Del Norte Local Transportation Commission

CALTRANS DISTRICT 1
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South Beach Transportation Climate Resilience Plan

June 04, 2025

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Executive Summary

Previous studies, including the 2019 Crescent City Harbor District Sea Level Rise (SLR) Assessment and the 2019 Del Norte Local Hazard Mitigation Plan, indicate that the South Beach shoreline and Anchor Way are susceptible to increased inundation and flooding from SLR and storm events. Important infrastructure within these vulnerable areas, including transportation assets, public utilities, and other public resources, warrants further study and adaptation planning.

The South Beach Transportation Climate Resilience Plan (Plan) addresses significant flooding and damage issues in the South Beach area, impacting critical transportation corridors like Highway 101 and Anchor Way. Initiated due to community frustration and concern with traffic and safety, the project builds on the previous studies, which highlighted the area's vulnerability to SLR and storm events, by evaluating the combined impacts of waves and SLR.

The project process involved assessing existing and future coastal hazards, conducting a vulnerability assessment, and developing adaptation strategies. Coastal hazards such as waves, SLR, tsunamis, and shoreline change were analyzed to create flood and asset maps, identifying how assets in the project area are vulnerable. Adaptation strategies were developed and evaluated using a multi-criteria analysis, incorporating public feedback and advisory committee input. A preferred solution was then developed, combining different strategies to enhance resilience for the local and regional transportation facilities of Anchor Way and Highway 101. The Plan framework is presented in Figure ES-1.

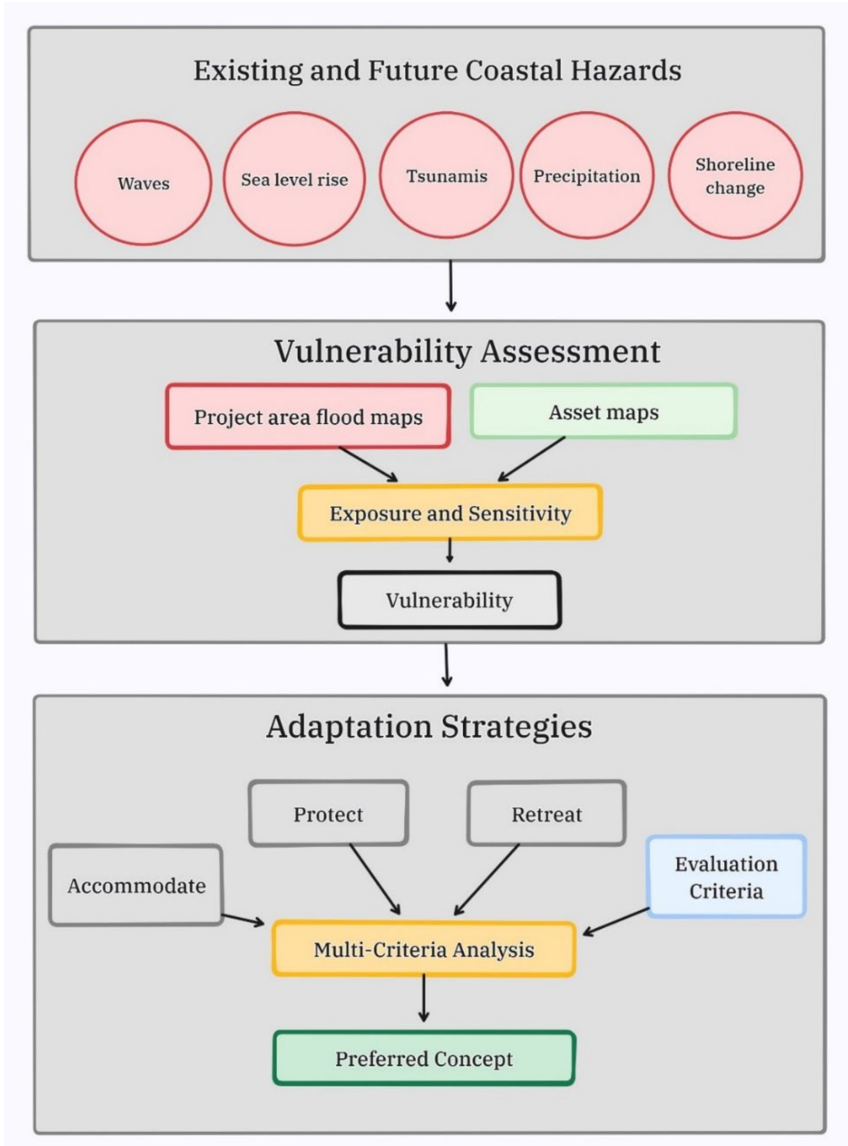


Figure ES-1. South Beach Transportation Climate Resilience Plan framework

Coastal Hazards Analysis

This Plan builds on prior coastal hazards analyses to understand how these hazards may evolve with SLR projections consistent with the Ocean Protection Council (OCP) 2024 SLR Guidance. The analysis examines present and future coastal hazards, including coastal flooding (wave runup and tidal inundation) and shoreline erosion, which are the predominant hazards for Highway 101 and Anchor Way. Future coastal hazards are evaluated for the near, mid, and long term (i.e., 2050, 2070, 2100) based on prior studies, publicly available data sources, and empirical relationships.

The 2019 Crescent City Harbor District SLR Assessment provided asset maps, SLR flood maps, and adaptation strategies for different assets. Building on this analysis, coastal hazard information related to future projected wave overtopping and shoreline change was evaluated for a range of water levels and wave conditions along Highway 101 and Anchor Way using methods described in the EurOtop Manual (2018). Typical and extreme events were evaluated to understand the magnitude of overtopping associated with different storm events. Three scenarios were evaluated using tidal water levels, storm surge, wave runup, and SLR. Post-storm damage reports were used to correlate the intensity of storms to resulting damage.

A summary of each hazard that was analyzed is presented below.

1. **Waves**: Wave conditions at the site are presented and discussed using 14 years of wave data from the North Spit Humboldt Bay Buoy.
2. **Water Levels and Flooding**: Tidal inundation analysis is essential for understanding the regular and extreme high tide events that can lead to flooding. Tidal data from the Crescent City tide gauge is presented, along with the Federal Emergency Management Agency flood insurance maps. A recent example of flooding in the project area is discussed.
3. **Sea Level Rise:** Analyzing SLR projections is critical for understanding future risks and informing adaptation strategies. SLR can exacerbate other coastal hazards, making it essential to incorporate these projections into resilience planning. Historical and future projections of SLR are presented and discussed. Historical SLR trends are provided from the National Oceanic and Atmospheric Administration's Crescent City tide gauge and future projections are provided in the OPC 2024 SLR Guidance.
4. **Wave Overtopping**: Assessing wave runup is crucial as it determines the extent to which waves can travel inland, potentially causing flooding and damage to infrastructure. Understanding wave runup helps in designing effective coastal defenses and planning evacuation routes.
5. **Shoreline Change**: Evaluating shoreline change is vital for planning long-term coastal management strategies and protecting infrastructure and habitats. Historical shoreline change was analyzed using CoastSat shoreline trend data, and seasonal shoreline trends are discussed. Future shoreline trends under SLR modeled by Coastal Storm Modeling System are presented and discussed.
6. **Tsunamis**: The effects of past tsunamis at the project area are qualitatively discussed. Tsunami impacts under SLR scenarios are not addressed in this report.
7. **Precipitation:** Evaluating precipitation is crucial as increased rainfall can lead to flooding from the east of Highway 101, especially when combined with other coastal hazards like storm surge and tidal inundation. Understanding precipitation patterns helps in planning for stormwater management and flood mitigation. While fluvial flooding and marsh hydraulics are only qualitatively discussed in this report, a summary of current and future precipitation data from Cal-Adapt is presented.

Vulnerability Assessment

A vulnerability analysis helps identify the extent of asset exposure, and their sensitivity to flooding. This analysis aims to answer several key questions:

- Which assets are exposed to flooding? Identifying the specific assets within the projected flood extents.

- What is the sensitivity of these assets to flooding? Evaluating how different types of assets (e.g., roads, buildings, utilities) respond to flood exposure.
- What are the potential impacts of flooding on these assets? Assessing the severity of the impacts based on the asset's function and importance to the community.
- How can adaptation strategies be tailored to mitigate these impacts? Developing site-specific adaptation plans to enhance resilience and reduce vulnerability.

Flooding along Highway 101 and Anchor Way can have significant impacts on the community. For instance, a detour due to flooding along Highway 101 can disrupt daily commutes and pose safety hazards to the communities that the detour goes through. Understanding the vulnerability of the project area to flooding is crucial for developing effective adaptation strategies and promoting community resilience against future flood events.

Using the results of the coastal hazards analysis, approximate flood extents for 100-year wave events under the High SLR scenario for three time horizons along Highway 101 (Figure ES-2) and Anchor Way (Figure ES-3) were developed to evaluate the vulnerability of various assets. Project area assets within these projected flood extents for each time horizon were identified and potential vulnerabilities evaluated. The assets exposed to projected flooding and their sensitivity to flooding are evaluated based on their respective sub-area, either Highway 101 or Anchor Way. This format is intended to support adaptation planning as it is anticipated that the adaptation strategies for each sub-area will need to be approached based on the site-specific characteristics of flooding.

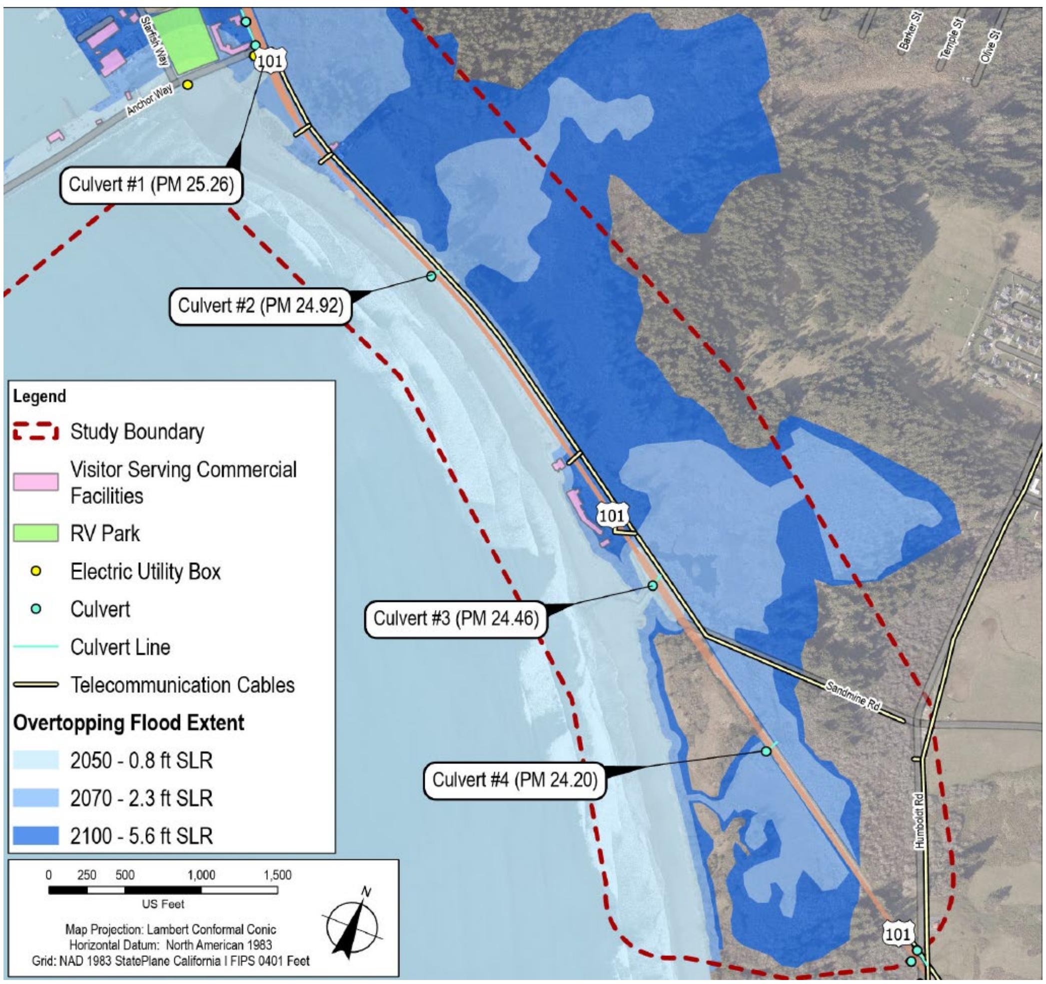


Figure ES-2. Approximate flood extents for 100-yr wave events under the High SLR scenario for three time horizons and existing assets along Highway 101

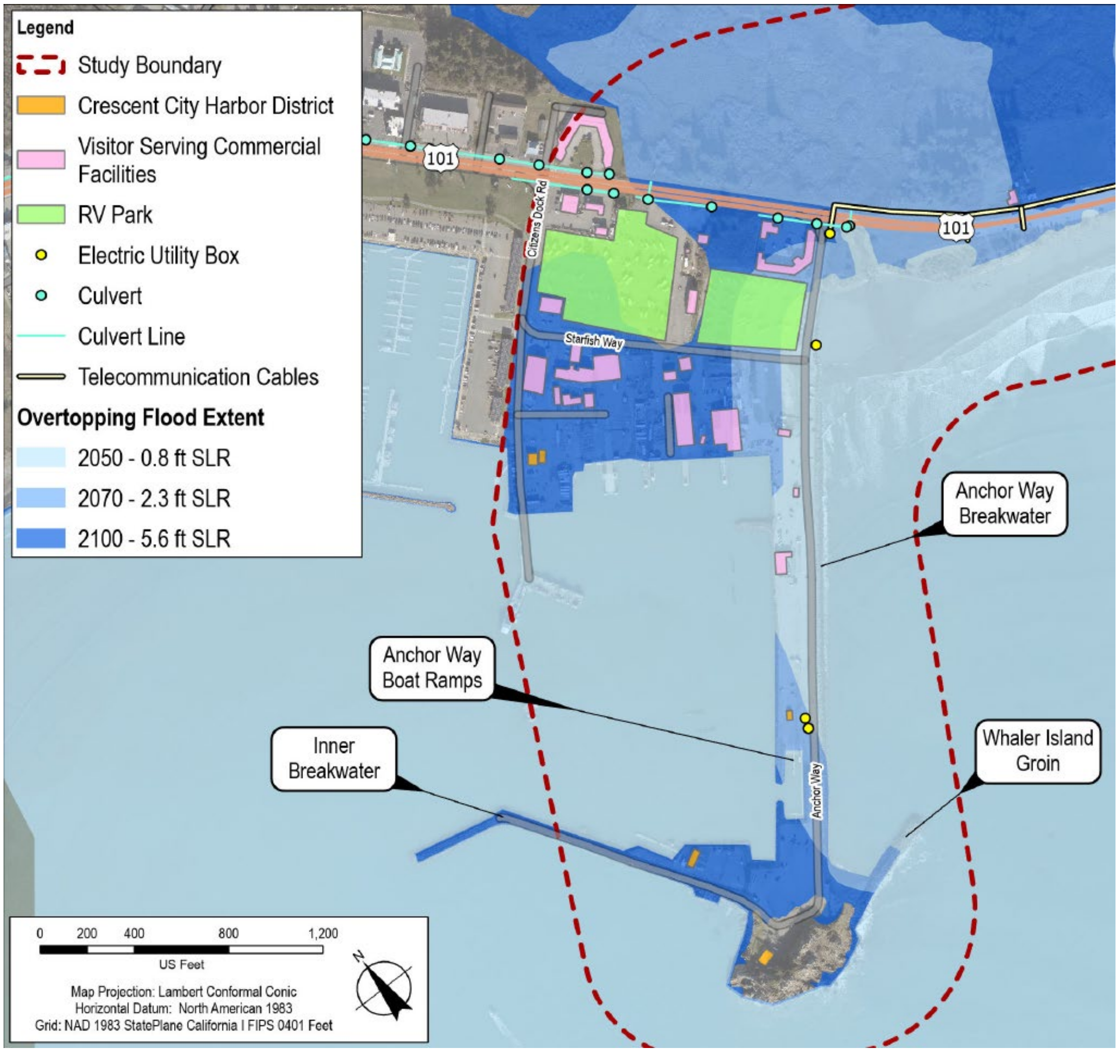


Figure ES-3. Approximate flood extents for 100-yr wave events under the High SLR scenario for three time horizons and existing assets along Anchor Way

Adaptation Strategies and Multi-Criteria Analysis

This Plan outlines various adaptation strategies to address flooding along Highway 101 and Anchor Way in the near, mid, and long term, ultimately enhancing resilience against future SLR scenarios and extreme weather events. These strategies are evaluated using a multi-criteria analysis to inform the preferred approach for each sub-area. The strategies are broken into three categories:

- **Retreat**: Relocating infrastructure and communities away from vulnerable coastal areas. For example, moving Highway 101 inland to avoid SLR and coastal erosion impacts.
- **Accommodate**: Adapting existing infrastructure to be more resilient, such as elevating highways, improving drainage systems, and implementing flood-proofing measures. An example is elevating Highway 101 along South Beach.
- **Protect**: Preventing flooding and erosion impacts through physical barriers and protective measures. Examples include building seawalls or rock revetments along Highway 101 and Anchor Way.

These strategies are developed separately for Highway 101 and Anchor Way, as their implementation and timing may differ.

A multi-criteria analysis is utilized to evaluate the viability of each proposed strategy. Criteria that reflect the goals of this project and stakeholder needs were developed for each sub-area based on project goals and Advisory Committee input. The key considerations used to frame the multi-criteria analysis are as follows:

- Strategies for Highway 101 to remain a functional multi-modal transportation corridor considering SLR, higher tide levels, and storm surge.
- Strategies for Anchor Way to remain functional considering SLR, higher tide levels, and storm surge.
- Strategies should maintain public access along Highway 101 to the existing South Beach area.

Criteria were presented at two public meetings, and public feedback was incorporated into the criteria. Other criteria mentioned by the community included projects with multiple benefits, economic development, and project flexibility. Criteria were used to qualitatively evaluate how each strategy would meet the project objectives. Summaries of the multi-criteria analysis for Highway 101 and Anchor Way are shown in Table ES-1 and Table ES-2, with "✓" highlighting the most feasible strategies at each location and "X" noting strategies that are not recommended by this Plan.

Table ES-1. Evaluation of Highway 101 adaptation strategies

Highway 101 Multi-criteria Analysis Summary	
Protect Strategies:	
X	**Revetment:** Provides near- and mid-term flood and erosion protection but reduces public access and would involve an extensive permit process with mitigation measures for potential adverse impacts. This strategy is not recommended for the Highway 101 reach.
✓	**Living Shoreline:** Preferred protection strategy because it provides effective mid-term flood and erosion resilience while enhancing public access, supporting habitat restoration, and offering a more adaptable and environmentally sustainable solution compared to hardened structures like revetments.
Accommodate Strategies:	
✓	**Raise Roadway Elevation:** Raising the roadway offers short-term benefits but is vulnerable to long-term erosion, which could reduce beach access and eventually threaten the road. However, if combined with a protection strategy (i.e., living shoreline), it enhances resilience to coastal hazards and remains a viable solution for the Highway 101 reach.
X	**Causeway:** Provides long-term resilience but comes at a very high cost along with challenges maintaining existing beach parking and access to adjacent properties. Due to cost and complexity this strategy is not recommended for the Highway 101 reach.
Retreat Strategies:	
X	**Existing Detour:** Eliminates flooding impacts but poses potential safety hazards and adverse impacts to the community, increases travel time, and has significant environmental justice concerns. This strategy was strongly opposed by the Advisory Committee and the public; therefore it is not recommended.
X	**Eastern Relocation:** Mitigates vulnerabilities to coastal hazards but has significant environmental and regulatory impacts, high costs, and strong opposition from the Advisory Committee and resource managers, therefore is not feasible.

Table ES-2. Evaluation of Anchor Way adaptation strategies

Anchor Way Multi-criteria Analysis Summary	
Protect Strategy:	
✓	**Whaler Island Groin Improvements:** Provides effective wave protection for a longer stretch of Anchor Way, increasing resilience to coastal hazards and SLR. However, this strategy in isolation would not be sufficient to provide flood protection through 2070 due to the low elevations along Anchor Way.
Accommodate Strategy:	
✓	**Raise Roadway and Revetment:** Raising the roadway and elevating the revetment/floodwall will reduce flooding from extreme events and SLR, while also improving pedestrian access, circulation, and recreational opportunities.

Preferred Alternatives

Highway 101

A hybrid adaptation strategy that combines protect and accommodate measures is the preferred approach for the Highway 101 reach because it effectively addresses both existing hazards and future coastal risks over short- and mid-term planning horizons. By integrating solutions such as a living shoreline for erosion control and flood protection with roadway elevation to mitigate storm impacts, this approach promotes a resilient transportation corridor that remains functional despite changing coastal conditions. This strategy also preserves public access to the coast, minimizes disruptions to the local community, and balances environmental, regulatory, and financial considerations. By leveraging the strengths of both natural and engineered solutions, the hybrid approach enhances long-term sustainability while reducing adverse impacts on surrounding habitats and infrastructure (Figure ES-4).

1. **Accommodate with Raised Roadway and Improved Drainage**

The highway will be shifted landward within the existing Caltrans right-of-way and raised to approximately 20 feet NAVD88. The current elevation of the highway ranges from 14 to 23 feet. Culvert 3 will be replaced with a bottomless culvert to improve drainage and reduce overtopping, enhancing the natural streambed and promoting ecological benefits. The roadway will be raised to mitigate overtopping under various SLR scenarios, with a target elevation of 20 feet NAVD88 to handle SLR projections up to 2070.

2. **Protect with Living Shoreline**

A nature-based living shoreline with a vegetated sand berm and cobble berm will protect the highway, matching the character of resilient adjacent coastlines. A robust monitoring program will evaluate vegetation growth and erosion, guiding regular maintenance and adaptive management. The design will preserve coastal access and recreation opportunities while allowing for dynamic reshaping of the cobble berm with increasing water levels. Dynamically stable structures are allowed to be reshaped by wave attack, resulting in steeper slopes and higher crest heights under extreme events. They have been shown to reduce erosion rates and can be resilient to sea level rise. These strategies aim to protect Highway 101 while enhancing public access, recreation, and habitat restoration, promoting resilience against future flood events.

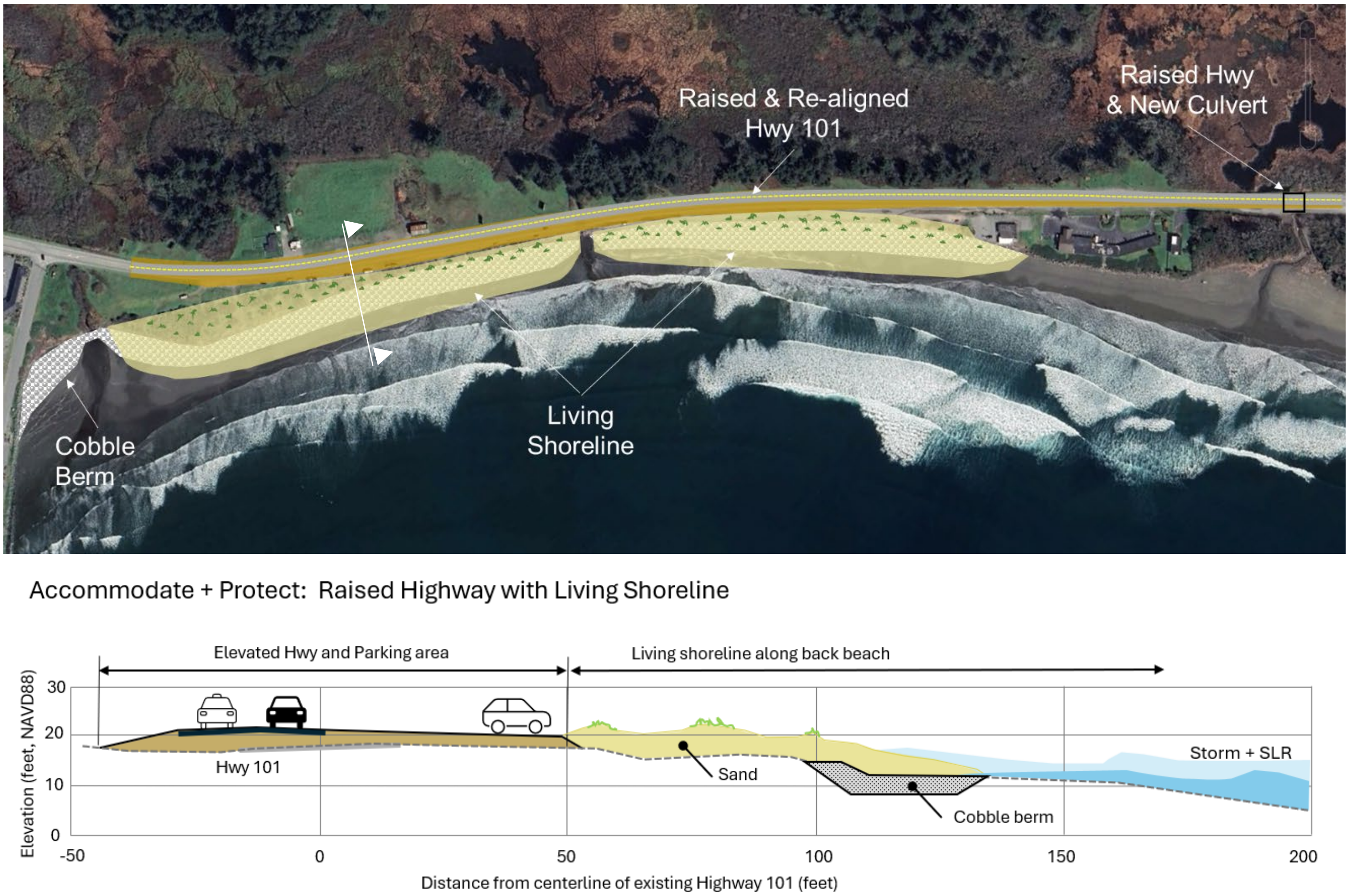


Figure ES-4. Plan view and typical section of Highway 101 preferred alternative

Anchor Way

The Anchor Way preferred alternative incorporates both accommodate and protect strategies for a comprehensive SLR adaptation approach (Figure ES-5).

1. **Protect with Repaired Whaler Island Groin Section**

Repairing the Whaler Island groin segment is crucial to protect the Anchor Way breakwater. Without repairs, the groin could progressively fail, increasing vulnerability to waves and SLR. The groin repairs, at a minimum, would restore a consistent crest elevation along the structure and restore the level of performance originally intended. Subsequent design phases will evaluate SLR scenarios to develop an adaptive pathway for maintenance and potential upgrades to this structure to address future conditions.

2. **Accommodate with Raised Revetment and Roadway**

The existing revetment crest elevation varies from 12 to 16 feet and will be uniformly raised to approximately 16 feet NAVD88. The revetment will be backed by a concrete floodwall with a crest elevation of around 18-20 feet NAVD88 to achieve a tolerable overtopping rate as described in the Coastal Engineering Manual and EurOtop Manual for a 100-year wave event and 2.3 feet of SLR. The roadway adjacent to the revetment, currently at 12 to 14 feet, will be raised to maintain views over the proposed flood wall. A new pedestrian pathway will be created between the debris wall and the road, enhancing safety and allowing fishing to continue off the revetment. These strategies aim to protect Anchor Way from the impacts of waves and SLR while improving infrastructure and public access.

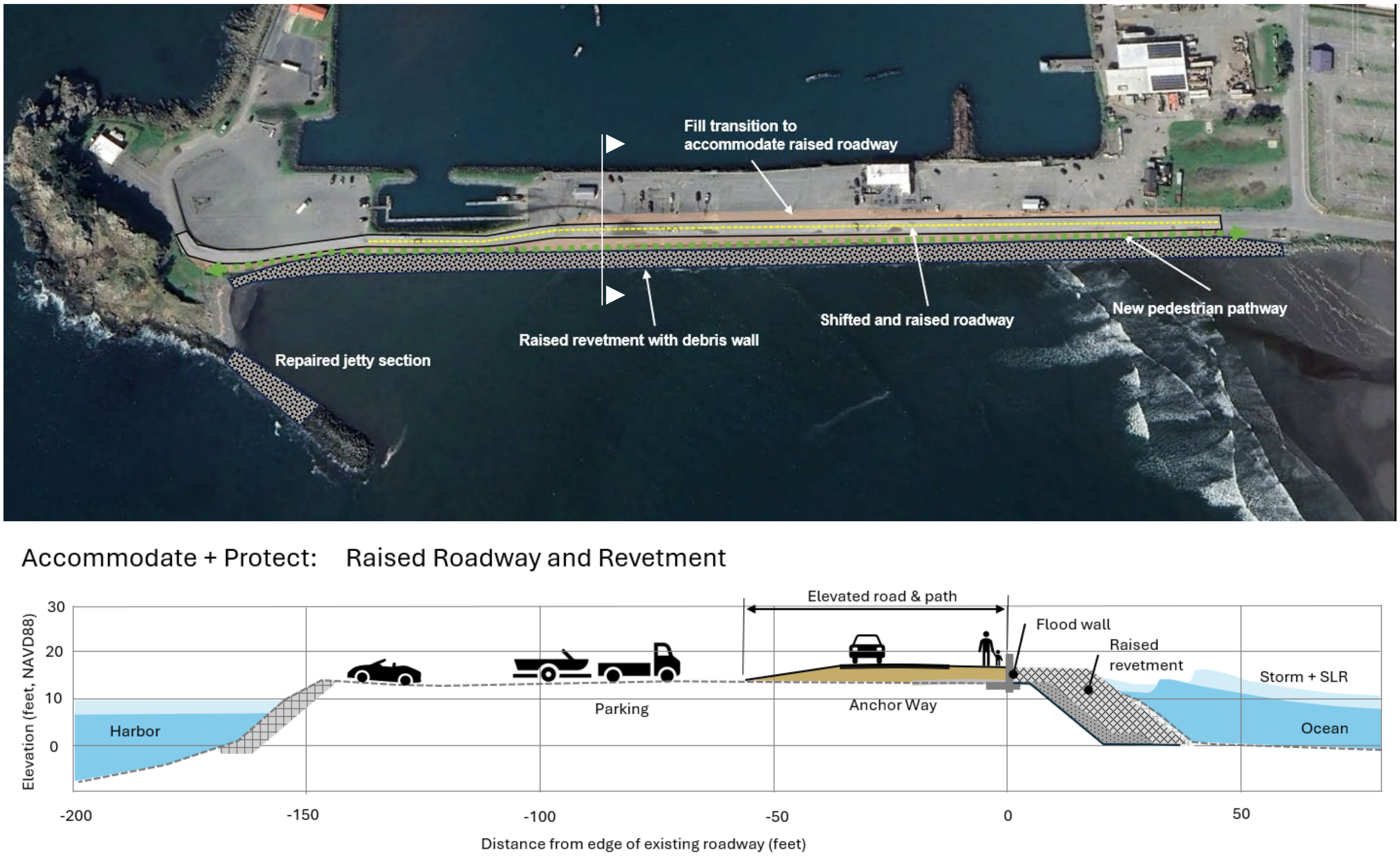


Figure ES-5. Plan view and typical section of Anchor Way preferred alternative

Contents

Table index

Figure index

Appendices

Acronym List

Term	Definition
Cal OES	California Governor’s Office of Emergency Services
CCHD	Crescent City Harbor District
Marsh Wildlife Area	Crescent City Marsh Wildlife Area
CDFW	California Department of Fish and Wildlife
CDIP	California Data Information Program
CEM	Coastal Engineering Manual
cm	centimeters
CoSMoS	Coastal Storm Modeling System
County	Del Norte County
DNLTC	Del Norte Local Transportation Commission
ESHA	Environmentally Sensitive Habitat Area
FEMA	Federal Emergency Management Agency
Harbor	Crescent City Harbor
IDS#3	FEMA’s third Intermediate Data Submittal
MCA	multi-criteria analysis
MHHW	Mean Higher High Water
MHW	Mean High Water
MLLW	Mean Lower Low Water
MLW	Mean Low Water
MOP	CDIP’s Monitoring and Prediction system
MPH	miles per hour
MSL	Mean Sea Level
MTL	Mean Tide Level
NAVD88	North American Vertical Datum of 1988
NOAA	National Atmospheric and Oceanic Administration
OPC	Ocean Protection Council
Plan	South Beach Transportation Climate Resilience Plan
PM	Post Mile
Project	South Beach Transportation Climate Resilience Planning Project
RSLR	Relative sea-level rise
SLR	sea-level rise
U.S.	United States
USGS	United States Geological Survey

1. Introduction

Both the South Beach area and Anchor Way have experienced flooding and damages due to elevated water levels and large waves. The stretch of Highway 101 along South Beach is an important transportation corridor. Its closure due to storm flooding and damages impacts the tsunami evacuation routes and detours traffic onto local residential roads, which adversely impacts the local community. Increased traffic through residential neighborhoods poses safety concerns for residents and leads to higher noise levels and air pollution. Emergency services response times can increase due to summer traffic through this area. The detour also contributes to wear and tear on local roads. Anchor Way's closure during and after storm events impacts access to the Harbor, closes the Harbor's tsunami evacuation route and impedes search and rescue boats from launching.

Previous studies, including the 2019 Crescent City Harbor District Sea Level Rise Assessment and the 2019 Del Norte Local Hazard Mitigation Plan, have indicated that the South Beach shoreline and Anchor Way are susceptible to increased inundation and flooding from sea level rise (SLR) and storm events. Within these vulnerable areas exist critical infrastructure including public utilities, transportation assets, and other public facilities that warrant further study and adaptation planning.

1.1 Project Goals

These ongoing issues and the expectations of increased impacts have led to frustration within the local community that prompted the Del Norte Local Transportation Commission (DLNTC) to initiate this project. DLNTC pursued Caltrans Climate Change Adaptation Planning Grant funding to implement a project to identify adaptation strategies and specific actions to remedy identified climate related vulnerabilities and decrease community impacts from the detour route by providing a focused community scale planning effort. Strategies would meet the following goals:

1. Develop strategies for Highway 101 to remain a functional multimodal transportation corridor in light of climate change caused SLR, increased precipitation, and storm surge.
2. Develop strategies for Anchor Way to remain functional in light of climate change caused SLR, increased precipitation, and storm surge.
3. Develop strategies to maintain public access along Highway 101 to the existing South Beach area.

1.2 Project Process

This South Beach Transportation Climate Resilience Plan (*the* Plan) is needed for the critically important local and regional transportation facilities of Anchor Way and Highway 101 in the South Beach area Del Norte County (*the* County). This report presents the information gathered and analyzed for the South Beach Climate Resilience Planning Project (*the* Project). This report builds on previous studies to understand how these hazards may evolve with SLR projections consistent with the Ocean Protection Council (OPC) 2024 SLR Guidance. While the previous studies assessed vulnerability associated with SLR, they did not evaluate the increased impacts of waves with SLR. Present and future coastal hazards examined include coastal flooding (tidal water levels, storm surge, and wave runup) and shoreline erosion, which are the predominant hazards for Highway 101 and Anchor Way.

A range of coastal flooding scenarios were developed and evaluated along the beach (Highway 101) and at the breakwater (Anchor Way). Typical and extreme events were evaluated to better understand the magnitude of overtopping associated with different storm events. Future coastal hazards were evaluated for the near, mid, and long term (i.e., 2050, 2070, 2100) based on publicly available data sources and empirical relationships.

Coastal hazard data was compiled on an ArcGIS platform to develop geospatial maps that depict hazards, resources, and Project site features. A vulnerability assessment of existing conditions was performed to identify potential flood impacts to the Project sites and inform the development of preliminary planning-level adaptation strategies. GHD worked with the Advisory Committee to develop adaptation strategies that provide resiliency for multiple scenarios along Highway 101 and Anchor Way. The strategies built upon previously identified projects in the AB691 SLR Assessment, Local Hazard Mitigation Plan, and other local sources. Adaptation strategies were evaluated using a multi-criteria analysis, incorporating public feedback and Advisory Committee input. A preferred solution was then developed, combining different strategies to enhance resilience for the local and regional transportation facilities of Anchor Way and Highway 101.

1.2.1 Engagement and Outreach

The Project is led by the Del Norte Local Transportation Commission (DNLTC) and supported by GHD and an Advisory Committee of local professionals, including representatives from Crescent City Harbor District (CCHD), Elk Valley Rancheria, Caltrans District 1, Del Norte County, and California Department of Fish and Wildlife (CDFW). These members, who have a deep understanding of the Project Area and local community, guided the Plan development to align with diverse community needs. Six Advisory Committee meetings occurred between 2024 to 2025, with details provided in Appendix A.

Public outreach was conducted to notify the public about the Project, learn about local experiences, and inform the selection of a preferred adaptation strategy from a suite of options. Outreach activities included creating a page on DNLTC's website for information and updates, collecting public input via DNLTC's virtual interactive dashboard, surveys, website feedback form, and holding four public meetings between November 2024 and May 2025. A summary of these activities and results is provided in Appendix B.

Input from public and Advisory Committee meetings was incorporated into the understanding of the site, evaluation of alternatives, and selection of the preferred adaptation strategy. The evaluation process involved assessing various adaptation strategies based on community feedback, technical feasibility, environmental impact, and alignment with local needs. Alternatives were developed and evaluated through a collaborative process involving both the Advisory Committee and public input. The results of public outreach were used to inform the selection process by incorporating community feedback into the evaluation criteria and decision-making, ensuring that the selected adaptation strategy reflects the preferences and needs of the local community.

In June 2025, the Plan will be presented to the DNLTC Board, Elk Valley Rancheria Tribal Council, and CCHD Board, with responses and/or resolutions from these meetings appended to the Plan (Appendix C).

1.3 Site Description

The Project Area is within the aboriginal territory of the Tolowa Dee-Ni' peoples, extending just south of Crescent City into unincorporated Del Norte County (Figure 1-1). The Project Area borders the Pacific Ocean to the west. While the Project focuses primarily on Highway 101 and Anchor Way transportation corridors, the Project considers impacts immediately adjacent to the highway, including the Crescent City Marsh Wildlife Area (*the* Marsh Wildlife Area) managed by CDFW to the east, South Beach to the west, and private property on both sides of the highway. The northern extent of the Project Area is Citizen's Dock Road (Post Mile [PM] 25.508) in the Crescent City Harbor (*the* Harbor), extending south 1.7 miles along Highway 101 corridor to Enderts Beach Road (PM 23.8).

Land and assets in the Project Area are owned and managed by multiple agencies and individuals including Del Norte County, CCHD, Caltrans, CDFW, and a variety of private property owners (Figure 1-2). Caltrans owns and manages Highway 101 and the culverts in the Project Area. Caltrans identified the entire stretch of Highway 101 in the Project Area as the highest priority for adaptation assessment based on its exposure to climate change induced impacts (Caltrans 2021). The CCHD owns and manages the land and tideland properties waterward of the 1948 Ordinary High-Water Mark, Crescent City Harbor, Anchor Way, and portions of South Beach up to Highway 101 road edge (CCHD 2018). Del Norte County also has jurisdiction in the Project Area. The Project Area is organized into two sub-areas, north and south of Anchor Way.

