Cal Poly Humboldt

Digital Commons @ Cal Poly Humboldt

Local Reports and Publications

Independent Spent Fuel Storage Installation (ISFSI)

1-1-2018

Humboldt County Humboldt Bay Area Plan Sea Level Rise Vulnerability Assessment

Aldaron Laird
hbslrplanner@gmail.com

Follow this and additional works at: https://digitalcommons.humboldt.edu/isfsi_local

Recommended Citation

Laird, Aldaron, "Humboldt County Humboldt Bay Area Plan Sea Level Rise Vulnerability Assessment" (2018). *Local Reports and Publications*. 4.
https://digitalcommons.humboldt.edu/isfsi_local/4

This Article is brought to you for free and open access by the Independent Spent Fuel Storage Installation (ISFSI) at Digital Commons @ Cal Poly Humboldt. It has been accepted for inclusion in Local Reports and Publications by an authorized administrator of Digital Commons @ Cal Poly Humboldt. For more information, please contact kyle.morgan@humboldt.edu.

Humboldt State University
Digital Commons @ Humboldt State University

Local Reports and Publications | Humboldt State University Sea Level Rise Initiative

1-2018

Humboldt County Humboldt Bay Area Plan Sea Level Rise Vulnerability Assessment

Aldaron Laird

Follow this and additional works at: https://digitalcommons.humboldt.edu/hsuslri_local

Humboldt County
Humboldt Bay Area Plan

Projected Inundation Area (Stillwater) on Humboldt Bay
for Mean Monthly Maximum Tide with 6.6 feet (2.0 meters) of Sea Level Rise

Sea Level Rise
Vulnerability Assessment

HUMBOLDT COUNTY

Humboldt Bay Area Plan

Sea Level Rise
Vulnerability Assessment

Prepared By

Aldaron Laird
Trinity Associates

January 2018

Acknowledgements

Sea level rise vulnerability assessments and adaptation planning on Humboldt Bay have been greatly enabled by the research and engineering of Jeff Anderson of Northern Hydrology and Engineers. Combined with the equally valuable research by geologist at Cascadia Geosciences, planners now have the tools to educate the public, agencies, and decision-makers about sea level rise on Humboldt Bay.

DISCLAIMER: The following Humboldt Bay Area Plan Sea Level Rise Vulnerability and Risk Assessment Report was prepared for Humboldt County. All statements are the sole responsibility of Aldaron Laird of Trinity Associates and do not necessarily reflect the views or policies of Humboldt County. This assessment is for planning purposes, and is not a substitute for site-specific analysis of vulnerability and risk from sea level rise.

This page intentionally left blank.

Table of Contents

List of Figures

List of Tables

Glossary

This report relies in part on terms and definitions that were derived from the California Coastal Commission (CCC) Sea Level Rise Policy Guidance, adopted August 12, 2015.

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which minimizes harm or takes advantage of beneficial opportunities.

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

Backwater or Backwater flooding: Upstream flooding caused by downstream conditions such as channel restriction or high tide blocking high river flows from entering estuaries.

Coastal-dependent development or use: Any development or use which requires a site on, or adjacent to, the sea to be able to function at all.

Coastal resources: A general term used throughout the Guidance to refer to those resources addressed in Chapter 3 of the California Coastal Act, including beaches, wetlands, agricultural lands, and other coastal habitats; coastal development; public access and recreation opportunities; cultural, archaeological, and paleontological resources; and scenic and visual qualities.

Development: On land, in or under water, the placement or erection of any solid material or structure; discharge or disposal of any dredged material or of any gaseous, liquid, solid, or thermal waste; grading, removing, dredging, mining, or extraction of any materials; change in the density or intensity of use of land, including, but not limited to, subdivision pursuant to the Subdivision Map Act (commencing with Section 66410 of the Government Code), and any other division of land, including lot splits, except where the land division is brought about in connection with the purchase of such land by a public agency for public recreational use; change in the intensity of use of water, or of access thereto; construction, reconstruction, demolition, or alteration of the size of any structure, including any facility of any private, public, or municipal utility; and the removal or harvesting of major vegetation other than for agricultural purposes, kelp harvesting, and timber operations which are in accordance with a timber harvesting plan submitted pursuant to the provisions of the Z'berg-Nejedly Forest Practice of 1973 (commencing with Section 4511).

Environmentally Sensitive [Habitat] Area (ESHA): Any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments.

Erosion: The wearing away of land and removal of shoreline, beach or sand dune sediments by wave action, high tides, tidal currents, and overtopping shoreline structures such as dikes.

Flood (or Flooding): Refers to normally dry land becoming temporarily covered in water, either episodically (*e.g.*, storm or tsunami flooding) or periodically (*e.g.*, tidal flooding). Annual king tides are an example of tidal flooding of lands normally not covered by daily or monthly high tides. Coastal Hazard planning generally addresses episodic 100-year floods that have 1% probability of occurring in any year but like all floods are unpredictable as to when they might occur. Floods do recede, and flooded lands generally do dry out again.

Inundation: Inundation as used in this report is a form of tidal flooding. Inter-tidal areas are those lands above the lowest tide and below the highest tide elevations that periodically experience tidal inundation. Areas that are below the lowest tide elevation are submerged lands, and thus are permanently inundated. Tidal inundation datums are generally described as to their frequency of occurrence and elevation, such as daily mean low or high water (MLW and MHW); mean monthly and mean annual maximum high water are additional tidal datums (MMMW and MAMW). Tidal inundation is very predictable. Tide charts are published each year that identify when, and how low or high, the tides are expected reach common daily tidal datums: mean lower low water (MLLW), MLW, MHW, and mean higher high water (MHHW). Inundation maps used in this report depict areas that could be inundated by MMMW under various sea level rise scenarios, absent storm surge or wind wave conditions.

Mean sea level: The average relative sea level over a period, such as a month or a year, long enough to average out transients such as waves and tides.

Relative sea level: Combination of regional sea level measured by a tide gauge and vertical land motion trends of the land upon which the gauge is situated.

Risk: Commonly considered to be the combination of the likelihood of an event and its consequences – *i.e.*, risk equals the probability of climate hazard occurring multiplied the consequences a given system may experience.

Sea level: The height of the ocean relative to land; tides, wind, atmospheric pressure changes, heating, cooling, and other factors cause sea level changes.

Sea level change/sea level rise: Sea level can change, both globally and locally, due to (a) changes in the shape of the ocean basins, (b) changes in the total mass of water and (c) changes in water density. Factors leading to sea level rise under global warming include both increases in the total mass of water from the melting of land-based snow and ice, and changes in water density from an increase in ocean water temperatures and salinity changes. Relative sea level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence.

Sea level rise impact: An effect of sea level rise on the structure or function of a system.

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (*e.g.*, a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (*e.g.*, climatic or non-climatic stressors may cause people to be more sensitive to additional extreme conditions from climate change than they would be in the absence of these stressors).

Shore protection: Structures or sand placed at or on the shore to reduce or eliminate upland damage from wave action or flooding during storms.

Shoreline protective devices: A broad term for constructed features such as seawalls, revetments, riprap, earthen berms, cave fills, and bulkheads that block the landward retreat of the shoreline and are used to protect structures or other features from erosion and other hazards.

Shoreline vulnerability rating: A quantitative measure of vulnerability that uses combinations of shoreline attributes (cover type and relative elevation to modeled MMMW) to rank shoreline segment's vulnerability to erosion and/or overtopping due to extreme tides, storm surges, and sea level rise. (Laird and Powell 2013)

Still water level: The elevation that the surface of the water would assume if all wave action was absent.

Storm surge: A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes the rise in water level due to atmospheric pressure reduction as well as that due to wind stress.

Subsidence: Sinking or down-warping of a part of the earth's surface; can result from seismic activity, changes in loadings on the earth's surface, fluid extraction, or soil settlement.

Tectonic: Of or relating to the structure of the earth's crust and the large-scale processes that take place within it.

Tidelands: Lands which are located between the lines of mean high tide and mean low tide.

Vulnerability: The extent to which a species, habitat, ecosystem, or human system is susceptible to harm from sea level rise impacts. More specifically, the degree to which a system is exposed to, susceptible to, and unable to cope with, the adverse effects of sea level rise, and tidal extremes.

This page intentionally left blank.

Sea Level Rise Projections - Inundation Modeling/Mapping

Pursuant to the California Coastal Commission (CCC) Sea Level Rise Policy Guidance dated August 12, 2015, and the CCC's January 2017 Memorandum summarizing steps for conducting sea level rise vulnerability assessments and practical lessons learned, sea level rise exposure scenarios associated with specific planning horizons based on high sea level rise projections should be considered for vulnerability assessments and adaptation planning. Utilizing specific water elevations in addition to planning horizons is also encouraged to reduce concerns over uncertainty of sea level rise projections, particularly for planning horizons after 2050.

All surface elevations in this report are North American vertical datum of 1988 (NAVD 88) and measured at the North Spit tide gauge (National Oceanic and Atmospheric Agency (NOAA) Station 9418767). California planners and engineers/scientists often use different units of measure. Sea level rise planning documents generally refer to sea level rise in feet (ft.) while engineers/scientists who create sea level rise models and maps are likely to use meters (M). To facilitate the public's use of information presented in this report, it relies on English units of measure (feet) and offers metric conversions.

This report uses three approaches to address sea level rise on Humboldt Bay:

1) sea level rise projections for specific planning horizons,
2) shoreline elevation profile, and
3) inundation modeling and mapping.

Projections for sea level rise have been prepared for Humboldt Bay by Northern Hydrology and Engineering (NHE) for the North Spit tide gauge. High projections for the following planning horizons are utilized in this report: 2030 (0.9 ft.), 2050 (1.9 ft.), 2070 (3.2 ft.), and 2100 (5.4 ft.) (NHE 2014). A shoreline elevation profile, utilizing as a baseline the mean monthly maximum water (MMMW) elevation of 7.7 ft., was used to identify shoreline segments that are vulnerable to sea level rise, in one-foot increments (Laird and Powell 2013). Sea level rise vulnerability assessment efforts on Humboldt Bay have selected the MMMW as a baseline because it correlates well with the current upper boundary of tidal vegetation on the shoreline.

Hydrodynamic modeling and inundation vulnerability mapping prepared for Humboldt Bay by NHE depicts areas that are potentially vulnerable to being inundated, with the assumption that shoreline structures (dikes) are absent or not functioning, by specific water elevations: MMMW (7.7 ft.), mean annual maximum water (MAMW) (8.8 ft.), MMMW+0.5-meter (M) (9.3 ft.), MMMW+1.0 M (11.0 ft.), and MMMW+1.5 M (12.6 ft.) (NHE 2015). The inundation maps depict stillwater conditions, with no wave run-up or storm surge incorporated. Unfortunately, the recommended sea level rise planning horizons and their high projections do not coincide exactly with the water elevations listed above that are represented in the inundation maps prepared by NHE (Table 1).

Table 1. Relationship between sea level rise planning horizons, high sea level rise projections, NAVD 88 elevations at the North Spit gauge for these high projections, the corresponding NHE inundation maps used to depict areas that are potentially vulnerable, and the NAVD 88 elevation for these maps.

SLR Planning Horizon	High Projection NHE 2014	North Spit Elevation NAVD 88	Corresponding NHE 2015 Map	North Spit Elevation NAVD 88
2030	0.9 ft.	8.6 ft.	MAMW (1.1 ft.)	8.8 ft.
2050	1.9 ft.	9.6 ft.	0.5 M (1.6 ft.)	9.3 ft.
2070	3.2 ft.	10.9 ft.	1.0 M (3.3 ft.)	11.0 ft.
2100	5.4 ft.	13.1 ft.	1.5 M (4.9 ft.)	12.6 ft.

The NHE inundation maps of Humboldt Bay are the best maps available and are used as the basis for identifying areas that are potentially vulnerable to sea level rise and quantifying impacts for purposes of this report. For example, they are used to visually depict the extent of tidal inundation from sea level rise absent the effects of protective barrier-like structures such as dikes and road grades, commonly referred to as a "bathtub model". The integrity of the entire protective shoreline in a common hydrologic unit needs to be maintained to prevent inundation of the low-lying areas behind the shoreline, not just the shoreline in front of an asset. A single breach would cause the inundation of the entire hydrologic unit and all assets residing behind that common shoreline. With six feet of sea level rise, 92% of the current artificial shoreline would be overtopped and the low-lying land behind inundated.

The inundation maps are also used to determine the number of acres of a particular land use, for example, that could be impacted by various levels of sea level rise. This means that in the case of this example of acreage calculations, the acreages may be somewhat overestimated or underestimated since as Table 1 indicates, the NHE maps depict inundation areas based on water elevations that may be more or less than the amount of sea level rise projected. The potential exists that the MAMW inundation map could slightly over estimate the areal extent of the sea level rise projection for 2030 by 0.2 ft. of water elevation. Conversely, the inundation map used for 2050 (0.5 M) could under estimate the areal extent by 0.3 ft. of water elevation, and for 2070 over estimate by 0.1 ft., and 2100 under estimate by 0.5 ft. of water elevation. However, in some areas, depending on existing surface topography, the difference would be relatively minor as the areal extent of inundation may not significantly increase with rising sea level, but rather the depth of inundation would increase.

Executive Summary

Today, there are approximately 52 miles of shoreline on Humboldt Bay that form a barrier protecting nearly 10,000 acres of low-lying areas from tidal inundation (Figure 1). A New Year's Eve 2005 king tide and storm surge caused sea levels to rise 1.8 feet, the highest water level ever recorded on Humboldt Bay; the Governor declared a State of Disaster. With three feet of sea level rise, roughly 35 miles of barrier shoreline (58% of the artificial shoreline) could be overtopped. King tides could reach that level as early as 2050, based on current high projections for sea level rise. In addition, approximately 10,000 acres of agricultural land; Highways 101 and 255; municipal water and wastewater lines; electrical distribution infrastructure, gas lines, and optical fiber communications lines; and the communities of King Salmon, Fields Landing and Fairhaven, could all become tidally inundated if tidal waters on Humboldt Bay rise three feet.

Figure 1. Dike overtopped during a king tide tidally inundating low-lying lands on South Bay.

With three feet of sea level rise, all the sloughs on Humboldt Bay would overtop their banks and tidally inundate the lands down slope that are currently protected by shoreline dikes. Our current mean annual maximum tide (MAMW) of 8.8 ft., what we call king tides, would become our daily high tide with three feet of sea level rise. Nearly 62% of the agricultural lands, 32% of the industrial/commercial property, 29% of the coastal dependent industrial lands, 17% of the public facilities, and 11% of the residential area in the HBAP planning area would become tidally inundated with three feet of sea level rise. Three feet of sea level rise would tidally inundate the only access road to King Salmon, the Humboldt Bay Generating Station, and the interim spent nuclear fuel storage site. Highway 101 would be tidally inundated as it traverses South Bay, Elk River Slough, and Arcata Bay, as would Highway 255 on the Mad River Bottom. Roughly 12 miles of railroad and the current and future sections of the Humboldt Bay Trail within the Humboldt Bay Plan planning area would become tidally inundated. Approximately 9.6 miles of municipal water transmission lines, the Truesdale pump station, seven wastewater lift stations, and 10.5 miles of sewer lines would be tidally inundated. Approximately 30 electrical transmission towers and 113 transmission poles would be tidally inundated. Both the South and North Jetties would have submerged sections (867 ft. and 1,214 ft.). The only bulk cargo/commercial docks (3 out of 10) on Humboldt Bay that would not be tidally inundated are located on Samoa Peninsula. Humboldt Bay would expand from 20,462 acres to 33,451 acres (63.5%), eel grass habitat could expand 1,269 acres (22.0%), mud flats 5,984 acres (119.4%), and salt marsh 2,948 acres (190.8%). Approximately 52 Wiyot cultural sites on Humboldt Bay would be vulnerable to tidal inundation, and four sites would be impacted from bluff erosion and retreat.

The Humboldt Bay region, including the area included in the Humboldt Bay Area Plan (HBAP), a component of Humboldt County's Local Coastal Program (LCP), is vulnerable to sea level rise. All development located in vulnerable areas is at risk of becoming inundated by saltwater, or flooded by rising groundwater. Vulnerable assets include land uses and developments, public coastal access/recreation, natural and cultural resources, transportation facilities, and utility infrastructure. While it is necessary to locate and assess individual assets in areas vulnerable to sea level rise, to do so is not a complete assessment by itself. Assets do not exist in a vacuum, but are intricately linked to and served by multiple regional assets: municipal water, wastewater, electricity, natural gas, optical fibers, local streets and Highway 101. Focusing on just one asset or one location would miss the inter-connectedness of other related assets and their vulnerabilities. For example, if all the residences of a vulnerable community like King Salmon had their livable floor elevations above the 100-year sea level rise projection, they would still be vulnerable and at risk when local streets and utilities become tidally inundated.

Unique to the north coast region of California, relative sea level rise (a combination of vertical land motion trends and regional sea levels) projections and potential inundation

maps have been developed for Humboldt Bay. Both tools have informed the preparation of this vulnerability assessment report. The County's sea level rise planning work is building on previous regional vulnerability assessments and adaptation planning efforts as well as state guidance. This report emphasizes the assessment of certain rising water elevations [1.1 ft. (MAMW), 1.6 ft. (0.5 M), 3.3 ft. (1.0 M) and 4.9 ft. (1.5 M)] relative to various assets, rather than assessing a range of potential sea level rise projections for certain years (2030, 2050, and 2100). This report focuses on informing the public, agencies, and decision-makers about where, to what, and how a particular level of sea level rise could have impacts, regardless of when that sea level rise level might occur.

Sea levels on Humboldt Bay currently vary by three feet: daily Mean High Water (MHW) is 5.8 ft. and MAMW is 8.8 ft. Sea levels on Humboldt Bay tend to be highest in the winter months when king tides provide real time examples of the impacts of one or more feet of sea level rise. Despite the conclusions of recent federal and state sea level rise reports (NRC 2012 and Griggs 2017), Humboldt Bay has the highest rate of sea level change on the west cost of the United States, rising 18 inches over the last century. Fortunately, local geologists and engineers have studied regionally specific vertical land motion (Patton 2017) and tidal modeling (NHE 2015); these studies and models are the basis for this vulnerability assessment.

The primary near-term sea level rise impacts to the assets within the HBAP planning area are shoreline erosion and the resultant tidal inundation due to extreme tidal events and storms. Long-term impacts include backwater flooding (a result of downstream blockage from higher tides), rising groundwater and salt water intrusion. Because in the long-term sea level rise would likely overcome barrier-like shoreline structures, and coupled with rising groundwater, Humboldt Bay would expand and reclaim thousands of acres of former tidelands.

This sea level rise asset vulnerability and risk assessment identifies areas and assets that could be tidally inundated now if shorelines are breached, by MAMW, and from sea level rise of 1.6 ft. (0.5 M), 3.3 ft. (1.0 M) and 4.9 ft. (1.5 M). This report describes the location and characteristics of assets, the extent and timeframe of exposure, and how susceptible assets are to tidal inundation, including salt water intrusion and flooding. The broad classes of assets in the HBAP planning area that are vulnerable and at risk from sea level rise by 2100 include the shoreline, land uses (agriculture, natural resources, residential, industrial, public facility, and commercial), transportation (surface, marine, air and rail), utilities (municipal water, wastewater, electrical, and natural gas), and coastal resources (public access, environmentally sensitive habitat areas, and Wiyot cultural sites).

The next step in planning for sea level rise is to develop adaptation policies and measures. Humboldt County is preparing adaptation polices for the HBAP planning area. However, the Coastal Commission retains the authority to issue coastal

development permits pursuant to the Coastal Act for tidelands, submerged lands and public trust lands. In the case of Humboldt Bay, the Coastal Commission retains permit jurisdiction on approximately 7,273 acres (74%) of the 9,826 acres that are vulnerable to tidal inundation with 4.9 ft. (1.5 M) of sea level rise. The challenge for Humboldt County and Coastal Commission will be to integrate the application of their authorities to effectively and efficiently address the impacts of sea level rise on coastal resources and developments.

1 Introduction

The purpose of this report is to inform the public, property owners, agencies, and land use and resource decision-makers of the vulnerability and risk from sea level rise and tidal inundation that exists on Humboldt Bay.

This vulnerability assessment is needed to apply the tidal inundation modeling and mapping prepared for Humboldt Bay and inform people about areas and assets that are vulnerable to and at risk from sea level rise and tidal inundation. Relative sea level rise projections have also been developed for Humboldt Bay that can be utilized to assess risk to areas and assets. A region-wide vulnerability assessment of sea level rise exposure can provide opportunities for coordinating adaptation strategies, policies and measures across jurisdictional boundaries.

Humboldt County is updating the HBAP and desires to identify areas in the HBAP planning area that may be exposed to sea level rise. The County has received grants from the California Coastal Commission (CCC) and Ocean Protection Council (OPC) to address sea level rise exposure in the HBAP planning area. This inventory and assessment of the assets at risk to sea level rise builds on prior work by the Humboldt Bay Sea Level Rise Adaptation Planning Project. The County would also like to assess what developments or land uses (assets) may be vulnerable (exposed, susceptible, and unable to cope) to sea level rise.

This report relies on the CCC's Sea Level Rise Policy Guidance (2015) and 2017 Memorandum as the definitive reference for conducting this vulnerability and risk assessment. The Policy Guidance presents a six-step adaptation planning process to address sea level rise (Figure 2). This report would address the first three steps:

- Step 1: choose a range of sea level rise projections relevant to Humboldt Bay,
- Step 2: identify potential sea level rise impacts in the HBAP, and
- Step 3: assess vulnerability and risk to coastal resources and development in the HBAP.

The County would also be implementing steps 4 and 5: identify adaptation goals, strategies and measures and drafting Local Coastal Plan (LCP) policy options, and draft an updated LCP for certification with the CCC.

This report would describe current sea level; sea level rise projections (NHE 2014a), impacts, and inundation areas (NHE 2014b); and current shoreline conditions on Humboldt Bay (Laird 2013). This report builds on previous vulnerability and risk assessments that were prepared by regional sea level rise adaptation planning efforts on Humboldt Bay (Laird and Powell 2014, NHE 2015, Laird 2015, and Laird 2016).

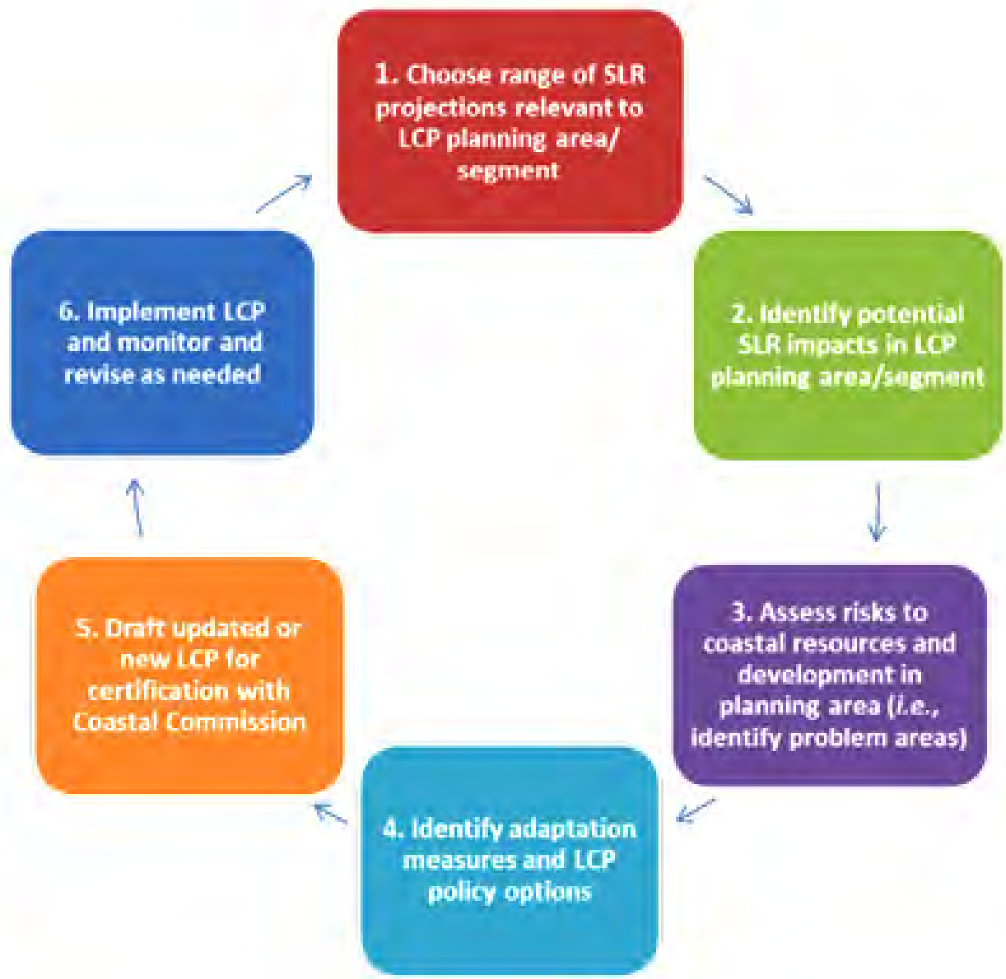

Figure 2. Sea level rise adaptation planning process steps (CCC 2015).

This report's assessment of asset vulnerability and risk is presented under five major asset classes: shoreline, land uses, transportation, utilities, and coastal resources. While this report summarizes and presents information based on available GIS-based shoreline and inundation mapping of Humboldt Bay, it is not a substitute for using these mapping tools for site-specific information.

In summary, this vulnerability and risk assessment utilizes the best available science to identify areas and assets that might be exposed to sea level rise. This report would also describe existing asset vulnerabilities and risks not directly attributable to sea level rise but due to potential barrier-type (dike) shoreline failures. This information is critical to property owners, the public, and the County to inform land use decisions. The information in this report would also be of value to other local, state, and federal resource agencies.

Humboldt Bay has been the focus of several regional sea level rise vulnerability assessments and adaptation planning efforts, specifically the State Coastal Conservancy-funded *Humboldt Bay Sea Level Rise Adaptation Planning Project, 2010-2015.* That planning effort began with inventorying and mapping (structure, cover, and elevation) the 102 miles of shoreline on Humboldt Bay and assigning a vulnerability rating to the shoreline reflecting its vulnerability to erosion or overtopping by extreme tides or projected sea level rise by 2050 (Laird and Powell 2013). The Humboldt Bay sea level rise adaptation planning project also involved preparing relative sea level rise projections through 2100 (NHE 2014a) and a sea level rise hydrodynamic model and potential inundation maps of areas surrounding Humboldt Bay (NHE 2015). These potential inundation maps are available to the public as GIS shapefiles and Google Earth kmz files from the Humboldt Bay Harbor, Recreation and Conservation District (Harbor District) sea level rise adaptation planning project web site, http://humboldtbay.org/humboldt-bay-sea-level-rise-adaptation-planning-project .

The Humboldt Bay sea level rise adaptation planning project also involved the formation of a regional sea level rise adaptation planning group which included the County and twenty-one other regional stakeholders with land use, land management, or resources management responsibilities or advisory roles on lands adjacent to Humboldt Bay that are vulnerable to sea level rise impacts, and culminated in the production of a regional vulnerability assessment adaptation plan for Humboldt Bay (Laird 2015). These assessment and planning efforts led all three LCP authorities on Humboldt Bay (Humboldt County and the cities of Arcata and Eureka) to request and secure grants from the CCC and Ocean Protection Council (OPC) to address sea level rise as part of the update of their LCPs.

Humboldt Bay occupies approximately 29,187 acres above or landward of mean sea level (MSL) which is 3.4 ft. (Figure 3). The Coastal Commission retains the authority to issue coastal development permits pursuant to the Coastal Act for tidelands, submerged lands and public trust lands. In the case of Humboldt Bay, the Coastal Commission's retains permit jurisdiction on approximately 7,273 acres (74%) of the 9,826 acres that are vulnerable to tidal inundation with 4.9 ft. (1.5 M) of sea level rise. There are an additional 569 acres of Humboldt Bay in the unincorporated area of the County that are vulnerable to tidal inundation with 4.9 ft. (1.5 M) of sea level rise, which are inland of the HBAP planning area and Coastal Zone boundaries.

Regionally, the combined LCP jurisdictions on Humboldt Bay (the County and the cities of Eureka and Arcata) occupy 35,149 acres, of which 12,618 acres are vulnerable to tidal inundation with 4.9 ft. (1.5 M) of sea level rise. An additional 730 acres inland of the LCP jurisdictions are also similarly vulnerable. The total potential tidal inundation area is approximately 13,348 acres.

Figure 3. Humboldt County's Humboldt Bay Area Plan, City of Eureka and Arcata boundaries.

The hydrodynamic model of Humboldt Bay produced in 2014 (NHE 2014b) is the source of potential tidal inundation (still-water) area predictions used to assess vulnerability and risk in this report. The inundation mapping assumes there are no shoreline structures and identifies potential conditions that could occur if barrier-like shoreline structures are breached or overtopped, and if nothing is done to adapt to or prepare for sea level rise (NHE 2015). The limits of inundation that have been delineated are based on 2012 surface elevations (Figure 4). The Federal Emergency Management Agency (FEMA) has revised its Flood Insurance Rate Maps (FIRM) for Humboldt Bay. FEMA also did not consider existing shoreline structures on Humboldt Bay when it mapped flood hazard zones, unless they were federally certified structures; there are no federally certified structures on Humboldt Bay (FEMA 2016).

In this report, asset exposure is described using the following criteria:

- Assuming failure of barrier-like shoreline structures,
- Exposure to 1.1 ft. of sea level rise, equivalent to the MAMW elevation (8.8 ft.), and
- Sea level rise above the MMMW elevation in increments of 1.6 ft. (0.5 M) to 4.9 ft. (1.5 M).

The planning horizons used to describe sea level rise exposure to assets include: current, 2030, 2050, 2070 and 2100. As previously described in the section on sea level rise projections and inundation modeling/mapping, projection scenarios identified for this vulnerability assessment do not coincide exactly with the water elevations represented in the inundation maps. Therefore, to characterize the impacts of the various sea level rise scenarios used in this report, the sea level rise projections and NHE inundation maps have been matched as follows: 2030 is represented by MAMW, 2050 by 0.5 M, 2070 by 1.0 M, and 2100 by 1.5 M.

Figure 4. Potential tidal inundation areas (stillwater) on Mad River Slough, Arcata Bay and Mad River Bottom, based on 2012 surface elevations, assuming barrier-like shoreline structures are breached, for 1.1 ft. (MAMW), 1.6 ft. (0.5 M), 3.3 ft. (1.0 M), and 4.9 ft. (1.5 M) of sea level rise.

2 Sea Level Rise

2.1 Humboldt Bay Tidal Datums

There are a variety of different reference points, or tidal datums, used to measure tidal elevations, depending on the tidal phase of interest and the type of tides present along a shoreline (NOAA 2001). A typical tidal cycle involves two high tides and two low tides within a single daily cycle. On Humboldt Bay, the two high tides are not equivalent; one is higher than the other. The same is true for the low tides. These types of mixed tidal cycles result in tidal datums such as mean lower low water (MLLW) and mean higher high water (MHHW). Other recognized tidal datums include mean low water (MLW), mean sea level (MSL), mean high water (MHW, considered representative of the wetted shoreline), and mean annual maximum water (MAMW), often referred to as king tides (Table 2). The North Spit tide gauge record can be found at (http://tidesandcurrents.noaa.gov/stationhome.html?id=9418767).

Table 2. Tidal datums and elevations for Humboldt Bay as measured at the NOAA North Spit tide gauge.

Tidal Datum	Description	Elevation (ft.)
MLLW	Mean Lower Low Water	-0.34
MLW	Mean Low Water	0.91
MSL	Mean Sea Level	3.36
MHW	Mean High Water	5.8
MHHW	Mean Higher High Water	6.51
MMMW	Mean Monthly Maximum Water	7.74
MAMW	Mean Annual Maximum Water	8.78

Because sea level is expected to rise in the future in response to climate change, the tidal datum against which sea levels are referenced should be consistent. The Regional Humboldt Bay Sea Level Rise Adaptation Planning Project utilized MMMW of 7.7 ft., known as spring tides, as the tidal base elevation to assess shoreline vulnerability and to map areas that could be vulnerable to tidal inundation should the existing barrier-like shoreline be breached. While not an official tidal datum that NOAA normally provides for its tide gauges, MMMW was selected because on Humboldt Bay MMMW is closely

associated with the upper elevation of tidally influenced vegetation on natural shorelines and the tidal and upland boundary, and is easy to delineate.

During a single year, sea levels on Humboldt Bay can vary by three ft. (±1.0 M). Daily MHW is 5.8 ft. and MMMW is 7.7 ft., and annual king tides (MAMW) are 8.8 ft. Sea levels on Humboldt Bay tend to be highest in the winter months. Mean annual maximum tides (MAMW) occur in winter and are typically one foot higher than MMMW. In addition, El Niño events, low pressure systems, stormwater runoff, and storm surges can also add up to one foot to winter tidal elevations. In 1983, a severe El Niño raised tides to 9.4 ft. Since 2001, there have been four years where annual maximum tides reached similar or greater elevations than the last significant El Niño events: 2001 (9.3 ft.), 2003 (9.5 ft.), 2005 (9.5 ft.), 2006 (9.5 ft.) (Figure 5).

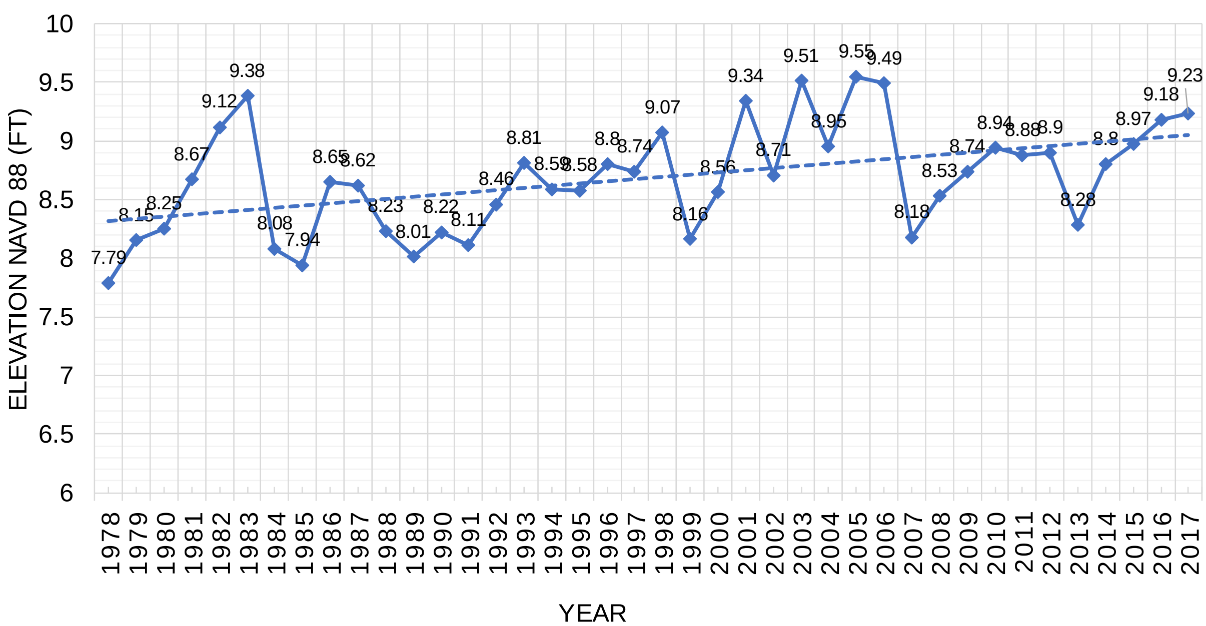

Figure 5. Annual maximum high tide elevations (king tides) at the North Spit tide gauge.

