Capitola. However, because the vulnerability study includes a fluvial analysis for Soquel Creek, the study area for the purpose of this report extends outside of the Coastal Zone along Soquel Creek (Figure 1).

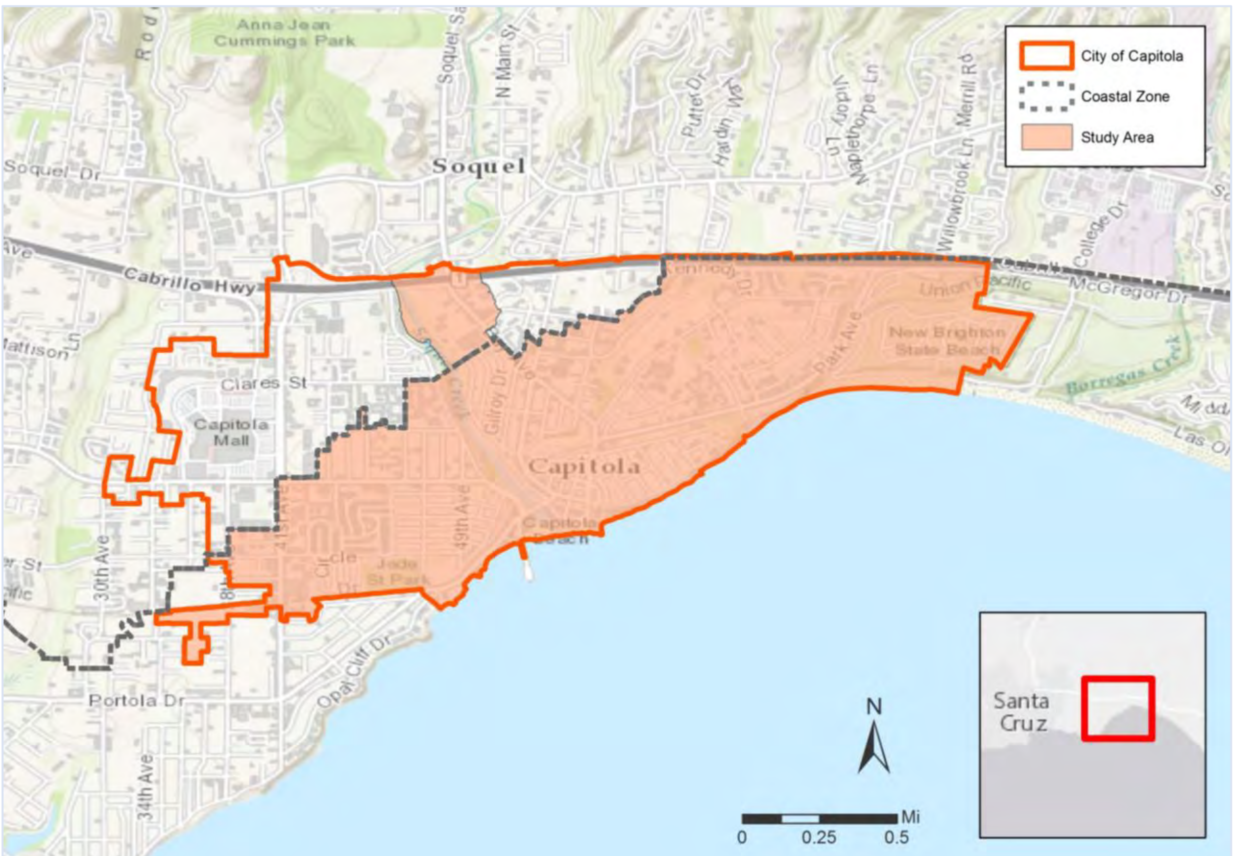

Figure 1. City of Capitola Vulnerability Assessment Study Area with Soquel Creek floodplain

2. Community Profile

2.1 Setting and Climate

Capitola is a small coastal city located in Santa Cruz County in California's Monterey Bay Area (figure 1.). The town was founded in the late 1800's first as a vacation resort. Capitola's main beach is located at the mouth of the Soquel Creek, buffered by coastal cliffs and pocket beaches to the East and West. The Capitola Esplanade provides a pleasant stroll along a row of restaurants, historic homes and small shops and unique vistas of Monterey Bay. In September, Capitola hosts a number of beach front events (Begonia Festival and the Capitola Art & Wine Festival) along the Esplanade.

According to the United States Census Bureau[5], the city has a total area of 1.7 square miles, of which 1.6 square miles is land and 0.1 square miles (5%) is water of Soquel Creek. Capitola's climate is mild with summer temperatures in the mid-70s and winter temperatures in the mid-50s. Capitola has an average of 300 sunny days a year with low humidity for a coastal city. Average rainfall is 31 inches per year, with most of the rainfall occurring between November and April.[4]

2.2 Demographics

The community has a population of 10,189 residents, 52.4% female and 47.6% male. 80.3% identify as white, 1.2% identify as black, 4.3% identify as Asian, and 19.7% identify as Hispanic or Latino (of any race). The median household income is $56,458, and 7.1% of the civilian workforce is unemployed, with 7.4% of people under the poverty line. 92.7% of people have a high school diploma, and 38.3% have a bachelor's degree or higher.[5]

2.3 Community Resources and Assets

Land Use

Critical Facilities*:* Capitola's Police and Fire Stations, as well as City Hall, are located downtown, in close proximity to the beach and the Village. Emergency shelters are located at Jade Street Community Center and New Brighton School, and the Public Library is used as a backup emergency response center. There are several storm and wastewater pump stations, one of which is located in Esplanade Park.

[4] National Oceanic and Atmospheric Administration. NowData – NOAA Online Weather Data. Retrieved from http://w2.weather.gov/climate/xmacis.php?wfo=ilx (Aug 6, 2016)

[5] United States Census Bureau. 2015. American Community Survey 5-Year Estimates. Retrieved from https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml (April 2, 2016)

Capitola Village: The downtown commercial and visitor serving district of Capitola supports about 45 tourist shops and 27 other businesses, 20 restaurants and 10 cafes, 4 hotels, and 30 vacation rentals (28 listed).[6] The Village is a true mixed-use district with a diversity of visitor-serving commercial establishments, public amenities, and residential uses.[7,8] Capitola has a popular beach and waterfront area, with the beach area used for tourism, junior lifeguarding, surfing, and more.

Capitola Wharf: The Wharf is a popular destination for fishermen. With its restaurant and great views of Capitola and the ocean, the wharf is popular with tourists and provides access to boat rentals and boat moorings offshore.

Historical Buildings and Districts*:* Based on a 1986 architectural survey of structures prior to 1936, that had retained architectural integrity, Capitola has approximately 240 buildings that "best represented traditional architectural styles locally or the community's vernacular architecture." As a result of the survey, three National Register Historic Districts were established in Capitola in 1987: Venetian Court District, Six Sisters/Lawn Way District, and Old Riverview Historic District.[9]

Recreation and Public Access

Beaches and Parks*:* Capitola Beach is a popular tourist destination and is in close proximity to Capitola Village's shops and restaurants, and the Capitola Wharf. The beach (averaging 5.8 acres of summer sand) supports numerous sports and community events including junior lifeguards program, surfing lessons, sand castle contests, volleyball and other beach activities. There are eight City parks in Capitola, totaling 18 acres, including Monterey Avenue Park, Noble Gulch Park, Peery Park, Soquel Creek Park, Jade Street Park and Esplanade Park. New Brighton State Beach is also located within Capitola.

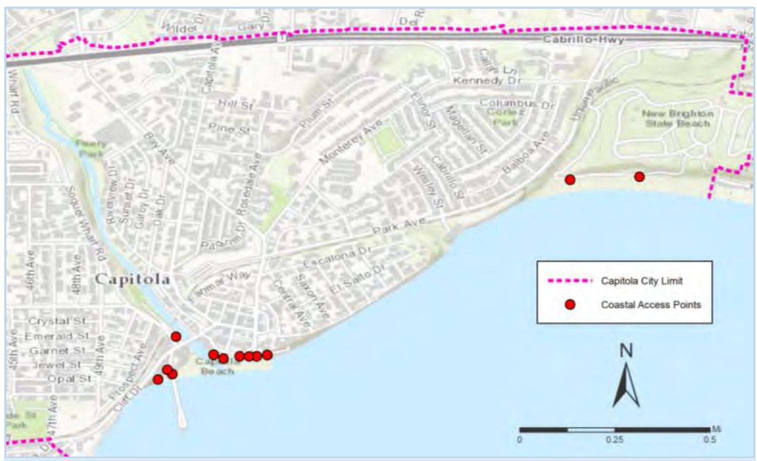

Figure 2. Coastal access points within the City of Capitola

Coastal Access: Defined coastal access points (with specific access ways to coastal resources) were mapped specifically for this project (Figure 2). There are two stairway coastal access ways and one partially paved ramp near the wharf that are used extensively by the public to reach Capitola beach. The low wall along the Venetian Court allows easy access to

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[6] Capitola Village Business Industry Association. Capitola Village. Retrieved from www.capitola village.com (March 2, 2016)

[7] City of Capitola. 2014. Capitola General Plan.

[8] For the purpose of this analysis Capitola building land use was cross-walked with Santa Cruz County and Monterey County land uses so that the analysis could be consistent between jurisdiction, however many of the buildings in the village are actually designated as mixed-use by the City of Capitola.

[9] Swift, C. 2004. Historical Context Statement for the City of Capitola. Prepared for City of Capitola Community Development Department.

the beach along its entire stretch. There are numerous access ways along the Esplanade, all of which can be blocked during winter storms to restrict incoming waves.

Public Visitor Parking: Public parking is distributed throughout the community and includes metered parking along the Esplanade and other downtown streets, several parking lots within the downtown area, and parking lots located within Noble Gulch and above City Hall.

Coastal Trail: The Coastal Trail in Capitola runs along the railroad track and the coastline.

Transportation

Roads*:* Some of the main roads in Capitola Village include Monterey Ave, Cliff Drive, Wharf Road, Stockton Avenue, and the Esplanade. The Stockton Bridge crosses Soquel Creek and connects the cliffs to the Village.

Summer Shuttle*:* There is a free weekend summer shuttle that transports people from parking lots to the beach.

Railroad*:* The railroad through Capitola has been closed to passengers since the 1950s but was recently purchased by the county to provide pedestrian, bike and rail opportunities in the future.[10] The railroad trestle bridge crosses Soquel Creek north of Stockton Bridge.

Natural Resources

Wetland: Soquel Creek and Noble Creek are mapped as Riverine systems by the National Wetland Inventory. The mouth of the creek is mapped as an Estuarine and Marine Wetland.[11]

Kelp Forest: Kelp forests persist offshore of Capitola and provide valuable habitat and fishing opportunities within a short boat ride of the wharf.

Critical Habitat*:* The Soquel Creek is home to several endangered species such as Steelhead Trout and Coho Salmon.[12] Restoration efforts are underway to help these populations recover.

Utilities

Water Infrastructure: The City of Capitola has extensive below ground drinking water, storm drain and wastewater infrastructure within the areas identified as vulnerable. There is a wastewater pump station located next to the Esplanade Park restroom. Storm drain structures discharge to the river and beach.

[10] Whaley, D., Santa Cruz Trains, Capitola. retrieved from: http://www.santacruztrains.com/2014/11/capitola.html (July 8, 2016)

[11] US Fish and Wildlife Service. National Wetland Inventory. Retrieved from https://www.fws.gov/wetlands/Data/Mapper.html (July, 8, 2016)

[12] California Natural Diversity Database (CNDDB). 2015. Records of Occurrence for Capitola USGS quadrangle. Sacramento, California. 2014. Retrieved from http://www.dfg.ca.gov/biogeodata/cnddb/mapsanddata.asp (October 2015)

Utility Infrastructure*:* PG&E electric and natural gas infrastructure data were not available for this study.

2.4 Historic Events

Capitola has experienced many coastal flooding events caused by high wave action during winter high tides. Table 1 provides a list of these storms. The 1982-1983 El Niño was an extreme example of the periodic impacts this coastal community faces from severe winter storms (Figure 3).

Historical flooding from the river is well documented, including the December 1931 flood, which is depicted as:

> *"Soquel "River" widens to sixty feet, the highest since 1890, damaging property in Soquel and all the way to the mouth at Capitola. Orchards are lost with the rapid rise of water. Hundreds gather to watch the tides batter the concessions at the beach. There is a "vortex of water where the river and sea meet." The waterfront is piled high with flood debris thrown back up the beach."*[13]

On March 26, 2011, a large flood event occurred on the Noble Creek causing a subsurface storm drain pipe to fail during a large winter storm, causing creek waters to flow down Noble Gulch, flooding the downtown commercial district. Commercial and residential properties, including the fire and police stations, were flooded, leading to significant costs for repair.

Figure 3. January 23rd, 1983: high tide, high river flow event in Capitola. (Photo: Minna Hertel)

[13] City of Capitola Historical Museum. 2013. Capitola Local Hazard Mitigation Plan, Appendix A: Timeline of Natural Hazard events impacting the City of Capitola

Table 1. Major Floods in Soquel and Capitola Villages 1890 to Present
(adapted from Appendix A of the Capitola Hazard Mitigation Plan)

NEWSPAPER DATE	HAZARD	DESCRIPTION OF DAMAGE
1862	Flood	Major event—Soquel village inundated; mills, flumes, school, town hall, houses and barns were destroyed. Massive pile of debris went out to sea and then washed ashore at Soquel Landing
1890	Flood	Capitola floods, footbridge and span of wagon bridge destroyed. Esplanade flooded
1906	Flood	Buildings from Loma Prieta Lumber Company camp above Soquel are destroyed. Debris at Capitola.
1913	Storms and Tide	Waves ran across the beach to the Esplanade and water spread "clear to the railroad tracks." Union Traction Company racks covered with sand. Water reached the Hihn Superintendent's Building (Capitola and Monterey Avenues), and waves were described as "monster." About 200 feet of wharf washed away.
1914	Flood	Flood along Soquel Creek
1926	High Tide	High Tide: Waves to 20 feet. Wharf damaged. Sea wall promenade broken at Venetian Courts. Apartments flooded. Breakers slammed into Esplanade, destroying boathouse/bathhouse, beach concessions. Tide hits the second floor of Hotel Capitola. Water runs a foot deep through village
1931	Storm and High Tide	Soquel "River" widens to sixty feet, the highest since 1890, damaging property in Soquel and all the way to the mouth at Capitola. The creek cuts across the beach and moves sand below the new outlet.
1935	Flood	Capitola Village floods; thirty feet of the sea wall is taken out. Beach playground disappears. Venetian Courts hit hard but damage minimal.
1940	Flood	Logs pile against bridge in downtown Soquel and village floods. Landslides in watershed.
1955	Flood	Capitola exceeded $1 million damage including the Venetian Courts. Noble Creek and Tannery Creek also flooded.
1982-1983	El Nino Storm and High Tide	Early winter storms initiated erosion and left the beaches eroded and vulnerable to subsequent storms in January-February 1983.
1995	Flood	The creek rose near the village.
1997-1998	Flood	Yards and basements of homes along both sides of Soquel Creek near the village were flooded.
2011	Flood	Noble Creek floods village; Tannery Creek rushes through New Brighton State Park parking lot and undermines the cliff roadway within the State Park

2.5 Coastal Protection Infrastructure and Management

There are 1.2 miles of sea walls and rip-rap that protect coastal structures from winter storms and wave impacts. Capitola's downtown commercial district is currently protected from winter storms by low hip-walls along the Esplanade and Venetian Court and a large concrete wall that protects portions of the eastern cliff from erosion. Two rip-rap groins on the east end of the beach lay perpendicular to the Esplanade and help accumulate sand and increase the width of the beach. Rip-rap protects the cliffs west of the wharf and concrete walls maintain the edge of the creek under restaurants along the Esplanade (Figure 4). Table 2 outlines the existing coastal armoring that helps protect Capitola from coastal hazards.

The Soquel River mouth lagoon is actively managed to minimize flooding during the winter and maximize recreational opportunities during the summer. The river mouth is closed before Memorial Day and remains closed (draining excess flow through the concrete spillway) until after Labor Day. The river is mechanically breached in the fall to reconnect the lagoon with the ocean and prepare for increased flows during winter storms. The lower 2000 feet of the river are channelized and restricted by a combination of wood and concrete channel walls. Private yards and a public access trail parallel the channel from the Stockton Ave Bridge inland 800 feet to the Noble creek culvert and Blue Gum Ave.

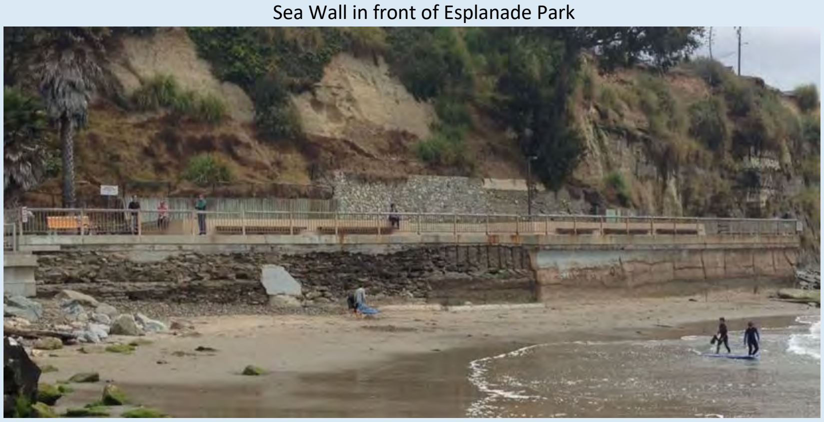
Table 2. Inventory of Existing Coastal Protection Structures in Capitola

STRUCTURE LOCATION	TYPE OF STRUCTURE	PUBLIC OR PRIVATELY OWNED
Grand Ave, eastern end of promenade, below Crest apartment	Retaining wall	Public
Grand Ave, eastern end of promenade, below Crest apartment	Concrete wall	Private
Esplanade, seaward of road and parking lot	Concrete wall	Public
Esplanade, in front of restaurant	Revetment	Public
Esplanade, in front of Zeldas at inlet of river	Revetment	Public
Seaward of Venetian Court adjacent to Capitola Beach	Wall	Private
Cliff Drive, seaward of residences at beach	Revetment	Private
Cliff Drive, at the top of coastal bluff underneath recreation path	Retaining wall	Public
Cliff Drive, seaward of road at base of bluff	Revetment	Public
Opal Cliff Drive, seaward of residence on the upper portion of bluff	Surface armor	Private
Grove Lane, base of cliff	Revetment	Private

COASTAL PROTECTIONS

The coastal protection structures within Capitola are of various ages, conditions and levels of service. The current condition of these structures (sea walls, rip-rap and groins) was evaluated with the intent of estimating the expected future lifespan of these structures. Observational data were collected for the dominant structures along the city coastline. The technical team determined that these field observations can be used to provide some estimate of future life expectancy, but not at a level of certainty any more precise than assuming that all current coastal protection infrastructure will need to be replaced or significantly improved at some point between 2030 and 2060.

Sea Wall in front of Esplanade Park

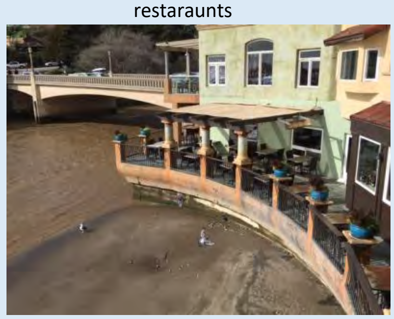


Hip wall in front of the Venetian

Rip rap against cliff below Cliff Drive

Rip rap along Capitola Beach looking West

Hip wall in front of Village Center restaraunts



Jetty off Capitola Beach looking East

Hip wall in front of the Esplanade

Figure 4. Coastal Protection Structures around the City of Capitola

(Photos: Ross Clark and Sarah Stoner-Duncan)

3. Projecting Impacts

3.1. Disclaimer: Hazard Mapping and Vulnerability Assessment

Funding Agencies

The hazard GIS layers were created with funding from The Coastal Conservancy and this Vulnerability Analysis was prepared with funding from the Ocean Protection Council. The results and recommendations within these planning documents do not necessarily represent the views of the funding agencies, its respective officers, agents and employees, subcontractors, or the State of California. The funding agencies, the State of California, and their respective officers, employees, agents, contractors, and subcontractors make no warranty, express or implied, and assume no responsibility or liability, for the results of any actions taken or other information developed based on this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. These study results are being made available for informational purposes only and have not been approved or disapproved by the funding agencies, nor has the funding agencies passed upon the accuracy, currency, completeness, or adequacy of the information in this report. Users of this information agree by their use to hold blameless each of the funding agencies, study participants and authors for any liability associated with its use in any form.

ESA PWA Hazard Layers

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CCWG Vulnerability Assessment

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Data Usage

These data are freely redistributable with proper metadata and source attribution. Please reference ESA PWA as the originator of the datasets in any future products or research derived from these data. The data are provided "as is" without any representations or warranties as to their accuracy, completeness, performance, merchantability, or fitness for a particular purpose. Data are based on model simulations, which are subject to revisions and updates and do not take into account many variables that could have substantial effects on erosion, flood extent and depth. Real world results will differ from results shown in the data. Site-specific evaluations may be needed to confirm/verify information presented in this dataset. This work shall not be used to assess actual coastal hazards, insurance requirements or property values, and specifically shall not be used in lieu of Flood insurance Studies and Flood Insurance Rate Maps issued by FEMA. The entire risk associated with use of the study results is assumed by the user. The Monterey Sanctuary Foundation and ESA shall not be responsible or liable to you for any loss or damage of any sort incurred in connection with your use of the report or data."

3.2. Coastal Hazard Processes

The ESA coastal hazard modeling and mapping effort[14] led to a set of common maps that integrate the multiple coastal hazards projected for each community (i.e. hazards of coastal climate change). There is however a benefit to evaluating each hazard (or coastal process) separately. Two important limitations of the original hazard maps were addressed within this focus effort for Capitola. ESA was contracted for this project to model the combined effects of rising seas and increased winter stream flows due to future changes in rainfall. CCWG staff further accounted for reductions in potential hazards provided by current coastal protection infrastructure (see section 3.4). This refinement of coastal hazard mapping helped to better understand the future risks Capitola may face from each coastal hazard process.

Each modeled coastal process will impact various coastal resources and structures differently. This report evaluates the risks to infrastructure from each coastal hazard process for each time horizon. The following is a description of the hazard zone maps that were used for this analysis. For more information on the coastal processes and the methodology used to create the hazard zones please see the Monterey Bay SLR Vulnerability Assessment Technical Methods Report.[15]

FEMA

FEMA flood hazard maps are used for the National Flood Insurance Program and present coastal and fluvial flood hazards. These flood maps were used to identify current hazards as defined by FEMA. These maps, however, are believed to underestimate coastal flood hazards for future time horizons.

Combined Hazards

CCWG merged the coastal hazard layers provided by ESA to create a new combined hazard layer for each planning horizon (2030, 2060 and 2100). These merged layers represent the combined vulnerability zone for "Coastal Climate Change" for each time horizon. Projections of the combined hazards of Coastal

[14] ESA PWA. 2014. Monterey Bay Sea Level Rise Vulnerability Assessment Technical Methods Report

[15] Ibid.

Climate Change are intended to help estimate the cumulative effects on the community and help identify areas where revised building guidelines or other adaptation strategies may be appropriate. Combined hazards however, do not provide municipal staff with the necessary information to select specific structural adaptation responses. Therefore, this study also evaluates the risks associated with each individual coastal hazard.

Rising Tides

These hazard zones show the area and depth of inundation caused simply by rising tide and ground water levels (not considering storms, erosion, or river discharge). The water level mapped in these inundation areas is the Extreme Monthly High Water (EMHW) level, which is the high water level reached approximately once a month. There are two types of inundation areas: (1) areas that are clearly connected over the existing digital elevation through low topography, (2) and other low-lying areas that don't have an apparent connection, as indicated by the digital elevation model, but are low-lying and flood prone from groundwater levels and any connections (culverts, storm drains and underpasses) that are not captured by the digital elevation model. This difference is captured in the "Connection" attribute (either "connected to ocean over topography" or "connectivity uncertain") in each Rising Tides dataset. These zones do not, however, consider coastal erosion or wave overtopping, which may change the extent and depth of regular tidal flooding in the future. Projected risks from rising tides lead to reoccurring flooding hazards during monthly high tide events.

Coastal Storm Flooding

These hazard zones depict the predicted flooding caused by future coastal storms. The processes that drive these hazards include (1) storm surge (a rise in the ocean water level caused by waves and pressure changes during a storm), (2) wave overtopping (waves running up over the beach and flowing into low-lying areas, calculated using the maximum historical wave conditions), and (3) additional flooding caused when rising sea level exacerbate storm surge and wave overtopping. These hazard zones also take into account areas that are projected to erode, sometimes leading to additional flooding through new hydraulic connections between the ocean and low-lying areas. These hazard zones do NOT consider upland fluvial (river) flooding and local rain/run-off drainage, which likely play a large part in coastal flooding, especially around coastal confluences where creeks meet the ocean. Storm flood risks represent periodic wave impact and flooding.

Cliff and Dune Erosion

These layers represent future cliff and dune (sandy beach) erosion hazard zones, incorporating site-specific historic trends in erosion, additional erosion caused by accelerating sea level rise and (in the case of the storm erosion hazard zones) the potential erosion impact of a large storm wave event. The inland extent of the hazard zones represents projections of the future crest of the dunes, or future potential cliff edge, for a given sea level rise scenario and planning horizon. Erosion can lead to a complete loss of habitat, infrastructure and/or use of properties.

Fluvial Flooding

An additional river flooding vulnerability analysis was done as part of this study to evaluate the cumulative impacts of rising seas and future changes in fluvial discharge due to changes in rainfall within the Soquel watershed. The ESA modeling team expanded hydrologic models of the Soquel watershed provided by the County to estimate discharge rates under future climate scenarios. The fluvial model estimates localized flooding along the Soquel Creek when discharge is restricted by future high tides. The model results are presented here and reviewed within the separate Fluvial Report by ESA.[16]

3.3. Scenario Selection and Hazards

The California Coastal Commission guidance document[17] recommends all communities evaluate the impacts from sea level rise on various land uses. The guidance recommends using a method called "scenario-based analysis" (described in Chapter 3 of this Guidance). Since sea level rise projections are not exact, but rather presented in ranges, scenario-based planning includes examining the consequences of multiple rates of sea level rise, plus extreme water levels from storms and El Niño events. As recommended in the Coastal Commission guidance, this report uses sea level rise projections outlined in the 2012 NRC Report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*[18] (Figure 5). The goal of scenario-based analysis for sea level rise is to understand where and at what point sea level rise and the combination of sea level rise and storms, pose risks to coastal resources or threaten the health and safety of a developed area. This approach allows planners to understand the full range of possible impacts that can be reasonably expected based on the best available science, and build an understanding of the overall risk posed by potential future sea level rise. The coastal climate change vulnerability maps used for this study identify hazard zones for each climate scenario for each of the three planning horizons. For clarity, this report focuses the hazard analysis on a subset of those scenarios,

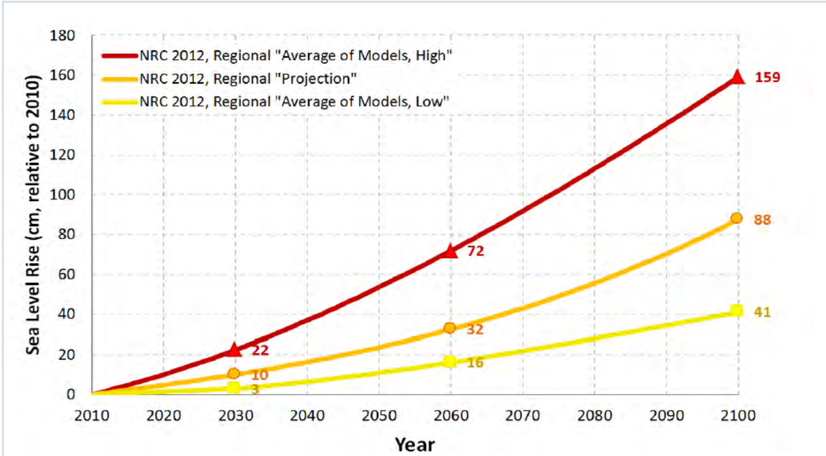


Figure 5. Sea Level Rise scenarios for each time horizon
(Figure source: ESA PWA 2014)

[16] ESA. 2016. Climate Change Impacts to Combined Fluvial and Coastal Hazards. May 13, 2016.

[17] California Coastal Commission. 2015. California Coastal Commission Sea Level Rise Policy Guidance: Interpretative Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits. Adopted August 12, 2015.

[18] National Research Council (NRC). 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Report by the Committee on Sea Level Rise in California, Oregon, and Washington. National Academies Press, Washington, DC. 250 pp.

recommended by local and state experts (Table 3).

The Coastal Commission recommends all communities evaluate the impacts of the highest water level conditions that are projected to occur in the planning area. Local governments may also consider including higher scenarios (such as a 6.6 ft (2m) Scenario) where severe impacts to Coastal Act resources and development could occur from sea level rise. We use a similarly high scenario of 1.59m with an increase in projected storm intensity for this analysis (Table 3). In addition to evaluating the worst-case scenario, planners need to understand the minimum amount of sea level rise that may cause impacts for their community, and how these impacts may change over time.

Table 3. Sea level rise scenarios selected for analysis

TIME HORIZON	EMISSIONS SCENARIO	SLR	NOTES
2030	med	0.3 ft (10 cm)	Erosion projection: Includes long-term erosion and the potential erosion of a large storm event (e.g. 100-year storm)
2060	high	2.4 ft (72 cm)	Erosion projection: Includes long-term erosion and the potential erosion of a large storm event (e.g. 100-year storm) Future erosion scenario: Increased storminess (doubling of El Niño storm impacts in a decade)
2100	high	5.2 ft (159 cm)	Erosion projection: Includes long-term erosion and the potential erosion of a large storm event (e.g. 100-year storm) Future erosion scenario: Increased storminess (doubling of El Niño storm impacts in a decade)

3.4. Assumptions and Modifications to ESA Hazard Zones

Coastal Armoring

The ESA coastal hazard projections do not account for the protections that existing coastal armoring provide. The areas identified as vulnerable by the original coastal erosion ESA GIS layers overestimate future hazard zones (as recognized within the ESA supporting documentation). A GIS layer of existing coastal armoring was referenced within this analysis to recognize areas where some level of protection currently exists.[19]

To account for the protections provided by coastal armor, properties and structures located behind those structures were in most cases reclassified as protected from erosion for the 2030 erosion vulnerability analysis. Coastal flooding layers, however, did account for the height of coastal structures (hip walls etc.) and estimate wave overtopping and flooding that may occur with those structures in place. Some structures were therefore identified as protected from coastal erosion and vulnerable to coastal flooding.

[19] California Coastal Commission. 2014. GIS layer of existing coastal armor structures in Santa Cruz County.

Because the life span of coastal infrastructure is limited, this vulnerability analysis assumes that all existing coastal protection infrastructure will fail and may need to be removed, replaced or significantly redesigned at some point between 2030 and 2060. If these structures are removed once they fail, erosion will accelerate and quickly meet projected inland migration rates (as documented at Stilwell Hall, Fort Ord) unless protective measures are implemented. Therefore, the vulnerability analysis for the 2060 and 2100 planning horizons assumes that current coastal armoring will no longer function and that the modeled hazard zone layers provided by the ESA technical team fully represent future hazards for these time horizons.

Erosion

Cliff erosion and dune erosion were originally two sets of separate coastal hazard layers provided by ESA-PWA. Cliff erosion was characterized as erosion of mudstone cliff sides generally along the Santa Cruz County coastline. Whereas dune erosion was characterized as erosion of sandy slopes predominantly found along the Monterey Bay coastline. Since these two hazards were functionally different and spatially separate, it was decided to merge them into one set of 'Erosion' coastal hazard process layers using the 'Merge' tool within ArcGIS. Therefore, for each time horizon both cliff erosion and dune erosion impact zones were combined into a single erosion impact zone. The 'erosion' coastal hazard series was used throughout the analysis and included in the tables. Erosion hazard layers were modified as described above to account for the protections provided by existing seawalls through 2030.

Coastal Storm Flooding

The ESA hazard layers included cliff areas predicted to have eroded during previous time horizons as being vulnerable to coastal flooding hazards, because the land elevation within those areas was assumed to have been reduced due to that cliff erosion. For example, sections of cliff in Capitola that are projected to erode by 2060 (after coastal armoring is assumed to no longer function) are also projected to experience coastal flooding and wave over-topping within those newly eroded coastal areas. This is an accurate interpretation of the projected coastal processes but does not reflect the progression of asset losses. For simplicity, Cliff top assets predicted to be vulnerable to coastal flooding for the 2060 and 2100 planning are reported as vulnerable. This is likely inaccurate because those assets would likely no longer be present but lost due to previous impacts from coastal erosion.

To more accurately represent coastal flooding and wave over-topping vulnerabilities of low-lying assets behind coastal armoring for the Existing (2010) and 2030 planning horizons, assets located below the 20- foot topographic contour line along the base of existing cliffs were reported to be vulnerable.

3.5. Assets Used in Analysis

For this study, city infrastructure and assets were categorized as: Land Use and Buildings; Water and Utility Infrastructure; Recreation and Public Access; Transportation; Natural Resources and Other. GIS layers were obtained from data repositories, or created by the Central Coast Wetlands Group. In some cases, assets that were used in the analysis fell outside of the planning area and therefore were not included in this report. Further, several data layers that were intended to be used in this analysis were not available. Table 4 lists the assets used in the analysis.

Table 4. List of Data Layers used for Analysis

ASSET CATEGORY	ASSET	STATUS OF ASSET IN ANALYSIS
Land Use	Building footprints	Analyzed
	Commercial, Residential, Public, Visitor Serving	Analyzed
	Emergency Services: Hospitals, Fire, Police	Analyzed
	Schools, Libraries, Community Centers	Analyzed
	Parcels	Not used in analysis[20]
	Farmland	None in Planning Area
	Military	None in Planning Area
	Historical and Cultural Designated Buildings	Analyzed, but not reported[21]
Water and Utilities	Sewer Structures & Conduits	Analyzed
	Water Main Lines	Analyzed
	Gas	Unable to obtain for analysis
	Storm Drain Structures & Conduits	Analyzed
	Tide gates	None in Planning Area
Recreation and Public Access	Coastal Access Points	Analyzed
	Parks	Analyzed, but not reported[22]
	Beaches	Analyzed
	Coastal Trail	Analyzed
	Coastal Access Parking	Analyzed
Transportation	Roads	Analyzed[23]
	Rail	Analyzed
	Bridges	Analyzed
	Tunnels	None in Planning Area
Natural Resources	Wetlands	Analyzed
	Critical Habitat	Analyzed, but not reported[24]
	Dunes	None in Planning Area
Other	Hazmat cleanup sites, Landfills, etc.	None in Planning Area

[20] Building foot print layers were used instead of parcels maps to better project future structural vulnerabilities.

[21] The data are available but not reported within this document.

[22] The parks layer included acres of State Beaches as well as City Parks and was duplicative with the Beach impact analysis. City parks vulnerable to various hazards are listed within the text but not included in tabular form.

[23] All projected impacts to Hwy 1 were determined to be unreliable in this area due to the height of the roadway.

[24] Critical habitat data layers were not of high enough resolution to provide accurate estimates of impacts.