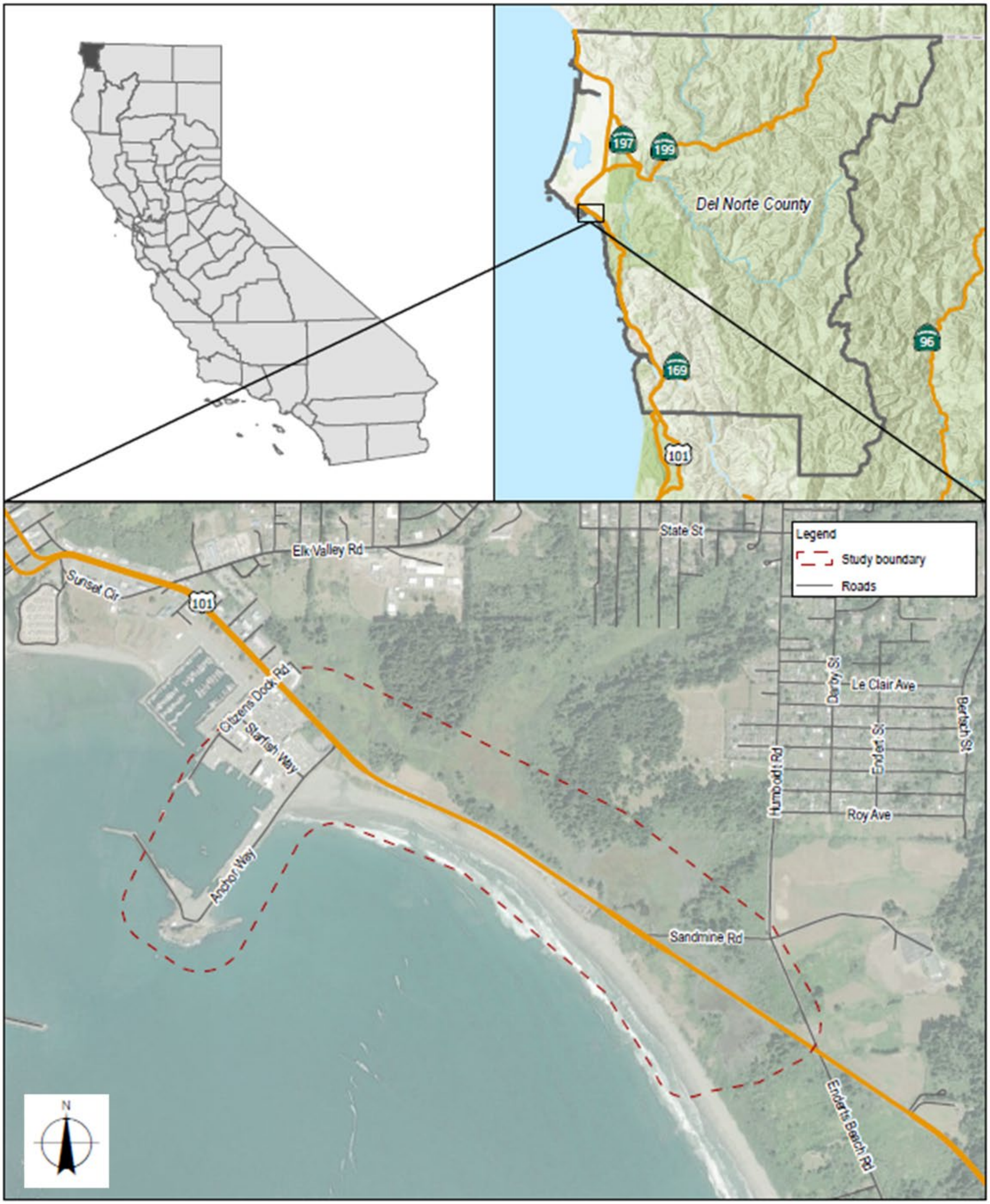


Figure 1-1. Project Area

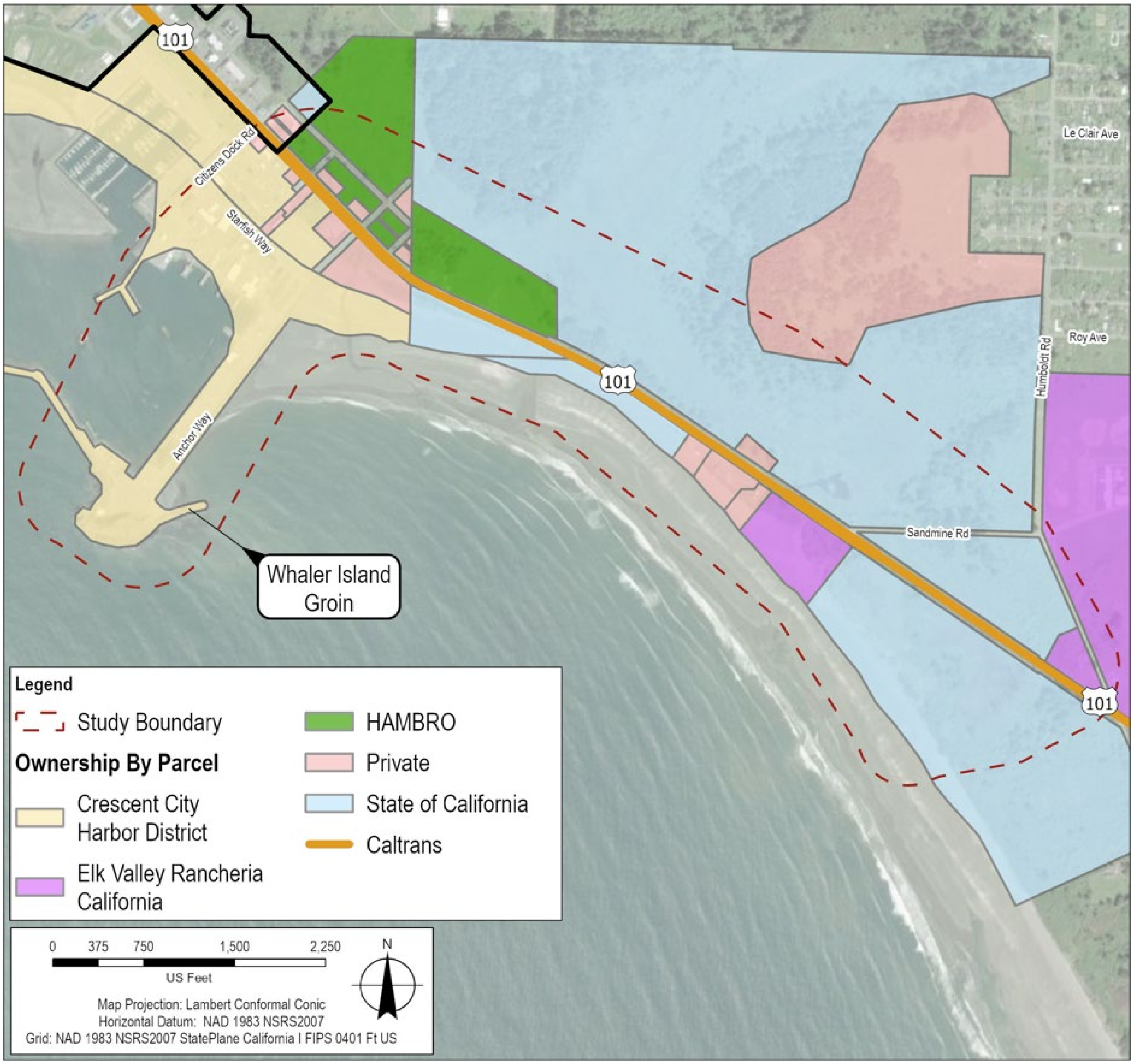


Figure 1-2. Municipal and ownership boundaries. The Crescent City city limit is outlined in black in the top left corner

1.3.1 Highway 101 Sub-Area

The Highway 101 sub-area focuses on a 2-lane section of Highway 101 that is 1.4 miles long, extending from Anchor Way to Enderts Beach Road and is in unincorporated Del Norte County. Highway 101, a significant 2- and 4-lane highway, links Crescent City in the north to Eureka in the south, facilitating connectivity across Mendocino, Humboldt, and Del Norte Counties. The Highway is a key link in connecting the Elk Valley Rancheria, Yurok and Pulikla Tribes with Crescent City. It caters to local traffic and forms part of the National Highway System, State Highway Network, Interregional Road System, and interregional Pacific Coast Bike Route. The land within the Project Area is designated as commercial-recreational, industrial, and agricultural grazing (County of Del Norte 1983). There are multiple private properties in this area, including the Crescent Beach Motel on the seaward side of Highway 101, a mostly empty vegetated parcel at the intersection of Anchor Way and Highway 101, and a parcel with structures on the landward side of Highway 101 owned by HAMBRO. Two Redwood Coast Transit bus routes go through the Project Area along Highway 101, Route 4 and Route 20, respectively.

South Beach borders the west side of Highway 101, south of Anchor Way. South Beach is a wide, sandy beach backed by an unarmored vegetated shelf up to approximately 4 to 5 feet tall. South Beach is a popular recreation area used for walking, beach combing, surfing, and fishing. South Beach is considered part of the California Coastal Trail (Caltrans 2023a). There are multiple informal beach access locations along the Highway 101 corridor. Between Highway 101 and South Beach is a band of vegetation varying in width with unvegetated spaces used as public parking for beach access, as well as the Crescent Beach Motel and other private property. Fronting the Crescent Beach Motel is an armor stone revetment. The Elk Valley Rancheria, a federally recognized tribe of the Tolowa and Yurok people, owns property just south of the Crescent Beach Motel.

There are two culvert outlets on the northern end of South Beach and two on the southern end of the Project Area (Figure 1-3). Each of these provides hydraulic connection between the watershed and wetlands east of Highway 101 to South Beach, underneath the highway. The culverts were designed to convey the Mill Creek watershed into the Pacific Ocean. The elevation of the highway ranges from 14 to 23 feet North American Vertical Datum of 1988 (NAVD88) (Figure 1-4, Figure 1-5). The lowest elevation occurs at the intersection with Anchor Way, while the highest elevation occurs at the intersection with Enderts Beach Road. Additional lower elevations, between 14 and 16 feet, occur between the motel and the first culvert south of Sandmine Road. Flooding of Highway 101 around the middle culverts has been reported to be a common occurrence during the winter season and is expected to worsen over the coming decades due to climate change induced effects such as more frequent severe storms and SLR (TetraTech 2019). Current flooding has been reported to be a consequence of high tides and large waves overtopping the roadway (Caltrans 2003, Shaaf and Wheeler 2015, TetraTech 2019). This has causes flooding and road closures that have lasted 12-14 hours (Caltrans 2003).

Additionally, the Marsh Wildlife Area is located east of Highway 101, which is owned and managed by CDFW. The Marsh Wildlife Area is a flora-diverse area. CDFW’s management goal for the wildlife area is to maintain and enhance the existing habitats and restore freshwater wetland areas. The federally endangered western lily (*Lilium occidentale*) exists within the marsh (Bencie and Wear 2004).

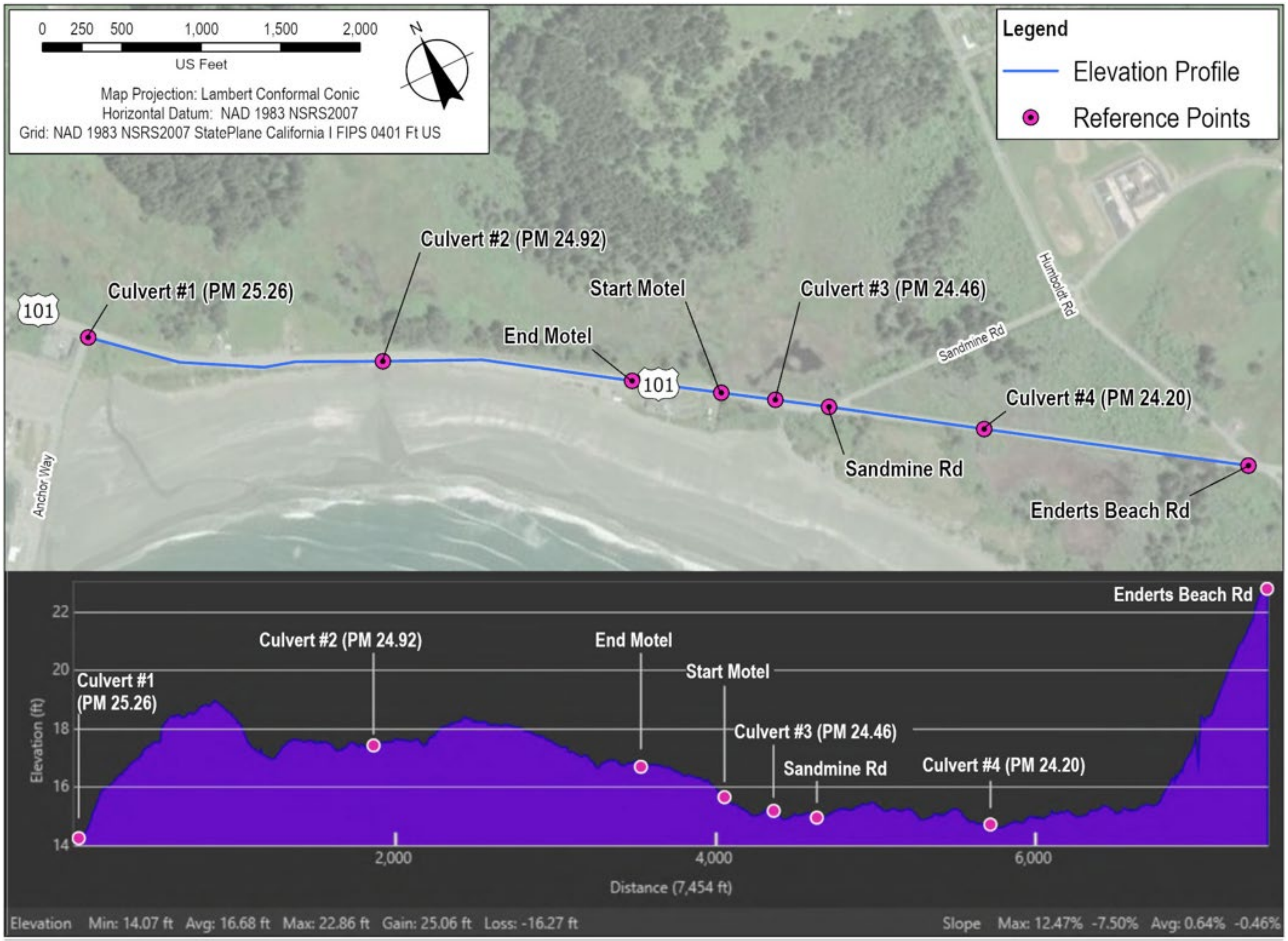


Figure 1-3. Elevation profile of Highway 101 within the Project Area shown in feet (NAVD88)

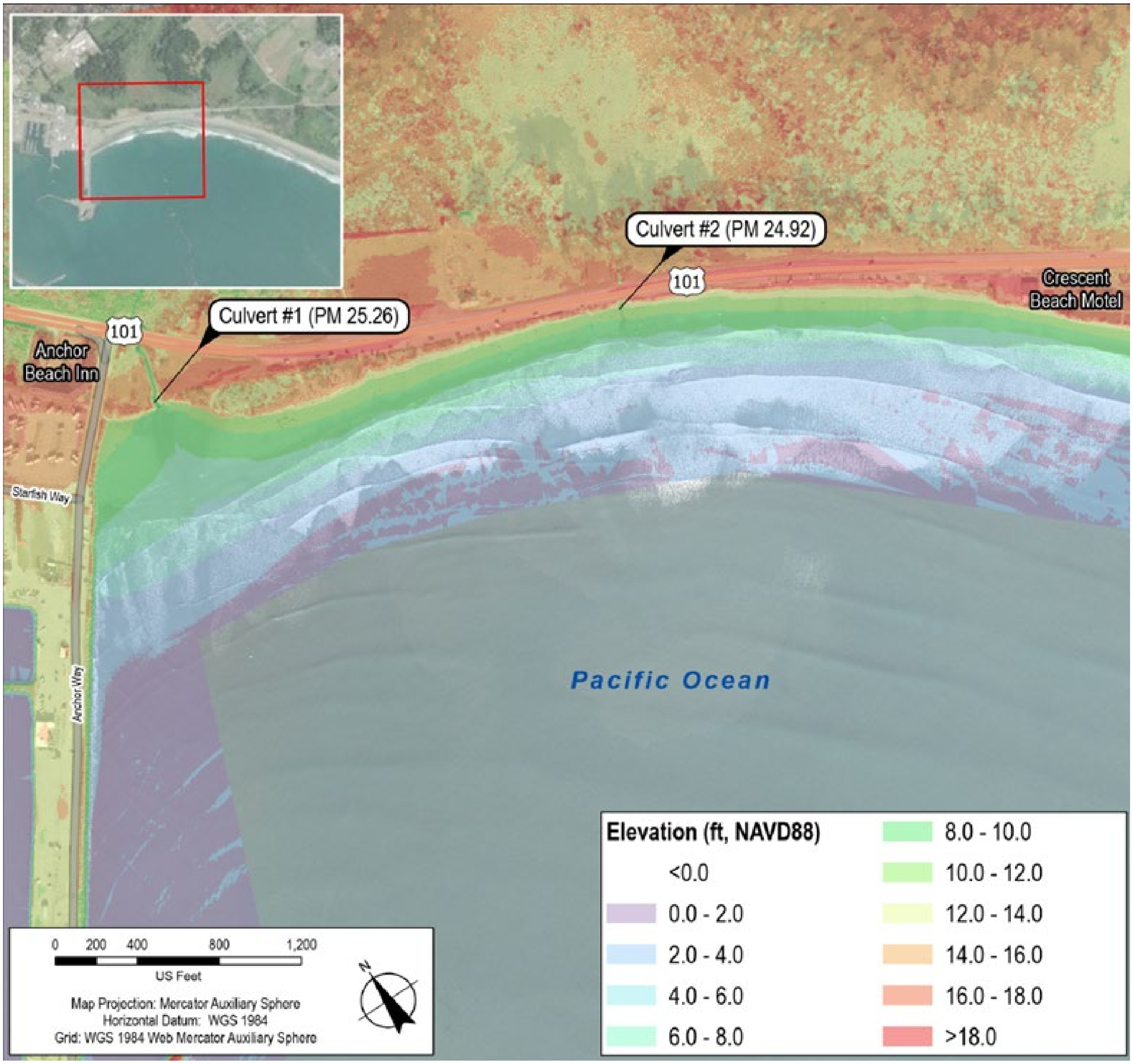


Figure 1-4. Northern Highway 101 elevation heatmap

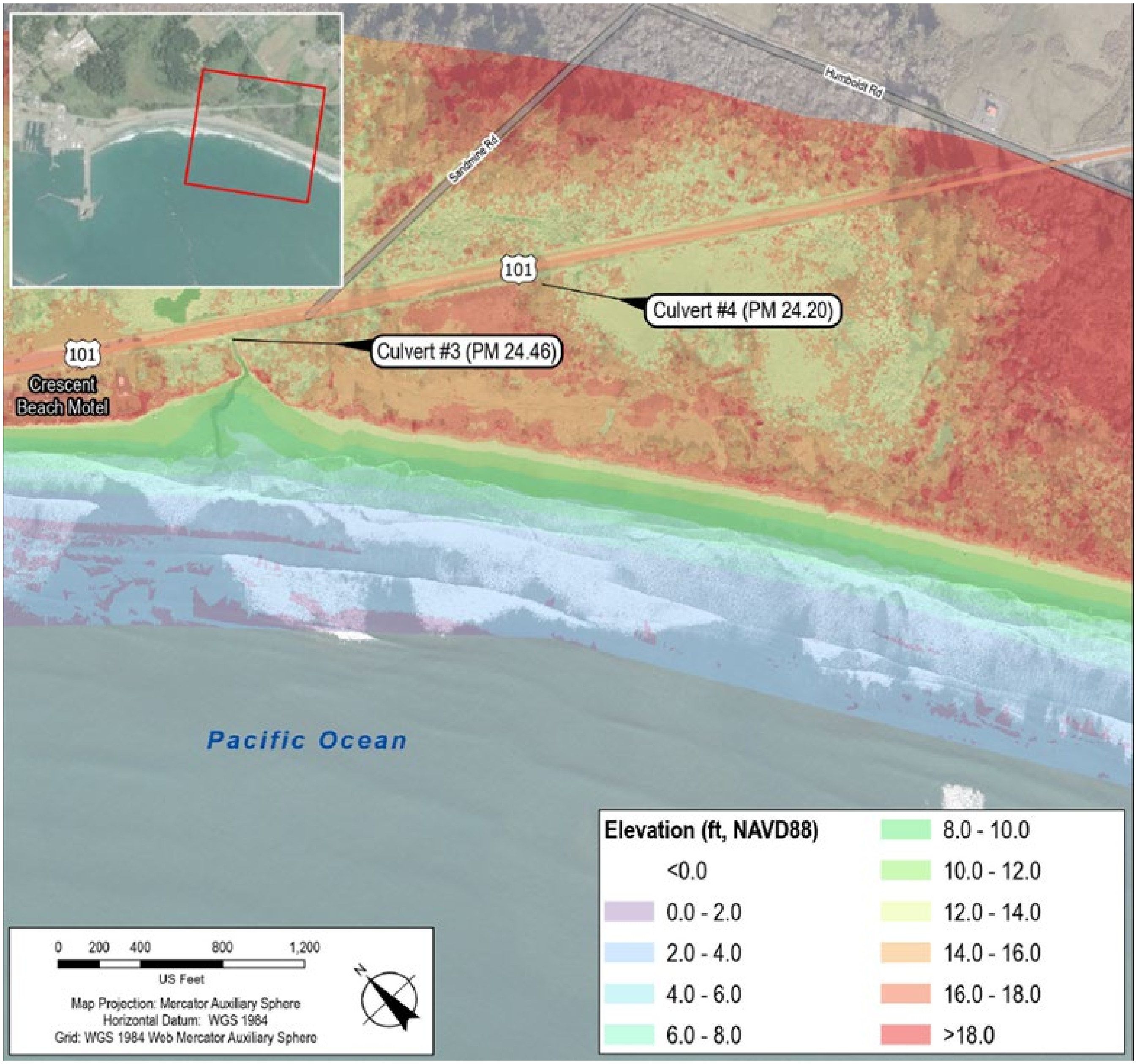


Figure 1-5. Southern Highway 101 elevation heatmap

1.3.2 Anchor Way Sub-Area

The Anchor Way sub-area contains the southern half of the Crescent City Harbor, from Citizen's Dock Road to Anchor Way. Anchor Way is maintained by the CCHD; except for the portion from Highway 101 to Starfish Road, which is maintained by the County. The Harbor is owned and managed by the CCHD. This sub-area is used for a myriad of purposes and includes restaurants, commercial, industrial, and recreational spaces. Crescent City Harbor is a critical shallow-draft harbor of refuge, providing Coast Guard access for search and rescue operations, commercial and sport fishing, and leisure boating. It functions as a commercial basin for various fishing vessels including salmon, shrimp, tuna, cod, and Dungeness crab, in addition to serving recreational watercraft (Planwest Partners 2023).

In total there are five maintenance storage buildings, thirteen office retail spaces, five restrooms, multiple parking areas, the Bayside RV Park, the Anchor Beach Inn, and four restaurants. Throughout the Harbor there are electric utilities, sewer lines, and telecommunications lines. There is also a large solar array providing power to the Harbor buildings. The majority of the sub-area is paved with limited areas of maintained lawn. The shoreline is nearly all armored with rock slope protection and/or sea walls. Whaler Island, at the terminus of Anchor Way, is an exception and is a natural rock feature. The elevation along Anchor Way is 12 to 14 feet NAVD88 (Figure 1-7).

Access to South Beach from the Harbor is facilitated by an informal path from Anchor Way to the beach that is used primarily by pedestrians and occasionally for emergency vehicles. At the end of Anchor Way, Whaler Island is a popular scenic site and contains a small cove that both surfers and kayakers use between the Whaler Island groin and Anchor Way.

Anchor Way serves as a designated tsunami evacuation route and is an important accessway for emergency services. It also provides direct access to Harbor facilities. The Harbor is the first defense of Crescent City against large swell waves and tsunamis and has endured multiple natural disasters, causing the CCHD to have to rebuild its marina multiple times (CCHD 2018). Most recently, the inner boat basin was rebuilt in May 2014 to withstand a 50-year tsunami event. The current protective armoring of the Harbor includes 5,000 feet of riprap in the inner boat basin and 5,800 feet of riprap along the Whaler Island groin. Citizen's Dock is connected to the Harbor via sand filled jetty.

Marine resources are defined in the Del Norte County General Plan (1983) as “any portion of the oceanic environment of monetary, aesthetic or other value,” and are abundant within in the Project Area. Offshore of the Project Area are marine fisheries providing fish, crab, and shrimp that contribute to the local economy. The intertidal area (area of the shoreline between high and low tide) contains a variety of invertebrates, and the rocky areas of the Harbor, including Whaler Island, provide resting sites for migratory marine mammals such as the California and Stellar sea lion (County of Del Norte 1983).

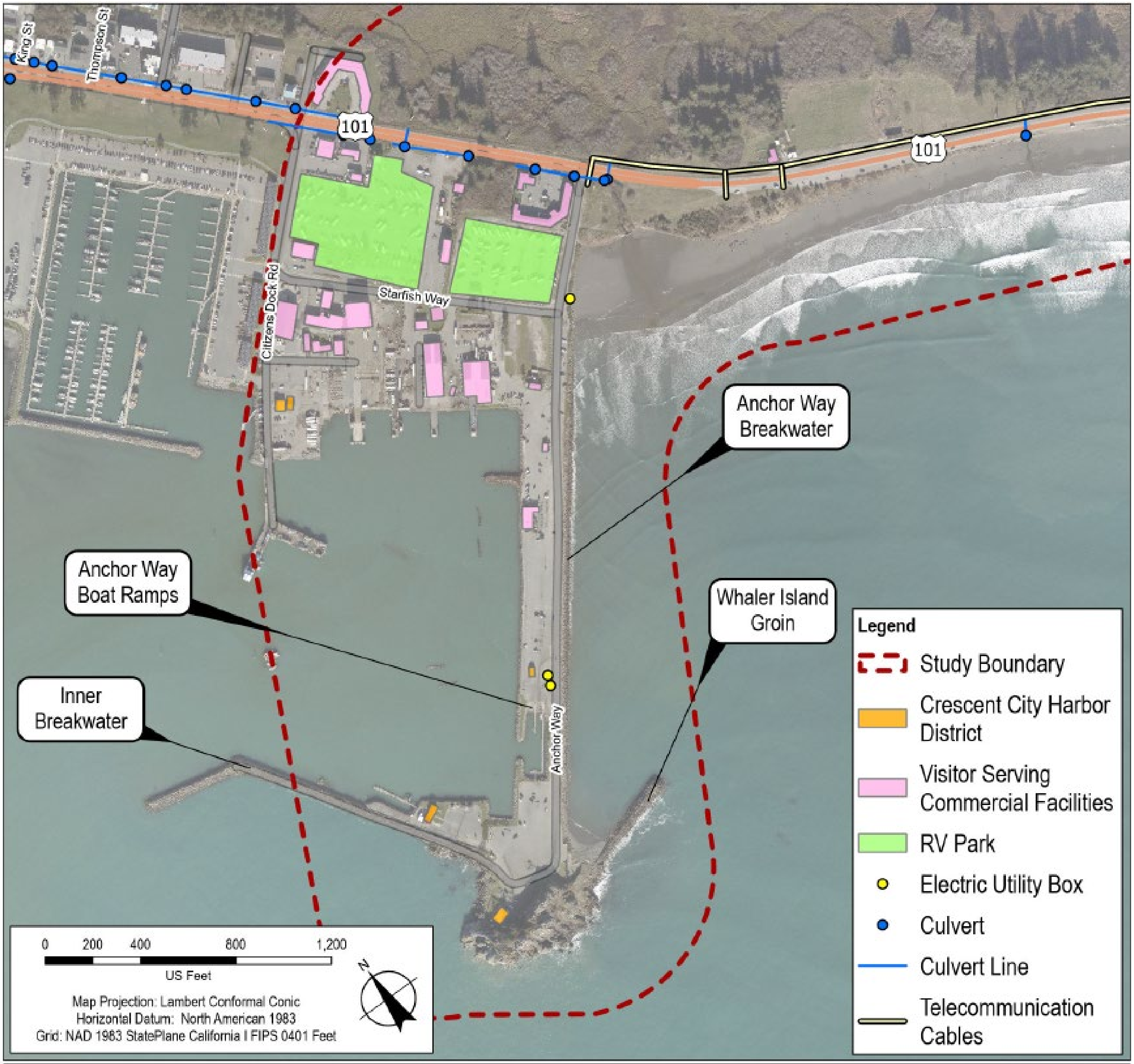


Figure 1-6. Anchor Way asset map

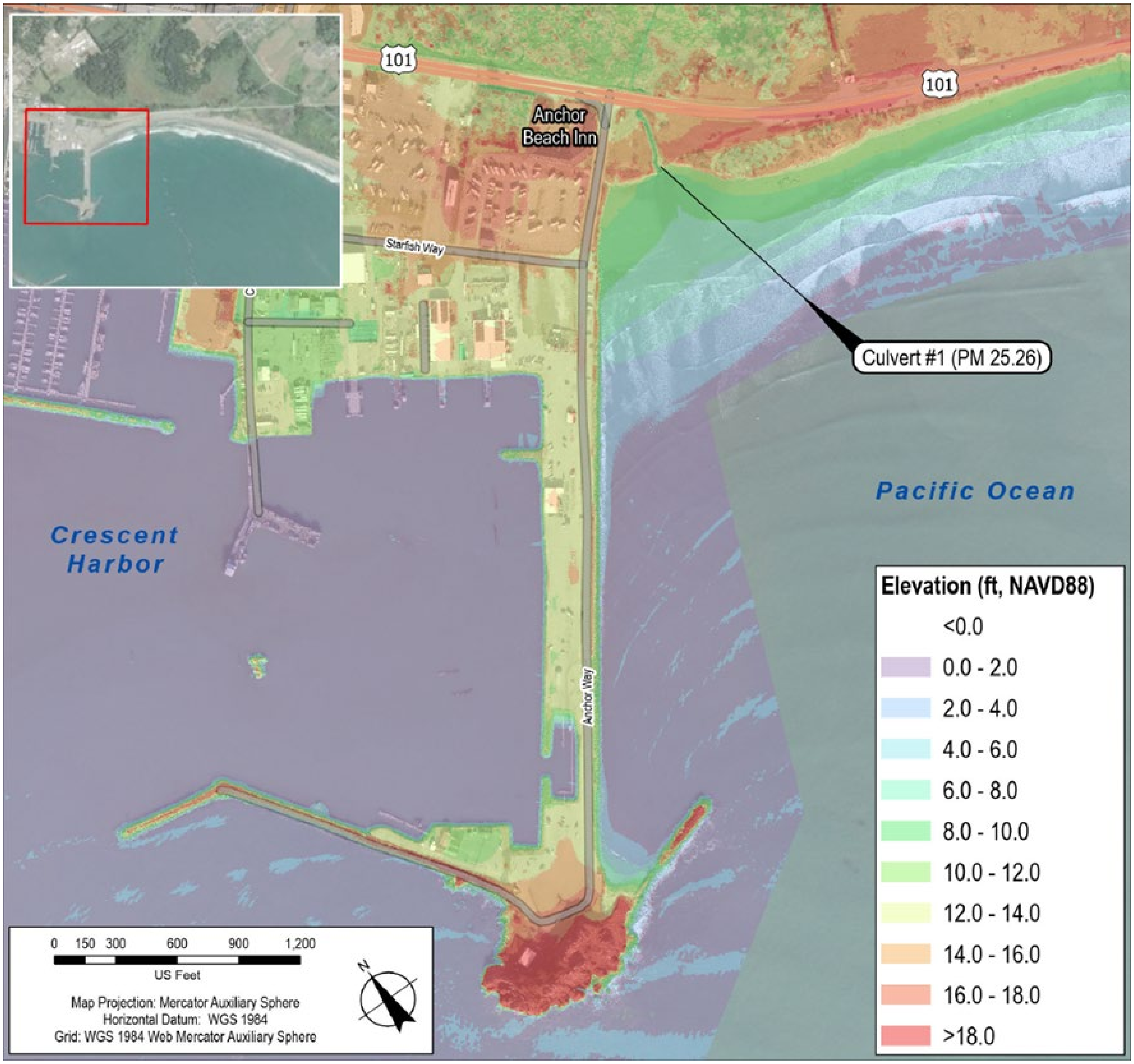


Figure 1-7. Anchor Way elevation heat map

1.4 Past Closures and Damages

During storm events, a Caltrans on-call maintenance crew monitors the site and clears debris to keep the roadways open. However, road closures occur when safe travel through the area cannot be achieved due to the rate and magnitude of flooding and debris deposition. Damage reports are developed in instances where larger interventions and repairs are needed. Since 2010, one Director’s Order was submitted for a culvert repair in fiscal year 2018/19 costing under $1 million.

When Highway 101 is closed, traffic is diverted to Elk Valley Road, which is dangerous due to high crash rates and poor road conditions. Elk Valley Road crosses Elk Valley Rancheria and residential streets. It has narrow lanes, steep hills, blind curves, and no shoulders, making it hazardous for all users, including cyclists and pedestrians. The intersection of Howland Hill and Elk Valley Road has crash rates much higher than the statewide average. Few roads in this area have sidewalks. Adding hundreds of vehicles per hour would make the road even more unsafe. The detour also contributes to wear and tear on local roads. Emergency services response times can increase due to traffic congestion through this area. Furthermore, the Redwood Coast Transit Authority has routes on Highway 101, and when the highway is closed, the transit service must use Elk Valley Road. This forces transit riders to cross the road to reach relocated stops, creating a dangerous situation. This change negatively impacts the underserved community that relies on transit for essential trips.

Flooding along Anchor Way is a common secondary hazard to severe weather. The last seven severe storms (six of which occurred during winter) had a damage assessment of $799,000 at the harbor and along Anchor Way (PND 2019). In the last 80 years, 39 tsunamis have been detected within Del Norte County; four of which caused more than $37 million in cumulative damage to the Harbor (PND 2019). In addition to high monetary impacts, when Anchor Way is closed, it limits critical emergency services. Anchor Way is the sole access to the boat launching facility used by the Coast Guard and Sheriff patrol boat search and rescue operations, which are often needed during storm events. Anchor Way is the designated tsunami evacuation route in the Harbor (Anchor Way to Whaler Island), and when it is closed there is no available alternative for evacuation from the inundation zone

Some of the recent storm events are described below.

- A 2006 tsunami resulted in the docks being damaged. They were removed and replaced, with a total cost of $4-million.
- During a tsunami on March 11, 2011, the roads were closed from PM 22 to PM 28.
- Storm in 2018 produced substantial debris and impairment to the Anchor Way Breakwater (PND 2019).
- Following a period of heavy rainfall on January 5, 2019, the culvert at PM 24.92 was damaged, resulting in the loss of embankment material and a portion of the shoulder on the northbound side of Highway 101. The highway was closed and detoured from Anchor Way to Sandmine Road via Elk Valley Road.
- During a storm event on January 5, 2023, in which there were large waves and elevated water levels, Highway 101 was closed due to flooding and debris removal (Figure 1-8 through Figure 1-10).
- In June 2023, repair work commenced after sinkholes in the highway appeared, a subsequent investigation revealed that the culverts below them had failed, leading to their replacement. At PM 23.2, a 36-inch corrugated steel pipe (CSP) was removed and replaced, and at PM 25.42 a 24-inch CSP was replaced with a 24-inch fusion weld high-density polyethylene (HDPE) (Figures 1-11 and 1-12).

Figure 1-8. Damage in the Harbor from March 2011 tsunami (PND 2019)

Figure 1-9. Damage after a large wave event in 2018 along Anchor Way (PND 2019)

Figure 1-10. Overwash along Highway 101 during a January 5, 2023 storm (Photo courtesy of Kevin Pratt)

Figure 1-11. Scour at the culvert at PM 24.92 from a January 5, 2023 storm (Photo courtesy of Kevin Pratt)

Figure 1-12. Culvert at PM 24.92 filled with driftwood and debris during a January 5, 2023 storm (Photo courtesy of Kevin Pratt)

1.5 Site History and Uses

1.5.1 Development History

Del Norte County was founded in 1857 from part of the territory of Klamath County following the California Gold Rush. Klamath County ceased to exist in 1874. Historically, the economy of the area was largely driven by the logging and fishing industries, which led to cycles of economic growth and decline. As these industries dwindled, so did the population. The construction of Pelican Bay State Prison in 1989 marked a significant shift, as it expanded the City's boundaries and doubled its population with the addition of inmate residents. Today, the City, including the prison, accounts for about 30% of Del Norte County's population.

The City stands out as one of the few larger commercial hubs in the predominantly rural northern coastal redwoods region, with a significant portion of its land dedicated to commercial and service uses. The local economy benefits from the tourism and fishing industries, supported by hotels and Harbor facilities. The housing landscape is diverse, ranging from high-end beachfront properties to modest wood frame rental units.

The City's downtown commercial district, which was severely damaged by the 1964 tsunami, has never fully recovered. Instead, new commercial developments have sprung up along Highway 101 (TetraTech 2019).

Historical photographs from the early and mid-20th century show the Harbor Area, characterized by a sandy beach and coastal dunes, prior to development of more extensive Harbor facilities (Figures 1-13, 1-14, 1-15). Over time, development and Harbor-related facilities have transformed this landscape. Today, the once dune-covered area is now predominantly developed. The transformation included extensive filling along the breakwater leading to Whaler Island and the creation of infrastructure for parking, buildings, an inner boat basin, and fish processing facilities (Planwest Partners 2023).

Figure 1-13. Looking east towards the Harbor in 1944 (Photo ID2001.01.0836, Shuster Arial Photography Collection, Cal Poly Humboldt Library)

Figure 1-14. Looking north towards the Harbor in 1951 (Photo ID2001.01.1633, Shuster Arial Photography Collection, Cal Poly Humboldt Library)

Figure 1-15. Looking south over Crescent City towards the Harbor and South Beach in 1957 (Photo ID2001.01.2262, Shuster Arial Photography Collection, Cal Poly Humboldt Library)

1.5.2 Demographics

According to the 2020 Del Norte County Regional Transportation Plan, between 2005 and 2015, Del Norte County experienced a population decrease of 4%, from 28,281 to 27,103 (Green Dot Transportation Solutions 2020). According to the 2024 Del Norte Regional Transportation Plan, it remained fairly steady, increasing to 27,246 people by 2022 (Green Dot Transportation Solutions 2024). Approximately 23% of the County's population live within the City of Crescent City (U.S. Census Bureau 2023). As of 2022, the largest age group in the County was 5-19 years old (17.7% of the total population), followed by 25-34 years old (14.3% of the total population). The percentage of the population over 65 years old was 19.2%, which was a 2.5% increase since 2018. Shifts towards an aging population could potentially impact the labor availability in the County (PND 2019). In 2022, 14% of residents fell below the poverty threshold and the County unemployment rate was 6.3%. the Del Norte population is predominately white (64%), Hispanic (21%) and Native American (8%).

A community qualifies as disadvantaged if its median household income is less than 80% of the statewide median ($80,000), according to the most recent Census Tract data from the American Community Survey. The Project Area is in two census tracts. The median household income in Census Tract 1.02 is $61,149 and in Census Tract 2.03 is $48,276, which are both less than 80% of the statewide median (U.S. Census Bureau 2023). The Project Area also includes Senate Bill 535 disadvantaged communities federal tribal areas (OEHHA 2022).

According to the 2024 Del Norte County Economic & Demographic Profile (DLNTC 2024), 72% of people in the County drive to work alone, 14% carpool, and almost 4% take public transportation. The remaining bicycle, walk, use other means of transportation, or work from home.

1.5.3 Traffic Volumes and Forecasts

Highway 101 corridor traffic volumes north of the Project Area at Elk Valley Road and south at Sandmine Road include a peak A.M. hour volume of 276 vehicles, with 66.03% of these vehicles in the southbound direction. The peak P.M. hour volume is 293 vehicles, with 57.79% of these vehicles in the northbound direction (Caltrans 2022a). Traffic volumes on Highway 101 within the Project Area has a growth factor of 1.07, meaning a 7% increase in traffic is expected over the next 20 years (Larson 2024).

2. Regulatory Guidance and Standards

The Project Area is located in the Coastal Zone. The California Coastal Commission retains coastal development permitting jurisdiction in portions of the Project Area, including areas of the Harbor and along South Beach. The 1983 Del Norte County Local Coastal Program and 2023 Crescent City Harbor Port Land Use Plan and Harbor-Specific Implementation Program are the local planning documents that guide development in the Project Area outside of the State's retained jurisdiction. In areas of Commission retained permit jurisdiction, including submerged lands, tidelands, and public trust lands, these local documents can provide guidance, however project review standards are the California Coastal Act Chapter 3 policies. The following is a description of regulatory guidance and standards pertaining to SLR vulnerability and adaptation projects including policies on shoreline access, hazards evaluation, and coastal resource protection.

2.1 Del Norte County Local Coastal Program

The Del Norte County General Plan Coastal Element was certified as the local coastal plan in 1983. Consistent with the California Coastal Act, the Local Coastal Program includes policies related to protection of environmentally sensitive habitat areas and wetlands, protection of agricultural and forestry resources, maintaining and enhancing the quality of coastal waters and marine resources, and protection and enhancement of visual resources. The Local Coastal Program examines existing and proposed public works systems, including roads, solid waste management, and sewage disposal and discusses the capacity and future expansion of these systems. The Local Coastal Program also includes goals and policies related to hazards, SLR, and tsunamis. These include assessing rates of coastal shoreline retreat and potential for tsunami run-up in areas adjacent to coastline erosion areas, establishing setback areas to mitigate potential coastal erosion hazards, minimizing risks to life and property, avoiding siting critical facilities in areas susceptible to tsunami inundation, and requiring that buildings meant to accommodate public safety activities and equipment are constructed to support continued operations and availability of services after an earthquake or tsunami.