Annual maximum or king tides elevations have varied by 1.8 ft. (ranging from 7.8 to 9.5 ft.) during the North Spit's 40-year record. The highest tide was 9.55 ft. and is illustrative of 1.9 ft. of sea level rise over the MMMW elevation of 7.7 ft., which is the high projection for 2050. The Governor declared a state of disaster on Humboldt Bay in 2006 in the aftermath of storm damage largely due to high rainfall and high winds, with storm surge combined with that extreme tide of 9.5 ft. as a contributing factor. This same tidal elevation could become the MMM—the monthly norm— tide elevation by 2050.

Unlike extreme storm events also known as 100-year floods that have 1% probability of occurring in any year, sea levels are very predictable, and the date, time, and expected

height of king tides are known. Local and regional weather can affect water levels; therefore, there are often observable differences from the predicted tide elevations. This report, unlike hazard mitigation plans, does not utilize extreme storm events to conduct its vulnerability and risk assessment of assets on Humboldt Bay.

Tide frequency is also a predictable parameter. For example, the number of days that current MAMW elevation of 8.8 ft. is equaled or exceeded is 4 days per year, but with 1.6 ft. (0.5 M) of sea level rise, these high tides would equal or exceed 8.8 ft. 125 days per year. With 3.3 ft. (1.0 M) of sea level rise, these same high tides would equal or exceed MAMW 355 days per year (NHE 2017). Sea level rise would likely manifest as tidal inundation from king tides as nuisance flooding and increase in frequency with sea level rise to become chronic flooding and ultimately tidal conversion.

2.2 Sea Level Rise Projections

Currently, tidal elevations in Humboldt Bay are affected by regional sea levels and vertical land motion trends. Combining sea level rise and tectonic subsidence would result in a greater net change in water elevations than what would be experienced from sea level rise alone. Conversely, sea level rise combined with tectonic uplift could result in no net change in water elevation, which appears to be what is occurring at Crescent City. According to Cascadia GeoSciences, since 1977 Humboldt Bay has been subsiding -0.09 inches/yr. and its average rate of relative sea level rise is 0.18 inches/year (18 inches per century), which is greater than anywhere else in California (Patton 2014). A dataset of relative sea level rise projections has been prepared for the North Spit tide gauge from 2000 to 2100, including low, projected, and high greenhouse gas emission scenarios (Figure 6, NHE 2014a). While the CCC's Policy Guidance recommends assessing impacts from sea level rise for 2030, 2050, and 2100, this report also assesses potential impacts for current conditions and 2070. Under present shoreline conditions, 51% of the diked shoreline on Humboldt Bay could be breached or be overtopped by approximately three feet of sea level rise, which is equivalent to the high projection for 2070.

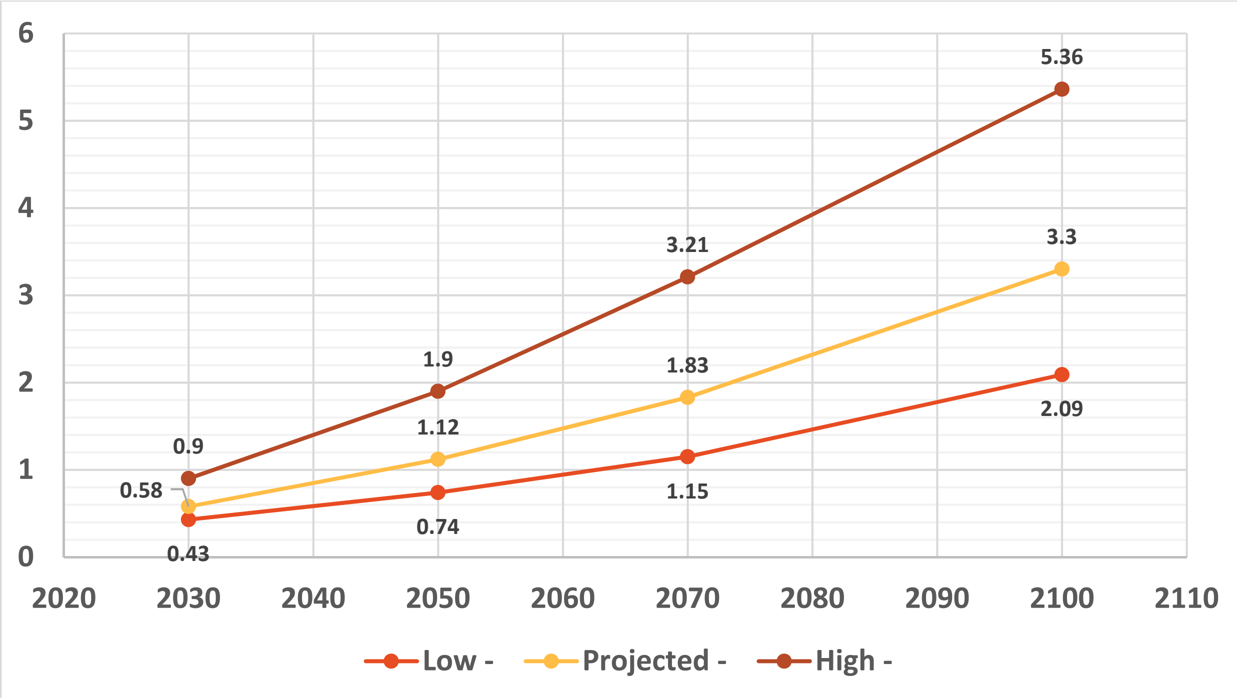

Figure 6. Relative sea level rise projections for four planning horizons (2030, 2050, 2070, and 2100), including low, projected, and high greenhouse gas emission scenarios (NHE 2014a) in ft.

The OPC Science Advisory Team (SAT) recently released its *Rising Seas in California: An Update on Sea-Level Rise Science* report (Griggs et al. 2017). The OPC and California Natural Resources Agency (CNRA) are now seeking comments to update *California's Sea-Level Rise Guidance* document (2010 and 2013). The following letter authored by Jeff Anderson, Aldaron Laird, and Jay Patton was submitted in 2017 to the CCC and OPC.

> *Griggs et al. (2017) provides a much needed and timely update regarding the state of the science on sea-level rise projections along the California coast, particularly with our current scientific understanding of potential Greenland and Antarctic ice sheet loss. Unfortunately, the update report falls short in providing the best and most up to date sea-level rise science to the largest California coastal population north of the San Francisco Bay Area.*
>
> *The Humboldt Bay-Eel River Delta region of Humboldt County has the highest concentration of people, development, and coastal agriculture on the North Coast of California. Humboldt Bay is the second largest estuary and bay in California. The Bay is surrounded by 102 miles of shoreline and several critical regional assets (port/harbor and coastal dependent infrastructure, U.S. Highway 101, Humboldt Bay Power Plant and nuclear storage facility, and two municipal wastewater treatment plants) that are exposed to sea-level rise.*

There are two tide gauges operated by NOAA located north of Cape Mendocino: one at North Spit on Humboldt Bay and another near Crescent City in Del Norte County. The updated report utilized data from the Crescent City tide gauge, which has recorded the least sea-level change in California rather than the North Spit tide gauge on Humboldt Bay, which has recorded the highest sea-level rise rate in California (Russell and Griggs 2012; NHE 2015; Patton et al. 2017).

The update report attempts to provide a synthesis of the state of the science of sea-level rise. Yet, references for two critical scientific sea-level rise studies of the North Coast are notably missing: Cascadia Geoscience's Tectonic Land Level Changes and their contribution to sea-level rise, Humboldt Bay region, Northern California (Patton et al. 2017), and Northern Hydrology and Engineering's Humboldt Bay: Sea Level Rise, Hydrodynamic Modeling, and Inundation Vulnerability Mapping (NHE 2015). The Patton et al. vertical land motion and sea-level rise work produced working updates in 2013, 2014, 2015, and 2016.

Land subsidence (or downward vertical land motion) in the Humboldt Bay region contributes to relative sea-level rise at rates that are two to three times greater than anywhere else in California. In fact, sea-level change at the Humboldt Bay North Spit tide gauge is much greater than any other tide gauge in the Pacific Northwest (Patton et al. 2017). The Crescent City tide gauge does not accurately represent the level of exposure to most of the people and developments north of Cape Mendocino. However, data from the North Spit tide gauge, and more importantly the local scientific and engineering work of Patton et al. (2017) and NHE (2015) does. Methods used by Patton et al. (2017) and NHE (2015) are based upon methods published in peer review journals (e.g. Mitchell et al. 1994; Burgette et al. 2009).

To demonstrate this, the median (50% probability) projected sea-level rise rates for Crescent City, San Francisco and San Diego (Griggs et al. 2017) are compared to estimated sea-level rates for Trinidad, Mad River Slough, North Spit, and Hookton Slough (Table 3). Trinidad is located just north of Humboldt Bay, and Mad River Slough, North Spit and Hookton Slough are located on Humboldt Bay. The estimated sea-level rise rates for these four Humboldt Bay region locations were determined using the Crescent City rates from Griggs et al. (2017) and the vertical land motion estimates from Patton et al. (2017) using the same approach for adjusting sea-level rise projections outlined in NHE (2015).

Results clearly demonstrate that the estimated relative sea-level rise projections for the Humboldt Bay region well exceed the California projections provided in the update report for the same time periods. This is especially evident when comparing the projections for Crescent City, which is the nearest location to the Humboldt Bay region, and, as discussed earlier, the only tide gauge north of Cape Mendocino included in the Griggs et al. (2017) update report.

Table 3. Summary of sea level rise projections for California and the Humboldt Bay region. Projections for Crescent City, San Francisco and San Diego (highlighted in green) are from Table 1 in Griggs et al. (2017). Estimated projections for Trinidad, Mad River Slough, North Spit and Hookton Slough (highlighted in yellow) are based on vertical land motion estimates from Patton et al. (2017). Analysis is based on the approach outlined in NHE (2015).

Year / Percentile	Median (50% Probability) Sea-level Rise Projections (Feet Above 1991-2009 Mean)						
	Crescent City	San Francisco	San Diego	Trinidad	Mad River Slough	North Spit	Hookton Slough
2030	0.1	0.4	0.5	0.5	0.5	0.6	0.8
2050	0.4	0.9	0.9	1.1	1.1	1.3	1.5
2100 (RCP 2.6)	0.7	1.6	1.7	2.1	2.1	2.5	2.9
2100 (RCP 4.5)	1.0	1.9	2.0	2.4	2.4	2.8	3.2
2100 (RCP 8.5)	1.5	2.5	2.6	2.9	2.9	3.3	3.7
2100 (RCP H++)	9.3	10	10	11	11	11	12
2150 (RCP 2.6)	1.0	2.4	2.5	3.0	3.1	3.7	4.4
2150 (RCP 4.5)	1.6	3.0	3.1	3.6	3.7	4.3	5.0
2150 (RCP 8.5)	2.6	4.1	4.3	4.6	4.7	5.3	6.0
2150 (RCP H++)	21	22	22	23	23	24	24

> *It should be noted that the issues associated with the high rate of land subsidence and the resulting high rates of relative sea-level rise at the North Spit tide gauge is not unique to the NHE (2015) or Patton et al. (2017) work. These elevated rates have been documented in other sea-level rise work, such as NOAA (2013). Furthermore, the OPC-SAT should have been aware of this situation based on Griggs' earlier work which stated*
>
>> *The State's two northernmost stations record the complex land motion along the northern California coast, just offshore of Cape Mendocino, where three large tectonic plates come together. At Humboldt Bay's North Spit, sea level is rising by 18.6 inches per century (4.73 millimeters per year), the highest rate in California. Just 80 miles north at Crescent City, sea level is dropping relative to the coastline by 2.5 inches per century (0.65 millimeters per year). The shoreline at Humboldt Bay is subsiding, whereas Crescent City's coastline is rising (Russell and Griggs 2012, pg. 8).*

Likewise, both the high rates of land subsidence and relative sea-level rise unique to the Humboldt Bay region of California were noted in by the CCC (2015):

> *Humboldt Bay has not experienced the regional uplift that characterizes most of the coast north of Cape Mendocino, and instead has shown the highest subsidence recorded for the California coast. As a result, the projections for north of Cape Mendocino may not be appropriate for use in or near Humboldt Bay and the Eel River Estuary. Please see Humboldt Bay: Sea Level Rise Hydrodynamic Modeling, and Inundation Vulnerability Mapping (Northern Hydrology and Engineering 2015) for additional information on sea level rise projections for the Humboldt Bay region (CCC 2015, pg. 17).*

There has been much effort over the past few years by the local scientific, planning and engineering community to educate the public regarding the unique tectonic and relative sea-level rise issues specific to the Humboldt Bay region. These efforts have been supported through federal, state and local funds, along with a large proportion of professional in-kind contributions. Given the current politics regarding climate change and sea-level rise science, it seems that any state funded sea-level rise science document should use the best available science for all regions of California. Particularly any locally generated science that describes and/or explains unique regional issues that affect relative sea-level rise rates, such as the tectonic land level changes of the Humboldt Bay region.

To put this into perspective, the high rates of tectonic land level change unique to the Humboldt Bay region is as critical to understanding relative sea-level rise rates in this area, especially up to the year 2100, as the polar ice sheet losses are to long-term global sea-level rise.

The update of California's Sea-Level Rise Guidance document must use the best available science to inform local and state decision makers of their exposure to sea-level rise, particularly north of Cape Mendocino in the Humboldt Bay region.

2.3 Sea Level Rise Impacts

Sea level rise is an effect of climate change, specifically from the warming of the atmosphere and oceans up until now. Melting ice from areas like Greenland and Antarctica have the potential to greatly accelerate the rate and elevations of sea level rise, particularly after 2050. Sea levels can also increase or decrease because of vertical land movement, from tectonic forces. Rising sea levels would directly affect the shoreline and consequently adjacent lands and developments.

Sea level rise would likely exacerbate coastal hazards experienced in Humboldt Bay, including: tidal inundation (shoreline breaching via erosion and/or overtopping), flooding (drainage impaired backwater and emerging groundwater), shoreline erosion and retreat, and salt water intrusion. Sea level rise would increase the hazard effects of extreme tides, wind waves, low-pressure systems/storm surges, and El Nino events on the shoreline of Humboldt Bay, would reduce drainage capacity of water control structures, and would result in rising groundwater and salt water intrusion.

Rising sea level effects include:

- Increase in elevation of daily and monthly high tides as well as extreme high tides and 100-year storm flood elevations.
- Shoreline erosion and retreat.
- Overtop, slump, and/or breach of barrier-type shoreline structure such as earthen dikes.
- Increase in elevation of low tides and increased flooding of low-lying areas by delaying drainage through tide gates, impeding stormwater runoff.
- Increase in groundwater elevations and flooding of low-lying areas.
- Saltwater intrusion of low-lying agricultural lands, adjacent aquifers or underground structures such as sewer lines and potentially wastewater treatment facilities.
- Expand Humboldt Bay's tidal prism as diked former tidelands become inundated, which could increase wave heights in the entrance channel and affect sediment movement in and throughout Humboldt Bay.

Diked shorelines can and have breached under existing tidal and storm conditions, sea level rise would increase the frequency of these breaches until dikes are overtopped resulting in the tidal inundation of the lands behind the dikes. Flooding refers to normally dry land becoming <u>temporarily</u> covered in water, either episodically (*e.g.*, storm or tsunami flooding) or periodically (*e.g.*, tidal flooding). Floods do recede, and flooded lands generally do dry out again. Inundation as used in this report is a form of tidal

flooding. Inter-tidal areas are those lands above the lowest tide and below the highest tide elevations. Areas that are below the lowest tide elevation are submerged lands, and thus are permanently inundated. Inundation maps used in this report depict areas that could be inundated by MMMW under various sea level rise scenarios, absent storm surge or wind wave conditions.

Sea level rise has the potential to adversely affect assets (land uses, coastal resources, utilities, and transportation modes) located in the coastal zone. Coastal developments are vulnerable and at risk from tidal inundation, and flooding caused by rising groundwater, stormwater runoff backwater, and increased 100-year flood elevations. For those developments, land uses, utilities and transportation corridors on diked former tidelands, if these dikes are eroded or breached these assets could be tidally inundated now. Low-lying areas are subject to saltwater intrusion, and flooding as the capacity of drainage structures such as tide gates and culverts are reduced by rising low tides. Saltwater intrusion of shallow agricultural wells particularly in areas behind dikes may increase. Coastal habitats such as dunes, seasonal freshwater wetlands may be eroded or converted while other habitats like inter-tidal wetlands may drown if there are no physical pathways for their migration inland in response to sea level rise. Public access to the Bay and Sloughs may become impaired by shoreline erosion, tidal inundation, or flooding of boating facilities. There are also tribal cultural resource sites located on the lands around the Bay that may become tidally inundated by 2100. Open, or un-treated contaminated sites could become tidally inundated or flooded resulting in pollution of waterways and degradation of water quality.

While not a sea level rise impact, shoreline erosion under the current tidal regime could have significant consequences on Humboldt Bay. The Humboldt Bay Shoreline Inventory, Mapping, and Sea Level Rise Vulnerability Assessment provided the first comprehensive evaluation of shoreline conditions (Laird and Powell 2013). Seventy-five percent (77 miles) of Humboldt Bay's shoreline is artificial, predominately consisting of earthen dikes (53%, 41 miles) and railroad beds (14%, 11 miles). These two types of linear shoreline structures were constructed between 1890 and 1915, which today, more than a century later, are approximately 1.5 ft. lower relative to current sea levels due to tectonic subsidence and global sea level rise (Russell and Griggs 2012). The dikes were built to hold back extreme high tides around the turn of the 20th century; those extreme high tide elevations are currently reached by our annual maximum tides (king tides) due to sea level rise and subsidence of land in and around Humboldt Bay (NHE 2014a). At this time, the railroad has not been used commercially for more than two decades and much of the railroad bed has not been maintained. This helps explain why so much of the diked and railroad beds shoreline is currently vulnerable to overtopping by MAMW, storm surges and stormwater runoff, low pressure systems, wind waves, and El Niño conditions.

The vulnerability of these shoreline structures is compounded by the fact that no single entity is responsible for their improvement or maintenance. Approximately 21 miles of

shoreline composed of dikes and railroad beds are rated highly vulnerable to breaching or being overtopped (Laird and Powell 2013; Figure 7). Shoreline vulnerability rating is a quantitative measure of vulnerability that uses combinations of shoreline attributes (cover type and relative elevation to modeled MMMW) to rank shoreline segment's vulnerability to erosion and/or overtopping due to extreme tides, storm surges, and sea level rise (Laird and Powell 2013).

Figure 7. An example of a diked shoreline segment rated highly vulnerable and at risk of breaching that could tidally inundate former tidelands.

These dikes are a historical legacy that could have a profound effect, tidal inundation of the assets behind these dikes if they are breached, which is happening with increasing frequency on Humboldt Bay. Sea level rise would only increase the risk posed by these dikes on protected assets, unless adaptation measures are employed to increase their ability resiliency.

3. Vulnerable and At-Risk Assets

Coastal hazard assessments can occur at many scales: regional, city-wide, or parcel specific. This sea level rise vulnerability and risk assessment report addresses assets within the HBAP planning area, which includes the unincorporated area on and

surrounding Humboldt Bay. This assessment includes assets that are in areas that could be tidally inundated by sea level rise of up to 4.9 ft. (1.5 M), which is an approximate elevation of 12.6 ft. at the North Spit tide gauge. Assets have been treated equally regardless of ownership. Many assets critical to a region like Humboldt County are privately owned (PG&E's HBPP, HBGS, and ISFSI or under the control of another agency (Caltrans Highways 101 and 255).

Ultimately, assessment of asset vulnerability and risk from sea level rise may be required for individual developments, and would include identification of site-specific surface elevations, individual pathways for tidal inundation and flooding and, if appropriate, calculation of 100-year storm wave run-up elevations. Understanding site-specific conditions would facilitate developing site-specific adaptation standards for buildings and other developments that may be exposed to sea level rise over the next 100 years.

Broadly speaking, there are two types of assets at risk from sea level rise: those assets located underground such as sewer lines and those located above ground such as urban development. Generally, underground assets would be at risk earlier from sea level rise due to tidal inundation, rising ground water, and salt water intrusion. Impacts to most above ground assets, except for current shoreline structures such as dikes and those assets located behind dikes on former tide lands, would follow. It is important to note that most of the underground assets are utilities essential to sustaining above ground developments and land uses, independent of whether the above ground assets are presently vulnerable to or at risk from sea level rise or flooding.

Diked former tide lands have compacted as much as two to three feet over the last century and are very prone to flooding by rising ground water, stormwater runoff, and rising tides that reduce drainage capacity of water control structures such as dikes and culverts. Because of compaction these lands will have increased water depths due to stormwater runoff and tidal inundation should the dikes be breached or overtopped and maintenance of utilities traversing these lands will be much more difficult.

The assets that are vulnerable and at risk from sea level rise have been grouped into five broad classes: shoreline structures, land uses, transportation, utilities, and coastal resources. These asset classes are further stratified into discrete asset types composed of individual assets (Table 4).

Table 4. Summary of asset classes and individual assets affected by sea level rise.

Asset Class	Individual Assets
Shoreline Structures	Artificial Natural
Land Uses	Agricultural Residential Coastal Dependent Industrial Commercial Industrial Public
Transportation	Surface Air Rail
Utilities	Drinking (Municipal) water Wastewater Electrical Natural Gas
Coastal Resources	Port facilities Public access sites Environmentally sensitive habitat areas Cultural sites

3.1 Existing Shoreline

The shoreline of any coastal waterbody is where the effects of changing sea levels are likely to manifest first. Shoreline structures are the first line of defense in protecting assets inland from the shoreline. Depending on surface topography, a breach or overtopping of a shoreline structure in one location can result in the tidal inundation of low-lying areas away from the shoreline. It is often the case that the owners of vulnerable assets inland of shoreline structures do not own or maintain the structures protecting their assets. On Humboldt Bay, many shorelines result from historical legacies of tideland developments and are among the most critical assets to the future of the Humboldt Bay region as it adapts to sea level rise.

The shoreline on Humboldt Bay consists of 670 individual assessor parcels and several layers of overlapping shoreline development authorities and jurisdictions. Pursuant to the California Coastal Act, there are three LCPs that cover the Humboldt Bay area: Humboldt County's Humboldt Bay Area Plan (450 parcels or 67.2% of the total number of parcels), City of Eureka LCP (191 parcels or 28.5%) and the City of Arcata LCP (29 parcels or 4.3%). LCP's contain land use and zoning regulations applicable within the coastal zone, and provide the local jurisdiction with coastal development permitting authority in areas outside retained state permit jurisdiction. In areas within the state's retained jurisdiction, which is generally the entire shoreline on Humboldt Bay, coastal development permits are issued by the CCC. The HBAP planning area also includes nearly 20 miles of open ocean beach shoreline, which also falls under the state's (CCC) retained jurisdiction, as well as being sovereign lands under the State Land Commission's jurisdiction.

Humboldt Bay and its shoreline are comprised of "sovereign" lands which include tide and submerged lands and the beds of navigable waterways. The common law Public Trust Doctrine protects sovereign lands for the benefit, use and enjoyment of the public. The legislation that established the Harbor District transferred ownership of these lands to the District along with the obligation to maintain the Public Trust, with the State Lands Commission overseeing the Harbor District's management with respect to Public Trust purposes.

This chapter describes Humboldt Bay's existing shoreline conditions, and shoreline exposure and sensitivity to the current tidal regime (Figure 8) and future sea levels. This chapter relies on the comprehensive field work and findings of the *Humboldt Bay Sea Level Rise Adaptation Planning Project's Shoreline Inventory, Mapping, and Vulnerability Assessment* (Laird and Powell 2013).

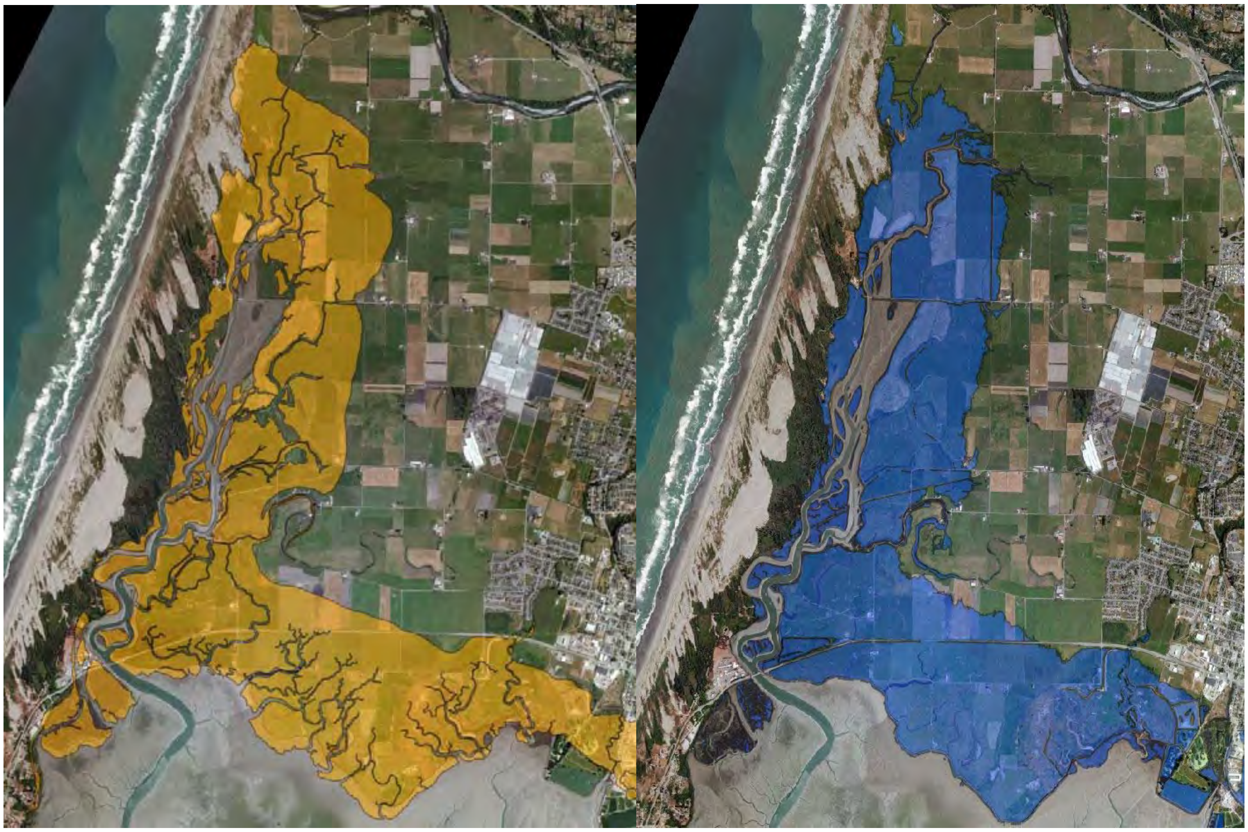

Figure 8. Historic extent of tidal inundation on Mad River Slough and Arcata Bay (1870, yellow) and potential tidal inundation (stillwater), today by mean monthly maximum tides, if protective shoreline dikes are breached (blue).

3.1.1 Affected Shoreline Structures

Historically, as depicted in the original U.S. Surveyor General Township Plats of 1854, Humboldt Bay occupied approximately 25,800 acres: 15,300 acres (60%) was open water and inter-tidal mudflats, and 10,500 acres (40%) was inter-tidal wetlands (Laird 2007). Today Humboldt Bay still has roughly 15,300 acres of open water/mudflats. Only 1,545 acres of salt marsh remain today due to tideland reclamation for agricultural uses.

The shoreline of Humboldt Bay is defined as the boundary between the upper reach of the tidal zone and adjacent upland, often visible as the boundary between salt tolerant vegetation versus freshwater vegetation. Humboldt Bay naturally had approximately 60 miles of shoreline, which has increased to 102 miles under present conditions due to reclamation. On Humboldt Bay, the natural shoreline is closely associated with the MMMW surface elevation. Shorelines can be described, and their vulnerability assessed based on three attributes: structure, cover, and elevation.

There are two basic types of shoreline structure: natural and artificial (Figure 9). Beginning in 1892, the natural shoreline of Humboldt Bay underwent dramatic changes

as the era of “tideland reclamation” began with the construction of a series of dikes (dykes), an artificial shoreline structure, to isolate salt marsh areas from tidal inundation. A dredger was used to excavate a ditch, usually at the boundary between salt marsh and mudflat, and the excavated bay muds were deposited along the ditch to create an earthen barrier, high enough in elevation to keep the highest tides of the year from overtopping and inundating the reclaimed salt marsh fields. After a few years of rainfall, salt would be washed from the former salt marsh soils. Tidegates were installed to allow the reclaimed fields to drain stormwater runoff during ebbing tides while preventing salt water inundation. By the 1930s, approximately 41 miles of earthen dikes had been constructed and nearly 8,100 acres (90 percent) of the salt marsh on Humboldt Bay was reclaimed for agricultural uses.

Over the last century, with the loss of sediment accretion from daily tidal inundation, the surface elevation of these diked former tidelands has lowered due to compaction as organic material in the former salt marsh soils decomposed. Also, tectonic subsidence, as recorded at the North Spit tide gauge, has lowered the elevation of lands on Humboldt Bay by 15 inches in the past 100 years. Today, the combination of compaction and subsidence has caused former tidelands behind dikes to be much lower in elevation than adjacent salt marsh in Humboldt Bay. This circumstance combined with the increased susceptibility of dikes overtopping by increasingly high tides results in significant inundation risks to diked former tidelands as a result of sea level rise.

Figure 9. 1870 USCS survey of Humboldt Bay, with 1870 shoreline (blue) and 2009 shoreline (red for artificial and green for natural) serves to illustrate the magnitude of change to the bay.

In 1895, a second wave of shoreline development ensued with construction of the first railroad tracks from the Eel River to Eureka, and then on to Arcata and Samoa. By 1904, railroad tracks would form 11 miles of shoreline on Humboldt Bay, isolating hundreds of acres of salt marsh. In 1912, the Redwood Highway (Highway 101) was constructed parallel to the railroad on the eastern shoreline of Humboldt Bay, thereby further reinforcing the tidal barrier and isolation of these former tidelands. Since the dramatic shoreline changes of the 1890s to 1910s, there have been only localized changes to the location of the shoreline. Today, there is no single entity responsible for the maintenance of the artificial shoreline on Humboldt Bay, which consists of 670 individual parcels and many different property owners. Consequently, a comprehensive inventory and mapping of the artificial shoreline structure, cover, and elevation did not exist and was sorely needed.

For purposes of this vulnerability assessment, and because tides do not recognize property boundaries, the 102 miles of shoreline have been segregated into six individual hydrologic units: Arcata Bay (20.5 miles), Eureka Bay (15.9 miles), South Bay (21.8 miles), Mad River Slough (13.7 miles), Eureka Slough (20.8 miles), and Elk River Slough (9.7 miles) (Figure 10).

Figure 10. Humboldt Bay's hydrologic areas (Arcata-Eureka-South Bays and Mad River-Eureka-Elk River Sloughs) and potential 1.6 feet (0.5-meter) inundation areas (stillwater).

Structure

The 102-mile shoreline on Humboldt Bay is composed of artificial structures (75% or 76.7 miles) and natural shoreline with no structures (25% or 25.3 miles). It is significant that 75% of the shoreline is artificial. Artificial structures need to be maintained to retain their integrity and protect land uses and infrastructure behind these structures. A breakdown of the most prevalent types of artificial structures based on the 76.7-mile length of artificial shoreline includes:

1. dikes (56.9% or 40.7 miles),
2. railroad grade (14.7% or 10.5 miles),
3. fill (new Bay shoreline) (10% 7.7 miles),
4. fortified (armored natural shoreline) (10.7% or 7.6 miles), and
5. roadbeds (7% or 5.0 miles),

Based on shoreline length, earthen dikes are the most common shoreline structure on Humboldt Bay, totaling 41 miles. Railroad grades form another 10.5 miles of shoreline. These 51.5 miles of shoreline structures function as tidal barriers. However, most of these dikes and railroad grades were built over 100 years ago, when tides were approximately one foot or lower than they are today. In some instances, roads also function as tidal barriers, protecting low-lying lands behind these structures.

The shores of Eureka, Mad River, and Elk River Sloughs contain 64% of the 40.7 miles of dikes on Humboldt Bay. Dikes protect thousands of acres of low-lying former tideland from tidal inundation. Dikes may have provided a false sense of security and encouraged land uses, development and the siting of critical infrastructure behind these shoreline structures that could be inundated if these dikes were breached or overtopped. Besides protecting agricultural lands, dikes also protect important regional infrastructure (power plant and spent nuclear fuel storage site, wastewater treatment facilities, municipal water transmission lines, gas transmission lines, optical fiber lines, electrical transmission towers and distribution poles, interstate and state highways, county roads, city service streets, and a county airport). Together, dike and railroad shorelines cover 50% of the 102 miles of shoreline on Humboldt Bay. The vulnerability of the dikes and railroads would help determine the level of risk to sea level rise to important regional infrastructure.

Fortified and fill shoreline structures occupy approximately 15% of Humboldt Bay and are most commonly associated with industrial and commercial waterfront developments in Eureka, Samoa-Fairhaven, Fields Landing, and King Salmon. Fortified and fill shoreline structures are generally covered with rock rip-rap, and are non-former tidelands or backfilled with no low-lying areas behind the shoreline. A substantial fortified and rocked shoreline segment forms a 1.4-mile long seawall that provides protection for Highway 101, Humboldt Bay Generating Station (HBGS), and the former Humboldt Bay Power Plant (HBPP) spent nuclear fuels storage installation from

extreme high tides, storm surge, and wind waves rolling in from the entrance of the harbor.