4. Combined Impacts of Coastal Climate Change

4.1 Background

Predicted storm driven hazards to the Capitola shoreline and low-lying areas was derived by compiling the geographic extend of hazard areas for a combination of different coastal processes. Waves can damage buildings through blunt force impact, often damaging exterior doors and window, railings, stairways and walkways. Waves that overtop beaches and coastal structures lead to flooding of low lying areas. Flooding is often exacerbated by coastal walls and malfunctioning storm drains that impede drainage of those waters back to the ocean. Future risks of flooding and wave damage may be magnified as higher local sea levels and greater wave heights combined with higher river discharges during winter storms. Greater wave impact intensity may cause greater damage to coastal structures and greater wave heights may extend risks of damage further inland as waves overtop coastal structures more intensively and propagate further up the Soquel Creek. These cumulative threats are termed within this document as the risks of "Coastal Climate Change."[25]

4.2 Existing Vulnerability

FEMA

FEMA maps identify a large portion of the Capitola Village as vulnerable to riverine flooding during a 100-year flood event (Figure 6). Similar flooding occurred during the 2011 Noble Gulch event that flooded much of the downtown commercial district. A total of 262 mixed use buildings, more than 6,500 feet of roadway, 6,800 feet of storm drain pipe and 132 storm drain boxes are located within the FEMA hazard map 100-year flood zone (Table 5).

Flooding within the FEMA hazard map areas is expected to become more severe (although not currently recognized by FEMA) due to changing rainfall patterns associated with climate change. Future threats from increased river flows during these less frequent but more intense rain events were investigated within this project and are reported in Section 5.4.

[25] This study did not investigate the risks from increased heat, decreases in water supply or increases in threats from fire that are also predicted for Santa Cruz County due to climate change.

Existing (2010 with Armoring)

The combined risks of Coastal Climate Change from current climatic conditions (2010 model year) were evaluated for Capitola (Figure 6). The ESA coastal hazard modeling results for the 2010 planning year overlay 62 residential and 134 commercial properties, suggesting they are presently vulnerable to the impacts of storm flooding, classified as Coastal Climate Change (Table 5).

To note, FEMA flood maps do not account for projected sea level rise which may lead to greater regularity of flooding than that FEMA 100-year flood zone identifies. Figure 6 compares assets that lie within the FEMA hazard zone and the modified 2010 combined coastal climate change hazard zone. Many of the additional residents that fall within the FEMA hazard zone are located further upstream along the river outside of the zone threatened by storm induced ocean swells. One of the main emergency service facilities (Capitola fire station) is within this flood hazard area, and was impacted during the 2011 flood. The police station falls outside of the ESA modeled existing (2010) hazard zone, but within the FEMA 100-year flood hazard zone. The station was also impacted during the 2011 flood.

Figure 6. Existing (2010) Flood Hazard Zone Compared to FEMA 100-Year Flood zone

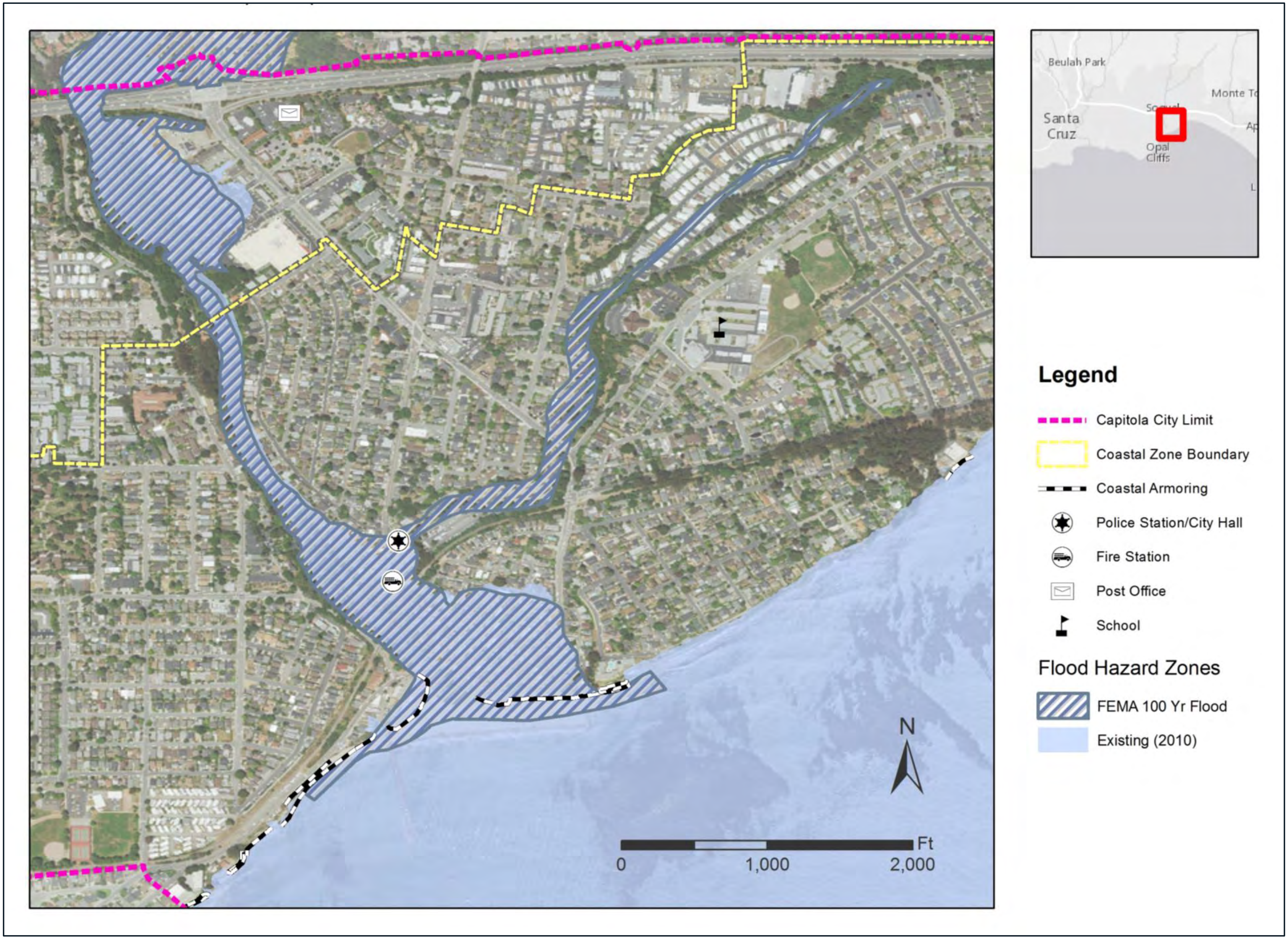


Table 5. Existing Conditions Comparison between FEMA and Existing (2010) hazard layers.

ASSET	UNIT	TOTAL	FEMA	2010 (WITH ARMOR)
Land Use and Buildings				
Total Buildings	Count	3,025	262	206
Residential	Count	2,600	122	62
Commercial	Count	326	132	134
Public	Count	67	6	6
Visitor Serving	Count	15	2	4
Other	Count	17	0	0
Schools	Count	1	0	0
Post Offices	Count	1	0	0
Emergency Services	Count	2	2	0
Transportation				
Roads	Feet	119,994	6,651	6,473
Rail	Feet	8,503	496	422
Bridges	Count	4	3	3
Recreation and Public Access				
Beaches	Acres	5.8	3.9	6
Coastal Access Points	Count	12	9	11
Parking Lots	Acres	4	1	0.7
Coastal Trail	Feet	9,543	0	0
Water and Utility Infrastructure				
Storm Drain Structures	Count	667	132	160
Storm Drain Conduits	Feet	50,173	6,869	8,039
Sewer Structures	Count	472	59	55
Sewer Conduits	Feet	118,365	12,555	12,636
Water Mains	Feet	144,206	11,946	12,857
Natural Resources				
National Wetlands	Acres	16	10	16

4.3 Summary of Future Vulnerabilities by Planning Horizon

Due to climate change, the cumulative number of Capitola properties and infrastructure at risk increases as projected ocean water elevation and storm intensity increase (Table 6). There is a significant increase in the number of properties projected to be at risk of coastal climate change impacts after the 2030 planning horizon. This increase in vulnerability is driven by two assumptions made when interpreting the model outputs. First, by 2060 ocean levels are estimated to rise by 72 cm[26], leading to a greater portion of the downtown area being vulnerable to flooding during winter storms. Flood waters in the downtown area are projected to be higher due to increased wave energy and higher tides pushing more water past current beachfront infrastructure. Some buildings within the downtown area at elevations that do not flood today may be affected by flooding in the future.

Secondly, the technical team determined that it is likely that all coastal protection infrastructure (sea walls, rip-rap, and groins) will need to be replaced or significantly improved at some point before 2060, and therefore the 2060 and 2100 coastal erosion analyses do not account for the protections provided by existing structures. Rather, the analysis accounts for the expected lifespan of coastal structures and assumes that future actions must be taken to replace structures if the community intends to protect structures from these projected hazards. This approach to future hazard analysis recognizes that current coastal armoring may continue to provide protection from wave impacts through 2030 but may fail prior to 2060.

2030

For 2030, the vulnerability analysis was completed assuming that current coastal protective structures would still be present and functioning. A total of 219 buildings are vulnerable to coastal climate impacts by 2030, only 13 more properties than currently at risk (2010 vulnerability assessment). This suggests that current coastal protection infrastructure does not provide full protection from all future hazards.

More than 7,000 linear feet of roadway may be vulnerable to coastal climate change (primarily flooding) by 2030 and approximately 10% of sewer and storm drain infrastructure is within the identified hazard areas. Roads and utilities are not equally vulnerable to different coastal hazards (flooding, erosion etc.) and therefore the analysis of individual coastal hazards (Section 5) may be more useful for response planning.

2060

By 2060, 113 residential buildings and 166 commercial mixed use buildings may become vulnerable to the combined effects of coastal climate change. Only 76 additional buildings are vulnerable to Coastal Climate Change by 2060 than are vulnerable in 2030 even though the 2060 vulnerability model no longer accounts for protections provided by current coastal armoring. Risks to roadways nearly double (in linear feet) by 2060, reflecting the predicted loss of protections provided by coastal armoring for Cliff

[26] National Research Council (NRC). 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.

Drive. Upgraded coastal armoring is estimated to cost between $20 and $52 million per mile ($10,000 per linear foot) to construct.[27]

2100

By 2100 the combined models used in this analysis project that much of the downtown area may be flooded during winter storms and high river discharges. Furthermore, most of the dry beach (98%) may be lost due to higher sea levels and beach erosion if back beach structures are rebuilt in their current locations. Further, hundreds of storm drain structures may be compromised and may become conduits for inland flooding if modifications are not made.

By 2100 the impacts experienced periodically during large winter storms may become more frequent and for many coastal properties, may become an annual event. Wave run-up energy may impact structures during most high tides causing flood and wave damage. River flooding is projected to be more frequent and threats of coastal erosion may become more significant as ocean forces migrate inland and impact structures more routinely and forcefully. Maintaining and replacing coastal armoring may become more costly and difficult to engineer. By 2100, portions of Capitola may be too difficult and costly to protect from the combined hazards of Coastal Climate Change.

[27] Evaluation of erosion mitigation alternatives for Southern Monterey Bay, ESA PWA 2012.

Figure 7. Future Combined Coastal Climate Change Hazard Zones (2030, 2060, 2100)

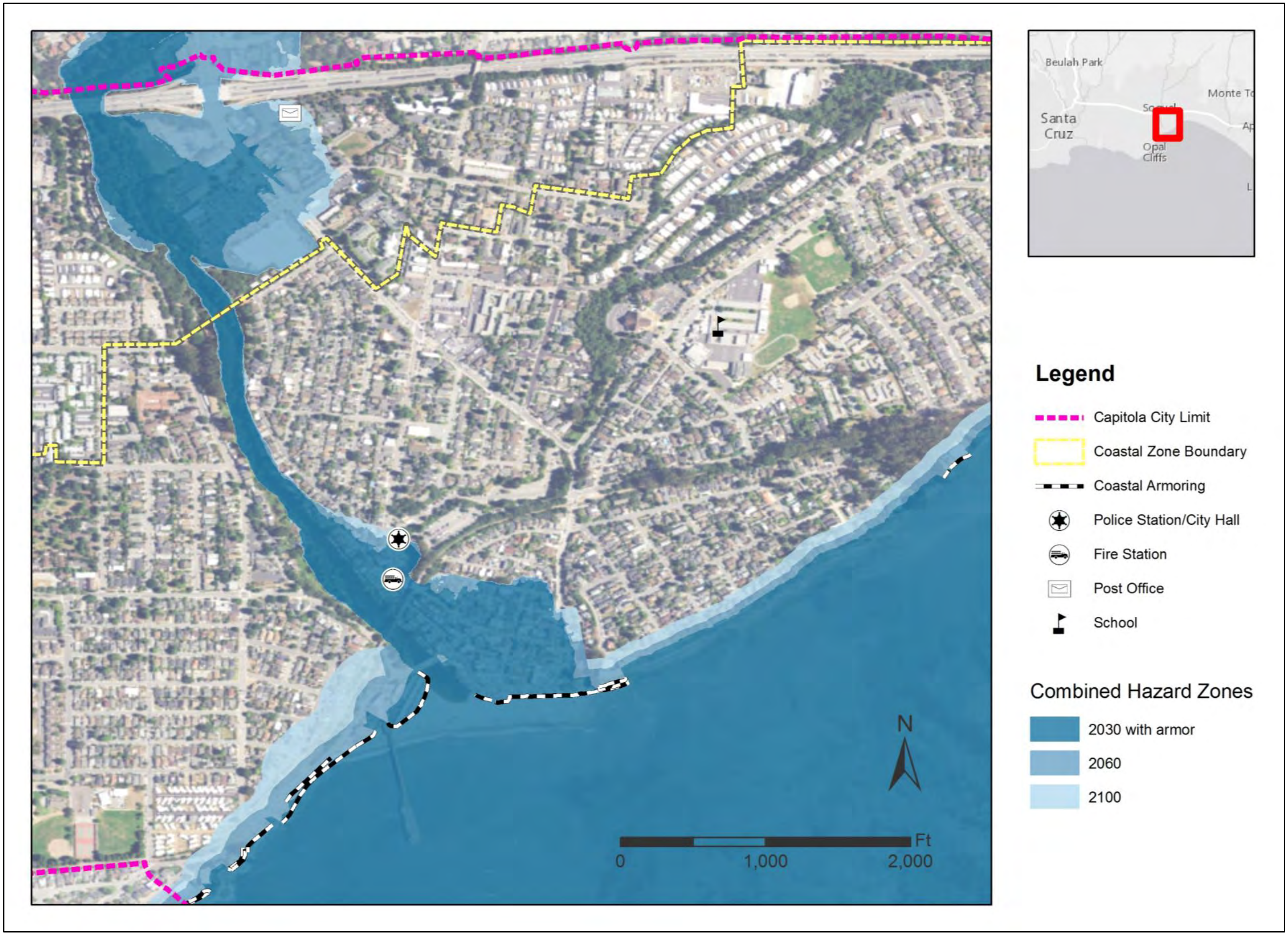
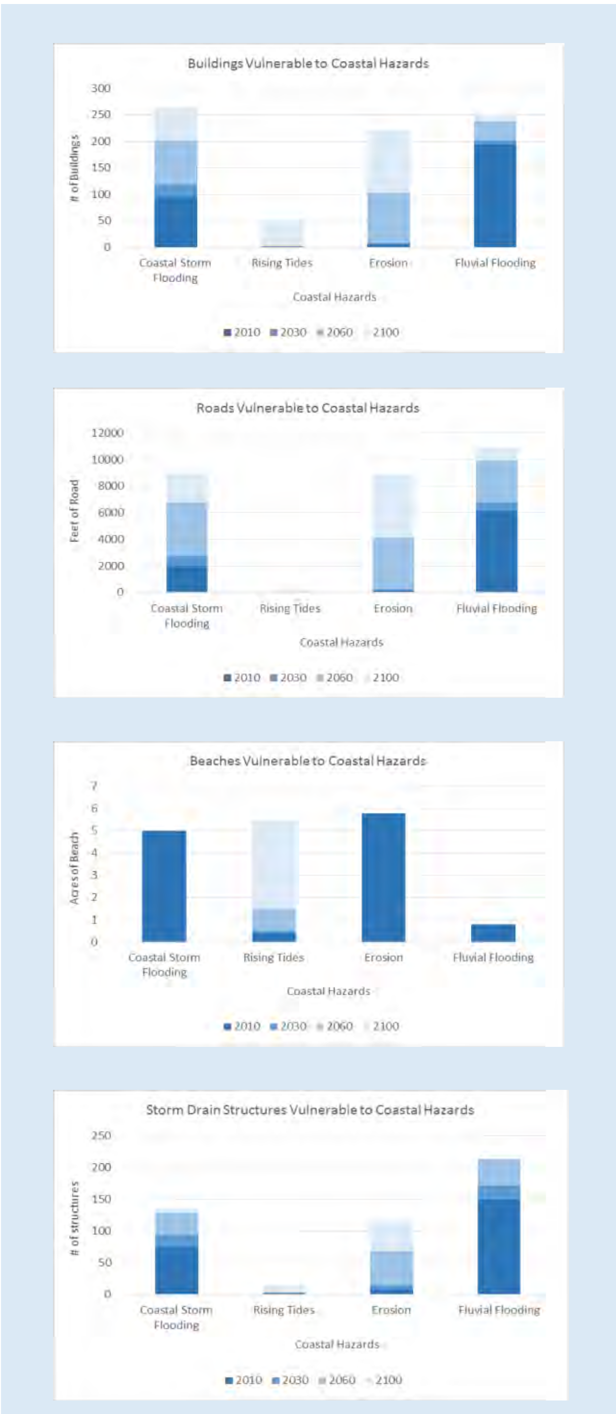


Table 6. Summary of Assets Vulnerable to all Coastal Hazards at 2030, 2060, and 2100

ASSET	UNIT	TOTAL	2030 (WITH ARMOR)	2060 (NO ARMOR)	2100 (NO ARMOR)
Land Use and Buildings					
Total Buildings	Count	3,025	219	295	370
Residential	Count	2,600	68	113	176
Commercial	Count	326	138	166	172
Public	Count	67	7	9	13
Visitor Serving	Count	15	6	7	9
Other	Count	17	0	0	0
Public Facilities	Count	16	0	0	0
Schools	Count	1	0	0	0
Post Offices	Count	1	0	0	1
Emergency Services	Count	2	1	2	2
Transportation					
Roads	Feet	119,994	7,012	13,316	17,138
Rail	Feet	8,503	422	2,076	3,261
Bridges	Count	4	3	3	4
Recreation and Public Access					
Beaches	Acres	5.8	5.8	5.8	5.8
Coastal Access Points	Count	12	11	12	12
Parking Lots	Acres	4	0.7	1.4	1.9
Coastal Trail	Feet	9,543	0	1,705	3,020
Water and Utility Infrastructure					
Storm Drain Structures	Count	667	185	239	244
Storm Drain Conduits	Feet	50,173	8,686	11,864	11,992
Sewer Structures	Count	472	56	83	102
Sewer Conduits	Feet	118,365	13,452	19,819	23,901
Water Mains	Feet	144,206	13,744	19,360	23,339
Natural Resources					
National Wetlands	Acres	16	16	16	16

5. Vulnerability by Individual Coastal Hazard



Estimating the risks from the combined hazards of Coastal Climate Change can help establish areas for modified building guidelines and estimate the cumulative effects on sectors of the social and economic community. Combined hazards, however, do not provide city staff with the necessary information to select appropriate adaptation responses. Therefore, to better link vulnerabilities with adaptation alternatives (Section 7), this project has evaluated the temporal risks of infrastructure for each time horizon and for each coastal hazard process separately.

The risks associated with each of the modeled coastal processes (wave run-up and overtopping, coastal erosion, rising tides and fluvial flooding) threaten various types of coastal infrastructure differently. Wave and fluvial flooding can damage buildings, temporarily restrict use of public amenities, make storm drains and tide gates ineffective and limit the use of roads and walkways. Many of these impacts are temporary and repairs can be made. Cliff erosion and monthly high tide flooding, however, are permanent impacts and may require extensive rebuilding, a change in property use or the abandonment of the property. In Section 7 of this report we investigate possible adaptation strategies for properties at risk from these various hazards.

Figure 8. Assets vulnerable to coastal climate change hazards at each time horizon

5.1 Vulnerability to Hazards by Time Horizon

Different hazards threaten different assets more significantly at different times (Figure 8). River and coastal storm flooding hazards threaten the greatest number of buildings up through 2030. Coastal erosion begins to threaten similar numbers of buildings between 2060 and 2100. Storm drains and roads are vulnerable to river flooding as well and erosion threatens more infrastructure by 2060. By 2100, Capitola beach is potentially lost due to frequent tidal flooding.

5.2 Vulnerability to Rising Tides

Flooding from the predicted increases in monthly high tides (due to local sea level rise) poses minimal threat to Capitola until 2100. Table 7 outlines the projected impacts to assets within Capitola from rising tides. Tidal inundation poses unique threats to low lying areas that may be difficult for many types of development to adapt. Specifically, monthly tidal flooding may lead to salt water damage and a reduction in reliability and availability of some properties and infrastructure. Monthly tidal flooding poses long term maintenance issues and the loss of public service reliability.

Land Use and Buildings

Projected inundation from 2060 high tides is limited. By 2100 high tides may become a more serious risk and may impact 23 residential and 23 commercial properties along Soquel Creek. The areas projected to be vulnerable to tidal flooding by 2100 (mainly properties along the creek) may need to be elevated by approximately 20-40cm to be above projected tidal range.

Transportation

Few roads are projected to be at risk from rising tides till 2100. By 2100, one street (Riverview Ave) may be flooded monthly.

Recreation and Public Access

Rising tides may lead to a reduction in beach width and a loss of recreational opportunities. By 2100 the Capitola main beach width is estimated to be reduced by 95% if back shore structures remain in their current location. By 2100 high tides may temporarily impact four of the 12 public access ways.

Water and Utilities

Two storm drains are already under water along the Soquel Creek. The number of storm drains that will be below mean water elevation in the river and ocean may increase to 13 by 2100.

Natural Resources

Higher tides driven by sea level rise may modify hydrology of the Soquel Creek and flood up to 2/3 of existing wetland habitat monthly with salt water by 2100. These wetlands will likely transition towards a brackish water ecosystem.

Figure 9. Buildings Vulnerable to Rising Tides

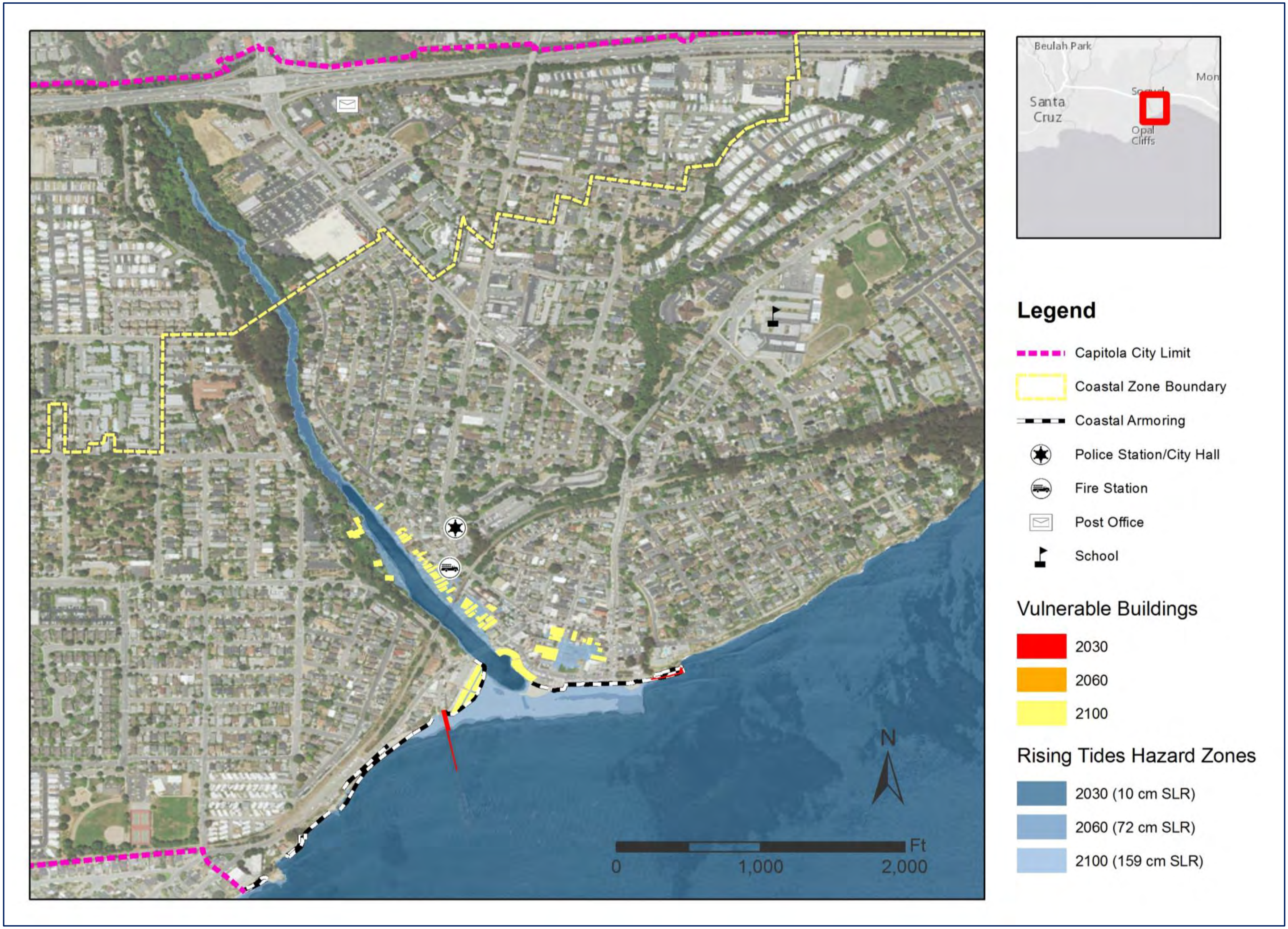


Table 7. Summary of Assets Vulnerable to Impacts by Rising Tides

ASSET	UNIT	TOTAL	2010 (WITH ARMOR)	2030 (WITH ARMOR)	2060 (NO ARMOR)	2100 (NO ARMOR)
Land Use and Buildings						
Total Buildings	Count	3,025	1	1	2	48
Residential	Count	2,600	0	0	1	23
Commercial	Count	326	0	0	0	23
Public	Count	67	1	1	1	1
Visitor Serving	Count	15	0	0	0	1
Other	Count	17	0	0	0	0
Schools	Count	1	0	0	0	0
Post Offices	Count	1	0	0	0	0
Emergency Services	Count	2	0	0	0	0
Transportation						
Roads	Feet	119,994	0	0	0	238
Rail	Feet	8,503	0	0	0	183
Bridges	Count	4	0	0	0	2
Recreation, and Public Access						
Beaches	Acres	5.8	0.4	0.5	1.5	5.5
Coastal Access Points	Count	12	0	0	1	4
Parking Lots	Acres	4.1	0	0	0	0
Coastal Trail	Feet	9,543	0	0	0	0
Water and Utility Infrastructure						
Storm Drain Structures	Count	667	2	2	2	13
Storm Drain Conduits	Feet	50,173	17	21	34	342
Sewer Structures	Count	472	0	0	0	1
Sewer Conduits	Feet	118,365	0	0	0	552
Water Mains	Feet	144,206	0	0	0	564
Natural Resources						
National Wetlands	Acres	16	1.6	1.6	2.1	10.3

5.3 Vulnerability to Coastal Storm Flooding

Coastal flooding due to high winter waves has long been a hazard to Capitola. The ESA hazard models estimated that both wave run-up force and the height of flood water within low lying areas may be greater over time. Infrastructure closest to the beach will continue to be impacted by the force of waves, the deposition of sand, kelp and other flotsam, and by the floodwaters that do not drain between waves. Infrastructure further inland is most vulnerable to flooding by a combination of ocean and riverine sources (Section 5.4). Table 8 outlines the projected impacts to assets within Capitola from coastal storm flooding.

Land Use and Buildings

Infrastructure projected to be at risk from coastal flooding by 2030 is similar to those properties currently vulnerable. In total, 27 residential and 84 commercial buildings may be vulnerable to storm flooding by 2030 (22 more than presently).

Coastal storm flooding may pose risks to 84 additional buildings by 2060 than are projected at risk in 2030, including the Capitola fire station. By 2100, even more structures may be at risk of flooding (48 additional residential and 11 commercial). Before 2060, structures adjacent to the shore may see more frequent and severe wave damage due wave run-up encroachment inland while infrastructure location remains static (Figure 10). However, for the 2060 and 2100 planning horizons projected flood zones may be misleading. For instance, cliff areas where coastal armoring is not replaced by 2060 are assumed to retreat as projected in the erosion hazard models (see Section 5.5). Houses within this erosion zone will be lost prior to this area becoming vulnerable to flooding in 2060.

Tidal inundation and wave run-up in Capitola Jan, 2008 (Photo: Patrick Barnard, USGS Santa Cruz)

Transportation

For the 2030 planning horizon, six local roadways (Esplanade Rd, San Jose Ave, Riverview Ave, Capitola Ave, Monterey Ave, and California Ave) are projected to be at risk of flooding during winter storms, restricting crosstown traffic and totaling more than 2,700 feet. Almost twice as many feet of roadway may be flooded by 2060.

Recreation and Public Access

Most of Capitola beach currently floods and may continue to flood during winter storms. Most coastal access ways may be unavailable during storms. Areas of Esplanade Park and Soquel Creek Park may be impacted by coastal storm flooding as early as 2030.

Water and Utilities

Currently, more than 70 storm drains are projected to be impacted by coastal storm flooding, with an additional 19 storm drains projected by 2030. Additionally, four of the storm drain discharge points along the Esplanade that provide coastal storm flood relief, may be compromised. Significant amounts of subsurface water and wastewater infrastructure is located within the flood zones and may see impacts from periodic flooding.

Natural Resources

Few natural resources are vulnerable to flooding by 2100 other than 6.8 acres of Soquel Creek, most of which is currently vulnerable.

Figure 10. Buildings Vulnerable to Coastal Storm Flooding

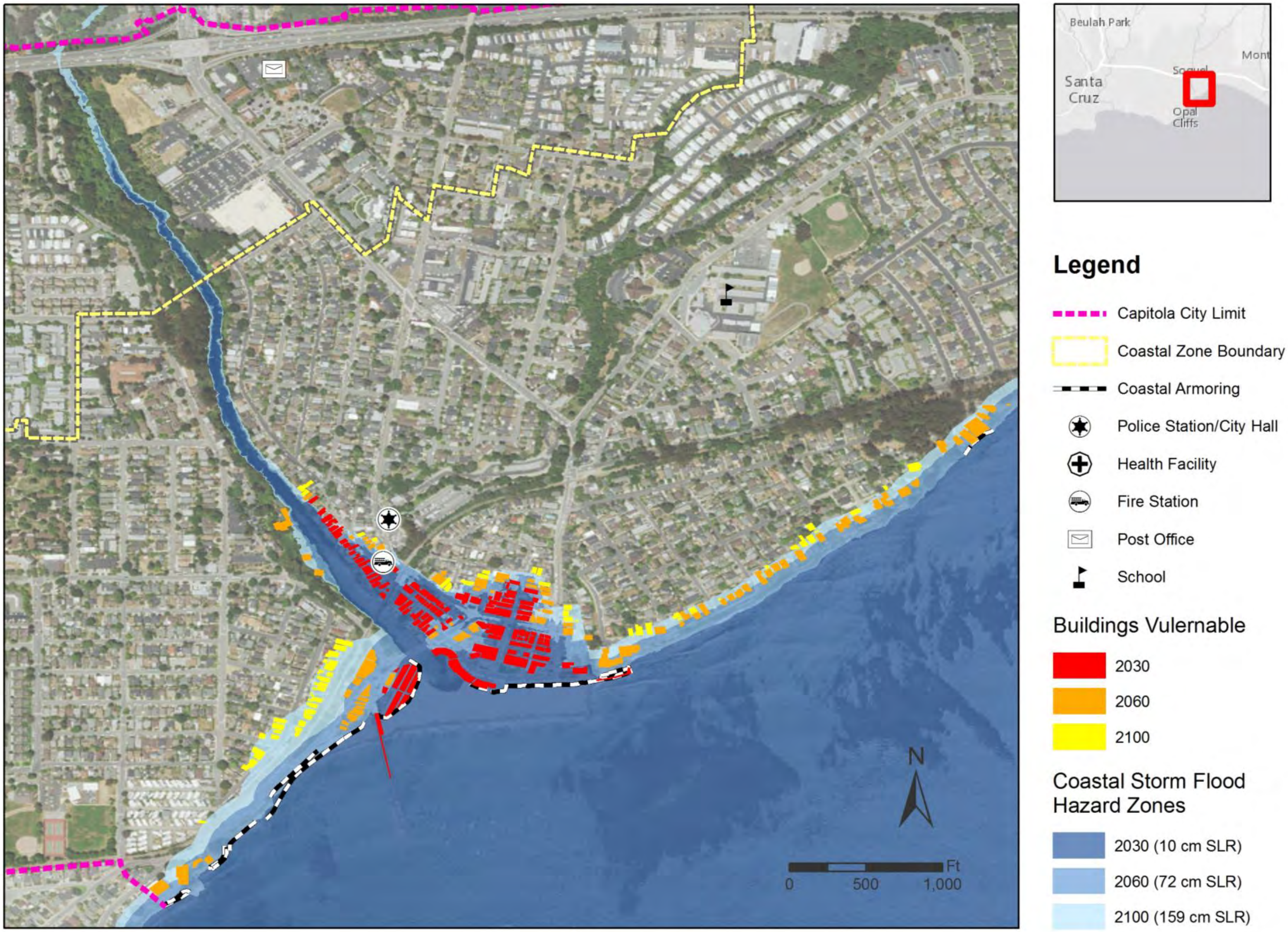


Table 8. Summary of Assets Vulnerable to Coastal Storm Flooding

ASSET	UNIT	TOTAL	2010 (WITH ARMOR)	2030 (WITH ARMOR)	2060 (NO ARMOR)	2100 (NO ARMOR)
Land Use and Buildings						
Total Buildings	Count	3,025	94	118	201	263
Residential	Count	2,600	24	27	66	114
Commercial	Count	326	65	84	122	133
Public	Count	67	4	4	6	7
Visitor Serving	Count	15	1	3	7	9
Other	Count	17	0	0	0	0
Schools	Count	1	0	0	0	0
Libraries	Count	0	0	0	0	0
Post Offices	Count	1	0	0	0	0
Emergency Services	Count	2	0	0	1	1
Transportation						
Roads	Feet	119,994	2,014	2,759	6,772	8,950
Rail	Feet	8,503	229	291	1,107	3,261
Bridges	Count	4	2	2	3	3
Recreation and Public Access						
Beaches	Acres	5.8	5.8	5.8	5.8	5.8
Coastal Access Points	Count	12	10	10	12	12
Parking Lots	Acres	4.1	0.4	0.5	1.3	1.7
Coastal Trail	Feet	9,543	0	0	1,428	1,684
Water and Utility Infrastructure						
Storm Drain Structures	Count	667	74	93	128	135
Storm Drain Conduits	Feet	50,173	2,429	3,125	5,007	5,869
Sewer Structures	Count	472	19	24	51	70
Sewer Conduits	Feet	118,365	4,741	5,916	12,925	16,219
Water Mains	Feet	14,4206	4,127	6,128	9,870	11,238
Culverts	Count	3	0	0	0	0
Natural Resources						
National Wetlands	Acres	16	5.2	5.3	6.3	6.8

5.4 Vulnerability to River Flooding

Storm intensity is predicted to increase within Santa Cruz County through 2100. These more infrequent but intense rain events are predicted to cause rivers and creeks to rise rapidly leading to localized flooding and erosion. This study evaluated the combined threats of higher ocean levels during storm events and higher river discharge caused by excessive localized rain events within the Soquel watershed. This fluvial analysis generated an additional hazard zone for each time horizon that was then used to evaluate structures vulnerable to this river flooding. The projected increase in fluvial discharge within Soquel Creek due to more intense rainfall during storms used for this analysis is outlined in Table 9.[28] River flooding height due to more intense rainfall is estimated to increase by approximately 2 feet (increasing depth to 8.5 feet in parts of downtown) between 2010 and 2060. Table 10 outlines the projected impacts to assets within Capitola from fluvial flooding.