The document outlines a comprehensive approach to managing coastal access resources in Del Norte County, including recognizing the importance of shoreline access for public recreation and balancing public recreation with environmental and property considerations. It also identifies existing and potential access points, and emphasizes the need for diverse and well-distributed public and private recreational facilities. While the Local Coastal Program's geographic scope is large, there are specific mentions of resources in the Project Area. According to the Local Coastal Program, South Beach recreational uses include walking, beachcombing, surfing, surf-fishing, and limited off-road vehicle driving. Recommendations to manage South Beach's heavy use and protect its ecological value are included. Anchor Way supports industrial uses such as fish processing plants and boat repair shops, and it offers views of the Harbor, maritime activities, and distant forested uplands. Whaler Island supports recreational uses such as fishing and surfing. The Local Coastal Program also recommends monitoring and managing the environmental impact of recreational activities in this area.

2.2 Crescent City Harbor Port Land Use Plan

The Crescent City Harbor Port Land Use Plan and Harbor-Specific Implementation Program are segments of the County's Local Coastal Program specific to the Harbor area, the majority of which is also under the jurisdiction of CCHD (granted by the State Lands Commission and lands owned fee and title by CCHD), and the northern portion of South Beach. The Land Use Plan is designed to reflect current and foreseeable conditions while being flexible enough to adapt to future opportunities. General development policies focus on locating new development close to existing development, ensuring adequate public services, and minimizing environmental impacts. Consistent with the California Coastal Act, the Land Use Plan includes policies related to protection of environmentally sensitive habitat areas and wetlands; minimization of pollutants in runoff and protection of coastal waters; protection and enhancement of scenic and visual qualities of the coastal zone; and protection of archaeological, paleontological, and cultural resources. The plan encourages the development of visitor-serving commercial recreational facilities to enhance public opportunities for coastal recreation.

The Land Use Plan emphasizes public access to and along the shoreline. Coastal access and recreation policies acknowledge that lateral (from Highway 101) and vertical (from Anchor Way) shoreline access could be improved, waterfront access is required, public trails shall be permitted, and that new public facilities shall include provisions for adequate access for people with disabilities. Policy 2.3.1-1 specifically promotes public recreational uses at South Beach and prohibits uses that would interfere with public access and enjoyment of coastal resources. Policy 3.1.1-5 notes that "Public access improvements unavoidably located within Environmentally Sensitive Habitat Areas (ESHAs) shall be sited, designed, and maintained in a manner to avoid or, where avoidance is infeasible, minimize ESHA impacts." The Land Use Plan details facilities for launching, berthing, and storing vessels, including the protection, improvement, and maintenance of the Whaler Island trailer launch ramp (Policy 3.2.1-1).

The Land Use Plan section 2.5 focuses on hazards and protective devices. It includes policies to minimize risks from geologic and flooding hazards, including SLR and tsunamis. The Land Use Plan calls for projects to consider site-specific hazard information using the best available scientific information regarding the effects of long-term SLR and to evaluate the worst-case, high projection over the anticipated life of the development. Analyses should be used to help guide site design and identify SLR thresholds to mitigate hazards and develop alternative adaptation strategies to promote safety. Overall, these policies emphasize maintaining and enhancing critical Harbor protective structures like breakwaters and seawalls and implementing adequate mitigation for adverse coastal resource impacts.

2.3 California Ocean Protection Council 2024

The Land Use Plan discussed above uses the 2018 OPC SLR guidance to inform its planning measures. In 2024, the OPC released new SLR Guidance, which updates the previous 2018 guidance to incorporate the latest scientific research and provide a comprehensive framework for resilience planning. The 2024 update includes new SLR projections that utilize plausibility rather than probability. See Section 3, Coastal Hazard Analysis for site-specific SLR scenarios and projections.

2.4 California Coastal Commission Guidance

The California Coastal Commission's 2024 SLR Guidance provides updated recommendations and strategies for addressing SLR along California's coast (CCC 2024). Major updates to the guidance incorporate the OPC 2024 State of California SLR Guidance best available science, emphasize the integration of environmental justice principles, and provide guidance related to adaptation plans required by Senate Bill 272. The guidance outlines regulations on the use of hardened engineered shoreline armoring (e.g., seawalls, groins) due to their adverse impacts on coastal ecosystems and natural sand supply and encourages the use of non-armoring responses to SLR, such as managed retreat and beach nourishment. The guidance also promotes the prioritization of nature-based adaptation strategies, such as wetland restoration and hybrid approaches that combine natural and engineered elements.

2.4.1 Early Consultation

The Advisory Committee met with Coastal Commission staff in December 2024, February 2025, and May 2025 to present the Project, analysis, and preferred concept. This plan and design concepts were shared with staff and their feedback was incorporated to the greatest extent feasible within the scope of the Plan. Additional consultation with staff will support the development of a project consistent with the Coastal Act.

2.5 Caltrans Guidance

Caltrans offers guidance on incorporating SLR considerations throughout all phases of project delivery on their website titled “Sea Level Rise and the Transportation System in the Coastal Zone” (Caltrans 2023b). Chapter 880 of the Caltrans Highway Design Manual outlines procedures, methods, devices, and materials commonly used to mitigate the damaging effects of wave action on transportation facilities and adjacent properties (Caltrans 2020). Additionally, Caltrans published a complementary resource to Chapter 880 that provides design guidance focused on nature-based adaptation strategies (Caltrans 2022c). Caltrans’s State Climate Resilience Improvement Plan for Transportation is a comprehensive plan developed in alignment with the federal requirements under the Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation program to inform immediate and long-range investments to enhance the resilience of the state's transportation system to climate change impacts (Caltrans 2023b).

3. Coastal Hazard Analysis

This section builds on prior coastal hazards analyses (the 2019 Crescent City Harbor District Sea Level Rise Assessment and the 2019 Del Norte Local Hazard Mitigation Plan) at the Project Area to understand how these hazards may evolve with SLR projections consistent with the OPC 2024 SLR Guidance. Present and future coastal hazards examined include coastal flooding (wave runup and tidal inundation) and shoreline erosion, which are the predominant hazards for Highway 101 and Anchor Way. Future coastal hazards are evaluated for the near, mid, and long term (i.e., 2050, 2070, 2100) based on prior studies, publicly available data sources, and empirical relationships.

The 2019 CCHD SLR Assessment provided asset maps, SLR flood maps, and adaptation strategies for different assets. Building on this analysis, coastal hazard information related to future projected wave overtopping and shoreline change were evaluated for a range of water levels and wave conditions along Highway 101 and Anchor Way using methods described in the EurOtop Manual (2018). Typical and extreme events are evaluated to better understand the magnitude of overtopping associated with different storm events. Three scenarios are evaluated using tidal water levels, storm surge, wave runup, and SLR. Post storm damage reports are used to correlate intensity of storms to resulting damage.

3.1 Coastal Processes

3.1.1 Waves

The closest available wave data is from the North Spit Humboldt Bay Buoy which sits offshore at 40 53.556' (N), 124 21.294' (W), approximately 8.7 miles offshore of Eureka, CA at a depth of 390 feet. The buoy measures wave energy, wave direction, and water temperature and is operated by the California Data Information Program (CDIP). Mean wave direction, spectral period (peak period), T_{m01}, and significant wave height, H_s, are recorded hourly, and the data record spans from 2/8/2010 to present. Wave and period roses are shown in Figure 3-1 and Figure 3-2. The 14 years of data presented in the two figures shows that the majority of the wave energy approaches the coast from WNW and NW directions. It is a very energetic coastline, with maximum periods of over 20 seconds and maximum wave heights of over 30 feet (Figure 3-3 and Figure 3-4). The mean wave direction shifts from 288 degrees in the summer to 310 degrees in the winter, and the distributions are rather uniformly distributed around the mean, except for summer, which is skewed slightly above the mean, illustrating the slightly more western directionality of wave conditions during that season. The mean wave heights vary throughout the year, from 5.6 feet in the summer to 9.3 feet in the winter. The tails on the right side of the distributions lengthen throughout the year, illustrating the shift to larger storm events occurring in the winter.

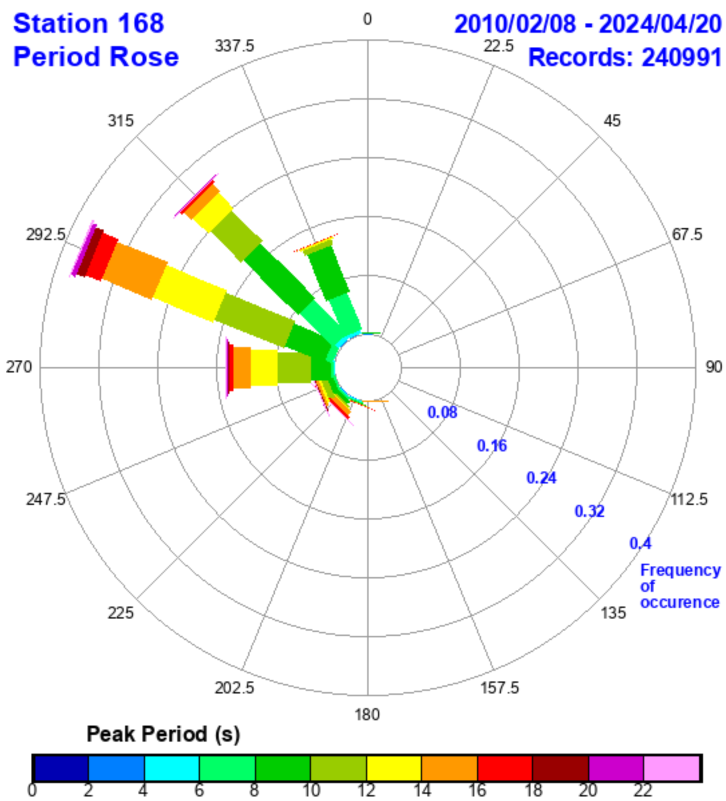


Figure 3-1. Period rose from CDIP wave buoy 168 offshore of Humboldt Bay

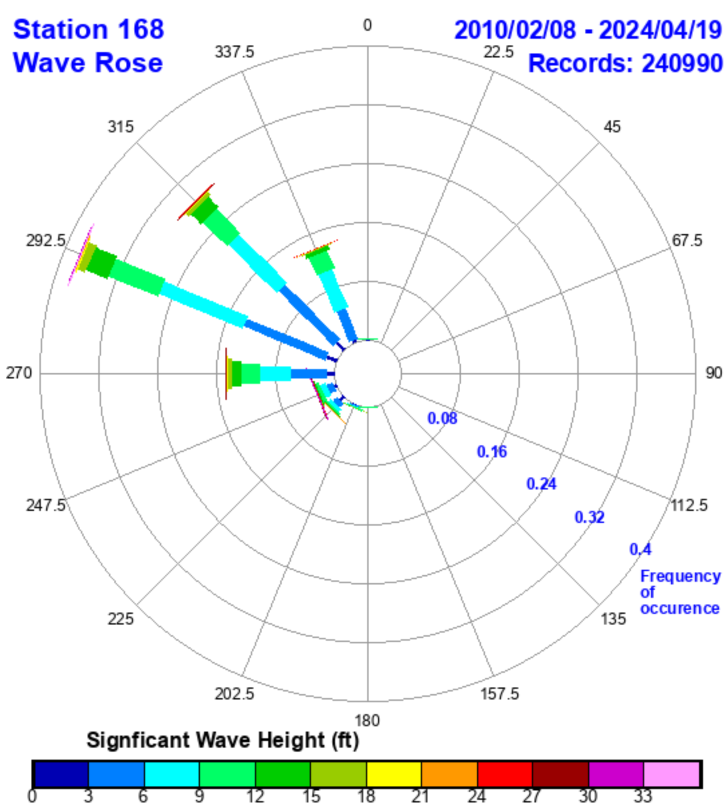


Figure 3-2. Period rose from CDIP wave buoy 168 offshore of Humboldt Bay

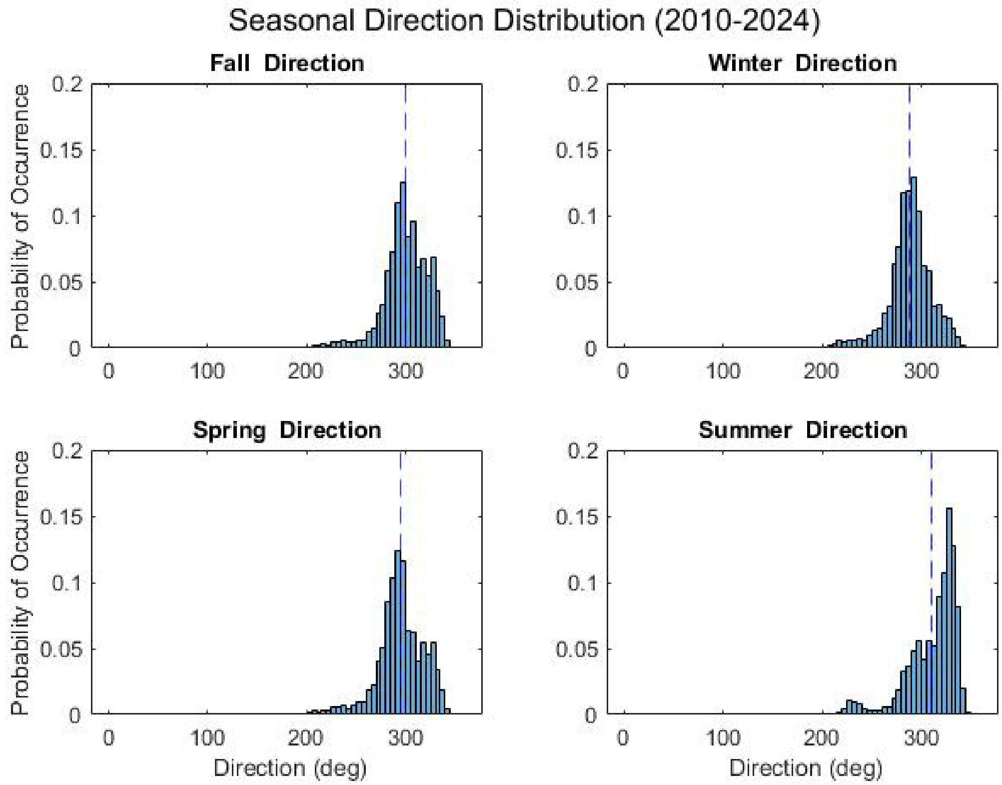


Figure 3-3. Seasonal distribution of wave direction with the mean of each dataset displayed as a blue dashed line

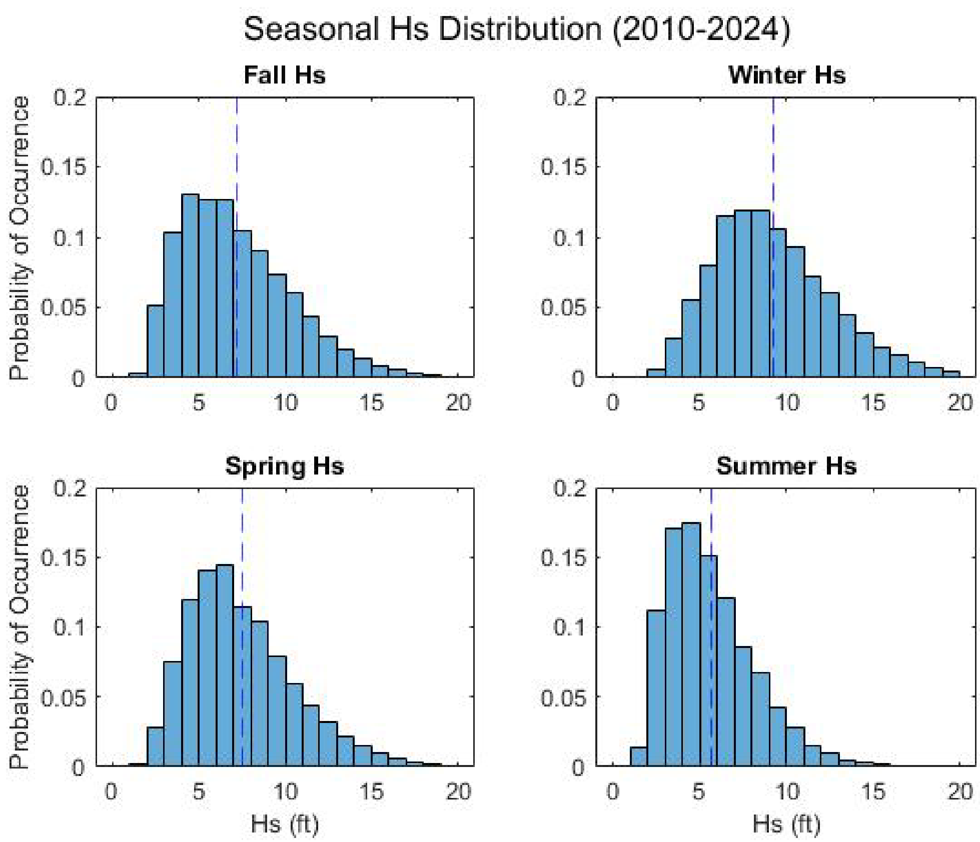


Figure 3-4. Seasonal distribution of significant wave height (Hs) with the mean of each dataset displayed as a blue dashed line

3.1.2 Water Levels and Flooding

The National Atmospheric and Oceanic Administration's (NOAA's) Crescent City tide gauge (Station ID 9419750) provides historic and real time tide data dating back to 1933 and is located in the Crescent City Harbor. The mean tidal range is 4.99 feet. The tidal datums based on the 1983-2002 epoch are shown in Table 3-1. The extreme water levels for this gauge are shown in Table 3-2.

Table 3-1. Tidal datums for Crescent City station 9419750

Datum	Elevation (ft NAVD88)
Highest Astronomical Tide	8.47
Highest Observed (1/29/1983)	10.28
Mean Higher High Water (MHHW)	6.49
Mean High Water (MHW)	5.85
Mean Tide Level (MTL)	3.36
Mean Sea Level (MSL)	3.32
NAVD88	0.00
Mean Low Water (MLW)	0.86
Mean Lower Low Water (MLLW)	-0.38
Lowest Astronomical Tide	-2.84
Lowest Observed (6/4/2008)	-3.52

Table 3-2. Extreme water levels for Crescent City station 9419750

Annual Exceedance Probability (Return Period)	Elevation (ft NAVD88)
1% (100-year)	9.99
10% (10-year)	8.69
99% (1-year)	7.79

The base flood elevation is the national standard developed by the Federal Emergency Management Agency (FEMA) and used by the National Flood Insurance Program for the purpose of regulating and informing development. The base flood elevation reflects the increase in water levels during the 1% annual chance event due to high tides, storm surge, and wave effects. The National Flood Insurance Program issues Flood Insurance Rate Maps that identify Special Flood Hazard Areas and the associated base flood elevation. The Project Area is largely within the FEMA Special Flood Hazard Areas Zone VE, which indicates areas where there is at least a 1%-annual-chance of flooding in addition to fast-moving or storm-induced waves of three feet or higher (FEMA 2020).

The base flood elevation is the combination of astronomical tides, storm surge, wave setup, and wave runup, also known as a total water level (TWL). Storm surge is the piling up of water on the coastal shelf that can occur during a large wave event, which adds to the overall water level at the shoreline. Wave setup occurs during wave shoaling and increases the water level at the shoreline. Wave runup is the maximum onshore elevation that waves reach relative to the shoreline position in the absence of waves. The base flood elevation varies throughout the Project Area due to differences in the shoreline aspect and geometry that result in a range of wave interactions. The resulting base flood elevation is +13 feet (NAVD88) inside the Harbor, +25 feet (NAVD88) at the Anchor Way Breakwater and the northern end of South Beach, and +28 feet (NAVD88) for the central and southern end of South Beach (FEMA 2020). Functionally, this means that there is a 1% chance each year that the water reaches this level for a duration of the peak of a tidal cycle, or during the peak of multiple tidal cycles for large wave events lasting multiple days. The base flood elevation is based on an extreme value analysis of the historical record of waves and tides from local wave buoys and tide gauges. This is likely to change in the coming decades due to projected climate-related changes in wave energy and frequency of storms. Future projections of extreme water levels with SLR are not reflected in FEMA's estimate.

As shown previously, Highway 101 elevations adjacent to South Beach are typically between 14 to 18 feet. The FEMA mapping extent uses the 1% annual "still water level", comprised of tide, storm surge and not the effects of wave runup. Figure 3-5 identifies base flood elevations reaching an elevation of 25 to 28 feet in the Project Area but the mapping of flooding hardly overtops the roadway which is at an elevation of 14 to18 ft NAVD88. Based on the documented event on January 5, 2023, overtopping of the roadway can occur in certain storm events. Personal communication with Caltrans maintenance workers also indicated flooding of the roadway at culvert 3 during that event, which is not shown in the flood extents in Figure 3-5.

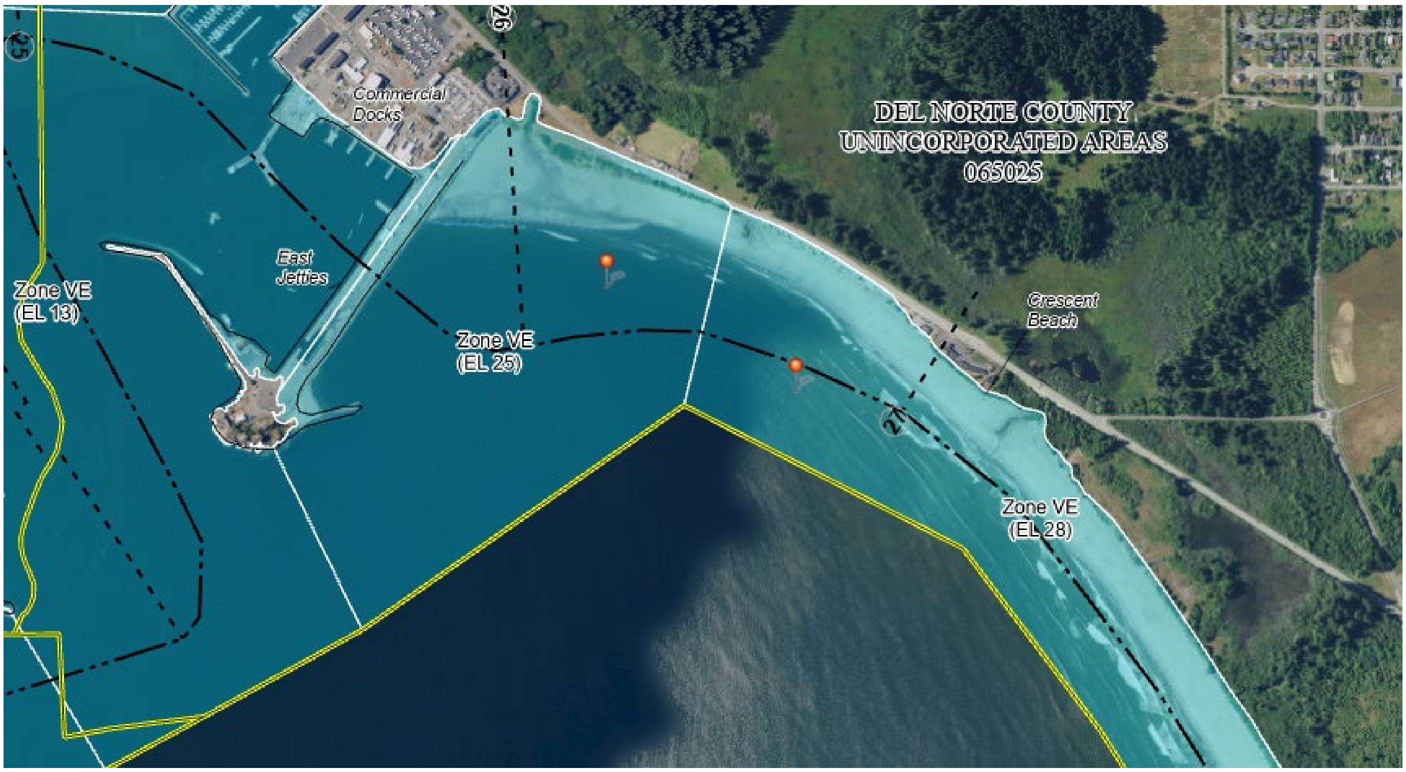


Figure 3-5. FEMA base flood elevation delineations and designations within the Project Area

3.1.2.1 January 5th, 2023 Storm Event

A recent example of wave runup and overtopping, during which both Anchor Way and Highway 101 were closed was on January 5, 2023. A Caltrans maintenance and repair crew documented scour behind the culvert headwall at culvert 2, clogging of the culverts, erosion and scarping of the vegetated shelf along Highway 101, wave overwash, and debris deposition onto Highway 101 and Anchor Way (Figure 3-6). The CCHD harbormaster reported sinkhole formation along Anchor Way due to the washout of material under the road during this event (personal communication). The Whaler Island groin was also reportedly damaged, leading to significant overwash and damage of the road behind the groin.

Wave and water level data from the CDIP Monitoring and Prediction System (MOP) and the Crescent City tide gauge from January 5th showed significant wave heights of 17 feet and a peak water level of 8.78 feet. An extreme value analysis of modelled wave heights at South Beach, detailed in the Wave Overtopping Analysis shows this event was a 2-year wave event. Overwash and debris are typical of serviceability limit criteria for a roadway along the coast, and a typical serviceability limit condition for a roadway or breakwater may be on the order of a 1- to 10-year return period. However, a higher level of serviceability may be more appropriate for this portion of Highway 101.

Figure 3-6. Scarping of the berm (left), overwash debris and ponding (right) caused by large waves and elevated water levels on January 5, 2023 (Photos courtesy of Caltrans)

3.1.3 Sea Level Rise

SLR is a primary issue of concern when considering how impacts from a changing climate could affect the Project Area. Increased flooding and increased shoreline erosion are directly correlated to increases in SLR. SLR trends are provided at NOAA's Crescent City tide gauge (Station ID 9419750) shown in Figure 3-7. The historic mean relative sea level trend is negative 0.78 millimeters/year based on monthly mean sea level data from 1936 to 2023 which is equivalent to a change of negative 0.26 feet in 100 years (NOAA 2024). This lowering of sea levels is due to the land currently rising faster than the sea level (2.83 millimeters/year) in this particular area, due to the shifting of tectonic plates (Patton et al. 2023). SLR is expected to outpace the vertical land motion.

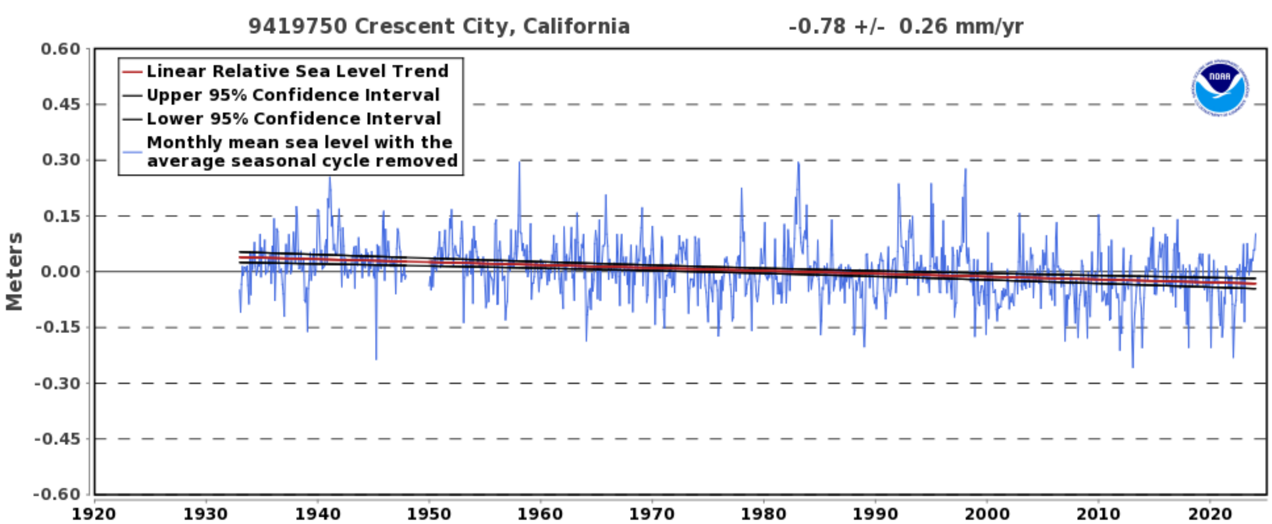


Figure 3-7. Historic mean relative sea level trend from 1936-2023 relative to the 1993 baseline (NOAA 2024)

SLR projections for the Crescent City tide gauge are provided in the State of California SLR Guidance document (OPC 2024). The projections are presented as five scenarios (Low, Intermediate-Low, Intermediate, Intermediate-High, and High) correspond to average global SLR magnitudes in the year 2100. The scenarios are based on the 'plausibility' of occurring. Plausible ranges of SLR means the credible and reasonable range of future SLR supported by published, peer-reviewed publications and the consensus assessment of the Intergovernmental Panel on Climate Change Assessment Report 6 (OPC 2024).

Figure 3-8 shows the 2024 SLR projections for the nearest tide gauge to the Project Area and Table 3-3 summarizes the 2024 projections. The 2024 scenarios, as described in the OPC's SLR Guidance, are as follows:

- **Low**: The scenario is on the lower bounding edge of plausibility given current warming and sea level trajectories, and current societal and policy momentum.
- **Intermediate-low**: A reasonable estimate of the lower bound of most likely SLR in 2100.
- **Intermediate**: Based on sea level observations and current estimates of future warming, a reasonable estimate of the upper bound of most likely SLR in 2100.
- **Intermediate-high**: Intermediate-to-high future emissions and high warming; this scenario is heavily reflective of a world where rapid ice sheet loss processes are contributing to SLR.
- **High**: High future emissions and high warming with large potential contributions from rapid ice-sheet loss processes; given the reliance on sea level contributions for processes in which there is currently low confidence in their understanding, a statement on the likelihood of reaching this scenario is not possible.

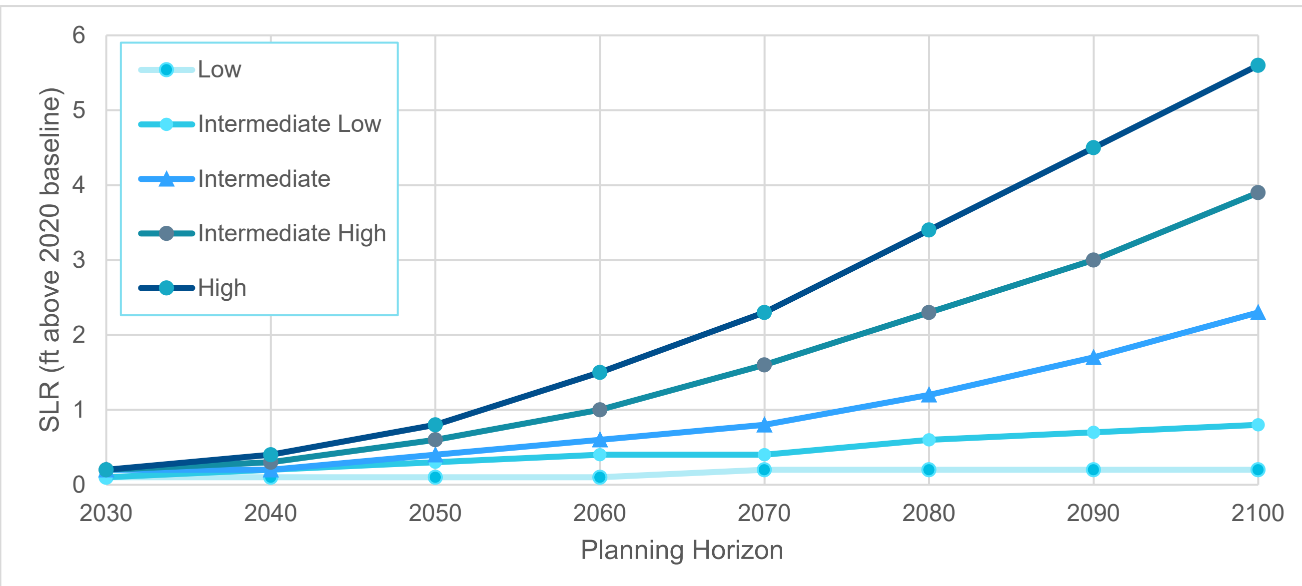


Figure 3-8. SLR projections for the Crescent City tide gauge (OPC 2024)

Table 3-3. Crescent City (Table 1) SLR values in feet from baseline 2000

Year	Low	Int-Low	Intermediate	Int-High	High
2030	0.1	0.1	0.2	0.2	0.2
2050	0.1	0.3	0.4	0.6	0.8
2070	0.2	0.4	0.8	1.6	2.3
2100	0.2	0.8	2.3	3.9	5.6

Three values of SLR, 0.8, 2.3, and 5.6 feet, will be used to analyze flooding along the Project Area. As shown in Table 3-3, 0.8 feet represents a conservative level of SLR by 2050 (High scenario), a plausible level of SLR by 2070 (Intermediate scenario), or a very plausible level of SLR by 2100 (Intermediate-Low Scenario). Next, 2.3 feet represents a conservative value of SLR in 2070, or a plausible value in 2100. Finally, 5.6 feet represents a conservative upper end of SLR by 2100. The choice of these three values covers multiple scenarios in the plausible to conservative range of estimates.

A preliminary assessment of coastal flooding exposure can be made by comparing still water level and SLR with existing roadway elevations. In Figure 3-9, three SLR projections (Intermediate, Intermediate-High, and High) are shown with the 100-year water level for 2050, 2070, and 2100. Only the High scenario in 2100 exceeds the lowest roadway elevation along Highway 101, which is +14 feet (NAVD88). This indicates that wave setup and runup are the main contributors to the current flooding and will continue to be in the future. The increase in still water level due to SLR will make flooding a more frequent occurrence, especially for mid- to end-century projections.

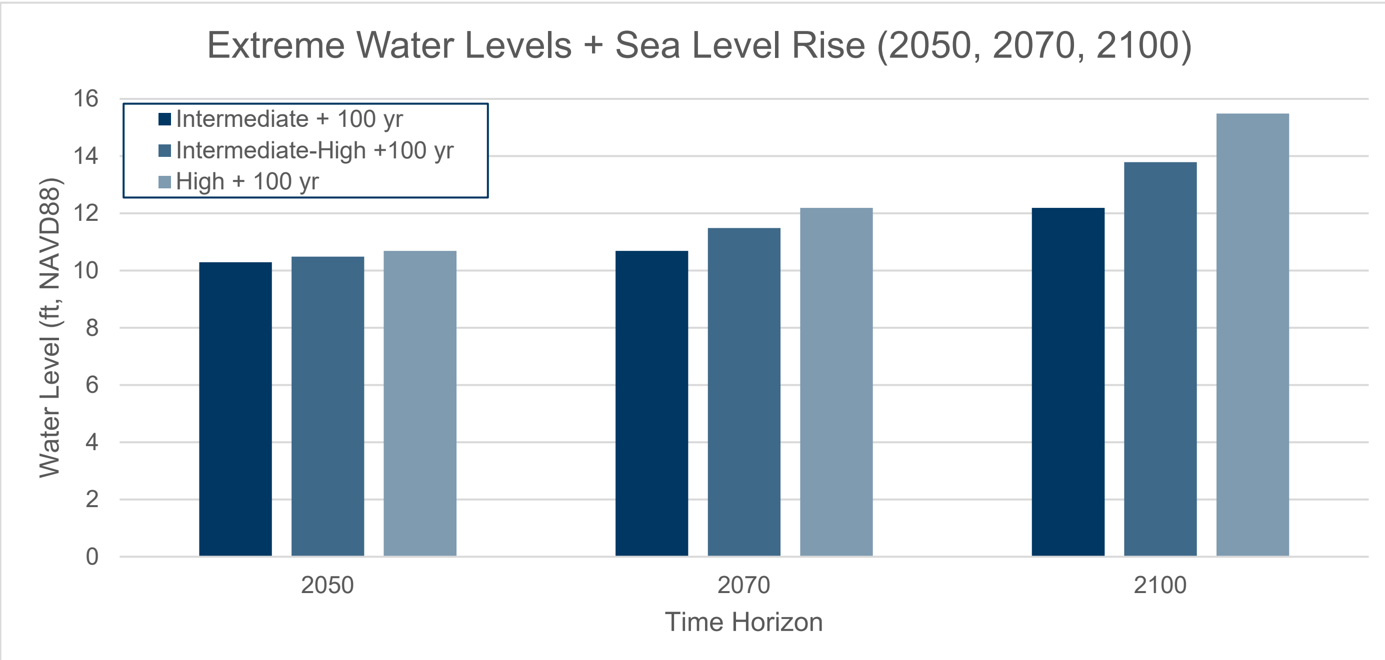


Figure 3-9. Future still water levels considering 2050 SLR projections for Crescent City

3.1.4 Wave Overtopping Analysis

Understanding the vulnerability of a frequently flooded roadway to flooding, erosion, maintenance, and closure is crucial for promoting its long-term functionality and safety. An overtopping analysis is particularly important in this context, as it helps identify the specific conditions under which waves exceed the height of coastal defenses and inundate the roadway. In the Project Area, wave overtopping is the primary mechanism of flooding, making it essential to accurately assess and predict these events. This section contains a summary of the methods and results of the overtopping analysis. For a more detailed explanation of the wave overtopping analysis methods and results, please refer to Appendix F.

Overtopping occurs when water flows over the top of coastal infrastructure structures like Anchor Way or Highway 101 due to wave action, high tides, storm surges, or SLR. Waves, especially during storms, can push water over these defenses, while high tides and storm surges elevate water levels, increasing the likelihood of overtopping. Long-term, SLR further raises baseline water levels, making it easier for waves to overtop these structures. This process can lead to flooding, erosion, and damage to infrastructure, highlighting the importance of understanding and predicting overtopping events for effective coastal management.

As part of the process of developing the base flood elevation results described in Section 3.1.3 of the Plan coastal hazard modeling was conducted by BakerAECOM in 2014 for FEMA's California Coastal Analysis and Mapping Project in Del Norte County. The modeling featured a one-dimensional transect-based analysis to develop the base flood conditions at the shoreline. Wave runup and setup were calculated to create a 50-year hindcast of total water levels, and a subsequent extreme value analysis provided the 1-, 2-, 20-, 50-percent annual chance flood elevation. While these results are useful for analyzing the present-day likelihood of flooding under extreme conditions, it does not provide a way to assess future levels of flooding under different SLR scenarios. Wave propagation in the nearshore zone is largely depth-dependent, so elevated water levels due to SLR will change how waves approach the coastline and, ultimately, the wave runup and overtopping of the coastal structures.

To assess future flooding of both Highway 101 and Anchor Way under different SLR scenarios for different time horizons, an overtopping analysis along Highway 101 and Anchor Way was completed. Four main steps were taken to get overtopping values:

1. Generate design wave conditions: An extreme value analysis was completed to get the design wave conditions offshore.
2. Profile extraction: Transects representing the varying shoreline orientation and back shore conditions along the Project Area were identified and bathymetry profiles were constructed at these locations.
3. Wave modeling: The design waves were transformed to the nearshore using the one-dimensional spectral wave model SWAN.
4. Runup and Overtopping calculations: The EurOtop manual was used to calculate overtopping for each scenario and location.

3.1.4.1 Profile Extraction

Bathymetry was extracted along four profiles within the Project Area to represent the varying shoreline orientation and backshore conditions shown in Figure 3-10. Profile 1 along Anchor Way was identified as the section of the breakwater most exposed to wave energy past the shadowing zone of the Whaler Island groin. Highway 101 at Profile 3 and Profile 4 was flooded and had debris along the road during the January 5, 2023 wave event. These locations were selected as they have been reported to be the most commonly flooded during large wave events (Caltrans, personal communication).