Starting at the north end of the Bay, the following describes the extent of artificial shoreline and of barrier-like structures (dikes and railroad) for each hydrologic area:

- Mad River Slough's shoreline is 80% artificial, with dikes covering 22% or 9.0 miles;
- Arcata Bay's shoreline is 91% artificial with railroad covering 62% or 6.5 miles and dikes covering 15% or 6.3 miles;
- Eureka Slough's shoreline is 80% artificial with dikes covering 35% or 14.3 miles;
- Eureka Bay's shoreline is 71% artificial with railroad covering 15.8% or 1.7 miles and dikes covering 1.4% or 0.6 miles;
- Elk River Slough is only 45% artificial with dikes covering 7% or 2.9 miles; and
- South Bay's shoreline is 68% artificial with dikes covering 18.7% or 7.6 miles and railroad covering 12.9% or 1.4 miles (Table 5).

As noted earlier, there is a historical legacy on Humboldt Bay of approximately 57 miles of linear barrier-type shoreline structures (dikes, railroad, and highway/roads) that were constructed across former tidelands. The former tidelands behind most of these linear shoreline structures are now lower in elevation than the salt marsh in Humboldt Bay today. Consequently, the land uses, structures, and critical utility and transportation infrastructure located on these former tidelands are at risk today from tidal inundation if these shoreline structures are breached or overtopped. Sea level rise would increase the risk to land uses and assets located on these former tidelands.

Ninety-seven tide gate structures are associated with these mostly diked former tidelands. These tide gates are needed to convey stormwater runoff and drain these low-lying lands. Most tide gates are set near MLLW elevation or lower. During periods of heavy rainfall and stormwater runoff, draining of agricultural lands can be delayed by undersized or too few tide gates. High tides are also a limiting factor, as tide gates can only drain during periods of ebbing tides. As tides increase, drainage capacity would also need to increase if the time these lands are saturated or inundated is to be minimized.

Table 5. Humboldt Bay's dominant artificial shoreline structure type, length in miles by hydrologic unit, and percentage of the total length of artificial shoreline.

Artificial Shoreline Structures	Arcata Bay	Eureka Bay	South Bay	Mad River Slough	Eureka Slough	Elk River Slough	Total Miles	Artificial Shoreline
Dike Length	**6.3**	**0.6**	**7.6**	**9.0**	**14.3**	**2.9**	**40.7**	**53%**
Percent of Total Dike	**15%**	**1%**	**19%**	**22%**	**35%**	**7%**		
Fill Length	**2.4**	**1.2**	**2.6**	**0.1**	**1.1**	**0.2**	**7.7**	**10%**
Percent of Total Fill	**32%**	**16%**	**34%**	**1%**	**15%**	**2%**		
Fortified Length	**0.1**	**5.6**	**1.5**	**0.3**	**0.0**	**0.1**	**7.6**	**10%**
Percent of Total Fortified	**1%**	**74%**	**20%**	**3%**	**0%**	**2%**		
Railroad Length	**6.5**	**1.7**	**1.4**	**0.6**	**0.1**	**0.3**	**10.5**	**14%**
Percent of Total Railroad	**62%**	**16%**	**13%**	**5%**	**1%**	**3%**		
Road Length	**1.3**	**0.7**	**0.7**	**1.0**	**0.7**	**0.7**	**5.0**	**7%**
Percent of Total Road	**26%**	**15%**	**14%**	**19%**	**14%**	**13%**		

Cover

The type and condition of shoreline cover is important when evaluating the ability of a shoreline to resist wave induced erosion or bank saturation and collapse. Man-made shoreline structures (artificial shoreline) occupy 75% of the shoreline on Humboldt Bay and protect thousands of acres of property, land uses, and critical infrastructure assets. Earthen dikes are the most prevalent shoreline structure (41 miles) on Humboldt Bay, functioning as an elevated tidal barrier shielding the lands behind them. The consequence of a dike breach can be substantial and extensive. For example, in 2003, a single dike breach on Mad River Slough flooded approximately 600 acres of former tidelands. On Humboldt Bay, transportation structures, including 10.5 miles of railroad and five miles of highways and roads, provide similar shoreline protection as dikes to the lands and assets behind them.

Shoreline cover or protection can be grouped in two broad types: fortified and unfortified. Fortified shorelines can be a form of revetment or rip rap composed of materials such as rock, concrete, or even fronted by a structure such as a bulwark made of wood or steel. Unfortified shorelines found on Humboldt Bay are either vegetated or exposed. Salt marsh plains, now often referred to as living shorelines, are a form of vegetated protection of the Bay's shoreline in that they are highly effective in attenuating wave energy, particularly in areas exposed to wind waves. Earthen dikes that are not fortified and without living shoreline protection are more vulnerable to wave induced erosion and breaching. On Humboldt Bay, there are approximately six miles of actively eroding artificial shoreline structures (Laird 2013).

Humboldt Bay's shoreline is predominately unfortified (72.9%), vegetative cover occupies approximately 63.9% (65.4 miles), and 9% (9.2 miles) is exposed or with no cover, while 26% (27.0 miles) of the shoreline cover is fortified (not to be confused with shoreline structure classified as fortified which occupies just 10.7% of the artificial shoreline), and salt marsh provides protection on 48% (48.5 miles) of the Bay in front of both unfortified and fortified shorelines (Table 6). Fortification of the shoreline is more prevalent in Eureka, Arcata and South Bays than on Mad River, Eureka, and Elk River Sloughs.

Table 6. Humboldt Bay shoreline cover percentage by hydrologic unit.

Shoreline Cover	Arcata Bay	Eureka Bay	South Bay	Mad River Slough	Eureka Slough	Elk River Slough	Total Miles	Total Percent
Unfortified Exposed	**0.9**	**2.0**	**3.1**	**1.6**	**1.3**	**0.4**	**9.2**	**9.0%**
Unfortified Vegetated	**12.3**	**5.2**	**12.0**	**9.2**	**17.9**	**8.9**	**65.4**	**63.9%**
Fortified	**7.3**	**8.3**	**6.6**	**2.9**	**1.5**	**0.5**	**27.0**	**26.3%**
Salt Marsh	**12.7**	**2.5**	**8.9**	**7.4**	**11.0**	**5.9**	**48.5**	**47.4%**
Total	**20.5**	**15.9**	**21.8**	**13.7**	**20.8**	**9.7**	**102.3**	

Elevation

Shoreline elevation is a critical attribute to the resiliency of shoreline structures to extreme high tides and sea level rise. While a well-fortified dike may not be vulnerable to coastal erosion on its waterward slope, if overtopped, a dike may be susceptible to breaching as the landward slope erodes.

In 2003, during an extreme high tide and storm surge/wind waves, a dike on Mad River Slough experienced a 230-foot breach which flooded approximately 600 acres of former tidelands. It was not until several years later, when FEMA funding was received to fortify the dikes, that this breach was repaired.

In 2006, a period of heavy precipitation combined with an extreme high tide on New Year's Eve resulted in a maximum high tide of record (9.55 ft.) and the Governor declaring a state of emergency on Humboldt Bay. Consequently, the CCC and Harbor District issued numerous emergency permits to property owners to repair their overtopped dikes that were at risk of breaching.

One of the three approaches to address sea level rise is to utilize the shoreline profile created for Humboldt Bay (Laird 2013). NOAA's 2012 LiDAR dataset, which reflects surface elevation in 2010, was used to generate a shoreline profile; an average relative elevation to MMMW elevation (7.7 ft.) was calculated in one-foot increments for each one-meter shoreline segment. With 75% of the shoreline on Humboldt Bay composed of man-made structures, it is important to establish the elevation of these structures. This

information is necessary for an assessment of the shoreline's vulnerability to overtopping and inundation of the lands behind. Table 7 lists the length of artificial shoreline for each hydrologic unit that is equal to or less than a specific elevation (1, 2, 3 and 6 feet). Most (92%) of the artificial shoreline is less than or equal to an elevation that is six feet higher than MMMW elevation (13.7 ft.), 27% is less than or equal to an elevation that is just two feet higher than MMMW (9.7 ft.), and the majority (58%) of the artificial shoreline is less than or equal to an elevation that is only three feet higher than MMMW (10.7 ft.). As noted earlier, the extreme high tide of record on Humboldt Bay reached 9.5 ft., just 1.8 ft. higher than MMMW elevation, and the resulting shoreline damage warranted the Governor declaring a state of emergency on the bay.

The five most prevalent shoreline structures are: dikes (40.7 miles), railroad (10.5 miles), fill (7.7 miles), fortified (7.6 miles), and roadways (5.0 miles). Table 8 lists shoreline length that is equal to or less than a specific elevation for these five structures. Approximately 59% of these structures are less than or equal to 10.74 feet, just three feet higher than MMMW elevation; 92% of these structures are less than or equal to 13.7 ft., 6 ft. higher than MMMW.

Table 7. Humboldt Bay hydrologic unit artificial shoreline length (miles) and percent by shoreline elevation (equal to or less than).

Artificial Shoreline Elevation	Arcata Bay	Eureka Bay	South Bay	Mad River Slough	Eureka Slough	Elk River Slough	Total Miles	Total Percent
MMMW 7.74'	0.1	0.4	0.9	0.1	0.3	0.5	2.3	**3.0%**
8.74'	0.9	1.1	2.2	0.6	1.1	1.8	7.6	**9.9%**
9.74'	3.7	2.4	6.0	2.6	3.6	2.6	20.9	**27.2%**
10.74'	10.2	5.4	11.0	5.8	8.6	3.3	44.3	**57.8%**
13.74'	16.8	8.6	14.2	10.4	16.2	4.1	70.3	**91.7%**
TOTAL	**18.7**	**11.3**	**14.8**	**10.9**	**16.6**	**4.3**	**76.7**	

Table 8. Shoreline structure length (miles) by elevation (equal to or less than) and the total length of the shoreline for five predominant structural types: dike, railroad, fill, fortified, and road. Elevations are shown in feet.

HUMBOLDT BAY SHORELINE STRUCTURE	Elevation (Feet)					TOTAL MILES
	MMMW 7.74'	8.74'	9.74'	10.74'	13.74'	
Dike	0.8	3.3	11.4	23.4	38.4	40.7
Railroad	-	0.1	1.5	6.9	9.5	10.5
Fill	0.7	1.6	3.5	5.3	6.9	7.7
Fortified	0.3	1.1	2.2	4.0	6.3	7.6
Road	0.1	0.5	1.3	2.8	4.7	5.0
Total	**1.9**	**6.6**	**19.9**	**42.4**	**65.8**	**71.5**
Percent	**2.6%**	**9.2%**	**28.0%**	**59.2%**	**91.9%**	

3.1.2 Exposure of the Existing Shoreline

Coastal hazards commonly associated with Humboldt Bay include: tidal inundation (shoreline breaching via erosion and/or overtopping), flooding (drainage impaired backwater and emerging groundwater), and salt water intrusion (Inflow/Intrusion). Sea level rise would likely increase the effects of extreme high tides, wind waves, low-pressure systems/storm surges, and El Nino events on the shoreline of Humboldt Bay. Sea level rise would reduce the drainage capacity of water control structures while simultaneously causing rising groundwater and salt water intrusion. Both natural and artificial shorelines are affected by extreme high tides and would be affected by sea level rise.

Natural Shoreline

Natural shorelines are primarily vulnerable to tidal inundation and flooding. Assets behind natural shorelines are at risk from flooding from stormwater runoff backwater, rising groundwater, and salt water intrusion.

➢ *Tidal Inundation*

Tidal inundation of interior lands can occur when barrier-like shorelines are breached as a result of wave erosion, slumping, or overtopping. Natural shorelines are generally not as vulnerable to breaching, unless there is a low-lying area like a wetlands immediately behind the shoreline that forms a barrier to high water like a dike making the back-side susceptible to erosion, which applies to the City of Eureka's Samoa Airport. Elk River Spit could also be breached at its narrowest points with a rise in sea levels of three feet above MMMW elevation. There are reports of historical storm wave or over wash, a type of breaching, on South Spit at its narrowest location, which could occur again with extreme high tides and sea levels greater than six feet above MMMW elevation. The areas of potential natural shoreline breaching could result in tidal inundation of transportation infrastructure, ESHA, and could change water and sediment circulation in the Bay.

➢ *Erosion*

Natural shoreline erosion on Humboldt Bay is limited, mostly occurring in undeveloped or natural areas exposed to waves. The bluffs on South Bay are a dramatic example of the effects of wind induced waves while the eroding forest area south of Fairhaven on the North Spit is an example of erosion caused by reflective waves bouncing off the sea wall across from the entrance of the harbor. Waves also erode and rebuild reaches of the beach and dunes on Elk River Spit on an annual cycle. Saturation and draining of shorelines can also lead to slumping and collapse of vertical shorelines. The erosion of natural shorelines may place ESHA at risk, such as the dune system on Elk River Spit, cultural resource sites, and private property.

➢ *Overtopping*

Overtopping of natural banks/shorelines along open tidal slough channels can cause inundation of land uses, infrastructure, and natural resources adjacent to the slough channels, and downriver where ponding of water may occur behind shoreline structures such as dikes. There are five open water tidal slough channels, not muted tidal channels, on Humboldt Bay where overtopping of natural banks/shorelines could occur from extreme high tides and sea level rise, summarized below.

- Mad River Slough: the upper most 2,000 ft. of the tidal channel are natural banks. Overtopping could occur on approximately 500 feet of the south bank by extreme high tides. Both banks could be overtopped by water levels that are two feet above MMMW elevation.
- Liscom Slough: 1,300 ft. of the south bank east of Jackson Ranch is a natural shoreline and is overtopped now by extreme high tides.

- Jacoby Creek: the 800 ft. of tidal channel east of Highway 101 are natural banks. The south bank currently is overtopped by extreme high tides.
- Freshwater Creek: the last 2,500 ft. of tidal channel has natural banks that are currently overtopped by extreme high tides in a few locations. Overtopping would increase with water levels that are two feet above MMMW elevation, and these banks would be completely overtopped with a three-foot rise.
- Elk River Slough: the last 4,850 ft. of the tidal channel has natural banks that are currently overtopped by extreme high tides.

Overtopping of natural banks/shorelines on Humboldt Bay by extreme high tides up to two feet above MMMW elevation could tidally inundate adjacent environmentally sensitive habitat areas (ESHAs) (dune systems, freshwater wetlands, riparian areas, ponds, and forest areas), cultural resource sites, residential areas (Fairhaven and 3rd Sloughs), utility and transportation infrastructure, and agricultural lands. With a three-foot rise in sea levels above MMMW elevation, additional residential areas in Fairhaven, 2nd Slough, and Manila would also be at risk of tidal inundation.

- *Flooding*

Flooding of natural shorelines can occur from extreme storm events (100-year floods that have a 1% probability of occurring any year). Flooding of lands behind the shoreline can occur during extreme storm events or extreme high tides as drainage is impaired resulting in backwater ponding, or when rising groundwater emerges onto the surface.

- *Saltwater Intrusion*

Rising sea levels and/or subsiding shoreline structures can increase salt water intrusion of surface and ground waters interior of the shoreline. Shoreline breaching and overtopping on Humboldt Bay would also lead to salt water intrusion of both surface and ground waters as previously discussed.

Artificial Shoreline

Artificial shoreline structures are primarily vulnerable to tidal inundation and flooding. Assets behind artificial shorelines are also at risk from tidal inundation, flooding, and salt water intrusion.

- *Tidal Inundation*

Barrier-like shoreline structures (dikes, railroad, and roads) can be breached by wave induced erosion, slumping, or overtopping. Independent of the size of the breach, this can tidally inundate significant areas of former tidelands.

Tidal inundation of other types of artificial shorelines (fortified and fill) can occur when tides overtop the shoreline structure. Under current conditions, overtopping would not tidally inundate significant areas of interior lands unless they are lower in elevation than the shoreline.

- ### *Erosion*

There are currently approximately a total of 9.2 miles of eroding shoreline on Humboldt Bay. A common element of many of these eroding shoreline segments is that they are in high wave energy areas and/or they lack salt marsh plains to attenuate wave energy. Focusing on artificial shorelines and the five dominant shoreline structures (covering 71.5 of the 76.7 miles of artificial shoreline), there are approximately 6.2 miles (8%) that are eroding and exposed resulting from wave action or slumping (Laird 2013) (Table 9). Of the 6.2 miles of eroding shoreline there are four miles of barrier-like shorelines that under their current eroding condition are vulnerable to breaching, potentially placing hundreds of acres at risk of tidal inundation today. While exposed and eroding fill or fortified shoreline segments (2.2 miles of the 6.2 miles of eroding shoreline) are vulnerable, they do not place areas interior at risk of tidal inundation unless there are low-lying areas capable of receiving tidal waters.

Table 9. Predominant shoreline structure total length, length of eroding shoreline, and percent of that structure by hydrologic units for five predominant artificial structure types.

Artificial Shoreline Cover-Exposed	Arcata Bay	Eureka Bay	South Bay	Mad River Slough	Eureka Slough	Elk River Slough	Total Feet	Total Miles
Dike	33,107	3,077	40,215	47,471	75,588	15,334	**214,792**	**40.7**
Length (ft)	116	-	3,429	7,969	6,098	74	**17,686**	**3.3**
Percent	0.1%	0.0%	1.6%	3.7%	2.8%	0.0%	**8.2%**	
Railroad	34,431	8,794	7,197	2,968	551	1,714	**55,655**	**10.5**
Length (ft)	525	-	346	25	-	-	**896**	**0.2**
Percent	0.9%	0.0%	0.6%	0.0%	0.0%	0.0%	**1.6%**	
Fill	12,935	6,309	13,816	469	6,059	955	**40,543**	**7.7**
Length (ft)	2,056	2,015	6,353	91	-	-	**10,516**	**2.0**
Percent	5.1%	5.0%	15.7%	0.2%	0.0%	0.0%	**25.9%**	
Fortified	330	29,657	8,019	1,345	163	749	**40,262**	**7.6**
Length (ft)	-	382	522	-	-	-	**904**	**0.2**
Percent	0.0%	0.9%	1.3%	0.0%	0.0%	0.0%	**2.2%**	
Roadway	6,788	3,851	3,607	5,050	3,666	3,443	**26,405**	**5.0**
Length (ft)	909	963	635	104	-	26	**2,636**	**0.5**
Percent	3.4%	3.6%	2.4%	0.4%	0.0%	0.1%	**10.0%**	

Eroding dike structures are at risk of breaching from wave action and/or bank saturation and collapse or slumping under the current tidal regime. The consequences of a dike breach can be significant spatially, potentially tidally inundating hundreds of acres of former tidelands and the assets residing in those low-lying areas. Currently, there are 3.3 miles of eroded dike shoreline (Table 8) mostly concentrated in three hydrologic units:

- Mad River Slough has 1.5 miles of exposed and eroding dike shoreline in 12 reaches, ranging from 104 to 2,030 ft. in length;
- Eureka Slough has 1.2 miles of exposed and eroding dike shoreline in 14 reaches, ranging in length from 24 to 1,183 ft.; and
- South Bay has 0.6 miles of exposed and eroding dikes shoreline in four reaches, ranging in length from 164 to 1,307 ft.

Dikes in these hydrologic units protect utility infrastructure (municipal water transmission lines and pump station, gas lines, optical fiber lines, electrical transmission towers and distribution poles, and wastewater lines and lift stations), transportation infrastructure (Highway 101 and 255, County roads, City streets, and County airport), agricultural uses, ESHA, and cultural resource sites.

Eroding railroad grade and roadways account for only 0.7 miles of shoreline at several limited locations on Arcata Bay and South Bay, which could cause localized tidal inundation of areas interior to their shoreline.

Fortified shorelines are not as susceptible to erosion; there are only 904 feet currently exposed out of 7.6 miles of fortified shoreline. South Bay has most of the fill areas with exposed shoreline segments (1.2 miles) mostly located in the Fields Landing and King Salmon areas. There is very little low-lying area behind the exposed fill shoreline in Fields Landing. In King Salmon, there are numerous residential properties that are at risk of tidal inundation behind exposed shoreline segments.

➢ *Overtopping*

Under current tidal conditions, 1.9 miles (2.6%) of the five dominant artificial shoreline structures are vulnerable to MMMW (7.7 ft.), of which 0.9 miles are barrier type structures with low-lying areas behind. Approximately 6.6 miles (9.2%) are vulnerable to MAMW (8.8 ft.), including 3.9 miles of barrier structures (Table 8).

Overtopping of shoreline structures is most likely to occur during MAMW or extreme high tides. Under the current tidal regime, MAMW elevation on Humboldt Bay is 8.8 ft., but it has varied by 1.8 ft. (7.8 ft. to 9.5 ft.) (Figure 5). In addition to the extreme high tides, FEMA has recently adopted new 100-year (1% probability of occurring in any year) or base flood elevation for Humboldt Bay of 10.2 ft., which is also capable of overtopping shoreline structures.

Sea Level Rise of 0.9 Ft.

The high sea level rise projection for 2030 on Humboldt Bay is 0.9 ft. (MMMW 8.6 ft.). The current MAMW (8.8 ft.) approximates this amount of sea level rise, albeit for a limited number of days, and can result in nuisance flooding. There are approximately 7.6 miles (9.9%) of artificial shoreline that are at risk of being overtopped (Table 7) with 0.9 ft. of sea level rise.

With 0.9 ft. of sea level rise, the frequency of overtopping by MMMW of 8.6 ft. would be much greater than it would with our current MAMW of 8.8 ft. With 0.9 ft. of sea level rise, the future MAMW would become approximately 9.7 ft., which is two feet higher than our current MMMW (7.7 ft.), and 20.9 miles of shoreline could be overtopped.

Sea Level Rise of 1.9 Ft.

The high sea level rise projection for 2050 on Humboldt Bay is 1.9 ft. (MMMW 9.6 ft.). There is a critical shoreline elevation threshold on Humboldt Bay between 9.7 feet and 10.7 ft. if the elevations of current artificial shoreline structures remain as they are today. Based on the 2050 sea level rise projection of 1.9 ft., MMMW and MAMW elevations would reach 9.6 ft. and 10.7 ft.

Approximately 20.9 miles (27.2%) of artificial shoreline structures that could be vulnerable to overtopping by MMMW (9.6 ft.), including 14.2 miles that are barrier type structures (dikes 11.4 miles, railroad 1.5 miles and roads 1.3 miles). There could be 44.3 miles (57.8%) of artificial shoreline vulnerable to overtopping by MAMW (10.7 ft.) including 33.1 miles of barrier type structures (23.4 miles, railroad 6.9 feet, and roads 2.8 miles).

Because earthen dikes are the most prevalent shoreline structure on Humboldt Bay (Table 4), the consequences of diked shorelines being overtopped by MMMW could be significant to the Humboldt Bay region (76% on Elk River Slough, 46% on South Bay, 24% on Mad River and 17% on Eureka Slough), and by MAMW (93% on Elk River Slough, 85% on South Bay, 56% on Mad River Slough, and 48% on Eureka Slough) (Table 10).

Sea Level Rise of 3.2 Ft.

The high sea level rise projection for 2070 on Humboldt Bay is 3.2 ft., MMMW could reach 10.9 ft. and MAMW 12.0 ft. elevation. Approximately 44.3 miles (57.8%) of artificial shoreline structures could be vulnerable to overtopping by MMMW (10.9 ft.), including 35.0 miles are barrier type structures (dikes 23.4 miles, railroad 6.9 miles and roads 4.7 miles).

➢ *Sea Level Rise of 5.4 Ft.*

The high projection for 2100 on Humboldt Bay is 5.4 ft. of relative sea level rise, which would raise MMMW elevation from 7.7 to approximately 13.1 ft. elevation. Based on existing artificial shoreline elevations, approximately 70.3 miles (91.7%) would be vulnerable to being overtopped by MMMW with 5.4 ft. of sea level rise, 52.6 miles of which are barrier type structures (dikes, railroad, and roads) protecting low-lying areas.

Table 10. Diked shoreline length (miles) that could be overtopped by 2, 3 and 6 foot increases in water elevation for each hydrologic unit.

Diked Shoreline Elevation	Arcata Bay	Eureka Bay	South Bay	Mad River Slough	Eureka Slough	Elk River Slough	Total Miles	Total Percent
9.74' (2' SLR)	1.0	0.2	3.5	2.2	2.4	2.2	**11.4**	**28.1%**
10.74' (3' SLR)	2.0	0.2	6.5	5.0	6.9	2.7	**23.4**	**57.5%**
13.74' (6' SLR)	5.0	0.3	7.6	8.7	14.0	2.9	**38.4**	**94.4%**
TOTAL	**6.3**	**0.6**	**7.6**	**9.0**	**14.3**	**2.9**	**40.7**	

The railroad grade is the second most prevalent artificial shoreline structure on Humboldt Bay, forming 10.5 miles of shoreline (Table 4). Based on existing conditions and with 1.9 ft. of sea level rise (MMMW potentially by 2050), 14.8% of the railroad grade could be overtopped, mostly on Arcata Bay. With 3.2 ft. of sea level rise (MAMW by 2050), 66.6% of the entire railroad grade could be overtopped. At six feet of sea level rise (13.1 ft. MMMW), 91.9% of the railroad could be overtopped (Table 11). If existing conditions persist, there is a threshold between two and three feet of sea level gain where the length of railroad grade that would be overtopped increases from 1.5 miles (14.8%) to 6.9 miles (66.6%). Currently, the Humboldt Bay Trail (Trail) is being constructed to the east of the railroad grade. The Trail should help reinforce the railroad grade. In the future, the Trail may be able to be elevated to continue to provide protection to assets to the interior of the shoreline.

Table 11. Railroad shoreline length (miles) equal to or less than MMMW and MAMW projected for 2050, and MMMW by 2100 for each hydrologic unit.

Railroad Shoreline Elevation	Arcata Bay	Eureka Bay	South Bay	Mad River Slough	Eureka Slough	Elk River Slough	Total Miles	Total Percent
9.74' (2' SLR)	1.4	0.1	0.0	0.0	0.1	0.0	**1.5**	**14.8%**
10.74' (3' SLR)	5.4	0.7	0.7	0.0	0.1	0.0	**6.9**	**66.6%**
13.74' (6' SLR)	6.5	0.9	1.4	0.5	0.1	0.2	**9.5**	**91.9%**
Total	**6.5**	**1.7**	**1.4**	**0.6**	**0.1**	**0.2**	**10.4**	

- *Flooding*

Flooding or overtopping of artificial shoreline structures can occur, infrequently, from extreme storm events (100-year flood that has a 1% probability of occurring any year).

Flooding of low-lying lands behind barrier type shorelines (dikes, railroad and road grades) can also occur during heavy rainfall when drainage to Humboldt Bay is impaired, resulting in backwater ponding. Flooding and ponding of water behind earthen dikes by stormwater runoff from interior watersheds can result in erosion and/or slumping of dike slopes, as fortification of dike slopes is generally limited to the bay side of the dikes.

Tsunamis are another form of flooding, and they are also not predictable. Tsunamis from a major Cascadia subduction event would overwhelm (overtop) any shoreline structures currently on Humboldt Bay, even if those shoreline structures were not affected by liquefaction. A tsunami would come into Humboldt Bay in waves. The height, velocity, and direction of these tsunami waves would likely be very different from normal tidal currents and or wind waves. The potential for erosion and overtopping of shoreline structures such as dikes or fill areas would depend on the height, velocity and direction of the tsunami waves.

- *Salt Water Intrusion*

Rising sea levels, as opposed to salt water intrusion, could corrode metal water control structures in dikes, or metal bulwarks protecting dikes. Saltwater intrusion should not adversely affect earthen dike structures.

3.1.3 Susceptibility

Susceptibility is the degree to which an asset may be adversely affected. By design, shoreline structures can be made to withstand coastal hazards such as erosion and tidal inundation. With appropriate design and maintenance, shoreline structures can continue to function even when exposed to sea level rise to some degree. There is no one entity responsible for maintaining the artificial shoreline, and there are 170 individual parcels that make up the diked shoreline on Humboldt Bay. Assets and land uses in a common hydrologic unit are very susceptible if a shoreline breach were to occur on just one of these 170 parcels.

Unfortified shoreline structures are susceptible to erosion because of wave action. Unfortified shoreline structures are also susceptible to slumping from the effects of flooding and ebbing tides. Most of the artificial shoreline structures on Humboldt Bay are barrier type structures (dikes, railroad and roads) (71.5 miles) with two slopes (Table 7). They are more vulnerable to coastal hazards than shorelines with just one slope, fortified or not, that have been filled behind or the land behind the shoreline is naturally higher. Overtopped barrier shoreline structures are susceptible to erosion on their back-slopes and subsequent breaching. There are approximately 14.2 miles of barrier type structures that could be overtopped by two feet of sea level rise and 33.1 miles by three feet (Table 7). Nearly, all barrier shoreline structures (93.6%) are vulnerable to being tidal inundation by six feet of sea level rise.

A Humboldt Bay shoreline vulnerability index, a quantitative measure of vulnerability that was developed for the Humboldt Bay Shoreline Inventory, Mapping, and Sea Level Rise Vulnerability Assessment (Laird and Powell 2013). The vulnerability index uses combinations of shoreline attributes (cover type and relative elevation to modeled MMMW) to rate a shoreline segment's vulnerability to erosion and/or overtopping due to extreme tides, storm surges, and future sea level rise. Shoreline segments are given a rating between 2 and 10, 2 being the least vulnerable and 10 being highly vulnerable.

Structure types of dikes and railroads were extracted from the shoreline mapping GIS dataset for the vulnerability index analysis because they are the most prevalent structures and most vulnerable to extreme tides, storm surges, and sea level rise. Dike and railroad shoreline segments were given a rating between 1 and 3 based on their cover type (Table 12). Fortified shoreline segments are considered to be the least vulnerable to erosion and exposed segment are considered to be the most vulnerable.

Table 12. Vulnerability index values based on cover type.

Cover	Index Value
Fortified	1
Vegetated	2
Exposed	3

Relative elevations to the modeled MMMW surface, tidal baseline, were assigned to 1-meter segments of the bay shoreline. Using these relative elevations, we rated each segment of shoreline using the values in Table 13.

Table 13. Vulnerability index values based on relative elevation to MMMW.

Relative Elevation (ft)	Index Value
<1	7
1-2	6
2-3	5
3-4	4
4-5	3
5-6	2
>6	1

Shoreline cover and relative elevation index values were added together to assign a final index value between 2 and 10 to each individual 1-meter shoreline segment in Table 14. Relative shoreline elevations of <1 to 2 ft. have been given high vulnerability index values because they are within current tidal elevations during MAMW and storm surges on Humboldt Bay. Relative shoreline elevations of 2 to 4 ft. are rated moderately vulnerable at this time as they represent extreme high tide elevations with 1 to 2 ft. of sea level rise, which is not expected to occur until 2050 or later. Relative shoreline elevations of 4 to >6 ft. are considered the lease vulnerable at this time. Shoreline elevations of <1 to 2 ft. are ranked highly vulnerable regardless of the shoreline cover conditions, with a vulnerability index of 7 to 10. Relative shoreline elevations of 2 to 4 ft. are ranked moderately vulnerable but shoreline conditions of vegetated and exposed at

relative elevations of 2 to 3 have combined vulnerability index ratings of 7 and 8, which is a high vulnerability ranking, likewise at the relative elevation of 3 to 4 ft. the exposed shoreline cover condition results in a highly vulnerable ranking of 7. The same staggered vulnerability ranking occurs at 4 to 5 ft. and 5 to 6 ft. due to shoreline cover conditions causing higher vulnerability ranking than what would be if we just considered relative elevation.

Table 14. Combined shoreline vulnerability index values create high-moderate-low ranking.

Relative Elevation	Index Value	Cover Index Value	Vulnerability Index
<1	7	1-2-3	**8-9-10**
1-2	6	1-2-3	**7-8-9**
2-3	5	1-2-3	**6-7-8**
3-4	4	1-2-3	**5-6-7**
4-5	3	1-2-3	**4-5-6**
5-6	2	1-2-3	**3-4-5**
>6	1	1-2-3	**2-3-4**

Shoreline vulnerability index results for dike and railroad shoreline segments are shown in Table 15.

Table 15. Diked and railroad shoreline vulnerability index for Humboldt Bay summarized as length in miles.

Sum of Length (miles)	**Vulnerability Index**								
	Low							**High**	
Area	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	Total
Arcata Bay	**0.68**	**0.88**	**0.98**	**1.41**	**2.82**	**3.38**	**1.88**	**0.26**	**0.00**	12.30
Eureka Bay	**0.67**	**0.41**	**0.03**	**0.14**	**0.40**	**0.34**	**0.19**	**0.09**	**0.00**	2.26
Elk River Slough	**0.08**	**0.13**	**0.06**	**0.05**	**0.20**	**0.48**	**0.74**	**1.49**	**0.00**	3.23
Eureka Slough	**0.00**	**0.46**	**0.98**	**1.85**	**3.93**	**4.63**	**1.98**	**0.58**	**0.03**	14.44
Mad River Slough	**0.04**	**0.34**	**0.68**	**1.68**	**2.43**	**1.90**	**1.74**	**0.62**	**0.12**	9.54
South Bay	**0.01**	**0.07**	**0.15**	**0.82**	**2.25**	**3.81**	**1.34**	**0.43**	**0.12**	9.00
Total	**1.48**	**2.28**	**2.88**	**5.94**	**12.03**	**14.5**	**7.87**	**3.47**	**0.28**	50.78

The total length of diked and railroad shoreline that is ranked highly vulnerable covers 26.2 miles (Figure 11). Eureka Slough has the greatest length of shoreline ranked highly vulnerable 7.2 miles; South Bay 5.7 miles, Arcata Bay 5.5 miles, Mad River Slough 4.4 miles, Elk River Slough 2.7 miles, Arcata Bay 1.5 miles, and Eureka Bay 0.3 miles. Arcata Bay has the greatest length of railroad shoreline ranked highly vulnerable, 4.0 miles; South Bay 0.6 miles, Eureka Bay 0.4 miles, Eureka Slough 0.01 miles, and Elk and Mad River Sloughs negligible lengths of railroad bridge ramps that are vulnerable.