Table 9. Increase in 100-year Discharge for Soquel Creek Relative to Historic Period (1950-2000)

EMISSIONS SCENARIO	2030	2060	2100
Medium (RCP 4.5 5th percentile)	13%	15%	20%
High (RCP 8.5 90th percentile)	62%	68%	95%

Land Use and Buildings

Large areas of Capitola and Soquel are vulnerable to river flooding along Soquel Creek, Capitola Village and the Nob Hill shopping center (Figure 11). Fifty-nine residential properties (along Riverview Dr. and within Capitola Village) are currently projected to be vulnerable to flooding from the combined threat of high river levels during high tide events. In total, 84 more buildings are identified as at risk of river flooding by 2030 than identified within the coastal flooding layer for 2030.

Transportation

Twice the length of roadway is projected to be at risk of flooding from the Soquel River than is projected to be at risk from coastal storm flooding alone. Access to Highway 1 may be compromised due to flooding of on-ramps by 2100.

Recreation and Public Access

River flooding poses a lesser risk to coastal access but may impact parks adjacent to Soquel Creek such as Soquel Creek Park. Peery Park, although adjacent to the Soquel Creek, is at an elevation where it should not be impacted.

[28] ESA. 2016. Monterey Bay Sea Level Rise: Climate Change Impacts to Combined Fluvial and Coastal Hazards.

Water and Utilities

Currently 149 storm drains are projected to be impacted by Soquel Creek flood waters (twice that of coastal flooding) and an additional 22 storm drains may be compromised by the higher ocean and river elevation by 2030. Several drains that currently provide flood relief may be further compromised due to higher river water levels and may become conduits for inland flooding by 2060 to areas isolated from current flooding.

Natural Resources

Wetland and Riparian resources along Soquel Creek are identified within the fluvial hazard layer as early as 2030 but are likely resilient to these hazards.

Capitola Avenue flooded from Noble Gulch Creek on Saturday March 26, 2011 (Photo: Santa Cruz Sentinel)

Figure 11. Buildings Vulnerable to River (Fluvial) Flooding

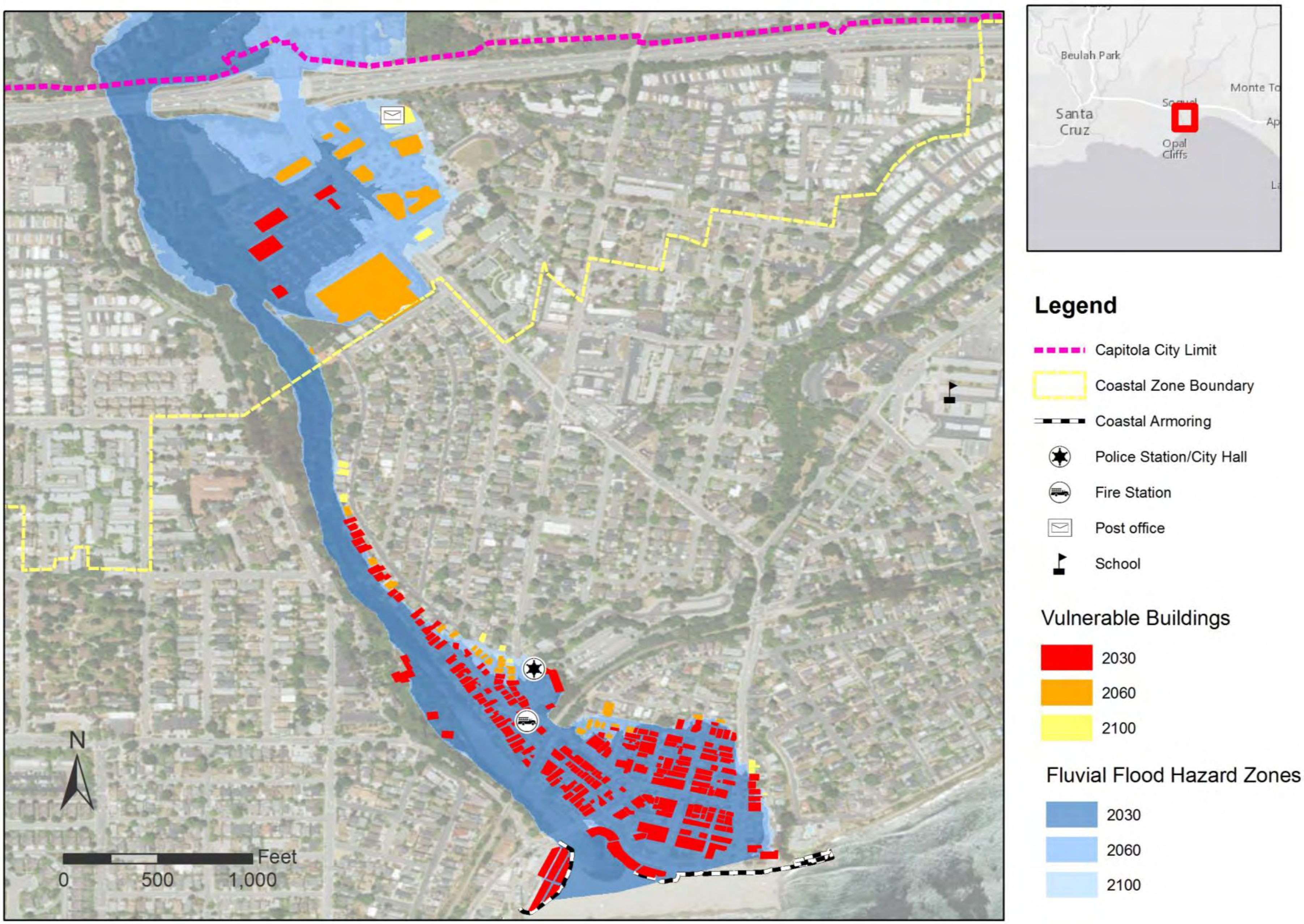


Table 10. Summary of Assets Vulnerable to River (Fluvial) Flooding

ASSET	UNIT	TOTAL	2010	2030	2060	2100
Land Use and Buildings						
Total Buildings	Count	3,025	194	202	238	248
Residential	Count	2,600	59	62	78	82
Commercial	Count	326	130	134	154	160
Public	Count	67	4	4	4	4
Visitor Serving	Count	15	1	2	2	2
Other	Count	17	0	0	0	0
Schools	Count	1	0	0	0	0
Post Offices	Count	1	0	0	0	1
Emergency Services	Count	2	1	2	2	2
Transportation						
Roads	Feet	119,994	6,128	6,783	9,932	10,889
Rail	Feet	8,503	428	431	435	435
Bridges	Count	4	3	3	3	3
Recreation and Public Access						
Beaches	Acres	5.8	0.8	0.8	0.8	0.8
Coastal Access Points	Count	12	2	2	2	2
Parking Lots	Acres	4.1	0.6	0.6	0.7	0.8
Coastal Trail	Feet	9,543	0	0	0	0
Water and Utility Infrastructure						
Storm Drain Structures	Count	667	149	171	213	214
Storm Drain Conduits	Feet	50,173	7,319	8,068	10,685	10,836
Sewer Structures	Count	472	44	45	58	61
Sewer Conduits	Feet	118,365	8,846	9,703	12,301	12,854
Water Mains	Feet	144,206	11,078	11,911	14,539	15,326
Natural Resources						
National Wetlands	Acres	16	7.2	7.2	7.3	7.3

5.5 Vulnerability to Erosion

Capitola is vulnerable to impacts from coastal erosion along the cliff edges west and east of downtown. There are rip-rap and concrete structures in place along the base of portions of these cliffs that have reduced bluff erosion significantly. If these structures are not upgraded or replaced they may continue to decay as climate change stresses add to current intensity of storm damage. Table 11 outlines the assets vulnerable to beach and cliff erosion. Project specific studies however may be needed to better estimate site specific erosion rates.

Photo Source: Timeline of Natural Hazard Events Impacting the City of Capitola, City of Capitola

Land Use and Buildings

Several residential and commercial structures are currently threatened by coastal erosion in areas where seawalls or other structures are not present. Five buildings are at risk of bluff erosion currently and this may increase to 8 properties by 2030. The number of properties vulnerable to erosion may increase significantly (32) by 2060 as new areas not protected by armoring begin to become vulnerable. An additional 100 properties are at risk by 2060 if current coastal armoring is not upgraded or replaced. A total of 98 homes are at risk of being lost by 2100 along Grand Avenue and Cliff Drive if coastal armoring is allowed to deteriorate or is removed. Bluff erosion is also predicted for the base of the Wharf and the Venetian Courts if sea walls are not maintained or rebuilt. As many as 221 properties are within the bluff erosion zone by 2100 if protective structures are not maintained, expanded or replaced.

Although many of these homes are more than 200 feet from the current bluff edge, the models highlight the significant erosion risk to this area in the future if existing coastal armoring fails. If bluff retreat is halted by replacing coastal armoring, however, many beach access ways and most of Capitola beach may be lost (Figure 12) as ocean tides progress inward towards these stationary structures (aka Coastal Squeeze).

Transportation vulnerable to erosion

Lateral road access along the east side of town has already been lost due to cliff erosion. Cliff Drive remains a key western access road into the downtown area and is vulnerable to cliff erosion by 2060 if protective measures are not implemented. Additional transportation infrastructure that is in jeopardy include the public access way along what remains of Grand Avenue and the rail corridor which was recently purchased by the county to provided alternate transportation corridor throughout the county.

Recreation and Public Access

Cliff erosion threatens numerous parks and visitor serving resources within Capitola. Five coastal access points are currently vulnerable to bluff erosion and by 2060 all access ways may be at risk unless coastal protection is updated. Loss of beach area (95% by 2100) is reported within Section 5.4 (Tidal Inundation).

Water and Utilities

A significant number of storm water and wastewater structures are currently vulnerable to erosion, when accounting for coastal protective structures. The number of structures and feet of pipe at risk increase significantly by 2060 if coastal armoring is not maintained or replaced. Sewer and water mains are vulnerable during all time horizons to failure due to coastal erosion.

Natural Resources

Approximately half of the wetland habitat along Soquel Creek is vulnerable to erosion by 2100.

Figure 12. Buildings Vulnerable to Erosion

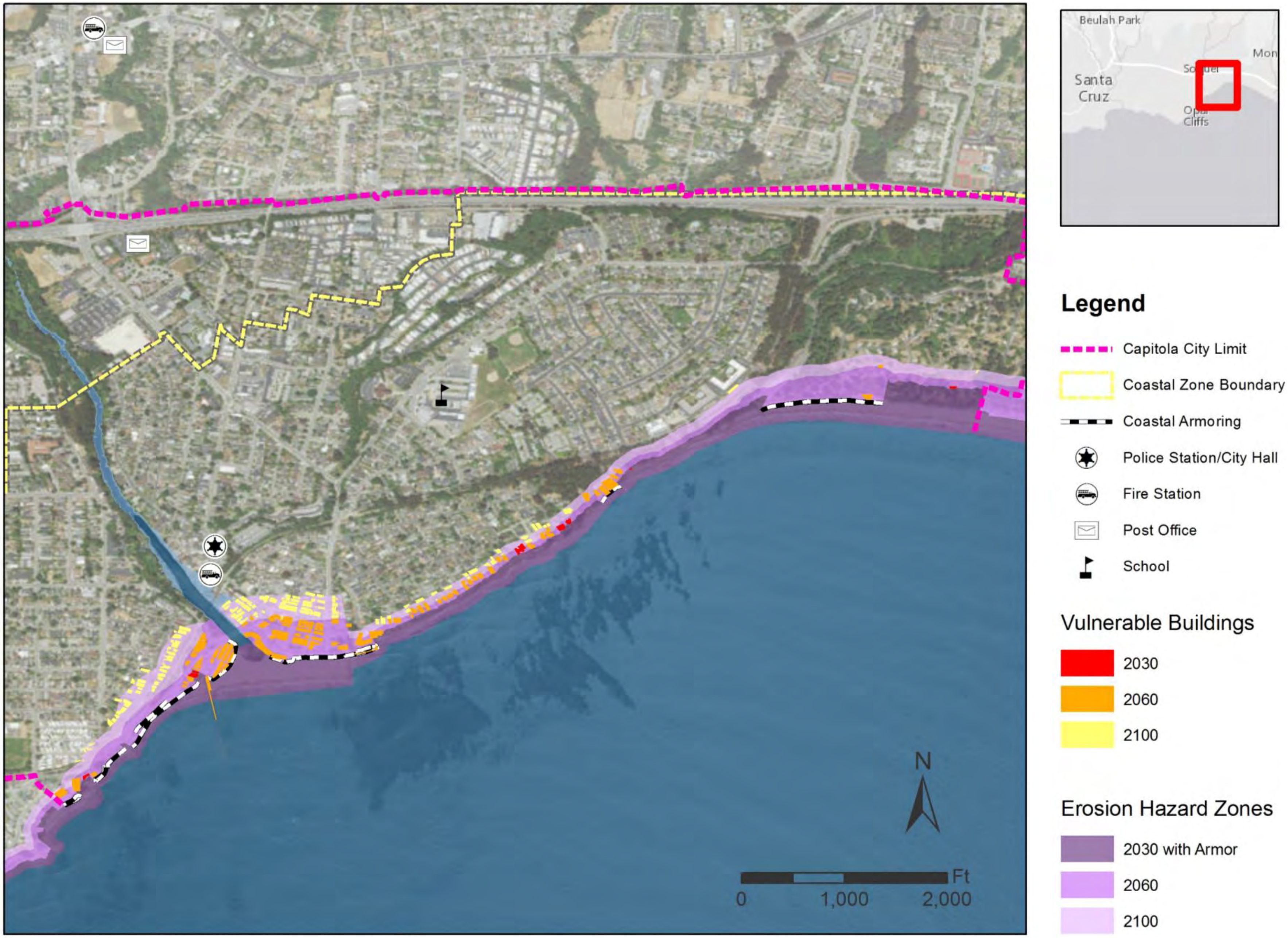


Table 11. Summary of Assets Vulnerable to Erosion

ASSET	UNIT	TOTAL	2010 (WITH ARMOR)	2030 (WITH ARMOR)	2060 (NO ARMOR)	2100 (NO ARMOR)
Land Use and Buildings						
Total Buildings	Count	3,025	5	8	103	221
Residential	Count	2,600	0	3	39	98
Commercial	Count	326	2	2	52	105
Public	Count	67	1	1	6	10
Visitor Serving	Count	15	2	2	6	8
Other	Count	17	0	0	0	0
Schools	Count	1	0	0	0	0
Post Offices	Count	1	0	0	0	0
Emergency Services	Count	2	0	0	0	0
Transportation						
Roads	Feet	119,994	152	247	4,140	8,891
Rail	Feet	8,503	0	0	986	3,142
Bridges	Count	4	0	0	0	1
Recreation and Public Access						
Beaches	Acres	5.8	5.8	5.8	5.8	5.8
Coastal Access Points	Count	12	5	8	12	12
Parking Lots	Acres	4.1	0.1	0.0	1.4	1.9
Coastal Trail	Feet	9,543	3	32	1,550	2,404
Water and Utility Infrastructure						
Storm Drain Structures	Count	667	8	14	68	114
Storm Drain Conduits	Feet	50,173	387	500	2,914	4,568
Sewer Structures	Count	472	3	3	38	63
Sewer Conduits	Feet	118,365	892	950	9,808	17,192
Water Mains	Feet	144,206	756	1,038	6,966	13,898
Natural Resources						
National Wetlands	Acres	15.6	0.9	1.2	8.3	8.3

5.6 Summary of Specific Vulnerable Assets

Venetian Court

The Venetian court hip-wall provides protection from mild winter storms and maintains a sand free walkway adjacent to the beach. Currently the beach and walkway are approximately the same elevation on opposite sides of the wall. As ocean encroachment progresses, the wall will provide a hard backshore resisting the migration of the beach inward but may provide less protection from wave overtopping and wave damage.

Capitola Esplanade

The Esplanade walkway provides a defined boundary between the urban area and the beach. The hip-wall adjacent to the walkway provides a key protective function during winter high wave events, reducing wave impacts and flooding to the Village. The Esplanade includes several public access points that can be blocked off during winter storms. There are discharge holes that provide minimal drainage and several storm drain discharge points seaward of the wall. As wave height and sea levels rise, the hip-wall may provide less and less protection to the commercial district along the Esplanade. Wave run-up energy may be more significant in the future, leading to greater volumes of water overtopping the wall, causing additional flooding downtown. Greater wave heights may possibly lead to greater structural impacts from water and debris. The Esplanade may need to be realigned landward in the future if the community wishes to maintain beach width and storm protection capacity.

Historic Districts

All three of the designated Historic Districts in Capitola are projected to be impacted by coastal climate change hazards. The proximity of the Venetian Historic District to coastal hazards leaves it vulnerable to coastal erosion, coastal storm flooding and wave impacts. The Old Riverview Historic District is adjacent to Soquel Creek making it most vulnerable to river flooding. Six Sisters/Lawn Way Historic District lies within the low-lying areas of Capitola Village and is vulnerable to coastal wave impacts and storm flooding, river flooding, and erosion after 2030 if coastal armoring begins to fail.

River walkway

The river walkway parallels the east side of Soquel Creek from the Stockton St. Bridge inland to the Noble Creek culvert near Riverview and Blue Gum avenues. The walkway provides a valuable public access way along the river and a pedestrian link between the residential area and the coast. Presently there are private patios and yards westward of the walkway. The yards and the walkway are approximately 3 feet above base flow within the creek. During extreme river flow conditions, this area is prone to flooding. In addition, a number of storm drains flow under the walkway and discharge to the creek. Flood water depths along the river walkway are estimated to be as much as 8 feet by 2060.

Parking lots and public access ways

Parking spaces along the Esplanade are already vulnerable to periodic flooding during storm events. By 2030 such flooding may occur more often. Beach and Village Parking Lots number 1 and 2 near City Hall are also vulnerable to river flooding. A number of public access ways are vulnerable to flooding due to higher river levels, wave impacts and coastal erosion. By 2060 use of all 12 public access ways may be periodically restricted due to various coastal climate risks.

Emergency services and city hall

The Capitola fire station is currently at risks of coastal storm flooding and river flooding (FEMA flood maps). City Hall and the police station, which are currently located in the 100-year FEMA flood zone, are vulnerable to river flooding by 2030.

Schools

No schools are at risk.

Storm drains

Capitola already experiences periodic flooding of the downtown during winter storms. During these storms the storm drain system may back up or be overwhelmed when submerged during ocean storms and high river elevations. These submerged discharge pipes may also become a conduit for inland flooding, bypassing coastal protection structures. Field surveys were completed to document the surface elevation of storm drains and drop inlets throughout the village. Storm drain elevations were correlated with tidal water height for each planning horizon to document when these storm drains may act as conduits for inland flooding (Figure 13). By 2060, five storm drain drop boxes located within city streets may be below high tide elevations, posing a monthly flood risk to these areas of the community. Some of these storm drains are inland of the Rising Tides hazard zones, suggesting that storm drains may prove to exacerbate tidal flooding by mid-century.

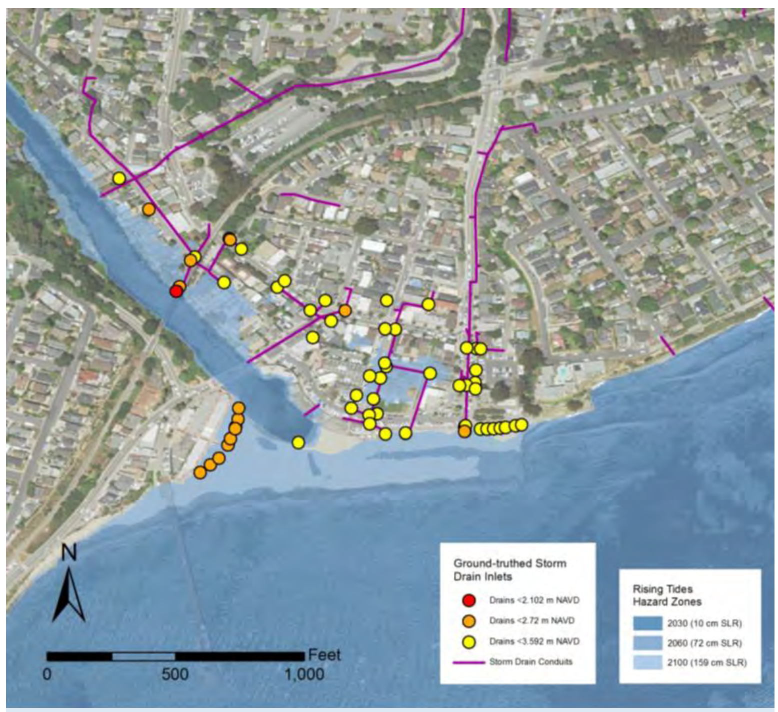


Figure 13. Storm drains with elevations within the projected tidal range for each time horizon

Table 12 further outlines the earliest time horizon that specific assets may become vulnerable to each of the coastal hazards.

Table 12. Important Assets Vulnerable to Coastal Hazard Impacts

FACILITY	TYPE	COASTAL HAZARD IMPACT	IMPACT THRESHOLD
Fire Station	Emergency	Coastal storm flooding River flooding	2060 2030
Police Station	Emergency	River flooding	2030
City Hall/ Emergency Operations	Public	River flooding	2030
Post office	Government	River flooding	2100
Capitola Historical Museum	Public/Visitor Serving and Historic District	River flooding	2030
Capitola Venetian (and Historical District)	Visitor Serving	Coastal storm flooding River flooding Erosion Rising Tides	2010 2010 2060 2100
Capitola Wharf	Public/Visitor Serving	Coastal storm flooding Erosion	2030 2060
Soquel Creek Park	Park	Coastal storm flooding River flooding Rising tides	2010 2030 2100
Esplanade Park	Park	Coastal storm flooding Erosion	2010 2030
Capitola Beach	Beach	Coastal storm flooding Erosion River flooding	2010 2030 2030
Beach access at Esplanade	Coastal Access	Coastal storm flooding Erosion Rising tides River flooding	2010 2030 2060 2030
Cliff Drive beach access	Coastal Access	Erosion	2060
Coastal Trail	Trail	Coastal storm flooding Erosion	2060 2060
Esplanade parking lot	Parking lot	Coastal storm flooding Erosion River flooding	2010 2060 2030
Wharf Rd parking lot	Parking lot	Coastal storm flooding Erosion	2030 2060

Attachment: Capitola Coastal Climate Change Vulnerability Report (Coastal Climate Change Vulnerability Report)

FACILITY	TYPE	COASTAL HAZARD IMPACT	IMPACT THRESHOLD
Cliff Drive parking	Parking lot	Erosion	2060
Prospect Avenue parking	Parking lot	Erosion	2100
City Hall parking lot	Parking lot	River flooding	2030
Esplanade Road	Road	Coastal storm flooding Erosion River flooding	2010 2060 2030
Cliff Drive	Road	Erosion	2060
Wharf Avenue	Road	Coastal storm flooding	2030
Grand Avenue	Road	Erosion	2030
Prospect Drive	Road	Erosion	2100
Stockton Bridge	Bridge	Erosion	2060
Soquel Creek	Creek/Wetland	Coastal storm flooding Rising Tides	2010 2030
Six Sisters/Lawn Way Historic District	Historic District	Coastal storm flooding Erosion River flooding Rising Tides	2010 2060 2030 2100
Old Riverview Historic District	Historic District	Coastal storm flooding Erosion River flooding Rising Tides	2010 2060 2010 2100

CUMULATIVE RISKS TO CAPITOLA FROM COASTAL CLIMATE CHANGE

This study suggests that by 2030 flooding during winter storms may increase in intensity as ocean wave run-up energy and increases in river discharge act together. Coastal erosion currently threatens five unprotected structures in Capitola including two commercial properties (Figure 12). By 2030 eight structures may be at risk including two residential properties if current coastal protection structures remain in place but no new structures are constructed. A significant number of storm, water and wastewater structures and many feet of pipe are vulnerable from coastal erosion during all time horizons. Cliff Drive remains a key western access road into the downtown area and is vulnerable to cliff erosion by 2060 if protective measures are not replaced. A table of key facilities at risk of various hazards and time horizons (Table 12) is intended to aid adaptation planning. This study confirms that coastal flooding may remain a primary risk for Capitola. This study also finds that river flooding may be of greater risk to the community than previously realized and that sea level rise may greatly impact the beach and public areas by 2100 unless retreat policies are adopted.

6. Economics of Future Climate Risks

The costs to repair damage caused by wave impacts and flooding can be quite large. For example, the Capitola Public Works Director estimated that approximately $500,000 worth of damage to city property, and several million dollars' worth of damage to the city-owned Pacific Cove Mobile Park occurred as a result of the 2011 flood event in Capitola Village.

The protection of structures and properties within the coastal and fluvial flood hazard zones is a high priority for the community. Understanding the cumulative value of the properties and infrastructure that are vulnerable to the identified hazards may aid the selection of protection and adaptation strategies, and help to direct limited public and private resources towards the most pragmatic and effective actions. Longevity of various protection and adaptation strategies, the costs to construct and the future reliability of coastal infrastructure should all be weighed before response strategies are selected.

Property valuation of vulnerable properties and infrastructure

Some studies (Santa Cruz County Hazard Mitigation Plan[29] and Coastal Regional Sediment Management Plan for the Santa Cruz Littoral Cell[30]) have estimated future property loss separately for building values and land values. This technique allows impacts to be calculated separately for structural impacts (due to coastal and river flooding) and property loss (due to coastal erosion and sea level rise). Unfortunately, the property value estimates used within these studies are linked to County assessor data which are often much lower than current appraised value and thus underrepresent real economic risks.

A simple economic estimation of costs of the projected climate hazards was completed to provide rough estimates of property loss for each time horizon. The average property value for residential and commercial properties within Capitola were estimated (Table 13) and used to quantify the cumulative economic impact of replacing or relocating these buildings and services. The Capitola Hazard Mitigation Plan identified costs to replace or move critical municipal infrastructure found to be at risk of various natural hazards (not including price of property to relocate).

[29] County of Santa Cruz. 2015. Santa Cruz County Local Hazard Mitigation Report
[30] United States Army Corps. 2015. Coastal Regional Sediment Management Plan for the Santa Cruz Littoral Cell, Pillar Point to Moss Landing. Prepared for The California Coastal Sediment Management Workgroup.

Table 13. Property valuation data sources for economic analysis

ASSET	VALUATION	SOURCE
Residential properties	$930,000	Capitola average sale price[31]
	$2,100,000	Capitola beach front sale price[32]
	$662,631	US Census[33]
	$809,860	Santa Cruz Littoral Cell report[34]
	$1,400,000	Pacific Institute Report 2009[35]
	$987,727	SCC-LHMP fire residential[36]
	$958,043	**Average of studies**
Commercial properties	$145,005	SCC-LHMP fire commercial
	$2,600,000	Average LoopNet Listings[37]
Public	$4,000,000	Capitola Local Hazard Mitigation Plan[38]
Emergency Services	$1,500,000	Capitola Local Hazard Mitigation Plan
Roads /ft	$280	TNC 2016[39]
Rail /ft	$237	SJVR Business Plan[40]
Storm Drain conduit /ft	$1,080	TNC 2016
Waste Water conduit /ft	$1,080	TNC 2016
Drinking Water conduit /ft	$189	TNC 2016

[31] Zillow. Capitola. http://www.zillow.com/capitola-ca/ (Dec 2016)

[32] Ibid.

[33] United States Census Bureau. Capitola Quick Facts. http://www.census.gov/quickfacts/table/PST045215/0611040 (Dec 2016)

[34] United States Army Corps. 2015. Coastal Regional Sediment Management Plan for the Santa Cruz Littoral Cell, Pillar Point to Moss Landing.

[35] Heberger M, H Cooley, P Herrera, PH Gleick, E Moore. 2009. The Impacts of Sea-Level Rise on the California Coast. Prepared by the Pacific Institute for the California Climate Change Center.

[36] County of Santa Cruz. 2015. Santa Cruz County Local Hazard Mitigation Report

[37] LoopNet. Capitola. http://www.loopnet.com/for-sale/capitola-ca/?e=u (Dec 2016)

[38] City of Capitola. 2014. Capitola Local Hazard Mitigation Plan

[39] Leo, K.L., S.G. Newkirk, W.N. Heady, B. Cohen, J. Calil, P. King, A. McGregor, F. DePaolis, R. Vaughn, J. Giliam, B. Battalio, E. Vanderbroek, J. Jackson, D. Revell. 2017. Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay. Technical Report prepared for the California State Coastal Conservancy by The Nature Conservancy. SCC Climate Ready Grant #13-107.

[40] Railroad Industries Incorporated. 2011. Business Plan for Operations of the SJVR in Fresno County. Prepared for Fresno Council of Governments

Currently $211 million in property and infrastructure are vulnerable to the combined hazards of coastal climate change within the City of Capitola (Table 14). By 2030, the total value increases to $227 million in property and infrastructure. By 2030 $62 million (26% of potential losses) in residential properties are at risk. Almost $130 million in commercial properties (57% of potential losses) are vulnerable to 2030 hazards. Approximately $35 million in public properties and infrastructure are within the hazard zone for 2030. Waste water and storm drain conduit are the infrastructure at greatest risk of projected hazards within the City.

Table 14. Total Value (2016 dollars) of Capitola Properties at Risk

ASSET	VALUE PER UNIT	2010 (WITH ARMOR)	2030 (WITH ARMOR)	2060 (NO ARMOR)	2100 (NO ARMOR)
PROPERTIES					
Residential	$930,000	$56,730,000	$62,310,000	$104,160,000	$162,750,000
Commercial	$930,000	$124,620,000	$128,340,000	$154,380,000	$159,960,000
Public	$500,000	$4,500,000	$7,500,000	$12,500,000	$17,500,000
Emergency Services	$2,000,000	$0	$2,000,000	$4,000,000	$4,000,000
Property losses		*$185,850,000*	*$200,150,000*	*$275,040,000*	*$344,210,000*
TRANSPORTATION					
Roads (ft)	$280	$1,812,440	$1,963,360	$3,728,480	$4,798,640
Rail (ft)	$280	$118,160	$118,160	$581,280	$913,080
Transportation losses		*$1,930,600*	*$2,081,520*	*$4,309,760*	*$5,711,720*
WATER AND UTILITY INFRASTRUCTURE					
Storm Drain conduit (ft)	$1,080	$8,678,466	$9,376,932	$12,807,727	$12,945,909
Waste Water conduit (ft)	$1,080	$12,872,500	$12,872,500	$21,839,205	$28,457,898
Drinking Water conduit (ft)	$189	$2,603,030	$2,603,030	$3,666,667	$4,420,265
Utility Losses		*$24,153,996*	*$24,852,462*	*$38,313,598*	*$45,824,072*
TOTAL COMBINED LOSSES		**$211,934,596**	**$227,083,982**	**$317,663,358**	**$395,745,792**

Property values within the 2060 coastal climate hazard zone increase to $317 million unless current coastal armoring is replaced and new structures are constructed to protect infrastructure vulnerable to 2060 hazards. If almost one mile of coastal armoring within the city is upgraded or replaced before 2060 (at an estimated cost of $20-52 million to construct), the total value of properties at risk is reduced by relatively small $56 million. The total value of private residential properties at risk increases to $162 million (41% of all assets at risk) by 2100.

Many of the properties identified during each time horizon are vulnerable to multiple hazards (i.e. erosion and coastal flooding). Depending on the engineering complexity and costs of replacing these coastal protection structures, and the secondary environmental and economic impacts of such construction, protecting all of the identified properties is likely cost prohibitive.

This initial economic evaluation highlights the need for constructive discussions between city decision makers, public citizens and private property owners to establish protection and adaptation policies that fairly allocate costs of protection and adaption efforts and that weigh public and private property concerns equitably.

A more comprehensive economic analysis that accounts for relative scale of property damage for each projected hazard (i.e. temporarily flooded or total loss of property) is possible with the current data but is beyond the scope of this study. Using the compiled hazard and vulnerability data generated by this project, coastal armor construction costs and the secondary environmental and economic impacts resulting from constructed structures can be compared with costs to move structures and losses resulting from abandoning vulnerable structures. Together these data can be used to generate temporal cost/benefit/consequence scenarios for each section of coastline and each time horizon.

7. Adaptation

The risks associated with each of the modeled coastal processes (wave run-up and overtopping, coastal erosion, rising tides and fluvial flooding) threaten various types of coastal infrastructure differently. Selection of adaptation options must be driven by consideration of the possible damage of each risk and the frequency of reoccurring impact. Unfortunately, the models used for this report estimate the likelihood of each hazard for each of three time horizons, but do not report the likely frequency.

Wave and fluvial flooding can damage buildings, and temporarily restrict use of public amenities, make storm drains ineffective and limit the use of roads and walkways. Storm flood risks represent periodic impacts and require periodic responses.

Cliff erosion and flooding during high tides are permanent or reoccurring impacts that can lead to a complete loss of infrastructure and use of those properties. Such hazards require extensive rebuilding or reinforcement, a change in use of the property, or abandonment of the property entirely.

Future investments in the protection of public and private structures need to be weighed by city staff and property owners against the property's value, construction costs of selected adaptive measures, limitations provided by regulatory agencies, and the expected effectiveness and longevity of the adaptation strategy selected. Secondary implications of adaptation options should also be considered, including restrictions to coastal access, loss of beach and the visual degradation of the coastline. This adaptation analysis highlights the need for long-range coastal management planning to best balance property values and adaptation measures costs with the resulting changes to the public beach and coastline.

7.1 Current Strategies Used by the City of Capitola

Capitola currently relies on various storm protection strategies to reduce winter storm flooding. These include building sand berms on the beach to reduce wave impacts (Figure 14), placement of flashboards at access points in the Esplanade hip-wall, sandbags within door and access ways, opening Soquel Creek to the ocean and ensuring that storm drains have been services and are functioning properly. Capitola has also installed 1.2 miles of sea walls along the coastline to reduce cliff erosion and flooding during winter storms. Residents and businesses in Capitola prepare for impacts by boarding doors and windows and placing sand bags.

Figure 14. Berms built at Capitola Beach help to decrease coastal flooding of the Village (Photo: R. Clark)

During storms, City staff provides response services including visual monitoring of creeks and storm drain inlets throughout the city and manned response with equipment including pumps and generators as needed to address localized flooding. Once storms have ended, cleanup of sand and debris and repair of damaged infrastructure begins. Response and municipal repair costs for the 2014-2015 El Niño winter totaled an estimated $20,000 to date with another $130,000 pending.

Costs of storm response for the 2016-2017 winter La Niña are not tallied as of completion of this report but are expected to be significantly higher. Early estimates for 2017 road repairs for Santa Cruz County exceed $30 million.

Strategies listed within existing Capitola Plans

General Plan

On June 26 2014, the Capitola City Council adopted the General Plan Update to replace the City's previous 1989 General Plan. The General Plan Update provides new goals and policies to promote sustainability, improve protections of residential neighborhoods and historic resources, and enhance economic vitality.[41] Among the Guiding Principles described within the General Plan for Environmental Resources is to:

> *"Embrace environmental sustainability as a foundation for Capitola's way of life. Protect and enhance all natural resources—including the beaches, creeks, ocean, and lagoon—that contribute to Capitola's unique identify and scenic beauty. Reduce greenhouse gas emissions and prepare for the effects of global climate change, including increased flooding and coastal erosion caused by sea-level rise."*

Hazard Mitigation Plan

The 2014 Capitola Local Hazard Mitigation Plan[42] evaluates risks from river and coastal flooding and makes programmatic and project related recommendations to address these risks. A number of those recommended actions will directly address the risks identified within this report (Table 15).

[41] City of Capitola. 2014. Capitola General Plan.