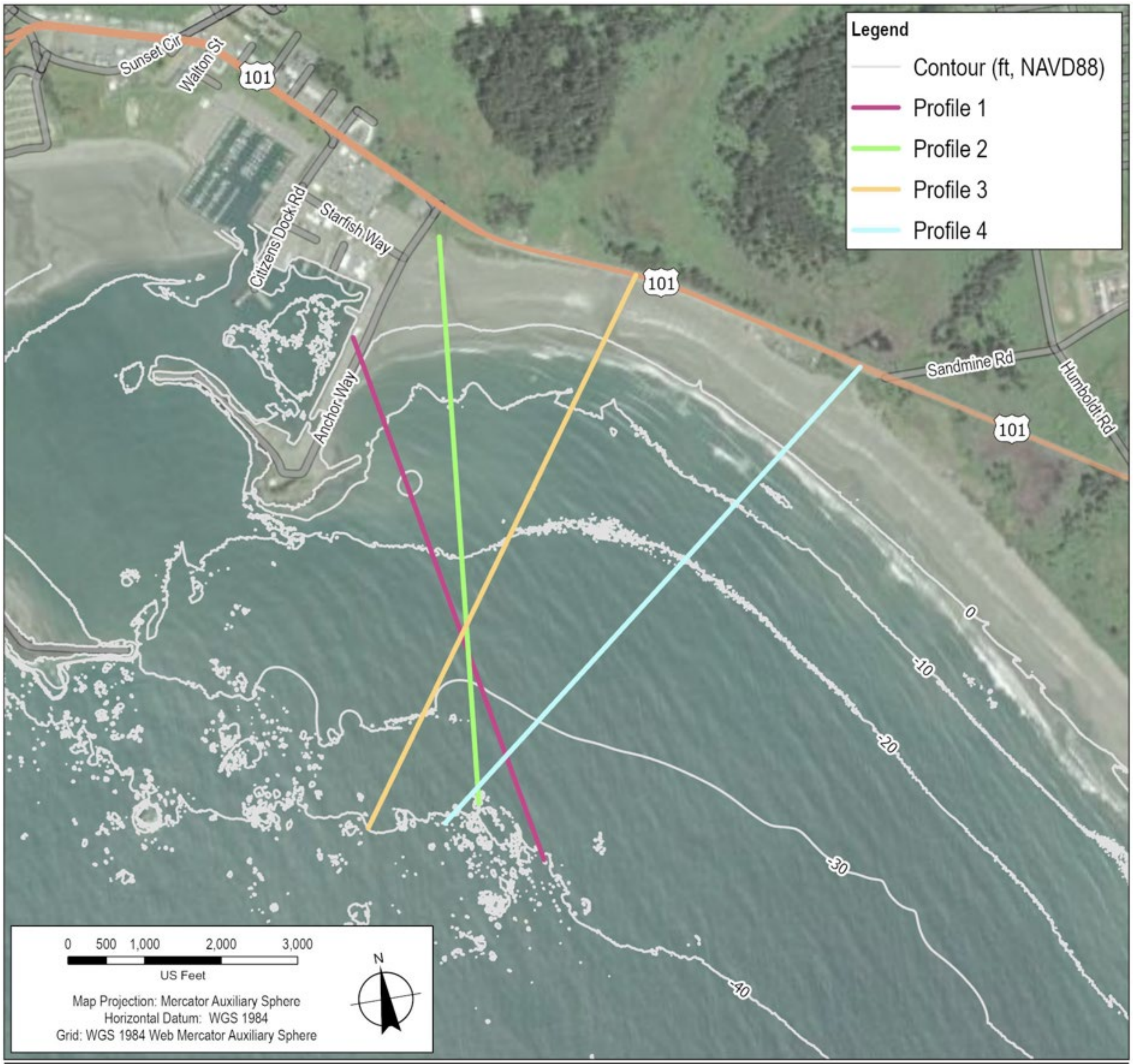


Figure 3-10. Bathymetry profile locations and extents

3.1.4.2 Runup and Overtopping Calculations

Once wave conditions at the toe of the structure were identified for each scenario and location, they were used in runup and overtopping calculations. Wave runup is the maximum elevation waves reach above still water levels, often extending far above actual backshore elevations like breakwater crests or road elevations. Overtopping occurs when wave runup exceeds these backshore features, leading to coastal flooding. The process depends on factors like slope and roughness of the vegetated shelf or breakwater. Overtopping is measured as the average discharge per linear meter of width and is highly variable. The overtopping rate for each scenario was determined using the EurOtop Manual, which provides guidelines for predicting wave overtopping and assessing its impact on vehicular safety and structural integrity. The Coastal Engineering Manual (CEM) offers critical permissible overtopping values for road safety (Table 3-4), with exceedance indicating potential damage or danger to driving safety.

Table 3-4. Overtopping rate threshold guidance from EurOtop and CEM

Overtopping Rate Thresholds (liters/second/meter [l/s/m])			
EurOtop – Close before debris in spray becomes dangerous on highways and roads	EurOtop – Erosion of unprotected crest or landward slopes	EurOtop and CEM – Unsafe to drive at any speed	CEM – Damage to road
<1	1	10-20	>200

The results of the overtopping analysis are shown in Table 3-5. The present-day mean overtopping rate for a 100-year event is approximately 1 liter/second/meter, which, according to CEM and EurOtop guidelines, would cause erosion of the parking area and the backside of the road prism on the eastern side of Highway 101, posing a danger to vehicles. Erosion of the adjacent parking area could undermine the road's stability. The January 5, 2023, storm highlighted substantial debris accumulation, which would be expected in larger events. By 2050, increased overtopping discharges would lead to greater flood depths and debris on the roadway, potentially eroding the unprotected backside of the roadway embankment. By 2070, overtopping discharges could increase tenfold compared to 2050, causing prolonged closure of Anchor Way and Highway 101 for cleanup and repairs. In 2100, overtopping rates would significantly exceed CEM and EurOtop thresholds, necessitating major adaptations to maintain transportation infrastructure. Additionally, wave erosion of the vegetated shelf along Highway 101 during storms would increase overtopping risks by reducing the berm's height and steepening the slope, potentially undermining the roadway.

Table 3-5. Mean overtopping discharges for each scenario at each location

Mean Overtopping Discharge, q (l/s/m)				
Location	**Existing: 100 yr storm**	**2050: 100 yr storm+ 0.8 ft SLR**	**2070: 100 yr storm + 2.3 ft SLR**	**2100: 100 yr storm + 5.6 ft SLR**
Profile 1	80	103	242	904
Profile 2	1	3	22	428
Profile 3	1	2	21	438
Profile 4	1	3	30	569

3.1.4.3 Results Comparison with Recent Event

Comparing the results of the analysis with recent storm events in the Project Area can help frame the results and resolve some of the uncertainty of different processes that were not included in the analysis, such as erosion of the existing road prism and debris deposition. A recent documented example of wave runup and overtopping at the Project Area occurred January 5, 2023. The storm had significant wave heights of 17 feet, which, according to the analysis presented in Section 3.1.1, corresponds to a 3-year return period; water levels peaked near 9 feet, which corresponds to a 10-year return period (Table 3-2). Waves overtopped the vegetated shelf near Profile 3, Profile 4, and Anchor Way.

Figures 3-11 and 3-12 show the overtopping of Highway 101 during the January 5th storm event. Debris deposited on the roadway and water flowed across the roadway and down the grass embankment on the landward side of the road. While it does not appear that the flow caused erosion on the landward side of the road, debris was carried onto the embankment and no signs of erosion were observed in the photos. The vegetated shelf on the seaward side of Highway 101 exhibited multiple feet of erosion, as indicated by the exposed roots (Figure 3-13), causing a vertical scarp to form. The formation of a scarp changes the dynamics of runup and overtopping, increasing the forces with the abrupt elevation change, which can further accelerate erosion. Erosion occurred around the headwall of the culvert at PM 24.92 (Profile 3 in the overtopping analysis), as shown in Figure 3-14. Debris was also forced in the culvert entrance which can prevent water from draining the Marsh Wildlife Area.

Figure 3-11. Overtopping of Highway 101 during the January 5, 2023 storm near PM 24.92 looking west (Photo courtesy of Keven Pratt)

Figure 3-12. Overtopping of Highway 101 during the January 5, 2023 storm near PM 24.92 looking north (Photo courtesy of Keven Pratt)

Figure 3-13. Erosion of the berm during the January 5, 2023 storm near PM 24.92 (Photo courtesy of Keven Pratt)

Figure 3-14. Debris stuck in the culvert entrance and scour around the headwall during the January 5, 2023 storm near PM 24.92 (Photo courtesy of Keven Pratt)

3.1.5 Shoreline Change

3.1.5.1 Historical Shoreline Change

Historical shoreline change provides valuable insight into the coastal system at South Beach. Seasonal variation and historic erosional or depositional patterns are important to understand when considering how SLR will affect these processes. CoastSat is an open-source software toolkit developed by the University of New South Wales and the United States Geological Survey (USGS) that enables users to obtain time-series of shoreline position at any sandy coastline worldwide for the past 40 years (Vos et al. 2019). The datasets are derived from publicly available satellite imagery and are shown in Figure 3-15. The data shows zero change or a slightly positive linear trend, with an average of 0.1 m/year. This stable or accretionary trend may be influenced by relative SLR (RSLR) in this area has been negative, with the land rising faster than the sea level, as discussed in Section 3.1.2. South Beach is also slightly shadowed from the prevailing wave direction by the headland system to the north.

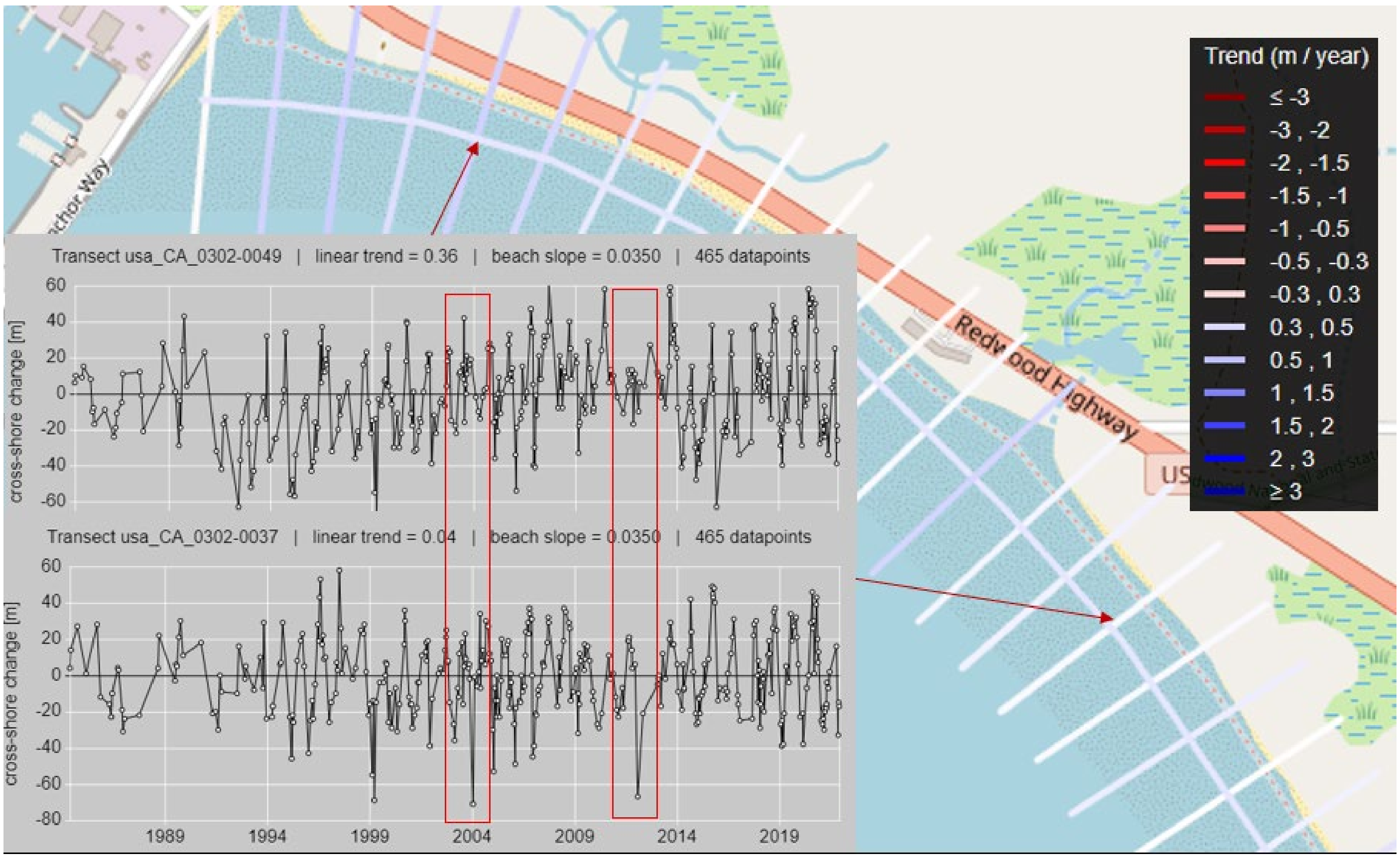


Figure 3-15. CoastSat transects along South Beach are color-coded with their rate of change (m/year). Data from two transects is shown in the popout graphs that show cross-shore change since 1980

The pop out graphs in Figure 3-15 show a large seasonal variability of around 100 meters (328 feet), with the maximum beach in the summer and minima occurring in the winter. The eroded state of the beach leaves the back beach more vulnerable to flooding as waves experience less energy dissipation due to shoaling as they approach the shoreline, illustrated in Figure 3-16. The sediment in the surf zone, swash zone, and upper shoreface from approximately -10 to 10 feet NAVD88 is likely eroded and deposited offshore on the lower part of the profile in the winter, shown in Figure 3-13. The plots also show alongshore variation. The red rectangles highlight two instances in 2004 and 2012 where the southern transect had a much more eroded beach that the northern end of the beach.

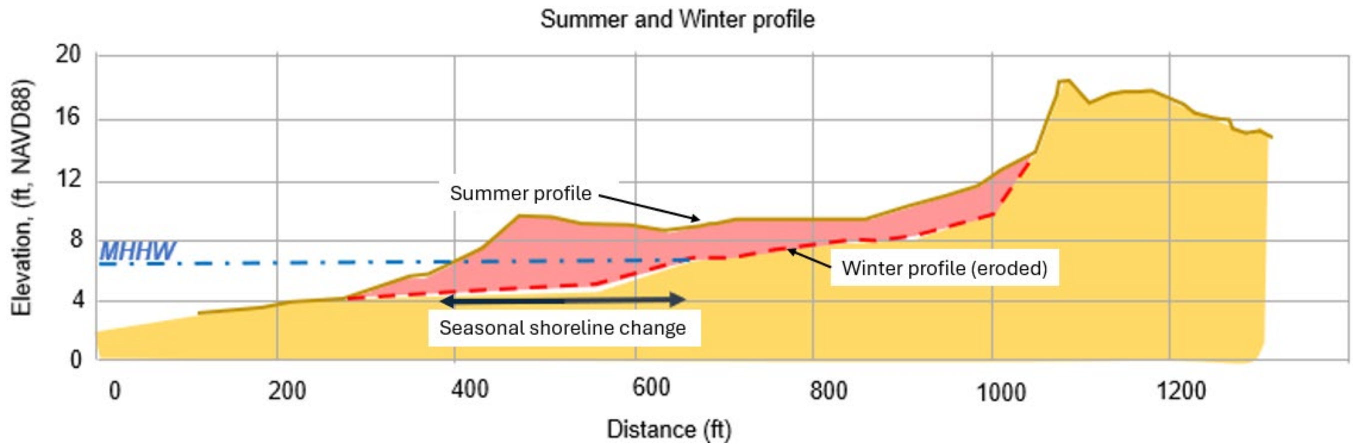


Figure 3-16. Conceptual summer and winter beach profile at South Beach

3.1.5.2 Future Shoreline Change

The USGS conducts scientific research and provides data on natural resources, natural hazards, and the landscape of the United States to support informed decision-making and public safety, developed the Coastal Storm Modeling System (CoSMoS). CoSMoS makes projections of mean sea-level shoreline change resulting from a SLR range of 25 to 500 centimeters (0.8 feet to 16.4 feet), using a one-line model, in increments of 25 to 50 centimeters. A one-line shoreline model is a mathematical model used to simulate the evolution of shoreline positions over time. Shown below in Figure 3-17 and Figure 3-18 are the CoSMoS projections for 0.8, 2.3, and 5.6 feet, which correspond to the High SLR projections in 2050, 2070, and 2100, respectively. The CoSMoS data applies to sandy beaches and only extends to the northern extent of South Beach and therefore does not take into account change along the Anchor Way Breakwater.

The figures show a retreating shoreline as SLR increases. These results are useful for understanding the influence of SLR on shoreline position for each projection. In other words, under a 5.6-foot SLR projection, we would expect the shoreline to be approximately 400 feet landward of the 0.8-foot SLR scenario. We would caution use of the real-world shoreline positions depicted by this data. As evidenced by the underlying aerial image, present day seasonal shoreline change can result in erosion farther landward than depicted in the 5.6-foot SLR scenario in Figure 3-17 and Figure 3-18. Based on our understanding of coastal processes in this area, the shoreline positions for each SLR scenario would extend further landward than depicted by the CoSMoS shorelines. For each increment of SLR and corresponding shoreline retreat, it is likely that high tide flooding would become more frequent, even without storm surge or large waves.

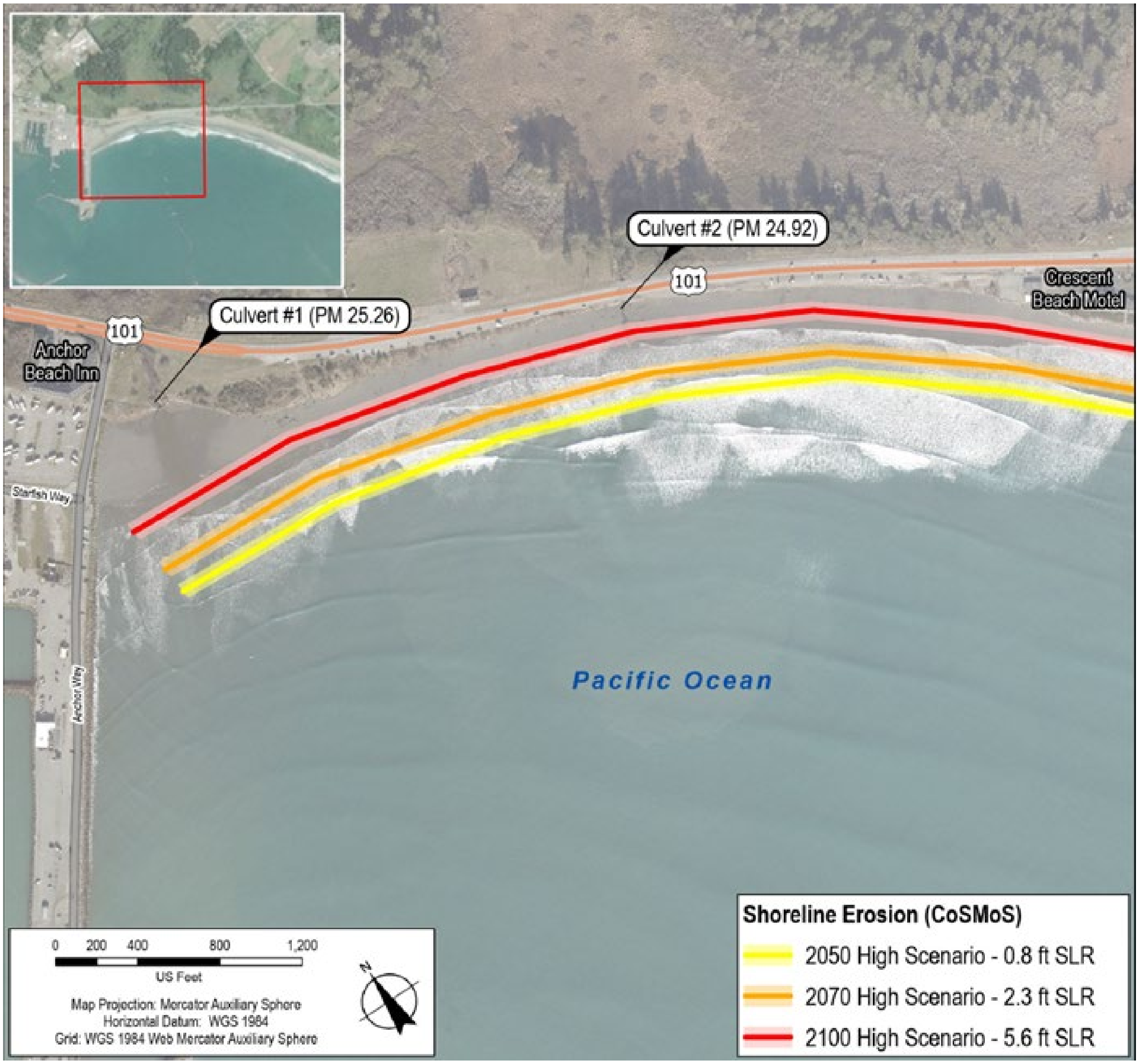


Figure 3-17. CoSMoS future shoreline positions under the High SLR scenario for 2050, 2070, and 2100 at northern South Beach

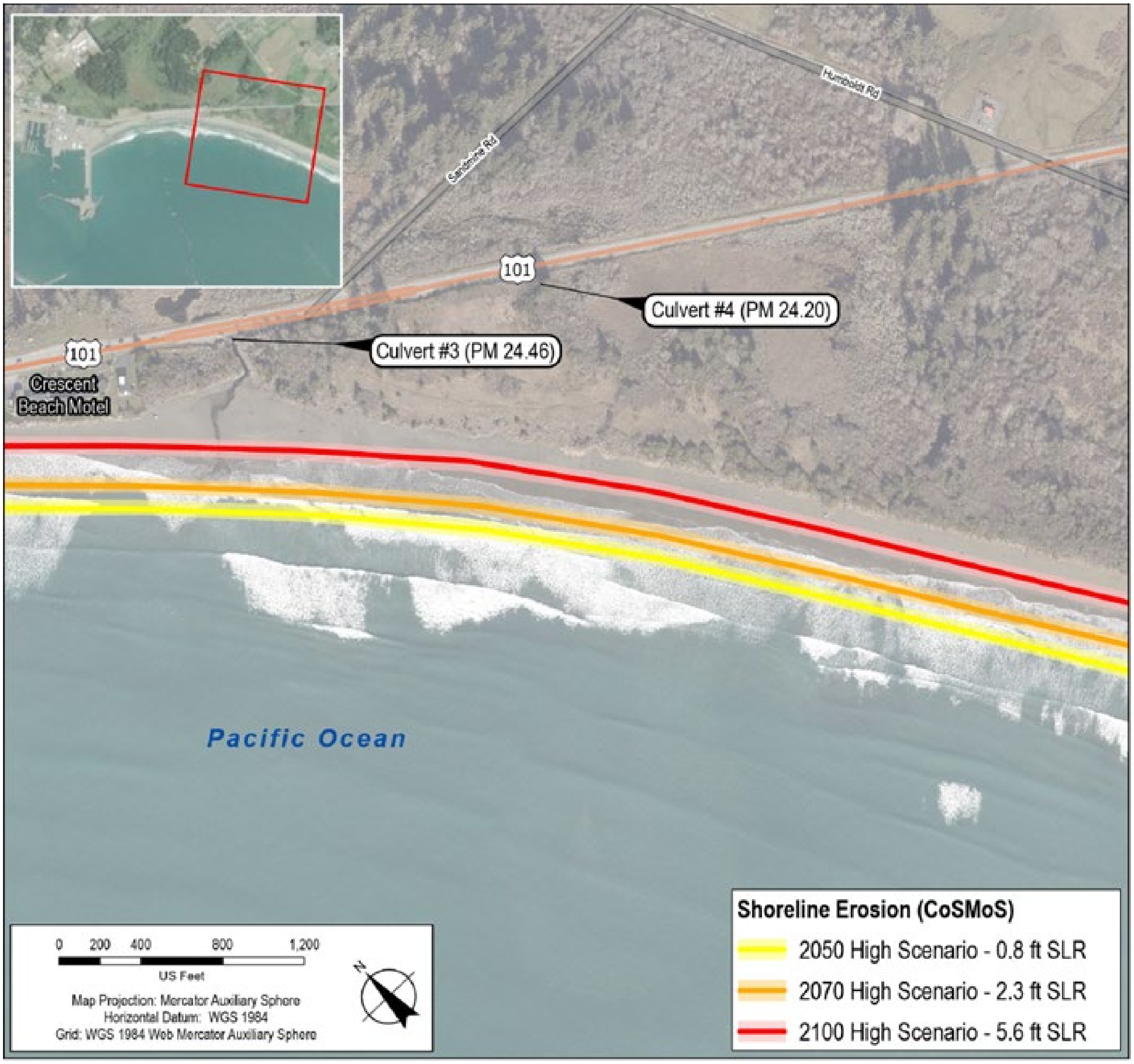


Figure 3-18. CoSMoS future shoreline positions under the High SLR scenario for 2050, 2070, and 2100 at southern South Beach

3.1.6 Tsunamis

The Project Area is vulnerable to tsunamis, which are produced by earthquakes, landslides, and submarine volcanic explosions. The entire Project Area is within the California Tsunami Hazard Area, located within the maximum considered tsunami runup associated with a 975-year return period seismic event. Highway 101 is an important evacuation route. Not only do tsunamis themselves have incredible destructive potential, but secondary impacts can also be destructive and dangerous. Secondary impacts can include floating debris, clogging of sewer systems, and failed power generation systems due to flooding. In the past 80 years, 39 tsunamis have been detected in Del Norte County (PND 2019). With increased water levels due to SLR, the potential for tsunami waves to propagate over land will increase.

3.2 Precipitation Data

The frequency, duration, and intensity of precipitation is expected to change as the climate changes, which can affect the dynamic between the Marsh Wildlife Area and the ocean. As seas are rising, the ability for the low-lying inland area to drain becomes diminished, and backed up culverts can potentially lead to flooding from the inland side of Highway 101. Combined rainfall and large wave events can become even more damaging as this occurs. Damage to the western lily habitat in the Marsh Wildlife Area can also occur if the plants are inundated by freshwater that cannot properly drain through debris clogged culverts (Caltrans 2003).

The change of the character of precipitation events will result in a change of extreme events, as the data record changes to include the more intense storms. Existing infrastructure is typically designed to be functional during an extreme event, denoted by its return period, or annual chance of occurrence. For example, a 100-year return period has a 1% chance of occurring in any given year. Return periods are statistically derived from the data record, and as the data record changes to include more intense rainfall events, future values of duration and intensity for different return periods will increase. These changes have been modelled based on different emissions scenarios and are summarized for California in the Cal-Adapt Application Programming Interface. The total annual precipitation for Crescent City is not projected to change significantly for the medium or high emissions scenarios through the end of the century, and neither is the timing of extreme events, which occur mainly in December and January. The frequency of events per year increases from an average of 6 to 8 for the mid- and end-century horizons under the Medium Emissions scenario. The return periods of intensity for a duration of one day under the Medium Emissions scenario are summarized in Table 3-6. The values show that the intensity peaks mid-century and decreases to values that are still larger than the existing conditions.

Table 3-6. Estimated intensity of extreme precipitation events with a duration of 1 day for different return periods using the "average" global climate model in the RCP 4.5 scenario

Return period (years)	Existing (in)	Mid-Century: 2035-2064 (in)	End-Century: 2070-2099 (in)
20	4.5	5.5	4.9
50	5.1	6.5	5.7
100	5.4	7.3	6.2

4. Vulnerability Assessment

A vulnerability analysis helps identify the extent of asset exposure and their sensitivity to flooding. This analysis aims to answer several key questions:

- **Which assets are exposed to flooding?** Identifying the specific assets within the projected flood extents.
- **What is the sensitivity of these assets to flooding?** Evaluating how different types of assets (e.g., roads, buildings, utilities) respond to flood exposure.
- **What are the potential impacts of flooding on these assets?** Assessing the severity of the impacts based on the asset's function and importance to the community.
- **How can adaptation strategies be tailored to mitigate these impacts?** Developing site-specific adaptation plans to enhance resilience and reduce vulnerability.

Flooding along Highway 101 and Anchor Way can have significant impacts on the community. For instance, a detour due to flooding along Highway 101 can disrupt daily commutes and pose safety hazards to the communities that the detour goes through. Understanding the vulnerability of the Project Area to flooding is crucial for developing effective adaptation strategies and promoting community resilience against future flood events.

Using the results of the coastal hazards analysis, approximate flood extents along Highway 101 and Anchor Way were developed to evaluate the vulnerability of various assets. This was accomplished by using the approximate flood extent from the recently documented storm event on January 5, 2023 as a baseline and creating buffers relative to each SLR scenario's mean overtopping rate. The extent of these buffers was initially estimated based on simulations of wave overtopping provided by EurOtop. The buffers were then manually adjusted based on existing structures and topographic features. This provided a representative exhibit of the approximate flood extents expected.

Project Area assets within these projected flood extents for each time horizon were identified and potential impacts evaluated. While an asset may be exposed to flooding, this does not necessarily indicate an impact, which is based on the type of asset and its sensitivity to flooding. The assets exposed to projected flooding and their sensitivity to flooding are evaluated in the following sections based on their respective sub-area, either Highway 101 or Anchor Way. This format is intended to support adaptation planning as it is anticipated that the adaptation strategies for each sub-area will need to be approached based on the site-specific characteristics of flooding.

4.1 Highway 101

Flooding of Highway 101 has been reported to be a common occurrence during the winter season as high tides and large waves overtop the roadway (Caltrans 2003, Shaaf and Wheeler 2015, TetraTech 2019). This has caused road closures that have lasted 12 to 14 hours (Caltrans 2003). The projected flood extents indicate that following 2050, the east side of the road could become exposed to flooding as any overtopping waves would deposit into this low-lying area (Figure 4-1). The assets identified within this projected flood zone are described in Table 4-1 and further evaluated to characterize impacts.

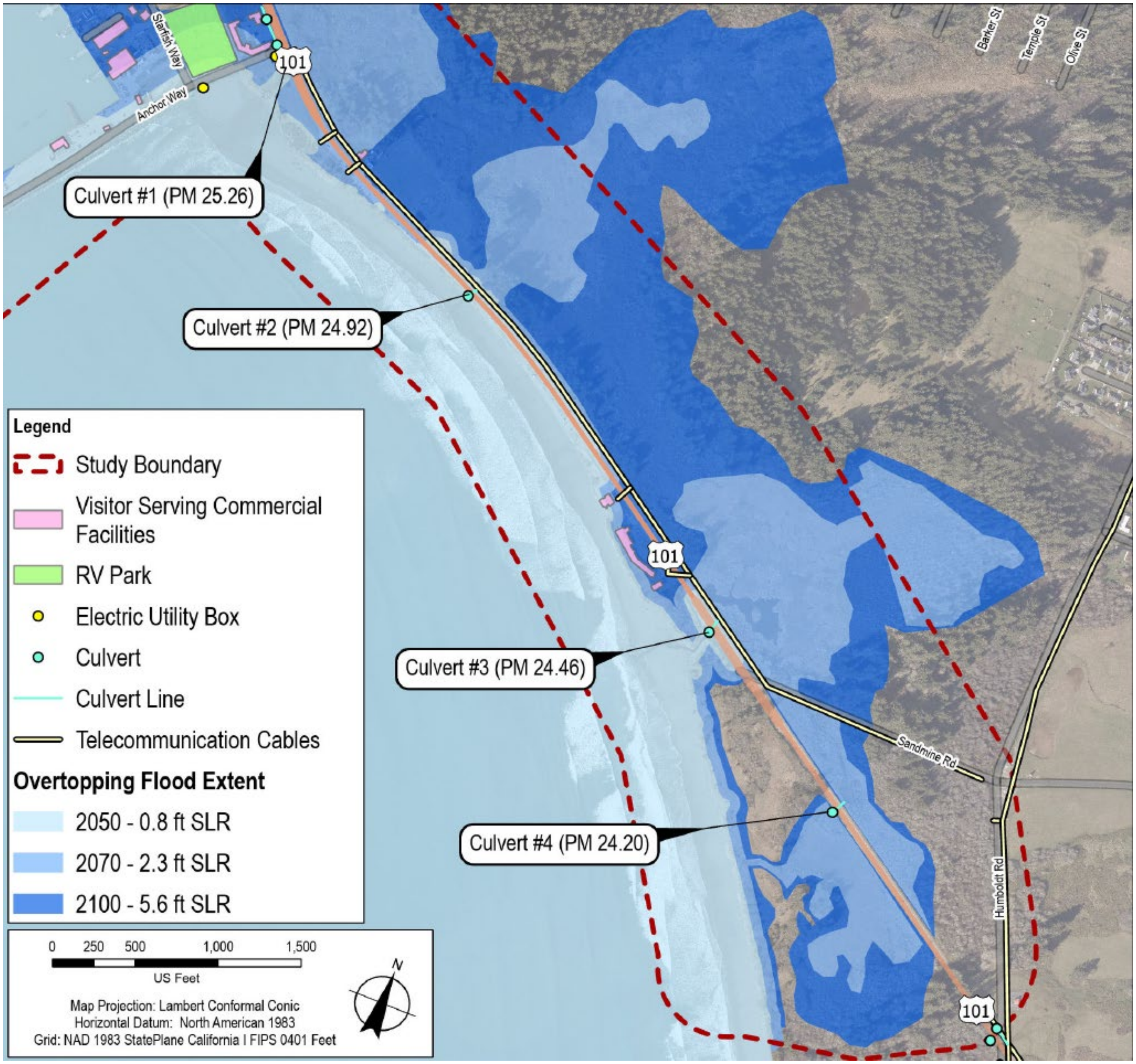


Figure 4-1. Approximate flood extents for 100-yr wave events under the High SLR scenario for three time horizons and existing assets along Highway 101

Table 4-1. Highway 101 sub-area asset list and associated exposure

Asset Type	2050	2070	2100
Visitor Serving Commercial Facilities (three total)	• N/A	• Crescent Beach Motel • HAMBRO structures • Elk Valley Rancheria property	• Crescent Beach Motel • HAMBRO structures • Elk Valley Rancheria property
Transportation including roads and parking areas	• Central section of Highway 101 • Near intersection of Highway 101 and Sandmine Road • Bus Route 4 and Route 20	• North half of Highway 101 to Crescent Beach Motel revetment • Near intersection of Highway 101 and Sandmine Road • Section of Highway 101 between Sandmine Road and Humboldt Road • Bus Route 4 and Route 20	• Almost entire length of Highway 101 within Project Area • West end of Sandmine Road • Bus Route 4 and Route 20
Detour route	• Entire length of detour route	• Entire length of detour route	• Entire length of detour route
Culverts (four total)	• PM 25.26 • PM 24.92 • PM 24.46	• PM 25.26 • PM 24.92 • PM 24.46 • PM 24.20	• PM 25.26 • PM 24.92 • PM 24.46 • PM 24.20
Telecommunication Utilities	• Utilities along central section of Highway 101	• Utilities along north half of Highway 101 to Crescent Beach Motel revetment • Utilities near intersection of Highway 101 and Sandmine Road • Utilities along section of Sandmine Road	• All utilities along Highway 101 • Utilities along section of Sandmine Road
South Beach access and recreational trails	• All features besides access points within vegetated bluff zone on north end of South Beach and backing Crescent Beach Motel revetment	• All features	• All features
Crescent City Marsh Wildlife Area	• Limited intrusion into wetlands directly adjacent to Highway 101	• Modest intrusion into wetlands along existing low-lying channels	• Heavy intrusion into wetlands along low-lying extent

Under the 2050 time horizon, flooding is generally limited westward of Highway 101 due to the vegetated shelf fronting it alongside the Crescent Beach Motel. The only anticipated breaches of this limit were along the central section of the sub-area where the vegetated shelf edge was closest to the road and directly south of the Crescent Beach Motel. This would indicate that along these sections of Highway 101 a moderate amount of overtopping could be expected, bringing debris onto the road along with limited flooding. This may cause road closures, diverting traffic, including the public transit bus Routes 4 and 20, to the designated detour route. Since the overhead telecommunication cables follow these roadways, the base of the telephone poles supporting them in these exposed sections would also be expected to experience this flooding. The base of the poles would experience periodic flows of water running by them, which is unlikely to undermine the poles or damage them, as they are designed to withstand much higher loads (i.e. impacts from cars). Behind these same sections of the roadway, the Marsh Wildlife Area would anticipate relatively limited tidal inflow to the wetlands from this overtopping. The culverts underlying these exposed sections of the road, PM 25.26, PM 24.92, and PM 24.46, that allow for drainage from the marsh to South Beach are also susceptible to these flood impacts. With SLR, debris accumulation within the culverts may be more frequent.

The projected flooding in this scenario is limited to the beach area due to the elevation change in the narrow area between Highway 101 and the beach along the vegetated shelf. It is anticipated the shoreline (as defined by the mean sea level elevation contour) will erode in conjunction with SLR, moving further inland over time. This would reduce the extent and duration of dry beach area available on South Beach and may exacerbate storm impacts to the infrastructure backing it because waves have a shorter distance to travel up the beach before hitting the vegetated shelf. More frequent use of the detour route during flooding continues the environmental justice concerns for a disadvantaged community as well as the increased traffic, longer travel distances, and pedestrian safety risks.

Under the 2070 time horizon, the projected flood extent would encompass the entire length of Highway 101 along South Beach, besides the section fronted by the Crescent Beach Motel's revetment. Flooding would also reach the southern end of this roadway between Sandmine Road and Humboldt Road due to the propagation across low elevation areas. However, while anticipated to bring debris over the roadway near South Beach, this southern area would likely only be exposed to shallow flooding. This may cause road closures, diverting traffic, including the public transit bus Routes 4 and 20, to the designated detour route. This flood exposure would similarly apply to the telecommunications cables along Highway 101 and Sandmine Road. Although, the increased overtopping rate along South Beach is unlikely to damage the base of the telephone poles. The anticipated deeper flooding and highwater velocities from a storm event would also expose culvert PM 24.20, located south of Sandmine Road as the low-lying areas becomes flooded. Existing low-lying channels within the Marsh Wildlife Area are expected to be exposed to this flooding, resulting in higher water levels and longer inundation periods.

Due to the higher water levels and waves, the vegetated shelf and revetment provide limited attenuation of wave energy and overtopping rates increase. Access to the beach would be limited under this scenario, as trails to the beach would be exposed to flooding, and the parking areas along Highway 101 would be exposed to flooding and debris deposition. Also, further erosion of the beach and the vegetated shelf would reduce their inherent ability to reduce wave energy. Waves experience less shoaling due to the deeper eroded profile of the beach, and the vegetated shelf becomes steeper which increases runup and overtopping rates. This loss of effectiveness by the existing protective features would result in the exposure of structures on private property along Highway 101 (including Crescent Beach Motel and HAMBRO) and Elk Valley Rancheria property to flooding. This would increase the likelihood of damage to these facilities as they become directly exposed to this flooding and any debris accompanying it. The detour route would be used more frequently, worsening the environmental justice concerns for a disadvantaged community as well as the increased traffic, longer travel distances, and pedestrian safety risks.

Under the 2100 time horizon, all the described flood impacts would be exacerbated by higher overtopping rates in the sub-area. The entire length of Highway 101 located north of Sandmine Road would be directly exposed to this flooding, leaving it vulnerable to damage. This may cause road closures, diverting traffic, including the public transit bus Routes 4 and 20, to the designated detour route. Following this, the telephone poles backing this road would be expected to be placed under a much higher hydrodynamic and debris load, leaving them more susceptible to damage and/or collapse. This same load could be expected to cause erosion around the edges and along the culverts at PM 25.26, PM 24.92, and PM 24.46 that eventually wash out the road. Anticipating the impacts to the culverts and roads, the Marsh Wildlife Area would be expected to be impacted as large amounts of sea water would flood the freshwater habitat and exceed its storage capacity. This would result in flooding that would persist for an extended period of time within the Marsh Wildlife Area, which could impact freshwater species and disrupt specific hydrologic needs, such as that of the western lily population.

South Beach itself would be expected to be completely flooded during a storm event. This high level of flood exposure combined with an eroded shoreline, alongside the large overtopping rates, would indicate that private properties along Highway 101 and Elk Valley Rancheria property would be impacted due to the large volume of incoming water. The detour route would be used more frequently than the 2050 and 2070 time horizons, worsening the environmental justice concerns for a disadvantaged community as well as the increased traffic, longer travel distances, and pedestrian safety risks.