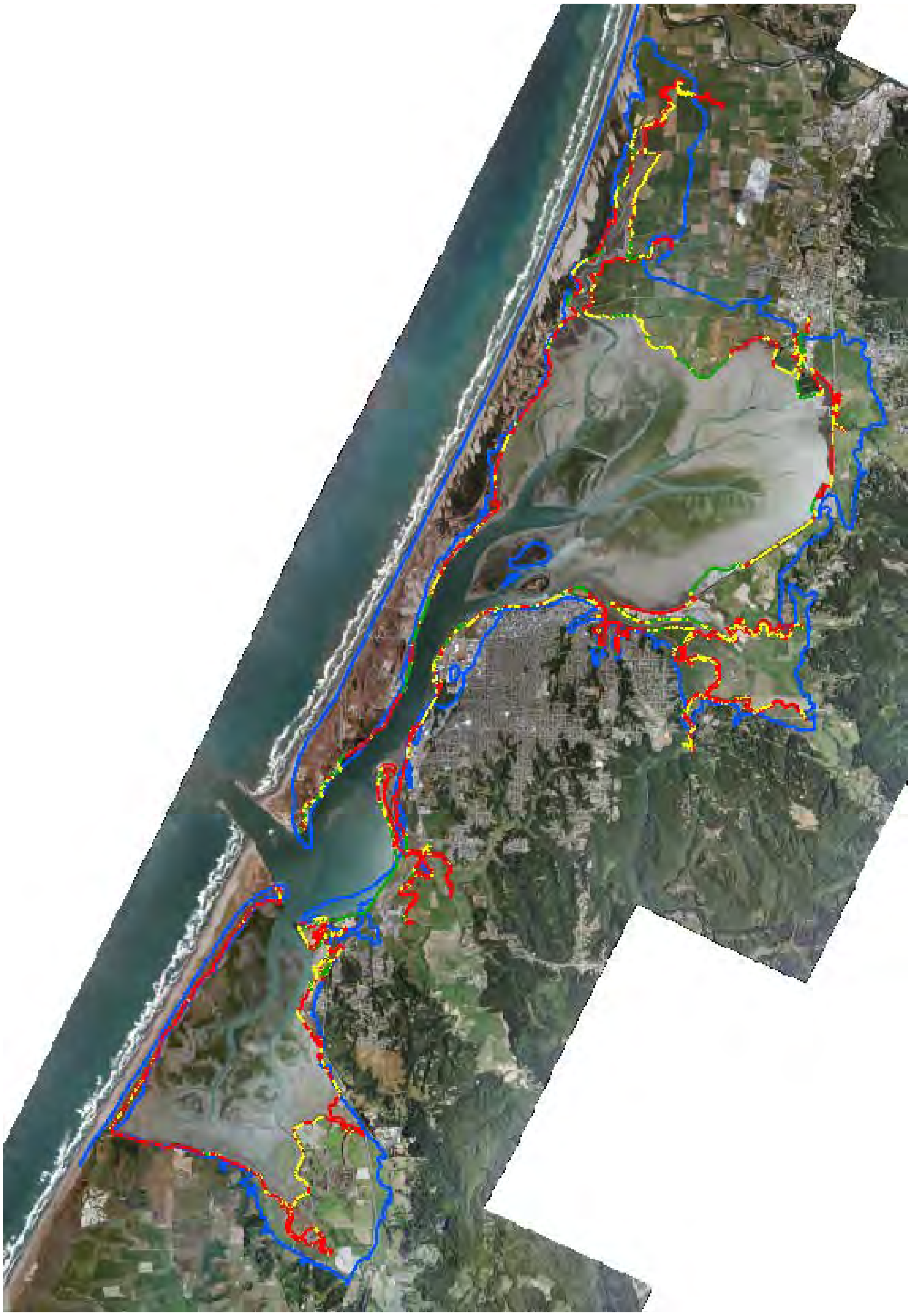

Figure 11. Humboldt Bay shoreline vulnerability rating: high (red), moderate (yellow) and low (green).

3.2 Land Uses

On Humboldt Bay, the HBAP, one of six area plans that comprise the County's LCP, establishes allowable land uses and standards by which development would be evaluated within the Coastal Zone. The County's Coastal Zoning Regulations, also a component of the LCP, implement the six-coastal area plans and control the specifics of how land can be used. In the Coastal Zone including on Humboldt Bay, the Coastal Commission, pursuant to the Coastal Act, has retained jurisdiction on current and former tidelands. Within these areas of state retained jurisdiction, the Coastal Commission has the coastal development permitting authority, and issues coastal development permits relying on Coastal Act standards, using the County's LCP for guidance only. The state's retained jurisdiction on Humboldt Bay encompasses 72% of the area that is vulnerable to approximately 4.9 ft. (1.5 M) of sea level rise, including 70% of the vulnerable area in the HBAP planning area. Also, below MHHW elevation, the legislature has granted development authority to the Harbor District, except where the state previously granted such jurisdiction to the cities of Eureka and Arcata.

3.2.1 Affected Land Use Types

The HBAP covers approximately 21,315 acres of unincorporated area in and around Humboldt Bay, excluding areas of the Bay below MHHW. Lands around Humboldt Bay are predominately rural and undeveloped (15,637 acres, 73%), with a lesser amount of urban and developed areas (5,678 acres, 27%). The six dominate HBAP land use types that are vulnerable to sea level rise by area are: agriculture (50%), natural resources (22%), residential (13%), coastal dependent industrial (5%), industrial/commercial (3%), public (3%), and recreation (2%) (Humboldt County GIS Portal 2017) (Table 16, Figure 12). There are several other land uses that collectively make up the remaining 2% of the HBAP that are vulnerable to sea level rise.

Table 16. HBAP land use types vulnerable to sea level rise, their acreage, and percentage of total HBAP area.

HBAP Land Use	Total Acres	Total %
Agriculture	10,680	50%
Natural Resources	4,740	22%
Residential	2,741	13%
Coastal-Dependent Industrial	968	5%
Industrial/Commercial	656	3%
Public Facility	693	3%
Recreation/Commercial/Public	408	2%
Total	**21,315**	

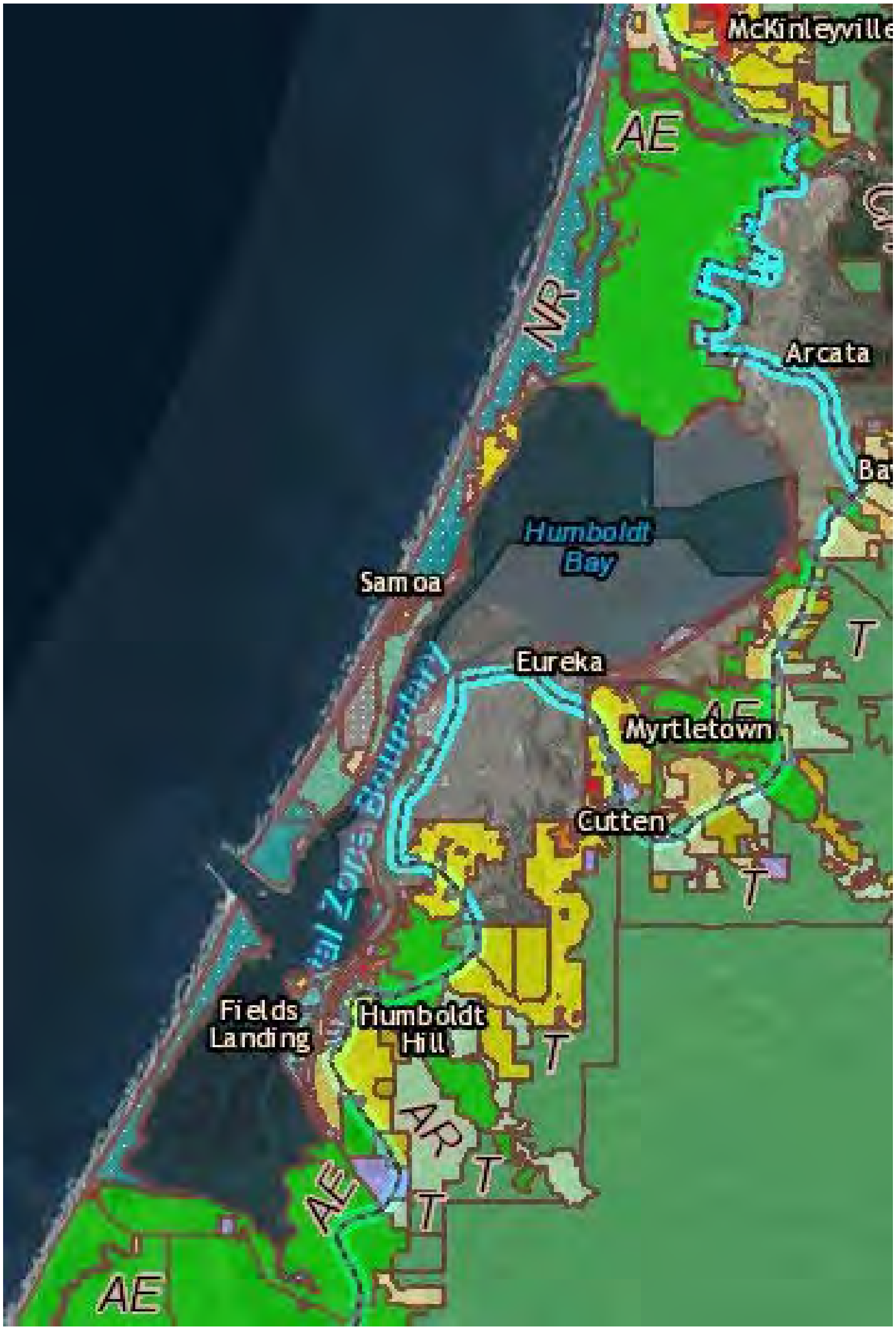

Figure 12. Humboldt Bay Area Plan land use designations: agricultural (green), natural resources (blue), residential (yellow) industrial (red), commercial (brown), and public (purple) (Humboldt County GIS Portal 2017).

In the HBAP, there are three coastal-dependent related land use designations: Industrial/Coastal-Dependent (CDI), Commercial Recreation, and Public Recreation.

As previously discussed, there are two broad categories of shoreline structures: natural and artificial. Artificial shorelines can also be segregated into two general types: barrier, and fill. Barrier-like structures are elevated structures (dikes, railroad, and roads) that prevent tidal inundation of low-lying areas behind the shoreline, while fill shorelines generally have no low-lying areas behind either a fortified or an un-fortified shoreline face. Agricultural lands are strongly associated with barrier type shorelines, natural resource lands with natural shorelines, and urban lands with filled shorelines. The vulnerability of land uses in the HBAP is strongly associated with the shoreline structures that are protecting these uses from coastal hazards.

In the HBAP planning area, there are undeveloped natural resource lands that are vulnerable to tidal inundation, shoreline erosion, and rising groundwater, which are concentrated on North and South Spits behind natural shorelines. Agricultural lands are mostly on diked former tidelands in several hydrologic units: Mad River Slough, Eureka Slough, Elk River Slough, and South Bay. The urban-developed areas in the HBAP planning area that are vulnerable to sea level rise are clustered mostly on the eastern shore of Humboldt Bay: Bracut-Indianola, Eureka Slough, South Eureka, King Salmon-Fields Landing, Fairhaven-Samoa, and Manila. Barrier structures protect urban-developed areas in Bracut-Indianola, Eureka Slough, and South Eureka. King Salmon-Fields Landing are protected by filled shorelines, and Fairhaven-Samoa and Manila are protected by a combination of fill and natural shorelines. A description of vulnerable uses, structures, utilities and access for each of the six dominate HBAP land use types is provided below:

Agriculture

In the HBAP planning area the dominant agricultural land use vulnerable to sea level rise is livestock grazing, on pasture lands, and raising livestock feed. Mad River Slough and North Arcata Bay have the largest extent of agricultural lands on Humboldt Bay, consisting of both diked former tidelands and alluvial river bottom land. California Department of Fish and Wildlife's (DFW) Mad River Slough Wildlife Reserve is located on actively grazed agricultural land behind a protective diked shoreline. Structures common to most agricultural lands consist of fences, tide gates, farm buildings, single-family residences, and well/pump facilities. Urban utilities, except for electricity and communications, are generally absent. Agricultural parcels may also include individual septic systems for wastewater disposal. The Mad River Slough and North Arcata Bay agricultural area also supports the largest extent of irrigated agriculture, approximately 1,859 acres.

Nearly all the agricultural lands on Eureka Slough are diked former tidelands, including approximately 113 acres of irrigated agriculture. DFW's Fay Slough Wildlife Reserve is located on actively grazed agricultural lands behind a protective diked shoreline.

Agricultural lands on Elk River Slough include both diked former tidelands and alluvial river bottom lands with approximately 119 acres of irrigated agriculture. DFW's Elk River Wildlife Reserve is located on actively grazed agricultural lands behind a protective diked shoreline.

Most of the agricultural lands on South Bay are protected by diked shorelines. The diked shoreline on South Bay is nearly entirely on the Humboldt Bay National Wildlife Refuge (HBNWR).

Natural Resources

In the HBAP planning area, there are approximately 19.2 miles of open ocean beach and dune shoreline. On Humboldt Bay, there are approximately 1.8 miles of open water beach and dune shoreline on Elk River Spit, although 1.25 miles are in the City of Eureka's LCP. Natural resource lands on the north and south spits that are vulnerable to tidal inundation include dunes, transitional brackish/freshwater wetland habitats, and coastal pine forest.

Residential

Residential areas vulnerable to sea level rise include:

- Portions of residential areas in Manila behind railroad and natural shorelines.
- An area in Eureka Slough behind dikes south of Indianola Cut-off at the end of Fay Slough.
- A small area behind dikes north of Myrtle Avenue and Tower Drive on Freshwater Slough.
- Fairhaven, where 181 parcels are vulnerable behind natural shorelines.
- King Salmon, where 164 parcels are vulnerable behind filled shorelines.
- Fields Landing, where 84 parcels are vulnerable behind fortified/filled shorelines.
- A mobile home park behind a natural shoreline that is not located on residential zoned on Meadowbrook Drive on Elk River Slough.

Coastal Dependent Industrial

On Eureka Bay, there are vulnerable CDI areas along 4.2 miles of natural and artificial shorelines from Samoa south through Fairhaven and to the area fronting Eureka's Samoa Airport, of which 3.4 miles are vacant (81%). On South Bay, PG&E's HBPP, HBGS, and Interim Spent Fuel Storage Installation (ISFSI) facilities are on CDI lands

behind 0.5 miles of fortified and road shorelines in King Salmon. There are 1.3 miles of fortified/filled shorelines in Fields Landing, of which 1.0 mile (80%) is vacant.

In the HBAP planning area, there are seven docks on CDI property, five on North Spit on the North Bay-Samoa Channel and two at Fields Landing on the Fields Landing Channel. The North Bay-Samoa Channel is 5.1 miles long and 38 feet deep, and the Fields Landing channel is 2.3 miles long and 26 feet deep.

Harbor District Redwood Marine Terminal 1: Redwood Dock 1 has poor onshore access, is located at the shipping channel turning basin, and requires more dredging than docks further to the south due to its location further up the shipping channel. This light use dock is partially functional, experiences ongoing repairs, and currently supports crab and hag fish operations. Oyster use is planned in the future as more repairs are completed. The Harbor District believes this dock is in a good location to support the commercial fishing industry. To the south of Redwood Dock 1 is the "red tank dock". This is a small light use access dock planned to be used for oyster culturing.

Harbor District Redwood Marine Terminal 2: This is a single purpose conveyance dock in good condition. All infrastructure to support a conveyance system remains. The interior of the dock is used for oyster culturing which does not impact the ability to reconstruct the conveyance system. To the north of this main dock is a smaller dock called "No Name Dock" which is a light access dock planned for oyster culturing use.

California Redwood Company Dock: This is a bulk loading dock with a conveyance system for chips. This dock is currently being used for that purpose.

Fairhaven Dock (Sequoia Investments X LLC): The Fairhaven dock is a multi-purpose heavy loading dock, is deep on both the inside and outside, and is the only dock in the bay with natural scouring (i.e. not dependent on dredging). There is currently no use on the dock, but the landowner is considering oyster culture on the inside portion of the dock.

Humboldt Bay Forest Products: There are two docks in Fields Landing owned by Murphy/ Humboldt Bay Forest Products. The main dock to the north is a multi-purpose dock previously designed for heavy loading, but is in poor repair with no structural integrity. This dock area has not been dredged in years, and is thus very shallow. The dock needs to be reconstructed in order to regain functionality. There is a smaller dock to the south that was the old Eureka Fish Company dock that is also in poor repair.

Industrial/Commercial

Most of the industrial (general and light) land use properties that are vulnerable to sea level rise are located on Arcata Bay, on Mad River Slough behind railroad/roadway and fortified shorelines, at Bracut behind dikes, and in a small area behind natural shoreline on Freshwater Slough. On South Bay, resource dependent commercial lands are located behind dikes in King Salmon and east of Highway 101 in the Buhne Slough area, and behind fortified/filled shorelines in Fields Landing areas. Vulnerable commercial general properties are located at Samoa Bridge and Bracut on Arcata Bay, South Broadway area on Buhne Slough, and in Fields Landing.

Public

On Humboldt Bay Public recreation areas vulnerable to sea level rise exist behind natural shorelines at Manila Park on Arcata Bay, Samoa Dunes State Recreation Area on Eureka Bay, and behind fortified shorelines at Samoa Boat Ramp Park on Eureka Bay, Fields Landing Boat Launch and Table Bluff Park on South Bay. Public facility properties that are vulnerable are Highway 101 behind dikes on Arcata Bay, Elk River Slough, and South Bay at King Salmon. The U.S. Coast Guard Station (USCG) behind fortified and bulwark shorelines is vulnerable on the North Spit in Eureka Bay.

Recreation

Commercial recreation (CR) properties that are vulnerable are located north of Samoa Bridge behind railroad shoreline and Bracut on Arcata Bay behind dikes. There are also properties east of South Broadway near King Salmon, west of Highway 101 and in King Salmon, and several properties in Fields Landing.

3.2.2 Exposure

A significant portion of the lands in the HBAP planning area vulnerable to sea level rise are already exposed to coastal hazards such as tidal inundation and flooding. There are approximately 7,000 acres of low-lying areas in the HBAP planning area behind dikes that are vulnerable to tidal inundation today if protective shoreline structures are compromised or breached. These diked areas are also in FEMA’s 100-year flood zone (BFE of 10.2 ft.) as are most of the areas vulnerable to 3.3 ft. (1.0 M) of sea level rise. All the areas vulnerable to sea level rise of 4.9 ft. (1.5 M) are also in California’s tsunami evacuation area.

Tidal Inundation

Shoreline structures and lands vulnerable to tidal inundation would be exposed first to extreme tides like the MAMW, often called king tides that can occur from October

through January, with the frequency of these exposures increasing to MMMW, then weekly and eventually daily high tides (MHHW) (Table 1). Sea level rise vulnerability assessments on Humboldt Bay have utilized MMMW (7.7 ft.) elevation as the base from which to measure sea level changes. When assessing an asset's exposure to a specific level of sea level rise, evaluation of the corresponding MMMW elevation is necessary. The MAMW would also increase in elevation with sea level rise; MAMW are the event that would likely place vulnerable assets at risk of being tidally inundated. For example, areas exposed to two feet of sea level rise on a monthly frequency as measured by MMMW elevations would also be exposed to approximately three feet of sea level rise, although less frequently, by MAMW or as they are now commonly referred to, king tides. Both water levels would be assessed to understand the degree of exposure in the near-term that assets may experience in a given year from one to two feet of sea level rise. As stated earlier in the Executive Summary, the frequency that MAMW (8.8 feet elevation) are equaled or exceeded is currently four times a year. With two feet of sea level rise, there could be 125 days a year that tides exceed 8.8 feet.

➢ *Sea Level Rise of 0.9 Feet*

Every year Humboldt Bay experiences (October through January) on average 0.9 ft. of sea level rise above MMM tides, reaching 8.8 ft. (MAMW or king tide). If the diked shorelines were breached during these king tides, multiple land uses would be affected (Table 17 and Table 18), including:

- 5,975 acres (56%) of agricultural lands,
- 607 acres (13%) of natural resource lands,
- 219 acres (8%) of residential lands, including 113 acres in King Salmon, Fields Landing, and Fairhaven,
- 149 acres (23%) of industrial/commercial lands,
- 79 acres (8%) of the CDI lands,
- 77 acres (19%) of commercial recreation lands, and
- 76 acres (11%) of public facilities.

Table 17. HBAP land use types, acres of each land use type in the HBAP, percentage of the total HBAP area the use occupies, and percentage of the HBAP land use acreage (see Table 13) that could be tidally inundated by 0.9 (MAMW), 1.6 ft. (0.5 M), 3.3 ft. (1.0 M), and 4.9 ft. (1.5 M) of sea level rise by land use type.

Land Use	HBAP Acres	% of HBAP	0.9 Ft.	1.6 Ft.	3.3 Ft.	4.9 Ft.
Agriculture	10,680	50%	56%	58%	62%	66%
Natural Resources	4,740	22%	13%	14%	19%	26%
Residential	2,741	13%	8%	9%	11%	13%
Coastal Dependent Industrial	968	5%	8%	12%	29%	41%
Industrial/Commercial	656	3%	23%	25%	32%	38%
Public	693	3%	11%	12%	17%	21%
Commercial Recreation	408	2%	19%	21%	25%	36%
Total	20,886		**7,182**	**7,525**	**8,557**	**9,507**

Table 18. HBAP land use types, acres of each land use type in the HBAP, percentage of the total HBAP area the use occupies, and the acres of each land use type that could be tidally inundated by 0.9 (MAMW), 1.6 ft. (0.5 M), 3.3 ft. (1.0 M), and 4.9 ft. (1.5 M) of sea level rise.

Land Use	HBAP Acres	% of HBAP	0.9 Ft.	1.6 Ft.	3.3 Ft.	4.9 Ft.
Agriculture	10,680	50%	5,975	6,176	6,600	6,997
Natural Resources	4,740	22%	607	669	950	1,223
Residential	2,741	13%	219	237	294	350
Coastal Dependent Industrial	968	5%	79	113	278	400
Industrial/Commercial	656	3%	149	162	213	246
Public	693	3%	76	84	119	144
Commercial Recreation	408	2%	77	84	103	147
Total	20,886		**7,182**	**7,525**	**8,557**	**9,507**

With 0.9 feet of sea level rise (high projection for 2030), MAMW (king tides) would increase on average from 8.8 ft. to 9.7 ft., two feet higher than our current MMMW of 7.7 ft. Currently, there are approximately 0.8 miles of dikes vulnerable to MMMW of 7.7 ft. With 0.9 ft. of sea level rise, the length of dikes vulnerable to MMMW could increase to 3.3 miles (8% of the total existing dike length), and the length of dikes vulnerable to MAMW (king tides) could increase to up to 11.4 miles. Therefore, just 0.9 ft. of sea level rise (possibly by 2030) could increase the vulnerability of diked shorelines to king tides from 3.3 miles to 11.4 miles, a 245% increase.

There is a total of 444 residential parcels in the communities of King Salmon (164), Fields Landing (84), and Fairhaven (196); 47.5% (211) of these parcels are vulnerable to tidal inundation by current MAMW of 8.8 feet (Table 19). These parcels could be inundated by king tides as often as four times a year under present conditions.

There is approximately 2.9 miles of shoreline fill protecting the community of King Salmon from tidal inundation. Primarily along the King Salmon Canal, there are 1.7 miles of shoreline rated highly vulnerable with two feet of sea level rise (or 0.9 ft. of sea level rise with a king tide) (Figure 13). There are approximately 121 (74%) residential parcels in King Salmon that are vulnerable to 0.9 ft. of sea level rise.

Fields Landing is bordered by three miles of shoreline, of which1.5 miles are rated highly vulnerable. Residential parcels are located inland from the shoreline; a low-lying former salt marsh area connects with the shoreline to the north and south and may provide a pathway for tidal inundation of the community. The shoreline directly to the west of the residential area is bay fill and of a higher elevation (Figure 13). All 84 residential parcels in Fields Landing are vulnerable to 0.9 ft. of sea level rise.

In Fairhaven, there are only 0.6 miles of shoreline, but it is rated highly vulnerable. Only 6 (3%) residential parcels in Fairhaven are vulnerable to tidal inundation by 0.9 ft. of sea level rise.

Table 19.HBAP planning area residential parcels that could be tidally inundated by 0.9 (MAMW), 1.6 ft. (0.5 M), 3.3 ft. (1.0 M), and 4.9 ft. (1.5 M) of sea level rise for the communities of King Salmon, Fields Landing and Fairhaven.

Residential	0.9 Ft.	1.6 Ft.	3.3 Ft.	4.9 Ft.	Total Parcels
King Salmon	121	154	162	164	164
Fields Landing	84	84	84	84	84
Fairhaven	6	35	114	181	196
Total	**211**	**273**	**360**	**429**	**444**

Figure 13. Shoreline vulnerability rating, King Salmon and Fields Landing: high (red), moderate (yellow) and low (green) (Laird and Powell 2013).

➢ *Sea Level Rise of 1.6 Feet*

With 1.6 feet (0.5 M) of sea level rise, which is the inundation map used to represent the high projection (1.9 ft.) for 2050 (Table 1), approximately 7,525 acres of the HBAP planning area could be vulnerable to tidal inundation (Table 18). Potentially, 11.4 miles (28%) of diked shoreline would be vulnerable to overtopping (Table 10), putting various land uses at risk from tidal inundation, including:

- 6,176 acres (58%) of agricultural lands,
- 669 acres (14%) of natural resources lands,
- 237 acres (9%) of residential area, including 144 acres of urban residential,
- 162 acres (25%) of industrial/commercial,
- 113 acres (12%) of CDI,
- 84 acres of public lands (12%), and
- 84 acres of commercial recreation lands (21%).

Approximately 273 (61.5%) of the residential parcels in King Salmon, Fields Landing, and Fairhaven could be tidally inundated by 1.6 ft. (0.5 M) of sea level rise (Table 14). The 211 parcels that could be inundated by king tides of 8.8 ft. with 0.9 ft. of sea level rise as projected for 2030 could become inundated as often as 125 times a year with 1.6 ft. (0.5 M) of sea level rise (NHE 2017).

Associated with the 1.9 ft. sea level rise projection, MAMW (king tides) would increase from 8.8 ft. to 10.7 ft., which is three feet higher than current MMMW of 7.7 ft. Therefore, 1.9 ft. of projected sea level rise (2050) could increase the length of diked shorelines vulnerable to king tides from 11.4 miles (28%) as projected for 2030 to 23.4 miles (57.5%), a 105% increase (Table 9).

➢ *Sea Level Rise of 3.3 Feet*

With 3.3 ft. (1.0 M) of sea level rise, which is the inundation map used to represent the high projection (3.2 ft.) for 2070 (Table X), approximately 8,557 acres of the HBAP planning area could be vulnerable to tidal inundation (Table 13). Potentially 23.4 miles (57%) of diked shoreline would be vulnerable to overtopping (Table 9), putting various land uses at risk, including:

- 6,600 acres (62%) of agricultural lands,
- 950 acres (19%) of natural resource lands,
- 294 acres of residential (11%) area, including 190 acres of urban residential,
- 213 acres (32%) of industrial/commercial,
- 278 acres (29%) of CDI, including most of the dock properties at Fields Landing and Redwood Terminal 1 at Samoa are inundated, and partial inundation of PG&E's HBGS/HBPP facilities at King Salmon,
- 119 acres (17%) of public lands, and

- 103 acres (25%) of commercial recreation lands.

Approximately 360 (81.5%) of the residential parcels in King Salmon, Fields Landing and Fairhaven could be tidally inundated by 3.3 ft. (1.0 M) of sea level rise (Table 14). The 211 parcels that could be inundated by king tides of 8.8 ft. with 0.9 ft. of sea level rise as projected for 2030 could be inundated as often as 355 times a year with 3.3 ft. (1.0 M) of sea level rise (NHE 2017).

➢ *Sea Level Rise of 4.9 Feet*

With 4.9 ft. (1.5 M) of sea level rise, which is the inundation map used to represent the high projection for 2100 (Table 1), approximately 9,507 acres of the HBAP planning area are vulnerable to tidal inundation. Potentially, 38.4 miles (94%) of diked shoreline would be vulnerable to overtopping, putting multiple land uses at risk of tidal inundation, including:

- 6,997 acres (66%) of agricultural lands,
- 1,223 acres (26%) of natural resource lands,
- 350 acres of residential (13%) area, including 236 acres of urban residential mostly in King Salmon-Fields Landing, Fairhaven, Manila, Elk River Valley-Martins Slough, and Eureka Slough-east of Walker Point,
- 246 acres (38%) of industrial/commercial,
- 400 acres (41%) of CDI,
- 144 acres (21%) of public lands, and
- 147 acres (36%) of commercial recreation lands.

Of special note, significant portions of PG&E HBPP/HBGS facilities and property would be tidally inundated as would the only surface access route, King Salmon Avenue. The ISFS facility is not projected to be tidally inundated. The docks and associated properties at Fairhaven, Green Diamond and, Redwood Terminal 2 at Samoa are the only CDI bulk cargo facilities not inundated on Humboldt Bay. Approximately 96.6% (429) of the residential parcels in King Salmon, Fields Landing and Fairhaven are vulnerable to 4.9 ft. (1.5 M) of sea level rise.

Flooding

Flooding or overtopping of artificial shoreline structures can occur infrequently from extreme storm events (100-year flood). Flooding during a 100-year event (BFE 10.2 ft.) (1% probability of occurring any year) would likely overtop the same 23.4 miles (58%) of diked shoreline that are vulnerable to three feet of sea level rise with a MMMW of 10.7. As a result, putting 8,557 acres of land uses at risk of flooding, including:

- 6,600 acres (62%) of agricultural lands,
- 950 acres of natural resource areas (19%),

- 294 acres (11%) of residential area, including 360 residential parcels in King Salmon, Fields Landing and Fairhaven),
- 213 acres (32%) of industrial/commercial,
- 278 acres (29%) of CDI,
- 119 acres (17%) of public lands, and
- 103 acres (25%) of commercial recreation lands.

Flooding of low-lying lands behind barrier type shorelines (dikes, railroad and highway grades) can also occur during heavy rainfall as drainage to Humboldt Bay is impaired resulting in backwater ponding. Flooding and ponding of water behind earthen dikes by stormwater runoff from interior watersheds can result in erosion and/or slumping of dike slopes, as fortification of dike slopes is generally limited to the bay side of the dikes.

Likewise, flooding can occur when rising groundwater emerges onto the surface in low-lying areas in response to winter storms or rising sea levels. Regardless of the type or condition of shoreline structures, fortifications, or elevation, low-lying areas such as diked former tidelands are vulnerable to flooding from rising groundwater in response to sea level rise. With sea level rise, this type of flooding would likely begin as nuisance flooding during the winter and slowly increase in duration over time until it becomes chronic flooding. The average elevation of groundwater on land adjacent to the shoreline is generally above MSL elevation of 3.4 ft. Diked former tidelands that were salt marsh were generally equal to or less than 6.5 ft. (MHHW) in elevation but have compacted as organic material in the original salt marsh soil has oxidized and are now much lower in elevation.

Groundwater elevations depend on surface elevations and the season. For example, groundwater near Mad River Slough can fluctuate from being at the surface down to three feet below the surface (Hoover 2015) (Figure 14 and Figure 15). As sea level rises, the denser saltwater would push fresh groundwater to higher elevations until the groundwater eventually emerges and floods the surface. Rising groundwater flooding would cause vegetative conversions, adversely affecting agricultural lands and natural resource areas. Rising groundwater can also affect foundations of structures such as building and roads, as well as permanently flood low-lying areas.

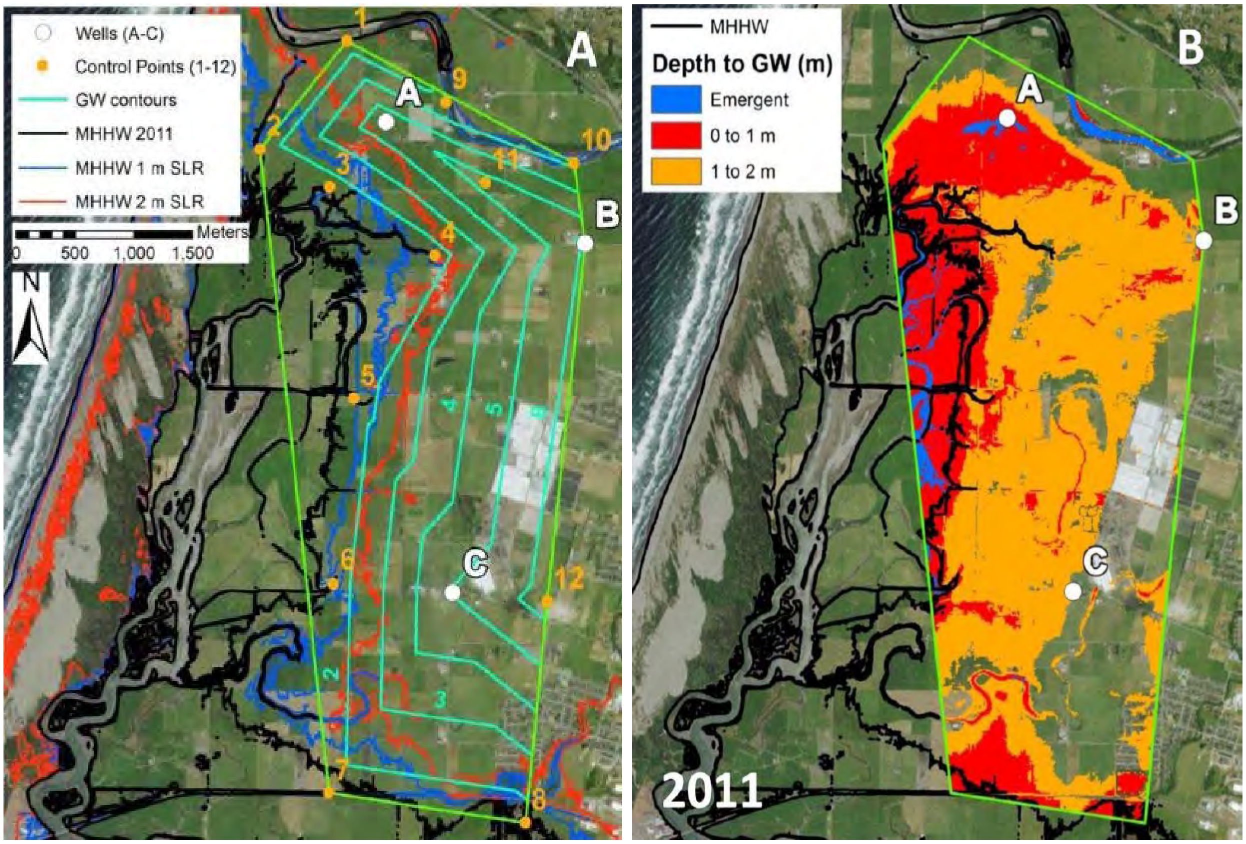

Figure 14. From Hoover 2015, as based on Willis 2014. Fresh groundwater floats on higher-density seawater, and the average elevation of the water table would be above MSL 3.4 ft. MHHW is 6.5 ft.