[42] RBF and Dewberry. 2013. Capitola Local Hazard Mitigation Plan

Table 15. City of Capitola Local Hazard Mitigation Plan Recommendations

ACTIONS WITHIN HAZARD MITIGATION PLAN THAT ADDRESS PREDICTED CLIMATE RISKS
▪ Evaluate the likelihood of debris flow impacts to the Stockton Avenue bridge during a catastrophic flooding event. ▪ Relocate or elevate critical facilities (e.g. City hall, police, fire, etc.) above the level of the 100-year flood elevation. ▪ Assist in the planning and/or improvement of infrastructure (sewers) and facilities to help minimize flooding impacts, particularly in critical flood-prone areas (e.g. Capitola Village). ▪ Continually monitor and review FEMA's National Flood Insurance Program (NFIP) requirements to ensure the City's floodplain management regulations are in compliance. ▪ Review and update the city's existing ordinances as they relate to storm / flooding hazards, consistent with the risks identified in this LHMP. ▪ Work in close coordination with state and local agencies and organizations to protect and preserve the coastline and its coastal bluffs through restoration efforts to help ensure safe coastal access and the protection of adjacent infrastructure and facilities. These efforts may include beach replenishment, coastal bluff protection, seawall construction, and other appropriate measures. ▪ Support the timely and accurate update of tsunami inundation maps within the Monterey Bay area. Then integrate the new tsunami inundation maps into the risk assessment of this Local Hazard Mitigation Plan ▪ Continue to update and enhance mapping data and the City's GIS for all hazards *(including coastal climate change).* ▪ Integrate the results of the Monterey Bay Sea Level Rise Study (this report) into the Local Hazard Mitigation Plan risk assessment and the General Plan Safety Element. ▪ As part of the General Plan Update process, develop a plan to address climate change/ climate adaptation issues within the City and its surroundings. ▪ Protect and preserve the coastline through permit review and continue to review coastal development for conformance with applicable City regulations (e.g. geologic, flood). ▪ Review and update the city's existing ordinances as they relate to hazards and risks identified in this LHMP

7.2 Future Adaptation Options and Strategies

Numerous reports have compiled lists of sea level rise adaptation options and described their use in addressing different climate risks.[43] Information on the costs to implement these strategies is limited but examples of most strategies exist. Local public works departments are best able to estimate the true costs of various construction projects and municipal planners, NGOs and consultants continue to evaluate the feasibility and efficacy of planning and regulatory options. Table 16 provides an overview of which adaptation strategies may be appropriate for each coastal climate change hazard. A special investigation of the role that natural habitats may play in reducing the vulnerabilities identified within this report was completed by Center for Ocean Solutions[44] (Appendix A). Policy options are also discussed within the report.

7.3 Potential Strategies for Capitola Climate Adaptation

2017-2030 Adaptation Options

Adopt policies to limit municipal capital improvements that would be at risk (Building Codes and Resilient Designs)

Prudent adaptive management to climate change begins with not placing new municipal infrastructure at risk to known future hazards. City policies that establish review processes for proposed Capital Improvement Projects located within future hazard zones have been adopted by the City of San Francisco.[45] These guidelines help staff to review proposed infrastructure projects and ensure that those projects will not become vulnerable to projected climate risks within the projects expected lifespan.

Improve resiliency to flooding along the Creek and Coast (Flood Wall and Elevate)

This risk assessment suggests that flooding of the downtown area will continue to be a primary hazard. Continued focus on emergency response and improved building guidelines (increase free board and first floor parking) can help reduce temporary impacts of flooding. A temporary or permanent flood wall along the Soquel Creek walking path may help to reduce flooding within high risk areas.

Investigate natural habitat buffering to reduce coastal flooding (beach and kelp management)

The Center for Ocean Solutions investigated the protective role that coastal habitats (Kelp, surf grass, wetlands, dunes) may play to reduce projected hazards.[46] Figure 15 shows locations of these habitats. For Capitola, the report finds that "the small beach and lagoon system at the mouth of Soquel Creek plays a relatively moderate role in reducing exposure to erosion and inundation." The report similarly

[43] Grannis, J. 2011. Adaptation Tool Kit: Sea Level Rise and Coastal Land Use

[44] Center for Ocean Solutions. 2016. Coastal Adaptation Policy Assessment: Monterey Bay

[45] City and County of San Francisco Sea Level Rise Committee. Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco: Assessing Vulnerability and risk to Support Adaptation. Prepared for the San Francisco Capital Planning Committee. Adopted by Capital Planning Committee December 14, 2015.

[46] Center for Ocean Solutions. 2016. Coastal Adaptation Policy Assessment: Monterey Bay

finds that “the proximity of Capitola’s commercial development to the coast limits the city’s options for nature-based adaptation strategies.” Maintaining Capitola’s beach and kelp forests, however, will likely provide some reduction in wave impacts.

Figure 15. Distribution of natural habitats that may play protective role in Capitola.
(Figure source: COS, 2016)

Storm drain upgrades (tidal (flap) gate and pumps)

Storm drains are currently vulnerable to high water during winter storms and these systems may be compromised further as water levels rise at discharge points along the coast and creek. Greater flood water volumes projected in the downtown by 2030 may further strain the effectiveness of the storm drain system. Coastal flood hazard models suggest that 93 storm drain structures may be compromised by high water levels by 2030 (Table 8, page 29). These submerged discharge pipes may become a conduit for inland flooding, possibly bypassing coastal protection structures. To address this issue, storm drain upgrades including gates and check valves should be investigated and additional pumping of storm water within vulnerable storm drains may be needed by 2030. The Capitola Hazard mitigation plan similarly identifies several structures (Noble Gulch Storm Pipe (already repaired), Capitola Pump Station and Soquel Pump Station (both wastewater facilities), and Lawn Way Storm Drain Pump Station) within the FEMA flood zone that may need to be upgraded.

STATE GUIDANCE

The Coastal Act allows for protection of certain existing structures. However, armoring can pose significant impacts to coastal resources.

To minimize impacts, innovative, cutting-edge solutions will be needed, such as the use of living shorelines to protect existing infrastructure, restrictions on redevelopment of properties in hazardous areas, managed retreat, partnerships with land trust organizations to convert at risk areas to open space, or transfer of development rights programs. Strategies tailored to the specific needs of each community should be evaluated for resulting impacts to coastal resources, and should be developed through a public process, in close consultation with the Coastal Commission and in line with the Coastal Act

Coastal Commission support of Cities that update their Local Coastal Plans to include the adaptation measures prioritized by the community can aid successful implementation of a community's adaptation strategy

Living shorelines provide an alternative to bulkheads and seawalls, while also providing critical habitat. (Photo: Tracey Skrabal)

Table 16. List of Adaptation Strategies (short= 0-5 years, med= 5-30 years, long= 30+ years)

TYPE	DURATION OF PROTECTION	RIVER FLOODING	COASTAL STORM FLOODING	EROSION	WAVE IMPACTS	RISING TIDES
Hard						
Levee	medium	●	●			●
Seawall or Revetment	medium		●	●	●	
Tidal Gate	medium		●			●
Flood wall	medium	●	●			●
Groin	medium		●	●	●	
Soft						
Wetland shoreline	medium		●		●	
Dune restoration	medium		●	●	●	●
Beach Nourishment	short		●		●	
Offshore structure	medium		●		●	
Accommodate						
Elevate	medium	●	●			
Managed Retreat						
Retreat	long	●	●	●	●	●
Rolling easement	long	●	●	●	●	●
Strict land use re-zone	long	●	●	●	●	●
Regulatory Tools						
Stricter Zoning	long	●	●	●	●	●
Floodplain Regulations	long	●	●		●	●
Building Codes and Resilient Designs	long	●	●		●	●
Setbacks/Buffers	long	●	●	●	●	●
Rebuilding Restrictions	long	●	●	●	●	●
Planning Tools						
Comprehensive Plan	long	●	●	●	●	●

Rebuild current beach groins

Capitola currently has two groins located on the east end of the main beach. These structures were designed and constructed in response to changes in sediment supply that occurred after the construction of Santa Cruz harbor breakwater. The two groins were constructed in the 1960's to capture sediment being transported east and to build the width of Capitola beach. The groins have since deteriorated, reducing their height and sediment capture efficiency. Rebuilding or upgrading these structures may be a cost-effective adaptation response to mitigate short term beach loss. Long term (2060-2100) capacity of these structures to retain beach width may be reduced as ocean elevations rise.

Using groins to capture sand may lead to accelerated cliff erosion along Grand Avenue. The 2016 TNC report[47] found that the combination of groin construction and beach nourishment was a cost effective medium duration adaptation measure that helped reduce the loss of public beaches and natural habitats for an estimated twenty years (periodic sand replenishment would be required). Although this analysis was done in Monterey County, it provides useful information that may be transferable to Capitola.

Investigate beach nourishment in concert with groins

Small to medium scale opportunistic beach nourishment has been found to be a cost effective, although temporary, adaptation measure when material is available.[48] Such materials are routinely diverted from the Santa Cruz harbor down current towards Capitola (providing beach sands for the Pleasure Point area). Other sources may include excess accumulation in local rivers that compromise flood management. Sediments from dam maintenance projects may also be obtained. Off shore sand has also been examined by the 2016 TNC report and may be cost effective but may also initiate more complex regulatory processes. Groins are recommended to extend sand retention time and upgrades to existing groins should be considered in Capitola to support any beach nourishment project.

Large sand placement projects were estimated to cost approximately $3,300,000 per linear km and opportunistic nourishment was estimated at $400,000 per linear km but must be repeated more often.[49] An example opportunistic sand placement project occurred along Del Monte Beach in Monterey where approximately 8000 cubic meters of sand was placed on the beach between 2012 and 2013. Sand helped protect inland structures but, because no groins were present to limit sand movement, much of the sand was redistributed during 2015 winter storms.[50]

Prioritize coastal protection structures for upgrade and replacement (seawall and revetment)

The most common community response to cliff erosion that threatens private and public property and infrastructure is to construct or upgrade coastal armoring structures. The costs to replace or construct new coastal armoring however, is high. Recent estimates for constructing new seawalls that withstand

[47] Leo et al. 2017. Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay.
[48] Ibid.
[49] Ibid.
[50] The Watershed Institute, California State University Monterey Bay. A Small-Scale Beach Nourishment Project in Monterey. California. Publication No. WI-2015-05. 25pp.

periodic wave impacts are estimated at up to $52 million per mile.[51] Therefore, completion of a coastal bluff and beach management plan for Capitola that outlines short and long term coastal bluff management strategies will help to establish local protection and adaptation priorities.

The secondary environmental and economic impacts that result from the construction of sea walls are significant. The 2016 TNC report found that coastal armoring was less expensive than beach nourishment and groin construction (although Capitola already has groins in place that may lower costs) and effectively reduced municipal and private property losses. Economic and community impacts from the loss of beach area, however, were estimated to be twice the value of the properties those structures were intended to protect. Therefore, the future allocation of public funds to protect current infrastructure should to be prioritized and weighed against the longevity and feasibility of the proposed protective structures.

Depending on cost, construction feasibility and legality of replacing current protective structures, it may be decided that some of the sea walls may be replaced or upgraded while other development may need to adapt to the projected hazards or be lost. Both the construction costs as well as the secondary implications of such armoring on coastal resources (access, beach width, view) may likely be significant.

Consider resiliency improvements to protect coastal access ways

The City may consider additional resiliency improvements and/or new protective structures to maintain critical vehicular and coastal access ways (including Cliff Drive and the Wharf. note: the City is currently evaluating resiliency improvements for the wharf).

2030-2060 Adaptation Options

Protection of all properties and infrastructure identified at risk during each time horizon is likely infeasible. Therefore, Capitola will need to establish adaptation strategies that best meet local long-term goals. Coastal municipalities will need to set adaptation policies that weigh public cost considerations, longevity of adopted strategies and resultant changes to the community. Establishing equitable managed retreat policies for coastal properties years before they are implemented will benefit successful long-term implementation of these policies and help to ensure the sustainability of the community. Selecting time horizons and climate conditions for which next phase adaptation strategies are triggered will allow the community to anticipate and prepare for future actions.

Identify priority areas for future protection accounting for costs, structural feasibility and secondary implications. (flood wall, seawall or revetment)

This study assumes that the 1.2 miles of coastal protection infrastructure will need to be replaced, upgraded or removed sometime after 2030. Decisions regarding which structures to rebuild in their current location and which structures to remove or relocate (managed retreat) will need to be made.

[51] ESA-PWA. 2012. Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay. Report prepared for the Monterey Bay Sanctuary Foundation and the Southern Monterey Bay Coastal Erosion Working Group. http://montereybay.noaa.gov/research/techreports/tresapwa2012.html.

Secondary impacts of coastal protection should be considered including loss of public access, beach area, economic valuation of the beach and impacts to community identity.

Between 2060 and 2100, Capitola is at risk of losing much (95%) of its public beach if all current coastal protection structures are rebuilt in their current location. Additionally, some structures (Venetian Court and Esplanade hip walls) would need to be raised significantly to protect structures from future projected wave impacts. The raising of these walls would likely compromise public and private valuation of the coastline significantly, making such actions undesirable and contrary to Capitola community values.

TNC ECONOMIC ANALYSIS REPORT 2016

The 2016 TNC report suggests that net benefits of non-armoring approaches are consistently greater than armoring approaches for almost all near-term scenarios. Future funding should be sought to further investigate the cost benefit relationships of various adaptation strategies and the legal and financial strategies necessary to offset municipal and private losses with public benefits.

Identify priority areas for managed retreat to retain sufficient beach area for recreational use (Stricter Zoning, Floodplain regulation, Rolling Easements, Retreat)

Further site-specific modeling is needed to identify which areas can be protected from the combined forces of sea level rise and increased storm intensity. Between 2060 and 2100, some properties may be too difficult or expensive to protect in place and therefore a change in use may be necessary. Such policy decisions should be made early enough for property owners to accommodate these changes. Coordination with State and federal agencies can help municipalities implement these policies and ensure that programs are established to compensate private property owners for the transition of private properties to public use (i.e. beaches, public access and river and bluff setbacks).

2060-2100 Adaptation Options

Between 2060 and 2100, increased coastal wave damage, greater flooding frequency and depth, and higher tides may threaten significant portions of current beach front properties. Protection of all properties from these risks may be costly, technically challenging and may degrade *Capitola's unique identity and scenic beauty*. Decisions regarding what the urban/beach front area may look like in 2100 will need to be made much earlier (i.e. coastal bluff and beach management plan) if adaptation is to be strategic and cost effective. Adopting coastal adaptation and retreat policies once all efforts to protect existing infrastructure fail is a more costly strategy.

Implement managed retreat strategies (Comprehensive Plan, Strict land use Re-zone, Rolling Easement)

There are a number of theoretical managed retreat strategies that have been described within the literature. Examples of coastal communities adopting re-zoning, building restrictions and other land use policies to drive the removal of buildings and infrastructure from the California coast, however, are few.

How retreat strategies can be adopted within a fully developed community like Capitola is unclear. Restrictions on redevelopment triggered by coastal development permit actions may lead to individual property owners implementing setbacks and building restrictions while neighbors are not required to comply. Such a case by case (or "Swiss Cheese") approach will most likely have limited success protecting either coastal properties or coastal resources. Rather, adaptation strategies and future land use decisions (that account for the costs to private property owners and the city) should be drafted long before they become enforceable. Programs to systematically implement adopted adaptation strategies along stretches of coastline (similar to Pacifica) will need support of state agencies and non-governmental organizations. The Local Coastal Program could be an excellent tool to drive these strategies.

Cost sharing between private property owners and state and local agencies will need to be defined and local land trusts may play an important role in administering these programs in years to come. Coastal Hazard (similar to Geologic Hazard) Abatement Districts where neighbors collect taxes on their properties to fund neighborhood scale

EXPLORING ADAPTATION POLICY

The Coastal Commission 2015 Guidance references strategies that include:

> *"restrictions on redevelopment of properties in hazardous areas, managed retreat, partnerships with land trust organizations to convert at risk areas to open space, or transfer of development rights programs"*

The 2014 Pacifica LCP[52] sets policy for coastal bluff development so that,

> *"All new development proposed on or adjacent to a coastal bluff shall require a site stability survey conducted by a licensed Certified Engineering Geologist or Geotechnical Engineer to determine the necessary setback, taking into account bluff retreat projected over the economic life of the development."*

This and most revised municipal policies set a process to establish setbacks for new development, there are no policies yet adopted that outline areas where current development will be modified or removed due to changing coastal hazards projected from these climate models.

The Marin SLR Adaptation effort[53] completed focus area analysis of coastal communities (i.e. Bolinas) similar to this Capitola report and has identified infrastructure that will need to be raised or otherwise modified to respond to tides and coastal flooding. Agriculture lands have been identified for transition to wetlands. No residential or commercial private properties have been identified for removal and no procedures have been identified to support municipalities to *"convert at risk areas to open space."*

[52] Dyett and Bhatia. 2014. Draft Pacifica Local Coastal Land Use Plan. Prepared for City of Pacifica. March 2014.

[53] Sea-Level Marin: Adaptation Response Team and Marin County Community Development Agency. 2015. Marin Ocean Coast Sea Level Rise Vulnerability Assessment, Draft Report.

solutions have been suggested to serve this function.

Realign roads and utility infrastructure (Retreat and other building designs)

Future realignment of roadways and utility infrastructure is costly but those costs can be minimized if managed adaptation and retreat policies are established decades before implementation. City and utility districts and companies can integrate future land use changes into current infrastructure repair and replacement decisions to minimize future costs of infrastructure loss and realignment. Basic cost estimate (based on previous reports) to realign roads and infrastructure that may be at risk by 2100 is outlined in Table 14 (page 47).

A draft adaptation strategy for the City of Capitola is provided below (Table 17).

Table 17. Draft Adaptation Strategy for the City of Capitola

ADAPTATION CATEGORY:

1. hard protection 2. soft protection 3. accommodate 4. Managed retreat 5. regulatory 6. planning

COASTAL HAZARDS	THROUGH 2030	CATEGORY	THROUGH 2060	CATEGORY	THROUGH 2100	CATEGORY
Coastal Storm Flooding	employ temporary protective structures	1, 2	employ secondary containment	1, 2	Implement Managed retreat policies	5
	upgrade storm drains	3	upgrade building guidelines in vulnerable areas	6		
	integrate storm pumps into flood response	3	Establish Managed retreat policies	6		
	investigate secondary barriers to coastal flooding	1, 2				
	Maintain and upgrade building standards in vulnerable areas	5				
Wave Impacts	continue winter sand berm placement	2	Establish Managed retreat policies	6	Implement Managed retreat policies	5
	increase efficiency of sand bag deployment	2				
	upgrade building guidelines in vulnerable areas	6				
	maintain coastal protection structures	1				

Attachment: Capitola Coastal Climate Change Vulnerability Report (Coastal Climate Change Vulnerability Report)

COASTAL HAZARDS	THROUGH 2030	CATEGORY	THROUGH 2060	CATEGORY	THROUGH 2100	CATEGORY
River Flooding	Increase freeboard along riverwalk (hip wall)	1	Establish Managed retreat policies	6	Implement Managed retreat policies	5
	upgrade storm drains	3				
	integrate storm pumps into adaptation	3				
	upgrade building standards in vulnerable areas	5				
	investigate secondary barriers to river flooding	1, 2				
Erosion	Maintain current coastal protective structures	1	prioritize replacement of coastal protection structures based on cost, feasibility, longevity and secondary implications	1	Implement Managed retreat policies	5
	Upgrade groins on beach	1	Establish Managed retreat policies	6		
	Investigate beach nourishment options	1, 2	Implement Coastal management strategy	5		
	set strategies for unprotected areas identified at risk	6				
	Investigate long-term feasibility and costs of maintaining current placement of coastal structures	6				
Rising Tides	Identify areas vulnerable to tidal flooding and integrate into zoning and building guidelines	6	Establish Managed retreat policies	6	Implement Managed retreat policies	5
	Draft coastal management plan for 2030, 2060 and 2100 to inform land use policy and private investments	6				

Attachment: Capitola Coastal Climate Change Vulnerability Report (Coastal Climate Change Vulnerability Report)

8. Conclusion

This vulnerability analysis is intended to provide a projected chronology of future hazards in order to support local adaptation planning and inform discussions within the community and with State regulatory and funding agencies.

Capitola has responded to and adapted to numerous environmental hazards throughout its 150 years. Development has changed, hotels have burned, and the city has flooded. After each disaster, the community has responded through reconstruction, upgraded infrastructure, and modifications in land use, all intended to retain Capitola's unique charm while responding to nature's lessons.

This vulnerability assessment provides projections of future hazards so the community can begin planning for strategic adaptation to these hazards rather than responding to future climatic events without sufficient forethought or understanding of costs and consequences. Capitola is uniquely vulnerable to coastal climate change. Capitola has stepped forward to partner with County and State agencies to complete this vulnerability assessment and begin planning proper responses to these environmental risks. The State has recently begun providing funding for projects that implement adaptation strategies. This vulnerability report is intended to provide Capitola with necessary information to prioritize actions to become more resilient and to partner with state agencies to implement selected priority actions. Additional State and federal funding is needed to aid local municipalities like Capitola who have taken steps to identify appropriate adaptation strategies.

POSSIBLE NEXT STEPS

- Adopt Capital Improvement Project review guidelines for sea level rise hazard areas.
- Integrate 2030 hazard maps into future Capitola Local Hazard Mitigation Plan updates.
- Investigate beach groin upgrade costs and effectiveness.
- Identify and prioritize storm drain upgrades necessary to address future hazards.
- Work with California Coastal Commission to integrate preferred adaptation strategies into the Capitola Local Coastal Program.
- Continue to participate in regional discussions regarding climate hazard avoidance and adaptation best practices.
- Initiate public outreach and education efforts to inform citizens of projected future hazards.

Mechanisms to implement the identified adaptation strategies requires further investigation, coordination among municipalities within the Monterey Bay and coastal California and development of partnerships that ensure efficient implementation of adopted strategies. Additional strategic dialog with California Coastal Commission staff is needed. The climate report team will work with the City of Capitola and Santa Cruz County to obtain additional funding to extend the adaptation opportunity analysis to the rest of Santa Cruz County, expand the environmental and economic implication analysis and further develop an adaptation implementation strategy for integration into general plans and local coastal programs.

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City of Capitola

Coastal Climate Change Vulnerability Report

Appendices

JUNE 2017

CENTRAL COAST WETLANDS GROUP

MOSS LANDING MARINE LABS | 8272 MOSS LANDING RD, MOSS LANDING, CA

Appendix A.

Coastal Adaptation Policy Assessment: Monterey Bay

(Center for Ocean Solution, 2016)

CENTER FOR OCEAN SOLUTIONS

Coastal Adaptation Policy Assessment: Monterey Bay

August 30, 2016

To support decisionmakers in their efforts to manage coastal resources in a changing climate, the Center for Ocean Solutions (Center) engaged with Monterey and Santa Cruz Counties and other partners to model, map and assess the role of natural habitats along the coast of Monterey Bay in providing the ecosystem service of coastal protection. In addition, the Center evaluated existing and potential land use policy strategies that prioritize nature-based climate adaptation strategies. Ecosystem service modeling and assessment was conducted using the Integrated Valuation of Environmental Services and Tradeoffs (InVEST) decision support tool, a suite of tools to map and value the goods and services from nature. Specifically, the Center utilized the InVEST Coastal Vulnerability model for this assessment.

This ecosystem services and adaptation policy assessment focuses on the coastline of Monterey Bay and two specific geographic areas of interest: Capitola in Santa Cruz County and Moss Landing in Monterey County. For each location, we identify the distribution and ecosystem services provided by coastal habitats, map the role of those habitats in reducing exposure to storm impacts, evaluate land use policy adaptation strategies with the potential to maintain or improve nature's role in reducing exposure to these impacts, and highlight policy considerations relevant for each strategy. In addition, we include an introduction to our science-to-policy approach, a compilation of general considerations for pursuing land use policy approaches, as well as a summary of our analysis methodology.

This assessment addresses Task 4B of the Ocean Protection Council's grant entitled: "Collaborative Efforts to Assess SLR Impacts and Evaluate Policy Options for the Monterey Bay Coast." Results from this assessment will inform local planning in both Capitola and Moss Landing, as well as regional or county-wide planning in both Monterey and Santa Cruz Counties. This collaborative, regional project is underway in parallel with other coastal jurisdictions through a statewide investment in updating coastal land use plans in accordance with projections of rising sea levels and more damaging storms.

Coastal Adaptation Policy Assessment: Monterey Bay

Table of Contents

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Coastal Adaptation Policy Assessment: Monterey Bay

EXECUTIVE SUMMARY

As sea levels rise, the impacts of more frequent large storm events driven by the El Niño Southern Oscillation (ENSO) will be greater than those historic events of similar magnitude, exposing coastal areas to the combined effects of elevated tides, increased storm run up and enhanced wave impacts. This increase in the frequency and intensity of storms will likely lead to economic, social and environmental vulnerabilities for coastal communities. California has proactively prioritized coastal adaptation planning that addresses vulnerabilities associated with a changing climate. As a result, the Monterey Bay Region is one of many locations to receive significant funding support to conduct a regional assessment of coastal vulnerability. The results of this coastal adaptation policy assessment will provide information that municipalities can leverage as they engage in adaptation planning for coastal land use.

Successful local, regional and state climate adaptation planning should take into account the role of natural habitats in ensuring a resilient coastline. Coastal habitats can play a protective role in reducing exposure to wind and wave impacts while also providing many additional beneficial ecosystem services to people and nature. Through proactive climate adaptation planning, coastal communities should prioritize nature-based strategies (e.g., dune or wetland restoration, conservation easements, etc.) when and where they are most feasible. If nature-based strategies are not practical in a given location, then coastal planners should consider approaches that seek to maintain the integrity of natural habitats and allow for adaptive coastal planning in the future (e.g., planned retreat, redevelopment limits, etc.).

With combined funding from the State Coastal Conservancy's (SCC) Climate Ready and Ocean Protection Council's (OPC) Local Coastal Program Sea Level Rise grant programs, the Monterey Bay Region is a part of a statewide investment to update coastal land use plans in accordance with projections of rising sea levels and more damaging storms. In parallel with additional select counties, the SCC and OPC provided funding in 2013 for Monterey and Santa Cruz Counties to include impacts from rising sea levels in their ongoing Local Coastal Program updates. The full study area includes the Monterey Bay coastline from Año Nuevo in Santa Cruz County to Municipal Wharf Two in Monterey County. Through discussion with county and city planners as well as with grant organizers from Central Coast Wetlands Group, two community-level study areas were identified—Capitola and Moss Landing—for exposure of coastal assets analyses, the role of natural habitats in reducing coastal exposure and the implications for potential climate adaptation strategies. Detailed analysis and synthesis in these case study locations will be the catalyst for similar investigations throughout Monterey Bay and potentially other sections of the California coast.

Executive Summary: Key Messages

Monterey Bay Coastal Study Area

- The Monterey Bay coastline features diverse coastal habitats including: dense kelp forests; brackish wetland habitats along creeks, lagoons, and sloughs; and expansive beach and dune systems that cover the central and southern sections of the coastline.
- While each coastal habitat plays some protective role, the dune systems in southern Monterey Bay play the highest role in reducing exposure of coastal development to erosion and inundation during storms relative to the entire study area.
- Any climate adaptation strategies under consideration along the Monterey Bay coastline should conform with the strictures of the Coastal Act, consider the recommendations from the Coastal Commission's sea level rise guidance, and respect the cultural significance of the region.
- A primary consideration for proactive coastal adaptation is to incentivize proactive climate adaptation planning that utilizes a blend of approaches across multiple timescales; optimal strategies should not limit adaptation options for future generations.

Capitola

- The small beach and lagoon system at the mouth of Soquel Creek plays a relatively moderate role in reducing exposure to erosion and inundation in comparison with the entire study area.
- The proximity of Capitola's commercial development to the coast limits the city's options for nature-based adaptation strategies.
- Adaptation options for developed sections of Capitola include implementing overlay zones that account for anticipated rising seas. In addition, limiting redevelopment or implementing redevelopment guidelines in these zones can provide a plan for relocation in coming years.

Moss Landing

- Relative to the entire Monterey Bay study area, the large dunes north and south of Moss Landing provide the highest protective role from coastal storm impacts.
- Nature-based climate adaptation options in the Moss Landing case study area include restoration or preservation of dune and wetland habitats. In addition, nourishing beachfront locations with additional sediment can be an option if appropriate environmental concerns are addressed.
- Built structures—including some coastal dependent structures—limit adaptation options for parts of Moss Landing. Critical infrastructure such as the Moss Landing power plant, harbor infrastructure, and Highway 1 all present challenges to implementing many otherwise viable strategies.

Our Climate and Ecosystem Services Science-to-Policy Approach

Coastal decisionmakers are actively determining how coastal communities will adapt to rising sea levels and more damaging storms. Favorable adaptation approaches consider the role of natural habitats and prioritize resilient strategies that do not limit future planning options.[1] Since 2010, the Center for Ocean Solutions has worked with coastal planners and managers to incorporate the role of natural habitats in climate adaptation planning.[2] Below, we outline our scalable, transferable approach to bridging a spatial assessment of natural protective services with coastal land use policy decisions in an era of changing climate.[3]

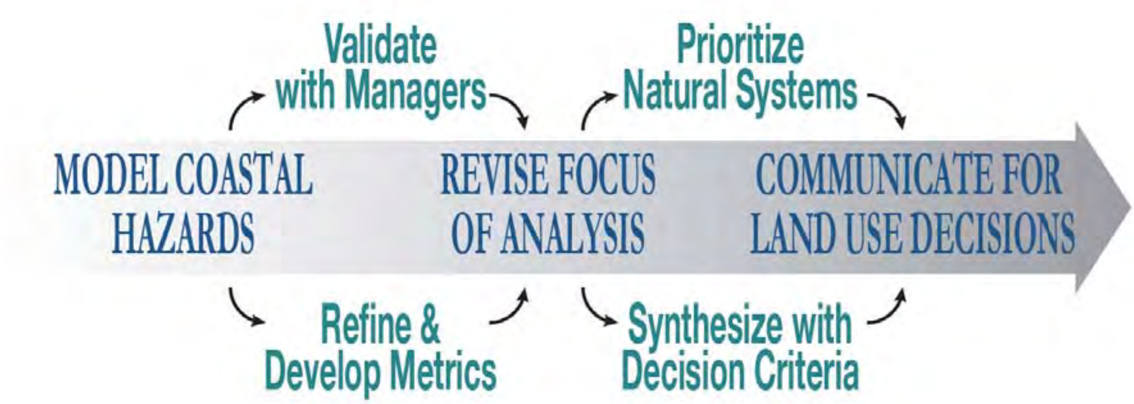

Fig. 1: Our transferable, scalable ecosystem services to coastal adaptation policy approach.

Coastal Ecosystem Services

Ecosystem services are the benefits that natural habitats provide to people (e.g., water purification, aesthetic attachment, carbon sequestration and coastal protection). Thriving, healthy ecosystems provide the greatest provision of services and are most resilient in the face of dynamic environmental conditions. In the coastal context, ecosystems play an important role in protecting shorelines against wave action by dissipating wave energy, or, in the case of sand dunes, physically impeding wave run-up. Climate change impacts, such as rising sea levels and increased storm intensity, are altering patterns of wave action along the coast and exposing new locations to physical forces. As waves travel from the open sea to coastal regions with shallower waters, they interact with the natural and geologic features of the seabed. Increased intensity and frequency of storms and rising seas, further emphasizes the important role of coastal habitats in reducing shoreline erosion and of increasing resilience in coastal areas.

[1] Jon Barnett & Saffron O'Neill, *Maladaptation* 20 GLOBAL ENVTL. CHANGE 211 (2010).

[2] Suzanne Langridge et al., *Key lessons for incorporating natural infrastructure into regional climate adaptation planning* 95 OCEAN & COASTAL MANAGEMENT 189 (2014); Sarah Reiter et al., *Climate Adaptation Planning in the Monterey Bay Region: An Iterative Spatial Framework for Engagement at the Local Level* 6 NATURAL RESOURCES 375 (2015); Lisa Wedding et al., *Modeling and Mapping Coastal Ecosystem Services to Support Climate Adaptation Planning*, *in* OCEAN SOLUTIONS EARTH SOLUTIONS 389 (Dawn J. Wright ed., 2016).

[3] *See* Figure 1. For further information on this approach, see also the "Analysis, Methodology and Assumptions" section *infra*.

Diverse habitats along California's coastline (e.g., sea grasses, kelp forests, salt marshes, dunes) play a role in reducing exposure to storm impacts while also providing a variety of additional services. As coastal development and rising sea levels degrade or damage these habitats, coastlines, communities and infrastructure become increasingly vulnerable to storms. An important challenge for decisionmakers is determining the best climate adaptation strategies that protect people and property while also protecting the ability of coastal habitats to provide a protective service into the future. To address this challenge, coastal communities need to identify where natural habitats provide the greatest protective benefits so that they may prioritize adaptation planning efforts that protect or restore their critical natural habitats.

Spatial Modeling and Mapping of the Protective Services

Modeling and mapping the ecosystem service of coastal protection can support the spatial prioritization of science-based climate adaptation strategies. For this assessment, we used InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) in combination with ArcGIS to identify areas where natural coastal habitats provide greater relative protection from storms and shoreline erosion.[4] The spatial models account for service supply (e.g., natural habitats as buffers for storm waves), the location and activities of people who benefit from services and infrastructure potentially affected by coastal storms. The InVEST Coastal Vulnerability model produces a qualitative estimate of coastal impact exposure to erosion and inundation during storms. By coupling exposure results with population information, it can identify the areas along a given coastline where humans are most vulnerable to storm waves and surge. The model does not value any environmental service directly, but ranks sites as having a relatively low, moderate or high risk of erosion and inundation through an exposure index.

The Coastal Exposure index is calculated by combining the ranks of the seven biophysical variables at each shoreline segment: geomorphology, natural habitats (biotic and abiotic), net sea level change, wind and wave exposure, surge potential and relief (bathymetry and topography). Model inputs serve as proxies for various complex shoreline processes that influence exposure to erosion and inundation. The resulting coastal exposure ranks range from very low exposure (rank=1) to very high exposure (rank=5), based on a mixture of user- and model-defined criteria. The model output helps to highlight the relative role of natural habitats at reducing exposure—also through a 1–5 ranking. This relative role output can be used to evaluate, how certain management actions can increase or reduce exposure of human populations to the coastal hazards of erosion and inundation. For this assessment, the model outputs were mapped on the shoreline of the Monterey Bay study area in order to interpret the relative role of natural habitats in reducing nearshore wave energy levels and coastal erosion—thus highlighting the protective services offered by natural habitats to coastal populations.

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[4] InVEST is a free and open-source suite of software models created by the Natural Capital Project at the Stanford Woods Institute for the Environment to map and value the goods and services from natural capital. *See* INTEGRATED VALUATION OF ECOSYSTEM SERVICES AND TRADEOFFS, http://www.naturalcapitalproject.org/models/coastal_vulnerability.html (last visited Aug. 30, 2016).

Coastal Vulnerability Model Considerations

While this vulnerability modeling approach includes average wave and storm conditions, the InVEST Coastal Vulnerability model does not account for coastal processes that are unique to a region, nor does it predict changes in fluvial flooding or shoreline position or configuration. The model incorporates a scenario-based approach to evaluate the role that coastal habitats play in reducing exposure to coastal impacts. We use the Coastal Vulnerability index here to better understand the relative contributions of different input variables to coastal exposure and highlight the protective services offered by natural habitats to coastal populations. Results provide a qualitative representation of erosion and inundation risks, rather than quantifying shoreline retreat or inundation limits. The compiled role of habitat map products depicts results from a "presence/absence" analysis that calculates the difference between erosion indices with and without habitats in place. In effect, this approach indicates the change in coastal exposure if natural habitats are lost or degraded.