4.2 Anchor Way

The structure of Anchor Way as a breakwater inherently places it in a position where it is constantly exposed to wave attack. Also, its relatively low elevation makes it susceptible to overtopping and flooding. While the Whaler Island groin has limited these impacts toward the southern end of Anchor Way, its northern side is fully exposed. Under the SLR scenarios investigated, it is anticipated that the overtopping and flooding will be exacerbated, resulting in flood extents reaching across the Anchor Way Breakwater and reaching as far as Citizens Dock Road (Figure 4-2). The assets identified within this projected flood zone are described in Table 4-2 and evaluated further.

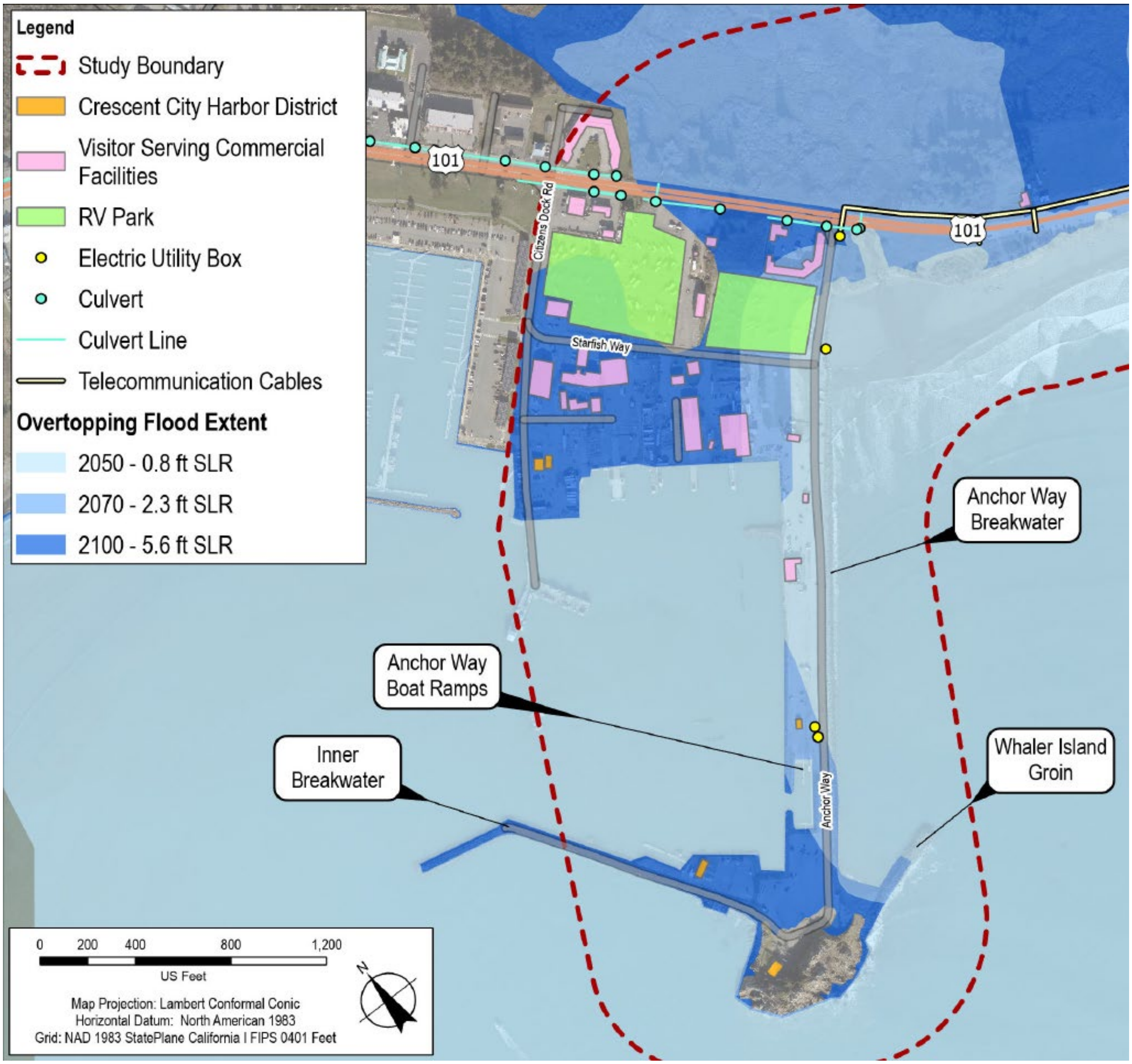


Figure 4-2. Approximate flood extents for 100-yr wave events under the High SLR scenario for three time horizons and existing assets along Anchor Way

Table 4-2. Anchor Way sub-area asset list and their associated exposure

Asset Type	2050	2070	2100
Crescent City Harbor District Buildings (five total)	• NA	• Restroom	• Restroom • CCHD Buildings
Visitor Serving Commercial Facilities (24 total)	• All facilities located directly on breakwater	• All facilities located directly on breakwater • Anchor Beach Inn • Safe Coast Seafoods	• All facilities besides those located in the north corner of the Harbor within the Project Area
RV Park (two total)	• East RV Park	• East RV Park	• East RV Park • West RV Park
Transportation (Roads and Parking Areas)	• Central section of Anchor Way • East end of Starfish Way	• Almost entire length of Anchor Way • East section of Starfish Way	• Entire length of Anchor Way • Entire length of Starfish Way • Southern half of Citizens Dock Road • East section of Highway 101 • Informal roads along docks
Electric Utilities (three total)	• Utility box at intersection of Anchor Way and Starfish Way	• Utility box at intersection of Anchor Way and Starfish Way • Utility boxes near restrooms on Anchor Way	• Utility box at intersection of Anchor Way and Starfish Way • Utility boxes near restrooms on Anchor Way
Culverts	• NA	• NA	• Culverts along east section of Highway 101
Anchor Way Protective Structures	• North half of Anchor Way Breakwater	• Almost entire Anchor Way Breakwater besides near Whaler Island • Whaler Island groin	• Entire length of Anchor Way Breakwater • Whaler Island groin • Inner Breakwater
Boat Ramps	• Crescent City Harbor Launching Facility	• Crescent City Harbor Launching Facility	• Crescent City Harbor Launching Facility

Under the 2050 time horizon, only a limited area of the Anchor Way sub-area is expected to be exposed to flooding. The Anchor Way Breakwater is expected to limit most of the overtopping with the Whaler Island groin providing a wave shadow zone that assists in decreasing the extent of the overtopping and flooding. This would result in the exposure of most of Anchor Way and the east end of Starfish Way to flooding at overtopping rates (10-20 liters/second/meter) that would be considered unsafe to drive on based on the overtopping limits described in the CEM and EurOtop Manual. This would directly impact Anchor Way's ability to act as its designated tsunami evacuation route as well as impede access for emergency services that utilize the boat ramp All the CCHD buildings and visitor serving commercial facilities located on the breakwater are also exposed to this flooding, likely rendering them inaccessible and susceptible to damage. Part of the East RV Park would also be exposed; however, this is expected to have a relatively low impact due to its location at the edge of the projected flood extent. Southwest of this RV park at the intersection of Anchor Way and Starfish Way, an electric utility box would be directly exposed to the oncoming waves, making it vulnerable to potential damage.

Under the 2070 time horizon, almost the entire length of Anchor Way is anticipated to be exposed to flooding as the effectiveness of the Whaler Island groin is reduced. This loss of the wave shadow zone on the south end of Anchor Way results in the exposure of the Anchor Way Boat Ramp, two electric utility boxes, and one of the CCHD's buildings. The projected flood extent would also reach further along the north side of Anchor Way into the Citizens Dock area, exposing additional commercial facilities, and most of the East RV Park. Due to the notably larger overtopping rate under this scenario and historical impacts, road damage is expected along Anchor Way, further impeding access for any travel. The exposed facilities are also more vulnerable to damage due to the higher hydrodynamic and debris loads expected from the oncoming waves. It is anticipated that the electric utility boxes would be damaged from this flooding because of their proximity to the edge of the breakwater and their platform elevation at a lower elevation than the breakwater crest.

Under the 2100 time horizon, the significantly high overtopping rate for this breakwater suggests that both the Anchor Way Breakwater and Citizens Dock area up to Citizens Dock Road would be exposed to flooding. Due to this large rate, it is likely that direct damage to the road would occur, further obstructing access within Anchor Way and Citizens Dock. The only CCHD building not exposed to this projected flood extent is located at a high elevation on Whaler Island. The impact to the other CCHD structures on the docks would likely be limited due to their distance from the breakwater and location near the edge of the flood extent. The impacts to other visitor serving commercial facilities located further into the Citizens Dock area and away from the breakwater would similarly be limited. However, the low-lying conditions of the docks and RV parks, combined with the high overtopping rates would still indicate relatively deep and extensive flooding in the area.

5. Adaptation Strategies and Multi-criteria Analysis

This section presents an overview of multiple adaptation strategies that can be used to address flooding along Highway 101 and Anchor Way in the near, mid, and long term. The strategies are evaluated using a multi-criteria analysis to inform the selection of a preferred strategy for each sub-area.

5.1 Adaptation Strategies

Adaptation strategies for future SLR scenarios are described in this section. Strategies are developed for Highway 101 and Anchor Way separately as implementation and timing may be independent of each other. The strategies considered in this section are categorized as retreat, accommodate, and protect (Table 5-1).

Retreat strategies involve relocating infrastructure and communities away from coastal areas vulnerable to future SLR projections. This strategy is often considered when the cost of protecting or accommodating is too high or when the consequence of damage from coastal hazards is too great. An example would be relocating Highway 101 inland to avoid the impacts of SLR and coastal erosion.

Accommodate strategies adapt vulnerable infrastructure and implement practices that make existing structures and systems more resilient, reducing impacts and supporting quick recovery. An example in South Beach would be elevating the highway, modifying drainage systems, and implementing flood-reduction and flood-proofing measures.

Protect strategies aim to prevent flooding and erosion impacts to infrastructure and communities, in their existing footprint, from the impacts of SLR and extreme weather events. Methods typically include the construction of physical barriers and other protective measures. An example in the Project Area would be building a seawall or rock revetment along Highway 101 and Anchor Way.

Table 5-1. Adaptation strategies considered for each sub-area

Category	Highway 101	Anchor Way
Protect	Revetment	Raise revetment
	Living shoreline	Extend Whaler Island groin
Accommodate	Raise roadway	Raise roadway
	Causeway	n/a
Retreat	Relocate along detour route	n/a
	Relocate inland through Marsh Wildlife Area	n/a

5.2 Evaluation Criteria

A multi-criteria analysis (MCA) is utilized to evaluate the viability of each proposed strategy. Criteria that reflect the goals of this project and stakeholder needs were developed for each sub-area based and refined with Advisory Committee and public feedback. The key considerations used to frame the MCA are as follows:

- Strategies for Highway 101 to remain a functional multi-modal transportation corridor considering SLR, higher tide levels, and storm surge.
- Strategies for Anchor Way to remain functional considering SLR, higher tide levels, and storm surge.
- Strategies should maintain public access along Highway 101 to the existing South Beach area.

Criteria were presented at two public meetings, and public feedback was incorporated into the criteria listed in Table 5-2. Other possible criteria mentioned by the community included projects with multiple benefits, economic development, and project flexibility. The criteria were used to qualitatively evaluate how each strategy would meet the project objectives.

Table 5-2. Criteria used in qualitative evaluation of adaptation strategies

Criteria Categories	Highway 101 Criteria	Anchor Way Criteria
Coastal Hazards	• Flood Protection • Erosion Protection • SLR Resilience and Design Life	• Flood Protection • Erosion Protection • SLR Resilience and Design Life
Transportation	• Operational Downtime • Emergency Response • Traffic through Community • Multimodal Transportation Options*	• Operational Downtime • Emergency Response • Multimodal Transportation Options* (bus route)
Public Access	• Parking* • Scenic Resources / Views • Access to South Beach • Beach Space • Access to Amenities (restrooms*, etc.)	• Parking* • Scenic Resources / Views • Access to Whaler Island • Access to Amenities (shops, etc.) • Fishing/Recreational Fishing
Habitats	• Habitats* (dune, marsh) • Natural Strategies • Marsh Wildlife Area Drainage	• Whaler Island Habitat • Natural Features, if feasible
Constructability	• Design Standards • Temporary Impacts	• Design Standards • Temporary Impacts
Regulatory	• California Environmental Quality Act/National Environmental Policy Act • Permits	• California Environmental Quality Act/National Environmental Policy Act • Permits
Financial	• Construction Cost • Operation and Maintenance Costs	• Construction Cost • Operation and Maintenance Costs

* *Noted as important during public meetings in 2024*

5.3 Highway 101 Adaptation Strategies

An overview of each strategy considered is presented in the following sections and along with a summary of the MCA to highlight the key criteria influencing the applicability of each strategy within the Project Area. Please refer to Appendix E for more details on the evaluation for each specific criterion associated with each strategy.

5.3.1 Protect Strategies

Adaptation aimed at protecting coastal infrastructure can come in the form of hard and soft shoreline protection strategies. Hard protection strategies typically consist of rock revetments and/or seawalls. Soft protection strategies rely on natural materials such as sand and cobble to provide a protective buffer against elevated waves and water levels. Revetments and living shorelines are two protection strategies considered along Highway 101 at South Beach.

5.3.1.1 Revetment

Rock revetments are a common strategy applied to stabilize earthen embankments exposed to coastal processes. This strategy has proven effective along Anchor Way (Figure 5-1) and was evaluated for use along Highway 101 to prevent erosion and reduce wave overtopping. These structures are typically comprised of multiple layers of larger diameter (>3ft) armor stone over smaller (underlayer) stone and a geotextile filter.

Erosion and flood protection are a function of the revetment design configuration. The strategy evaluated in this section assumes a large armor stone revetment is backed by a concrete flood wall designed to be stable under an extreme storm event in combination with SLR. To reduce overtopping risk to tolerable levels through 2070 under the High SLR scenario (2.3 feet of SLR), the revetment crest would need to be raised to 18-20 feet NAVD88. This strategy is depicted in Figure 5-2 and would be built in front of the existing scarp to preserve the parking area along Highway 101.

A summary of MCA results is provided in Table 5-3. While revetments are effective and economical solutions to coastal erosion, they also create a barrier to natural littoral processes and inhibit coastal access. For these reasons, permitting new revetments pose a major challenge, particularly in demonstrating consistency with the Coastal Act.

Figure 5-1. Example of a rock revetment (Anchor Way)

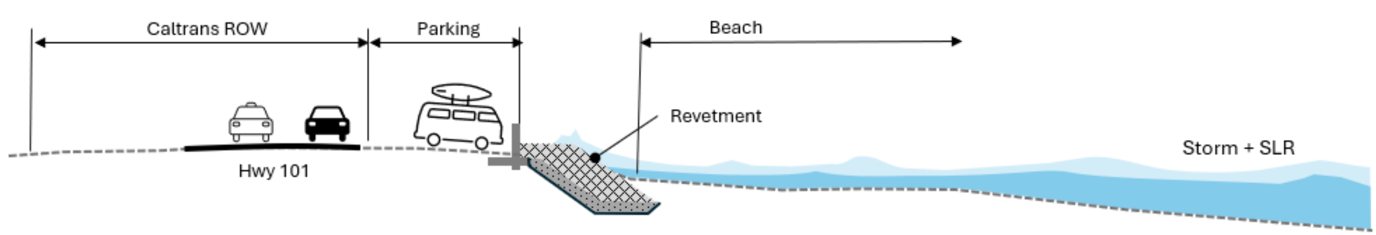
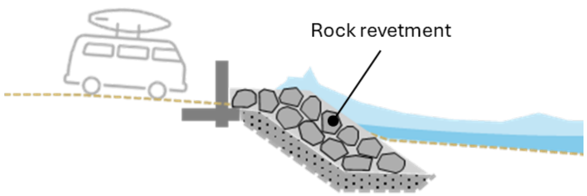


Figure 5-2. Revetment cross section concept

Table 5-3. Revetment MCA summary (“✓” notes opportunities or benefits and “X” notes challenges or drawbacks)

<table>
<tr><th colspan="2">Strategy Overview:</th></tr>
<tr><td>

Revetment



</td><td>

An armor stone revetment consists of two layers of large diameter (approx. 3 ft) stone over smaller (underlayer) stone and a geotextile filter. The revetment would be backed by a concrete flood wall to achieve desired flood protection for 2070 timeframe.

The revetment would follow an alignment along the existing scarp to prevent erosion of parking area and Highway 101.

</td></tr>
<tr><th colspan="2">MCA Summary:</th></tr>
<tr><td>✓</td><td>

Coastal Hazards:

- Revetments provide adequate protection from coastal erosion
- Crest of floodwall would be established to achieve adequate flood protection, likely at an elevation of 18-20 feet (NAVD88)

</td></tr>
<tr><td>X</td><td>

Public Access:

- Concrete floodwall would create a barrier, confining public beach access to designated locations
- Footprint of rock revetment would occupy beach space and prevent natural erosion processes
- Ongoing erosion of sand beach would result in “coastal squeeze” and loss of recreational beach area in front of revetment

</td></tr>
<tr><td>X</td><td>

Regulatory:

- Permitting for a new rock revetment would be a lengthy and challenging process due to potential adverse impacts to public access and local shoreline sand supply
- Coastal Act Section 30235 limits use of revetments to very specific circumstances which may not apply along the project reach

</td></tr>
<tr><th colspan="2">Applicability of Strategy:</th></tr>
<tr><td colspan="2">Although revetments can provide effective coastal hazard protection, concerns about adverse impacts to public access and local shoreline sand supply make this strategy very difficult to permit, except in unique circumstances. This strategy would involve an extensive permit process and mitigation measures for potential adverse impacts, so this strategy is not recommended for the Highway 101 reach.</td></tr>
</table>

5.3.1.2 Living Shoreline

A living shoreline is a coastal protection feature that uses natural materials such as plants, sand, and cobble to provide a dynamic (seasonal erosion and deposition) shoreline while limiting persistent erosion, and provide habitat for wildlife. Reference shorelines that consist of natural features subject to similar wave conditions can be utilized to inform design and selection of materials. Typically, beach sand would be placed at a slope similar to reference locations and planted with native vegetation, which functions to stabilize soil and reduce and absorb wave energy. The living shoreline also creates habitat for birds and other wildlife, enhancing biodiversity. The living shoreline would likely have the same extent along the highway as a revetment but would require a slightly larger footprint to accommodate gentler slopes and support more dynamic seasonal change.

Unlike hard structures (e.g., revetments and seawalls), living shorelines are designed to work with natural processes and adapt over time. Living shorelines subject to high energy environments with strong waves can be significantly altered by a storm event. Therefore, a routine maintenance and monitoring program is an important part of this strategy. Nature-based strategies have been proven effective on several projects in California (Figure 5-3) and the Pacific Northwest. Lessons learned continue to emerge from these projects and will be applied to a site-specific strategy along Highway 101. A living shoreline concept is provided in Figure 5-4 and consists of a cobble berm in front of an elevated, vegetated sand berm system. The cobble berm is intended to provide erosion protection and storm wave dissipation while the elevated sand berm provides additional flood protection to reduce wave overtopping and debris deposition across the highway. A summary of MCA results is provided in Table 5-4. For more detail on other evaluation criteria, please refer to Appendix E.

Figure 5-3. Example of a living shoreline (Cardiff State Beach, Encinitas, CA)

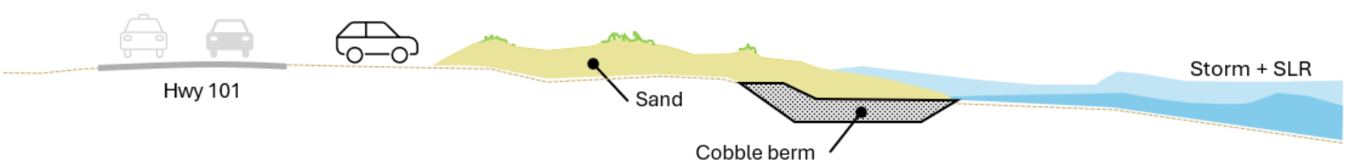
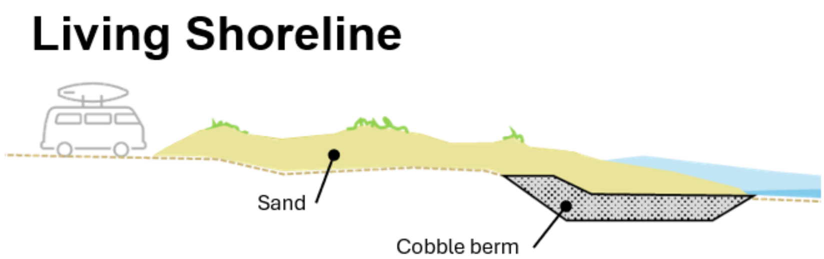


Figure 5-4. Living shoreline cross section concept

Table 5-4. Living shoreline MCA summary ("✓" notes opportunities or benefits and "X" notes challenges or drawbacks)

Strategy Overview:	
	A living shoreline consists of a cobble berm backed by an elevated sand berm system to achieve desired flood protection for 2070 timeframe. The living shoreline would follow an alignment along the existing scarp to prevent erosion of parking area and Highway 101.
MCA Summary:	
✓	**Coastal Hazards:** • Living shoreline would provide adequate protection from coastal erosion but will require monitoring and maintenance • Crest of dune system would be established to achieve adequate flood protection, likely at an elevation of ~20 feet (NAVD88)
✓	**Public Access:** • Trails through a sand berm system maintain beach access • Footprint of living shoreline would occupy more beach space but would still offer recreational value for beach users • Addition of sand/cobble to the littoral system will help offset the effects of "coastal squeeze" helping to maintain an accessible beach over a longer duration compared to a revetment strategy
✓	**Regulatory:** • Nature based shoreline protection strategies are still subject to a thorough review and permit process, but are viewed more favorably than hard structures (i.e. revetments)
X	**Financial:** • Initial construction cost on par with revetment, but subject to additional maintenance cost associated with sand/cobble re-nourishment throughout lifecycle
Applicability of Strategy:	
A living shoreline would provide flood protection and SLR resilience in the near- and mid-term but would require monitoring and maintenance activities consisting of sand/cobble re-nourishment to maintain protection along Highway 101. The multiple benefits associated with this strategy (i.e. habitat and public access) better align with permitting requirements and a living shoreline is considered applicable along the entire Highway 101 project reach.	

5.3.2 Accommodate Strategies

The accommodate approach aims to work within the Caltrans right-of-way to incorporate vertical and/or horizontal setbacks from coastal hazards to increase SLR resiliency. There are two approaches considered: raising the roadway and shifting landward (within right-of-way) or converting a section of Highway 101 into an elevated causeway.

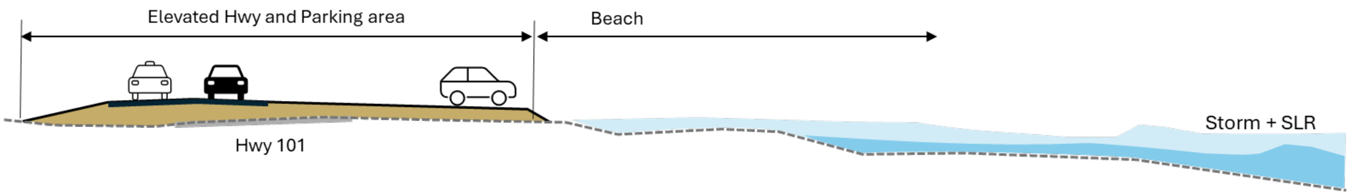
5.3.2.1 Raise roadway

Caltrans has considered raising the roadway along this segment of highway to reduce the frequency and magnitude of coastal flooding dating back to the 2003 Project Study Report. Raising Highway 101 would increase the buffer above extreme wave events. The strategy considered below would also shift the highway inland as much as possible (within the existing right-of-way) while maintaining design standards and avoiding ESHA to the extent feasible. To reduce overtopping risk to tolerable levels through 2070 under the High SLR scenario (2.3 feet of SLR), the revetment crest would need to be raised from 14-18 ft NAVD88 to 20-22 feet NAVD88. A summary of MCA results is provided in Table 5-5. For more detail on other evaluation criteria, please refer to Appendix E.

Table 5-5. Raise Roadway MCA summary ("✓" notes opportunities or benefits and "X" notes challenges or drawbacks)

Strategy Overview:

Accommodate: Raise Roadway



Highway 101 would be elevated on earthen fill and shifted landward within existing right-of-way to increase the horizontal and vertical setback from coastal hazards. The road would be elevated to 20-22 ft NAVD88 to achieve adequate flood protection for the 2070 timeframe.

MCA Summary:

✓	**Flooding:** Increased buffer reduces potential for flooding and debris overtopping
X	**Erosion:** • Road and parking areas vulnerable to undermining from coastal erosion
✓ to X	**Public Access:** • Benefits to parking and access over the short-term, but continued erosion will progressively reduce the parking area and may require emergency measures to stabilize roadway
✓	**Regulatory:** • Keeping work within right-of-way could streamline permitting
X to ✓	**Transportation:** • Temporary impacts associated with construction within existing right-of-way, but ultimately project will improve resilience of transportation infrastructure

Applicability of Strategy:

As a standalone strategy, there would be benefits over the short-term, but continued erosion would progressively damage the parking areas (reducing beach access) and eventually threaten the elevated roadway. However, in combination with a protect strategy (i.e. living shoreline) raising the roadway and shifting landward could increase the resilience to coastal hazards and would be applicable throughout the Highway 101 project reach.

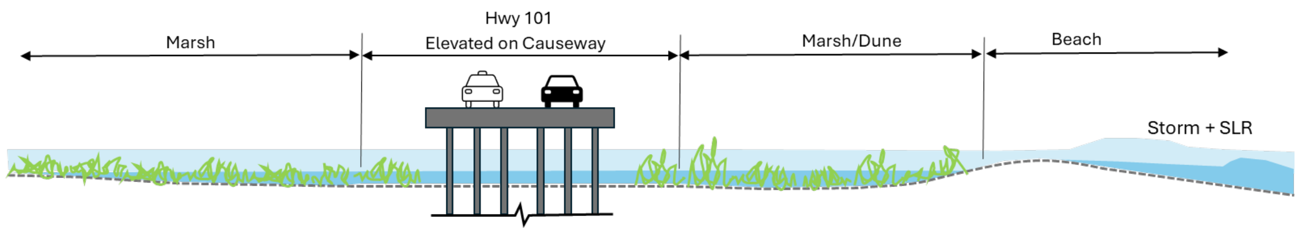
5.3.2.2 Causeway

Converting the existing Highway 101 to an elevated causeway would mitigate coastal hazards through avoidance. Coastal processes would continue to evolve under progressive SLR scenarios beneath the elevated roadway. This strategy assumes the causeway stretches over the entire South Beach area of Highway 101 and the current Highway 101 prism would be lowered to historic conditions. The causeway would be located in Caltrans existing right-of-way, though additional entitlements may be required for the on- and off-ramps to provide access to beach parking areas. A summary of MCA results is provided in Table 5-6. See Appendix E for more detail on other evaluation criteria.

Table 5-6. Causeway MCA summary ("✓" notes opportunities or benefits and "X" notes challenges or drawbacks)

Strategy Overview:

Accommodate: Causeway



Highway 101 would be elevated on a causeway to avoid exposure to current and future coastal hazards. The causeway elevation would likely be designed to address long-term coastal hazards.

MCA Summary:

✓	**Coastal hazards:** Elevated causeway mitigates coastal hazards through avoidance
X	**Public Access:** • Grade separation will reduce access to parking areas and adjacent properties • Beach parking areas would eventually be lost due to coastal erosion
✓	**Habitat:** • The causeway would alleviate the current drainage issues due to clogged culverts improving marsh conditions; long-term impacts to the marsh require further study • Natural shoreline erosion processes would continue without a fixed structure along the backshore
X	**Financial:** • Very high construction costs associated with this strategy (a similar strategy was evaluated for Highway 101 at Humboldt Bay but was found to be cost prohibitive)
X to ✓	**Transportation:** • Temporary impacts associated with construction within existing right-of-way, but ultimately the project will improve the resilience of the transportation corridor

Applicability of Strategy:

This strategy would provide long-term resilience to coastal hazards but also comes at a very high cost along with challenges maintaining existing beach parking and access to adjacent properties. This strategy is not considered applicable along the entire reach but could provide benefits at the low-lying segment of highway near culvert 3.

5.3.3 Retreat Strategies

This strategy evaluated options for the retreat of Highway 101 outside of the hazard zones described in Section 4. Ideally this strategy would locate Highway 101 on higher ground setback from current and future coastal hazards. However, this segment of highway is backed by low-lying marsh which supports a variety of sensitive habitat areas and rare/endangered plant species. Multiple retreat alignments are evaluated at a high level to facilitate discussion among the project team and Advisory Committee to inform the MCA. The retreat alignments considered are illustrated in Figure 5-5 and include using the existing detour (Alignment 1) and several routes relocating Highway 101 through the Marsh Wildlife Area (Alignment 2-4) to avoid disruption and adverse community impacts experienced along the detour route during recent closures.

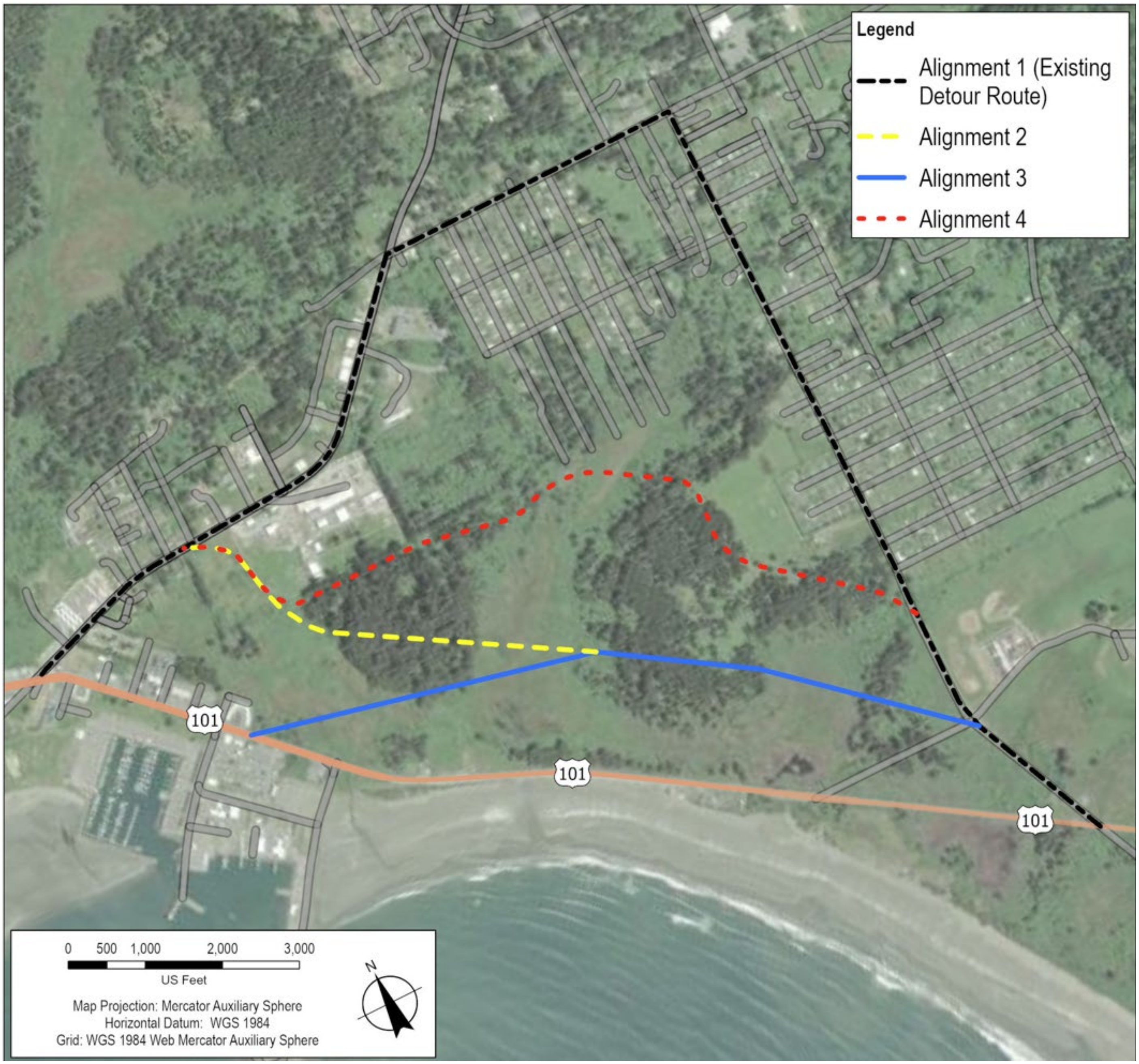


Figure 5-5. Highway 101 realignment options

5.3.3.1 Existing Detour

Alignment 1 considers the feasibility of converting the current detour route into the permanent Highway 101 route. From north to south, the route diverges from the current Highway 101 at Elk Valley Road, continues onto Howland Hill Road, and then merges back onto the existing Highway 101 using Humboldt Road. Current lane widths along Alternative 1 range between 11 and 12 feet with no shoulder. Speed limits along Humboldt Road are 45 miles per hour (MPH) and 40 MPH along Howland Hill Road.

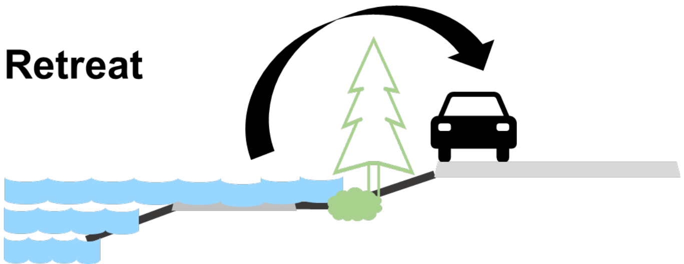
This alignment would utilize existing road infrastructure; however, the alignment would encounter many design challenges to accommodate larger traffic volumes and meet Caltrans design criteria. Caltrans does not own land or have a right-of-way along this alignment; land acquisition would significantly increase the cost of this alignment and have adverse impacts to the community. Additional constraints to relocating the highway include the high frequency of driveways and side streets as well as nonstandard geometric features such as superelevation. Substandard turning radius at Humboldt Road and Howland Hill Road would likely require property acquisition (Figure 5-6). Utilities would need to be relocated (overhead electric lines, underground water and sewer lines). Vegetation clearing and tree removal would be likely to provide adequate clear zones. Figure 5-7 illustrates the challenges of the narrow road width, vegetation, lack of sidewalk/shoulder space and pedestrian facilities, overhead utilities, driveways, fixed objects in the clear zone, residences, and utilities supporting the community.

Figure 5-6. Humboldt Road and Howland Hill Road intersection (Google Earth 2024)

Figure 5-7. Features along Humboldt Road (Google Earth 2024)

This option would effectively mitigate coastal flooding and storm impacts on Highway 101 but comes with high construction costs and impacts to the residential community along the detour route. While it minimizes effects on the Marsh Wildlife Area and forested areas compared to other inland retreat alignments, it would create environmental justice concerns for a disadvantaged community including the acquisition of residential, commercial, and Tribal properties. Increased traffic, longer travel distances, and pedestrian safety risks further reduce its viability. This option fails to meet one of the project's transportation criteria to decrease impacts to the community affected by the current detour route. This option will not be pursued further in this Plan. A summary of MCA results is provided in Table 5-8. For more detail on other evaluation criteria, please refer to Appendix E.

Table 5-7. MCA summary of Highway 101 detour retreat strategy ("✓" notes opportunities or benefits and "X" notes challenges or drawbacks)

Strategy Overview:	
	Retreat involves re-alignment of Highway 101 outside (landward) of the existing and future coastal hazard zones. This strategy would use the existing detour as shown in .

MCA Summary:	
✓	**Coastal hazards:** • Avoidance of existing and future coastal hazards
X	**Public Access:** • New inland route would not provide beach access
✓	**Habitat:** • Limited impacts
X	**Financial:** • High construction and land acquisition cost
X	**Transportation:** • Difficulty meeting highway design standards • Significant safety concerns with traffic routed through community • Limited space for multi-modal transportation (cyclists and pedestrians) • Contradicts project criteria of decreasing impacts of detour route on the community

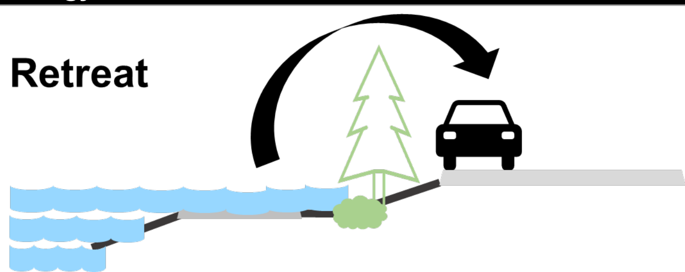
Applicability of Strategy:
A retreat strategy was determined to be infeasible over near- and mid-term planning horizons due to major challenges cited above and will not be considered as part of the preferred concept. There are other adaptation strategies presented in the following sections which better align with the project objectives. A managed retreat strategy may be worth additional consideration over long-term planning horizons (2100+) and high SLR scenarios but many of these challenges would remain.

5.3.3.2 Relocate Highway 101 Inland

Alignments 2-4 (Figure 5-5) consider retreat of Highway 101 inland and across the Marsh Wildlife Area for approximately 1.7 miles, utilizing higher elevations (in some areas) and distance from the coastline to avoid future coastal hazards. This new alignment would likely be constructed as a combination of a causeway/bridge over low-lying marsh areas and an elevated road prism along higher ground.

This option would fully mitigate coastal flooding on Highway 101 but would have the most significant environmental impacts, particularly on the marsh and forest. While causeways could reduce some effects, the road would still disrupt protected habitats, including endangered plant species. Additionally, this option has high costs due to construction, mitigation, and land acquisition, as Caltrans does not own the necessary right-of-way. Feedback from CDFW indicates this option is infeasible from a regulatory perspective, as the anticipated environmental impacts cannot be adequately mitigated. A summary of MCA results is provided in Table 5-8. Due to major environmental and regulatory concerns, this strategy is not considered viable and will not be pursued further.

Table 5-8. MCA summary of Highway 101 inland retreat strategy ("✓" notes opportunities or benefits and "X" notes challenges or drawbacks)

Strategy Overview:	
	Retreat involves re-alignment of Highway 101 outside (landward) of the existing and future coastal hazard zones, through the Marsh Wildlife Area as shown in .
MCA Summary:	
✓	**Coastal hazards:** • Avoidance of existing and future coastal hazards
X	**Habitat:** • Significant impacts to environmentally sensitive habitat areas and endangered species within the Marsh Wildlife Area • Environmental impacts would likely be significant and very difficult (or impossible) to mitigate
X	**Regulatory:** • High difficulty in securing permits for this strategy, best case would be a lengthy and expensive process, followed by extensive monitoring and mitigation costs
X	**Financial:** • High construction, acquisition, and mitigation costs
Applicability of Strategy:	
This retreat strategy was determined to be infeasible over all planning horizons due to major challenges cited above and will not be considered as part of the preferred concept.	

5.3.4 Highway 101 MCA Summary

An evaluation of Highway 101 adaptation strategies highlights key considerations for three main approaches: protect, accommodate, and retreat.

Table 5-9. Evaluation of Highway 101 adaptation strategies ("✓" notes opportunities or benefits and "X" notes challenges or drawbacks)

Highway 101 Multi-criteria Analysis Summary	
Protect Strategies:	
X	**Revetment:** Provides near- and mid-term flood and erosion protection but reduces public access and would involve an extensive permit process with mitigation measures for potential adverse impacts. This strategy is not recommended for the Highway 101 reach.
✓	**Living Shoreline:** Preferred protection strategy because it provides effective mid-term flood and erosion resilience while enhancing public access, supporting habitat restoration, and offering a more adaptable, cost-effective, and environmentally sustainable solution compared to hardened structures like revetments.
Accommodate Strategies:	
✓	**Raise Roadway Elevation:** Raising the roadway offers short-term benefits but is vulnerable to long-term erosion, which could reduce beach access and eventually threaten the road. However, if combined with a protection strategy (i.e. living shoreline), it enhances resilience to coastal hazards and remains a viable solution for the Highway 101 reach.
X	**Causeway:** This strategy provides long-term resilience but comes at a very high cost along with challenges maintaining existing beach parking and access to adjacent properties. Due to cost and complexity this strategy is not feasible along the entire reach.
Retreat Strategies:	
X	**Existing Detour:** Eliminates flooding impacts but increases travel time, poses safety hazards and adverse impacts to community, and has significant environmental justice concerns. This strategy was strongly opposed by the Advisory Committee and is not recommended at this time.
X	**Eastern/Inland Relocation:** Mitigates vulnerabilities to coastal hazards but has significant environmental and regulatory impacts, high costs, and strong opposition from the Advisory Committee and resource managers so is not feasible.