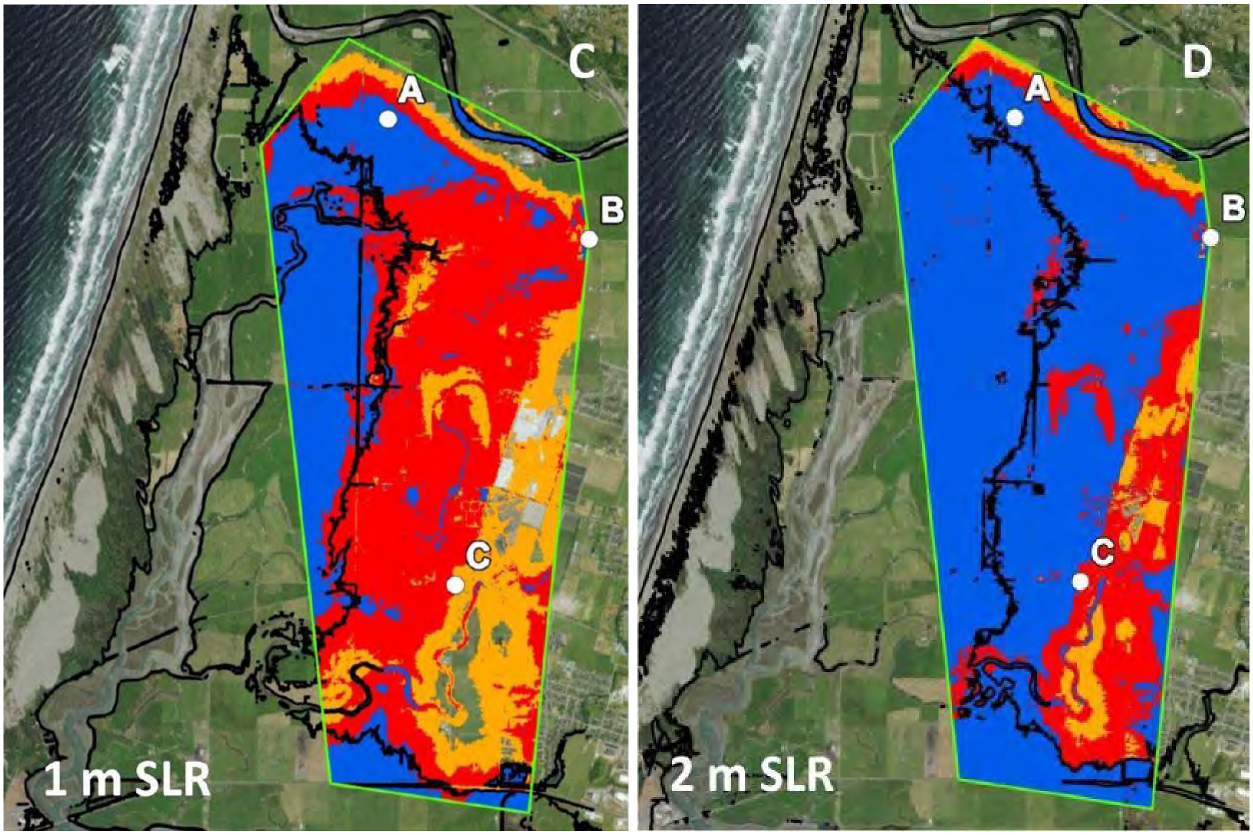

Figure 15. From Hoover 2015, based on Willis 2014, illustrating the difference of 1 M (3.3 ft.) of sea level rise. Blue = emergent, Red = 0 to 1 M, and Orange = 1 to 2 M (6.6 ft.).

Salt Water Intrusion

Salt water intrusion can contaminate shallow wells that support agricultural, residential, and other land uses. There are approximately 2,091 acres of agricultural lands irrigated from wells on Humboldt Bay (Schultz 2017). The largest extent of irrigated agricultural lands, 1,859 acres (88.9%), is in the HBAP planning area on the Mad River bottom lands (Figure 16).

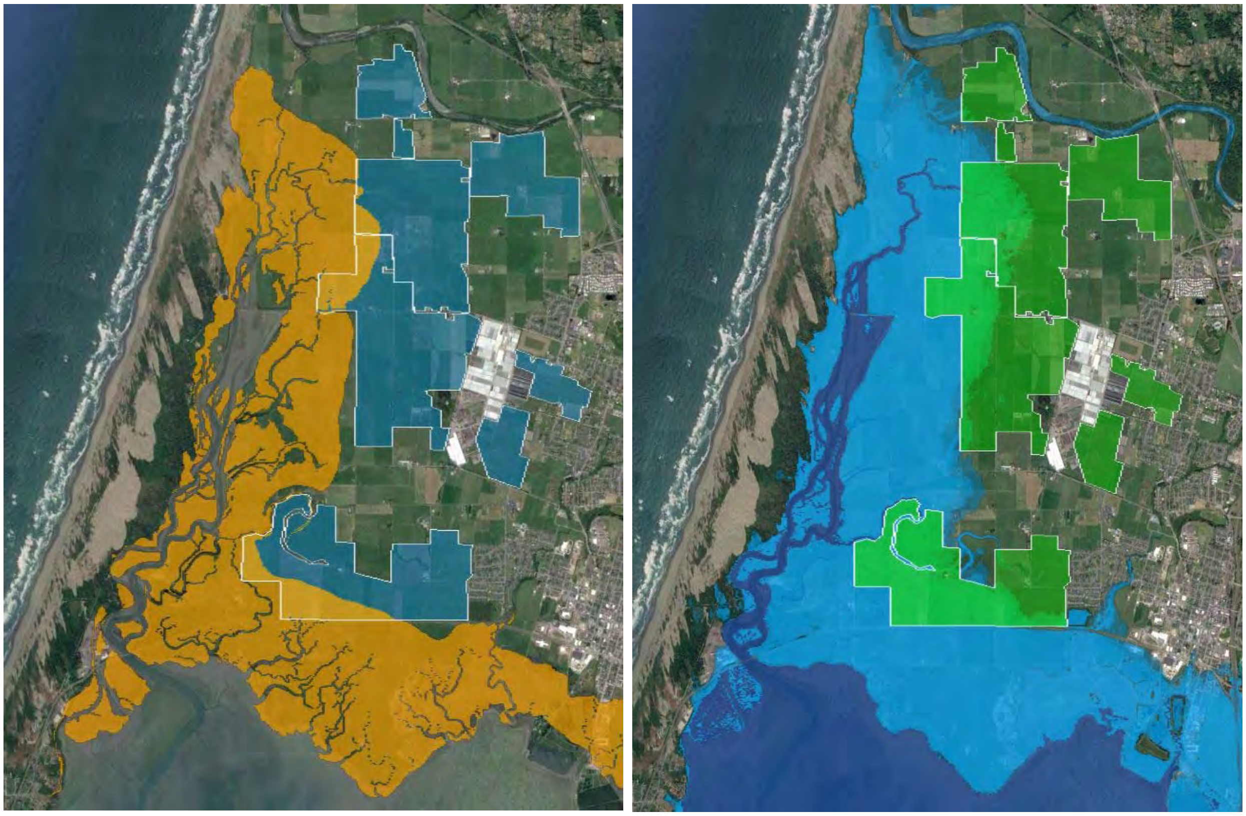

Figure 16. Irrigated agricultural lands on Mad River bottom land, in relation to diked former tidelands (orange area) and potential 4.9 ft. (1.5 meters) tidal inundation area (blue area).

Salt water intrusion can result in salt water entering the wastewater system in the form of infiltration to wastewater transmission lines, and can lead to impairment or collapse of the biological processes required to treat wastewater. Salt water intrusion can also corrode underground structures (pipelines and culverts) or equipment (lift and pump stations).

Salt water intrusion and rising fresh groundwater flooding are linked as fresh groundwater floats on higher-density seawater. The elevation of groundwater can range across MSL 3.4 ft., MHW 5.8 ft., and MHHW 6.5 ft. Salt water intrusion of freshwater areas can lead to significant vegetative conversions from salt intolerant species to salt tolerant species, which would lead to changes in agricultural practices, wildlife and habitat (ESHA) distribution and abundance.

Salt water intrusion may adversely affect 66% of the HBAP's agricultural lands based on the low elevation of these lands. There are much fewer low elevation areas on Elk River Slough than other sloughs; therefore, salt water intrusion may be less severe in this area (Figure 17.) The effect of salt water intrusion, combined with rising groundwater, could become much broader in extent over time.

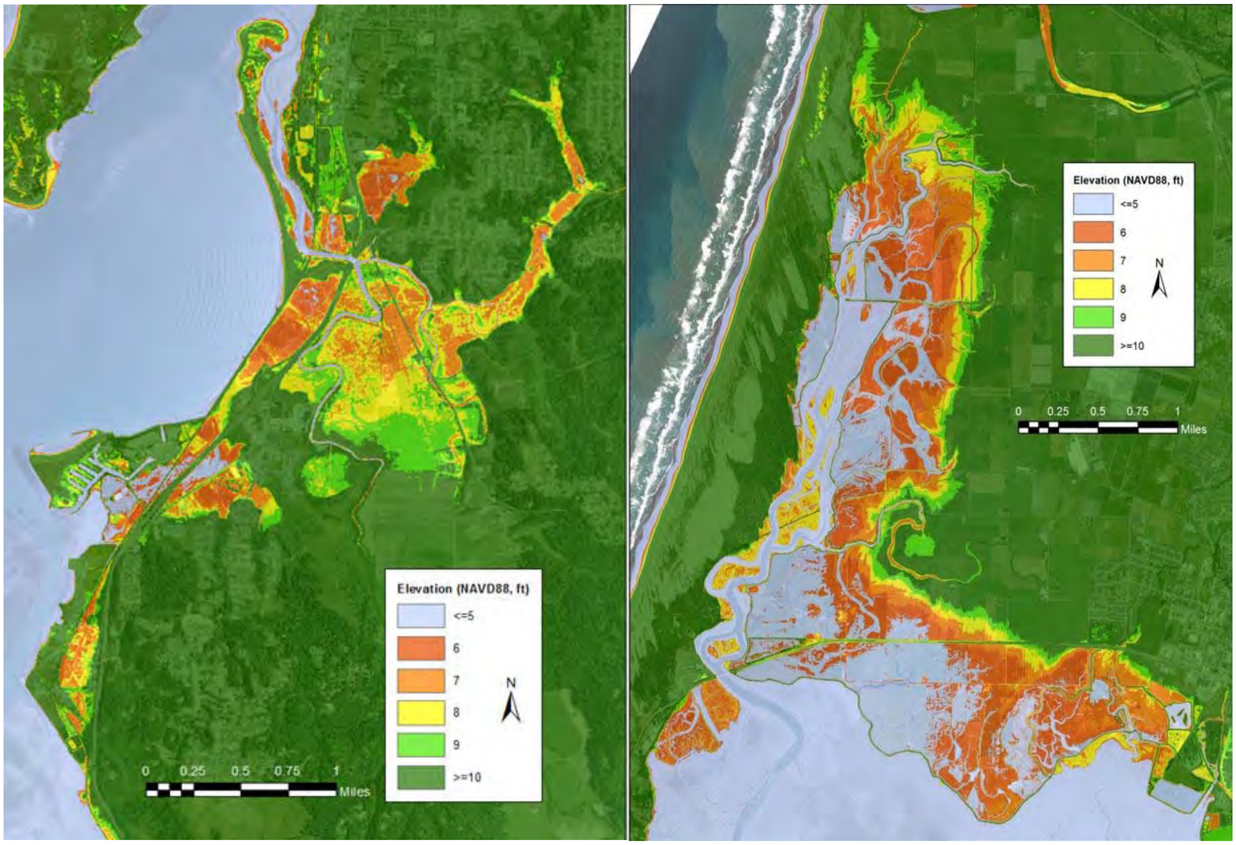

Figure 17. Extent of low elevation areas in relation to MHW (5.8 feet) on Elk River Slough compared to Mad River Slough.

3.2.3 Susceptibility by Land Use Type

Agriculture

The agricultural lands in the HBAP planning area that are vulnerable to tidal inundation are low-lying diked former tidelands. Approximately 50% of the agricultural lands in the HBAP are vulnerable to 4.9 ft. (1.5 M) of sea level rise. Grazing practices and pastures dominate the agricultural landscape in the HBAP planning area. Current agricultural uses are based on raising forage for livestock grazing. They are very susceptible to tidal inundation, which would lead to a cessation of these agricultural uses. Saltwater inundation, even for short durations, can have a significant impact on non-saltwater tolerant plants. Frequent or chronic saltwater flooding would likely result in a vegetative conversion to salt tolerant plant species, and the collapse of agricultural endeavors.

Flooding from extreme storm events is infrequent (100-year flood has a 1% probability of occurring any year), and current agricultural uses can recover from such flooding. Backwater flooding in the winter and spring months can seasonally restrict agricultural lands uses. Without improved drainage in response to rising sea levels, such flooding

may lead to pastures converting to freshwater or brackish water wetlands. Emerging groundwater in response to sea level rise may ultimately cause the conversion of forage to wetland vegetation, which would be a significant impediment to continuing agricultural uses. Saltwater intrusion of shallow wells would impact irrigated agricultural lands significantly. Saltwater intrusion of groundwater as it emerges in response to sea level rise would lead to vegetative conversions to salt tolerant species and a reduction or elimination of livestock grazing.

Natural resources

In the HBAP, the entire open ocean shoreline and coastal dune system are exposed to waves that can be affected by storm surges and sea level rise. This coastal ecosystem is the subject of a five-year Coastal Vulnerability and Adaptation Study led by the U.S. Fish and Wildlife Service and funded by the State Coastal Conservancy. The study would identify potential vulnerabilities and responses to sea level rise. On Humboldt Bay, approximately 22% of the natural resource lands in the HBAP planning area are vulnerable to 4.9 ft. (1.5 M) of sea level rise. Freshwater habitats would be significantly impacted from tidal inundation, likely resulting in the conversion to salt marsh. Infrequent flooding from extreme storms could cause shoreline erosion and toppling of forest habitats. Saltwater intrusion would likely lead to vegetative conversions to brackish or salt marsh.

Residential

Residential structures and the utility and transportation infrastructure that supports residential communities can recover from nuisance flooding. As the frequency of flooding increases and becomes chronic flooding, these structures, utilities and access/drainage infrastructure would become impaired, damaged, and economically infeasible to maintain. As mentioned earlier, a MAMW of 8.8 ft. is reached or exceeded on average four times a year, but with 1.6 ft. (0.5M) of sea level rise, the number of times tides would equal or exceed this 8.8 ft. elevation are likely increase to 125 times a year, resulting in chronic flooding, ultimately leading to weekly and then daily tidal inundation.

Approximately 13% of the residential areas in the HBAP planning area are vulnerable to 4.9 ft. (1.5 meters) of sea level rise, but 97% (429 parcels) of the residential parcels are vulnerable in the communities of King Salmon, Fields Landing, and Fairhaven. Existing residential structures, their utility infrastructure, and access streets are not designed to accommodate frequent or chronic flooding or permanent tidal inundation. Electrical systems and metal structures are susceptible to salt water corrosion. Unsealed underground pipes may experience saltwater infiltration, which would cause a significant impairment of the affected wastewater system. Chronic flooding or tidal inundation of residential communities would likely be reflected in insurance policies and

the willingness of financial institutions to finance repairs, improvements or new construction in areas subject to chronic inundation. Flooding from extreme storm events is infrequent, and residential areas can recover or rebuild from such nuisance flooding. Backwater flooding in the winter and spring months can impact streets and seasonally restrict access to residential areas, if not result in complete flooding of such areas. Residential areas in low-lying areas are also susceptible to flooding from rising groundwater and salt water intrusion.

Coastal-Dependent Industrial

The continued operation and function of CDI facilities such as bulk cargo or conveyance docks are dependent on continued marine access for shipment of products and on surface transportation infrastructure (Highways 101 and 255 and local streets) for the delivery of materials to be shipped. Rising sea levels may affect off-shore sediment transport and rates of sedimentation in the entrance channel and 5.1 miles of the North Bay-Samoa channel, likely requiring continual dredging by the federal government. Tidal inundation of surface transportation facilities providing access to CDI properties and bulk cargo docks would impair the continued operation of these facilities, even if these properties themselves are not tidally inundated.

Approximately 400 acres (41%) of the CDI properties in the HBAP planning area are vulnerable to 4.9 ft. (1.5 M) of sea level rise. Chronic flooding or tidal inundation of CDI property, docks, and structures would render them non-operational. Tidal inundation by 4.9 ft. (1.5 M) of sea level rise of the CDI property where PG&E's HBGS, and nuclear related HBPP and ISFSI are located is potentially significant to the Humboldt Bay region. Electrical equipment and facilities could be susceptible to flooding and tidal inundation. Flooding from extreme storm events is infrequent, and CDI areas can recover or rebuild from such flooding, but with sea level rise tidal inundation would increase in frequency from annual (MAMW), monthly (MMMW), weekly, to daily (MHHW) occurrences. CDI properties in the HBAP are not located in areas where stormwater runoff is likely to lead to flooding. Rising groundwater in response to rising sea levels could compromise building foundations, asphalt covered areas, and possibly the Samoa Field Airport runway. Salt water intrusion is not likely to adversely affect CDI properties or facilities.

Industrial/Commercial

Approximately 246 acres (38%) of the Industrial (general and light)/Commercial (general and recreation) properties in the HBAP planning area are vulnerable to 4.9 ft. (1.5 M) of sea level rise. Industrial general property at Mad River Slough and Arcata Bay is vacant but it is vulnerable to tidal inundation, as is Highway 255 which provides access to this property. The industrial general property at Bracut is vulnerable to tidal inundation now if its dikes breach, as it is low-lying former tidelands. This property is also vulnerable to

backwater flooding during periods of heavy rainfall when its tide gates cannot drain the property. Similarly, rising groundwater could flood this low-lying area, as well. Most of the vacant resource dependent (commercial general, industrial, and recreation) properties in the King Salmon and Fields Landing areas are vulnerable to tidal inundation, flooding and rising groundwater.

Public

Approximately 144 acres (21%) of the Public Facility properties in the HBAP planning area are vulnerable to 4.9 ft. (1.5 M) of sea level rise. The Public Facility properties include Highway 101, which traverses low-lying areas on Arcata Bay, Elk River Slough, and South Bay at King Salmon, and the USCGS on North Spit. Chronic tidal inundation of USCG property and structures, and the highway road prism and surface, would render them non-operational. Flooding from extreme storm events is infrequent, and these structures can recover from such flooding or rebuild if necessary. The USCGS property is not located in an area where stormwater runoff is likely to lead to flooding. However, stormwater runoff does and would lead to flooding of the highway road prism and surface that provides access to the USCGS. Rising groundwater in response to rising sea levels could compromise building foundations, asphalt covered areas, and possibly Highway 255. Salt water intrusion is not likely to adversely affect these properties or facilities.

Public Recreation properties and structures and access to these properties on North Spit and Fields Landing would be impaired and possibly eliminated by tidal inundation. Flooding from extreme storm events is infrequent, and these properties and structures can recover from such flooding or rebuild if necessary. These properties are not located in areas where stormwater runoff is likely to lead to flooding. Rising groundwater could result in habitat conversions at the Samoa Dunes State Recreation Area on the North Spit and Manila Park, but is not likely to adversely affect the boat launch facilities at Samoa and Fields Landing. Salt water intrusion is also not likely to adversely affect Public Recreation properties and facilities.

Recreation

Commercial Recreation properties at Samoa Bridge that are vulnerable to sea level rise impacts are mostly vacant except for several residences. The Commercial Recreation properties west of Highway 101 in King Salmon are vacant open spaces without structures. The remaining Commercial Recreation properties in King Salmon and Fields Landing have residential/commercial buildings and private boat dock facilities on the canals in King Salmon. These properties and their structures, and supporting utilities and surface access, are vulnerable infrequently from extreme flood events and MAMW, and to 0.9 ft. of sea level rise, and rising groundwater.

3.3 Transportation

There are four general categories for the various modes of transportation and supporting infrastructure in the HBAP planning area: surface, including streets, roads, highways, trails, and bike paths; marine; railroad; and air. Due to extensive storm damage, the rail line from Sonoma County to Arcata was officially closed by the Federal Railroad Authority in 1998, and the northern end of the line remains closed. Infrastructure for all modes of transportation on Humboldt Bay is in areas that are vulnerable to 4.9 ft. (1.5 M) of sea level rise projected for 2100. Other than local roads and possible future segments of the Humboldt Bay Trail which is currently under construction adjacent to the railroad grade along the eastern shoreline of Humboldt Bay, the County does not own and is not responsible for the maintenance of transportation infrastructure. Caltrans is responsible for the primary transportation infrastructure on Humboldt Bay which includes Highways 101 and 255. The City of Eureka's Samoa Field Airport is less significant as a regional transportation facility.

3.3.1 Affected Transportation Resources

Surface

In the HBAP planning area, the vulnerable local transportation system of County roads and streets is concentrated in several unincorporated communities: King Salmon, Fields Landing, Fairhaven, Samoa, and Manila. A network of vulnerable collector roads links these communities and other rural areas in the Humboldt Bay region. The main surface transportation corridor on Humboldt Bay is located on the eastern shore and includes Highway 101. Surface access to the North Spit communities of Manila, Samoa, and Fairhaven, as well as the CDI properties and docks, is provided by Highway 255. In the HBAP planning area, there are approximately 90 miles of local roads and streets, 23.6 miles of collector roads, and 16.2 miles of highways, of which 22.6 miles of local roads and streets, 5.6 miles of collectors, and 9.6 miles of highways are vulnerable to 4.9 ft. (1.5 M) of sea level rise (Table 20).

On Humboldt Bay, there are 11.3 miles of shoreline vulnerable to sea level rise that are made up of surface transportation infrastructure (1.8 miles of roadways and 9.5 miles of abandoned railroad). Only a limited length (1.8 miles or roadways) of functioning surface transportation infrastructure is vulnerable because it forms the shoreline of Humboldt Bay. A far larger portion of the HBAP planning area's surface transportation infrastructure (37.8 miles) is vulnerable and at risk from tidal inundation by 4.9 ft. (1.5 M) of sea level rise because of diked shoreline breaching or overtopping, and backwater flooding effects from stormwater runoff. Much of the surface transportation infrastructure traverses low-lying hydrologic units (former tidelands) with predominately diked shorelines. If these shorelines are compromised, surface transportation infrastructure could become tidally inundated in these low-lying units.

Table 20. Surface transportation infrastructure (miles) vulnerable to 0.9 to 4.9 ft. of sea level rise, and the total number of miles of infrastructure in the HBAP planning area.

Surface Transportation Type	0.9 Ft.	1.6 Ft.	3.3 Ft.	4.9 Ft.	HBAP Total Miles
Local Roads	9.8	11.0	16.5	22.6	90.1
Collectors	1.0	1.6	3.4	5.6	23.6
Highways 101 & 255	5.4	6.1	8.1	9.6	16.2
Total	16.2	18.7	28.0	37.8	129.9

There are two surface transportation authority's responsible for infrastructure maintenance: Humboldt County Public Works and Caltrans. Humboldt County Public Works maintains major/minor collectors and local roads and associated drainage structures in unincorporated areas. Caltrans is responsible for State Highway 255 and U.S. Highway 101. Unfortunately, there are 170 individual parcels that form the diked shoreline on Humboldt Bay, most of which the County and Caltrans do not own or maintain.

U.S. Highway 101 forms a critical transportation corridor that traverses approximately 18 miles of the eastern shore of Humboldt Bay. However, Highway 101 does not form the shoreline of Humboldt Bay, except for where it traverses a tidal slough. Highway 101 is primarily protected from tidal inundations by shorelines made of dikes or the railroad grade. The corridor is located east of the railroad grade and traverses diked former tidelands that are susceptible to tidal inundation now if protective shorelines are breached, and flooding from extreme events, and by future sea level rise. On Humboldt Bay, there are three low-lying segments that Highway 101 traverses: a north segment along the shoreline of Arcata Bay (5.8 miles), a middle segment between King Salmon and South Eureka (2.3 miles), and a south segment on South Bay (2.7 miles) (Figure 18 - Figure 20).

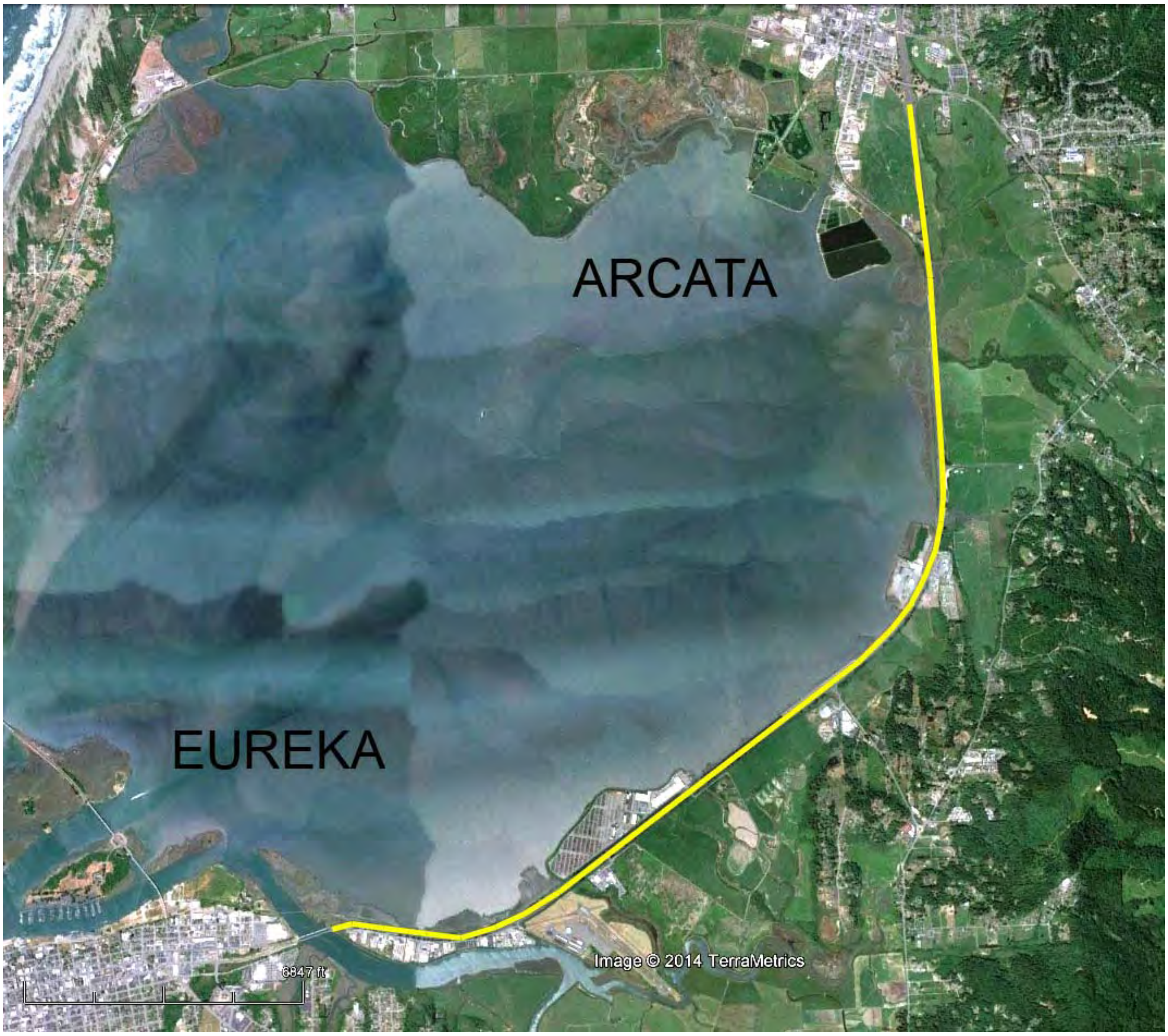

Figure 18. The Highway 101 (yellow line) north segment between Eureka and Arcata on Arcata Bay extends 5.8 miles.

Figure 19. The Highway 101 (yellow line) middle segment on Elk River Slough south of Eureka extends 2.3 miles.

Figure 20. The Highway 101 (yellow line) south segment on South Bay from Hookton Road to Tompkins Hill Road extends 2.7 miles.

State Highway 255 extends west from U.S. Highway 101 in the City of Eureka approximately 8.6 miles north and east to Highway 101 in the City of Arcata. Highway 255 is the only means of vehicular access to the North Spit and the communities of Manila, Samoa, and Fairhaven, as well as CDI properties and docks.

Air

There is one public airport in the HBAP planning area, Samoa Field Airport, owned and operated by the City of Eureka and located on the Samoa Peninsula on 359 acres of former dunes. Surface elevations of the airport runway range from 11 to 14 feet. To the east, New Navy Base Road is located between the airport and Humboldt Bay. To the west, the airport is surrounded by coastal dunes and the Humboldt County Samoa Dunes Recreational Area. The airport is accessible from New Navy Base Road and Highway 255.

The airport provides services for recreational and personal business. The airport does not operate at night; there are no lights on the runway and no aviation services are provided. Although Samoa Field Airport is classified as a Community General Aviation Airport, it does not meet all the minimum standards of this airport class. The airport's longest runway, 2,700 ft. by 60 ft., does not reach the minimum length, width, or weight-bearing FAA standards. Additionally, the airport does not have visual aid equipment, 24-hour on-field weather services, or an instrument approach procedure (HCAOG 2013). The City of Eureka maintains 15 hangers at the airport.

Railroad

The North Coast Railroad Authority (NCRA) owns the railroad grade and associated sea wall and drainage structures on Humboldt Bay. There are approximately 26.2 miles of railroad grade (Main Line, Korblex Branch, and Samoa Branch) on Humboldt Bay, 10.5 miles of which form Bay shoreline. There are 20.8 miles of railroad grade that are vulnerable to being tidally inundated by 4.9 ft. (1.5 M) of sea level rise. In the HBAP planning area, there are 17.2 miles of railroad, and approximately 13.8 miles are vulnerable to tidal inundation by 4.9 ft. (1.5 M) of sea level rise.

There is a sea wall between Elk River Slough and PG&E's HBPP property that is approximately 4,100 ft. in length, opposite the entrance to Humboldt Bay. Following the construction of the two jetties, the Northwest Pacific Railroad built the sea wall to protect the railroad. This is one of the most significant shoreline protection structures on Humboldt Bay. In 2007, the NCRA conducted emergency shoreline repairs on the sea wall. In 2008, the NCRA completed additional shoreline repairs of the sea wall in this same reach. Railroad infrastructure, including the sea wall on Humboldt Bay, are currently not being maintained and are in a degraded state (Figure 21).

Figure 21. NCRA railroad tracks behind sea wall, damaged during winter storms of 2015 and 2016.

3.3.2 Exposure

Surface

Sea level rise would impact transportation assets that are in low-lying coastal areas. These impacts can manifest directly through erosion of road and highway fill/embankments or bridge abutments, and/or inundation of road and highway surfaces and drainage structures. Impacts can also manifest indirectly through impacts to road and highway fill/embankments or surfaces from rising groundwater and saltwater intrusion, which could corrode underground structures such as culverts.

Currently in the HBAP planning area, king tides with an elevation of 8.8 ft. or greater cause nuisance flooding on average four times a year, affecting approximately 10.8 miles of roads and collectors, often compounded by backwater flooding during storm events. In the HBAP planning area, flooding impacts are most prevalent on Hookton Road, Pine Hill Roads, and Jackson Ranch Road. With approximately 1.6 ft. (0.5 M) of sea level rise, flooding from 8.8 ft. tides or greater would become chronic, potentially occurring up to 125 times a year (NHE 2017).

➢ *Sea Level Rise of 0.9 Feet*

Local streets and roads and collectors located behind diked shorelines are vulnerable and at risk now from tidal inundation if the dikes are overtopped or breached, or from backwater flooding. With 0.9 ft. of sea level rise, the high projection for 2030, when MMMW would approximately equal our current MAMW (8.8 feet) and king tides, there are approximately 10.8 miles of local streets and roads and collectors located in low-lying areas that are potentially vulnerable and at risk from tidal inundation if segments of protective shoreline structures are overtopped or breached, including:

- Jackson Ranch Road (Liscom Slough),
- Pine Hill Road (Swain Slough),
- Halibut, EZ Landing, Perch, Crab, Cod, Sole and Herring Streets (King Salmon), and
- Hookton Road (Salmon Creek),

➢ *Sea Level Rise of 1.6 Feet*

By 2050, the high sea level rise projection is 1.9 ft. and MMMW could reach 9.6 ft. In addition to areas vulnerable and at risk from tidal inundation by 0.9 ft. of sea level rise, additional local streets and roads and collectors (12.6 miles total) could be tidally inundated by 1.6 ft. (0.5 M) of sea level rise, including:

- Lanphere Road (Mad River Slough),
- Foster Ave (Liscom Slough),

- Old Samoa Road and Pacheco Road (Liscom Slough and Arcata Bay),
- Vance Avenue (Arcata Bay),
- Park Street in Fairhaven (Eureka Bay),
- New Navy Base Road (Eureka Bay),
- Myrtle Avenue and side streets in several segments south of Indianola Roundabout to Flying Ranch Road (Fay Slough),
- Felt, Spears, and Devoy Roads, and Park Street (Freshwater Sloughs),
- Mitchell Road (Ryan Slough),
- Elk River Road (Elk River Slough),
- South Broadway Avenue/Hill Road, Eich Road, Humboldt Hill Road, and Purdue Drive (Buhne Slough),
- Buhne Drive (King Salmon),
- C Street, Railroad Avenue, Central Avenue, and Depot Road, and all cross streets in Fields Landing (South Bay),
- Thompkins Hill Road (South Bay), and
- South Jetty Road (South Bay).

Sea Level Rise of 3.3 Feet

By 2070, the high sea level rise projection is 3.2 ft. and MMMW could reach 10.9 ft. King Salmon Avenue could be tidally inundated by 3.3 ft. (1.0 M) of sea level rise, which provides the only surface access to the HBGS and the ISFSI. In addition to areas vulnerable and at risk from tidal inundation by 1.6 feet of sea level rise, there may be an additional 7.3 miles of local streets and roads and collectors (combined total of 19.9 miles) that could be tidally inundated, including:

- Polaris Lane (Mad River Slough),
- Bay School Road (Liscom Slough),
- Vaissade Road Young Lane and Peninsula Drive, (Arcata Bay),
- Cookhouse Road, Bay Street (Eureka Bay),
- Bendixon Street, Broadway Street, Lindstrom Avenue, Duprey Street in Fairhaven (Eureka Bay),
- Myrtle Avenue and Stagecoach Lane (Freshwater Slough),
- Loma Avenue and King Salmon Avenue (Buhne Slough and South Bay), and
- Fields Landing Drive (South Bay).

Sea Level Rise of 4.9 Feet

By 2100, the high sea level rise projection is 5.4 ft. and MMMW could reach 13.1 feet. An additional 28.2 miles of local streets and roads and collectors could be tidally inundated by 4.9 ft. (1.5 M) of sea level rise more frequently and to greater depths, including:

- Old River Road and Mad River Road (Mad River Slough),
- V Street (Arcata Bay),
- Peninsula Drive, Youngs Lane, and Midway Court in Manila (Arcata Bay),
- Vance Avenue, Comet Street, Fay Street, Cole Avenue, and Bay Street in Finn Town (Eureka Bay),
- Lincoln Avenue, Rick's Avenue, Selvage Street, Simpson Road in Fairhaven, (Eureka Bay),
- Herrick Avenue (Martin Slough),
- Meadowbrook Drive (Elk River Slough), and
- Aspen Way near King Salmon (Buhne Slough).

U.S. Highway 101

At present, 9.6 miles of shoreline protecting Highway 101 have been rated highly vulnerable to breaching because of their low elevation, less than two feet higher than MMMW (Figure 22 - Figure 25). They can be overtopped by either extreme tides or king tides and/or storm surges that rise two feet or more above MMMW to approximately 9.7 ft. A moderate vulnerability rating was given to shoreline segments that are two to four feet above MMMW elevations, and a low rating was given to segments that are greater than four feet. Eroding shoreline segments at any elevation were rated highly vulnerable (Laird and Powell 2013).