Connecting Spatial Modeling to Planning

Understanding the role that nearshore habitats play in the protection of coastal communities is increasingly important in the face of a changing climate and rising seas. To develop this analysis, we integrated feedback from coastal planners to better understand their information needs on coastal vulnerability and potential adaptation options. The map products created from the InVEST Coastal Vulnerability model support the spatial evaluation of nature-based adaptation planning alternatives with rising sea levels, and highlight how protective services might change in the future. Connecting these model results with existing land use planning and zoning information and current policies provides a pathway for identifying locations in which nature-based strategies can be prioritized as more effective and feasible than competing traditional strategies.

Monterey Bay Coastal Study Area

Monterey Bay Coastal Management Context

The study area from Año Nuevo in Santa Cruz County to Wharf Two in Monterey County features a diverse range of land uses and densities. This range includes the City of Santa Cruz's highly developed coastline, the sparsely populated coastal properties of southern Santa Cruz County, and undeveloped beaches in Santa Cruz and Monterey Counties.[5] Farmlands dominate much of the inland areas, especially around Watsonville, Castroville, and Salinas. The main feature of the coastline is the Monterey Bay itself, which includes a submarine canyon leading seaward from Elkhorn Slough and the coast of Moss Landing. The Moss Landing power plant is the largest structure on the Bay, and the coastline features numerous important points of interest, roads, critical infrastructure, and research and educational facilities.

Fig. 2: Satellite image of Monterey Bay.

Several governmental agencies oversee the Monterey Bay coastline. For instance, the California Department of Parks and Recreation manages the state parks and reserves. The California Department of Transportation (CalTrans) oversees the coastal roadways, particularly the Pacific Coast Highway (Highway 1). The California Energy Commission regulates the Moss Landing power plant. The U.S. Fish and Wildlife Service governs the Salinas River National Wildlife Refuge. The National Oceanic and Atmospheric Administration (NOAA) administers the Elkhorn Slough National Estuarine Research Reserve (ESNERR) in partnership with the California Department of Fish and Wildlife. ESNERR and the non-profit Elkhorn Slough Foundation protect 5,500 acres of land, comprising property owned and managed by the reserve and property owned or managed by the foundation in the surrounding hillsides.[6] NOAA also administers the Monterey Bay National Marine Sanctuary and has jurisdiction over the marine mammals in the area. The most active land management agencies in the coastal zone include: the California Coastal Commission, which oversees land use and public access; the State Coastal Conservancy, which strives to protect or improve natural coastal ecosystems; and the State Lands Commission, which manages California's public trust lands.[7]

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[5] The full project study area includes the Monterey Bay coast from Año Nuevo in Santa Cruz County to Municipal Wharf Two in the City of Monterey. Note that this study area does not include sections of Santa Cruz County north of Año Nuevo or sections of Monterey County west and south of Wharf 2. *See* Figure 2.

[6] ELKHORNSLOUGH.ORG, http://www.elkhornslough.org/conservation/what.htm (last visited Aug. 29, 2016).

[7] Public trust lands are held and managed by the state for the benefit of the public. In the coastal zone, public trust lands include all ungranted tide and submerged lands. The Coastal Commission also retains some oversight over the use of granted tide and submerged lands.

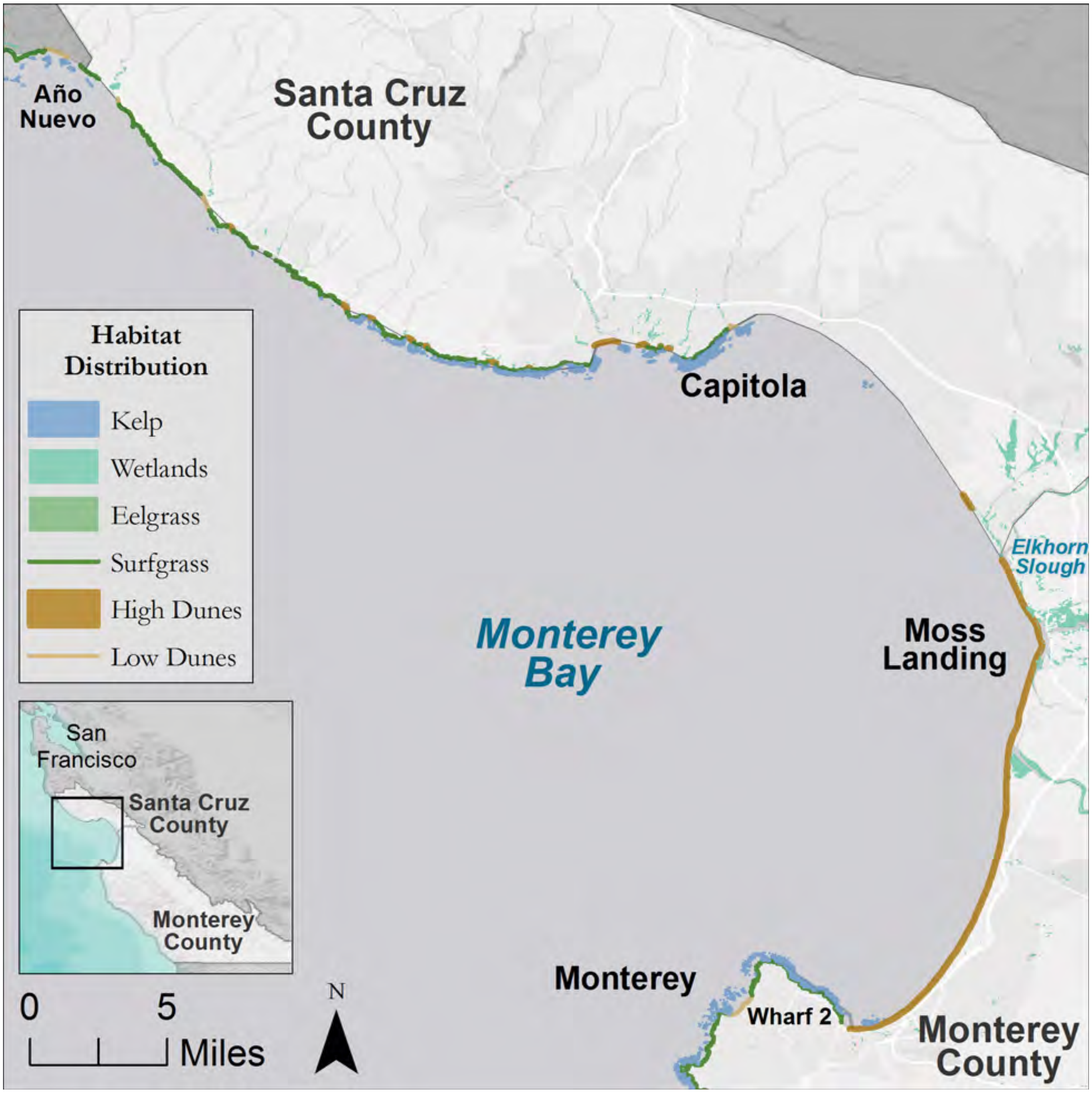

Fig. 3: Coastal habitats in Monterey Bay and surrounding area.

The Pacific coast of Santa Cruz and Monterey Counties has extensive natural habitats including some of the most imperiled habitats in the United States. Freshwater wetlands, coastal prairie and maritime chaparral, as well as kelp forests, estuarine wetlands, small and large beaches, and dunes are all present in the region.[8] The northern section of the study area (Año Nuevo to Capitola) includes a mostly rocky coastline fronted by seaweeds and surfgrass, backed by open agricultural lands. Occasional pocket beaches, typically fed by creeks, interrupt the bluffs and provide coastal access. Near the river mouths of the city of Santa Cruz, there is a greater concentration of small pocket beaches and wetland habitats than elsewhere in the area. The central section of the study

[8] *See* Figure 3.

area (Capitola to Moss Landing), is predominantly characterized by beaches and low dune systems backed by cliffs that decrease in size from north to south. The southern section of the study area (Moss Landing to Monterey) is dominated by large dune systems at the southern extent of the Santa Cruz littoral cell—the cycle of sediment sources and sinks from Pillar Point to the Monterey Canyon.[9] These habitats are all locally important and provides significant ecosystem services and benefits to certain communities.

Monterey Bay Protective Role of Habitats
Coastal habitats provide the ecosystem service of coastal protection for people, property and infrastructure by providing a natural buffer to mitigate erosion and inundation from ocean waves and storms. Our analysis focused on the direct effects of sea level rise on the risk of coastal communities to erosion and flooding. Our model results suggest that with rising sea levels the ability of dune systems to mitigate coastal exposure and keep this section of coastline in the low-moderate exposure range could be compromised.[10] Rising seas will likely impact the protective role of many beaches and dune habitat backed by coastal armoring that could result in the loss of existing beach area and the associated recreation and tourism income to coastal communities.[11] Overall, the loss of coastal dunes, wetlands, kelp forests and seagrass habitats would increase the exposure to erosion and flooding along the Monterey Bay study area. The extensive high dune systems throughout the southern section of Monterey Bay play a relatively high protective role compared to other natural habitats along the coastline. Storm surge is an important model factor from Marina to Monterey which alludes to the high role of coastal habitats in this area for protecting people and property along the coast. The coastal dune habitat in the Monterey Bay region suffers from high rates of erosion.[12] As a result, shoreline armoring has been used extensively along developed areas to address erosion and protect infrastructure and other areas of coastal development from waves, erosion and inundation. With increasing human pressure on these coastal ecosystems, there is a need to prioritize adaptation planning efforts in these important dune systems and other habitats that play significant roles in coastal protection.

Coastal wetlands along Monterey Bay stabilize shorelines and protect coastal communities by attenuating waves. Wetland habitat in the study area provides a relatively moderate role in mitigating erosion and inundation during storms. As sea levels rise, wetlands need to migrate to maintain their protective role. A recent study in Santa Cruz found that 17% of wetland habitat will be unable to migrate with sea level rise due to existing development.[13] The model does not predict migration or loss of habitat under the different sea level rise scenarios. Further research is needed to understand the extent to which habitats will be able to adapt to climate change effects.[14]

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[9] U.S. ARMY CORPS OF ENGINEERS, COASTAL REGIONAL SEDIMENT MANAGEMENT PLAN FOR THE SANTA CRUZ LITTORAL CELL, PILLAR POINT TO MOSS LANDING (2015).
[10] *See* Figure 4.
[11] Philip G. King et al., THE ECONOMIC COSTS OF SEA-LEVEL RISE TO CALIFORNIA BEACH COMMUNITIES (2011).
[12] Gary Griggs & Rogers Johnson, *Coastline erosion: Santa Cruz County, California* 32 CALIFORNIA GEOLOGY 67 (1979); Edward Thornton et al., *Sand mining impacts on long-term dune erosion in southern Monterey Bay* 229 MARINE GEOLOGY 45 (2006).
[13] MATTHEW HEBERGER ET AL., THE IMPACTS OF SEA-LEVEL RISE ON THE CALIFORNIA COAST (2009).
[14] Langridge, *supra* note 2.

The southern coastline of Monterey Bay is exposed to high wave energy, which was a substantial driver of the high coastal exposure in this area. Surfgrass provides some wave attenuation for the adjacent shoreline but compared to other habitats in the study area, it plays a relatively low role in reducing overall exposure. Although kelp forest habitats along the broader Monterey Bay coastline also play a relatively low role in reducing exposure to coastal hazards compared to the coastal dune habitats, these habitats offer important co-benefits to California's people and the economy such as fisheries habitat and recreation.

Monterey Bay Ecosystem Services of Coastal Habitats

The Monterey Bay is nationally regarded as a culturally important marine habitat. This section of the coast includes six state marine protected areas as well as a national marine sanctuary.[15] Monterey Bay also supports a diverse ocean and coastal-based economy including agriculture, tourism, industry, aquaculture, fishing as well as a number of marine research and education institutions. Many tourists flock to the area for offshore whale watching, coastal birding, kayaking, surfing, boating, fishing, and beach-going. The diverse habitats noted below play an important role in preserving the open natural system of this region.

Creeks, Rivers, and Lagoons

Along the Northern coast of Monterey Bay there are numerous creeks and rivers reaching coastal lagoons and beaches along the Pacific shoreline. Several waterways also weave through the urbanized residential areas in Santa Cruz or Capitola, along with more rural neighborhoods such as in Aptos. These coastal waterways provide habitat for commercially important fish species (e.g., salmon and steelhead) during juvenile stages of their lifecycle. Many non-commercial fish and birds are also endemic to these creeks, while amphibians and reptiles use the damp banks for shelter and a source for food.[16] These riparian corridors and their lagoons provide aesthetic value and streamside recreation opportunities in the form of parks and trails, particularly in more urbanized neighborhoods. They also perform water filtration services, and nutrient cycling. When this habitat remains intact, it can aid in flood control and water storage during the wet season and major storm events.[17]

[15] The Marine Protected Areas include: Greyhound Rock and Elkhorn Slough State Marine Conservation Areas as well as Año Nuevo, Natural Bridges, Elkhorn Slough, and Moro Cojo State Marine Reserves.
[16] Mary E. Power et al., *Rivers*, *in* ECOSYSTEMS OF CALIFORNIA 713 (Harold Mooney & Erika Zavaleta eds., 2016).
[17] Walter G. Duffy et al., *Wetlands*, *in* ECOSYSTEMS OF CALIFORNIA 669 (Harold Mooney & Erika Zavaleta eds., 2016).

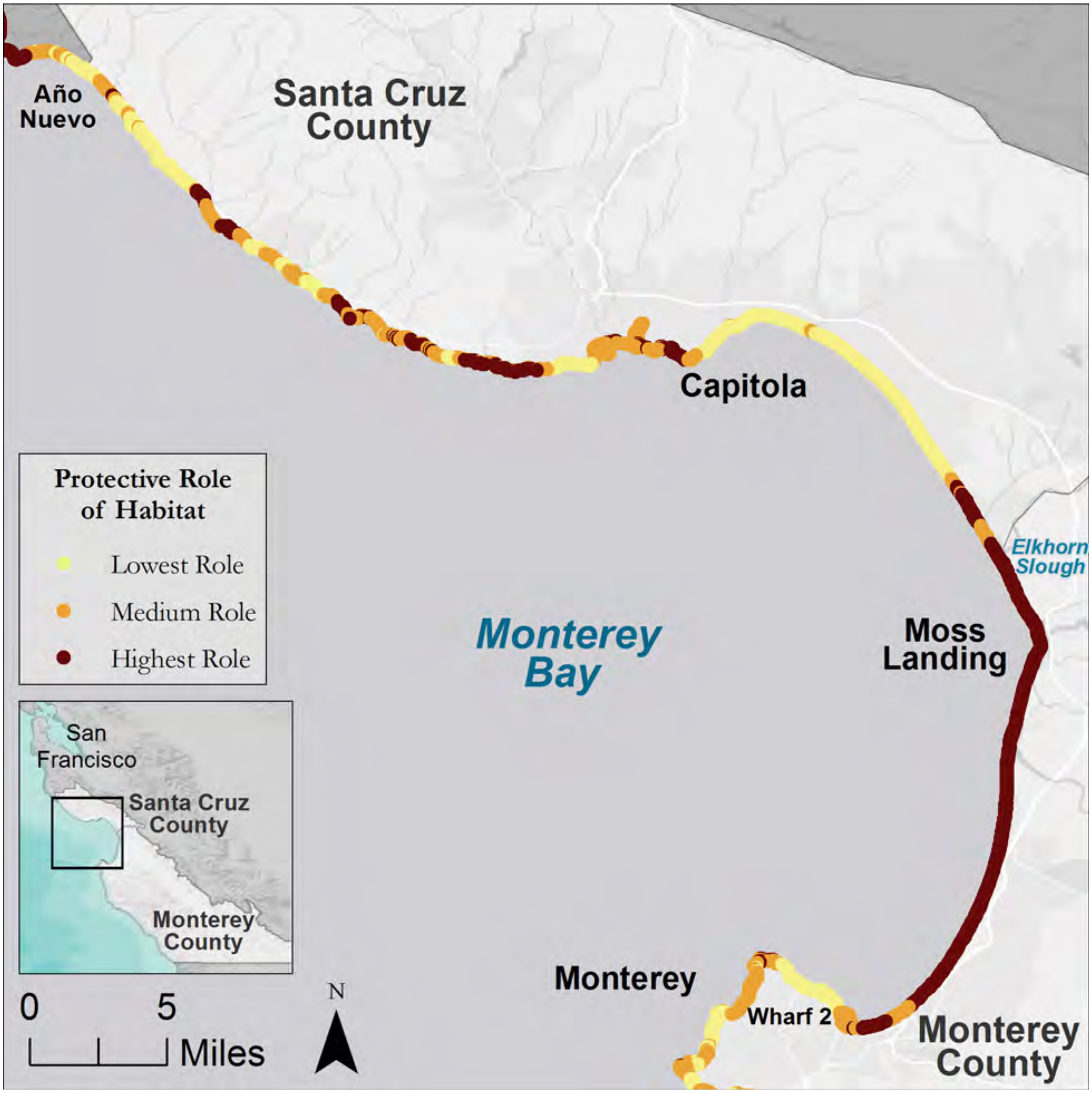

Fig. 4: Relative role of coastal habitats around Monterey Bay in reducing exposure to erosion and inundation.

Kelp Forests of Monterey Bay's Northern Coast

On the Northern end of the bay, near Año Nuevo, dense kelp forests grow from the sandstone and claystone reefs offshore. Kelp forests provide juvenile fish habitat and shelter them from predation. Kelp is also harvested at small scales to provide food for abalone aquaculture, particularly for abalone farms along the wharfs of Monterey.[18] Since no recreational or commercial fishing of any abalone species is allowed south of San Francisco, local aquaculture operations are the only source

[18] Mark H. Carr & Daniel C. Reed, *Shallow Rocky Reefs and Kelp Forests*, *in* ECOSYSTEMS OF CALIFORNIA 311 (Harold Mooney & Erika Zavaleta eds., 2016).

of Monterey Bay abalone for human consumption.[19] Forests of giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis luetkeana*), nourished by cold, nutrient-rich waters, are highly productive and support a food web of hundreds of fish and invertebrate species along with a diverse assemblage of birds and marine mammals.[20] In addition, litter from broken kelp fronds washes up on local beaches as wrack and detritus, sustaining a separate food web of terrestrial insects and shorebirds.[21] Kelp require high light levels and cool water temperatures to grow. As such they are sensitive to excess sedimentation and nutrient overloads that stimulate growth of light-blocking organisms. Strong wave action from storms can rip out entire kelp patches and significantly damage the remaining fronds. Accordingly, shifts in ocean thermal regimes or winter storm patterns such as El Niño can pose threats to sustaining kelp habitats.[22]

Wetlands of Elkhorn Slough

At the heart of Monterey Bay is Elkhorn Slough, an estuarine system known for its biological significance. Its channels, mudflats, eelgrass beds, salt marshes, and hard substrates provide habitat for more than 100 fish, 265 bird, and 500 marine invertebrate species, and more than two dozen rare, threatened, or endangered species.[23] Elkhorn Slough also provides safe habitat for several species of marine mammals. Sheltered from larger marine predators, harbor seals and Southern sea otters use the Slough as a safe feeding and pupping ground. Because of its rich diversity of birds and mammals, Elkhorn Slough's sheltered waters are a popular location for kayaking, paddle boarding, and wildlife viewing. These wetlands contribute to flood control, water filtration, and nitrogen runoff control services.[24] Wetlands provide additional benefits as sinks for carbon through their vegetation growth and accumulation of slowly decomposing sediment.[25]

Coastal Dune and Beach Systems

Extensive coastal dune systems along the southern coast of Monterey Bay support important plant communities between mean high tide and the furthest reach of storm waves.[26] The Monterey Bay beaches and dunes are also a favorite for locals and tourists alike due to its pristine coastline and sandy shores along many coastal access sites. The beach and dune habitats in this region also

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[19] CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE, STATUS OF THE FISHERIES REPORT (2011).

[20] Yuri Springer et al., *Toward ecosystem-based management of marine macroalgae—the bull kelp, Nereocystis luetkeana* 48 OCEANOGR. MAR. BIOL. ANNUAL REVIEW 1 (2010); *see also* Carr & Reed, *supra* note 18.

[21] Jenny Dugan et al., *The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California* 58 ESTUARINE COASTAL AND SHELF SCIENCE 25 (2003).

[22] Yuri Springer et al., *Toward ecosystem-based management of marine macroalgae - the bull kelp, Nereocystis luetkeana* 48 OCEANOGRAPHY AND MARINE BIOLOGY: AN ANNUAL REVIEW 1 (2010); Paul Dayton & Mia Tegner, *Catastrophic Storms, El Niño, and Patch Stability in a Southern California Kelp Community* 224 SCIENCE 283 (1984).

[23] CHANGES IN A CALIFORNIA ESTUARY: A PROFILE OF ELKHORN SLOUGH 4 (Jane Caffrey et al. eds., 2002) (Elkhorn Slough's habitats include "the slough's channels, mudflats, eelgrass beds, salt marsh, and hard substrate; the adjacent harbor, coastal dunes, and open beaches; and the grasslands, oak, woodlands, chaparral, and other upland areas.").; Jessica Lyons, *Scientists and Activists Aim to Save Elkhorn Slough from Erosion and Development Before it is too Late*, MONTEREY CNTY. WEEKLY, Dec. 13, 2007, *available at* http://www.montereycountyweekly.com/news/cover/article_11c69d2e-dfd5-502d-92ca-bada34be8709.html.

[24] James E. Cloern et al., *Estuaries: Life on the Edge, in* ECOSYSTEMS OF CALIFORNIA 359 (Harold Mooney & Erika Zavaleta eds., 2016).

[25] John Callaway et al., *Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands* 35 ESTUARIES AND COASTS 1163 (2012).

[26] Iris Hendriks et al., *Photosynthetic activity buffers ocean acidification in seagrass meadows* 11 BIOGEOSCIENCES 333 (2014).

provide numerous benefits to people and nature, such as critical shoreline bird habitat, mammal haul out locations, as well as coastal recreation and shoreline fishing spots.

General Policy Considerations

There are several general policy considerations that apply to the entire study area, regardless of the adaptation strategy implemented.[27] Most importantly, any climate adaptation strategies should conform to the various strictures of the Coastal Act, and take into account the Coastal Commission's sea level rise recommendations. Additionally, adaptation solutions should be place-based, designed with each specific location's characteristics and limitations in mind. Adaptation strategies should also incentivize proactive planning and limit subsidizing building in hazardous locations. Finally, the cultural significance of the study area should be considered. These considerations are investigated below.

The Coastal Act sets out various legal requirements with which all coastal adaptation policies must be consistent.[28] Likewise, the Commission's Sea Level Rise Guidance (Guidance) contains several persuasive and compelling recommendations. The Guidance recommends pursuing a suite of actions designed to protect in the short term, accommodate in the midterm, and promote retreat in the long term, instead of focusing on any one strategy type or time scales.[29] This hybrid approach permits flexibility and allows communities to tailor adaptation strategies to their unique circumstances. For instance, it would allow the use of protection, accommodation, and retreat strategies simultaneously—as needed and as appropriate—and would also allow these strategies to change over time.[30] Under such an approach, protection of existing structures is allowed but may be limited by certain factors, such as the economic life of a structure.

While a variety of coastal adaptation strategies for adjusting coastal land uses in response to climate impacts are possible in any given area, the appropriate adaptation measures for specific locations will depend on factors such as those locations' topographies and existing infrastructure. Accordingly, each location's unique characteristics should inform the adaptation strategies employed there. For example, the strategies suitable for the study area's open and undeveloped coastlines are likely unsuitable for the city of Santa Cruz and other highly developed areas. Furthermore, specific strategies should take into account predicted rates of local sea level rise and an area's vulnerability to storm events. Finally, existing regulations for each targeted location—such as local coastal programs, rules specific to the Monterey Bay National Marine Sanctuary[31] and any other applicable federal, state or local laws[32]—should be noted and followed.

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[27] These considerations are in addition to the overarching policy consideration of this assessment: that nature-based solutions could be prioritized when possible to ensure maximum co-benefits and beneficial services associated with these strategies.

[28] *See, e.g.*, CAL. PUB. RES. CODE §30235.

[29] CALIFORNIA COASTAL COMMISSION, SEA LEVEL RISE ADOPTED POLICY GUIDANCE 125 (2015) *available at* http://www.coastal.ca.gov/climate/slrguidance.html.

[30] *Id.* at 122-23 ("In many cases, a hybrid approach that uses strategies from multiple categories will be necessary, and the suite of strategies chosen may need to change over time.").

[31] *See, e.g.*, 15 C.F.R. § 922.132 (listing prohibited or otherwise regulated activities in the MBNMS).

[32] For instance, the National Historic Preservation Act of 1966 would govern efforts to move or alter historic buildings on the National Register of Historic Places. 16 U.S.C. §§ 470 *et seq.*

Keeping these limitations in mind, communities should pursue strategies that internalize the risks associated with building and buying properties in hazardous locations and incentivize proactive planned retreat and relocation where appropriate. Proactive planning is especially important in areas with a large number of repetitive loss properties, such as Aptos.[33] Superstorm Sandy and other disasters have proven that making decisions early is less expensive, and potentially less devastating, than waiting until the effects of a disaster take hold.[34] One way governments could internalize the risks associated with building in hazardous locations would be to stop spending public funds to rebuild private structures on sites damaged by rising seas and storms. Another option to internalize these risks would be to amend existing flood insurance policies.[35]

The cultural significance of California's beaches and the Monterey area can also be considered. California's beaches are important to Californians and play a large part in the State's identity. Furthermore, Monterey, and its surrounding areas, are culturally important for many reasons. Coastal adaptation planning can take the area's rich heritage into account when considering which coastal adaptation strategies to pursue. Particularly, adaptation decisions should consider the potential social impacts of decisions affecting culturally and socially significant areas. Moreover, culturally important points of interest in the area should be preserved if possible. Accordingly, decisionmakers can consider the social impacts of any proposed adaptation actions when prioritizing coastal adaptation strategies.

[33] Particularly State Park Drive and Beach Drive in Aptos, CA. COUNTY OF SANTA CRUZ LOCAL HAZARD MITIGATION PLAN 2015-2020 64 (2015) *available at* http://www.sccoplanning.com/Portals/2/County/Planning/policy/2015%20LHMP%20Public%20Review%20Draft.pdf.

[34] *See, e.g.*, Anne R. Siders, *Anatomy of a Buyout—New York Post-Superstorm Sandy*, Vermont Law School 16th Annual Conference on Litigating Takings Challenges to Land Use and Environmental Regulations (Nov. 22, 2013) (explaining lessons learned in acquisition and buyout programs post-Sandy in New York).

[35] Such a change would need to come at the federal level through amendment to the National Flood Insurance Program. 42 U.S.C. § 4001.

Community-Level Study Areas

Capitola: Coastal Setting

Capitola was one of the earliest populated beaches on the west coast and hosts a highly developed coastline. Similar to the neighboring city of Santa Cruz, Capitola faces flooding, cliff erosion and episodic bluff failure during King Tides—highest annual tides—and ENSO storm events. Soquel Creek bisects Capitola, and its beach, and plays a large role in riverine inundation in the area. Riprap lines the beach and protects both the beach and development beyond it, such as a modest commercial area that is the economic center of the community.

Fig. 5: Satellite image of Capitola.

Capitola's unique characteristics inform the adaptation policies and strategies that might be prioritized in the area.[36] The coastal city of Capitola is dominated by steep cliffs, pocket beaches and low dune systems. Surfgrass beds line the shore and kelp forests populate nearshore reefs from the mouth of Soquel Creek westward toward the city of Santa Cruz. There are a number of low coastal terraces and cliffs that allow coastal access to these scattered beaches. Downtown Capitola and Capitola Beach are saddled between two steep coastal cliffs forming an economically important beachfront tourist destination and coastal recreation site for the community. Soquel Creek runs through downtown Capitola, housing a string of wetlands before flowing to the ocean through an ephemeral lagoon system.

Capitola: Protective Role of Habitats

The low dune and beach habitat in Capitola plays a relatively moderate role in reducing the exposure of Capitola Village and the mouth of Soquel Creek to erosion and inundation during storms compared to the lower protection provided by rest of the adjacent coastline.[37] Beach sands in front of the creek mouth buffer wave run-up and the reach of salt water upstream during storm surge. The main drivers of coastal exposure in the Capitola area are the low elevation and erodible geomorphology surrounding Soquel Creek. The presence of wetlands reduces wave heights along the overall Monterey Bay coastline as coastal wetland and creek vegetation serve as a shoreline buffer. However, model results suggest that Soquel Creek does not serve a strong role in protecting the Capitola shoreline in all locations or scenarios due to the low-lying elevation and coastal flooding during storm events. This phenomenon is not unique to Soquel Creek as large scale regional erosion and river outflow can often overwhelm the ability of vegetation to attenuate waves.[38] The Capitola area is less exposed to wind and waves compared to the broader Monterey Bay study region, yet the relatively greater distance from the continental shelf drives an increase in storm surge potential. Kelp forest habitats along the broader Capitola coastline play a relatively low protective role, based on the model ranking methodology, in reducing exposure compared to the coastal dune and wetland habitats in this area.

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[36] *See* Figure 5.
[37] *See* Figure 6.
[38] Keryn Gedan et al., *The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm* 106 CLIMATIC CHANGE 7 (2011).

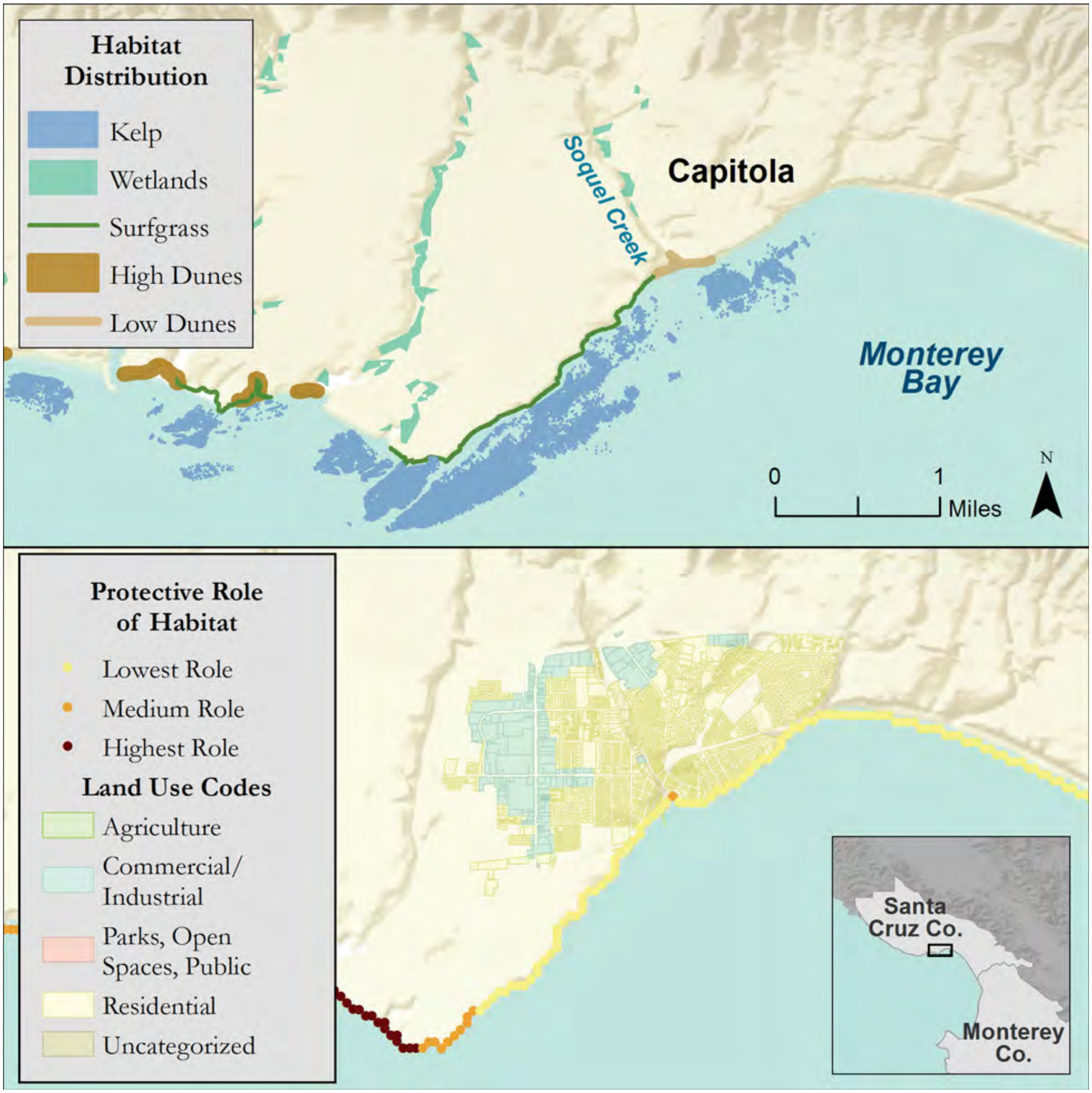

Fig. 6: Coastal habitats around Capitola, CA (Top). The relative role of coastal habitats along the shoreline of Capitola in reducing exposure to erosion and inundation with relevant land use zoning information (Bottom). Land use categories from the General Plan Land Use Codes were aggregated into four broad land use codes (see Bottom legend). Nearly all areas belonged distinctly to one category of land use. Only one land classification, Visitor Serving/L-M Density Residential, had uses from multiple categories, and it was categorized as Residential for this map.

Capitola: Ecosystem Services of Coastal Habitats

Wetlands in Riverine System

As Soquel Creek approaches the Pacific Ocean, the change in slope provides opportune locations for wetland habitats that slow the pace of the river and filter nutrients and pollutants, which leads to an improvement in water quality.[39] Closer to the coast, the river may transition into a lagoon

[39] Duffy et al., *supra* note 17.

system depending on the extent of the beach and low dune system at the mouth. Fish, small invertebrates and birds inhabit the lagoon as a feeding and breeding ground.[40] During strong rains, the lagoon typically breaches to create a direct opening to the ocean.[41] The distinction between this tidal versus lagoon interface plays a significant role in managing flood risks for the city of Capitola, particularly due to the many homes that line the creek and lagoon. While lagoon status influences the volume of tidal water that enters the creek system, intact wetlands can buffer surrounding areas against inundation. For instance, water is absorbed into soils instead of collecting on impermeable surfaces.[42]

Coastal Dune and Beach Systems

The beach and low dune habitat along the mouth of Soquel Creek provides the coastal community with recreation opportunities (e.g., surfing, fishing, kayaking, swimming, beach access). The Capitola Village and beach areas near the mouth of the creek draw over twenty percent of Santa Cruz County's tourism visitors annually.[43] The lagoon system at the mouth of Soquel Creek is actively managed by articifical breaching to release water as part of flood control and water quality maintainence. When open to the ocean, lagoons effectively function as small estuaries. Breaching alters the amount of tidal exchange, temperatures, salinity profiles and water flow for the lower portion of the creek. Depending on time of year and conditions surrounding the breaching event, the shift from closed to open system may influence patterns of species movement and habitat use.[44] Controlled breaching events are typically closely overseen by City Watershed Management monitoring teams, with crews on hand to keep threatened and endangered fish in their respective habitats with nets or transport upstream if needed.[45]

Kelp Forests and Surfgrass

Surfgrass and kelp forest habitats near the Capitola shoreline serve an important natural service by providing food and habitat for a suite of marine species that are also important to recreational fishing for residents and visitors. Kelp forests of the Monterey Bay support rockfish, urchins, crabs and many other commercially valuable species, while surfgrass acts as a nursery for juveniles of these adult kelp forest species.[46] Detritus from kelp forests washes out into open water and submarine canyons, providing subsidies of nutrients and food material to the Monterey Bay's deeper habitats.[47]

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[40] Cloern et al., *supra* note 24.
[41] *Id.*
[42] Walter Duffy and Sharon Kahara, *Wetland ecosystem services in California's Central Valley and implications for the Wetland Reserve Program* 21 ECOLOGICAL APPLICATIONS S18 (2011).
[43] LAUREN SCHLAU CONSULTING, SANTA CRUZ COUNTY VISITOR PROFILE (2010).
[44] Cloern et al., *supra* note 24.
[45] Jessica York, *Beach lagoon breached to alleviate flooding*, SANTA CRUZ SENTINEL, August 17, 2015, http://www.santacruzsentinel.com/article/NE/20150817/NEWS/150819676.
[46] Kevin Hovel, *Habitat fragmentation in marine landscapes: relative effects of habitat cover and configuration on juvenile crab survival in California and North Carolina seagrass beds* 110 BIOLOGICAL CONSERVATION 401 (2003); Carey J. Galst & Todd W. Anderson, *Fish-habitat associations and the role of disturbance in surfgrass beds* 365 MARINE ECOLOGY PROGRESS SERIES 177 (2008); *see also* Carr & Reed, *supra* note 18.
[47] Christopher Harrold et al., *Organic enrichment of submarine-canyon and continental-shelf macroalgal drift imported from nearshore kelp forests benthic communities by macroalgal drift imported from nearshore kelp forests* 43 LIMNOLOGY & OCEANOGRAPHY 669 (1998).