5.3.4.1 Hybrid Adaptation Strategy

A hybrid adaptation strategy that combines protect and accommodate measures is the preferred approach for the Highway 101 reach because it effectively addresses both existing hazards and future coastal risks over short- and mid-term planning horizons. By integrating solutions such as a living shoreline for erosion control and flood protection with roadway elevation to mitigate storm impacts, this approach promotes a resilient transportation corridor that remains functional despite changing coastal conditions. This strategy also preserves public access to the coast, minimizes disruptions to the local community, and balances environmental, regulatory, and financial considerations. By leveraging the strengths of both natural and engineered solutions, the hybrid approach enhances long-term sustainability while reducing adverse impacts on surrounding habitats and infrastructure. More detail on this approach is provided in Section 6.

5.4 Anchor Way Adaptation Strategies

Anchor Way offers important economic and recreational opportunities for the community and the region. The applicable strategies are constrained at Anchor Way due to the important function of the corridor as a jetty/breakwater. This coastal infrastructure protects Crescent City Harbor from large waves and sedimentation from the south. Strategies that would eliminate this important function (i.e. retreat) were deemed inapplicable because they would alter the function of the Harbor. This section evaluates protect and accommodate strategies aimed at maintaining the Harbor function and building resilience to coastal hazards and SLR.

5.4.1 Protect Strategy

Protection strategies are focused on improvements to the existing coastal structures such that they can withstand increased water levels and wave action expected with SLR.

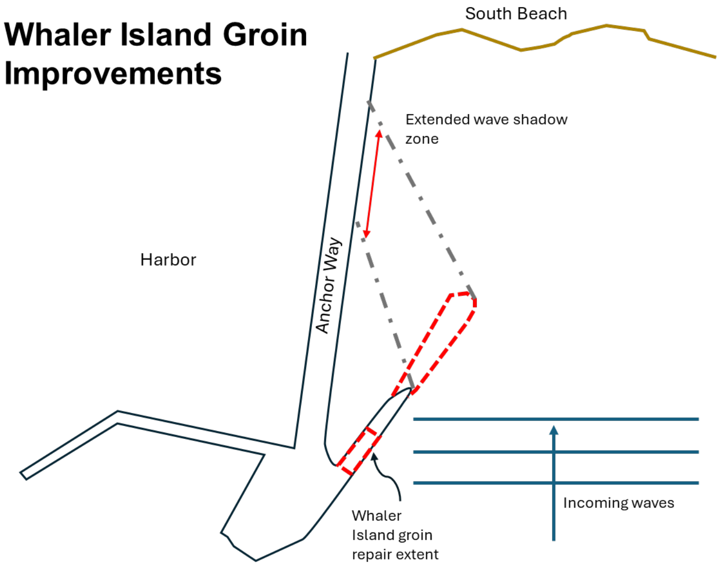
5.4.1.1 Whaler Island Groin Improvements

Extending the Whaler Island groin at the seaward end of Anchor Way involves lengthening and repairing the existing groin structure to further intercept and dissipate incoming wave energy from reaching Anchor Way. Repairs of the groin would entail rebuilding the damaged section with properly sized core and armor stone to achieve a consistent crest elevation. The extent of the damaged groin is shown in Figure 5-8. In addition to repairing damage, the structure could be extended. This option is included in CCHD’s 2019 SLR Assessment. The extension of the groin would further reduce wave energy reaching Anchor Way, thereby decreasing flooding risks. A summary of MCA results is provided in Table 5-10. For more detail on other evaluation criteria, please refer to Appendix E.

Figure 5-8. Photo showing damaged section of the Whaler Island groin on November 23, 2024 (top) and the damaged section of the Whaler Island groin getting overtopped and flooding of Anchor Way on January 5, 2023 (bottom)

Table 5-10. Whaler Island Groin Improvements MCA summary

Strategy Overview:



Improvements to the Whaler Island Groin would consist of repairing the damaged section ( ) to provide a consistent crest elevation and extending the groin to increase the wave shadow zone along Anchor Way.

The extended groin would consist of multiple layer of large armor stone similar to the materials used in the existing structure. The crest elevation would be equal to or slightly higher than the existing breakwater to offer wave protection through the 2070 timeframe.

MCA Summary:

✓	**Coastal Hazards:** • Groin improvements will reduce the wave energy reaching Anchor Way, reducing the amount of wave runup and associated overtopping/flooding of the road; however, the low elevation of Anchor Way may still be susceptible to flooding under extreme water levels + SLR
✓	**Public Access:** • Groin improvements would maintain the pocket beach which currently provides beach/water access for hand launched recreational watercraft • Extended groin would need to be evaluated in more detail to understand potential for impacts to surfing resources adjacent to Whaler Island
X	**Habitat/Regulatory:** • Permitting for a new groin extension would be a lengthy process due to potential adverse impacts on coastal resources associated with placing a rock structure on the sea floor and required mitigation • Coastal Act Section 30235 limits use of coastal structures to serve coastal dependent uses

Applicability of Strategy:

This strategy would provide effective wave protection for a longer stretch of Anchor Way increasing resilience to coastal hazards and SLR. However, this strategy in isolation would not be sufficient to provide flood protection through 2070 due to the low elevations along Anchor Way. Groin improvement would be most effective in combination with an accommodate strategy discussed in the next section.

5.4.2 Accommodate Strategies

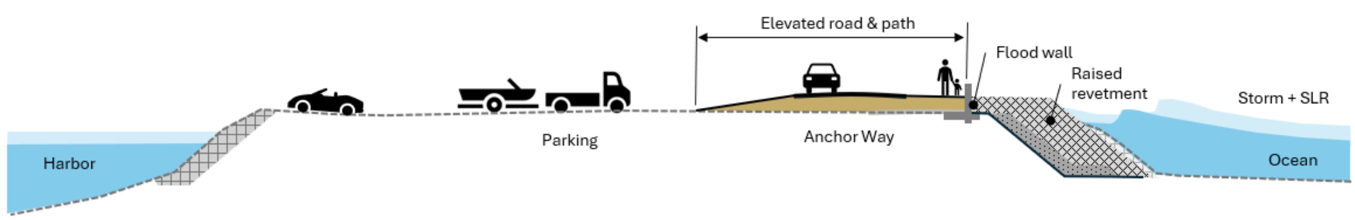
The accommodate strategy evaluated below focuses on elevating the existing infrastructure (road and revetment) such that they can withstand increased water levels and wave action expected with SLR.

5.4.2.1 Raise Roadway and Revetment

By enhancing the existing roadway, revetment, and flood wall, this strategy aims to provide greater resistance against wave action and higher water levels, thereby reducing the risk of overtopping and erosion, and is in line with CCHD's 2019 SLR Assessment. A summary of MCA results is provided in Table 5-11. For more detail on other evaluation criteria, please refer to Appendix E.

Table 5-11. Raise Roadway and Revetment MCA summary

Strategy Overview:



Anchor Way would be elevated on earthen fill and shifted landward behind a defined pedestrian path. The existing revetment would be elevated and backed by a concrete floodwall (replacing existing K-rail) to achieve adequate flood protection for the 2070 timeframe.

MCA Summary:

✓	**Coastal Hazards:** Elevated revetment provides adequate protection from coastal erosion. Crest of floodwall would be established to achieve adequate flood protection, likely at an elevation of 18-20 feet (NAVD88)
✓	**Public Access:** • Re-aligned roadway provides designated path for pedestrian use along floodwall improving pedestrian experience and safety
X	**Regulatory:** • Permitting of an elevated revetment could be a lengthy process, but if all improvements occur within or landward of existing revetment, then it's feasible to minimize/avoid adverse impacts to coastal resources
X to ✓	**Transportation:** • Temporary impacts associated with construction within existing right-of-way, but ultimately project will improve resilience of transportation infrastructure

Applicability of Strategy:

This strategy will enhance coastal resilience by reducing overtopping and flooding associated with extreme events and SLR. Additionally, the improvements will enhance pedestrian access, circulation, and recreational opportunities, promoting continued and improved public access to local businesses and Whaler Island.

5.4.3 Anchor Way MCA Summary

Protect and accommodate adaptation strategies were evaluated for Anchor Way to assess how the existing coastal infrastructure could be adapted to improve resilience to SLR. Retreat strategies were not assessed because the Anchor Way corridor serves a crucial role as a breakwater and jetty, essential for maintaining Harbor operations.

Table 5-12. Evaluation of Anchor Way adaptation strategies

Anchor Way Multi-criteria Analysis Summary	
Protect Strategy:	
✓	**Whaler Island Groin:** Improvements would provide effective wave protection for a longer stretch of Anchor Way increasing resilience to coastal hazards and SLR. However, this strategy in isolation would not be sufficient to provide flood protection through 2070 due to the low elevations along Anchor Way.
Accommodate Strategy:	
✓	**Raise Roadway and Revetment:** Raising the roadway and elevating the revetment/floodwall will reduce flooding from extreme events and SLR, while also improving pedestrian access, circulation, and recreational opportunities.

5.4.3.1 Hybrid Adaptation Strategy

A hybrid adaptation strategy that combines protect and accommodate measures is the preferred approach for the Anchor Way reach because it effectively addresses both existing hazards and future coastal risks over short- and mid-term planning horizons. The accommodate strategy could provide equivalent resilience to the hybrid strategy although the design of the revetment and floodwall would need to account for the wave sheltering (or lack thereof) based on how the Whaler Island groin will be maintained over short- and mid-term planning horizons.

6. Concept Design

Current hazards such as coastal erosion, storm surges, and flooding already pose significant risks to infrastructure. Hybrid adaptation strategies were developed along Highway 101 and Anchor Way to leverage benefits associated with the variety of strategies considered in Section 5 in conjunction with feedback from the Advisory Committee. The conceptual designs described in this section represent the preferred adaptation strategy at each location.

6.1 Preliminary Design Criteria

Design life and acceptable levels of risk are important factors to determine at an early stage of project design. The amount of SLR to build into these adaptation strategies depends on the risk tolerance of the community and when these risk thresholds could be exceeded. Based on feedback gathered from the Advisory Committee and during public meetings, the following preliminary design criteria was applied in conceptual design.

– Design life of 50 years was assumed for the proposed adaptation strategies, corresponding to a mid-term horizon for SLR projections. By focusing on the mid-term horizon, actions can be prioritized that mitigate immediate threats while building resilience against future conditions.
– Provide resilient flood protection for an extreme coastal storm event with an estimated return period of 100-years. Some wave overtopping would be tolerable in this event, provided there is minimal damage to transportation infrastructure and a relatively quick post-storm recovery.
– Provide limited wave overtopping (<1 liter/second/meter) for more frequent storm events (i.e. 10-year return period).
– Project features will be designed for 2.3 feet of SLR corresponding to the 2070 High SLR scenario. This amount also corresponds to the Intermediate-High scenario in 2080 and the Intermediate scenario in 2100.

Planning for SLR requires a balance between preparing for the most likely future conditions and remaining flexible in the face of uncertainty. Designing adaptation strategies around the more probable SLR scenarios enables infrastructure upgrades to occur incrementally, making it more feasible to integrate SLR considerations into existing capital improvement cycles without overwhelming available resources. This approach supports adaptive pathway strategies that allow decision-makers to respond over time as conditions change or new information becomes available.

In contrast, immediately designing infrastructure to withstand high-end SLR projections for 2100 would demand major, upfront investments and extensive alterations to existing systems. These high-impact but low-probability scenarios often involve difficult trade-offs, such as sacrificing public access and recreational amenities (like beach parking) in favor of large-scale adaptation measures. Without a flexible planning approach, these decisions risk locking communities into expensive and potentially unnecessary solutions.

A mid-term focus, with phasing for longer time horizons allows communities to address current vulnerabilities while preserving options for the future. For example, Highway 101—an essential transportation corridor threatened by coastal erosion and rising seas—can be fortified through erosion-resistant materials, elevation of low-lying segments, and nature-based solutions such as living shorelines. Similarly, the Anchor Way breakwater, which shields the Harbor from wave action and storm surge, can be incrementally strengthened by raising the revetment. These types of mid-term investments improve resilience today while building capacity to respond to more severe SLR impacts if and when they materialize.

By aligning adaptation strategies with more likely SLR scenarios and incorporating flexibility for adaptive pathways, communities can better navigate the trade-offs between preserving valuable public resources and preparing for uncertain but potentially severe climate futures.

6.2 Highway 101 Preferred Alternative

By integrating strategies such as a living shoreline for erosion control and a raised roadway to mitigate storm impacts, this hybrid approach promotes a resilient transportation corridor that remains functional despite changing coastal conditions. The main project elements are illustrated in Figure 6-1 and will vary in scale along the Project reach.

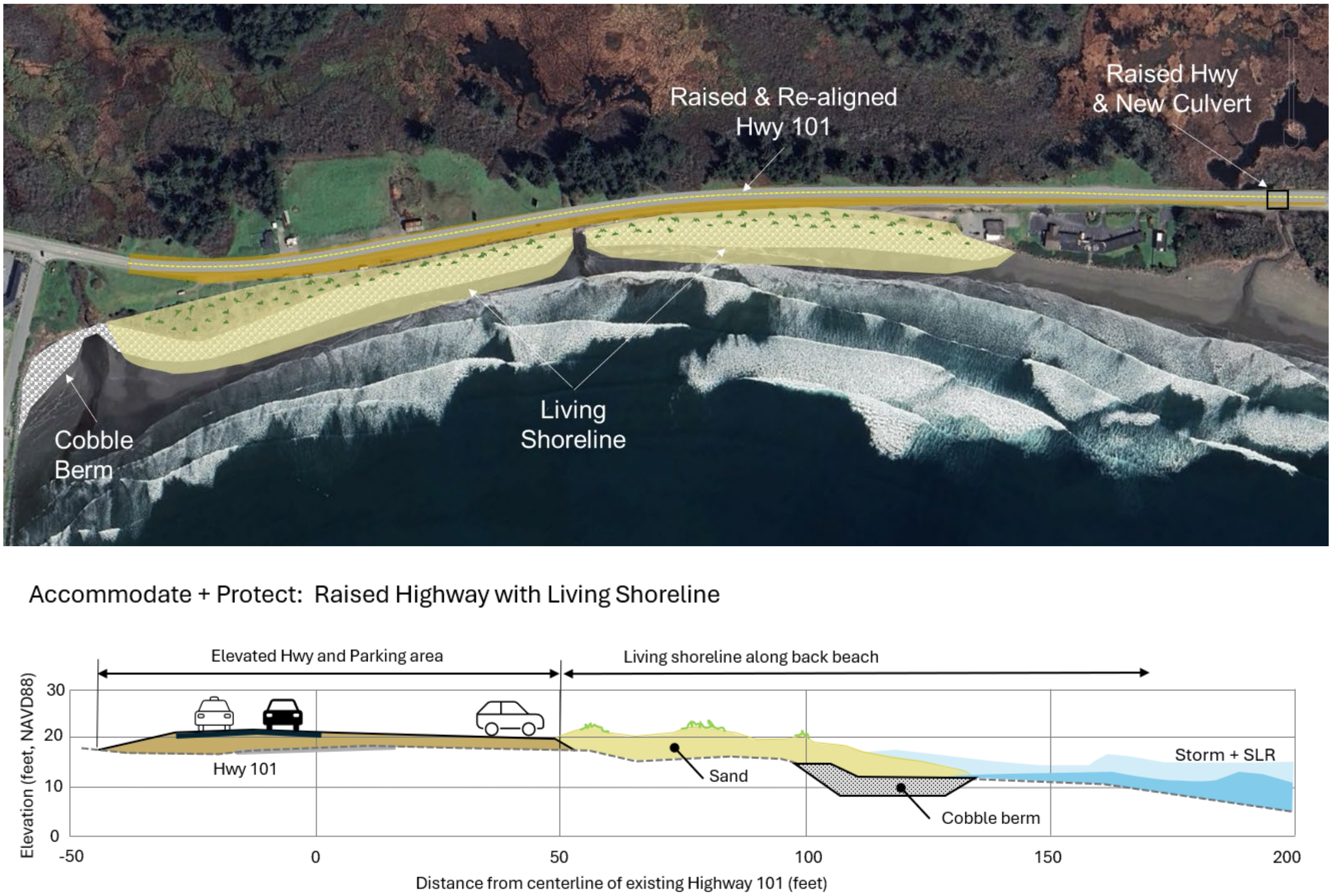


Figure 6-1. Plan view and typical cross section of Highway 101 preferred alternative

The scale and footprint of the structure is an important consideration in the design. A footprint that does not encroach significantly onto the beach and reduce beach access is preferable. The crest height of the living shoreline provides a first estimate of the footprint of the structure. An estimate of the necessary crest height of the structure was calculated by assessing the overtopping rates for the flooding scenarios presented in Section 4 and comparing them with the tolerable overtopping rates from the CEM and EurOtop Manual that are presented in Table 3-4. Overtopping rates provide an indication over of flooding extent, driving safety, woody debris deposition, and damage to the roadway. The rates were calculated using the EurOtop Manual (2018). A detailed description of the methodology used to calculate the overtopping rates can be found in Appendix F.

Figure 6-2 shows the estimates of overtopping rates for a 100-year storm event with different SLR scenarios and crest heights. The x-axis shows revetment crest heights, and the y-axis shows overtopping rates. The overtopping rates decrease as the crest height increases from the existing berm crest height of 16.7 feet NAVD88. The different bars plotted for each crest height indicate overtopping rates calculated for a 100-year storm under different SLR scenarios. The EurOtop equations were not designed for composite cobble/sand slopes and may have limited applicability on a living shoreline, but the overtopping rates provide a good first estimate of crest height and footprint. Raising a living shoreline crest height to 21-22 feet NAVD88 appears to mitigate overtopping until 2.3 feet of SLR is reached. This corresponds to 2070 under the High scenario, 2080 under the Intermediate- High scenario, and 2100 under the Intermediate scenario. Mitigating SLR with 5.6 feet of SLR would require a different strategy, or a significant increase in the scale of sand and cobble applied. A 100-year storm event larger than in combination with SLR larger than 2.3 feet appears to be threshold where overtopping rapidly increases and requires crest heights larger than what may be feasible in the project area.

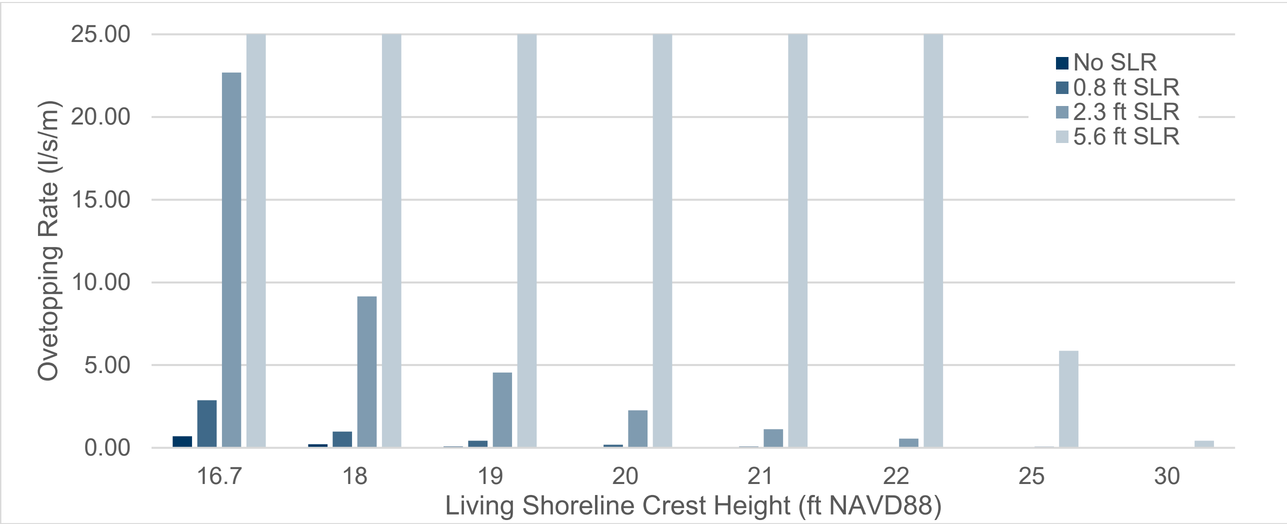


Figure 6-2 Overtopping rates for different living shoreline crest heights under the flooding scenarios presented in Section 4

6.2.1 Accommodate with Raised Roadway and Improved Drainage

The Highway 101 preferred strategy includes shifting the highway landward within the existing Caltrans right-of-way along the entire project reach, raising the roadway to approximately 20 feet NAVD88, and adding protection via a living shoreline. The current elevation of the highway ranges from 14 to 23 feet NAVD88. Therefore, the specific roadway elevation proposed may vary along the profile as the design progresses and more detailed analyses are performed that account for uncertainties associated with living shoreline performance.

The shifted roadway alignment is constrained by Caltrans standards, the Marsh Wildlife Area extent, and private property. While there is not a large space to re-align the roadway with Caltrans right-of-way, a 10-20 foot adjustment landward is feasible in many locations and provides space for preserving beach parking and multimodal transportation opportunities.

Culvert 3 would be replaced with a bottomless culvert (or similar structure) to improve drainage from the Marsh Wildlife Area and decrease the localized overtopping and debris deposition that occurs during coastal storm events. An example of this type of culvert is provided in Figure 6-3. The natural bottom of the culvert promotes a natural streambed substrate, enhancing the ecological function of the culvert. The roadway elevation above the culvert would be increased to meet the flood protection criteria and may require retaining walls along segments to minimize encroachment into the wetlands.

The culvert dimensions should be evaluated in more detail as part of a focused study on the Marsh Wildlife Area hydrology and hydraulics to balance the need for improved drainage with potential for increases in salinity during coastal storm events. The effects of saltwater intrusion into the marsh and the western lily habitat are unknown and require further study and analysis. Culvert 3 is also near the Elk Valley Rancheria's Bush parcel, which is undergoing planning for restoration and public access enhancements. The proposed concept would complement public access at the parcel via similar finish grades and safety improvements.

Figure 6-3. Example of bottomless culvert to be used at Culvert 3

6.2.2 Protect with Living Shoreline

The nature-based living shoreline and cobble berm strategy aims to protect Highway 101 with a vegetated sand berm that matches the character of adjacent natural coastline areas that have shown resiliency to erosion. This approach includes initial beach nourishment to increase beach width and allow vegetation to establish. The living shoreline would span the most eroded areas, with a crest height of around 20-22 feet NAVD88 to mitigate flooding. The foot of the structure would consist of a cobble berm to provide dynamic resilience during wave attack.

Living shorelines are intended to be dynamic and would require a robust monitoring program to evaluate native vegetation growth, monitor event-based erosion, and inform regular maintenance and adaptive management of the living shoreline. Management of the living shoreline and beach may be necessary to maintain the desired level of protection by placing additional sand and cobble to offset material which has dispersed.

The cobble would act as a dynamically reshaping structure, where the crest can build with increasing water levels. This also helps the strategy evolve with SLR, provided there is sufficient cobble along the beach profile. Monitoring of the cobble berm performance would be essential to estimate any cobble volume increases necessary to keep pace with SLR.

This concept would compliment existing public access and recreation at South Beach as well as some habitat restoration. The vegetated sand berms would be planted with native coastal shrubs and low-lying herbacsous vegetation that is regionally and ecologically appropriate. Delineated trails through the living shoreline would provide safe pedestrian access to the beach and limit disturbances to newly vegetated areas.

6.3 Anchor Way Preferred Alternative

The Anchor Way preferred alternative incorporates both accommodate and protect strategies for a comprehensive SLR adaptation approach (Figure 6-4). The concept presented below includes repairs to the existing groin, but not an extension of the groin. The intent of this preferred concept is to work within the footprint of the existing infrastructure to increase resilience to current and future hazards and avoid environmental and regulatory challenges associated with extending the Whaler Island Groin.

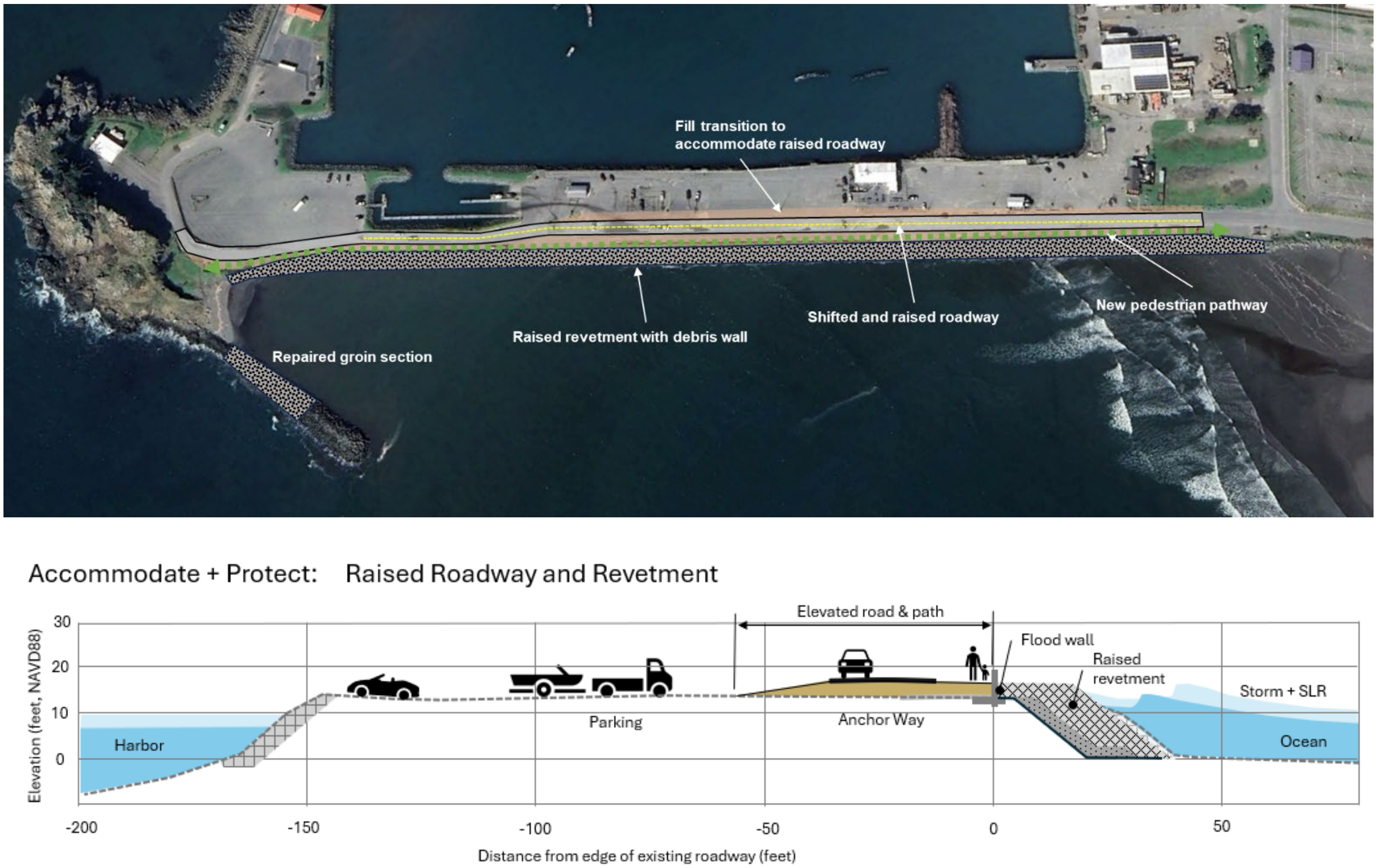


Figure 6-4. Plan view and typical cross section of the preferred alternative for Anchor Way

6.3.1 Protect with Repaired Whaler Island Groin Section

The repaired Whaler Island groin segment is an important strategy to restore wave protection along Anchor Way. Without repairing it, a progressive failure of the entire groin may occur over time, leaving Anchor Way more vulnerable to impacts of waves and SLR. The groin repairs will involve placement of additional armor stone to restore the original function of this structure by providing a consistent crest elevation and width along the groin.

6.3.2 Accommodate with Raised Revetment and Roadway

The existing elevation of the revetment ranges from 12 to 16 feet NAVD88. This strategy would raise the revetment uniformly to 16-18 feet NAVD88 along Anchor Way by building landward of the existing structure. The revetment would be backed by a concrete floodwall with an elevation of approximately 18-20 feet NAVD88 to achieve tolerable overtopping rate during the design event for a 2.3 feet SLR scenario (2070 under the High scenario, 2080 under the Intermediate-High scenario and 2100 under the Intermediate scenario). The raised revetment will extend landward of the current footprint to minimize impacts to subtidal habitats.

The existing elevation of the roadway ranges from 12 to 14 feet. The roadway next to the revetment would be raised to an elevation of 16-18 feet NAVD88, with the grade on the inboard of the road merging with the current parking lot. This would reduce some parking area along Anchor Way but provide improved circulation and pedestrian access. Parking and striping within the parking lot would be reconfigured for efficient use of the space. A new pedestrian pathway would be located between the flood wall and road, as there is currently no formal walkway on the seaward side of Anchor Way. This would also allow for fishing to continue to occur along this revetment.

7. Next Steps

The preferred alternatives described in Section 6 are considered the most feasible adaptation strategies among those evaluated in the multi-criteria analysis. These concepts have the highest likelihood of satisfying the project objectives to improve the resilience of transportation infrastructure along Highway 101 and Anchor Way and preserve valuable coastal resources in the project vicinity. These concepts are still in the early stage of design and may evolve as they are subject to greater level of scrutiny as the design evolves and more information is gathered about opportunities and constraints along the Project reach. This section outlines the anticipated next steps toward implementation of these concepts.

Improve Understanding of Marsh Wildlife Area Hydrology:

The Highway 101 preferred concept will require more analysis to better understand the hydrology and hydraulics through the culverts and marsh characteristics. The effects of changing the culvert hydrology at culvert 3 on the marsh, and in particular the western lily, should be studied to inform the basis of design. This will be an important analysis to develop a concept that avoids and minimizes impacts to environmentally sensitive habitats.

Continue Stakeholder Outreach and Communication:

Further communication and coordination with local landowners, including HAMBRO, Elk Valley Rancheria, and the private property adjacent to culvert 3, with the aim of collaborating toward a solution that aligns with existing or planned land uses. Stakeholder engagement should continue, building on the partnerships with DNLTC, CDFW, Del Norte County, CCHD, the Elk Valley Rancheria, and Caltrans. Public engagement will be an important piece of the project to update the public on project progress and receive feedback to incorporate into the design process. Coordination with Redwood Coast Transit as well as advocates for the Crescent Beach Trail and California Coastal Cycleway should be pursued to further consider multimodal and public transit in resilience planning efforts.

Establish Project Delivery Framework:

The development of this Plan was led by DNLTC, but the concepts identified would likely be implemented by other agencies. Highway 101 improvements would likely be administered by Caltrans and supported by local partners as needed for specific project elements. Anchor Way improvements would likely be administered by the CCHD. Defining the ownership and partnerships will be an important step toward implementation as both locations will likely be pursuing grant funds to advance through detailed design, permitting and construction.

Collect Data to Support Design:

Several surveys should be done to this end, including but not limited to a botanical survey, wetland delineation, biological survey, topographical survey, and a geotechnical survey. The botanical and biological surveys should include the Highway 101 prism and shoulders, beach, Marsh Wildlife Area, vegetated areas around each culvert, and living shoreline reference sites south of the Project Area (i.e., Enderts Beach). The topographic survey should include the Highway 101 prism, the subaerial beach, and the culverts. Property and right-of-way extents should be confirmed. The geotechnical survey should focus on beach sediment samples and bore samples from the eastern and western side of the road prism.

Incorporate Public Access and Connectivity Improvements:

The community strongly values South Beach and the public access opportunities in the area. Public engagement showed interest in improving access and constructing new amenities. Future projects should evaluate opportunities for improved connectivity with existing and planned recreational amenities at the northern and southern ends of South Beach. This could include California Coastal Trail and Coastal Cycleway connections, more accessible and safe paths to Harbor businesses, parcel acquisition for park and restroom amenities, and coordination with the Elk Valley Rancheria's Bush parcel recreational plans.

Consider Environmental Review Process:

The survey data described above will be important for refining the design concepts to avoid adverse impacts to the extent feasible and develop appropriate mitigation measures for coastal resource impacts. The refined design drawings will be used to develop a preliminary project description and kickoff the environmental review process and early consultation with the regulatory agencies. Project alternatives should also be identified and evaluated pursuant to local and state regulations.

Pursue Funding:

This report presents possible adaptation strategies to increase the resilience of the South Beach area transportation network. Additional considerations and studies described above are needed to further evaluate project feasibility and public needs. Funding for these studies would support enhanced coastal resilience, public access, and safety for a critical transportation lifeline in Del Norte County. Possible sources of grant funding to consider include the Active Transportation Program, Infrastructure and Investments and Jobs Act, Highway Safety Improvement Program, Proposition 4, Regional Surface Transportation Program, Sustainable Transportation Planning Grant, and Transformative Climate Communities.

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Appendices

Appendix A

Advisory Committee Summary

Advisory Committee Summary

1. Background

An Advisory Committee (Committee) was developed to oversee the development of the Project. The Committee was a collaboration of local and regional jurisdictions and governments. Committee members provided baseline conditions information based on their expertise of the Project Area and provided guidance on feasible project alternatives. The other important role of the Advisory Committee was to review project deliverables and share information with their stakeholders to ensure the Plan aligns with diverse community needs.

2. Advisory Committee Members

Members were invited by Del Norte Local Transportation Commission to participate in the Project's Advisory Committee.

Organization	Name, Title	Contact
Del Norte Local Transportation Commission (DNLTC)	Tamera Leighton, Executive Director	tameraleighton@dnltc.org
Crescent City Harbor District (CCHD)	2024-2025: Mike Rademaker, Asst. Harbormaster 2024: Tim Petrick, Harbormaster	mrademaker@ccharbor.com tpetrick@ccharbor.com
Elk Valley Rancheria (EVR)	2025: Crista Stewart, Chief Operations Officer 2024: Rob Jacob, Tribal Administrator Alternate 2025: Heather Pardue	cstewart@elk-valley.com rjacob@elk-valley.com hpardue@elk-valley.com
Caltrans District 1 (Caltrans)	Clancy De Smet, Climate Change Adaptation Branch – Senior Specialist, Caltrans – D1 Planning	clancy.desmet@dot.ca.gov
Del Norte County (County)	Heidi Kunstal, Director, Community Development Department	HKunstal@co.del-norte.ca.us
California Department of Fish & Wildlife (CDFW)	Michael van Hattem, Senior Environmental Scientist Supervisor, Eureka Field Office	michael.vanhattem@wildlife.ca.gov

3. Roles and Responsibilities

The Committee roles and responsibilities are as follows:

- Share information with the project team, including site data, issues, complexity, history and nuances of the Project and Project Area.
- Review monthly project update (action items and schedule).
- Review the agenda materials prior to the meetings and provide comments on the materials at least one day before the meeting.
- Attend quarterly meetings.
- Review all draft deliverables for all tasks.
- Review and approve all project materials before distribution to the stakeholder groups and to the public.
- When needed, the members will return to the groups they represent to request feedback regarding Committee agenda topics at every phase of the Project development.

4. Meetings

Six Committee meetings occurred over the course of the Project between 2024 to 2025. An agenda was sent to the Committee approximately one week prior to each meeting. A brief summary of each meeting is provided below.

4.1 Quarter 1 Meeting

Date: February 28, 2024

Attendees: DLNTC, CCHD, EVR, Caltrans, County, CDFW

Agenda and Notes Summary: At the first quarterly meeting the Project team provided a Project overview and discussed the roles and responsibilities of the Committee. The team presented an overview of their understanding of the site and the Committee provided additional context and feedback on historic and existing conditions. Members noted information and references they could share with the Project team.

4.2 Quarter 2 Meeting

Date: June 6, 2024

Attendees: DLNTC, CCHD, EVR, Caltrans, County, CDFW

Agenda and Notes Summary: GHD provided an overview of their data collection and document review. GHD described the coastal hazards analysis, which looked at coastal setting, sea level rise (OPC 2024 SLR Guidance), coastal flooding (FEMA), shoreline erosion (CoSMoS) and stability (CoastSat), and wave runup and overtopping (EurOtop and CEM). The sea level rise scenarios are evaluated at 0.8 feet, 2.3 feet, and 5.6 feet. The Committee provided input and validation of the presented site understanding and preliminary analysis, sharing observations of areas and events that seem consistent or in conflict with preliminary results. The group then discussed and planned for public outreach activities, including an online survey and public meetings.

4.3 Quarter 3 Meeting

Date: September 17, 2024

Attendees: DNLTC, CCHD, EVR, Caltrans, County

Agenda and Notes Summary: GHD presented draft vulnerability assessment maps of flooding extents and the Committee agreed the results looked reasonable based on past flooding events. GHD presented adaptation strategies (retreat, accommodation, and protection options). The group discussed potential locations for strategies and various tradeoffs. No retreat option was identified as feasible due to social and environmental impacts. GHD then presented example criteria to inform the selection of preferred alternatives; the Committee provided feedback. Lastly, the group continued public outreach planning.

The team followed up with CDFW in a separate individual meeting.

4.4 Quarter 4 Meeting

Date: December 16, 2024

Attendees: DNLTC, CCHD, EVR, Caltrans, County, CDFW, California Coastal Commission

Agenda and Notes Summary: The Committee reviewed the public meeting feedback received at two public meetings held in November and December. The Committee confirmed the criteria to use in selecting a preferred alternative. California Coastal Commission staff attended at the invitation from Caltrans and requested a meeting to further discuss the project and regulatory requirements.

4.5 Quarter 5 Meeting

Date: February 27, 2025

Attendees: DNLTC, EVR, Caltrans, County, CDFW

Agenda and Notes Summary: GHD presented the evaluation of the adaptation strategies and then presented the preferred solutions for Highway 101 and Anchor Way. Lastly, the group discussed the upcoming review schedule and expectations for Project deliverables. The Committee asked GHD to highlight more clearly the public access opportunities and potential impacts to sensitive natural communities and wetlands. Clarifying questions were also asked about transportation connections to private property and EVR's Bush parcel.

The team followed up with CCHD in a separate individual meeting.

4.6 Quarter 6 Meeting

Date: May 20, 2025

Attendees: DNLTC, CCHD, EVR, Caltrans, County, CDFW, California Coastal Commission

Agenda and Notes Summary: GHD reviewed the Plan and provided a high-level overview of some of the edits from Advisory Committee and Coastal Commission staff recommendations. Committee members felt the edits were responsive to their requests and that critical input had been incorporated into the Plan. Comments that were not addressed should be considered in future phases of the project. GHD reviewed the 30% design plans, and the Committee provided no recommendations for substantial changes. The Plan will be presented at upcoming DNLTC, CCHD, and EVR board/council meetings for review or approval.

5. Conclusion

The Committee provides valuable institutional knowledge about past and current conditions and represents views of the diverse needs and uses of the Project Area. It would be valuable for the Committee to continue meeting as South Beach transportation projects progress and consider adding additional members from the California Coastal Commission.

Appendix B

Public Engagement Summary

South Beach Climate Resilience Plan

Outreach Summary

Prepared by:

Green DOT Transportation Solutions

Prepared for:

Del Norte Local Transportation Commission

Table of Contents

List of Tables

List of Figures

0 EXECUTIVE SUMMARY

The Del Norte Local Transportation Commission (DNLTC) gathered extensive community feedback on the South Beach Climate Resilience Plan through surveys and public outreach in 2024–2025. In addition to comments specific to South Beach, the process also invited general input from the community on broader climate resilience and transportation concerns. Participation was strong overall, with 121 survey responses collected (approximately 86% from local Crescent City residents), plus dozens of public comments from community meetings, an online map input tool, and other general forums.

The community's sentiment underscores serious concern about frequent flooding and storm damage along South Beach's roadways, coupled with frustration at congestion during peak tourist seasons. Flooding, wave-driven debris, and traffic accidents emerged as dominant themes in public comments. At the same time, many respondents expressed a resilient attitude toward these disruptions, with some noting they "are used to them – that's what makes us Del Norte." Public feedback also offered constructive ideas—from improving drainage infrastructure to adding bike/pedestrian facilities—to enhance corridor resilience and safety. Additional general community comments supported similar priorities, emphasizing the need for region-wide flood mitigation and safe multi-modal access.