Shorelines to the west and east of Highway 101 on Arcata Bay, Eureka Slough, Elk River Slough, and South Bay protect the highway from tidal inundation. These shorelines have both publicly and privately owned and maintained tide gates. In the three low-lying shoreline segments that Highway 101 traverses, many tributaries (Gannon-Beith Creeks, Jacoby Creek, Washington-Rocky Gulch, Freshwater Creek, Elk River, and Salmon Creek) drain watersheds to the east. Stormwater runoff from these streams, particularly during high tides, can overwhelm water control and drainage structures, resulting in overbank flows that flood areas to the east and the road prism of Highway 101 (Figure 26).

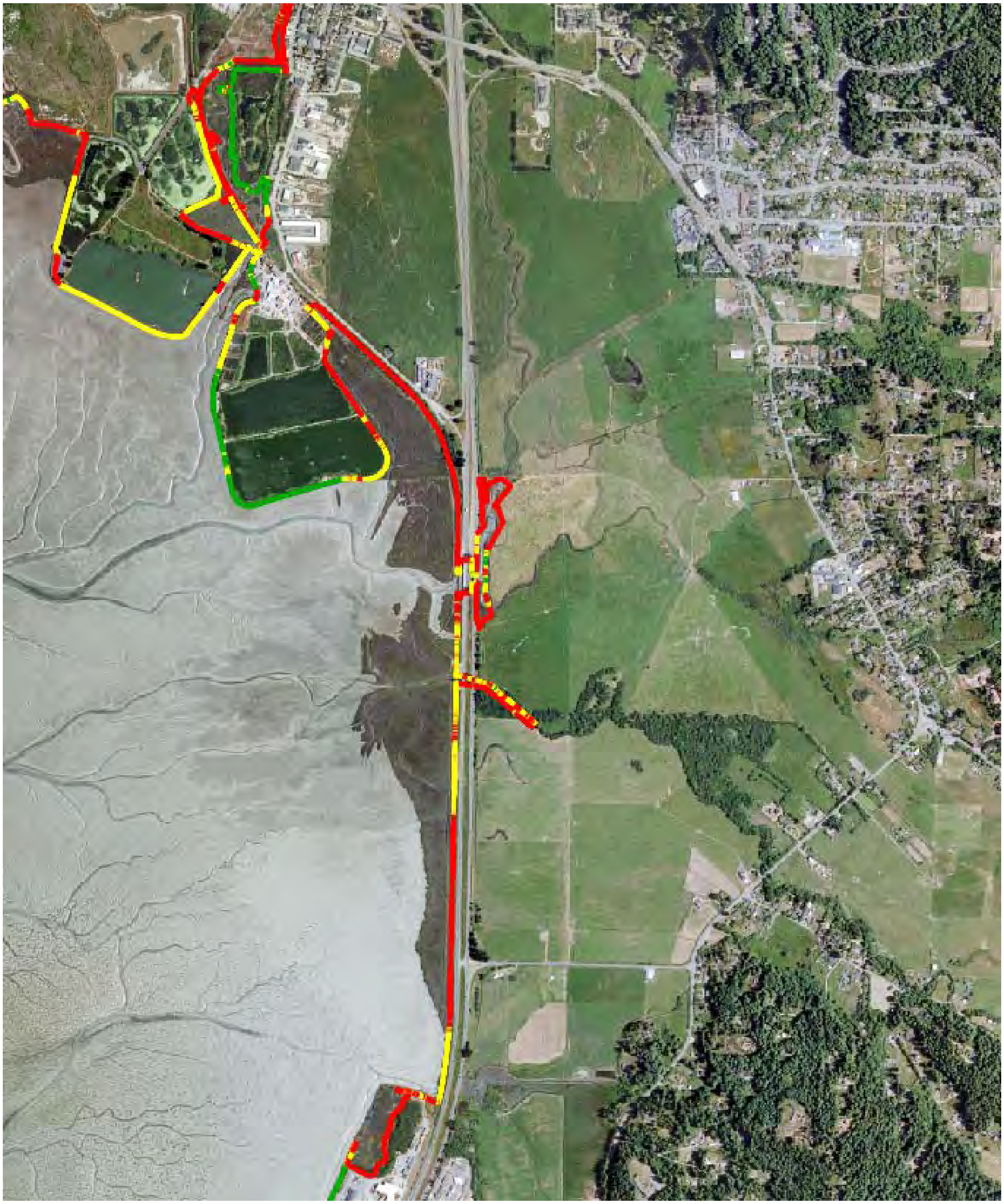

Figure 22. North segment, shoreline vulnerability rating of the upper reach of Highway 101 on Arcata Bay: high (red), moderate (yellow), and low (green) (Laird and Powell 2013).

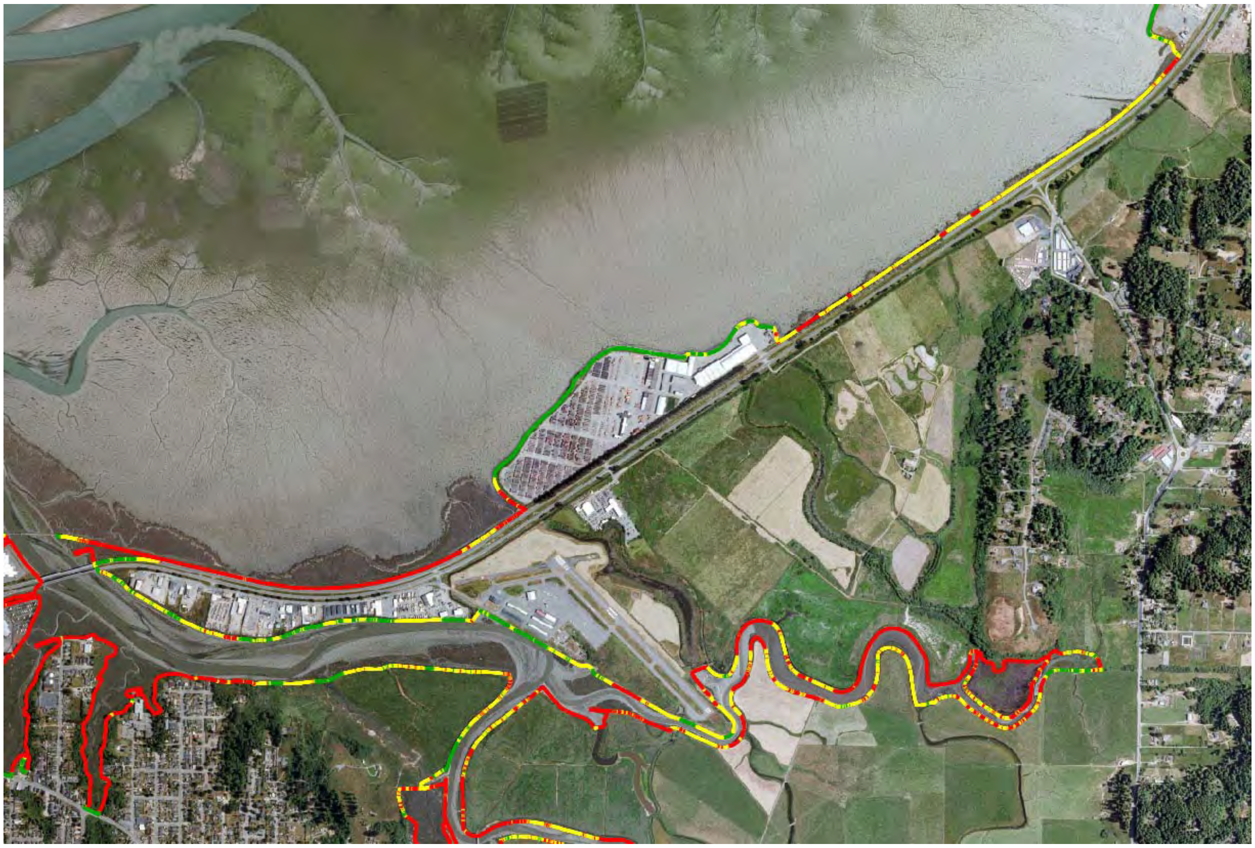

Figure 23. North segment, shoreline vulnerability rating of the lower reach of Highway 101 on Arcata Bay: high (red), moderate (yellow), and low (green) (Laird and Powell 2013).

Figure 24. Middle segment, shoreline vulnerability rating, Highway 101 south of Eureka: high (red), moderate (yellow), and low (green) (Laird and Powell 2013).

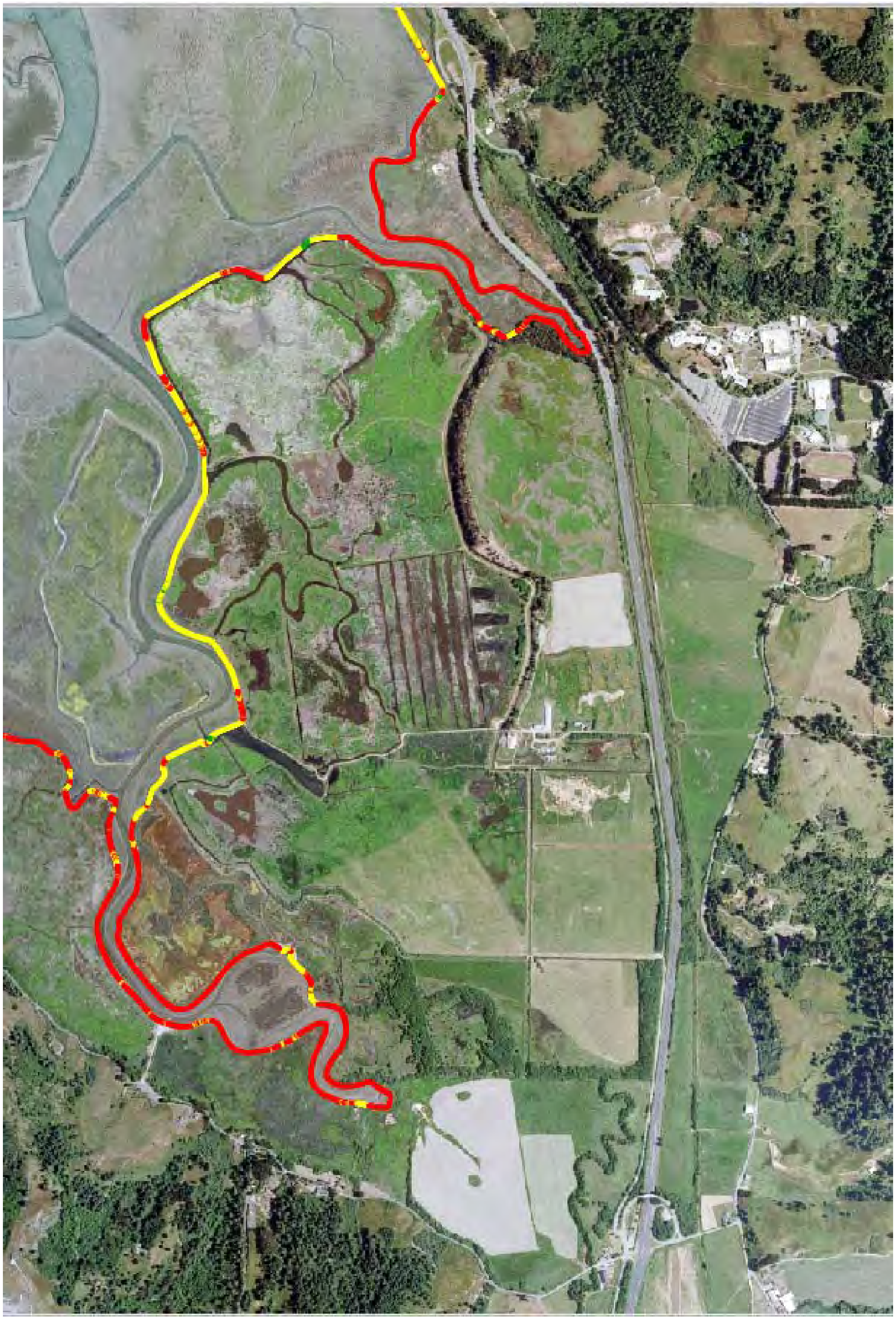

Figure 25. South segment, shoreline vulnerability rating of Highway 101 on South Bay: high (red), moderate (yellow), and low (green; Laird and Powell 2013).

Figure 26. The north segment of Highway 101 traverses several tributaries and streams to Arcata Bay that convey stormwater runoff and can flood land to the east of Highway 101.

Under current MMMW conditions, if the protective shorelines to the west and east are compromised by breaching or overtopping, Highway 101 would become a causeway, similar in function to a dike, traversing the three low-lying segments on Humboldt Bay. The highway would continue as a causeway until it became inundated by rising tides. If the water control and drainage structures located in the protective shoreline to the east or beneath Highway 101 fail or are impaired, flooding of lands behind the protective shorelines may occur, flooding the road prism and surface of Highway 101.

The north segment of Highway 101 traversing Arcata Bay can be segregated into two reaches on either side of Bracut that are vulnerable to inundation and flooding at different elevations. The 2.3-mile segment north of Bracut is higher, and the 3.5-mile segment south of Bracut (Brainard's Point) is generally lower in elevation. The 2.3-mile middle segment south of Elk River Slough and a 2.7-mile segment south segment on South Bay south of King Salmon are more uniform in their elevation and vulnerability to inundation and flooding. These low-lying segments are tidally inundated and flooded at different relative sea level rise elevations (Table 21).

Table 21. Shoreline segment sea level rise and flood impacts from sea level rise through 2100. Bold indicates flooding/inundation of the Highway 101 road surface.

SHORELINE SEGMENTS	2015–2030 MMMW + Shoreline Breaches	2030–2050 MMMW + 0.5 meters	2050–2100 MMMW + 1.0 meters
North Segment: Upper Arcata Bay	Tidally inundates road embankments and adjacent lands	Tidally inundates road embankments and adjacent lands	**Tidally inundates significant portions of north and south bound lanes**
	100-year event floods road embankments and adjacent lands	**100-year event floods north and south bound lanes**	→
North Segment: Lower Arcata Bay	Tidally inundates highway embankments and adjacent lands	**Tidally inundates north and south bound lanes**	→
	100-year event floods north and south bound lanes	→	→
Middle Segment	Tidally inundates road embankments and adjacent lands	Tidally inundates road embankments and adjacent lands	**Tidally inundates significant portions of north and south bound lanes**
	100-year event floods road embankments and adjacent lands	**100-year event floods north and south bound lanes**	→
South Segment	**Tidally inundates portions of north and south bound lanes**	**Tidally inundates north and south bound lanes**	→
	100 year event floods north and south bound lanes	→	→

➢ *Sea Level Rise of 0.9 Feet*

The tidal inundation vulnerability and flood mapping indicates areas that are vulnerable if the protective shoreline structures are breached or overtopped, not areas that are currently inundated (NHE 2014b). Sea level rise of 0.9 ft. was modeled using MAMW (8.8 ft.), with the assumption that current shoreline protection was no longer functioning. The inundation vulnerability maps show that much of the former tidal lands that are currently protected, especially lands to the east of Highway 101, could be inundated if the current diked shoreline is overtopped or breached. Highway 101 would be tidally inundated from the east (Figure 27 - Figure 30). In the HBAP planning area north of Eureka, approximately 0.73 miles of the north bound lanes could become tidally inundated if the diked shoreline on Fay Slough is overtopped or breached. An additional 1.1 miles of both lanes in the South segment could also be inundated if the dikes on South Bay are overtopped or breached.

However, under current conditions, the south bank of lower Jacoby Creek is the shoreline most vulnerable to overtopping, often leading to inundation of the highway road prism on the east side of the upper reach of the North segment. The dikes on Fay Slough currently hold MAMW of 8.8 ft. and prevent the lower reach of the North segment from being tidally inundated. The railroad on the west side of the North segment also appears to be able to contain MAMW of 8.8 ft.

The road prism of the Middle segment south of Elk River on the east side is tidally inundated by MAMW of 8.8 ft. On the South segment, the dikes in the Humboldt Bay National Wildlife Refuge (HBNWR) in the Salmon Creek unit are not overtopped under current conditions. Therefore, the South segment has not become tidally inundated by MAMW of 8.8 ft.

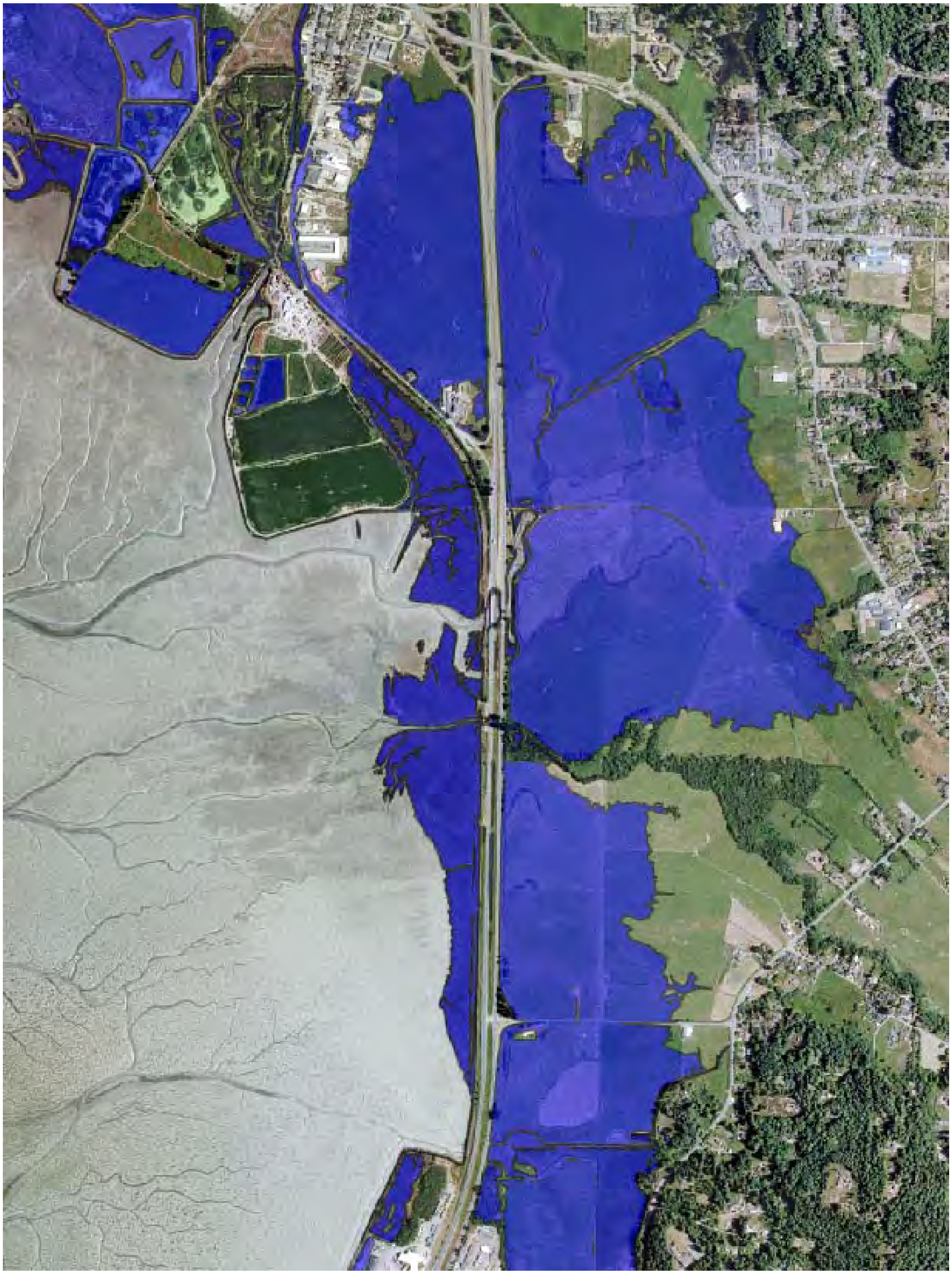

Figure 27. Upper reach of North segment with 0.9 ft. of sea level rise with a tidal elevation of 8.8 feet. (MAMW). Should the protective shoreline structures be compromised, the land adjacent to the road prism could be inundated to the east of Highway 101.

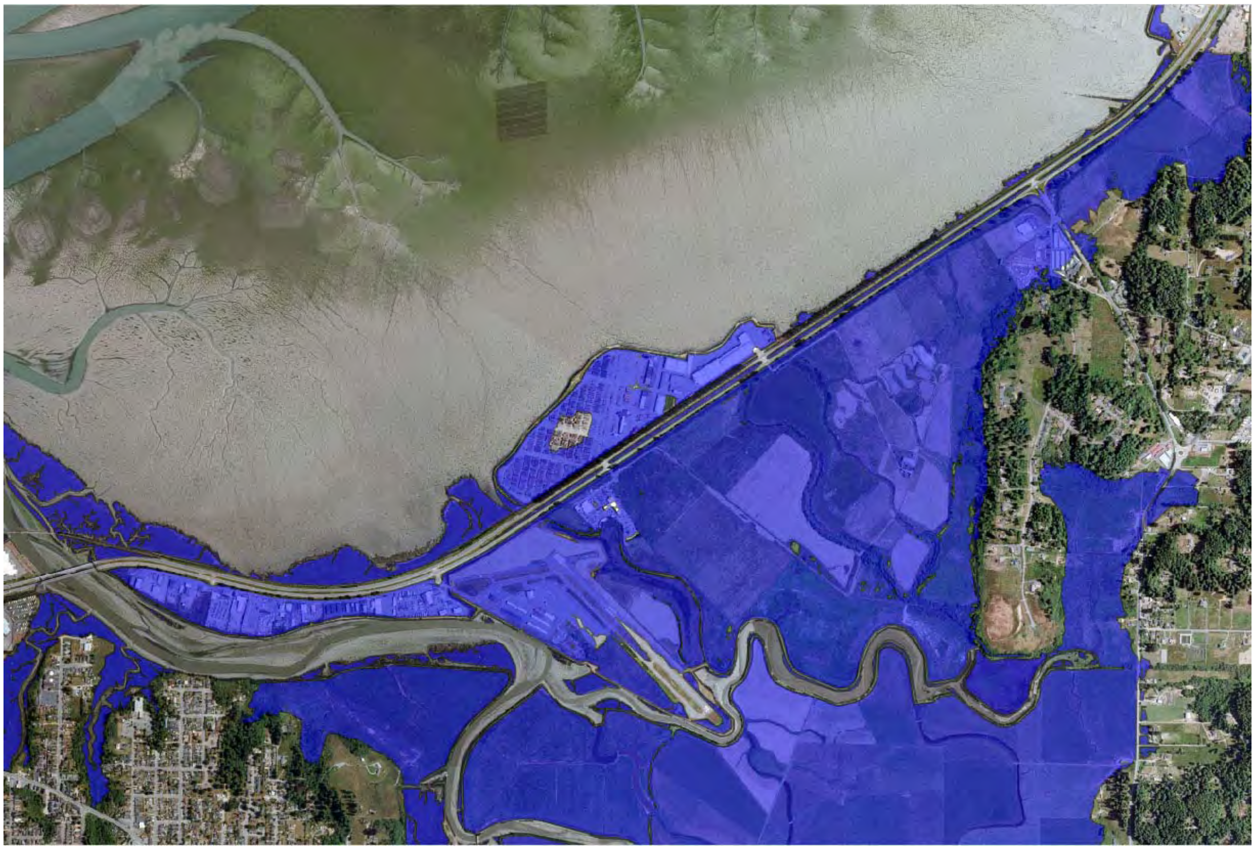

Figure 28. Lower reach of North segment with 0.9 ft. of sea level rise with a tidal elevation of 8.8 feet (MAMW). Should the protective shoreline structures be compromised, the land adjacent to the road prism could be inundated from the east of Highway 101. In the HBAP planning area, approximately 0.73 miles of the north bound lanes of the lower reach could become tidally inundated.

Figure 29. Middle segment with 0.9 ft. of sea level rise with a tidal elevation of 8.8 feet (MAMW). The protective shoreline structures to the east have been compromised. The land adjacent to the road prism is inundated from east of Highway 101, but no lanes become tidally inundated.

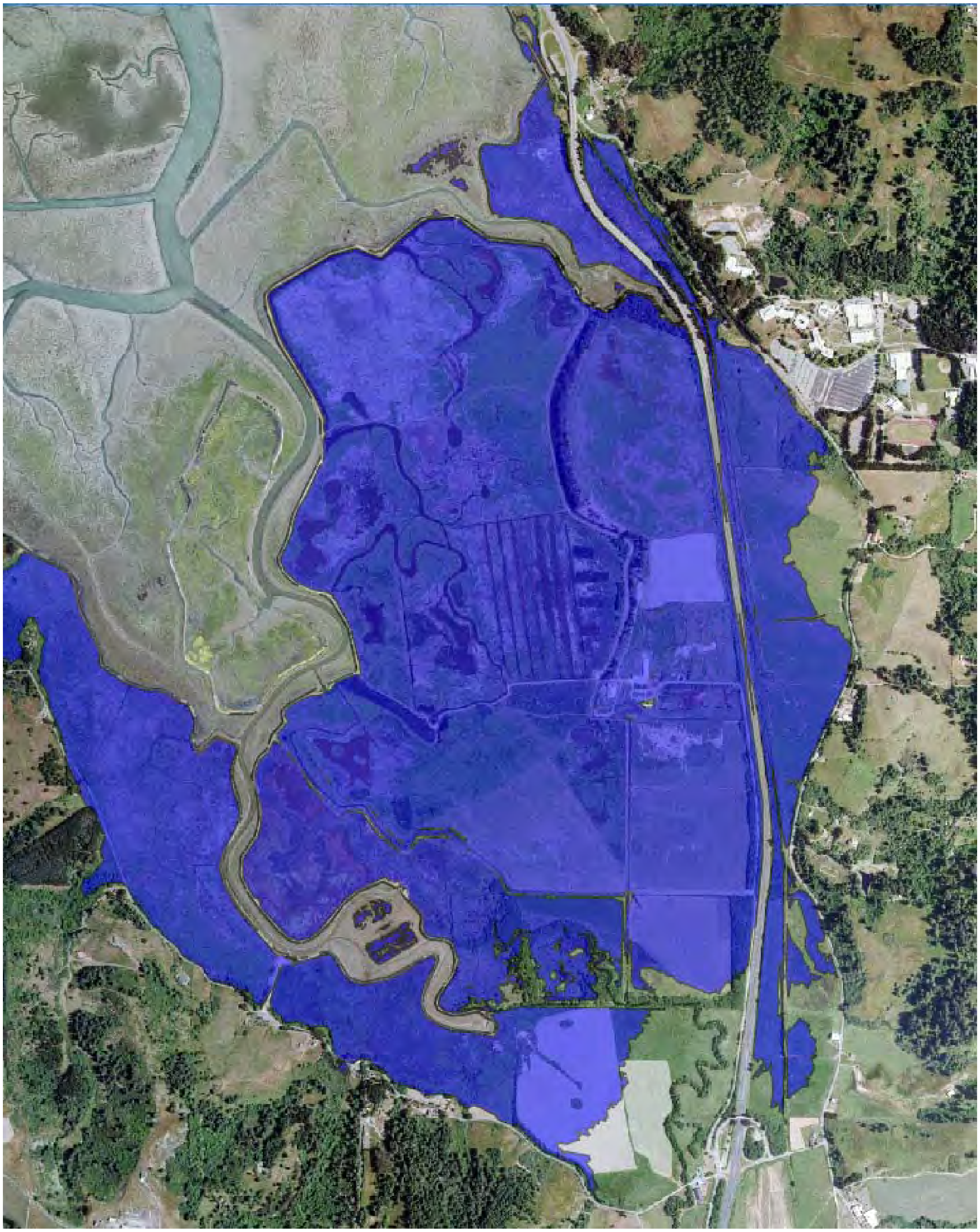

Figure 30. South Bay segment with 0.9 ft. sea level rise with a tidal elevation of 8.8 feet (MAMW). Scenario assumes that protective shoreline structures are compromised, and the land adjacent to the road prism is inundated from west of Highway 101. Approximately 1.1 miles of the north and south bound lanes could become tidally inundated.

➢ *Sea Level Rise of 1.6 Feet*

Sea level rise of 1.9 ft., the high projection for 2050, would result in a MMMW elevation of 9.6 ft. The elevation of MMMW, plus 1.9 ft. of sea level rise, is a half foot lower than the elevation of the 100-year event (1% probability of occurring any year) of 10.2 ft. Areas that would be infrequently flooded by the 100-year extreme storm event could be tidally inundated by MMMW in 2050.

Two miles of both north and south bound lanes in the lower reach of the North segment of Highway 101 could be tidally inundated by 1.6 ft. (0.5 M) of sea level rise if the protective dikes on Fay Slough are breached or overtopped, and 1.2 miles of both north and south bound lanes in the Highway 101 South segment could also be tidally inundated if the protective dikes on South Bay are breached or overtopped (Figure 31 and Figure 32).

Sea level rise of 1.6 ft. (0.5 M) would lead to overtopping of 20.9 miles of artificial shoreline, including 11.4 miles of dikes and 1.5 miles of railroad grade (Table 7). In the upper reach of the North segment, the dikes on Gannon Slough and Washington Gulch could be overtopped. This would inundate the highway road prism from the east but not the highway surface.

In the lower reach of the North segment, the railroad would be overtopped by 1.6 ft. (0.5 M) of sea level rise and tidal inundation of the highway road prism would occur, as would portions of the south bound lanes. The dikes on Fay Slough would be overtopped and north bound lanes would become tidally inundated.

The middle segment road prism would be tidally inundated by 1.6 ft. (0.5 M) of sea level rise from the east, but the highway surface would not be inundated. The dikes on the HBNWR in the Salmon Creek unit would be overtopped and lead to tidal inundation of both south and north bound lanes of the south segment.

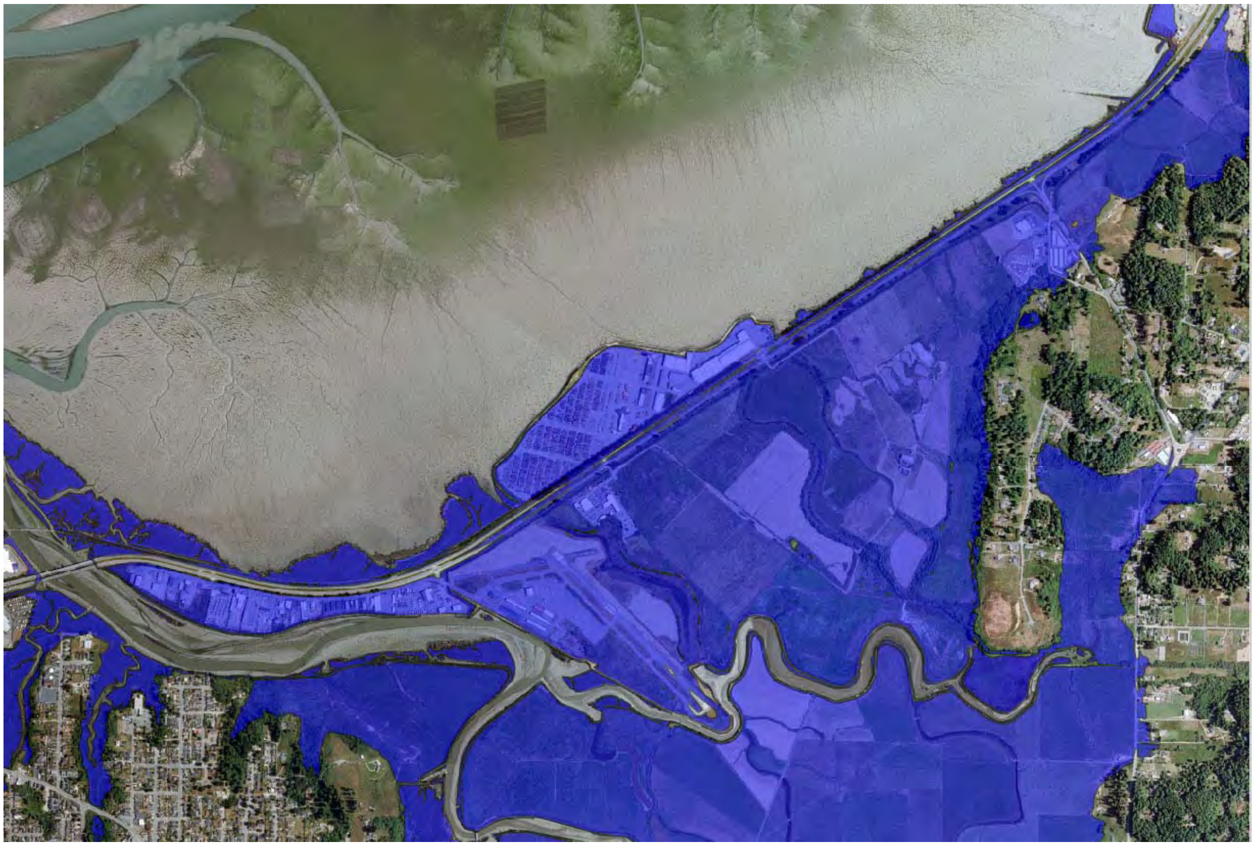

Figure 31. Lower reach of the Arcata Bay segment with 1.6 ft. (0.5 M) of sea level rise and a tidal elevation of 9.3 feet. Protective shoreline structures are overtopped on both sides of the highway, and the road prism is inundated. Approximately 2.0 miles of the north and south bound lanes of the lower reach could become tidally inundated.