Both kelp forests and surfgrass beds also have potential to sequester some carbon dioxide from the atmosphere and surrounding water by incorporating carbon into their tissues. On a short-term scale, photosynthesis temporarily removes carbon dioxide from the water during the day, potentially reducing the impacts of ocean acidification.[48] Over time, marine sediments slowly bury and trap the plant matter—and therefore the carbon—for longer time scales.[49] As carbon sequestration markets develop, this ecosystem function could be of economic interest to the Capitola area from both a hazard and emission mitigation perspective.

Capitola: Adaptation Strategies & Considerations

Coastal Adaptation Options

Capitola's highly developed coastline limits the available coastal adaptation options. Due to high-density development and the prevalence of cliffs and bluffs, limited opportunities exist to apply nature-based strategies, with the exception of Capitola's beach—a possible candidate for beach nourishment. Beach nourishment could reinforce the beach and surrounding areas, slowing coastal erosion due to rising seas. This strategy would also buffer the upland structures—at least in the short term—from rising seas and storm events.

Other adaptation options would also be feasible in Capitola. A particularly useful and flexible option would be to develop sea level rise overlay zones for Capitola's vulnerable areas.[50] An overlay zone is a tool that groups certain properties together because of a feature they share, or because of some regulatory aim that a local government wishes to accomplish. An overlay zone would allow additional zoning regulations or building code restrictions to be established in the future for the properties in that zone, as deemed necessary. Establishing a sea level rise overlay zone would provide immediate notice to owners of homes and businesses that they are in an area that is vulnerable to rising sea levels.[51] This zone could be coterminous with, or go beyond, existing floodplain zones in the area.[52]

Overlay zones can also designate certain areas as protection, accommodation, or retreat zones and implement appropriate regulations for restricting future development and redevelopment in each zone. For instance, regulations might allow rebuilding of structures in an "accommodation zone," but only if they are raised or otherwise built to withstand rising seas. Likewise, a "retreat zone" might include setbacks and other redevelopment restrictions, such as requiring certain uses to end after a specific time period. Finally, a "protection zone" could allow protection strategies for properties that feature coastal dependent structures, such as harbors.

An overlay zone might also include additional strategies to promote responsible coastal adaptation. For instance, redevelopment in vulnerable areas could be limited through downzoning. This

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[48] Hendriks, *supra* note 26; Lester Kwiatkowski et al., *Nighttime Dissolution in a Temperate Coastal Ocean Ecosystem Increases under Acidification* 6 SCIENTIFIC REPORTS 1 (2016).

[49] Elizabeth McLeod et al., *A blueprint for blue carbon: Toward an improved understanding of the role of vegetated coastal habitats in sequestering* CO_2 9 FRONTIERS IN ECOLOGY AND THE ENVIRONMENT 552.

[50] Capitola currently uses several overlay districts in its zoning classifications. *See, e.g.*, CAPITOLA CITY, CAL., MUNICIPAL CODE §17.20.010 (affordable housing overlay district).

[51] A building moratorium could be put in place while overlay zones are developed. The building moratorium could encompass all areas that might be included in these zones. *See* CAL. GOV. CODE § 65858 (outlining procedures for local governments adopting interim ordinances as urgency measures).

[52] CAPITOLA CITY, CAL., MUNICIPAL CODE §17.50.090.

strategy rezones land to less intensive uses. Currently, the properties at the greatest risk of flooding and rising seas in Capitola are those close to Soquel Creek. These properties are currently zoned for several different land uses and could be prioritized for efforts to downzone.[53] Downzoning would lead to nonconforming uses in the short term—i.e., uses not allowed under the new zoning ordinances, but nonetheless "grandfathered" in because they existed prior to the downzoning. Regulations can be framed to allow these nonconforming uses initially but require them to cease after some period of time.

To achieve these longer-term coastal adaptation strategies, Capitola could consider taking several proactive steps in the short term. For instance, retreat strategies require that uplands be identified and purchased to make space for relocated structures. Land banking properties now could satisfy this future need.[54] Since these lands might not be used for this purpose immediately, this strategy could proceed gradually through phased and voluntary purchases of suitable upland properties. If this strategy does not succeed, or if the timeline becomes more urgent due to rising seas, it could be accomplished through eminent domain.[55] Likewise, Capitola could use transfers of development rights (TDRs) (where landowners sell the rights to develop their property) of vulnerable properties to help facilitate retreat.[56] This strategy could monetarily incentivize coastal landowners to provide their properties for retreat, and it could keep undeveloped coastal land undeveloped.

Capitola's existing coastal protection structures might also be studied to determine their efficacy and need for replacement or removal. Capitola's large sandy beach currently relies on two rip-rap groins on its east end to accumulate sand. To facilitate managed retreat, some of the existing coastal protection structures might need to be phased out. Others might need to be replaced if they are deemed necessary to coastal protection and provided they fit within Capitola's overall coastal adaptation strategy now and in the projected future.

Barriers and Considerations

There are several considerations that should be taken into account when moving forward with any of these coastal adaptation strategies in Capitola. First, limited undeveloped land is available immediately upland of the vulnerable areas, limiting retreat options in the area. As a result, businesses and residences that relocate might have to be moved farther inland than would be necessary elsewhere on the coast. Furthermore, the vulnerability of properties on bluffs and cliffs are less predictable than those along the lower-lying coastline, making long-term planning in these areas more challenging.[57]

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[53] *See* Figure 6.
[54] Land banking is the buying of land for some future use. Michael Allan Wolf, *Strategies for Making Sea-Level Rise Adaptation Tools "Takings-Proof"* 28 J. LAND USE & ENVTL. L. 157, 182 (2013).
[55] Eminent domain is the power of the government to take land for a public purpose. This power is limited by the U.S. Constitution and the California Constitution. U.S. CONST. AMEND. V; CAL. CONST. ART. I § 19.
[56] JESSICA GRANNIS, ADAPTATION TOOL KIT: SEA-LEVEL RISE AND COASTAL LAND USE 57-60 (2011).
[57] Cliffs and bluffs are more vulnerable to episodic erosion than beaches, which alternatively face constant erosive pressures. *See, e.g.*, episodic erosion events at Pacifica Lands End Apartments.

Takings concerns routinely arise when local governments undertake proactive planning for rising seas.[58] To avoid takings concerns, restrictions could be tailored to avoid depriving property owners of all economic value of their parcels.[59] Furthermore, restrictions could account for the economic lives of properties to avoid takings concerns, or could be grounded in avoiding and abating nuisances. Furthermore, any building moratoria could be tailored to be temporary.[60]

Third, regarding zoning classifications, any changes to the current classifications would likely include a grandfather provision allowing existing nonconforming uses to continue.[61] If grandfathering provisions are included in new ordinances, downzoning would only immediately affect undeveloped properties or properties whose uses have been abandoned. But, "grandfathered" provisions could be written to require landowners to comply with new zoning restrictions after a landowner renovates or rebuilds on his property, or when s/he changes the use.[62] Furthermore, as explained above, nonconforming uses could only be allowed for a certain period of time, after which they must cease.

Finally, cost and ecological drawbacks of proposed coastal adaptation strategies are necessary considerations when planning coastal adaptation strategies in Capitola. Cost is an important consideration because Capitola is highly developed and much of its vulnerable areas are in private ownership. Some parcels will be more expensive to buyout or pay just compensation for than others. Likewise, buyouts of private property might be less feasible than comparable options involving state or city lands. Property buyouts to facilitate relocation and to promote retreat face similar concerns. Likewise, cost versus long-term benefits of competing coastal adaptation options should be considered. Similarly, the ecological drawbacks of strategies such as beach nourishment should be weighed against their cost and their relatively short-term effectiveness.

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[58] Governmental taking of private property for public good—as well as regulations that "go too far" and result in "regulatory takings"—are common themes and constant considerations that arise when considering coastal adaptation strategies that require retreat from increasingly dangerous coastlines due to rising seas. Penn Coal Co. v. Mahon, 260 U.S. 393 (1922).

[59] Lucas v. South Carolina Coastal Council, 505 U.S. 1003 (1992).

[60] Tahoe-Sierra Preservation Council, Inc. v. Tahoe Regional Planning Agency, 535 U.S. 302 (2002).

[61] *See, e.g.,* CAPITOLA MUNICIPAL CODE § 17.50.310 ("A structure which was lawful before enactment of this chapter, but which is not in conformity with the provisions of this chapter, may be continued as a nonconforming structure subject to the following condition: if any nonconforming structure is destroyed by flood, earthquake, tsunami or, for another cause to the extent of fifty percent or more of its fair market value immediately prior to the destruction, it shall not be reconstructed except in conformity with the provisions of this chapter.").

[62] Local governments may end nonconforming uses in a variety of ways. Declare nuisance, pay just compensation, or require use to stop after a date certain. CECILY TALBERT BARCLAY & MATTHEW S. GRAY, CALIFORNIA LAND USE & PLANNING LAW 60-61 (2016).

Moss Landing: Coastal Setting

Moss Landing's relatively undeveloped coastline, surrounded by large tracts of farmlands, provides more adaptation options than other more densely populated sections of the coast. The shores surrounding Moss Landing are lined with high dune and sandy beach habitats extending north to Rio Del Mar and south to the edges of the city of Monterey.[63] This area includes many state beaches as well as local beach access points. Sediment for these beaches originates from rivers draining into the Monterey Bay.[64] Just inland of Highway 1, Elkhorn Slough drains the seasonal creeks and rivers that supply water to the surrounding agricultural areas, creating a network of wetlands and estuaries of gradually changing salinity.[65] Within the estuary, eelgrass and salt marsh habitats are prevalent. Much of this area is part of the ESNERR or the California network of Marine Protected Areas. While agriculture often runs up to the boundaries of arable land, most public recreational access to the water is constrained to a few entry points in local parks or at the Moss Landing Harbor.

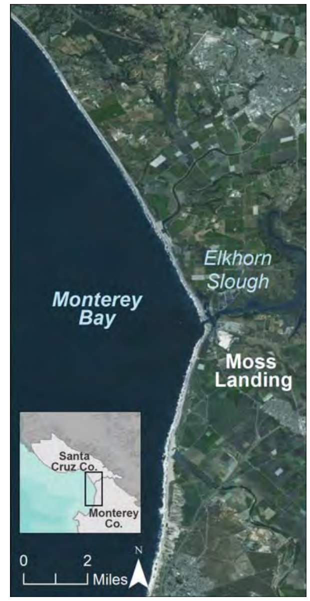

Fig. 7: Satellite image of Moss Landing.

Moss Landing is the center point of the Monterey Bay coastline and is adjacent to diverse natural systems, including extensive wetland habitats in nearby Elkhorn Slough, sand dunes along the open coast, and sandy beaches north and south of the harbor mouth. Along with this connection to multiple natural systems, Moss Landing is a primary commercial and party-boat fishing hub for the central California coast with landing locations for market squid, rockfish, crab, lingcod, groundfish and other fisheries. Moss Landing also functions as a key marine research center due to the confluence of ecosystems and direct access to the deep Monterey Submarine Canyon.[66]

Moss Landing: Protective Role of Habitats

The dune and beach systems starting just north of Moss Landing and continuing south to Monterey play a greater protective role relative to the full study area extent.[67] The orientation of the coastline in the Moss Landing study area, which directly faces predominant incoming waves, is a significant driver of exposure in this region. In addition, coastal geomorphology and low elevation contribute to high exposure index scores in this location, meaning that existing habitats are critical to countering this relatively high exposure to hazards. Model results indicate that the presence of wetlands can reduce wave heights and associated damages to property from storm events. Coastal wetlands are not as effective at reducing erosion in areas of high wave energy.[68] The Moss Landing coastline is a high wave energy environment and the wetlands in this area play a moderate role in reducing coastal exposure to erosion and inundation during storms compared to the large dune

[63] *See* Figure 7.
[64] *See* U.S. ARMY CORPS OF ENGINEERS, *supra* note 9.
[65] A key concern in this area is the historic changes in groundwater levels in the Pajaro and Salinas Valleys. These changes are further exacerbated by the effect of saltwater intrusion on highly productive agricultural lands as well as domestic potable water quality.
[66] Monterey Bay Aquarium Research Institute (MBARI) and Moss Landing Marine Labs (MLML) are two primary centers for marine research in the region.
[67] *See* Figure 7.
[68] Gedan, *supra* note 38.

systems. Loss of wetland habitat with rising seas will affect agriculture lands near Moss Landing. These wetland areas are highly exposed to waves mainly due to their large extent and proximity to the coastal zone.

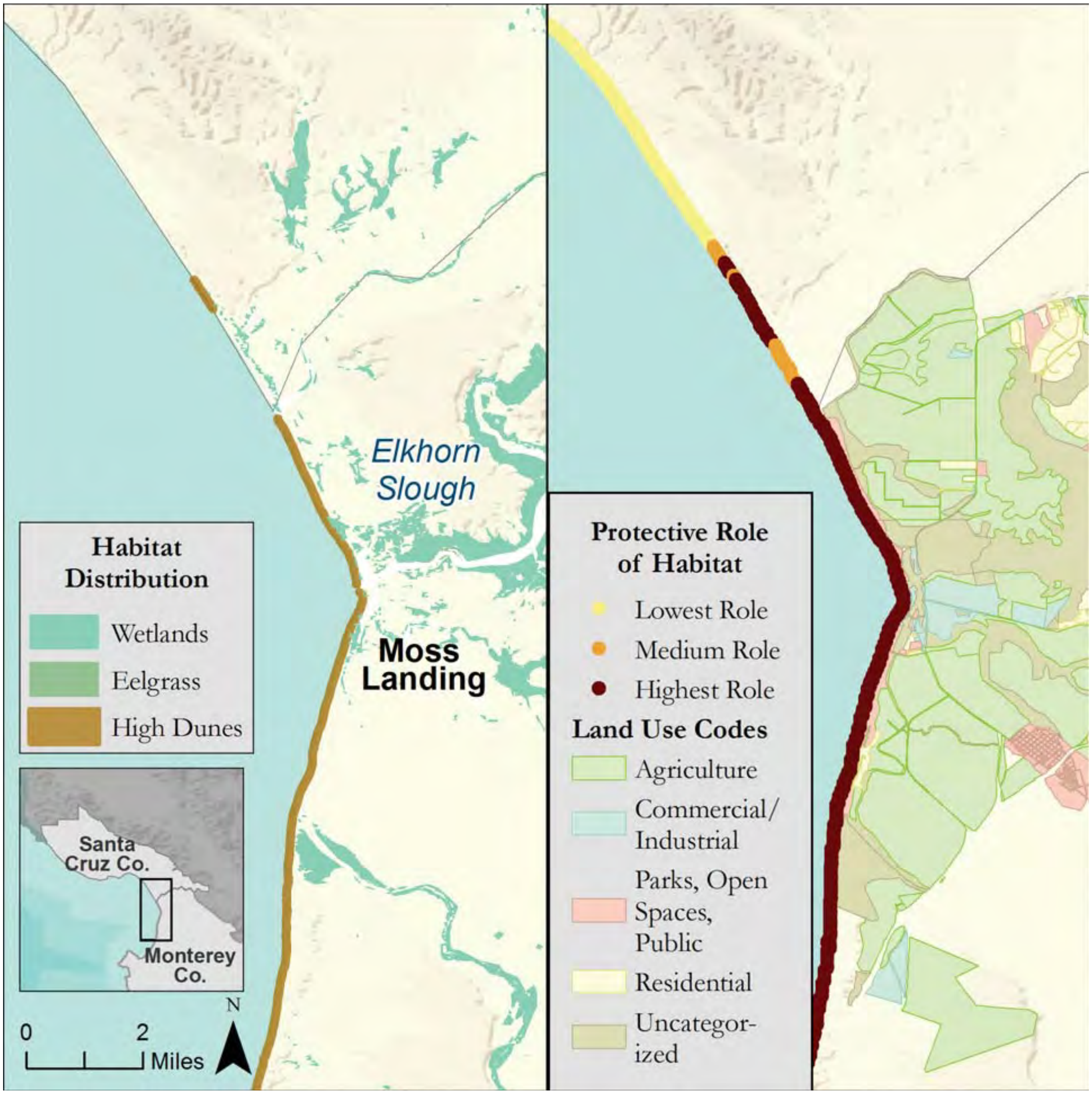

Fig. 7: Coastal habitats around Moss Landing, CA (Left). The relative role of coastal habitats near the mouth of Elkhorn Slough in reducing exposure to erosion and inundation with relevant land use zoning information (Right). Zoning information was distilled using the same methodology used for Capitola (Fig. 5).

Moss Landing: Ecosystem Services of Coastal Habitats

Coastal Dune and Beach Systems

The relatively dry areas on the high beach behind dunes are sheltered from wind and spray, serving as nesting grounds for endemic shorebirds and haul out spots for marine mammals. These beaches provide opportunities for coastal recreation, fishing, and wildlife viewing in the surrounding area in addition to their role protecting the coastline from high energy waves.

Elkhorn Slough

The estuarine system of Elkhorn Slough is the largest marsh habitat in California outside of San Francisco Bay and provides critical habitat for shorebirds and fishes. This area has also been home to a suite of competing human uses for more than 150 years (e.g., agriculture, cattle grazing, railroad and road construction, fishing, municipal energy production, marine research, tourism, recreation) that have led to the historical development of engineered structures (e.g., levees, embankments) and the construction of Moss Landing Harbor at the mouth of the estuary. These engineered structures have significantly influenced the structure and function of the estuarine system.[69] While the wetland systems in Elkhorn Slough are an ecologically and economically important feature of the area, they are also at risk due to a squeeze between rising sea levels and little room to migrate inland.[70]

Wetland habitats provide a number of key ecosystem services beyond coastal protection, including carbon sequestration, water quality improvement, flood abatement and biodiversity support.[71] The sheltered estuarine waters and seagrass meadows within the slough serve as a nursery for juveniles of commercially important fish species.[72] Elkhorn Slough is one of the few remaining freshwater and saltwater resting stops on the Pacific flyway. The slough is a critical habitat for migratory bird species and was designated a globally important bird area in 2000.[73] The banks of the Slough also serve as a major haul out area for marine mammals.

Additionally, wetland habitats store large amounts of carbon in their submerged soils when kept intact and have the potential to be used for carbon sequestration on the scale of decades or longer.[74] On a more immediate time scale, coastal vegetation helps buffer against ocean acidification by removing carbon dioxide from the water.[75] As larval fish and invertebrates experience more harmful effects from acidifying water conditions than adults, the wetlands and marshes of Elkhorn Slough may aid in protecting important species from harmful water chemistry in addition to protecting them from predators.[76]

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[69] Eric Van Dyke & Kerstin Wasson, *Historical Ecology of a Central California Estuary*: *150 Years of Habitat Change* 28 ESTUARIES 173, 179 (2005); *see also* CHANGES IN A CALIFORNIA ESTUARY: A PROFILE OF ELKHORN SLOUGH (Jane Caffrey et al. eds., 2002).
[70] Kerstin Wasson et al., *Ecotones as Indicators of Changing Environmental Conditions: Rapid Migration of Salt Marsh–Upland Boundaries* 36 ESTUARIES AND COASTS 654 (2013).
[71] WORLD RESOURCES INSTITUTE, ECOSYSTEMS AND HUMAN WELL-BEING: WETLANDS AND WATER SYNTHESIS (2005) (a report of the Millennium Ecosystem Assessment).
[72] Michael Beck et al., *The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates* 51 BIOSCIENCE 633 (2001).
[73] CHANGES IN A CALIFORNIA ESTUARY: A PROFILE OF ELKHORN SLOUGH, *supra* note 23.
[74] Cloern et al., *supra* note 24; McLeod, *supra* note 49.
[75] Hendriks, *supra* note 26.
[76] Haruko Kurihara, *Effects of CO2-driven ocean acidification on the early developmental stages of invertebrates* 373 MARINE ECOLOGY PROGRESS SERIES 275 (2008); Philip Munday et al., *Replenishment of fish populations is threatened*

Wetland habitats are threatened in the Elkhorn Slough area—and throughout the state—due to increased erosion from rising sea levels and land use development (agricultural, urban and/or rural). Fertilizer from agricultural runoff contributes to eutrophication and massive algal blooms that smother native flora, while urban pollutants may impair water quality.[77] Wetlands and coastal dunes that are exposed to coastal hazards could potentially migrate upslope given a path free of barriers from coastal development or shoreline hardening.

Moss Landing: Adaptation Strategies & Considerations

Coastal Adaptation Options

Moss Landing's coastline lends itself to several nature-based adaptation strategies. For instance, because the dunes in the area play a large role in protecting Moss Landing's coastline, adaptation strategies that protect, restore and enhance these areas could be targeted to maintain the integrity of the area. A dune restoration and enhancement project currently provides protection for MBARI. Additional suitable areas for dune restoration in Moss Landing could be identified and prioritized based on the protective role of specific dune habitats as well as factors specifically relevant to the local planning community. Beach nourishment might also be used to stem beach loss and to buffer these important dunes from erosion. Wetland restoration is another nature-based solution possible for Moss Landing. Wetland restoration in the area would carry various possible co-benefits including: sequestration of carbon dioxide, maintaining these areas as corridors for gradual coastline retreat and providing protection against storm surges.

Other nature-based options might be suitable here as well. Conservation easements could be implemented in some of these areas, particularly those most vulnerable to rising seas. This strategy involves either paying a landowner not to develop vulnerable land, or the landowner agreeing to do so without compensation, or in exchange for some other incentive, such as a tax break. This strategy would ensure that undeveloped lands stay undeveloped, and it could help transition currently developed but threatened lands to undeveloped lands. Rolling easements are another attractive but controversial option.[78] These can be used to allow the sea to migrate inland while slowly requiring the removal of structures within some distance of the approaching sea.[79]

In addition to the nature-based options outlined above, Moss Landing's coastline might also be suitable for other coastal adaptation strategies. For instance, accommodation and armoring might be appropriate for Moss Landing because it features a number of coastal dependent structures, such as the Monterey Bay Aquarium Research Institute, the Moss Landing Marine Laboratories, the Moss Landing power plant, and various boating and fishing facilities. Any of these structures might be protected or raised, depending on building design and construction, the anticipated

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by ocean acidification 107 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCE OF THE UNITED STATES OF AMERICA 12930 (2010).

[77] Brent Hughes et al., *Recovery of a top predator mediates negative eutrophic effects on seagrass* 111 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES 36444 (2014).

[78] *See generally* Meg Caldwell & Craig Holt Segall, *No Day at the Beach: Sea Level Rise, Ecosystem Loss, and Public Access Along the California Coast*, 34 ECOLOGY L.Q. 533, 535 (2007) (explaining that a rolling easement is "a device, rooted in statutory or common law or in permit conditions, that allows the publicly owned tidelands to migrate inland as the sea rises, thereby preserving ecosystem structure and function.").

[79] JAMES G. TITUS, ROLLING EASEMENTS (2011) *available at* https://www.epa.gov/sites/production/files/documents/rollingeasementsprimer.pdf.

building life cycle, end of use, and planned deconstruction. Furthermore, because of the various coastal-dependent buildings in the area, moveable structures could be installed and moved as needed in order to keep these structures on the coast as needed.

Other options can be pursued for undeveloped parcels in the area and existing structures that are not coastal dependent. Highway 1 could be moved inland or raised.[80] As was discussed for Capitola, an overlay zone could provide notice to the owners of vulnerable properties and restrict building and redevelopment in the area, as deemed appropriate. Furthermore, a moratorium on development could be imposed for some certain time period, while proactive coastal planning is pursued.

Moss Landing has a large amount of surrounding undeveloped and agricultural land.[81] Accordingly, some of these open spaces may be appropriate, stable sites for managed retreat of buildings in the area. Buyouts might be necessary in certain areas where planning is not able to sufficiently address increasingly rising seas.[82] Transfers of development rights might also be appropriate in certain similar circumstances.[83]

Barriers and Considerations

This area of the coastline is dominated by water, protected areas and sensitive ecosystems. The abundance of seawater and wetland areas might pose challenges for coastal adaptation for several reasons. For instance, the abundance of inland waterways and wetlands means that there is not much land immediately upland to move vulnerable buildings via managed retreat. Additionally, while this area features many coastal dependent facilities that might be protected or raised, there are drawbacks to pursuing these strategies. For instance, raising structures might bring additional regulatory requirements, such as those imposed by the Americans with Disabilities Act.[84]

Developing coastal adaptation strategies for coastal dependent structures carries with it its own set of unique challenges. Coastal dependent structures are prioritized for coastal land use under the Coastal Act.[85] Coastal dependent structures are not a high priority to move upland because of their dependence on water, but they need to be protected from rising seas nonetheless. Leaving these coastal dependent assets where they are makes them more susceptible to massive storm events than slowly rising seas. However, protecting these structures by armoring with seawalls would exacerbate erosion around these protective structures. If these coastal dependent structures are armored in the short term, long-term plans should be made to remove the armoring and move the structures.

Moving or raising Highway 1 presents issues as well. While raising Highway 1 in place is a possible short-term solution, Highway 1 may eventually need to be moved inland due to rising seas and repeated storm events. Moving Highway 1 immediately landward of its current location also presents drawbacks. Inland relocation would put it right in the middle of protected areas such

[80] The issues with this proposition are discussed *infra* in the Barriers and Considerations section.
[81] *See* Figure 7.
[82] *See, e.g.*, New York's Recreate NY Smart Home Buyout Program.
[83] *See, e.g.*, Penn Central Transportation Co. v. New York City, 438 U.S. 104 (1978).
[84] 42 U.S.C. §§12101-12213.
[85] CAL. PUB. RES. CODE §§ 30235 & 30255.

as Elkhorn Slough[86] and could restrict coastal access.[87] Moving Highway 1 would also require CalTrans to exercise its eminent domain authority, which can be controversial. Finally, moving Highway 1 to upland areas, such as those currently used for agriculture, will introduce additional complexities because of how these lands are currently prioritized in the current LCP.[88]

Managed retreat faces several challenges in this area. While Moss Landing is surrounded by open area, much of the region comprises wetlands or otherwise sensitive or protected areas. For instance, the area features Elkhorn Slough State Marine Conservation Area, Elkhorn Slough State Marine Reserve, Moro Cojo Slough State Marine Reserve, Moss Landing State Beach, and the Moss Landing Wildlife Area. The abundance of state lands and conservation lands creates challenges for managed retreat. On the other hand, public and open spaces might be well-suited for conservation easements such that they are set aside to become inundated and form new wetland and marsh areas. Section 30240 of the Coastal Act protects environmentally sensitive habitat areas (ESHAs), and further complicates using any of the areas surrounding these protected areas in Moss Landing for managed retreat.[89]

Another issue is possible challenges to zoning changes in the area. Property owners affected by new regulations sometimes claim that these regulations impermissibly "take" their property without just compensation. As was the case for Capitola, local governments should be weary of enacting regulations that possibly deprive property of all of its economic value and of instituting moratoria that do not specify end dates.

Summary

Communities in the Monterey Bay region, like many areas of California and the nation, are actively planning for a changing climate. Rising sea levels and increasingly damaging storm events are expected to cause increased erosion and inundation, which will further threaten people, property, infrastructure and coastal habitats. If these habitats are lost, degraded or unable to adapt by migrating inland, then local communities also lose the beneficial services they provide, including carbon sequestration, improving water quality, buffering ocean chemistry, providing nursery or nesting grounds, and protecting from erosion and inundation.

Proactive adaptation planning that takes into account the role of coastal habitats—coupled with advanced construction designs and technologies—and policy pathways for implementation, will allow local communities to proceed from planning to implementation more effectively. Ultimately, this approach—in concert with similar coastal adaptation decisions throughout California—can lead to coastal management processes that are consistent for statewide needs and flexible for local needs while ensuring a vibrant coastline for future generations.

[86] *See* list of protected areas in region *supra* note 15.
[87] The Coastal Act seeks to protect and maximize public coastal access. CAL PUB. RES. CODE. § 30211.
[88] MONTEREY COUNTY, NORTH COUNTY LAND USE PLAN 45-49 (1982).
[89] CAL. PUB. RES. CODE § 30240.

Habitat Type	Relative Protective Role*	Protective Attributes	Additional Ecosystem Services	Management Options
Kelp Forests	Relatively Low Role	Kelp forests attenuate low-energy wave action and have a dimished protective role as wave power increases.	Habitat for commercially viable fish and invertebrate species	Maintain healthy water conditions for kelp growth and reproduction.
			Vegetation harvested for commercial abalone aquaculture	
			Nutrient and vegetation export to local beach ecosystems	
			Integral ecosystem for culturally important species	
Wetlands	Relatively Moderate Role	Wetland ecosystems absorb water to reduce inundation and also serve to dissipate wave energy.	Flood control from inland inundation	Consider conservation of key areas of vegetation and soils before allowing development.
			Nutrient and sediment retention for improved water quality	
			Habitat for diverse species including marine mammals	Provide space for habitat to migrate inland as sea level rises.
			Carbon sequestration	
Seagrass	Relatively Low Role	Eelgrass beds attenuate low-energy waves which help decrease erosion of loose soils.	Wave attenuation	Provide space for habitat to migrate inland as sea level rises.
			pH buffer	Conserve existing habitat and restore damaged submerged aquatic vegetation.
			Nursery and essential habitat for fish and invertebrate species	
			Carbon sequestration	Maintain healthy water conditions and limit habitat degradation.
High Dune Systems**	Relatively High Role	Large dune systems dissipate high-energy waves and resist runup from powerful storms.	Cultural and aesthetic attachment	Maintain dune structure and vegetation.
			Location for recreation	
			Habitat for important bird and plant species	Regulate and/or limit dune sediment extraction.
Low Dunes & Beaches**	Relatively Moderate to High Role	Low dune systems and beaches dissipate low and moderate energy waves.	Habitat for important bird and plant species	Limit the implementation of built structures that impede migration of beach systems.
			Location for recreation	
			Cultural and aesthetic attachment	Maintain beach structure and access to continued sediment supply.

Table 1: Compilation of Ecosystem Services

*Protective role is based on model outputs created for and relative to the full study area (Año Nuevo to Wharf 2).
**Dunes were classified as “high dune” if their crest was higher than five meters. High dunes are less likely to lead to overwash and inundation from coastal storms.

Adaptation Strategy	Definition*	Example**	Potential Applications	Role of Natural System
Protection: *Hold the Line*	Employ built measure to defend development in current location	Wetland Restoration	Elkhorn Slough; northern section of Moss Landing Harbor; potentially in creeks near Capitola	Enhances extent of ecologically important natural areas
		Dune Restoration	North and south of Moss Landing on outer coast; southern Monterey Bay	Enhances extent of ecologically important natural areas
		Beach Nourishment	Soquel Creek Lagoon; outer coast of Moss Landing	Adds to natural system; requires thorough environmental monitoring
		Hard Protection	Near coastal-dependant or critical infrastructure such as power plant or critical transportation routes	Often limits natural habitat migration and increases erosion at edges of armoring
Accommodation: *Adjust to the line*	Modify existing or new development to decrease hazard risks	Overlay Zones	Existing flood zones or areas expected to be impacted by rising sea levels	N/A
		Limit Redevelopment	Locations that encounter repetitive loss or in (newly delineated) sea level rise overlay zones	May facilitate migration of natural systems or allow them to reestablish themselves
		Mobile Structures	Structures that are location dependent yet also encounter large episodic flood events	N/A
		Conservation Easement	Open and undeveloped areas in existing flood plain and areas adjacent to flood plains	Keeps natural system intact
Retreat: *Get away from the line*	Relocate existing development out of hazard areas and/or limit construction of new development in vulnerable areas	Planned Retreat	Highly vulnerable areas or locations with suitable upland areas available nearby	Removes structures allowing corridor for habitats to naturally migrate inland
		Buyout Programs	Lands suitable for becoming open areas	Can help promote natural system to replace previously developed area
Hybrid: *Maintain a flexible line*	Using strategies from multiple categories that may need to change over time	Accommodate over short term; relocate over long term	Hybrid adaptation options could be designed with enough flexibility to be applied across many different areas as needed	Provides pathway for taking actions that allow habitat to migrate and may provide opportunities for nature-based solutions
		Update land use designations and zoning ordinances		
		Redevelopment restrictions		
		Permit conditions		

Table 2: Compilation of Adaptation Strategies

* Definitions of adaptation strategies are distilled explanations derived from chapter seven of the California Coastal Commission's Sea Level Rise Guidance (Guidance).

** Many examples are summarized descriptions from figure 17 of the Guidance.

Analysis, Methodology, and Assumptions

This assessment involved a combination of ecosystem service modeling and adaptation policy research in an effort to identify and map priority locations for nature-based strategies that reduce vulnerability of critical assets using feasible land use policy methods.

To map and value the goods and services from natural habitats, we used the InVEST (Integrated Valuation of Environmental Services and Tradeoffs) free and open-source suite of software models created by the Natural Capital Project at Stanford University. The InVEST Coastal Vulnerability model incorporates a scenario-based approach to evaluate the role of natural habitats in reducing exposure to coastal impacts. [90] The InVEST Coastal Vulnerability model produces a qualitative estimate of coastal exposure. The Exposure Index differentiates areas with relatively high or low exposure to erosion and inundation during storms.

Data inputs included: 1) **Geomorphology**: Polyline representing coastal geomorphology based on the National Oceanic and Atmospheric Administration (NOAA) Environmental Sensitivity Index; 2) **Coastal habitat**: Polygons representing the location of natural habitats (e.g., seagrass, kelp, wetlands, etc.) from the Department of Fish and Wildlife website created for Marine Life Protection Act process; 3) **Wind and wave exposure**: Point shapefile containing values of observed storm wind speed and wave power across an area of interest using Wave Watch III data provided by NOAA; 4) **Surge potential**: Depth contour that can be used as an indicator for surge level default contour is the edge of the continental shelf. In general, the longer the distance between the coastline and the edge of the continental shelf at a given area during a given storm, the higher the storm surge; 5) **Relief**: A digital elevation model (DEM) representing the topography and (optionally) the bathymetry of the coastal area—this analysis includes a five meter bathymetric and topographic merge from US Geologic Survey for the California coast; 6) **Sea-level rise**: Rates of (projected) net sea-level change derived from the National Research Council 2012 report (highest range for 2030: 12" of sea level change);[91] 7) **Hard Armoring**: Data set inventory of man-made structures and natural coastal barriers that have the potential to retain sandy beach area in California. This armoring dataset is a compilation of the UC Santa Cruz Sand Retention Structures, Monterey County Barriers, and US Army Corps of Engineers Coastal Structures.

One main limitation with this modeling approach is that the dynamic interactions of complex coastal processes occurring in a region are overly simplified into the geometric mean of seven variables and exposure categories. InVEST does not model storm surge or wave field in nearshore regions. More importantly, the model does not take into account the amount and quality of habitats, and it does not quantify the role of habitats for reducing coastal hazards. Also, the model does not consider any hydrodynamic or sediment transport processes: it has been assumed that regions that belong to the same broad geomorphic exposure class behave in a similar way. In addition, using this model we assume that natural habitats provide protection to regions that are protected against erosion independent of their geomorphology classification (e.g., rocky cliffs). This limitation artificially deflates the relative vulnerability of these regions, and inflates the relative vulnerability

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[90] INTEGRATED VALUATION OF ECOSYSTEM SERVICES AND TRADEOFFS, http://www.naturalcapitalproject.org/models/coastal_vulnerability.html (last visited Aug. 30, 2016).