The key takeaways for DNLTC are to prioritize flood mitigation, efficient debris clearance, and traffic management in the South Beach area (and beyond), while preserving the beach's value to the community. The following report details the findings, including participation statistics, quantitative survey results, qualitative themes from open-ended responses, an overview of outreach efforts, and recommendations informed by the community's input—both from the South Beach-focused feedback and general comments about local climate resilience challenges.

1 OUTREACH METHODS

DNLTC undertook a comprehensive outreach program to gather both South Beach-specific and general community comments. Community feedback was collected via an online survey, in-person events, and an interactive comment database. The primary focus was on the South Beach Climate Resilience Plan, but survey respondents and meeting attendees were also encouraged to submit general comments about local transportation or resilience issues region wide. This multi-pronged approach ensured a robust dataset reflecting both the targeted needs of South Beach and the general perspectives of the broader community.

1.1. PUBLIC NOTICING

1.1.1. *Project Webpage*

A dedicated webpage on the DNLTC website was created to serve as a central hub for all information related to the Climate Resilience Plan. The webpage featured comprehensive details on the project's scope, the planning process, and a schedule of project milestones. It also provided information on community outreach meetings, project documents, and direct links to online surveys. The website was updated throughout the development of the Plan to reflect the latest progress and to encourage continuous community engagement.

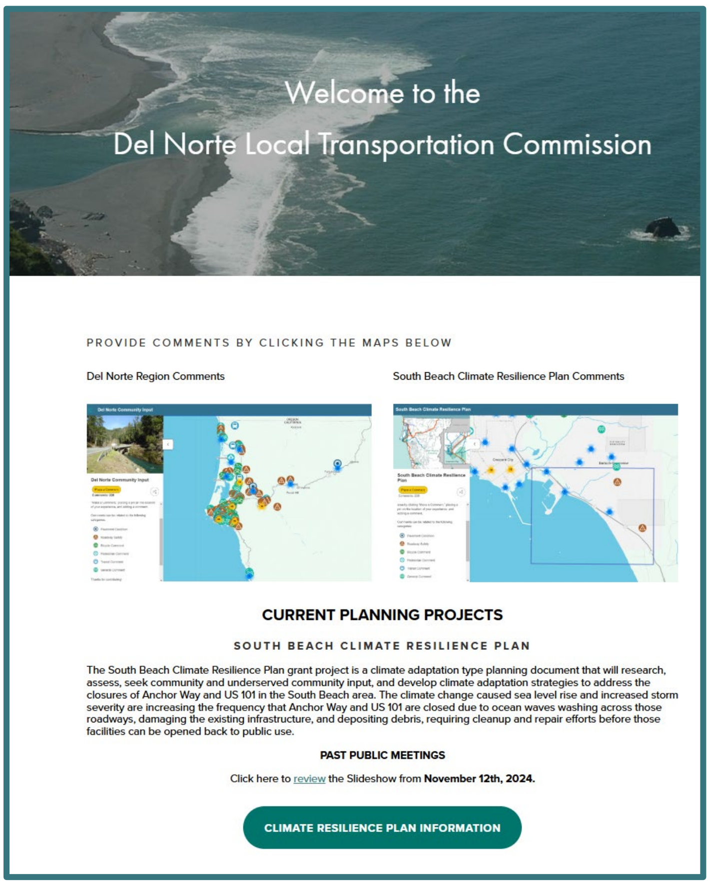


Figure 1.1: DNLTC Homepage

1.1.2. *Advertisements*

The Project Team distributed project information both online and in person. Graphics were posted on the DNLTC Facebook profile and flyers were posted a few weeks prior to ensure that community members could plan their schedules accordingly. Additionally, the Project Team reached out to various project partners, such as

Caltrans District 1, Crescent City Harbor District, and Elk Valley Rancheria to disseminate information through their available channels which included a digital fuel dispenser advertisement.

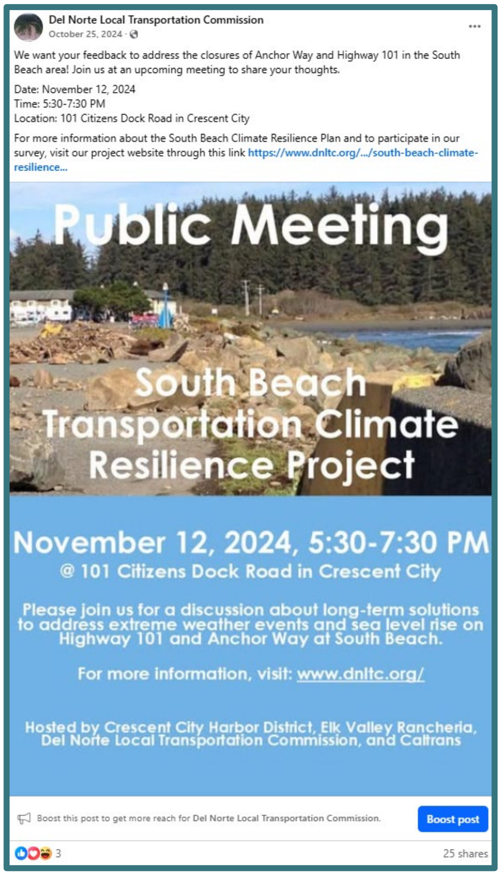


Figure 1.2: Public Meeting Advertisements

1.2. PUBLIC WORKSHOPS & EVENTS

1.2.1. *Del Norte Economic Summit (April 26, 2024):*

DNLTC Staff hosted a booth at the Del Norte Economic Summit on April 26, 2024. Information was provided to attendees while encouraging survey participation. In addition to collecting eleven paper surveys, general comments on resilience/transportation issues were noted.

1.2.2. *South Beach Workshops (November 12 and December 3, 2024):*

The Project Team hosted two public workshops on November 12, 2024 (19 attendees), and December 3, 2024 (15 attendees). Each meeting included a presentation introducing the Climate Resilience Plan, purpose of the plan, outreach process, hazards and vulnerabilities, and community needs. Throughout and after the presentation, community members were able to ask questions or give comments to the Project Team. Attendees shared location-specific concerns (on maps) and broader remarks on flood impacts, road safety, and climate adaptation. Fifteen paper surveys were completed on-site.

Presentation

The Project Team developed a presentation to deliver to attendees that described the purpose and goals of a Climate Resilience Plan and included important context to the corridor. Throughout the presentation there were opportunities for the public to interject and comment on the Plan or process.

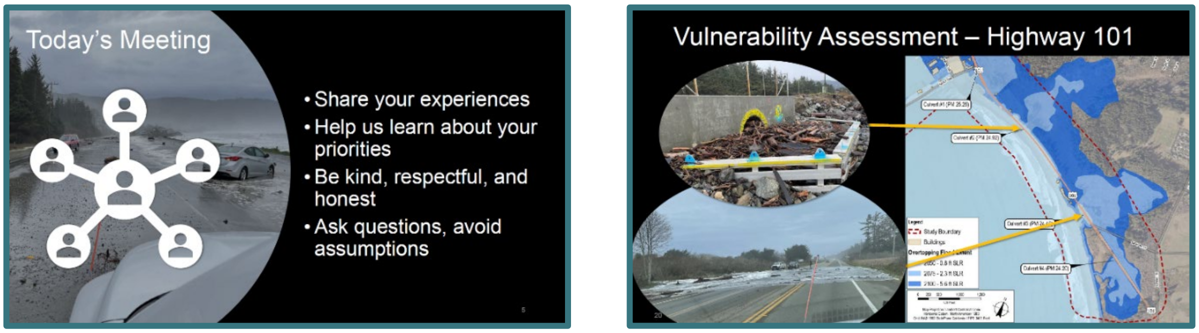


Figure 1.3: Presentation Slides

Corridor Map

The Project Team provided a map of the project area. Attendees were able to write or draw on the map to provide location specific feedback. This exercise allowed the attendees and the Project Team to collaborate on where potential improvements would be functional and practical based on the community's knowledge of the area.

Figure 1.4: Corridor Map Exhibit

1.2.3. *Final Workshop (May 22, 2025):*

The Project Team hosted a final public meeting online via zoom on May 22, 2025. Five members of the public attended. The meeting consisted of a 40-minute presentation of the draft Climate Resilience Plan and project recommendations as well as a 10-minute question/answer session. The meeting ended after no additional questions were posed.

Figure 1.5: Public Workshop Attendance

1.3. DATA COLLECTION

1.3.1. *Interactive Map & Comment Tool*

Community members were able to provide pinpointed feedback about specific sites or broader issues, tagged by category (e.g. Pavement Condition, Roadway Safety, Bicycle, Pedestrian, Transit, General). This tool captured both South Beach-specific and general community concerns about climate resiliency and the region. Over 70 comments were submitted, some addressing specific coastal trouble spots, others providing general concerns about drainage, pedestrian routes, or transit access.

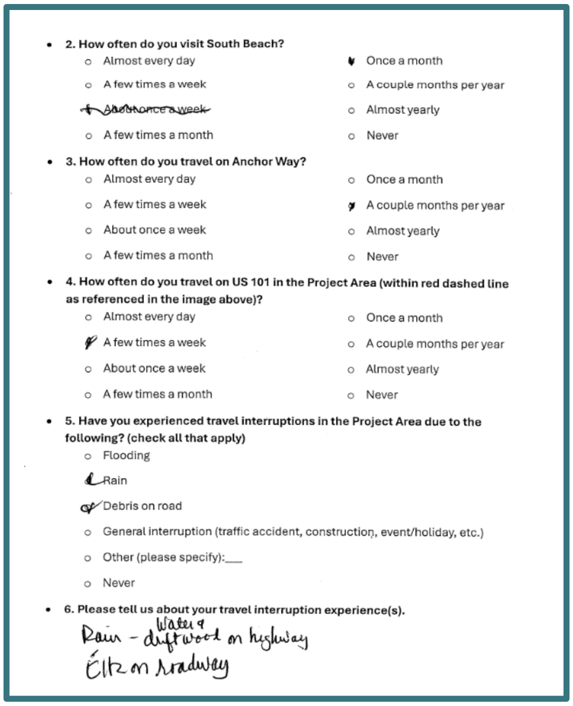
Figure 1.6: Community Input Tool

1.3.2. *Public Survey*

The public survey consisted of multiple-choice questions about travel frequency and experiences of disruptions, plus an open-ended question for further comments. It was made available on the project website and distributed during public events. Paper surveys filled out at the workshop were transcribed into the main survey database (contributing 26 responses).

Survey Participation

In total, 121 individuals completed the survey. The vast majority of respondents (about 86%) identified as local Crescent City residents, with a further ~9% working in the area and a small remainder being visitors or others. This indicates that feedback largely reflects the local community's perspective.



- 2. How often do you visit South Beach?
  - Almost every day
  - A few times a week
  - ~~About once a week~~
  - A few times a month
  - Once a month
  - A couple months per year
  - Almost yearly
  - Never
- 3. How often do you travel on Anchor Way?
  - Almost every day
  - A few times a week
  - About once a week
  - A few times a month
  - Once a month
  - A couple months per year
  - Almost yearly
  - Never
- 4. How often do you travel on US 101 in the Project Area (within red dashed line as referenced in the image above)?
  - Almost every day
  - A few times a week
  - About once a week
  - A few times a month
  - Once a month
  - A couple months per year
  - Almost yearly
  - Never
- 5. Have you experienced travel interruptions in the Project Area due to the following? (check all that apply)
  - Flooding
  - Rain
  - Debris on road
  - General interruption (traffic accident, construction, event/holiday, etc.)
  - Other (please specify):___
  - Never
- 6. Please tell us about your travel interruption experience(s).

Rain - Water & driftwood on highway
Elk on roadway

Figure 1.7: Physical Survey Response

2 DATA ANALYSIS

SurveyMonkey was used for the online survey, automatically compiling quantitative results. Open-ended answers (including transcribed remarks from paper surveys) were coded for key themes. The interactive map comments were exported to a database for analysis.

All input—South Beach-specific and broader community concerns—was reviewed and synthesized to identify common issues and suggestions. This report presents survey results with basic statistical summaries and visualization and qualitatively analyzes the narrative feedback. Direct quotes from participants are included (in italics) to highlight representative voices, and all data points are cross-referenced to the source records.

2.1. QUANTITATIVE ANALYSIS OF SURVEY RESULTS

2.1.1. *Frequency of South Beach Visits*

Survey participants reported how often they visit South Beach. The results show that South Beach is a popular and regularly frequented destination for locals. Nearly half of respondents visit at least once a week. About 16% visit almost daily and another 33% visit weekly or a few times per week, totaling ~49% who go at least weekly. Most others visit a few times per month—over 85% of respondents go to South Beach at least once a month. Only a very small minority (3%) said they "never" visit South Beach.

This indicates that any issues at South Beach (like road closures or travel hazards) potentially impact a large portion of the local community on a regular basis.

Table 2.1: How often do you visit South Beach?

Answer Choices	No. of Respondents	% Respondents
Never	4	3.31%
Almost every day	19	15.70%
A few times a week	19	15.70%
About once a week	21	17.36%
A few times a month	22	18.18%
Once a month	18	14.88%
A couple months per year	14	11.57%
Almost yearly	4	3.31%
TOTAL	121	100%

(Source: Survey Q2 results)

2.1.2. Travel on Anchor Way and Highway 101

Two key roadways serve the South Beach area—Anchor Way (the local access road) and US Highway 101 (the main regional corridor). Two survey questions asked how frequently people travel on each:

Anchor Way: Usage varies, with many locals using it somewhat regularly but not daily. The most common response was "a few times a month" (~30%). About 23% travel on Anchor Way at least weekly (8% almost daily, 15% a few times a week). Only ~3% said they never use Anchor Way, meaning 97% of respondents use it at least occasionally.

Highway 101 in Project Area: Highway 101 is heavily utilized by virtually all respondents. None reported "never" using Highway 101 in the South Beach project area, and over half (53%) drive it at least a few times a week. Nearly 80% use it at least monthly.

These patterns highlight that Highway 101's reliability is critical, and Anchor Way, while less traveled daily, is still a common route for beachgoers. Any long-term closure on Highway 101 would force the majority of residents to take lengthy detours, and problems on Anchor Way can affect local access to coastal businesses and recreation.

2.1.3. Travel Interruptions Experienced

The survey asked whether residents had experienced travel interruptions in the South Beach area (multiple answers allowed). As shown in Figure 2.1, nearly everyone has encountered some form of disruption, most often from natural hazards. Only 18% said they never experienced an interruption—meaning over 80% have dealt with disruptions at South Beach.

A small number (~8%) cited "Other" causes (e.g., wildlife on the road, Last Chance Grade closures). For example, one person noted "Tire rim destroyed on Last Chance Grade" – showing how regional highway issues compound local traffic.

These quantitative findings confirm that flood-related disruptions and roadway debris are commonplace in South Beach, and that traffic accidents or congestion events are similarly widespread. This aligns with general community comments as well, which emphasized the impacts of winter storms, sea-level rise, and seasonal traffic on local roads throughout the Del Norte region.

Debris on the road and traffic-related interruptions top the chart, each impacting roughly half of those surveyed, followed closely by flooding. Rain is a lesser but notable factor, while a small percentage have never had any interruption.

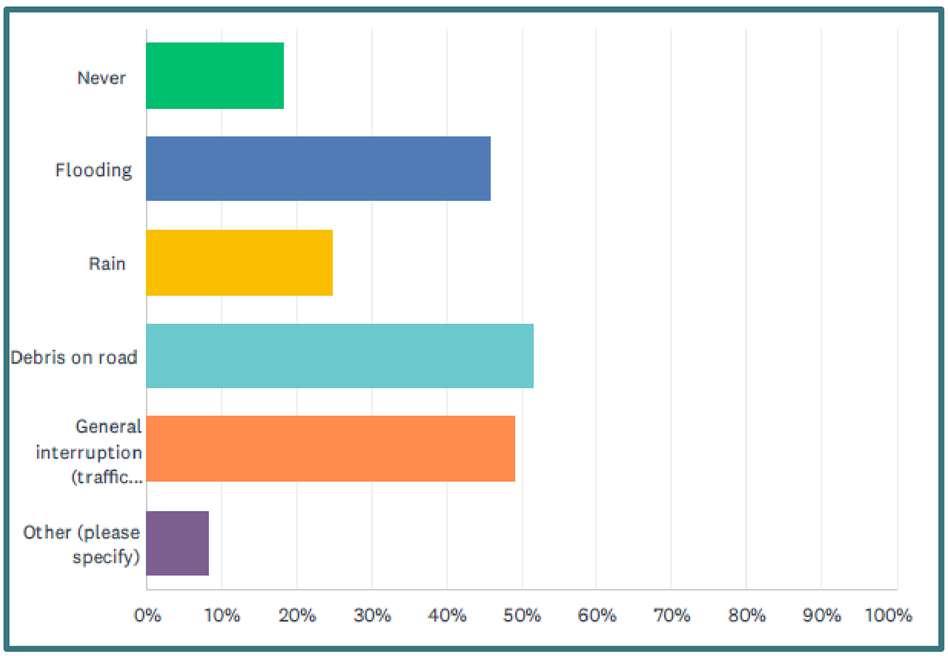


Figure 2.1: Causes of Travel Interruptions (Survey Q5)

Note: Share of respondents who have experienced interruptions from each cause (multi-select).

2.2. QUALITATIVE ANALYSIS OF COMMUNITY FEEDBACK

Open-ended survey responses and written comments (including general community feedback) were analyzed to identify recurring concerns, needs, and suggestions. The following major themes emerged:

2.2.1. *Coastal Flooding and Storm Impacts*

The most prevalent concern is the flooding of South Beach roadways during extreme high tides and storms. Dozens of respondents described King Tide inundation, waves overtopping the highway, and standing water on both Anchor Way and Highway 101. Flooding is often accompanied by driftwood and sand deposits.

> *"King tides with coastal storms are the most common blockage to the road."*

Several respondents noted entire road closures:

> *"Hwy 101 was flooded on multiple occasions – I had to be rerouted."*

When flooding shuts down Highway 101, travelers often detour via inland backroads (e.g., Howland Hill Road), adding time and complexity to trips. Concern is growing that these closures may increase with climate change.

Residents also flagged stormwater drainage issues, especially in low-lying areas near the harbor and wetlands. A few suggested infrastructure fixes (e.g., larger culverts, tide gates). One person wrote that a particular culvert needs maintenance because *"frequent debris clogs [it]; consider replacing with a tide gate"* to prevent backflow. General comments echoed similar flood concerns around Crescent City and other coastal stretches, indicating a region wide need for better drainage and protective measures.

2.2.2. *Roadway Debris and Maintenance*

Closely tied to flooding is the issue of debris on the road. Many respondents described encountering logs, branches, rocks, and other storm-driven materials.

> *"Debris on road caused by high tides. Flooding due to blocked culverts. Delays caused by heavy equipment needed to clear road."*

This highlights how debris and flooding often go hand-in-hand. While participants acknowledged Caltrans and the County typically respond to clear the highway, several suggested proactive measures: installing sand fences or barriers to catch driftwood, more frequent pre-storm street sweeping, and designating quick-response maintenance teams in winter. Windblown sand on Anchor Way's bike/ped path was also mentioned. General commenters also cited debris hazards on other county roads, suggesting a broader approach to roadway cleanup and maintenance.

2.2.3. *Traffic Congestion and Safety (Peak Seasons)*

Beyond weather, traffic congestion during tourist seasons was a major theme. On busy summer weekends and holidays (e.g., 4th of July), South Beach roads become crowded, leading to slow traffic and difficulty entering/exiting Highway 101.

> *"During the summer, the area is congested. I know that it floods with the King tides and avoid the area."*

Another noted:

> *"4th of July weekend is especially busy...It's always hectic and there are often accidents in that reach during the weekend."*

Such congestion also raises safety concerns; vehicles may queue on shoulders or make risky maneuvers. The Anchor Way & Hwy 101 intersection was repeatedly mentioned as problematic, especially for left turns. One "Other" write-in response said: "Inability to make left turn from Anchor Way onto 101 due to heavy traffic in summer months."

Suggestions included a dedicated turn lane, a traffic signal, or improved signage. Comments about speeding and pedestrian safety were common, too—locals want more enforcement and traffic control during peak times. General comments about tourism-related congestion in other coastal hotspots reinforced that crowding issues are not limited to South Beach alone.

2.2.4. Accidents and Road Closures

Several comments recounted specific traffic accidents causing delays, including vehicle collisions on the narrow stretch of Highway 101 near South Beach. Construction-related closures have had similar effects. When incidents occur on a flood-prone or debris-strewn highway, the impacts can be severe—traffic may back up for miles or be fully halted.

Community feedback suggested a desire for more redundancy and quick incident response. Some asked about alternate routes or emergency access roads for times when Highway 101 is blocked. General commenters connected this issue with larger regional chokepoints like Last Chance Grade, noting that closures in one area can divert or overload traffic in others.

2.2.5. Wildlife and Other Hazards

A few respondents mentioned hazards like elk on the road or pedestrians crossing illegally, which add to safety risks. Beach visitors sometimes cross Highway 101 away from designated crosswalks; one comment described families "dashing across high-speed traffic." Wildlife crossings (especially for the local Roosevelt elk herd) are harder to control, but signage could help.

Such hazards were also noted in general community inputs, which often cited encounters with elk or deer in other parts of the region. Overall, these issues, though less frequent than flooding or traffic, still contribute to local safety concerns.

2.2.6. *Community Value of South Beach*

Despite these challenges, South Beach is cherished by the community. Many described South Beach as a vital recreational and economic asset—

> *"It brings in tourism and is a significant community asset."*

People want it to remain accessible and safe. This sentiment underlies support for resilience measures that protect roads and beaches from climate impacts, as well as general improvements that keep residents and visitors safe. For instance, some suggested building an elevated multi-use path or seawall that doubles as protection from wave action. Others advocated for natural shoreline buffers to complement existing armor structures.

General comments throughout the region similarly stressed preserving scenic coastal resources while adapting to sea-level rise and extreme weather. In short, there is broad recognition that balancing recreational value, economic vitality, and resilience is crucial.

3 CONCLUSION AND RECOMMENDATIONS

The community feedback—specific to South Beach and more general—provides clear direction for improvements under the South Beach Climate Resilience Plan, as well as insights applicable throughout the Del Norte region. The highest priority is mitigating roadway flooding and debris issues that regularly impede travel on Highway 101 and Anchor Way.

Traffic management emerged as another major recommendation, especially during peak tourist seasons. Intersection improvements at Anchor Way/101 (e.g., a left-turn lane or a "smart" signal) could ease congestion and reduce crash risk. During high-traffic holidays or events, temporary signage or traffic control measures (like flaggers) may be warranted. General comments supported similar strategies at other busy corridors regionwide.

Further, improving multi-modal safety aligns with resilience by offering alternatives to driving when roads are compromised. Constructing a multi-use path linking Crescent City and South Beach—potentially on an elevated berm or seawall—was a popular suggestion for both recreational and protective benefits. In the short term, ensuring sidewalks and shoulders remain clear (e.g., vegetation trimming, crosswalk improvements) is vital, as many locals and visitors prefer walking or biking in coastal areas.

Lastly, the community values preserving South Beach's recreational and scenic character. Resilience measures should maintain or enhance beach access, scenic views, and economic potential. Where feasible, aesthetic features (e.g., attractive seawall designs, integrated overlooks) could support tourism and community enjoyment. General feedback around the region echoed a similar desire to balance environmental stewardship with infrastructure upgrades.

Moving forward, Del Norte region residents have voiced a strong desire for a corridor—and a broader transportation network—that remains safe and open year-round despite extreme weather and rising seas. They acknowledge current challenges and are ready to see tangible actions. To reflect the community's top priorities the following should be considered:

- **Reduce flood risk** on Highway 101 via drainage upgrades, raised roadbeds, and protective structures.
- **Streamline storm cleanup**, ensuring debris is removed quickly and proactively.
- **Enhance traffic flow and safety** at key conflict points, especially during peak visitor seasons (Anchor Way intersection, holiday congestion management).
- **Strengthen multi-modal options** (bike/ped facilities) to boost resilience and provide safe alternatives.
- **Preserve community assets**, ensuring any protective infrastructure maintains beach access, scenic quality, and recreational opportunities.

Embracing the input from both South Beach-focused participants and the broader community will ensure the plan's recommendations resonate with local values. It will also result in a stronger, more resilient South Beach corridor that aligns with wider region objectives for climate adaptation and transportation reliability. As one community member aptly put it:

> *"Community wants to keep South Beach… it is a vital part of the local community."*

Additionally, one project team member concluded:

"This is great project and ties into the Harbor's visioning. It provides a great mix of solutions and ideas to enhance use. We want to see this project move forward. This study will support funding applications, and we are identifying potential funding sources now."

By acting on this feedback, the connectivity to South Beach and the region can be safeguarded.

Appendix C

Board Review Document

Del Norte Local Transportation Commission Meeting June 3, 2025

The Del Norte Local Transportation Commission accepted the South Beach Climate Resilience Plan on June 3, 2025. The staff report is pictured below and can be found on dnltc.org.

900 Northcrest Drive, PMB 16
Crescent City, California 95531
www.dnltc.org

Del Norte Local Transportation Commission

Tamera Leighton, Executive Director
Tamera@DNLTC.org
Desk: (707) 465-3878
Cell: (707) 218-6424

Item E Staff Report

DATE: JUNE 3, 2025
TO: DEL NORTE LOCAL TRANSPORTATION COMMISSION
FROM: TAMERA LEIGHTON, EXECUTIVE DIRECTOR
SUBJECT: ACCEPT THE SOUTH BEACH CLIMATE RESILIENCE PLAN

REQUESTED ACTION and TAC RECOMMENDATION: By consensus, accept the South Beach Climate Resilience Plan.

BACKGROUND: The South Beach Climate Resilience Plan was initiated in FY 2023-24 and is funded with a Caltrans planning grant and DNLTC funds. With the leadership of GHC, inc. and partner agencies, the project has moved through the scope of work and the document is complete. Elk Valley Rancheria and Crescent City Harbor District are partners in the project.

This plan is the first of many future steps through the project development process. It is a high-level planning document for the benefit of the Del Norte community and partners who own the existing land and infrastructure in the South Beach area. The Plan addresses significant flooding and damage issues in the South Beach area, impacting critical transportation corridors like Highway 101 and Anchor Way. Initiated due to community concern with traffic and safety, the project builds on the previous studies, which highlighted the area's vulnerability to Sea Level Rise and storm events, by evaluating the combined impacts of waves and Sea Level Rise.

The project process involved assessing existing and future coastal hazards, conducting a vulnerability assessment, and developing adaptation strategies. Coastal hazards such as waves, Sea Level Rise, tsunamis, and shoreline change were analyzed to create flood and asset maps, identifying how assets in the project area are vulnerable. Adaptation strategies were developed and evaluated using a multi-criteria analysis, incorporating public feedback and advisory committee input. A preferred solution was then developed, combining different strategies to enhance resilience for the local and regional transportation facilities of Anchor Way and Highway 101.

The final presentation can be viewed for 10 days here: Passcode: #zz@^Cx0

https://us02web.zoom.us/rec/share/gflAHo2mt0_o7GZYEdaf-Der65bJLfE66B9R9vGzlxTUTf8EsaXPoS3aAPMbyP9F.DQjTjMV6sau4iM8d

Appendix D

Document List

GHD obtained reference material related to historic events, existing conditions, hazards, and policy from online sources and from the Technical Advisory Committee (Table D-1) during the initial stages of the project. These sources were utilized throughout the analysis, as relevant.

Table D-1. Document List

Date	Author/For	Document Name	Category
2015	DNLTC	Climate Change and Stormwater Management Plan	Existing Conditions, Hazards
2017	DNLTC	Elk Valley Multimodal Corridor Plan	Existing Conditions, Hazards
2019	CCHD	AB691 SLR Assessment	Historic and Existing Conditions, Hazards
2023	CCHD	Crescent City Harbor District Certified Harbor Land Use Plan	Historic and Existing Conditions, Policy
2021	CCHD	Del Norte County Offshore Wind Preliminary Feasibility Assessment	Existing Conditions
2018	CCHD	Crescent City Harbor District Strategic Plan 2018-2028	Existing Conditions
1978	County	Flood Drainage Study for an Area North of Crescent City	Existing Conditions, Hazards
1978	County	Hydrology Manual for an Area North of Crescent City	Existing Conditions, Hazards
1978	County	Drainage Plan Index Map	Existing Conditions, Hazards
1983	County	County of Del Norte Local Coastal Plan	Policy
2019	County	County Hazard Mitigation Plan	Existing Conditions, Hazards
2020	County	County Regional Transportation Plan	Existing Conditions, Hazards
2022	County	County Local Road Safety Plan	Existing Conditions, Hazards
2023	County	Del Norte Office of Emergency Services Emergency Evacuation Plan (May 30, 2023)	Existing Conditions, Hazards
	County	Ortho data	Existing Conditions
2003	Caltrans	Project Study Report (south of Enders Beach to north of Sand Mine Road)	Existing Conditions, Hazards
2021	Caltrans	Hambro Family Entertainment Center Comment Letter (May 27) (provided by DNLTC)	
2021	Caltrans	Caltrans District 1 Adaptation Priorities Report	Existing Conditions, Hazards
2019	Caltrans	Caltrans District 1 Vulnerability Assessment Summary Report	Existing Conditions, Hazards
2011, 2017, 2019, 2023	Caltrans	Post storm maintenance, emergency repair task orders, and damage photos	Historic and Existing Conditions, Hazards
2024	Caltrans	State Climate Resilience Improvement Plan for Transportation (SCRIPT)	Policy
	Caltrans	Culvert line work	Existing Conditions
	Caltrans	Traffic volumes	Existing Conditions
	Caltrans	Culverts drawings (Caltrans, County)	Existing Conditions, DWG
2018, 2024	California Coastal Commission	Sea Level Rise Policy Guidance and online tools (https://www.coastal.ca.gov/climate/slr/tools/)	Policy Guidance, Hazards

Date	Author/For	Document Name	Category
2021	California Coastal Commission	SLR Guidance for Critical Infrastructure	Policy Guidance
2003	CDFW	Crescent City Marsh Wildlife Area Draft Management Plan	Existing Conditions, Policy
2004	CDFW	Crescent City Marsh Wildlife Area Grazing Impacts Monitoring Plan: First Year	Existing Conditions
2015	CDFW	Crescent City Marsh Wildlife Area Coastal Development Permit Staff Report (drainage ditch repair)	Existing Conditions
2015	CDFW	Assessment Information for the Crescent City Marsh Wildlife Area Ditch Excavation Project	Existing Conditions
2017	CDFW	Proposed Mitigated Negative Declaration for the Crescent City Marsh Wildlife Area Endangered Western Lily Habitat Enhancement	Existing Conditions
2021	Smith River Alliance	Elk Creek Restoration Feasibility Study	Existing Conditions
2018, 2024	Ocean Protection Council	Sea Level Rise Guidance (2018 Update and 2024 Draft)	Policy Guidance, Hazards
	Cal Adapt	Precipitation and Runoff data	Hazards
	Pacific Institute	Coastal Hazard Maps	Hazards
	UCSD	Coastal Data Information Program (CDIP) Wave Buoy Data	Hazards
2022	State	California Climate Adaptation Strategy	Hazards
2015	FEMA	FEMA Intermediate Data Submission (IDS) 3 and 4	Existing Conditions, Hazards
2017	FEMA	Flood Insurance Study	Hazards
	FEMA	FEMA flood zones	Hazards, GIS
	NOAA (Mosaic of 2009, 2015 mosaic)	topographic/bathymetric data	Existing Conditions, GIS
	NOAA	(https://coast.noaa.gov/digitalcoast/)	Hazards
	NOAA	Tidal Gage data and projections for Crescent City area	Hazards
	USGS	Coastal Storm Modelling System (CoSMoS)	Hazards, GIS
	Census Places / Del Norte County Website	municipal boundaries, parcels/APNs, ownership	Existing Conditions, GIS
	National Hydrography layer	waterways	Existing Conditions, GIS
	ArcGIS statewide layer	disadvantaged community boundaries	Existing Conditions, GIS
	ArcGIS Coastal Zoning	land use/zoning	Existing Conditions, GIS
	Made from DEM	contributing watersheds	Existing Conditions, GIS

Appendix E

Multi Criteria Analysis Summary

The key criteria that is used to frame the MCA are as follows:

- Alternatives for US 101 to remain a functional multi-modal transportation corridor considering climate change caused sea level rise, higher tide levels, and storm surge.
- Alternatives for Anchor Way to remain functional considering climate change caused sea level rise, higher tide levels, and storm surge.
- Alternatives should maintain public access along US 101 to the existing South Beach area.
- Alternatives should consider short and long-term environmental effects to the marsh area.

Criteria	Considerations	Retreat: Detour route	Retreat: Inland through marsh	Protect: Revetment	Protect: Living shoreline	Accommodate: Raise roadway	Accommodate: Causeway	No Project
Coastal Hazards								
Flood Protection (runup)	Does project reduce the risk of flooding during extreme events? Does the project accommodate SLR?	Flooding mitigated in short-, medium-, and long- term	Flooding mitigated in short-, medium-, and long- term	Flooding mitigated in short- and medium-term (20-30 years)	Flooding mitigated in short- and medium-term (20-30 years)	Flooding mitigated in short-, medium-, and long- term	Flooding mitigated in short-, medium-, and long- term	No improvement, current delays/closures (couple times per year for less than 24 hours) will increase. 2070+100-year event=prolonged shutdowns of Anchor Way and Highway 101 for cleanup and repairs. 2100=erosion and frequent overtopping would likely destroy the existing roadway.
Erosion Protection	Erosion is currently occurring along the road prism. Will the project increase erosion here or elsewhere? Will the project provide low, moderate, or high erosion protection?	No coastal erosion	No coastal erosion	Increased erosion protection	Moderate erosion protection	No erosion protection	Roadway protection not needed	No erosion protection
Design Life / SLR Resilience	Anticipated longevity of the design of the structure, also considers typical engineering standards and estimates. Assuming time horizon scenarios are short-term 2050: 100-yr storm and 0.8 ft of SLR; mid-term 2070:100-yr storm and 2.3 ft of SLR; and long-term 2100: 100-yr storm and 5.6 ft of SLR.	Out of SLR vulnerability area	Out of SLR vulnerability area	Effective to medium-term	Effective to short- and medium-term	Effective to medium-term	Effective to long-term	Not effective
Transportation								
Operational Downtime	Operational downtime and maintenance includes closure of road due to flood and debris, debris removal, and repairs due to storm damage. Downtime to flooding induced maintenance may be: closed more often due to increase impact, no change from current downtime, or closed fewer times/year.	No downtime from coastal storm damage	No downtime from coastal storm damage	Decreased downtime from coastal storm damage	Decreased downtime from coastal storm damage	Decreased downtime from coastal storm damage	Decreased downtime from coastal storm damage	Increased due to increased storm frequency and severity
Emergency Response	Emergency vehicles can traverse the route.	Maintained	Maintained	Maintained	Maintained	Maintained	Maintained	Maintained, decreased due to access vulnerabilities during/after storms
Traffic through community	Increased traffic on residential and non-highway streets. Increased impact if traffic on is completely re-routed through residential and non-highway streets. Decreased impact if detours are reduced.	Significantly increased	Decreased	Decreased	Decreased	Decreased	Decreased	Increased, detours will occur more frequently due to increased storm frequency and severity

Criteria	Considerations	Retreat: Detour route	Retreat: Inland through marsh	Protect: Revetment	Protect: Living shoreline	Accommodate: Raise roadway	Accommodate: Causeway	No Project
Multimodal Transportation Options	Project effect on multimodal transportation options. Are there opportunities to improve biking, walking, or public transit?	Safety concerns due to increased traffic. Limited space to improve bike/pedestrian access and bus stops	Limited bike/pedestrian access, bus stops	Possible, space dependent	Possible, space dependent	Possible, space dependent	Possible, space dependent; may provide fewer opportunities due to cost of widening causeway	No change
Public Access								
Parking	Impacts to parking along the 101 could include further limiting parking, no change, or increase/formalize parking.	No parking provided on new alignment would provide beach access. Abandonment of existing Highway could reduce access/parking along South Beach unless the area is maintained through a separate project	No parking provided on new alignment would provide beach access. Abandonment of existing Highway could reduce access/parking along South Beach	Minor reduction in narrow areas from encroachment into parking to minimize encroachment into beach	Reduced from encroachment into parking at some locations	Minimal change	Reduced, no parking provided along causeway	Roadside parking may decrease as erosion occurs
Scenic Resources	Does the Project enhance the aesthetics or view corridors of the Highway 101, beach goers, and the community? Assumes that current view corridors are ideal but views of the marsh can be improved by raising the roads.	Scenic views from Highway reduced due to relocation of Highway 101	Scenic views from Highway reduced due to relocation of Highway 101	Maintained	Maintained/Improved	Maintained/Improved	Maintained/Improved; would change views of the project area the most compared to other strategies	No change
Access to South Beach	Informal trails to South Beach exist along 101. Project will either keep current informal trails, or provide adequate accessway to beach if informal trails are no longer available. Consider impact to access, equivalent access or improvement.	Beach access along Highway 101 eliminated (access could be provided by existing route in near term, if not protected it is vulnerable mid-long term)	Beach access along Highway 101 eliminated (access could be provided by existing route in near term, if not protected it is vulnerable mid-long term)	Designated access points via ramp/stairs	Designated access points via trails	Designated access points via ramp/stairs	Limits access to only two points: north and south, dependent on space for on-off ramps	No change, roadside access may become more dangerous as erosion occurs
Impacts to Beach	Impacts to 'towel space'/beach footprint. Strategies that maintain access to beach would be favorable to the California Coastal Trail while strategies that do not maintain the beach would have negative California Coastal Trail impacts.	Dependent on existing highway prism repurpose	Dependent on existing Highway repurpose	Larger footprint encroaches on beach space; limits shoreline erosion process; could impact coastal trail access	Larger footprint encroaches on beach space but sand and cobble provide additional recreation opportunities	No encroachment on beach space	Natural beach processes restored in some parts without beach backed by roadway	No change, continues to erode and shift landward; could impact coastal trail access
Access to Amenities (restrooms*, shops, etc.)	Is access to existing amenities maintained, decreased or are there opportunities for new amenities?	None likely provided along new route due to limited space and further distance from South Beach	None likely provided along new route due to limited space and further distance from South Beach	No change	No change	No change	Dependent on space for on-off ramps	No change
Habitats								
Habitats* (dune, marsh)	Can the project improve habitats? Will the project negatively impact habitats?	May impact roadside wetlands. Some areas of existing road prism could be restored	High impact, most environmentally damaging option. Rare plants and sensitive natural communities likely impacted. Some areas of existing road prism could be restored	Roadside wetlands likely impacted. Rare plants and sensitive natural communities may be impacted. Could impact low value habitats (invasive species), would reduce beach with rock	Roadside wetlands likely impacted. Rare plants and sensitive natural communities may be impacted. Could impact low value habitats (invasive species)	Roadside wetlands likely impacted. Rare plants and sensitive natural communities may be impacted	Roadside wetlands likely impacted. Rare plants and sensitive natural communities may be impacted. Some areas of existing road prism could be restored	None
Natural features in strategies	Can nature-based features be incorporated in the design?	Limited space to incorporate nature-based solutions due to nearby existing development	Not feasible	Could be paired with nature-based strategies	Includes nature-based strategies	Could be paired with nature-based strategies	Minimal opportunities on the north and south ends of the project area	None
Marsh Drainage	Is the Marsh drainage system improved to decrease clogging of the drains and facilitate SW outflow? Does the changed hydrology impact marsh species?	Dependent on existing highway prism repurpose	Uncertain	Maintained	Drainage risks from living shoreline materials blocking culverts, requiring maintenance	Maintained	Current drainage would be significantly modified with uncertain impacts to marsh and Western Lily	Impact from debris and flooding will increase, drainage will continue to be problematic

Criteria	Considerations	Retreat: Detour route	Retreat: Inland through marsh	Protect: Revetment	Protect: Living shoreline	Accommodate: Raise roadway	Accommodate: Causeway	No Project
Constructability								
Design Standards	Is it likely that Caltrans design standards can be met?	Difficulty meeting standards within limited space and existing development	Can be met	Can be met	Can be met	Can be met	Can be met	N/A
Temporary Impacts	How might the project impact the community temporarily? This concern was voiced by the community.	High construction impacts to community	Construction detour impacts to community	Construction detour impacts to community	Construction detour impacts to community	Construction detour impacts to community	Construction detour impacts to community	Minimal due to maintenance
Regulatory								
CEQA/NEPA Process	Length and complexity of environmental process. Are there likely to be significant unavoidable impacts? Are there likely to be environmental justice concerns?	Likely areas of high concern: aesthetics, air quality, greenhouse gas, noise, land use, transportation, environmental justice	Likely areas of high concern: biology, hydrology; extensive mitigation required	Typical process	Typical process	Typical process	Likely areas of high concern: noise, hydrology, public access	None
Permitting Process	Length and complexity of permits and/or major challenges for approval.	Construction would be typical for road improvements, difficulties could arise due to acquisition/condemnation	Significant permit concerns with retreat into marsh; extensive mitigation required	New revetment is rarely permitted	Benefits to incorporating natural solutions preferred by regulatory agencies	Typical for road improvements	Permit concerns related to marsh impacts and drainage	Frequent emergency repair permits
Costs								
Construction Cost	Initial cost of construction to implement each alternative and potential mitigation costs. Costs are considered comparatively between projects.	High construction and acquisition costs. Would likely require mitigation costs.	High construction and acquisition costs. Very high mitigation costs.	Low to medium construction costs. Would likely require mitigation costs.	Low to medium construction costs. Would likely require mitigation costs.	Low to medium construction costs. Would likely require mitigation costs.	Very high construction costs. Would likely require mitigation costs.	None
Long-term Maintenance & Operation Costs	Costs to maintain and adaptively manage the Project. Costs are relative to each option and based on recent similar projects within California.	Low maintenance costs. If existing route is kept for beach access, maintenance costs would increase.	Low maintenance costs. If existing route is kept for beach access, maintenance costs would increase.	Low maintenance costs	Occasional renourishment and culvert maintenance	Erosion maintenance costs would increase if no protection is incorporated	Low maintenance costs	Moderate maintenance cost increase due to increased storm severity and frequency

The key criteria that is used to frame the MCA are as follows:

- Alternatives for US 101 to remain a functional multi-modal transportation corridor considering climate change caused sea level rise, higher tide levels, and storm surge.
- Alternatives for Anchor Way to remain functional considering climate change caused sea level rise, higher tide levels, and storm surge.
- Alternatives should maintain public access along US 101 to the existing South Beach area.
- Alternatives should consider short and long-term environmental effects to the marsh area.