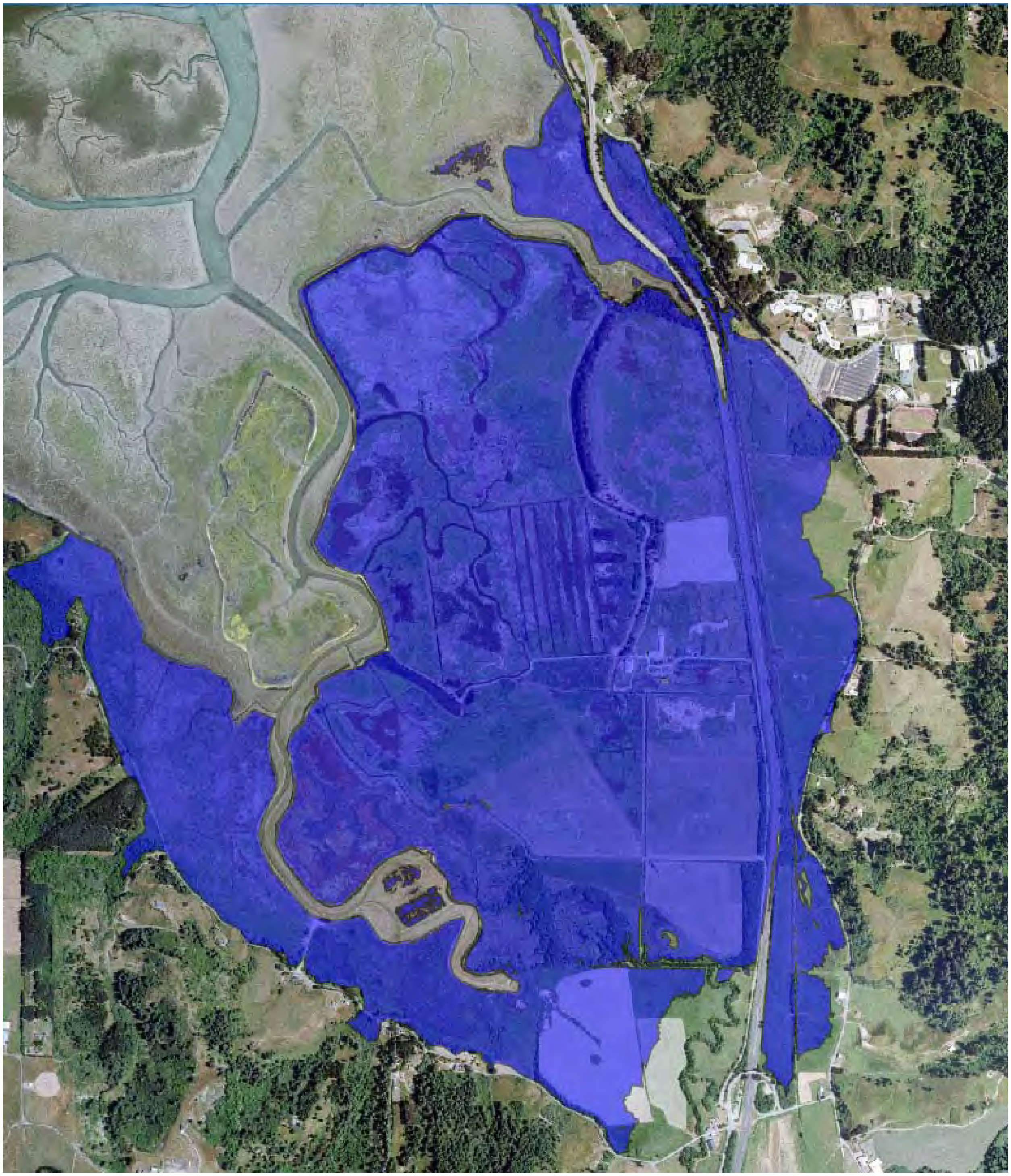

Figure 32. South Bay segment. With 1.6 ft. (0.5 M) of sea level rise and a tidal elevation of 9.3 feet. Protective dike shoreline structures are compromised, and 1.2 miles of the south and north bound lanes of Highway 101 are tidally inundated.

➢ *Sea Level Rise of 3.3 Feet*

Sea level rise of 3.2 ft. (1.0 M) is the high projection for 2070, and would result in a MMMW elevation of 10.9 ft. All protective shoreline structures of Highway 101 would have already been overtopped with 1.6 ft. (0.5 M) of sea level rise. In the HBAP planning area, 0.8 miles of the south bound lanes in the upper reach of the North segment would become tidally inundated from the west. Two miles of both north and south bound lanes in the lower reach could be tidally inundated from both the west and east. The middle segment would become tidally inundated from the east on 0.3 miles south of Elk River and another 0.3 miles from the west near King Salmon. Roughly 1.6 miles of both north and south bound lanes in South Bay would also be tidally inundated, (Figure 33 and Figure 34).

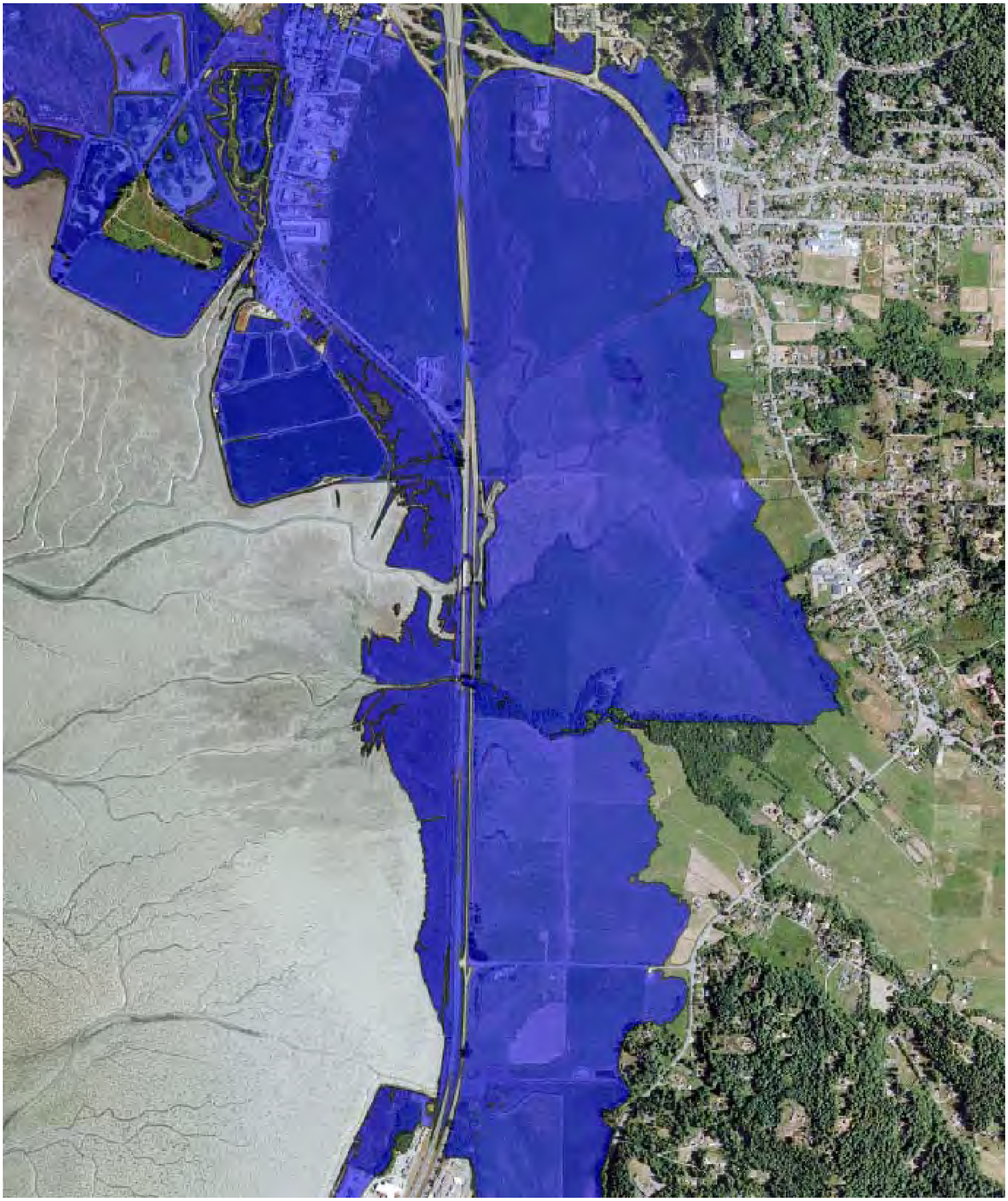

Figure 33. Portions of the upper reach of the North segment in 2070 could be tidally inundated by 3.3 ft. (1.0 M) of sea level rise as protective shoreline structures are compromised and portions of the south and north bound lanes are inundated.

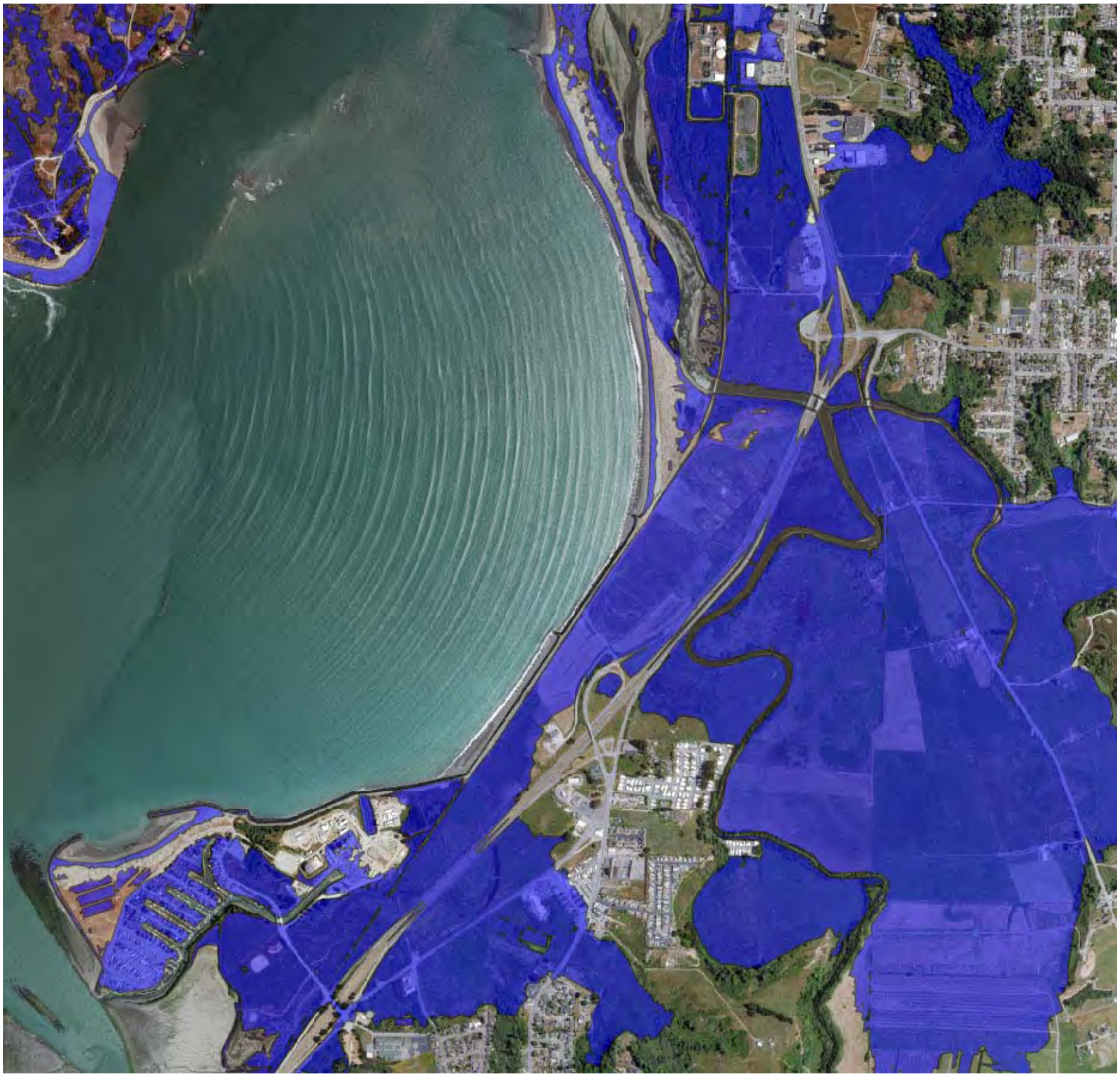

Figure 34. . Portions of the Middle segment in 2070 could be tidally inundated by 3.3 ft. (1.0 M) of sea level rise.

➢ *Sea Level Rise of 4.9 Feet*

Sea level rise of 5.4 ft. is the high projection for 2100, and would result in a MMMW elevation of 13.1 ft. Most reaches of the highway that would be inundated by 3.3 ft. (1.0 M) of sea level rise would be tidally inundated much more frequently and to greater depths if the projected 4.9 ft. (1.5 M) of sea level rise occurs. The inundation areas for 4.9 ft. (1.5 M) of sea level rise are very similar in areal extent to the 3.3 ft. (1.0 M) sea level rise inundation areas (Figure 35 and Figure 36). A notable difference is that both south and north bound lanes would be completely inundated.

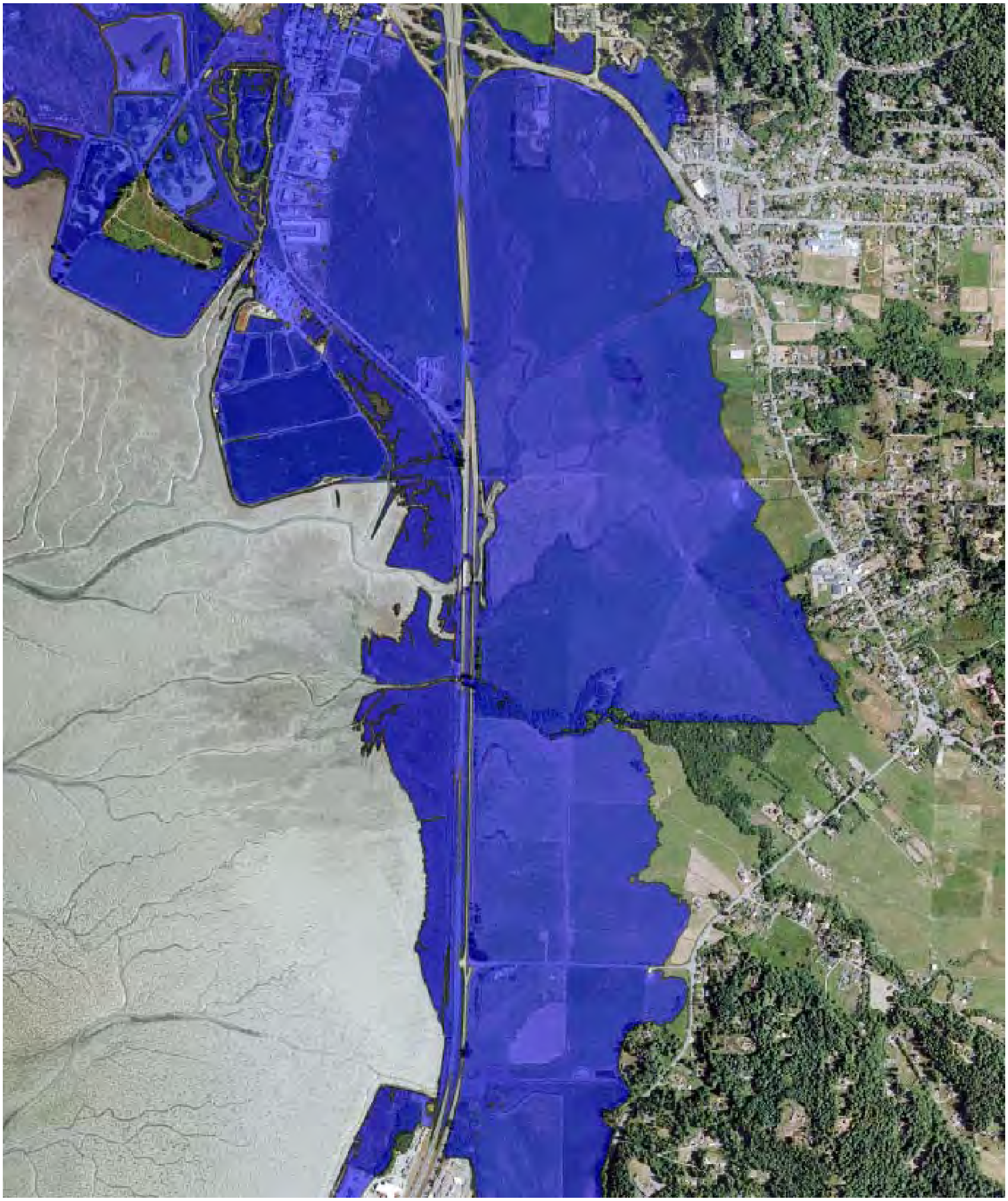

Figure 35. Upper reach of North segment by 2100, could be tidally inundated by 4.9 ft. (1.5 M) of sea level rise. Both north and south bound lanes are almost entirely inundated.

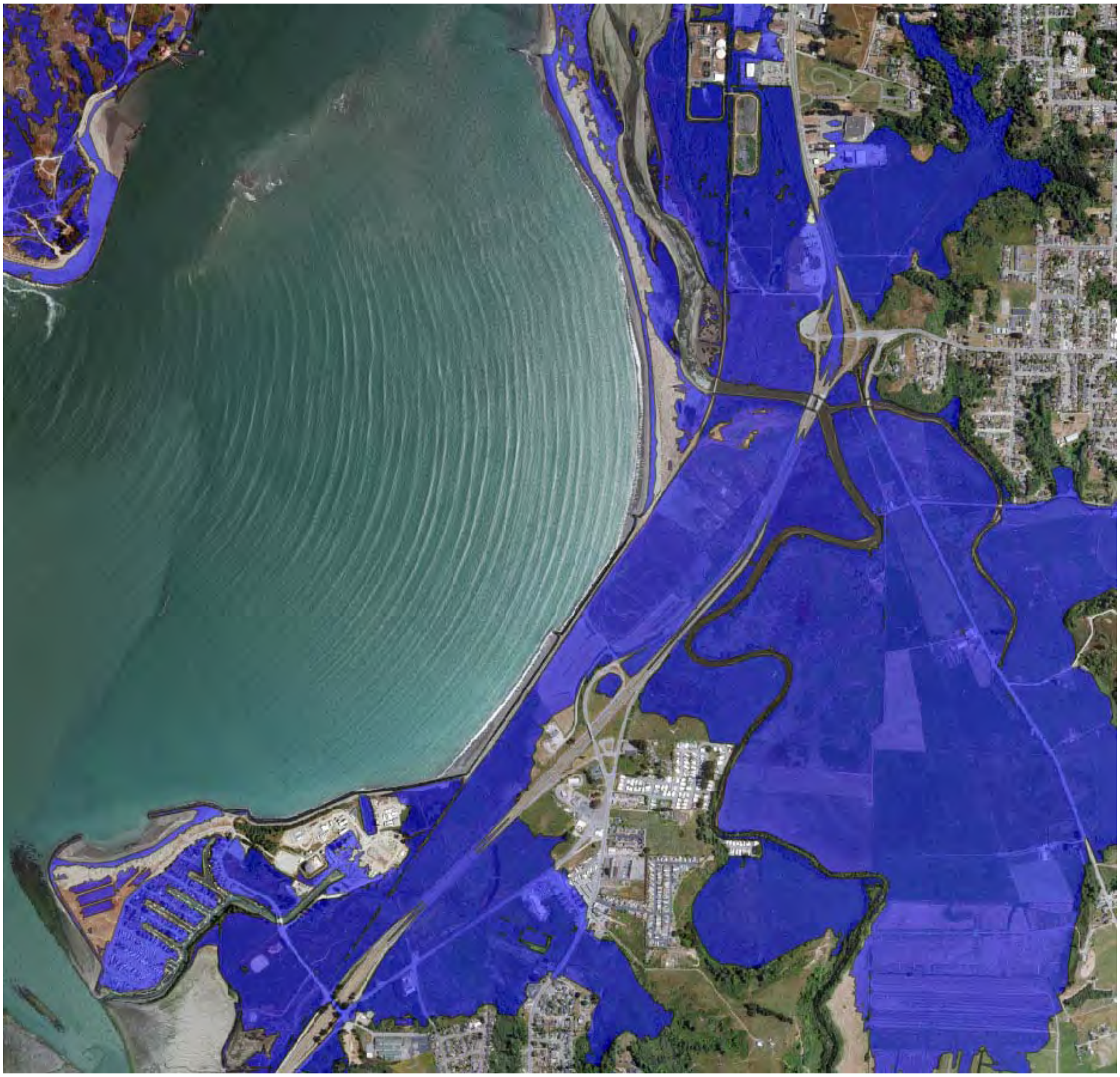

Figure 36. Middle segment by 2100, south of Eureka by 2100, could be tidally inundated by 4.9 ft. (1.5 M) of sea level rise. Both north and south bound lanes are almost entirely inundated.

State Highway 255

There are 2.7 miles of Highway 255 in the HBAP planning area that traverse diked former tidelands, and that are vulnerable if the protective diked shoreline on Arcata Bay, Mad River Slough, or Liscom Slough are breached or overtopped. The shoreline on Mad River and Liscom Sloughs is mostly rated highly vulnerable (less than two feet above MMMW elevation) (Figure 37). If this reach is closed, State Highway 255 from Eureka to Samoa Peninsula would become the sole means of access for the communities of Fairhaven, Samoa, and Manila.

Figure 37. State Highway 255 near Mad River and Liscom Sloughs and dike shoreline vulnerability rating (red=high, yellow=moderate, and green=low).

- ***Sea Level Rise of 0.9 Feet***

Presently, MAMW of 8.8 ft. overtops the south bank of Liscom Slough and inundates the fields north of Highway 255. These MAMW occur on average four times a year for short duration, causing nuisance flooding.

➢ *Sea Level Rise of 1.6 Feet*

The diked shoreline on the south bank of Liscom and Mad River sloughs and on Arcata Bay could be overtopped by 1.6 ft. (0.5 M) of sea level rise. The overtopping of these dikes would place a 1.7-mile reach of Highway 255 at risk of tidal inundation. Approximately 0.4 miles of the highway south of Manila and north of Samoa Bridge would also become a causeway, with open water on both sides. Under these conditions, the road prism could be exposed to wind-induced wave erosion and slumping from over saturation. Over time and under repeated flooding, the road base would become saturated, causing the asphalt to buckle and require resurfacing. Rising tides can impair the capacity and function of water control structures, such as tide gates and culverts, associated with the highway, which could increase flooding of adjacent areas.

With 1.6 ft. (0.5 M) of sea level rise, the current MAMW or 8.8 ft. tide would occur 125 times a year, causing chronic flooding or tidal inundation of up to 1.5 miles of Highway 255 east of Mad River Slough.

➢ *Sea Level Rise of 3.3 Feet*

By 2070, the high projection for sea level rise of 3.2 ft. (MMMW 10.9 ft.) would overwhelm most of the dikes on Mad River Slough and Arcata Bay protecting Highway 255, causing it to become tidally inundated from both the north and the south for 1.8 miles (Figure 38). A 0.3-mile segment of the highway north of Manila before the bridge over Mad River Slough would also be tidally inundated. A 0.4-mile segment of the highway south of Manila would become a causeway, resulting in 0.1 miles becoming tidally inundated.

➢ *Sea Level Rise of 4.9 Feet*

Tidal inundation by 4.9 ft. (1.5 M) of sea level rise would impact 2.6 miles of State Highway 255 across the diked former tidelands on Arcata Bay, approximately 0.5 miles of highway south of Manila on the shoreline of Arcata Bay and approximately 0.25 miles on Duluwat Island in the City of Eureka’s LCP.

The reaches of Highway 255 between Eureka and the Samoa Peninsula located on islands between the highway bridges are presently tidally inundated during MAMW and have likely been designed to withstand tidal inundation on both sides, and thus would suffer no new impacts from tidal inundation of the highway embankments. The embankments, if not fortified, would be susceptible to wave induced erosion.

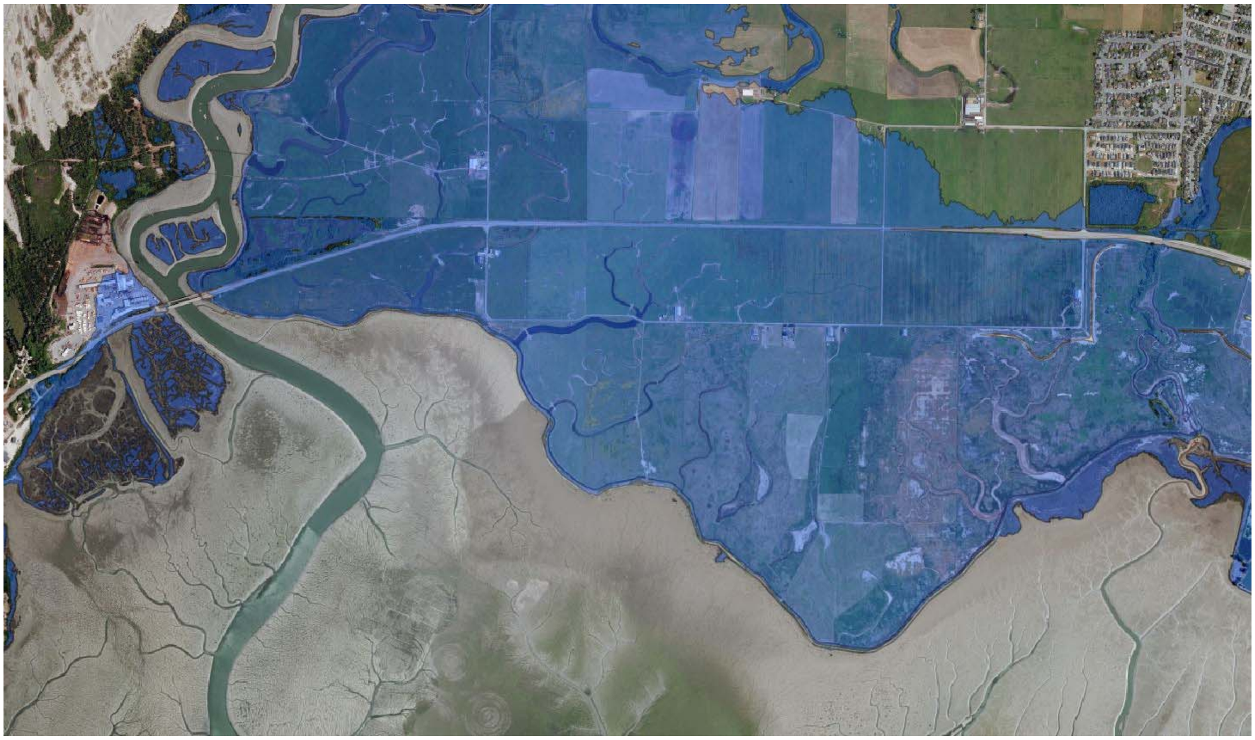

Figure 38. Highway 255 and tidal inundation by 3.3 ft. (1.0 M) of sea level rise).

Air

The Samoa Field Airport is vulnerable and at risk from tidal inundation by way of a low-lying wetland area southeast of the airport. The shoreline on the bay that protects the airport property is low in elevation and exposed, and is rated highly vulnerable to overtopping as it is less than two feet higher than MMMW (Figure 39). Old Navy Base Road bisects this wetland area and currently affords protection for the airport, but would be subject to overtopping by sea level rise. An inter-tidal wetland is located between the road and shore of Humboldt Bay. For shoreline erosion to affect the airport, Old Navy Base Road would have to be breached.

Figure 39. Shoreline vulnerability rating (red = high, yellow = moderate, and green = low) for the shoreline segment protecting Samoa Field Airport from tidal inundation (Laird & Powell 2013).

- ### *Sea Level Rise of 0.9 Feet*

The airport is not vulnerable to 0.9 ft. of sea level rise, as Old Navy Road forms a protective barrier to tidal inundation.

- ### *Sea Level Rise of 1.6 Feet*

With 1.6 ft. (0.5 M) of sea level rise, MMM tides would rise to 9.6 feet. Old Navy Road would be overtopped. Only the southeast corner of the airport property would be tidally inundated, not the runway.

> ➢ *Sea Level Rise of 3.3. Feet*

Even 3.3 ft. (1.0 M) sea level rise with of 10.7 ft., which could occur around 2070, would not inundate the airport runway. However, MAMW or king tides of 12.0 ft. could tidally inundate the airport property and portions of the runway. Surface elevations of the Samoa Field Airport and runway range from 11 to 14 ft.

> ➢ *Sea Level Rise of 4.9 Feet*

The high projection for MMMW is expected to reach 13.1 ft. by 2100, but 4.9 ft. (1.5 M) of sea level rise could result in tidal inundation of a significant portion of the runway and airport property (Figure 40).

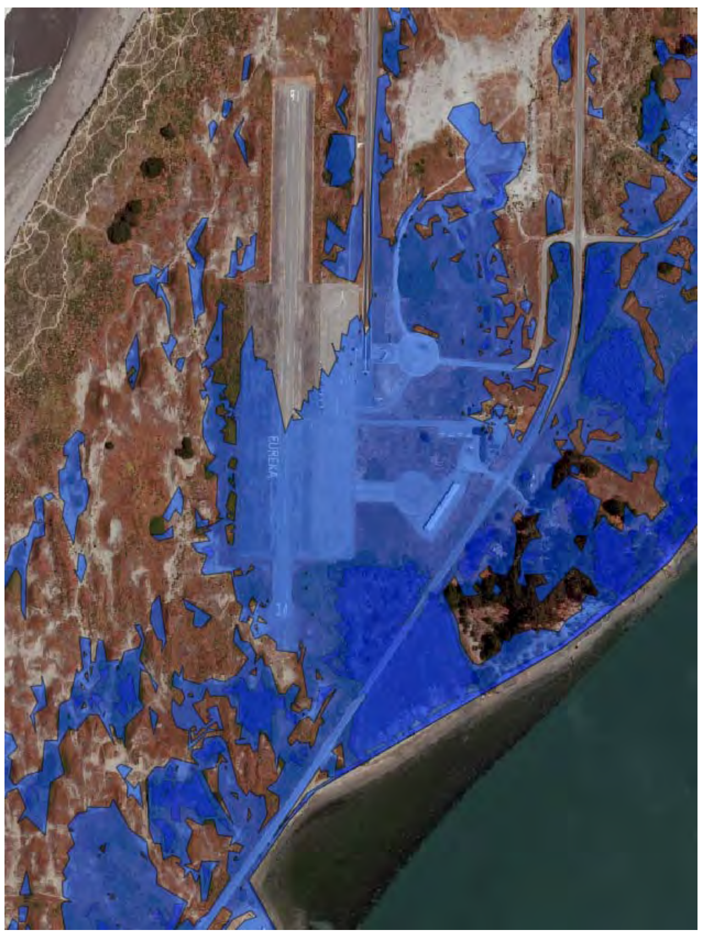

Figure 40. Potential tidal inundation area at Samoa Field Airport by 4.9 ft. (1.5 M) of sea level rise.

Railroad

The railroad on Humboldt Bay consists of the Main line along the eastern shore of the bay and the Samoa line that branches west from the City of Arcata along the western shore of the bay to Samoa (Table 22). There are approximately 26.2 miles of railroad grade on Humboldt Bay, but only 11 miles of the 26.2 miles of railroad form the shoreline. Overall, 20.8 miles of railroad grade are vulnerable to being overtopped by 4.9 ft. (1.5 M) of sea level rise.

There are several segments of railroad shoreline without protective salt marsh plains that are exposed to significant wave action during winter storms: on North Spit north of Samoa Bridge, between the diked shoreline at Bracut and California Redwood Company on the eastern shore of Arcata Bay, and across from the entrance to the harbor which is the segment that has the most exposure to wave energy. As a result, the segment across from the harbor entrance has been heavily fortified with a sea wall; this reach was last reinforced in 2007 and 2008. Recently, winter storm waves have been washing through and over this sea wall, forming deltas from the railroad base in the fields to the east. The sea wall is the *defacto* defense from sea level rise for Highway 101, which is just 700 ft. east of the sea wall at the narrowest point.

Table 22. Potential tidal inundation, in miles, of the North Coast Railroad Authority rail lines on Humboldt Bay.

Railroad Inundation	0.9 Ft.	1.6 Ft.	3.3 Ft.	4.9 Ft.
Main Line	2.7	5.3	14.1	15.6
Samoa Branch	1.9	2.7	4.3	5.2
Total	**4.6**	**8.0**	**18.4**	**20.8**

The railroad forms nearly the entire eastern shoreline on Arcata Bay, which protects U.S. Highway 101 from significant wave erosion caused by prevailing winds. In general, the railroad grade reaches that form the shoreline of Humboldt Bay are vulnerable and at risk from wave induced erosion washing away railroad ballast, and are at risk of being tidally inundated by king tides.

Sea Level Rise of 0.9 Feet

In the HBAP planning area, there are approximately 4.6 miles of railroad grade that could be tidally inundated by 0.9 ft. of sea level rise. If the protective dike shoreline on Arcata Bay is compromised, 2.7 miles of the Main line on Arcata Bay would be tidally

inundated. An additional 1.9 miles of the Samoa Line would be affected if the dikes on Arcata Bay or Liscom Slough are breached or overtopped (Table 23).

- *Sea Level Rise of 1.6 Feet*

There are approximately 6.3 miles of railroad grade in the HBAP planning area that could be tidally inundated by 1.6 ft. (0.5 M) of sea level rise, including 3.7 miles of main line on Arcata Bay between Bracut and California Redwood Company and on South Bay as the dikes and Highway 101 are tidally inundated. An additional 2.7 miles of the Samoa Line on Arcata Bay would also be overtopped dikes on Liscom Slough.

- *Sea Level Rise of 3.3 Feet*

There are approximately 12.3 miles of railroad grade in the HBAP planning area that could be tidally inundated by 3.3 ft. (1.0 M) of sea level rise, including eight miles of main line along Arcata Bay and from King Salmon south. An additional 4.3 miles of the Samoa Line along Arcata Bay would also be affected as the dikes are overtopped on Mad River and Liscom Sloughs, Arcata Bay, and Highway 255.

- *Sea Level Rise 4.9 Feet*

There are approximately 13.8 miles of railroad grade in the HBAP planning area that could be tidally inundated by 4.9 ft. (1.5 M) of sea level rise. This includes 8.7 miles of main line, nearly the entire length of railroad on South Bay from the sea wall across from the harbor entrance south. An additional 5.2 miles of the Samoa Line north of Samoa to Manila, and from Manila east to Arcata, would also be affected.

On Humboldt Bay, approximately 52.7% (13.8 miles) of the railroad that is vulnerable to sea level rise and at risk of tidal inundation by 4.9 ft. (1.5 M) of sea level rise is in the HBAP planning area. The remainder (7 miles) is in the City of Eureka's and City of Arcata's respective LCPs.

Table 23. Potential tidal inundation, in miles, of the North Coast Railroad Authority rail lines in the HBAP planning area.

Railroad Inundation	0.9 Ft.	1.6 Ft.	3.3 Ft.	4.9 Ft.
Main Line	2.7	3.6	8.0	8.7
Samoa Branch	1.9	2.7	4.3	5.2
Total	**4.6**	**6.3**	**12.3**	**13.8**

3.3.3 Susceptibility

Surface

Streets, roads, and highways that traverse low-lying regions on Humboldt Bay are vulnerable to sea level rise and at risk of being tidally inundated. If protective dikes or railroad shoreline structures are breached and tidal waters allowed to reach U.S. Highway 101, State Highway 255 and local road prisms could become exposed. Over time and under chronic flooding or repeated tidal inundation (MMMW), road bases would become saturated, causing the asphalt to buckle and requiring resurfacing. Rising tides can also impair the capacity and function of water controls structures that are part of the surface transportation infrastructure such as tide gates and culverts. Roadway embankments, if not fortified in reaches that are exposed to wave action, are susceptible to erosion as well as overtopping.