[91] NATIONAL RESEARCH COUNCIL (NRC) COMMITTEE ON SEA LEVEL RISE IN CALIFORNIA, OREGON, AND WASHINGTON, SEA-LEVEL RISE FOR THE COASTS OF CALIFORNIA, OREGON, AND WASHINGTON: PAST, PRESENT, AND FUTURE (2012).

of regions that have a high geomorphic index. Based on these limitations and assumptions, the InVEST Coastal Vulnerability tool is an informative approach to investigate *relative exposure* for a coastline and identify locations where coastal habitats play a relatively significant role in reducing exposure. However, for local scale decisions regarding locally specific geomorphic conditions, further analysis is needed (e.g., the InVEST Nearshore Wave and Erosion model).

Results can help evaluate tradeoffs between climate adaptation strategy approaches. In this assessment, we compared the InVEST Exposure Index results both with and without the protective services provided by natural habitats. This approach (computing the difference between exposure indices) provides a priority index for locations in which coastal habitats play the largest relative role in reducing exposure to erosion and inundation. These locations can then be further investigated for nature-based strategies to reduce vulnerability.

We began our policy research by exploring academic and practitioner guidance on potentially appropriate coastal adaptation strategies for sea-level rise. We reviewed a number of guidance documents that outline land use planning and regulatory options that should be considered in coastal areas. Next, we identified how priority or high-risk locations align with various land-use or zoning designations in Monterey and Santa Cruz Counties using land use zoning layers provided by Monterey and Santa Cruz Counties as well as from planning staff from the City of Capitola. The zoning designations and population density in the various high-risk areas guided our determination of the strategies most feasible in each location. For example, high-density zoning designations—in most cases—reduce the feasibility of habitat restoration or retreat options. We also researched relevant state- and county-level laws and policies on acceptable strategies for near- and long-term adaptation to rising sea levels. We identified the limitations these policies place on adaptation options in the Monterey Bay Region and explored potential changes to the existing policies that may increase adaptive capacity. Ultimately, these prioritized policy considerations may be relevant to both Santa Cruz and Monterey Counties—as well as local jurisdictions—through the development of the Local Coastal Program update process.

In addition to this specific engagement in the Monterey Bay Region, the Center for Ocean Solutions is also involved in Local Coastal Program updates throughout the state. The Center is playing a key role in compiling, distilling, and distributing information on incremental adaptation actions with current county partners (i.e., Sonoma, Marin, Santa Cruz, and Monterey Counties) as well as with the State Coastal Conservancy and California Coastal Commission through the development of the California Coastal Adaptation Network. By developing a transferable methodology that incorporates the role of natural capital into county-level coastal adaptation planning, the Center for Ocean Solutions is scaling these best practices to a statewide prioritization of adaptation strategies that preserve the integrity of natural systems. The Center's work advances the state's efforts for flexible consistency in accordance with the California Coastal Commission's Sea Level Rise Policy Guidance.

Appendix B.

Climate Change Impacts to Combined Fluvial and Coastal Hazards (ESA, 2016)

MONTEREY BAY SEA LEVEL RISE

Climate Change Impacts to Combined Fluvial and Coastal Hazards

Prepared for
Moss Landing Marine Labs with Funding from the
California Ocean Protection Council

May 13, 2016

ESA

MONTEREY BAY SEA LEVEL RISE

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1 INTRODUCTION

As part of the Sea Level Rise study for the Monterey County Local Coastal Program (LCP) ESA simulated and mapped the potential inundation from extreme coastal and fluvial conditions for multiple scenarios of future climate conditions. Two fluvial systems were analyzed for this effort (1) the Reclamation Ditch watershed which includes Gabilan Creek and Tembladero Slough the and drains to the Moss Landing Harbor, and (2) Soquel Creek which runs through the City of Capitola in Santa Cruz County. The Reclamation Ditch watershed is mostly agricultural while the lower reaches on Soquel Creek are mostly urbanized. These two systems were selected to enable risk assessment for a range of natural and manmade resources.

Climate data analysis was conducted to evaluate future extreme rainfall-runoff events and extreme coastal tide and wave events. For the rainfall-runoff and fluvial climate change analysis ESA used public climate model data to develop medium and high estimates of 100-year discharge for 2030, 2060, and 2100 time periods. ESA also developed estimates of extreme tide conditions with sea level rise for medium and high climate change scenarios for the three future periods. The flood levels and extents were then estimated for these scenarios using hydraulic modeling driven by combined watershed and coastal water level conditions under climate stress.

The study developed geospatial datasets for the extent and depth of inundation under flooding for existing conditions and future climate scenarios. The key products and findings for this study include:

- **Key products developed**
    - GIS layers of flood inundation extent for the Moss Landing Harbor and surrounding areas, and Soquel Creek in Capitola, for six scenarios (1) existing conditions 100-year flood, (2) future conditions 100-year flood under high emissions for 2030, (3 and 4) medium and high emissions for 2060, and (5 and 6) medium and high emissions for 2100.
    - GIS depth rasters for both systems and the six scenarios listed above.
    - Amendments to previously developed coastal flooding layers based on newly surveyed structural information in flooded areas in Monterey Bay.
    - Technical metadata and reporting contained herein
- **Key analysis findings**
    - Analysis of existing hydrologic climate data indicates an increase in peak flow for the 100-year discharge of 337 cfs (25%) for high emissions by 2100 on the Reclamation

Ditch system and by 1660 cfs (95%) for Soquel Creek for the same emissions and time horizon scenario.

- Analysis of existing sea level rise trends and anticipated coastal flood levels indicate an increase in downstream water level of 5.2 ft for high emissions by 2100.

- As anticipated the increase in rainfall intensity and 100-year discharge combined with the increase in sea level under climate change increases flood extent on both systems. In comparing the 100-year event under existing conditions with the year 2100 high-emissions scenario, the increase in flood extent for the Reclamation Ditch system is approximately 1736 acres (95%) and the change in flood depth is approximately 2.6 feet (36%). The same comparison for Soquel Creek, which is more topographically constrained, shows a total increase in flood extent of 65 acres (65%) and an increase in flood depth of 3.01 feet (29%).

The following four report sections lay out the technical analysis methodologies, flood hazard mapping results, and applications for the resulting information in planning and adaptation assessments. Specifically Section 2 describes the climate analysis conducted to develop boundary conditions for the hydraulic model for several scenarios representing change in 100-year discharge due to increased precipitation intensity and depth with climate change and the change in extreme ocean level coincident with the 100-year flow. Section 3 describes the model development process for both the Reclamation Ditch and Soquel Creek systems. Section 4 summarizes the flood hazard mapping analysis conducted to develop the geospatial datasets of flood hazard for the climate scenarios analyzed. Section 5 summarizes the applicability of the datasets to planning and adaptation efforts for the communities that may be at risk of additional flooding under stress by climate change.

2 CLIMATE ANALYSIS

2.1 Emissions Scenarios

The goal of the climate change data analysis was to review existing climate model data to estimate changes in extreme rainfall, coastal water level, and the resulting extent of flood hazards. The changes in extreme rainfall conditions were used to drive the inflow boundary for the hydraulic models of the two systems. Climate model data were evaluated for the latest set of General Circulation Models (GCMs) developed for the IPCC's fifth Assessment Report (AR5). The GCM data produced for AR5 has been aggregated by the World Climate Research Programme under the Coupled Model Intercomparison Project Phase 5 (CMIP5). The emissions scenarios used to drive the GCMs for CMIP5 are referred to as Representative Concentration Pathways (RCPs). The highest scenario, RCP 8.5, reflects a track with little mitigative measures to reduce greenhouse gas emissions resulting in a net increase in radiative forcing of 8.5 W/m^2 by 2100 relative to pre-industrial conditions. A medium level emissions scenario, RCP 4.5, reflects a future wherein changes in technology and energy usage stabilize the increase in net radiative forcing to 4.5 W/m^2 by 2100. These emissions scenarios, RCP 4.5 and RCP 8.5, were used to reflect respectively medium and high emissions trajectories for this study. Existing conditions was also modeled which is representative of a low emissions scenario thus the scenarios selected effectively span low, medium, and high climate change conditions.

These emissions scenarios supersede the scenarios developed in the Special Report on Emissions Scenario (SRES) utilized for the IPCC's fourth Assessment Report (AR4) and used to drive GCMs for CMIP Phase 3 (CMIP3). In general, the RCP4.5 emissions scenario tracks closely with the prior SRES B1 scenario, while RCP8.5 tracks slightly above SRES A2. The following figure (Figure 1) compares the change in mean surface temperature for the SRES and RCP emissions scenarios.

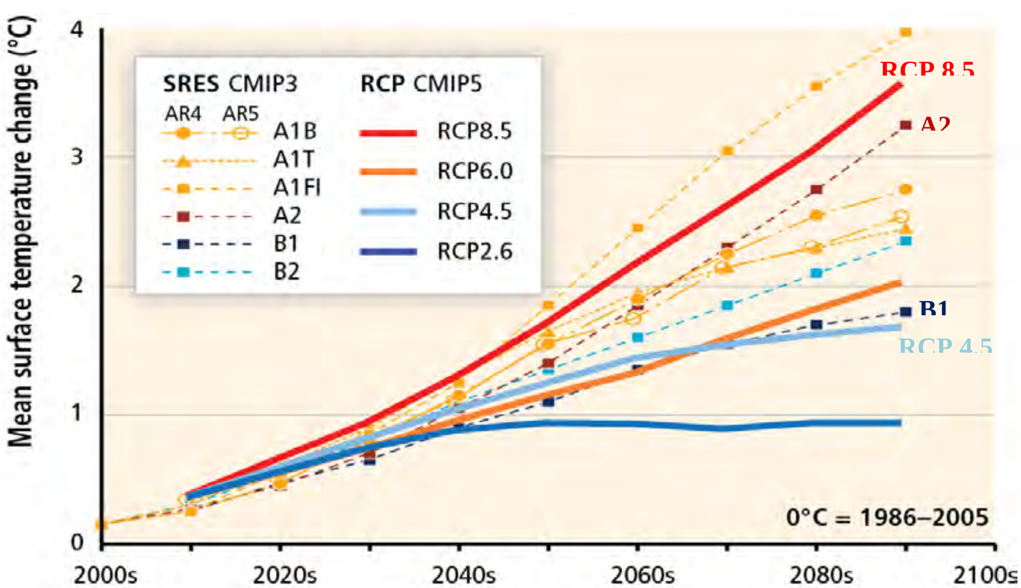

Figure 1. Comparison between SRES and RCP emissions scenarios. Reproduced from Figure 1-4 of IPCC AR5, WGII, Chapter 1

2.2 Extreme Fluvial Streamflow Analysis

Model output from GCMs driven by the RCP emissions scenarios was downscaled by CMIP5 institutions to regionalize the data from a global scale to higher resolution local scale. The downscaled data were then used to drive hydrologic models and estimate runoff for a daily timestep on a 12km x 12km grid from 1950-2100 in a study conducted by the USBR (2014). ESA used the resulting data from the USBR study to route baseflow and surface runoff and generate a time series of daily streamflow at the outlet of the two systems. The routing routine used is a component of the Variable Infiltration Capacity (VIC) model used in the USBR study to develop the runoff datasets.

The resulting daily streamflow time series from 1950-2100 was used to conduct flood frequency analysis to estimate 100-year discharge (Q_{100}) for medium and high emissions for 2030, 2060, and 2100. From the daily time series, peak annual flows were extracted for each year from 1950- 2100. A frequency curve was then fit to subsets of the peak annual flows using the Log Pearson III (LP-III) fitting method outlined in the USGSs Bulletin 17b (USGS, 1982). The USGS conducted a 2011 study updating many of the elements of Bulletin 17b based on updated gage records through water year 2006 for California gages (USGS, 2011). Two significant elements that were updated were the methods for estimating values for generalized skew (G_{gen}) and mean square error for generalized skew (MSE-G_{gen}) based on the average elevation of the basin. The average elevation of the basin is 479 feet for the Reclamation Ditch system and 1,141 feet for Soquel Creek. Based on the non-linear model for G_{gen} and the relationship between MSE-G_{gen} and average basin elevation summarized in USGS, 2011 Tables 7 and 8 respectively, the values estimated for G_{gen} and MSE-G_{gen} for the Reclamation Ditch watershed are -0.613 and 0.14, respectively, and -0.581 and 0.14 respectively for Soquel Creek.

Using these updated values in the LP-III method, we computed 100-year discharge for each GCM and each emissions scenario for an historical period, and three future time periods—2030, 2060 and 2100. A sample figure for the flood frequency curve for the historic time period for a single GCM for RCP4.5 is shown in Figure 2. Subsets of the data were selected for the time periods as summarized in Table 1.

TABLE 1
SUBSETS FOR TIME PERIODS USED IN FLOOD FREQUENCY ANALYSIS

Time period	Years for which peak annual flow was used in flood frequency analysis	Emissions scenario	GCM percentile	Resulting 100-year flow variable
2030	2015-2045	RCP 4.5 (medium)	50th	Q_{100}-2030-medium
		RCP 8.5 (high)	90th	Q_{100}-2030-high
2060	2045-2075	RCP 4.5 (medium)	50th	Q_{100}-2060-medium
		RCP 8.5 (high)	90th	Q_{100}-2060-high
2100	2070-2100	RCP 4.5 (medium)	50th	Q_{100}-2100-medium
		RCP 8.5 (high)	90th	Q_{100}-2100-high

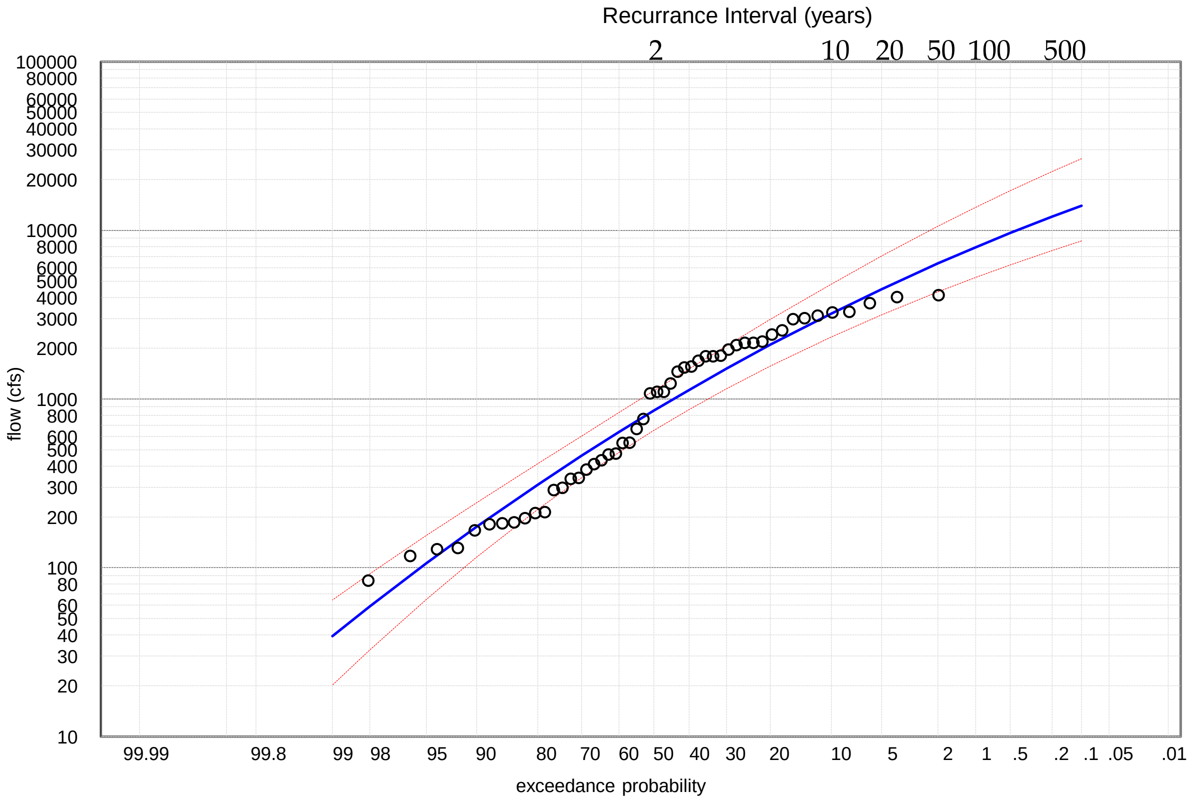

Figure 2. Log Pearson III flood frequency curve for historic time period (1950-2000) for GCM ACCESS[1] 1-0 for the RCP4.5 emissions scenario. The black dots show peak annual flow from routed GCM hydrology, the blue line shows the fitted LP-III curve, and the red lines show the 95- and 5-percent confidence intervals.

Because this analysis was conducted for each individual GCM, a distribution of GCMs can be created. The distribution highlights the discrepancy between individual models and the need to select a representative percentile for characterizing climate risk on any system. An example of the distribution of all models considered for a single emissions scenario and selected percentiles within the model distribution is shown for change in peak annual flow in Figure 3.

[1] Australian Community Climate and Earth-System Simulator (ACCESS)

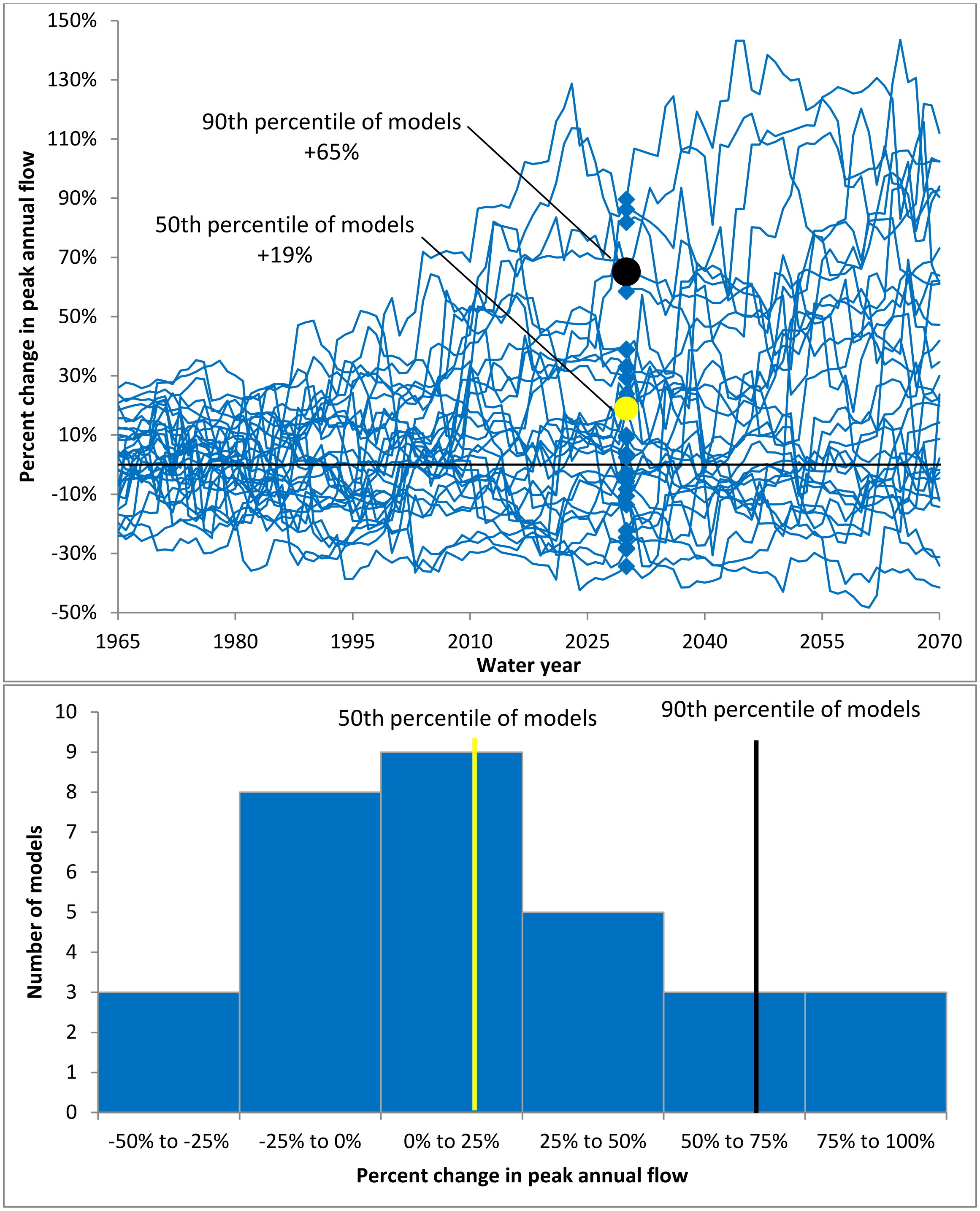

Figure 3. Percent change in peak annual flow relative to 1950-2000 average for all GCMs under RCP 4.5 emissions, blue lines show individual GCM trajectories and blue dots show result at year 2030 (top), and (bottom) histogram of total number of models for given ranges of percent change in peak annual flow

The 100-year discharge and the change in 100-year discharge for the three future time periods relative to the historic time period was calculated for each GCM based on the following equation:

$$\Delta Q_{100} = Q_{100-year-emissions} - Q_{100-hist}$$

Where ΔQ_{100} is the change in Q_{100} in cfs
$Q_{100\text{-year-emissions}}$ is the Q_{100} for a given GCM at a specific time horizon and emissions scenario
$Q_{100\text{-hist}}$ is the Q100 for the historical time period based on the GCM data

The distribution of GCMs for the change in Q_{100} on the Reclamation Ditch is shown for RCP 4.5 in Figure 4 and for RCP 8.5 in Figure 5. The distribution of GCMs for the change in Q100 on the Soquel Creek is shown for RCP 4.5 in Figure 6 and for RCP 8.5 in Figure 7.

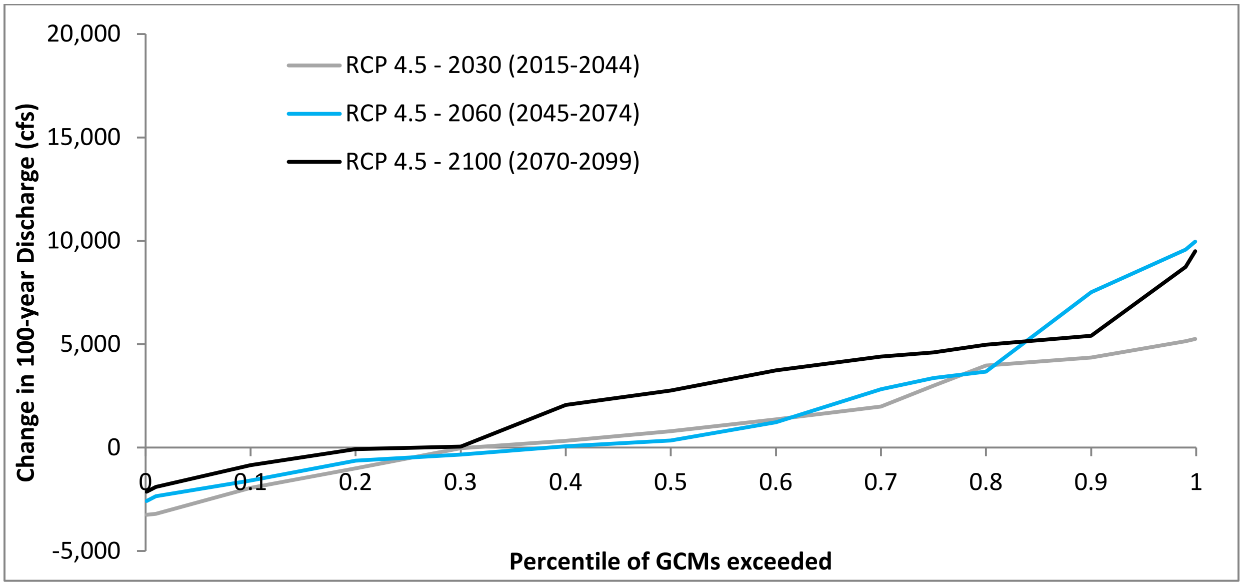

Figure 4. Distribution of change in Q_{100} for each GCM for 2030, 2060, and 2100 for RCP 4.5 on the Reclamation Ditch System

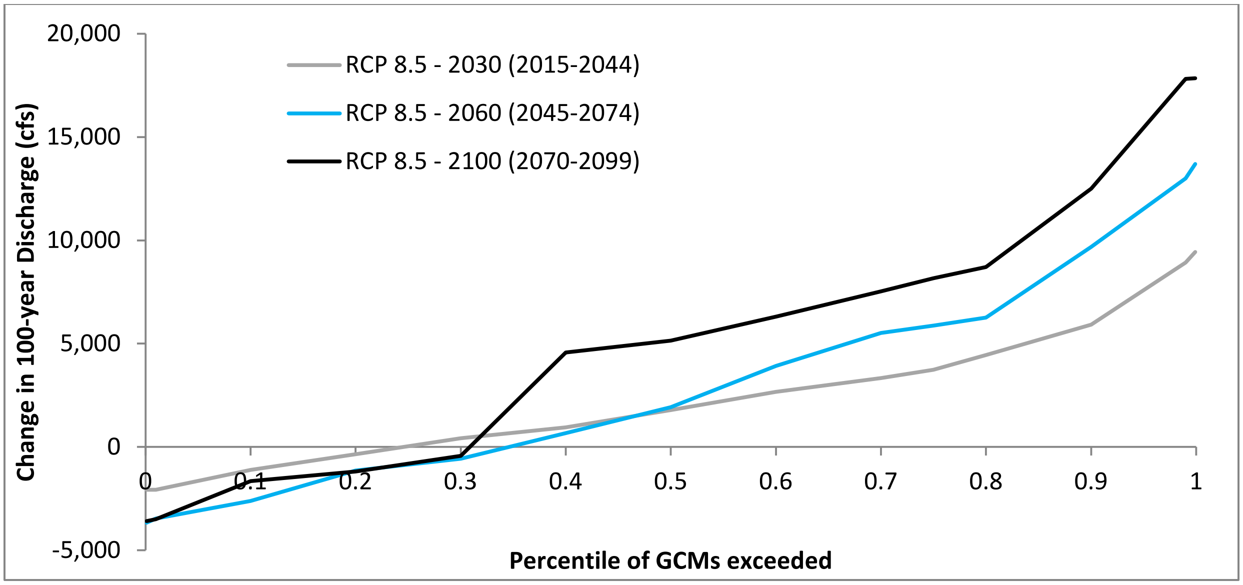

Figure 5. Distribution of change in Q_{100} for each GCM for 2030, 2060, and 2100 for RCP 8.5 on the Reclamation Ditch

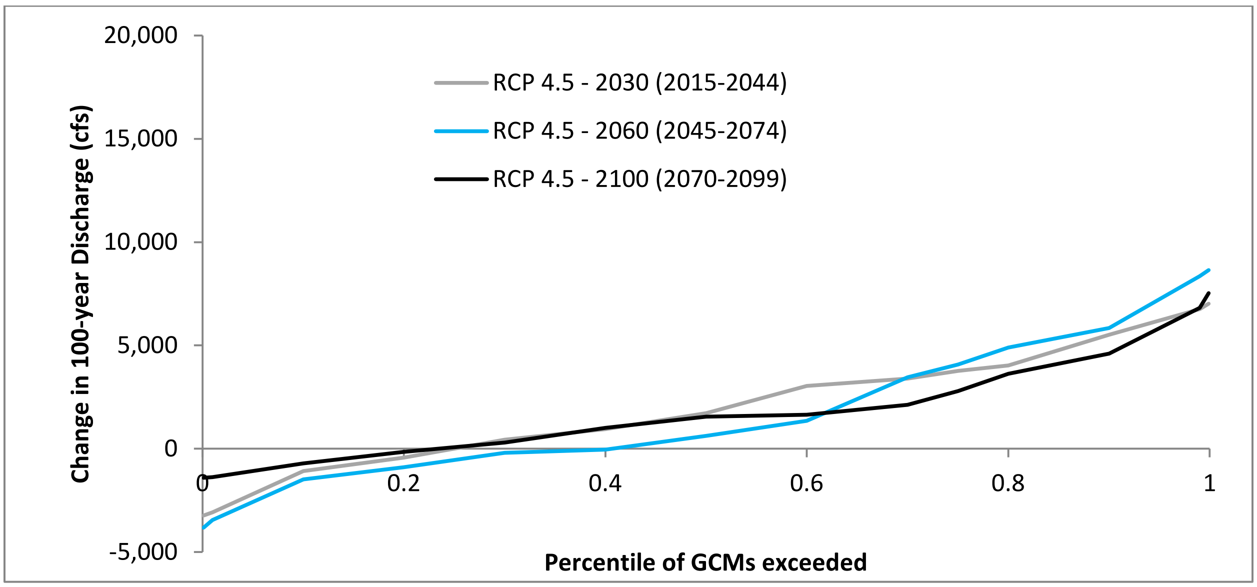

Figure 6. Distribution of change in Q_{100} for each GCM for 2030, 2060, and 2100 for RCP 4.5 on Soquel Creek

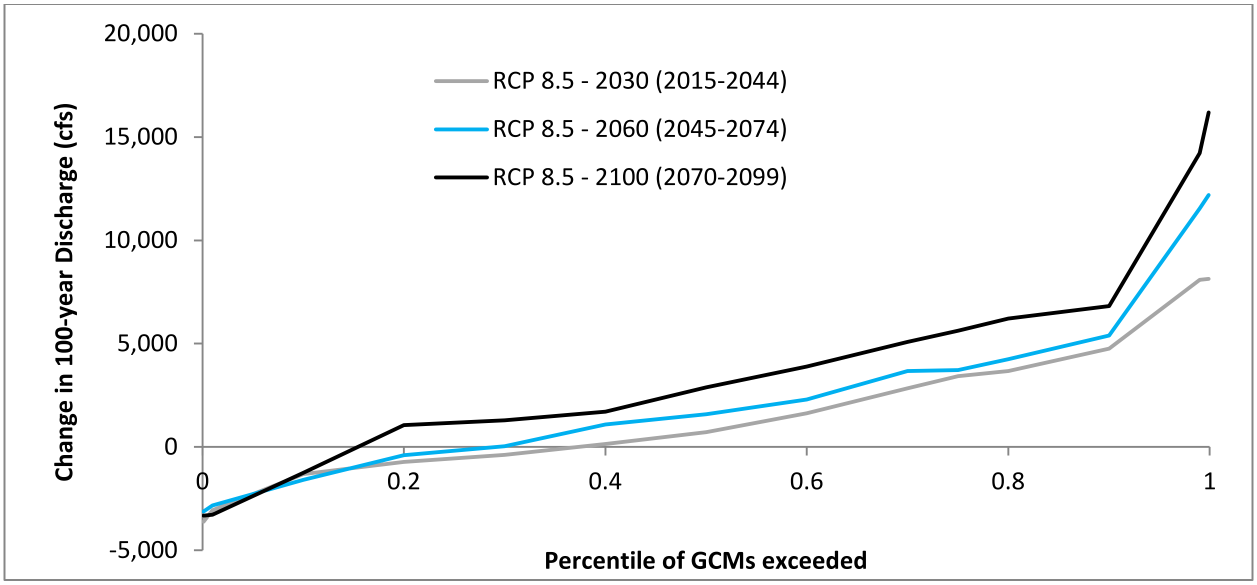

Figure 7. Distribution of change in Q_{100} for each GCM for 2030, 2060, and 2100 for RCP 8.5 on Soquel Creek

These figures indicate that for RCP 4.5, the emissions scenarios are grouped fairly closely for each future time period. The 'medium' emissions scenario was estimated from approximately the 50th percentile for the three time periods for RCP 4.5. It was determined that the 90th percentile of the models for RCP 8.5 for each individual year would be used to represent the 'high' emissions scenario. The changes estimated for 100-year discharge for both systems are summarized in Table 2.

TABLE 2
CHANGE IN 100-YEAR DISCHARGE FOR BOTH SYSTEMS RELATIVE TO HISTORIC PERIOD (1950-2000)

	Reclamation Ditch system			Soquel Creek		
Emissions scenario	**2030**	**2060**	**2100**	**2030**	**2060**	**2100**
Medium (RCP 4.5 50th percentile)	20%	40%	60%	13%	15%	20%
High (RCP 8.5 90th percentile)	140%	210%	275%	62%	68%	95%

The flows estimated in the extreme streamflow analysis were used to drive the hydraulic models which, in turn, were used to map inundation extents for existing conditions and the five future climate conditions (2030 high, 2060 and 2100 medium and high emissions). In addition to the extreme streamflow change, the downstream coastal water levels are influenced by sea level rise. The following section describes the analyses conducted to characterize the extreme coastal water level that would be coincident with the 100-year flood.

2.3 Extreme Coastal Water Level Analysis

2.3.1 Reclamation Ditch Extreme Tide Levels

The ocean boundary condition from the existing unsteady HEC-RAS hydraulic model consisted of a repeated tide cycle that peaked at about MHHW. To represent extreme tide conditions we used a 10-year tide as the ocean boundary for existing conditions. Given that the mouth of this system (the mouth to Moss Landing Harbor) is relatively deep we assumed that the mouth would not support wave setup, and therefore no additional water level increase was added for wave setup. The input ocean stage hydrograph was scaled up to peak at the 10-year water level (7.69 ft NAVD, from Monterey NOAA Buoy 9413450).

For future conditions the 10-year tide was increased at the rate of sea level rise based on the CA Coastal Commission guidance document (CCC, 2013). The total amount of SLR added for each scenario was estimated by fitting curves to the NRC 2012 SLR values, following this guidance. The peak tide elevation for each scenario is summarized in Table 3. These are the same water levels used by ESA for the Monterey Bay hazard mapping (ESA PWA, 2014).

TABLE 3
EXTREME TIDE CONDITIONS FOR RECLAMATION DITCH SYSTEM

	Sea level rise (ft)		10-year tide level + SLR (ft NAVD)	
Time period	Medium	High	Medium SLR	High SLR
2015	-	-	7.69	
2030	0.3	0.7	8.0	8.4
2060	1.1	2.4	8.8	11.0
2100	2.9	5.2	10.6	12.9

2.3.2 Soquel Creek Extreme Tide Levels

The Soquel Creek model is steady state thus there is no time dimension to the peak coastal water level. Recognizing this, it was deemed not representative to use the 10-year peak water level to represent extreme tide levels given that this elevation is only reached for a brief period during the 10-year event. We selected the 1-year recurrence interval as a tide level that would have a long enough time dimension to be considered credibly steady-state during an extreme tide event. Based on the Monterey Bay tide gauge (NOAA# 9413450), the 99% exceeded (1-year recurrence) tide elevation is 6.87 ft NAVD. Additionally, given the geomorphic configuration of this system, we added an additional increase in the steady state boundary to account for storm surge and wave setup. We selected 2-feet to account for these factors based historic data and previous studies of joint probability between coastal storm surge and high intensity rainfall as described below.

The steady downstream water surface boundary condition for Soquel Creek was chosen based on review of traditional practice and consideration of past analyses of joint probability of peak river discharges with elevated ocean water levels. A past study on San Lorenzo Creek by (USACE 2011) showed a correlation between peak discharges and storm surges, with average tidal residuals during river flood events ranging from 0.4 to 1.5 feet and wave setup ranging from 0.2 to 2 feet. We also examined historic data for Soquel Creek and nearby Aptos Creek for coastal storm events based on USGS stream gauge, CDIP buoy, and NOAA tide gauge records to estimate the wave setup during past events. We found similar patterns in the tide residuals, wave setup, and tide peak elevation during the storm. The wave setup and tide peak for a set of extreme tide and flow events is summarized in Table 4. The tidal peak water level that occurred around the time of the peak river discharge was found to be near the 1-year recurrence elevation with an average residual 0.5 feet and average estimated wave runup of 1.2 feet.