Criteria	Questions to consider	Accommodate: Elevate revetment & roadway	Protect: Repair & extend stub jetty	No Project
Coastal Hazards				
Flood Protection (runup)	Does project reduce the risk of flooding during extreme events? Does the project accommodate SLR?	Improves flood protection for Anchor Way in the short- and medium-term	Improves flood protection for Anchor Way in the short- and medium-term	No improvement
Erosion Protection	Erosion is currently occurring along the road prism. Will the project increase erosion here or elsewhere? Will the project provide low, moderate, or high erosion protection?	Increased erosion protection	Increased erosion protection	No improvement
Design Life / SLR Resilience	Anticipated longevity of the design of the structure, also considers typical engineering standards and estimates. Assuming time horizon scenarios are short-term 2050: 100-yr storm and 0.8 ft of SLR; mid-term 2070:100-yr storm and 2.3 ft of SLR; and long-term 2100: 100-yr storm and 5.6 ft of SLR.	Effective to medium-term	Effective to medium-term	No improvement
Transportation				
Operational Downtime	Operational downtime and maintenance includes closure of road due to flood and debris, debris removal, and repairs due to storm damage. Downtime to flooding induced maintenance may be: closed more often due to increase impact, no change from current downtime, or closed fewer times/year.	Decreased downtime from coastal storm damage	Decreased downtime from coastal storm damage	Increased due to increased storm frequency and severity
Emergency Response	Emergency vehicles can traverse the route. This includes access to boating facilities for aquatic rescues.	Improved access during storm events	No change	Decreased due to access vulnerabilities during/after storms
Multimodal Transportation Options	Project effect on multimodal transportation options. Are there opportunities to improve biking, walking, or public transit?	Improved biking/walking pathways	No change	No change
Public Access				
Parking	Impacts to parking along Anchor Way could include further limiting parking, no change, or increase/formalize parking.	Site circulation could be improved and parking formalized and improved	No change	No change
Scenic Resources	Does the Project enhance the aesthetics or view corridors of the harbor, beach goers, and the community? Assumes that current view corridors are ideal.	Revetment and formalized walkways would be designed to maintain or enhance views	No change or minimal	No change
Access to South Beach	Informal trails to South Beach exist along Anchor Way. Project will either keep current informal trails, or provide adequate accessway to beach if informal trails are no longer available. Consider impact to access, equivalent access or improvement.	Designated access points via trails, ramp, or stairs	No change	Erosion could impact access
Access to Whaler Island	Change to access and recreational opportunities on Whaler Island	Maintained	No change	Damage to revetment could impact access
Access to Amenities (restrooms*, etc.)	Change in access to existing amenities, opportunities for new amenities.	Maintained/improved	No change	Damage to revetment could impact amenities
Commercial & Recreational Fishing	Change to fishing access and opportunities.	Maintained/improved	Maintained	Damage to revetment could impact fishing access and harbor safety
Habitats				
Whaler Island Habitat	Can the project improve habitats? Will the project negatively impact habitats?	No encroachment into habitats	No impacts to Whaler Island are expected. Temporary impacts to surrounding habitats may occur; long term establishment of more intertidal habitat	None
Natural features in strategies	Can nature-based features be incorporated in the design?	None	None	None
Constructability				
Design Standards	Is it likely that relevant design standards can be met?	Can be met	Can be met	N/A
Temporary Impacts	How might the project impact the community temporarily?	Impacts to some operations and access	Impacts to some access and recreation	Minimal due to maintenance
Regulatory				
CEQA/NEPA Process	Length and complexity of environmental process; are there likely to be significant unavoidable impacts?	Typical process	Typical process	None
Permitting Process	Length and complexity of permits and/or major challenges for approval.	Typical permitting process if project remains within current footprint	New coastal structure rarely permitted	Frequent emergency repair permits
Costs				
Construction Cost	Initial cost of construction to implement each alternative. Costs are relative to each option and based on recent similar projects within California.	$10-20M	$5-10M	None
Long-term Maintenance & Operation Costs	Costs to maintain and adaptively manage the Project. Costs are relative to each option and based on recent similar projects within California.	Low maintenance costs	Low maintenance costs	Moderate maintenance cost increase due to increased storm severity and frequency

Appendix F

Wave Overtopping Analysis

Technical Memorandum

March 31, 2025

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From	Daniel Dedina	**Project No.**	12628980
Project Name	DNLTC - South Beach Climate Resilience Plan (Del Norte)		
Subject	Overtopping Analysis Appendix		

1. Overtopping Analysis

Understanding the vulnerability of a roadway to flooding, erosion, maintenance, and closure is crucial for ensuring its long-term functionality and safety. An overtopping analysis is particularly important in this context, as it helps identify the specific conditions under which waves exceed the height of coastal defenses and inundate the roadway. In the project area, wave overtopping is the primary mechanism of flooding, making it essential to accurately assess and predict these events.

Overtopping occurs when water flows over the top of coastal infrastructure structures like Anchor Way or Highway 101 due to wave action, high tides, storm surges, or sea level rise (SLR). Waves, especially during storms, can push water over these defenses, while high tides and storm surges elevate water levels, increasing the likelihood of overtopping. Long-term, SLR further raises baseline water levels, making it easier for waves to overtop these structures. This process can lead to flooding, erosion, and damage to infrastructure, highlighting the importance of understanding and predicting overtopping events for effective coastal management.

As part of the process of developing the BFE results described in Section 3.1.3 of the Plan, coastal hazard modeling was conducted by BakerAECOM in 2014 for FEMA's California Coastal Analysis and Mapping Project in Del Norte County. The modeling featured a one-dimensional transect-based analysis to develop the base flood conditions at the shoreline. Wave runup and setup were calculated to create a 50-year hindcast of total water levels, and a subsequent extreme value analysis provided the 1-, 2-, 20-, 50-percent annual chance flood elevation. While these results are useful for analyzing the present-day likelihood of flooding under extreme conditions, it does not provide a way to assess future levels of flooding under different SLR scenarios. Wave propagation in the nearshore zone is largely depth-dependent, so elevated water levels due to SLR will change how waves approach the coastline and, ultimately, the wave runup and overtopping of the coastal structures.

To assess future flooding of both Highway 101 and Anchor Way under different SLR scenarios for different time horizons, an overtopping analysis along Highway 101 and Anchor Way was completed. Four main steps were taken to determine overtopping values:

1. Generate design wave conditions: An extreme value analysis was completed to get the design wave conditions offshore.
2. Profile extraction: Transects representing the varying shoreline orientation and back shore conditions along the Project Area were identified and bathymetry profiles were constructed at these locations.

3. Wave modeling: The design waves were transformed to the nearshore using the one-dimensional spectral wave model SWAN.

4. Runup and Overtopping calculations: The EurOtop manual was used to calculate overtopping for each scenario and location.

1.1 Profile Extraction

Bathymetry was extracted along four profiles within the Project Area to represent the varying shoreline orientation and backshore conditions shown in Figure 1. Profile 1 along Anchor Way was identified as the section of the breakwater most exposed to wave energy past the shadowing zone of the Whaler Island groin. Highway 101 at Profile 3 and Profile 4 was flooded and had debris along the road during the January 5, 2023 wave event. These locations were selected as they have been reported to be the most commonly flooded during large wave events (Caltrans, personal communication). The bathymetry was extracted using the U.S. Army Corp of Engineers' 2015 topobathy lidar for the nearshore and beach face, and the Navionics bathymetric charts for depths beyond the extent of the topobathy to approximately -40 feet NAVD88. The nearshore data was collected by the Corp in the summer and is representative of a summer profile. An example of Profile 3 is plotted in Figure 2. The sediment in the surf zone, swash zone, and upper shoreface from approximately -10 to 10 feet NAVD88 is likely eroded and deposited offshore on the lower part of the profile in the winter.

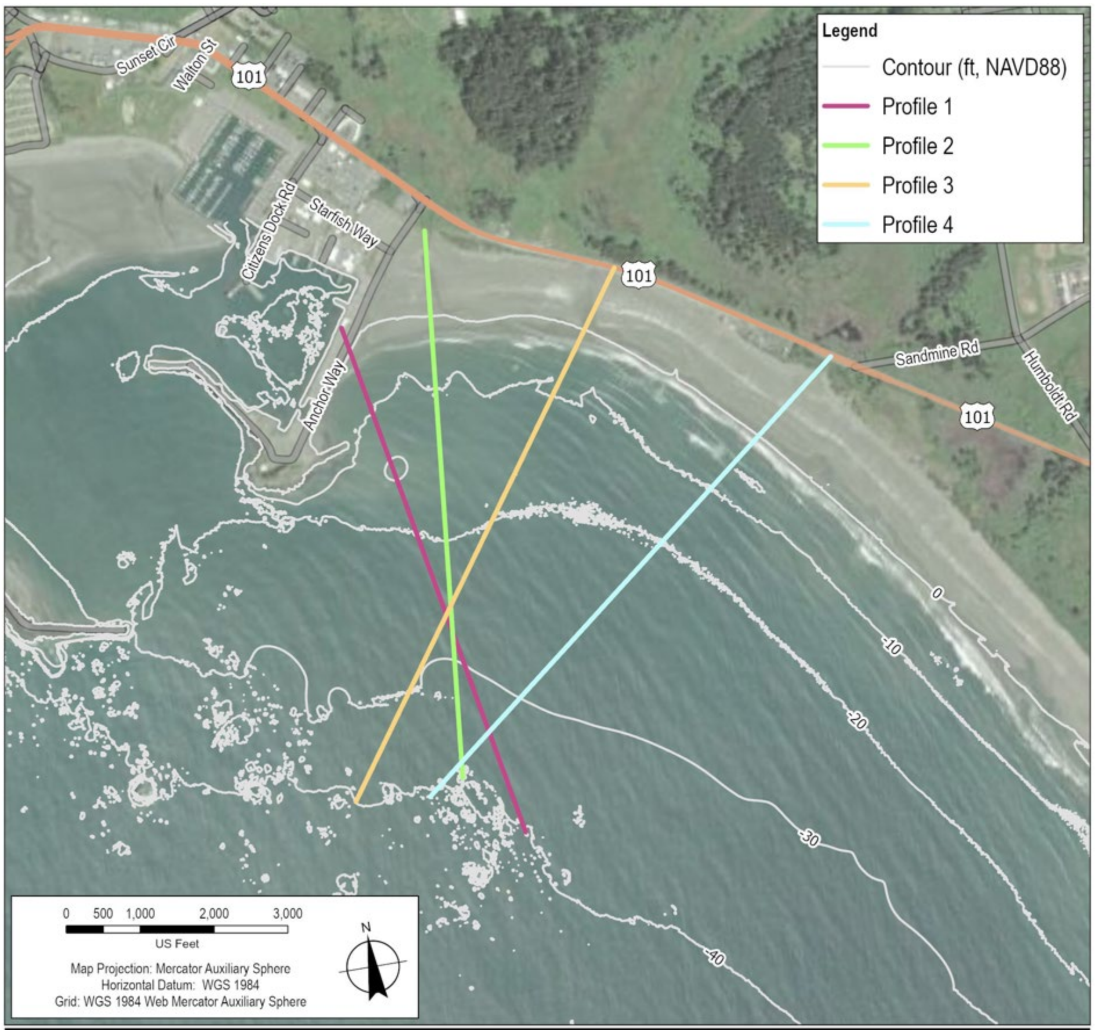

Figure 1. Bathymetry profile locations and extents

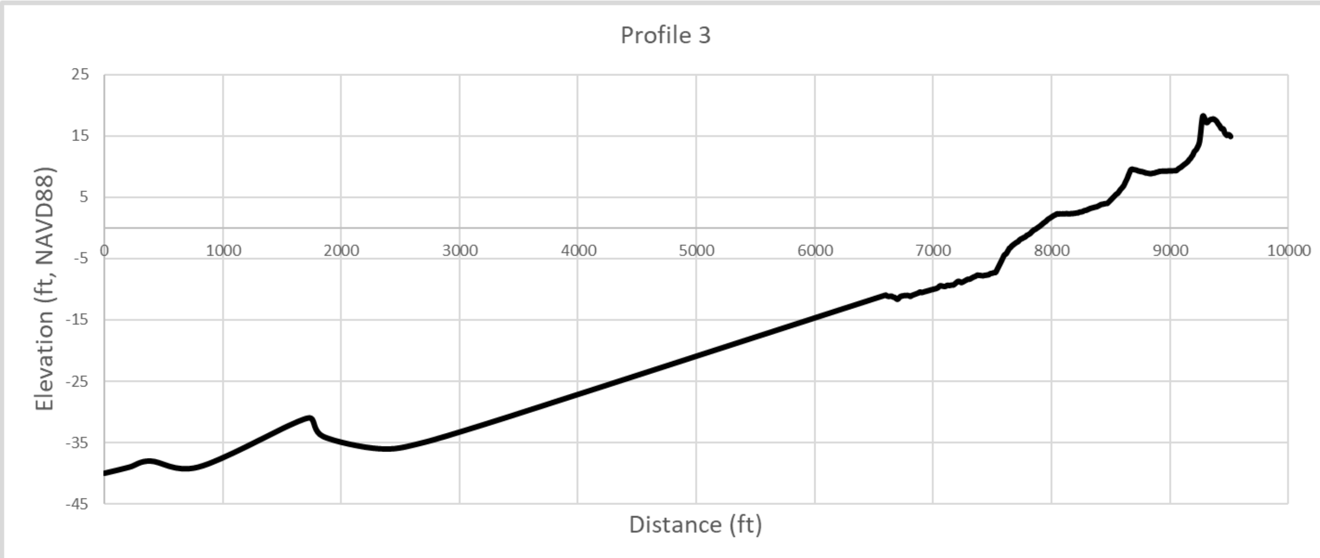

Figure 2. Profile 3 elevation

1.2 Design Wave Conditions

Extreme value analysis is a statistical method used to assess and quantify the likelihood of extreme, rare events. This makes it suitable for studying phenomena like extreme waves that do not occur frequently but can have significant impacts on coastal flooding.

An extreme value analysis of wave overtopping is particularly useful in the coastal zone where the most damage is observed during intense singular events. Overtopping can cause a serviceability limit state where minor flooding and debris require road closure. It can also cause an ultimate limit state where overtopping results in significant erosion of the roadway or damages other assets in the area (i.e. utilities, culverts, private structures).

Coastal structures (revetments or other shore protection devices) are often designed using a specific loading condition based on the risk of structure failure. For stochastic environmental conditions like ocean waves, a design condition is expressed as a return period, or the probability of an event happening in any given year. The California Coastal Commission often requires coastal protection structures to be designed to the 100-year storm. Any alternatives for shoreline protection devices will be compared against the baseline flooding conditions with no protection. For this reason, a 100-year return period (1% annual chance) event will be assessed for existing conditions and for each SLR scenario.

FEMA's third Intermediate Data Submittal (IDS #3) for their Coastal Analysis and Mapping Project presents the nearshore hydraulics, including nearshore wave modeling and runup results. IDS #3 Appendix A presents the transect maps where they modeled nearshore waves, and IDS #3 Appendix D presents the runup results for each transect. The two transects in the Project Area were profiles 26 and 27, shown in Figure 3. IDS #3 Appendix D includes the modeled annual maxima data at the offshore ends of the profiles from 1960-2009. The wave data is slightly larger for transect 27. Transect 27 data was used for calculating overtopping in the southern half of the Project Area, while data from transect 26 was used for the northern half.

These data were analyzed and return periods were calculated. The calculated return periods were extrapolated to 100 years using MATLAB's best fit toolbox to fit an extreme value distribution to the data, shown in Figure 4. Because of the sinusoidal nature of the data, the recurrences less than 1 year and greater than 20 were underestimated while in between they were overestimated.

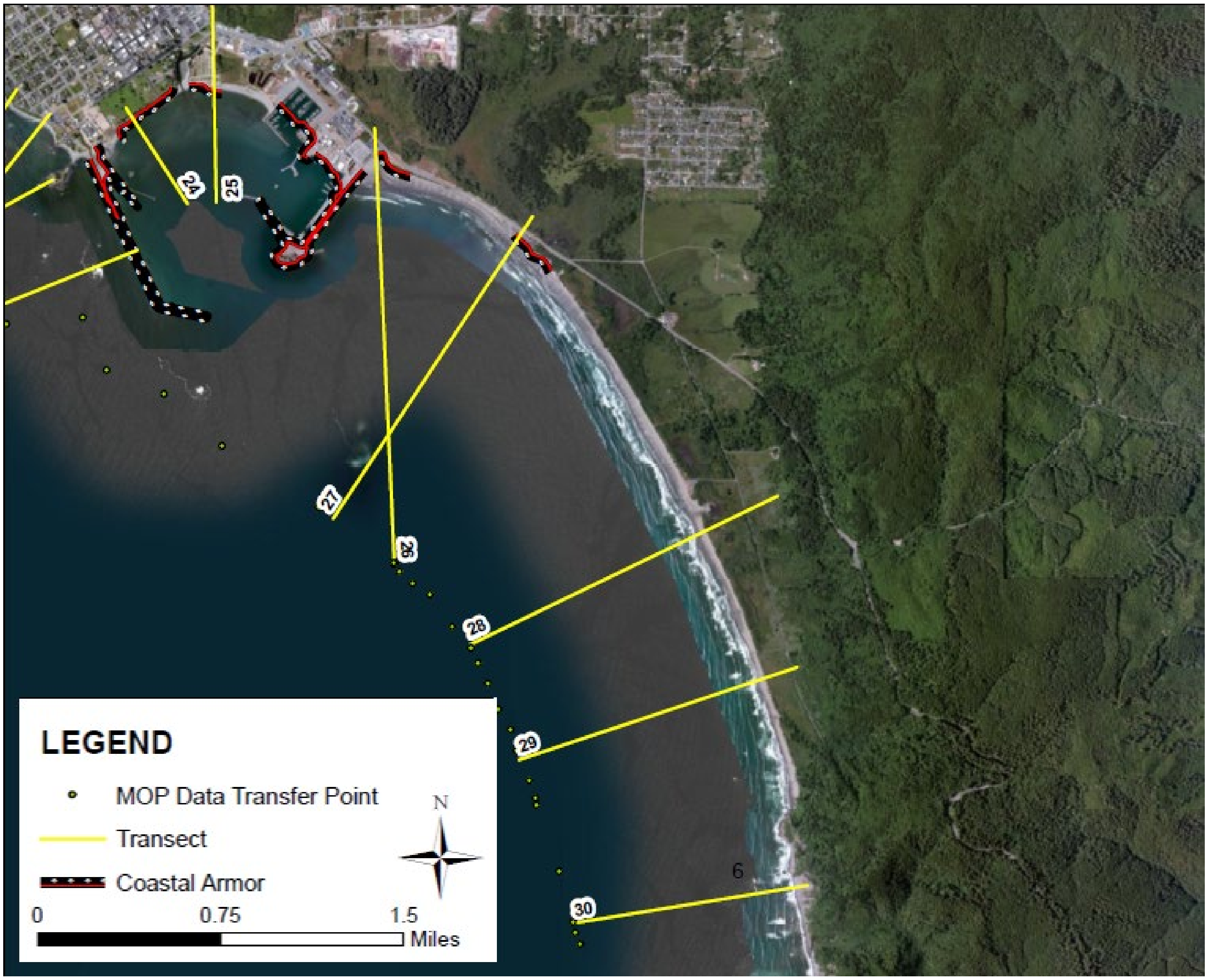

Figure 3. FEMA transect locations near the Project Area. Note that FEMA has designated areas along the shoreline as "coastal armor"

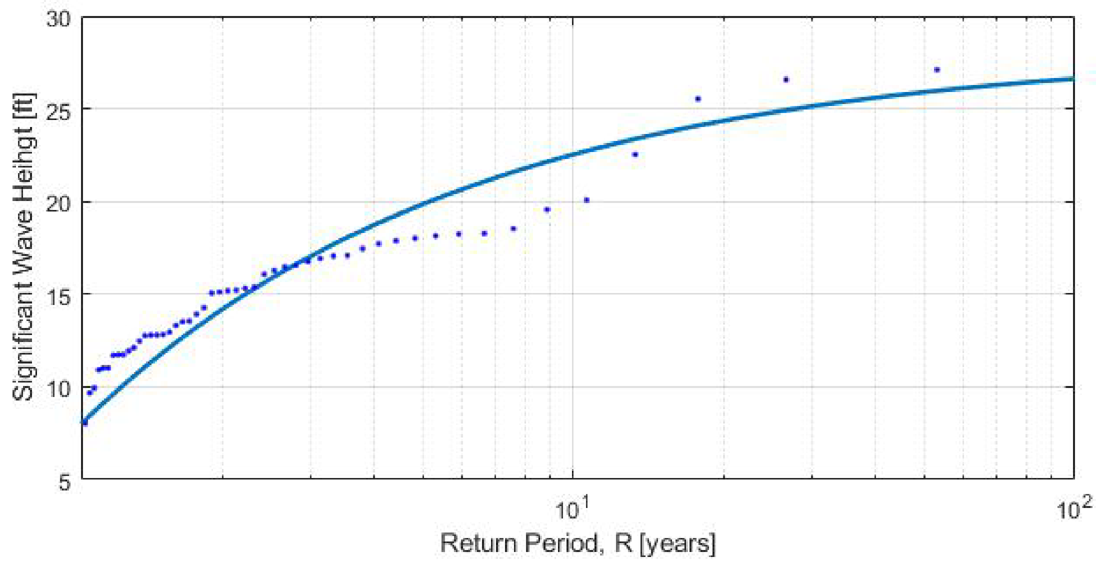

Figure 4. Log plot of return periods of wave heights and generalized pareto distribution best fit for transect 26

Table 1. Significant wave height values along two MOP transects for 1, 10, 50, and 100 years

	Significant wave height (feet)			
Return period (years)	**1**	**10**	**50**	**100**
Return period (years)	1	10	50	100
Transect 26	8.13	22.54	25.89	26.62
Transect 27	9.2	23.82	27.29	28.06

1.3 Wave Transformation

The spectral wave model SWANOne was used to transform the offshore design wave to the shoreline. The 1D model assumes that the offshore bathymetry can be represented by parallel bottom contours and that the bathymetry can be specified along one transect normal to the average coastline. The wave field is represented in terms of the 2D-frequency-directional wave spectrum and can include wind, currents, water level, depth, shoaling and refraction (TU Delft 2018). A MATLAB-based graphical user interface (GUI) is available to run the model. The model boundary conditions and results are shown in the following sections.

1.3.1 Boundary Conditions

Boundary conditions in SWANOne wave model are the constraints or inputs specified at the edges of the model domain to simulate wave behavior accurately. These conditions include water level, wave height, period, and direction, and they are derived from observations. Boundary conditions help define how waves enter and exit the model domain, ensuring realistic wave propagation and interaction within the specified area

The water levels were set to the average SWL in the annual maxima data given by the FEMA IDS #3 report for transects 26 and 27, which were 8.18 feet and 8.14 feet (NAVD88), respectively. The same method was applied to the wave period, which gave 12.66 and 12.62 seconds for transect 26 and transect 27, respectively. Wave set up was included in the calculation. No wind was used in the model as wind data was not expected to affect nearshore wave transformation significantly, although high winds are expected during storm conditions. Currents were not considered. Although wave-driven nearshore currents are also expected, they are not expected to affect wave transformation to the shoreline. The offshore wave directions for the four profiles were as follows: 45 degrees for Profile 1, 40 degrees for Profile 2, and shore normal (0 degrees) for Profiles 3 and 4. The offshore wave directions were not provided in the IDS #3 report and were assumed to be straight west. The offshore wave direction used in the model was the angular difference between west and the profile direction.

The wave condition run was the 100-year return period wave condition at a depth of 40 feet, as described in Section 1.1.2. For Profiles 1 and 2, wave heights associated with FEMA transect 26 were used. For Profiles 3 and 4, wave heights associated with FEMA transect 27 were used. The input data was then converted in the model to a default 2D JONSWAP spectrum with a peak enhancement factor $\gamma = 3.3$ and a $cos^2(\theta)$ directional spreading. The boundary conditions are shown below in Table 2.

Table 2. Baseline model input conditions for each profile. SLR is not included in the water level in this table

Profile	Hs (ft)	Tp (s)	Water level (ft, NAVD88)*	Wave direction (deg from shore-normal)
1	26.63	12.66	8.18	45
2	26.63	12.66	8.18	40
3	28.06	12.62	8.14	0
4	28.06	12.62	8.14	0

**Water level excludes SLR*

1.3.2 Results

In this section, the model results are presented, showing the wave heights, peak period, wave setup, and wave runup along the profiles. These results illustrate how these parameters vary under different SLR scenarios and wave conditions. Specifically, the spectral significant wave height (H_{m0}, m), spectral mean period (T_p, s), depth (m), and wave setup (m) were extracted from the model at the toe of the breakwater and vegetated shelf for each scenario and profile are detailed in the following paragraphs.

The spectral mean wave height, peak period and wave setup were extracted at a depth corresponding to the depth of the breakwater or vegetated shelf in the eroded condition, which varied between profiles. The eroded condition was estimated based on observations from recent storm events.

Figure 5 shows how four parameters: spectral significant wave height (H_{m0}, m), spectral mean period (T_p, s), depth (m), and wave setup (m), evolve across Profile 3 with a 100-year wave and 2.3 feet of SLR. Note that the wave height and period are different than the specified design wave because of the conversion from the wave parameters to wave energy at the boundary.

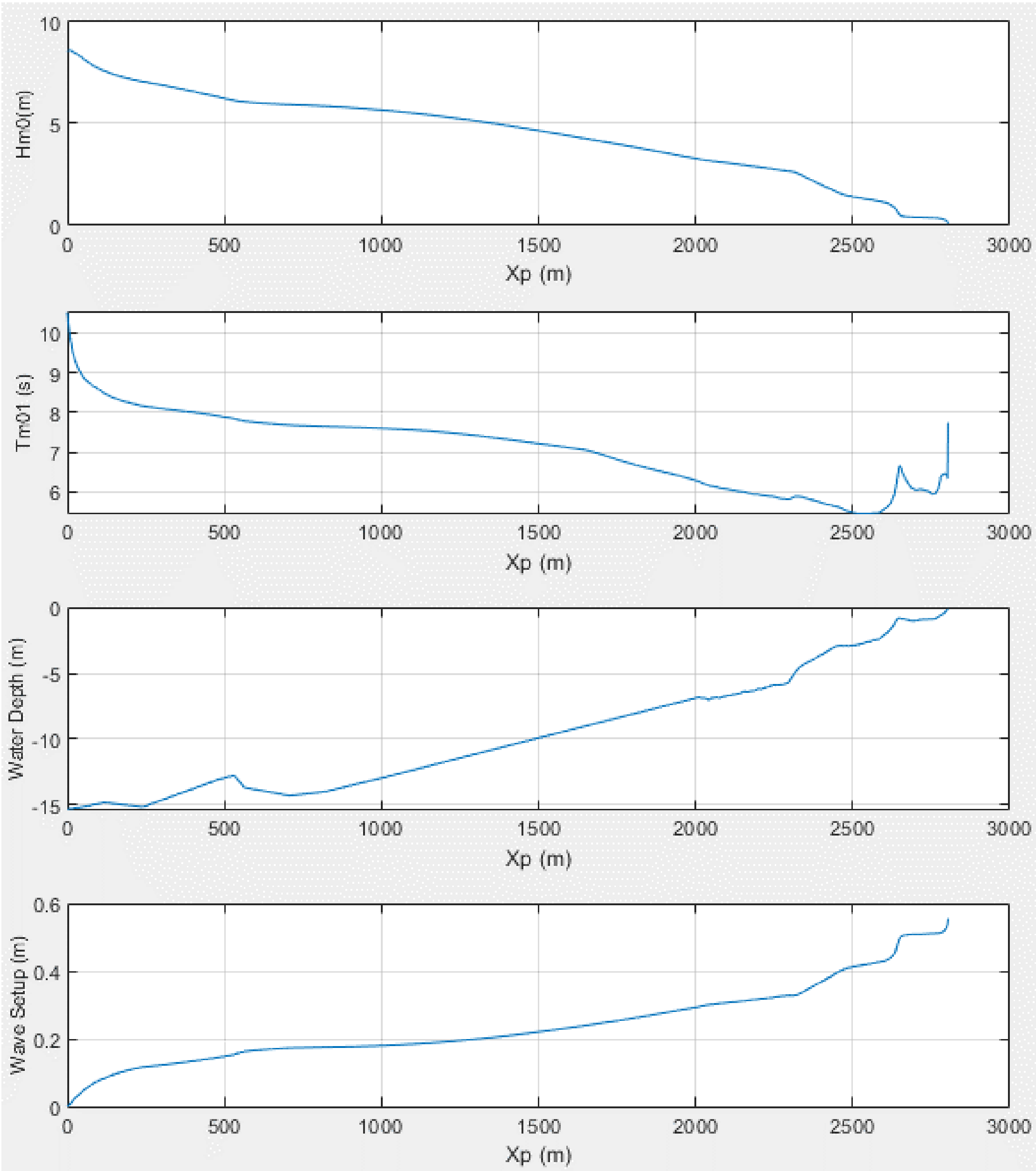

Figure 5. Spectral mean wave height (m), spectral mean period water depth (m), and wave setup (m) plotted against the horizontal distance across Profile 3 for a 100-yr wave and 2.3 feet of SLR

The wave parameters at the toe of the breakwater and berm for each scenario and profile are shown below in Table 3. Note that the wave heights at the toe of Profile 1 are larger than the others. This is because the toe of the breakwater is in deeper water and the waves undergo less shoaling than Profiles 2-4.

Table 3. Output wave heights at the toe of the berm for each profile

	$H_{m0,toe}$ (ft)			
Profile	**100-year event**	**100-year event + 0.8 ft SLR**	**100-year event + 2.3 ft SLR**	**100-year event + 5.6 ft SLR**
1	6.7	7.0	7.7	9.4
2	3.3	3.8	4.5	6.2
3	3.0	3.3	4.0	5.4
4	3.0	3.4	4.1	5.7

1.3.3 Runup and Overtopping Calculations

Once the wave conditions at the toe of the structure were identified for each scenario and each location, they were used in the runup and overtopping calculations. Wave runup and overtopping are important coastal processes that help determine how waves could impact facilities or structures. Runup is the maximum elevation that waves will runup the beach above SWLs. This theoretical runup value often extends far above the actual backshore elevation (i.e., breakwater crest, beach berm, or road elevation).

Overtopping results from wave runup in excess of this backshore feature. Overtopping is the amount of water that would be discharged over the backshore elevation, resulting in coastal flooding. As waves shoal and break on their approach to the beach, the resulting wave runup would overtop any structures backing it if there was sufficient water elevation and wave height. Runup and overtopping also depends on the characteristics of the vegetated shelf or breakwater (i.e., slope and roughness).

While runup is given as a maximum elevation a wave can reach on an infinite slope, wave overtopping takes into account the crest height of a structure and is given as the average discharge per linear meter of width, q (EurOtop 2018). Overtopping is very random in space and time, due to variation in depth and wave heights in time and space. The maximum discharge during an event may be more than 1000 times the mean. Mean overtopping discharge is widely used because it is readily measured in experiments and classified (EurOtop 2018).

Due to the presence of the Anchor Way Breakwater and the vegetated shelf fronting the roadways (Highway 101 and Anchor Way), respectively, the overtopping rate for each scenario was determined based on guidance from the EurOtop Manual on Wave Overtopping of Sea Defenses and Related Structures (2018). This manual is intended to aid in the prediction and analysis of wave overtopping of flood defenses attacked by wave action. The impact of these predicted wave overtopping rates were then evaluated based on EurOtop and Coastal Engineering Manual (CEM) guidelines for overtopping rate thresholds (Table 4). The EurOtop guidance largely focuses on vehicular safety and damage to slopes on the backside of a structure. The CEM provides critical permissible wave overtopping values for the structural safety of a paved road and vehicular safety. The exceedance of these values represents an expectation of damage to the breakwater or road, or a danger to driving safety.

Table 4. Overtopping rate threshold guidance from EurOtop and CEM

Overtopping Rate Thresholds (liters/second/meter [l/s/m])			
EurOtop – Close before debris in spray becomes dangerous on highways and roads	EurOtop – Erosion of unprotected crest or landward slopes	EurOtop and CEM – Unsafe to drive at any speed	CEM – Damage to road
<1	1	10-20	>200

Several assumptions were made when assigning values to the input parameters of the runup and overtopping equations. The slope and elevation data (crest height) were extracted from the 2015 USACE LiDAR dataset. The roughness of the slope of the vegetated shelf in Profiles 2, 3, and 4 was assumed to be grass. The slope in these profiles was also assumed to be constant, for modeling purposes. The berm is not an engineered structure and there is some variation in the slope.

1.3.3.1 Overtopping results

The results of each profile for each scenario are shown in Table 5. Profile 1 shows that the overtopping rates for existing conditions (100-year storm) and the 2050 scenario (100-year event and 0.8-feet SLR) to be greater than 20 l/s/m and greater than 100 l/s/m, respectively. Based on EurOtop and CEM allowable overtopping discharges, Anchor Way would be inaccessible to vehicles and pedestrians. The modeled 2070 and 2100 results, both of which are greater than 200 l/s/m, result in damage to the road and potentially wave transmission into the harbor.

Profiles 2, 3, and 4 have similar overtopping results, as they exhibit similar incident wave conditions, slopes, and crest heights. The difference between the results is the risk that the overtopping of the berm at these locations poses to transportation and infrastructure. Highway 101 at Profile 2 does not flood during high wave events according to damage reports and personal communication with Caltrans. This may be due to the large distance a wave would have to travel behind the vegetated shelf to reach the road, which is about 200 feet of tall grasses. So even if the overtopping rates are similar for Profiles 2,3 and 4 , the consequences of flooding at profile 2 are lower because the roadway is not impacted. However, Profiles 3 and 4 and the areas surrounding them have been reported to flood during wave events.

For the area around Profile 3, flooding is plausible as the vegetated shelf is directly adjacent to Highway 101 in this location. The area adjacent to Profile 4 are heavily vegetated and waves are not likely able to propagate through this area. However, the area in front of the culvert is fronted by no vegetation and connects almost directly with Highway 101.

Table 5. Mean overtopping discharges for each scenario at each location

Mean Overtopping Discharge, q (l/s/m)				
Location	**Existing: 100 yr storm**	**2050: 100 yr storm+ 0.8 ft SLR**	**2070: 100 yr storm + 2.3 ft SLR**	**2100: 100 yr storm + 5.6 ft SLR**
Profile 1	80	103	242	904
Profile 2	1	3	22	428
Profile 3	1	2	21	438
Profile 4	1	3	30	569

1.3.4 Discussion

The present-day mean overtopping rate for a 100-year event is ~1 l/s/m. According to CEM and EurOtop guidelines, this would result in erosion of the parking area and the backside of the road prism on the eastern side of Highway 101 and present a significant danger to vehicles. Furthermore, the erosion of the parking area adjacent to the roadway along Highway 101 can eventually undermine the stability of the road and damage the road indirectly. The 3-year storm event on January 5, 2023 was especially noteworthy due to the substantial debris accumulation. Debris accumulation would therefore be expected in larger events, capable of also moving larger debris.

Slightly increased overtopping discharges in 2050 would result in increased flood depths and an increase in debris deposited on the roadway. Furthermore, increased discharges could begin to cause erosion of the backside of the roadway embankment where it lacks protection (EurOtop 2018).

The results in 2070 showed a 10-fold increase in overtopping discharges compared to 2050 at Profiles 2,3, and 4, which indicates an increase in duration and extent of flooding, debris deposition, and damage to an unprotected embankment. When combined with shoreline erosion, 2.3 feet of SLR likely becomes the threshold at which damage from a 100-year event would result in prolonged shutdowns of Anchor Way and Highway 101 for cleanup and repairs. If looked at through other SLR scenarios such as the Intermediate High or Intermediate, the threshold would occur later, in 2080 and 2100 respectively.

In 2100, the overtopping results were significantly higher than the thresholds in the CEM and EurOtop guidelines. The combination of shoreline erosion and frequent overtopping would require regular repairs and maintenance. This magnitude of SLR would require major adaptation to maintain operable transportation infrastructure.

An effect that is not shown by these results is the erosive capability that waves have along the vegetated shelf on Highway 101. During the course of a storm event, the erosion of the unprotected vegetated shelf would further increase the risk of overtopping as the distance between the berm and the road decrease and the crest height of the vegetated shelf decreases. The scouring effect on the vegetated shelf steepens the slope, which further increases overtopping rates. The vegetated shelf could erode and expose an erosional pathway along the culverts that could result in undermining the roadway.

1.4 Results Comparison with Recent Event

Comparing the results of the analysis with recent storm events in the Project Area can help frame the results and resolve some of the uncertainty of different processes that were not included in the analysis, such as erosion of the existing road prism and debris deposition. A recent documented example of wave runup and overtopping at the Project Area occurred January 5, 2023. The storm had significant wave heights of 17 feet, which, according to the analysis presented in Section 1.1.2, corresponds to a 3-year return period; water levels peaked near 9 feet, which corresponds to a 10-year return period. Waves overtopped the vegetated shelf near Profile 3, Profile 4, and Anchor Way.

Figures 6 and 7 show the overtopping of Highway 101 during the January 5th storm event. Debris deposited on the roadway and water flowed across the roadway and down the grass embankment on the landward side of the road. While it does not appear that the flow caused erosion on the landward side of the road, debris was carried onto the embankment and no signs of erosion were observed in the photos. The vegetated shelf on the seaward side of Highway 101 exhibited multiple feet of erosion, as indicated by the exposed roots (Figure 8), causing a vertical scarp to form. The formation of a scarp changes the dynamics of runup and overtopping, increasing the forces with the abrupt elevation change, which can further accelerate erosion. Erosion occurred around the headwall of the culvert at PM 24.92 (Profile 3 in the overtopping analysis), as shown in Figure 9. Debris was also forced in the culvert entrance which can prevent water from draining the marsh.

Figure 6. Overtopping of Highway 101 during the January 5, 2023 storm near PM 24.92 looking west (Photo courtesy of Keven Pratt)

Figure 7. Overtopping of Highway 101 during the January 5, 2023 storm near PM 24.92 looking north (Photo courtesy of Keven Pratt)

Figure 8. Erosion of the berm during the January 5, 2023 storm near PM 24.92 (Photo courtesy of Keven Pratt)

Figure 9. Debris stuck in the culvert entrance and scour around the headwall during the January 5, 2023 storm near PM 24.92 (Photo courtesy of Keven Pratt)

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