TABLE 4
COASTAL STORM SURGE AND WAVE SETUP FOR EVENTS ON SOQUEL AND APTOS CREEKS

Creek	Date	Approximate peak flow (cfs)	Ocean Residual ft (1-day average)	Offshore Wave Height, H (ft) approx	Wave Setup hsetup (ft)[1]	Total ocean water anomaly (wave setup + residual) ft	Tide Peak During Storm (ft NAVD)
Aptos	2/6/1983	210	0.74	16	1.6	2.38	6.1
Aptos	2/25/1983	210	0.43	11	1.1	1.58	6.9
Aptos	2/23/2009	280	-0.04	7	0.7	0.7	5.6
Aptos	1/20/2010	210	1.17	21	2.1	3.3	6
Aptos	12/21/2010	310	0.65	10	1	1.63	7
Aptos	12/29/2010	140	0.23	16	1.6	1.87	6.3
Aptos	2/25/2011	n/a	0.12	8	0.8	0.94	5.6
Soquel	10/13/2009	4000	0.85	7	0.7	1.51	6.1

[1]steady (average) setup ~= 0.1*H

The future conditions 100-year discharge combined with the future conditions extreme coastal tide level were used as boundary conditions for the hydraulic modeling analysis. The modeling analysis is described in the following section.

Attachment: Capitola Coastal Climate Change Vulnerability Report (Coastal Climate Change Vulnerability Report)

3 HYDRAULIC AND HYDRODYNAMIC MODELING ANALYSIS

3.1 Reclamation Ditch Unsteady Modeling

The basis for the unsteady HEC-RAS hydraulic model was a model provided by the Monterey County Water Resources Agency (MCWRA) to ESA in 2014. The model is an updated version of the HEC-RAS model originally developed by Schaaf & Wheeler (1999) for flood analysis. The model has been periodically updated for flood mapping studies. However, the original channel data dates back to the original study. The existing conditions 100-year hydrology was also developed by Schaaf & Wheeler in 1999 using a HEC-1 hydrologic model for the Gabilan Creek watershed. This formed the basis for the existing conditions 100-year unsteady hydrograph boundary conditions used in the model. Updates to the model geometry required including positioning the model in real geospatial coordinates and updating overbank areas with LiDAR topography are described in the following section.

3.1.1 Model Geometry Development

Hydraulic Roughness – The parameter representing the resistance to flow within a channel or floodplain due to vegetation, bedform, and bed material is known as the manning's roughness or 'n' value. The manning's n values were adopted from the existing model. The values are 0.025 for channel roughness and 0.065 for floodplain roughness.

Georeferencing – The original model provided by Monterey County required georeferencing to spatially orient the model input and output. The original mode was shifted to correctly orient the confluence of the Tembladero Slough and drainage canal from Merritt Lake (just upstream of Castroville). Tembladero Slough was digitized from Moss Landing up the Reclamation Ditch to the Hwy 101 crossing in Salinas using the HEC-GeoRAS toolbar in ArcGIS and then imported to the HEC-RAS model. Cross section spacing was then adjusted in HEC-RAS to align known bridge crossings with their spatial location. The model layout is shown in Figure 8.

Figure 8. Reclamation Ditch hydraulic model layout

Update with LiDAR – Because the overbank representation of the existing model was limited, it was necessary to update the overbank topography from new sources. This was accomplished by first extending the channel cross sections to include the full floodplain and then updating the cross section station-elevation data with topography from the 2009-2011 CA Coastal Conservancy Coastal Lidar Project: Hydro-flattened Bare Earth DEM that was downloaded from http://coast.noaa.gov/dataviewer/. This was only done for cross sections downstream of the railroad crossing west of Hwy 183, as the focus was primarily on flood behavior downstream. We determined that the elevations of the existing model were vertically referenced to an old vertical datum NGVD29. We thus converted the elevations to NAVD88 using the conversion factors listed in the FIS (+2.7 ft for Tembladero Slough, +2.77 ft for Reclamation Ditch). The model was also expanded into the Moro Cojo Slough and historic slough area between the Tembladero and Moro Cojo to represent alternate flood pathways that became apparent during the December 2014 flood.

Incorporation of MLML data – Hydraulic structure data was provided by Ross Clark, Charlie Endris, that was used to develop preliminary geometry for hydraulic structures located in the expanded portions of the model including:

1. Cabrillo Hwy crossing over Moro Cojo Slough
2. Moss Landing Rd tide gates at Moro Cojo

Other minor structure crossings in the model area were not accounted for due to lack of data. One improvement to the model would be to survey these crossings and add them into the model geometry to improve the representation of flow routing in the system.

3.1.2 Model Hydrology Inputs

Future flows determined in the future Q_{100} climate analysis were simulated by scaling the existing unsteady 100-year hydrographs that came with the HEC-RAS model provided by Monterey County. Base flow was maintained for the input hydrographs by only scaling the peak of each input hydrograph (flows > ~75% of the existing peak discharge). Within each hydrograph peak, a polynomial scaling function was used to produce smooth transitions between the existing rising and falling limbs and the future hydrograph peaks.

Inflow hydrographs were developed for Moro Cojo Slough and the unnamed canals/historic slough watershed. Area was determined for each watershed using USGS streamstats online tools. Then hydrographs were scaled from nearby subwatersheds analyzed by Schaff and Wheeler that possessed similar attributes (drainage area, relief, and impervious percentage) using watershed area as the scaling factor. These were scaled for future conditions using the method described above.

The downstream boundary was driven by an unsteady tide as described in the extreme coastal tide level section for the Reclamation Ditch.

3.1.3 Model Validation

The results of the updated hydraulic model run with the existing conditions 100-year hydrology and MHHW tailwater were compared to flooding extent and hydraulic flowpaths from a flood event that occurred in December 2014. The MLML provided a map of estimated extents and observed flow directions during this event. One key observation for this event was that flow backing up at the Moss Landing tide gates overtopped adjacent farm fields contributing additional water into Moro Cojo Slough which routes water to the harbor through the culverts under Moss Landing Road. The model reproduced this observed pattern for the 100-year flow as shown in Figure 9.

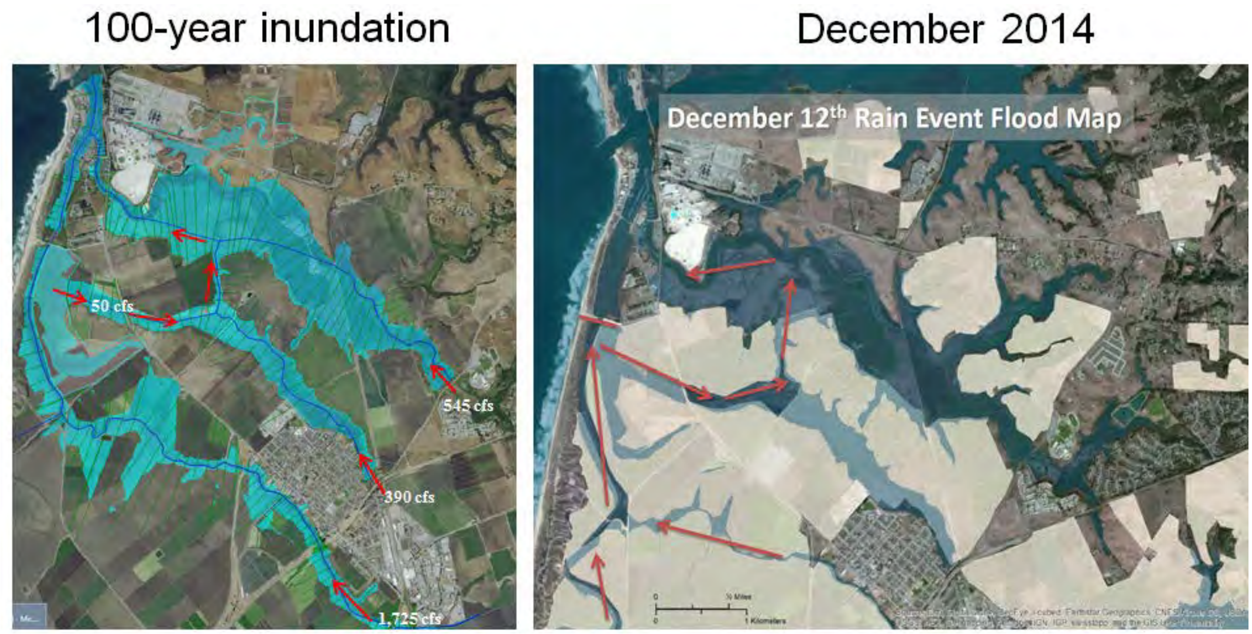

Figure 9. Comparison of Modeled 100-year flowpaths and observed flowpaths during December 2014 flood

3.1.4 Model Limitations

Flood mapping was truncated for Tembladero Slough at the Cabrillo Hwy, Moro Cojo up to the Railroad, and the historic slough in between. From the Tembladero up to the City of Salinas, the cross sections are limited to in channel portions, and floodplains were not mapped for any of the model coverage upstream. Given the uncertainty regarding the location of cross-sections an improvement to the model would be collecting new channel cross-sections and channel bathymetry in the model domain. Additionally, replacing the overbank areas with 2D flow elements would improve the routing of flow once it escapes the channel and goes out of bank. Lastly, the main Salinas River channel is not represented in the model. There are known interactions with the Salinas River and the Reclamation Ditch system including breakout flows from upstream entering the Reclamation Ditch and a water control structure connection between the mouth of the Salinas River and the old Salinas River alignment. The model could be improved significantly by combining the model with a model of the Salinas River and replacing the overbank areas with 2D flow elements.

3.2 Soquel Creek Steady State Modeling

3.2.1 Model Geometry Development

Hydraulic Roughness – The manning's n values were adopted from the existing FEMA model to maintain consistency. The channel and floodplain n values are 0.1 and 0.4 respectively.

Georeferencing – The existing conditions model for Soquel Creek came from the effective FEMA model for the system which was provided by FEMA as HEC-2 data-the precursor to HEC-RAS. The model was converted to HEC-RAS and georeferencing was performed to geospatially orient the model cross-sections and flood results. The georeferencing was accomplished by digitizing the length of Soquel Creek from the Pacific Ocean upstream to the limit of existing model coverage with HEC-GeoRAS tools in ArcGIS. Once the new stream centerline was imported to HEC-RAS, cross section spacing was adjusted to align bridge crossings with the known locations determined by the Terrain or aerial imagery. The model cross-section layout is shown in Figure 10.

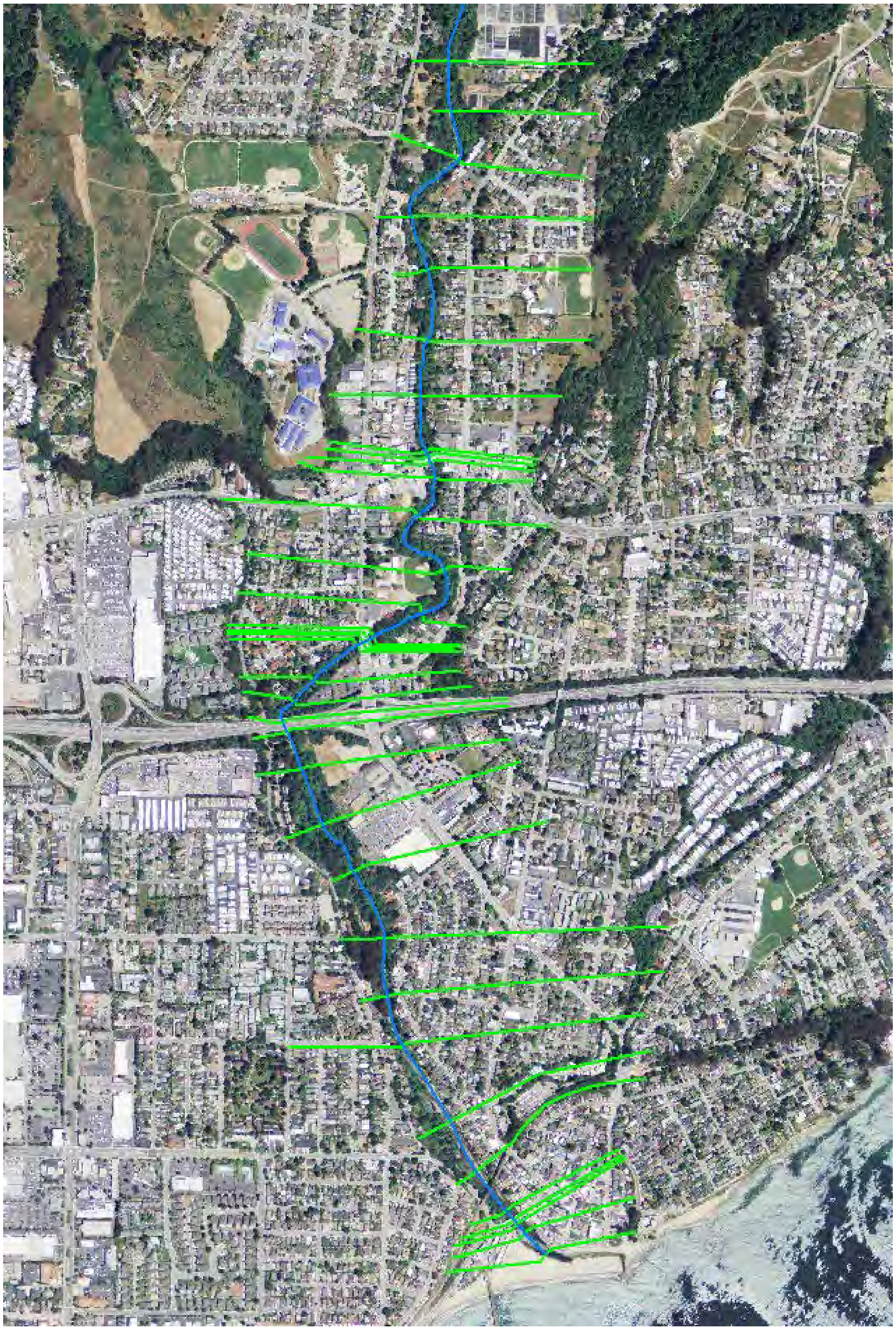

Figure 10. Soquel Creek hydraulic model layout

Update with LiDAR – Channel cross sections were extended to include the full floodplain and the cross section station-elevation data was updated with topography from the 2009 - 2011 CA Coastal Conservancy Coastal Lidar Project: Hydro-flattened Bare Earth DEM (downloaded here: http://coast.noaa.gov/dataviewer/). This was only done for cross sections downstream of Soquel Nursery Growers Plant Nursery. In-channel bathymetry and hydraulic structure data were maintained, and were shifted from NGVD29 to NAVD88 using the datum conversion factor from the FIS (+2.75 ft).

Incorporation of MLML data – Hydraulic structure data (stormdrains, manholes, etc.) were provided by Ross Clark, Charlie Endris, but were not used in the model. These data can (are going to) be used to update flood connectivity of previously mapped coastal flooding hazards (ESA 2014), and would serve to improve fluvial flood mapping from an unsteady model of Soquel Creek.

3.2.2 Model Hydrology Inputs

Future peak flows determined in the future Q_{100} climate analysis were modeled in steady state. Flows were increased by the percent change calculated for the medium and high emissions scenarios and the three future time horizons. The downstream boundary was driven by a steady tide as described in the extreme coastal tide level section for Soquel Creek.

3.2.3 Model Limitations

The geometry information in the model, including hydraulic structures and in-channel bathymetry, are out of date and may not be representative of current channel conditions. These should be updated to better represent the current conditions in Soquel Creek. Because the model is steady state, overbank flooding is potentially overestimated. Flooding extents could be improved by switching to an unsteady model.

4 MODEL RESULTS AND FLOOD HAZARD MAPPING

The hydraulic model results include water elevations in each cross-section which were translated into geospatial datasets of flood extent and depth for each of the scenarios modeled. This flood hazard mapping process was accomplished using the HEC-GeoRAS toolbar for ArcGIS which enables data transfer between GIS and HEC-RAS. Water surface profiles from the model results were exported to GIS and differenced against the underlying NOAA LiDAR topography to map flood extent. This topographic dataset does not include bathymetry below the water line thus flow depths in the channel are representative of depth above the water line at the time during which the LiDAR data were surveyed. Though some channel bathymetry for Tembladero Slough and the Reclamation Ditch was present in the original HEC-RAS model, no clear geospatial information was available for precisely locating these data. Thus the bathymetry from the cross-sections was not integrated into the topographic surface. The results of the inundation mapping are shown for the Reclamation Ditch system in Figure 11 and for Soquel Creek in Figure 12.

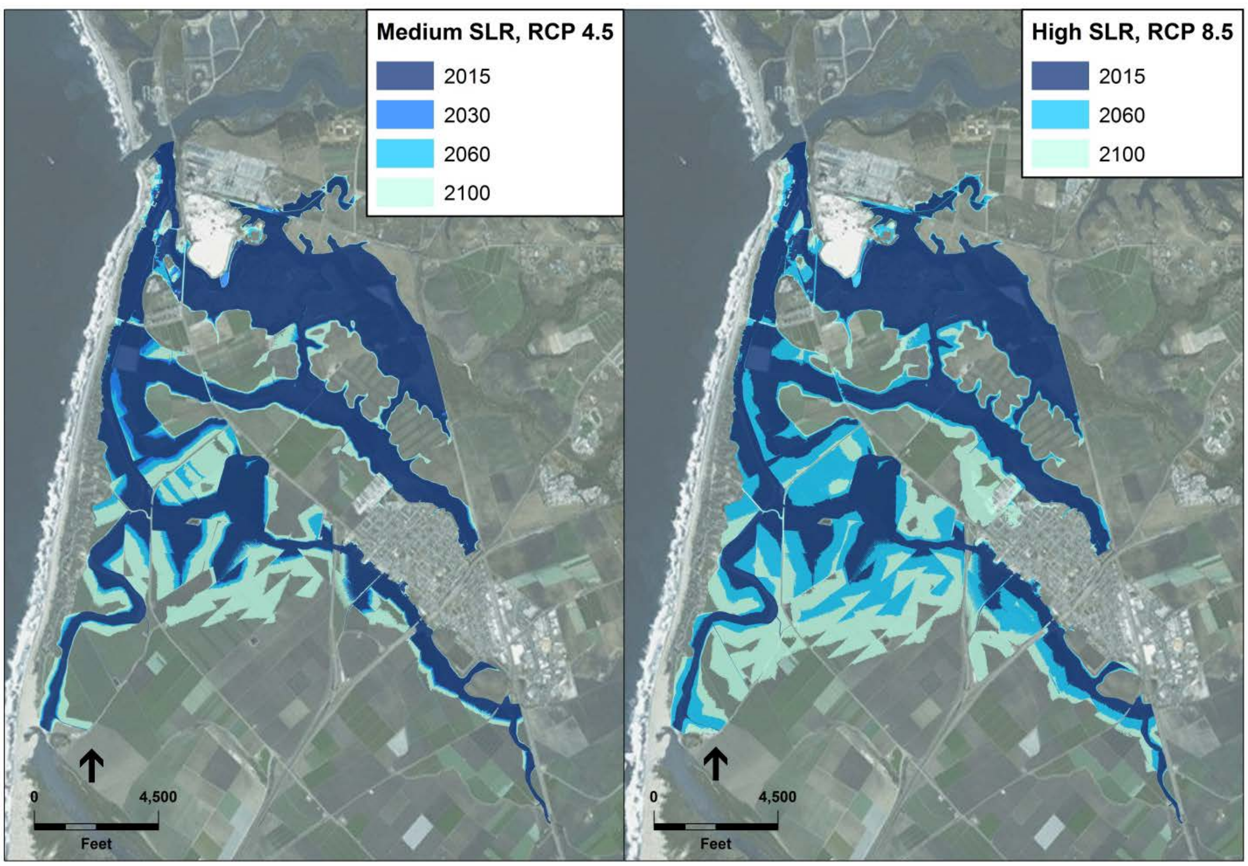

Figure 11. Flood inundation hazard maps for multiple climate scenarios on the Reclamation Ditch system

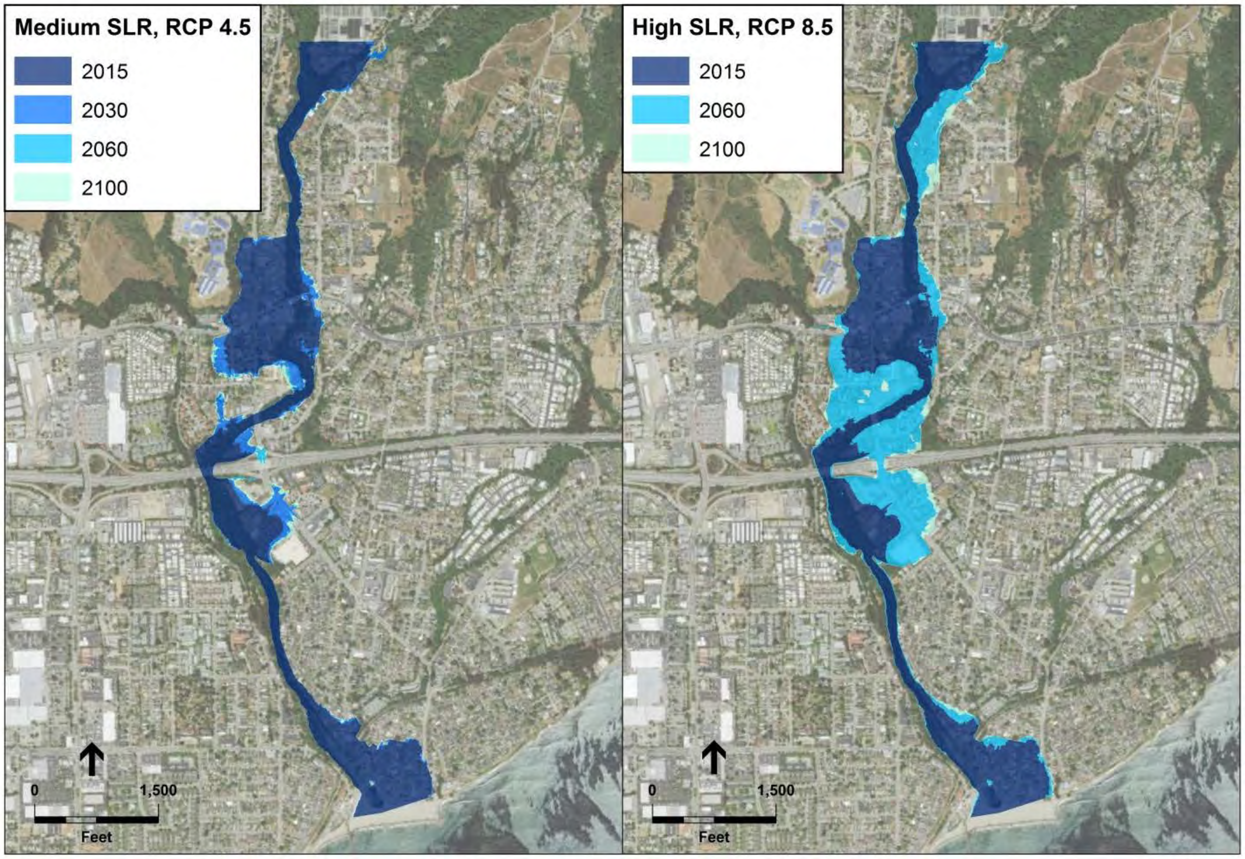

Figure 12. Flood inundation hazard maps for multiple climate scenarios on Soquel Creek

As Figure 11 shows, the flood extent increases significantly from existing conditions to 2100 on the Reclamation Ditch system. The majority of additional flooding is on the agricultural properties adjacent to Tembladero Slough and the Old Salinas River channel. The increase is exacerbated by the flatness of the terrain which results in a large increase in flooding for small increases in discharge. The additional flooded area is approximately 960 and 1740 acres for the Medium and High scenarios respectively, and the increase in flood depth is approximately 1.1 and 2.6 feet respectively. Depth measurements were sampled just upstream of the Hwy 156 crossings on Tembladero Slough.

For Soquel Creek, the change in 100-year discharge is less significant than on the Reclamation Ditch system. Additionally, the topography is more constrained in areas that are already flooded by the existing conditions 100-year flood. Thus the extent of flooding does not change as significantly on this system. The additional flooded area is approximately 18 and 65 acres for the Medium and High scenarios respectively, and the increase in flood depth is approximately 0.8 and 3.0 feet respectively.

In addition to the fluvial flood hazard mapping analysis, coastal storm flooding hazard zones were provided for the purposes of updating flooding connectivity in the Capitola and Salinas-Elkhorn areas. Coastal storm flooding hazards were previously mapped for the Monterey Bay Sea Level Rise Vulnerability Study (ESA PWA 2014) prepared for The Monterey Bay Sanctuary Foundation, and were provided in shapefile format for these two areas.

For the Capitola area (Soquel Creek), ESA provided MLML with intermediate coastal hazards shapefiles that contained separate polygons for the various hazards modeled. Equipped with the separated hazards and by using GIS data of storm drain networks and other flood management infrastructure, staff at MLML can make any warranted flood connectivity updates to the coastal flooding hazard layers provided in the MBSLR study (ESA PWA 2014). Described in the shapefile metadata, the separated versions of the coastal flooding hazards include layers for wave overtopping, wave runup, event tide flooding (100-yr tide), and erosion layers depicting eroded conditions of cliffs and dune areas (which would be considered as flooded in the future). Elevations associated with each flooding mechanism (except the erosion layers) are provided as attributes for each mechanism ("Method" in the attributes table).

As a part of a subsequent study "Economic Impacts of Climate Adaptation Strategies for Southern Monterey Bay" by ESA, The Nature Conservancy and others, flood connectivity was updated to reflect known water control structures in the area. The main structures considered are the tide gates on Tembladero Slough at Potrero Road, the Cabrillo Hwy road crest separating low lands from backwatering from the Moro Cojo Slough, and the water control structure between the Salinas Lagoon and Old Salinas channel to the north. In this update, flooding methods and associated flooding elevations for the Salinas River were altered to produce more accurate flood extents:

- Beach berm flooding – the elevation of flooding behind the beach berm at the Salinas River lagoon mouth was lowered from 4.88 m NAVD to 3.66 m NAVD (from 16ft to 12 ft) to represent the hydraulic control structure that diverts water north to the old Salinas River channel. These flooding layers also assume a 15 ft crest elevation for the levee on the north bank of the Salinas River, estimated from LiDAR.

- 100-yr tide flooding – flooding by the 100-year tide was updated to reflect the Potrero Rd tide gates and the road crest at Cabrillo Hwy, which affects primarily farmlands south of the Elkhorn Slough mouth.

The geospatial layers for the flood hazard extent and depths were compiled in an ESRI ArcGIS compatible geodatabase. The geodatabase was provided to MLML on 1/29/2016. Additionally the coastal flooding shapefiles adjusted to incorporate structural information on both systems was provided with this geodatabase. A table of the layers provided is included in Attachment A.

5 DISCUSSION

The climate analysis and hydraulic modeling show how future conditions flooding can change with increased precipitation intensity and higher coastal water levels with extreme coastal flood events. The flood hazard inundation extents can be used to inform planning efforts in the areas that are at risk of increased flooding as climate change puts added pressure on flood parameters. The range of scenarios provided allows for interpretation of potential flood risk given uncertainty in how climate will evolve. Planning efforts can be informed by considering a range of future scenarios and associated vulnerabilities, and the community's tolerance for risk, which should conceptually relate to the community's resilience.

The fluvial flood hazard maps add value to the previous coastal flooding analyses conducted by ESA by incorporating changes to watershed hydrology into the flood potential. This enables an assessment of the flood risk from combined changes in increasing coastal water levels and increased precipitation intensity. This is beneficial to communities at risk of flooding from both coastal and fluvial sources and provides a more complete set of scenarios for planning in those communities.

The resulting hazard maps can be used to assess risk as well as plan for future adaptation measures. By highlighting areas at risk currently and areas potentially at risk under different climate scenarios, communities can begin to develop and implement specific localized measures for adapting to these future risks. Future study should be considered to develop adaptation plans now that the tools for assessing risk have been developed and are available for further use.

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Monterey Bay Sea Level Rise

Climate Change Impacts on Combined Fluvial and Coastal Hazards

ATTACHMENT A

GIS Data Layers Provided With Report

Attachment A - Files transmitted via 20150126_fluvialHZ_w_Metadata.zip

Folder	Subfolder	File	Geographic Location	Type	SLR	Emissions
RecDitch_Tembladero_UTMz10						
	area					
		river100yr_floodplain_ec2010.shp	Tembladero Slough	Fluvial flooding extents polygon shapefile	none	none
		river100yr_floodplain_hi2060.shp	Tembladero Slough	Fluvial flooding extents polygon shapefile	High	RCP 8.5
		river100yr_floodplain_hi2100.shp	Tembladero Slough	Fluvial flooding extents polygon shapefile	High	RCP 8.5
		river100yr_floodplain_med2030.shp	Tembladero Slough	Fluvial flooding extents polygon shapefile	Medium	RCP 4.5
		river100yr_floodplain_med2060.shp	Tembladero Slough	Fluvial flooding extents polygon shapefile	Medium	RCP 4.5
		river100yr_floodplain_med2100.shp	Tembladero Slough	Fluvial flooding extents polygon shapefile	Medium	RCP 4.5
	depth					
		MaxDepth_100yr_ec2010.tif	Tembladero Slough	Fluvial flooding max depth raster	none	none
		MaxDepth_100yr_hi2060.tif	Tembladero Slough	Fluvial flooding max depth raster	High	RCP 8.5
		MaxDepth_100yr_hi2100.tif	Tembladero Slough	Fluvial flooding max depth raster	High	RCP 8.5
		MaxDepth_100yr_med2030.tif	Tembladero Slough	Fluvial flooding max depth raster	Medium	RCP 4.5
		MaxDepth_100yr_med2060.tif	Tembladero Slough	Fluvial flooding max depth raster	Medium	RCP 4.5
		MaxDepth_100yr_med2100.tif	Tembladero Slough	Fluvial flooding max depth raster	Medium	RCP 4.5
SoquelCreek_UTMz10						
	area					
		river100yr_floodplain_ec2010.shp	Soquel Creek	Fluvial flooding extents polygon shapefile	none	none
		river100yr_floodplain_hi2060.shp	Soquel Creek	Fluvial flooding extents polygon shapefile	High	RCP 8.5
		river100yr_floodplain_hi2100.shp	Soquel Creek	Fluvial flooding extents polygon shapefile	High	RCP 8.5
		river100yr_floodplain_med2030.shp	Soquel Creek	Fluvial flooding extents polygon shapefile	Medium	RCP 4.5
		river100yr_floodplain_med2060.shp	Soquel Creek	Fluvial flooding extents polygon shapefile	Medium	RCP 4.5
		river100yr_floodplain_med2100.shp	Soquel Creek	Fluvial flooding extents polygon shapefile	Medium	RCP 4.5
	depth					
		MaxDepth_100yr_ec2010.tif	Soquel Creek	Fluvial flooding max depth raster	none	none
		MaxDepth_100yr_hi2060.tif	Soquel Creek	Fluvial flooding max depth raster	High	RCP 8.5
		MaxDepth_100yr_hi2100.tif	Soquel Creek	Fluvial flooding max depth raster	High	RCP 8.5
		MaxDepth_100yr_med2030.tif	Soquel Creek	Fluvial flooding max depth raster	Medium	RCP 4.5
		MaxDepth_100yr_med2060.tif	Soquel Creek	Fluvial flooding max depth raster	Medium	RCP 4.5
		MaxDepth_100yr_med2100.tif	Soquel Creek	Fluvial flooding max depth raster	Medium	RCP 4.5

Key

SLR	High	high sea level rise (NRC 2012) of 159 cm by 2100, relative to 2010
	Med	medium sea level rise (NRC 2012) of 72 cm by 2100, relative to 2010
Emissions	RCP 8.5	future emissions scenario (IPCC, AR 5)
	RCP 4.5	future emissions scenario (IPCC, AR 5)

100-year fluvial flooding rasters and polygons are projected to UTM Zone 10N coordinates. Raster depths are in Feet.

Attachment A - Files transmitted via 20150129_Draft_UpdatedCoastalFloodHZ

Folder	File	Geographic Location	Type	SLR
coastal_storm_flood_MBSLR_Capitola				
subfolder "combined"	coastal_floodhz_ec2010_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	none
	coastal_floodhz_s12030_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	Low
	coastal_floodhz_s12060_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	Low
	coastal_floodhz_s12100_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	Low
	coastal_floodhz_s22030_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	Medium
	coastal_floodhz_s22060_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	Medium
	coastal_floodhz_s22100_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	Medium
	coastal_floodhz_s32030_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	High
	coastal_floodhz_s32060_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	High
	coastal_floodhz_s32100_dissolved.shp	Capitola / Soquel Creek	Coastal Storm flooding extents	High
subfolder "separated"	coastal_floodhz_ec2010.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	none
	coastal_floodhz_s12030.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	Low
	coastal_floodhz_s12060.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	Low
	coastal_floodhz_s12100.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	Low
	coastal_floodhz_s22030.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	Medium
	coastal_floodhz_s22060.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	Medium
	coastal_floodhz_s22100.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	Medium
	coastal_floodhz_s32030.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	High
	coastal_floodhz_s32060.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	High
	coastal_floodhz_s32100.shp	Capitola / Soquel Creek	Coastal Storm flooding extents, with separate EL and HZ type attributes	High
event_flood_SMB_SalinasElkhorn				
subfolder "combined"	event_flood_AER_ec2010.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents	none
	event_flood_AER_s22030.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents	Medium
	event_flood_AER_s22060.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents	Medium
	event_flood_AER_s22100.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents	Medium
	event_flood_AER_s32030.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents	High
	event_flood_AER_s32060.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents	High
	event_flood_AER_s32100.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents	High
subfolder "separated"	event_flood_AER_ec2010_EL.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents, with separate EL and HZ type attributes	none
	event_flood_AER_s22030_EL.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents, with separate EL and HZ type attributes	Medium
	event_flood_AER_s22060_EL.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents, with separate EL and HZ type attributes	Medium
	event_flood_AER_s22100_EL.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents, with separate EL and HZ type attributes	Medium
	event_flood_AER_s32030_EL.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents, with separate EL and HZ type attributes	High
	event_flood_AER_s32060_EL.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents, with separate EL and HZ type attributes	High
	event_flood_AER_s32100_EL.shp	Salinas River / Elkhorn Sloug	Coastal Storm flooding extents, with separate EL and HZ type attributes	High

Key

SLR	low sea level rise (NRC 2012) of 22 cm by 2100, relative to 2010
	medium sea level rise (NRC 2012) of 72 cm by 2100, relative to 2010
	high sea level rise (NRC 2012) of 159 cm by 2100, relative to 2010

coastal storm flooding rasters and polygons are projected to UTM Zone 10N coordinates

CITY OF CAPITOLA
COMMISSION ON THE ENVIRONMENT
Agenda Report

Meeting Date: December 6, 2017

Agenda Item: 2

Subject: 2018 Proposed Meeting Schedule

For 2018 it is proposed that the Commission on the Environment continue with the regular meeting and workshop meeting alternating monthly meeting schedule. Meetings will be held on the fourth Wednesday of the month.

January 24, 2018 – meeting

February 28, 2018 - workshop

March 28, 2018 - meeting

April 25, 2018 - workshop

May 23, 2018 - meeting

June 27. 2018 - workshop

July 25, 2018 - meeting

August 22, 2018 - workshop

September 26, 2018 - meeting

October 24, 2018 - workshop

*November 14, 2018 – meeting*****

*December 19, 2018 – workshop*****

*****Date change due to holiday*****

The Commission Meeting is defined as a full agenda on a wide range of topics, minutes, voting, etc.

The Commission Workshop is defined as a forum for more informal and in-depth discussion on a limited set of agenda topics.