Temporary or nuisance flooding (currently occurring approximately four times per year by MAMW of 8.8 feet) may result in temporary closures of roadways and re-routing of traffic. Frequent or chronic (predicted to occur 125 times per year by an 8.8-foot tide with 1.6 ft. [0.5 M] of sea level rise) tidal inundation of any road or highway segments would likely not be tolerable. The adaptive capacity to address sea level rise impacts on county or state (Caltrans) roadways is complicated by that fact that most of the roads and highways do not form the shoreline on Humboldt Bay. The shorelines in the hydrologic sub-units that protect the low-lying segments of roads and highways from tidal inundation or flooding consist of 170 parcels of diked shoreline owned by a mix of public and private entities.

Air

The Samoa Field Airport is not likely to be impacted by tidal inundation until sea level rise reaches 3.3 ft. (1.0 M) and the MAMW rises to 12.0 ft., as projected for 2070. A significant portion of the airport runway and property could become tidally inundated by 4.9 ft. (1.5 M) of sea level rise when MMMW rises to 12.6 ft. Tidal inundation would significantly impair the continued use of this airport and would be a significant adverse impact if the airport had to shut-down. Tidal inundation of the tarmac areas of the airport would raise safety concerns. Frequent tidal inundation or flooding of the tarmac areas is likely to not be acceptable under current aviation regulations. Frequent flooding and rising ground water of lands adjacent to the runways could convert these lands to wetlands and waterfowl habitat, which might pose a hazard to air traffic. The continued operation of the airport under these conditions may not be possible

Railroad

The railroad is susceptible to adverse impacts from tidal inundation during MAMW and wave action during storms and 100-year extreme storm events (1% probability of occurring any year). The railroad has not been used since 1998 and has only been maintained or repaired at the sea wall across from the harbor entrance, approximately 10 years ago. The railroad ballast in the reach of shoreline with the protective sea wall has been washed out by storm waves, leaving the rails twisted and suspended in the air. Without regular maintenance, railroad bridges, culverts and tide gates in a marine environment would degrade. In addition, the capacity and function of these drainage structures would be impaired with rising sea levels. Tidal inundation could result in slumping, erosion and washing away of ballast, as is currently occurring at the sea wall from storm waves.

3.4 Utilities

Urban land uses are enabled by utilities that provide essential services. The utility infrastructure and services in the HBAP planning area are municipal water, wastewater, energy (electrical and natural gas), and communications. Impairment of utility infrastructure can affect all land uses and properties served by the affected utility. Many of the utilities have underground infrastructure (water, sewer, gas, and optical fibers), exacerbating their vulnerability to sea level rise. The County is not responsible for the maintenance and operation of any utility systems in the HBAP planning area.

In the HBAP planning area, the Humboldt Bay Municipal Water District (HBMWD) delivers wholesale municipal water to two community services districts, Humboldt Community Services District (HCSD) and Manila Community Services District (MCSD), and retail municipal water to the communities of Samoa and Fairhaven. MCSD only serves the community of Manila, and HCSD serves several urban areas east and south of the City of Eureka, including Humboldt Hill, King Salmon, and Fields Landing. The City of Eureka owns and maintains two 48-inch municipal water transmission lines that traverse 6 miles of diked former tidelands in the HBAP planning area between the cities of Arcata and Eureka.

Wastewater collection systems in the HBAP planning area are operated by HCSD and MCSD in their respective service areas. There are no wastewater collection systems outside of these service areas and there are no wastewater treatment facilities in the HBAP planning area.

PG&E operates the HBGS in King Salmon, which provides electricity in the HBAP planning area and beyond. PG&E maintains a system of electrical transmission towers, sub-stations, and distribution poles to deliver electricity in the HBAP. PG&E also provides natural gas via underground gas lines and associated infrastructure throughout the HBAP planning area.

Communications systems (telephone, cable, optical fiber) in the HBAP planning area are privately owned and maintained. Infrastructure can consist of cell towers, utility poles and overhead lines, underground lines, and various types of above and below ground infrastructure.

The infrastructure and operations for the energy and communications utility services in the HBAP planning area are the responsibility of private companies. The exact location of underground natural gas and optical fiber infrastructure are not known due to utility company policies limiting access to location information for security purposes, making it difficult to assess the vulnerability of this infrastructure to sea level rise.

As discussed earlier under Land Use, as urban areas become tidally inundated, the underground utilities (municipal water, waste water, gas lines, and optical fibers) serving these areas would also become tidally inundated. Overhead utilities structures can also be impacted, as flooding or inundation can hamper access for their repair and maintenance, and can reduce the stability of above-ground structures supporting these utilities as they were not designed to be in water.

3.4.1 Municipal Water

- Humboldt Bay Municipal Water District

In the HBAP planning area, most of the municipal or potable/drinking water is supplied by HBMWD from their Mad River operations. Seven municipal agencies in the greater Humboldt Bay region purchase wholesale drinking water from HBMWD, including the cities of Eureka and Arcata as well as HCSD and MCSD, and distribute drinking water to customers within their jurisdictions. HBMWD also provides drinking water to the communities of Samoa and Fairhaven. HBMWD supplied untreated water to pulp mills on the Samoa Peninsula for decades, until the pulp mills shut down; the distribution infrastructure remains. Development in areas of the HBAP planning area that do not have access to municipal drinking water relies on private water such as well or spring water.

In the HBAP planning area, HBMWD has three underground water transmission lines consisting of two 42-inch diameter industrial pipelines and one 27-inch domestic pipeline that extend from Korblex on the Mad River across the Mad River bottom and Mad River Slough to the North Spit. The City of Eureka has two 48-inch municipal water transmission pipelines that move water from the HBMWD’s facilities in Arcata to the city. The City of Eureka’s main underground transmission pipelines traverse diked former tidelands that are vulnerable to tidal inundation now if the dikes are breached, or by 1.6 ft. (0.5 M) of sea level rise due to overtopping of the dikes.

In the HBAP planning area, water lines on trestles cross over Mad River Slough (HBMWD), Freshwater Slough (City of Eureka), and Elk River Slough (HCSD). These entities are responsible for maintaining these pipeline trestles. These pipeline trestles

are exposed to potential damage from floating debris during MAMW or king tides, 100-year flood events (1% probability of occurring any year), or rising sea levels.

The HBMWD has approximately 16.1 miles of domestic water pipeline in the HBAP planning area. When the HBMWD's 27-inch main domestic water pipeline reaches Manila, it drops down to 15-inch pipeline that extends south to Samoa, Fairhaven and the US Coast Guard Station (USCGS) on the North Spit. The HBMWD also runs a domestic water pipeline under Humboldt Bay to the Truesdale pump station located in Eureka and operated by the HCSD.

The HBMWD also has approximately 12.7 miles of industrial water pipelines comprised of two 42-inch pipelines that merge into one 42-inch pipeline at Manila and then proceed down the North Spit to provide untreated water to two CDI properties (former pulp mills) between Samoa and Fairhaven. The HBMWD pipelines traverse the Mad River bottoms and cross over Mad River Slough on two elevated trestles and then are again underground and extend south through the North Spit dune system to MCSD, Samoa, CDI properties, Fairhaven, and USCGS. The HBMWD distributes retail municipal water to Fairhaven. There are 181 parcels in Fairhaven that are vulnerable to 4.9 ft. (1.5 M) of sea level rise. Water distribution infrastructure serving areas that could become tidally inundated would also be affected when these parcels become inundated or before with rising groundwater and salt water intrusion. Residential property in Samoa is not located in areas vulnerable to sea level rise.

- City of Eureka

The City of Eureka's two 48-inch main municipal water transmission pipelines, the Mad River Pipelines (MRP) (concrete-cased steel and HDPE) convey water from the "Eureka Turnout," located at 7th and A Streets in Arcata, to the Eureka-owned Ryan Slough booster pump station near the intersection of Myrtle Avenue and Mitchell Road. The entire length of the MRP is located outside Eureka city limits, traversing lands that Eureka does not own. The pipelines, valves, and access roads traverse 6.3 miles of mostly low-lying former tidelands east of U.S. Highway 101 that are protected by shoreline dikes and used for agriculture and wildlife. The ground surface elevation along the route varies from 5 to 20 ft.

- McKinleyville Community Services District

MCSD provides retail municipal water that it receives from the HBMWD, to its service area from Samoa Bridge north to Mad River Slough. In the MCSD, there are residences (Pedro Lane, Vance Avenue, Victor Blvd., Holly Drive, Melvin Avenue, north Peninsula at Drive, Young Lane and Midway Court) and the former Sierra Pacific Industries (SPI) industrial properties that are vulnerable to sea level rise of 4.9 ft. (1.5 M). A 10-inch main provides water within the District to 343 metered customers, and formerly 1 industrial customer. In the MCSD, there are approximately 17 residences and the former SPI industrial property that are vulnerable to sea level rise of 4.9 ft. (1.5 M).

- Humboldt Community Services District

In the HBAP planning area, HCSD serves Fields Landing and King Salmon, both of which are vulnerable to sea level rise of 4.9 ft. (1.5 M). The HCSD distribution infrastructure consists of 14 different pressure zones, 87 miles of water main, 13 booster pumping stations, 10 water storage reservoirs, and 7 water interties with the City of Eureka. Only one intertie, at the Truesdale Street pump station, is within the potential tidal inundation footprint for 4.9 ft. (1.5 M) of sea level rise (13.1 ft.).

The HCSD obtains water for its customers from three sources. One-third of its water is purchased from HBMWD via a water pipeline that runs down the Samoa Peninsula and crosses under the bay to the Truesdale water booster pumping station (elevation 9.7 to 10.1 ft.), which also provides an intertie to the City of Eureka's municipal water system. This pipeline is the primary means that the HCSD receives water from HBMWD. HBMWD water via HCSD supplies the central areas of Cutten and Ridgewood, which are not otherwise vulnerable to sea level rise.

The HCSD purchases another one-third of its water from the City of Eureka through the Hubbard and Harris booster station, which supplies the northern areas of Myrtletown and Freshwater. Portions of these communities are vulnerable to 4.9 ft. (1.5 M) of sea level rise.

The final one-third of HCSD potable water traditionally came from three HCSD-owned wells located at the base of Humboldt Hill. They are known as the Spruce Point, the South Bay, and the Princeton wells. These groundwater wells supply potable water to the southern areas of Humboldt Hill, Pine Hill, King Salmon, Field's Landing, and College of the Redwoods. The groundwater wells are approximately 400 feet deep. The Princeton well is no longer active; its elevation is approximately 14 ft. The South Bay well has also been taken off-line temporarily to address an issue with coarse sand discharging with the water. The South Bay well is at approximately 10 ft. elevation. Investigation and repair of the South Bay well is significant because it is the highest producing well of the three HCSD-owned wells. The Spruce Point well is active and situated at approximately 40 ft. elevation. Groundwater treatment of the wells is achieved by chlorination at the well sites.

Exposure

Exposure of water systems in the HBAP planning area to tidal inundation jeopardizes access to infrastructure for maintenance and emergency repairs. The infrastructure itself such as pipelines, wells, trestles, pump stations, and water valves, is also at risk. In the HBAP planning area, the City of Eureka and HBMWD have water transmission lines located in diked former tidelands. Access to underground infrastructure in diked former tidelands could be compromised today if there is a breach or overtopping of the

diked shorelines and the former tidelands become inundated daily to a depth of two to three feet salt of water.

In the HBAP planning area, HBMWD has one municipal water transmission line and two industrial water transmission lines that traverse approximately 1.1 miles of the Mad River bottoms west of Liscom Slough to Mad River Slough, north of Highway 255, with most of the bottomland surface ranging from 3.0 to 6.0 ft. The diked shoreline on Liscom and Mad River Sloughs are currently vulnerable to being overtopped by MAMW or king tides, which could tidally inundate the area that the water transmission lines traverse. To the east of Humboldt Bay, the City of Eureka's MRP traverses approximately 6.1 miles of diked former tidelands through six hydrologic units with surface elevations that range from 4.0 to 6.0 ft. The diked shorelines in these sub-units are owned by numerous private and public entities that are responsible for their maintenance. A dike owned by DFW in the Walker Point area has breached, and the diked land where the City's MRPs traverses is now tidal. DFW does not plan on repairing the dike. The valves and corrosion protection systems for the pipelines must be accessed regularly for monitoring, maintenance and repairs. If the remaining dikes were to breach today, much of the area that the pipelines traverse could become tidally inundated daily to a depth of two to three feet salt of water and access to 2.4 miles of the MRPs may become difficult.

- ***Sea Level Rise of 0.9 Feet***

In the HBAP planning area, the current MAMW of 8.8 ft., is illustrative of what 0.9 ft. (8.6 ft.) the high projection for of sea level rise in 2030 could inundate, approximately 1.7 miles of HBMWD domestic transmission pipelines that traverse diked former tidelands south of Liscom Slough, if the dikes are breached. The municipal water distribution system operated by HCSD in King Salmon and Fields Landing can also become tidally inundated by MAM tide.

By 2030, the MAMW could reach 9.7 ft. Tidal inundation of the diked former tidelands, through which the HBMWD and City of Eureka's domestic water transmission pipelines run, could be three to four feet deep if the dikes are breached. As the diked former tidelands become saturated and/or tidally inundated, the access to these pipelines is likely to become more difficult and expensive. The access road to the Ryan Slough pump station (elevation 8.9 ft.) could become tidally inundated if the dikes on Freshwater or Ryan Slough are breached. The access road to the HCSD's South Bay well could also be tidally inundated (Figure 41).

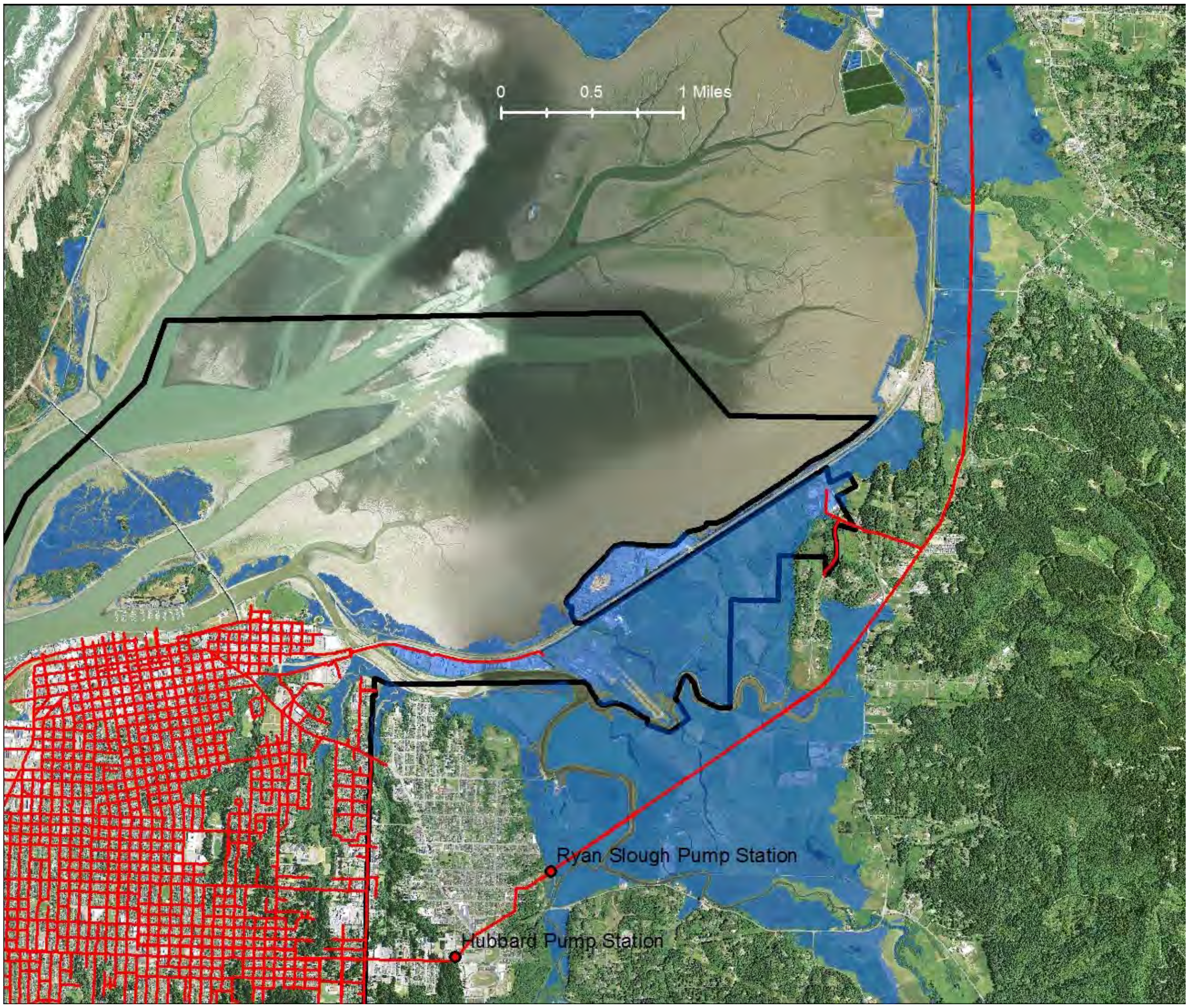

Figure 41. City of Eureka Mad River municipal water transmission lines, Ryan Slough and Hubbard pump stations, and City boundary with potential tidal inundation area for 2015 if dikes fail.

➢ *Sea Level Rise of 1.6 Feet*

In the HBAP planning area, with 1.6 ft. (0.5M) of sea level rise, approximately 2.0 miles of HBMWD domestic water lines that traverse diked former tidelands south of Liscom Slough could be tidally inundated if the dikes are breached. Approximately 4.9 miles of the earthen dikes that are protecting the six miles of Eureka's MRP are rated highly vulnerable due to exposure to erosion and potential overtopping by 1.6 ft. (0.5 M) of sea level rise. Tidal inundation of the diked former tidelands could be four to five feet in depth. The Ryan Slough pump station (elevation 8.9 ft.) is vulnerable and at risk from tidal inundation if the dikes on Freshwater or Ryan Sloughs are overtopped (Figure 42).

Figure 42. City of Eureka Ryan Slough municipal water pump station, and Mad River Pipe Lines that could potentially become tidally inundated by 1.6 ft. (0.5 M) of sea level rise, if the dikes are overtopped.

The HCSD's Truesdale pump station (elevation 9.7 to 10.1 ft.) and South Bay well at elevation 10.0 ft. are potentially vulnerable and at risk from tidal inundation (Figure 43). It is assumed that the wellheads and the annulus around the well casing are sealed to prevent salt water intrusion.

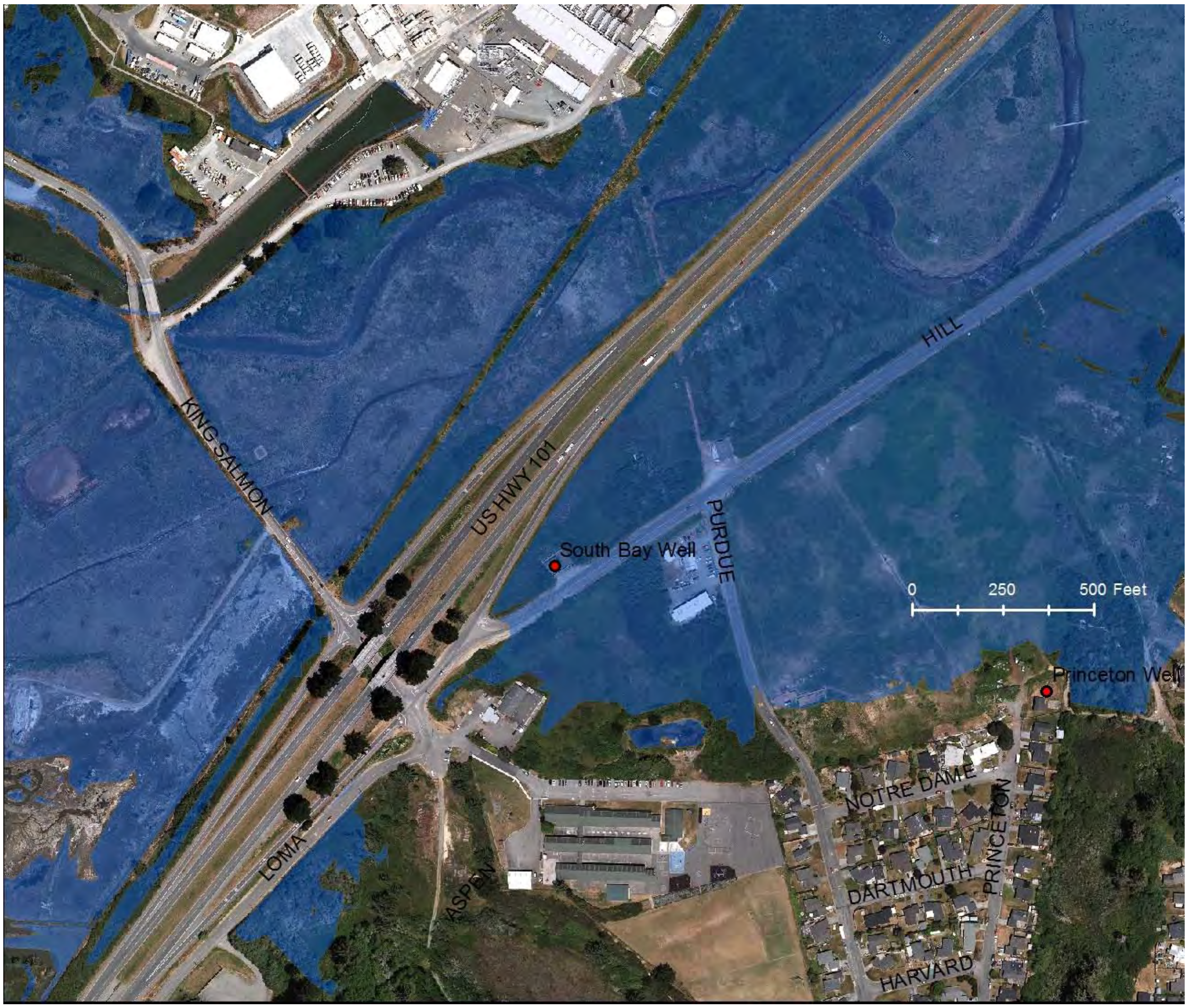

Figure 43. Humboldt Community Services District's South Bay municipal water well and the potential tidal inundation area of 1.6 ft. (0.5 M) of sea level rise.

Sea Level Rise of 3.3 Feet

In the HBAP planning area, with 3.3 ft. (0.5M) of sea level rise, approximately 3.9 miles of HBMWD domestic water lines that traverse diked former tidelands south of Liscom Slough could be tidally inundated as the dikes are overtopped. Nearly all the dikes protecting the City of Eureka's MRPs could be overtopped, resulting in six feet of tidal inundation on former tidelands averaging 5 ft. in elevation. HCSD's Truesdale pump station (elevation 9.7 to 10.1 ft.) would also become tidally inundated by 3.3 ft. (1.0 M) of sea level rise (11.0 ft.) (Figure 44).

Figure 44. Humboldt Community Services District's Truesdale municipal water pump station and inter-tie to the City of Eureka water system, with the potential tidal inundation area by 2700 of 3.3 feet (1.0 M) of sea level rise.

➢ *Sea Level Rise of 4.9 Feet*

In the HBAP planning area, with 4.9 ft. (0.5M) of sea level rise, approximately 5.6 miles of HBMWD domestic water lines that traverse diked former tidelands south of Liscom Slough would be tidally inundated as the dikes are overtopped. The dikes protecting the City of Eureka's MRP would be overtopped and the former tidelands tidally inundated.

Susceptibility

The underground water transmission pipelines (HBMWD and City of Eureka) and the distribution network (HCSD and MCSD) are not susceptible to the adverse effects of sea level rise. However, older pipes are chronically susceptible to corrosion if the cathodic protection systems are not maintained. They are also susceptible to differential settlement should the ground supporting the pipes become saturated and mobile, which is likely to occur with rising groundwater and tidal inundation. Municipal water systems are susceptible to indirect impacts from tidal inundation if the ability to perform maintenance and emergency repairs is impaired. Without regularly scheduled maintenance and repair, pipelines can develop holes and cracks. With older pipelines, the probability of emergency repairs may increase. Flooding or inundation over pipelines or access to the pipelines resulting from overtopped dikes would make access for repairs and maintenance very difficult. The main water transmission pipelines (HBMWD and City of Eureka) could potentially be tidally inundated now if dikes breach, and become increasingly vulnerable and at risk from tidal inundation with sea level rise of 1.9 ft. to 5.4 ft.

In the HBAP planning area, the HBMWD's water transmission pipeline trestles (2) span approximately 800 to 1,000 ft. of Mad River Slough. The water transmission pipeline trestles that span Eureka Slough (1) and Elk River Slough (1) are much shorter. The supports and trestles are vulnerable to damage by debris during high tides, floods, and increased wave action.

Pump stations include mechanical and electrical systems that are susceptible to damage should they be tidally inundated. The mechanical systems (valves and pumps) need regular maintenance. The Truesdale Street pump station (elevation 9.7 ft. to 10.1 ft.) is a key component to the HCSD water system and is the City of Eureka's back-up system. The Ryan Slough pump station (elevation 8.9 ft.) is integral to the conveyance of water to the City of Eureka and HCSD.

Municipal wells are susceptible to tidal inundation. One of HCSD's four municipal wells (South Bay, elevation 10 ft.) could potentially be tidally inundated by 1.6 ft. (0.5 M), which is the high projection for 2050.

Providing a safe and reliable supply of drinking water to Humboldt County residents and businesses is crucial. If the dikes that are preventing tidal inundation of municipal water transmission pipelines fail, then emergency repairs may eventually become extremely

difficult if not impossible if vehicles and heavy equipment cannot access them. Deferred maintenance could cause long-term, chronic problems with the conveyance system, resulting in significant interruption of service and eventually complete failure of the system. The MCSD and HCSD have a limited number of days of water storage. Repairs that take longer would be consequential to the MCSD and HCSD and likely necessitate drastic conservation efforts.

3.4.2 Wastewater

There are no community wastewater collection or treatment systems in the HBAP planning area outside of the MCSD and HCSD jurisdictions. These community services districts have approximately 17.1 miles of wastewater lines in the HBAP planning area, of which 4.4 miles are in areas that could be tidally inundated by 4.9 ft. (1.5 M) of sea level rise. The MCSD wastewater treatment facilities (WWTF) is in an upland area that is not vulnerable to sea level rise of 4.9 ft. (12.6 ft.). The HCSD's wastewater treatment facility resides in the City of Eureka.

There are some small wastewater treatment systems that serve local development. The College of the Redwoods has a wastewater collection and treatment facility that services its needs.

In the town of Samoa, there are two separate wastewater treatment facilities currently in use. The western system serves twenty-five homes and discharges to a septic tank and leach field system west of New Navy Base Road. Its design capacity is reported to be 7,500 gallons per day. The eastern system serves seventy-five homes, the hostelry, and the Samoa Cookhouse, and consists of a septic tank, two defunct bark filters, an oxidation treatment pond, and a percolation basin. Combined, the systems serve 100 homes and 20 commercial buildings. The western system leach field is within the watershed of the Pacific Ocean. The eastern system is located within the watersheds of Humboldt Bay and the Pacific Ocean. There are no developed lots in Samoa that are vulnerable to tidal inundation by 4.9 ft. of sea level rise.

The communities of Fairhaven and Finntown consist of approximately 83 single-family residences and the Fairhaven Business Park, which are currently un-sewered. The Regional Water Quality Control Board has concerns about groundwater quality in this area, and have stated that the current septic systems are not protective of groundwater quality since the soils are mostly sand. Fairhaven has small lots, with many of the septic systems are failing.

Work is in progress for a new WWTF that would serve all of the Samoa Peninsula south of the Highway 255 bridge. The new system proposes to utilize the existing ocean outfall pipe located on the Harbor District's Redwood Terminal II property. The project is in its very early stages, with no definitive location for the facility at this time.

The MCSD relies on a STEP system that collects liquid effluent by way of pumping from septic tanks into a force main to its WWTF consisting of three constructed surface wetlands, two surface aerated facultative ponds, and four percolation ponds.

The HCSD has a wastewater collection system comprised of approximately 70 miles of sewer mains and 29 lift stations, and owns capacity rights in the City of Eureka's Elk River WWTF equivalent to 30.5% of the plant's dry weather capacity. Treated, dechlorinated wastewater effluent is discharged by gravity flow into Humboldt Bay, in Eureka's jurisdiction, on the outgoing tide through a 36-inch diameter outfall pipe that terminates in a diffuser near the bottom center of the navigation channel west of Elk River Spit. Eureka's WWTF often approaches the peak wet weather design flows during storm and high tide events, indicating that the City and HCSD collection systems already has problems with inflow and infiltration (I/I).

Exposure

Inflow and infiltration is an existing problem that could be exacerbated by tidal inundation and rising groundwater, which could adversely impact affected portions of the collection system and the operation of the receiving WWTF.

The MCSD WWTF is not located in an area that is vulnerable to 4.9 ft. (1.5 M) of sea level rise. As stated earlier, as residential, industrial, and commercial areas become tidally inundated (see Land Use section), underground utilities such as wastewater collection systems serving these areas would also be tidally inundated. In Manila, there are residential and industrial parcels that are vulnerable to sea level rise of 4.9 ft. (1.5 M).

The College of the Redwoods' collection system does not appear to be vulnerable to sea level rise. However, its WWTF would be partially inundated by sea level rise, greater in elevation than 3.3 ft. (1.0 M).

The HCSD owns and operates a wastewater collection system, which consists of an underground network of pipes, manholes, and lift/pump stations. The communities of King Salmon and Fields Landing, with wastewater service from HCSD, have five lift stations that are vulnerable to sea level rise of 4.9 feet (1.5 M) (Figure 45).

An integral part of a wastewater collection system is the lift and pump stations. Pump stations are typically housed within a building. Lift stations are outside and typically subsurface and flush with the surrounding ground. HCSD has nine wastewater lift/pump stations within the tidal inundation area for 4.9 feet (1.5 M) of sea level rise (Table 24).

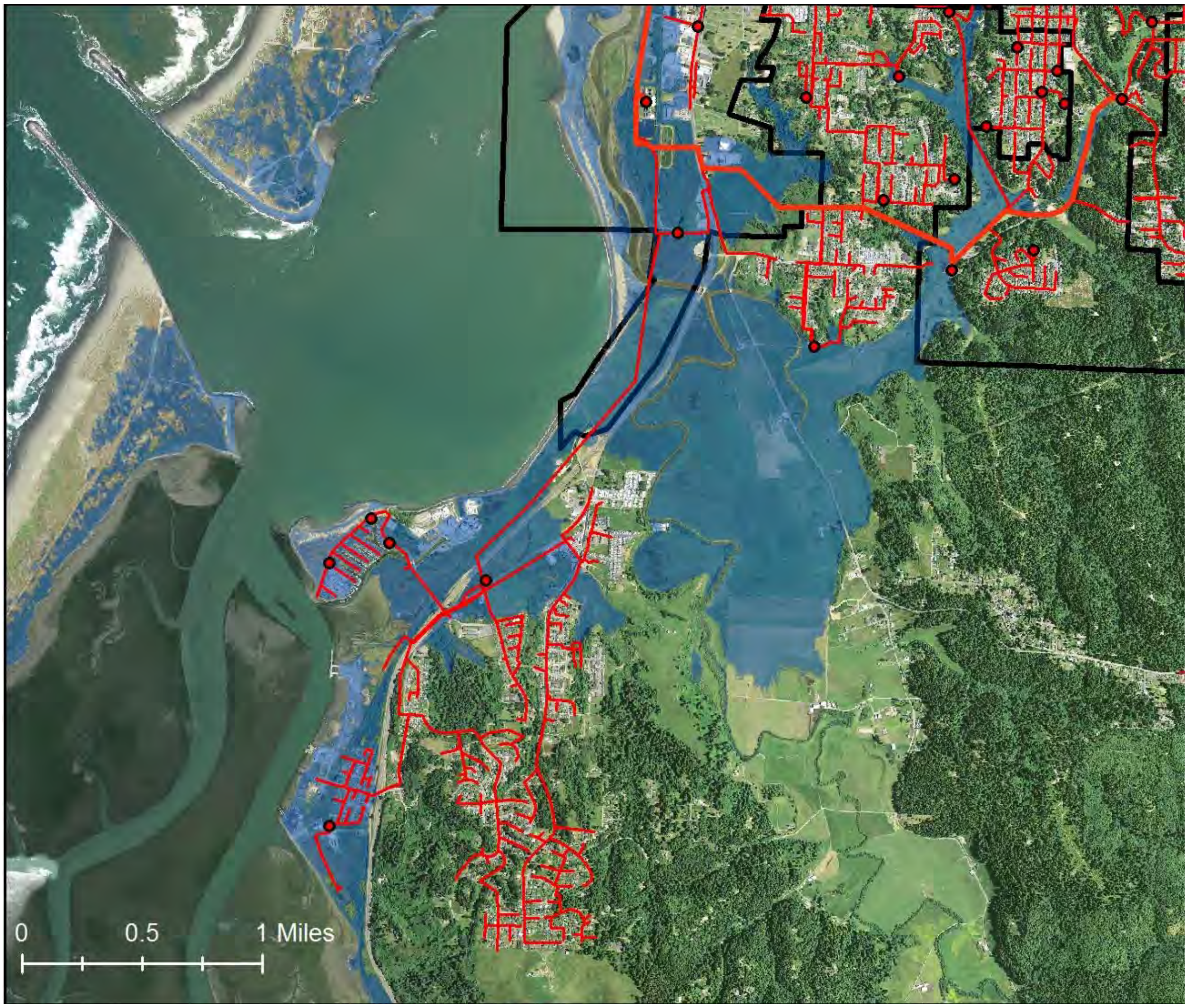

Figure 45. Humboldt Community Services District's waste water collection system, including collection pipes, force mains (bold red), lift stations (red dots), and potential tidal inundation area by 2100. The City of Eureka's service boundary for the Elk River Waste Water Treatment Facility, (black line).

Table 24. Humboldt Community Services District's sewage lift and pump stations in the tidal inundation area for 4.9 feet of sea level rise, and their surface elevation.

Lift/Pump Station	HCSD	Elevation (ft.)*
King Salmon Ave.	Lift	8.2
Buhne Drive	Lift	11.9
Perch Street	Lift	9.55
Field's Landing	Pump	7.9
S. Broadway Street	Pump	7.3
Pine Hill Road	Lift	9.2
Sea Ave	Lift	10.0
Hoover Street	Pump	9.9
Edgewood Road	Lift	10.2

*Elevations are approximate and taken from DEM data at a single location per site.

Outside of the communities of King Salmon and Fields Landing, the HCSD has two lift stations (Pine Hill Road and Sea Ave.) on Martin Slough south of Eureka. Two additional lift stations are located north of Eureka on Eureka and Freshwater Sloughs (Hoover Street and Edgewood Ave.) (Figure 46).

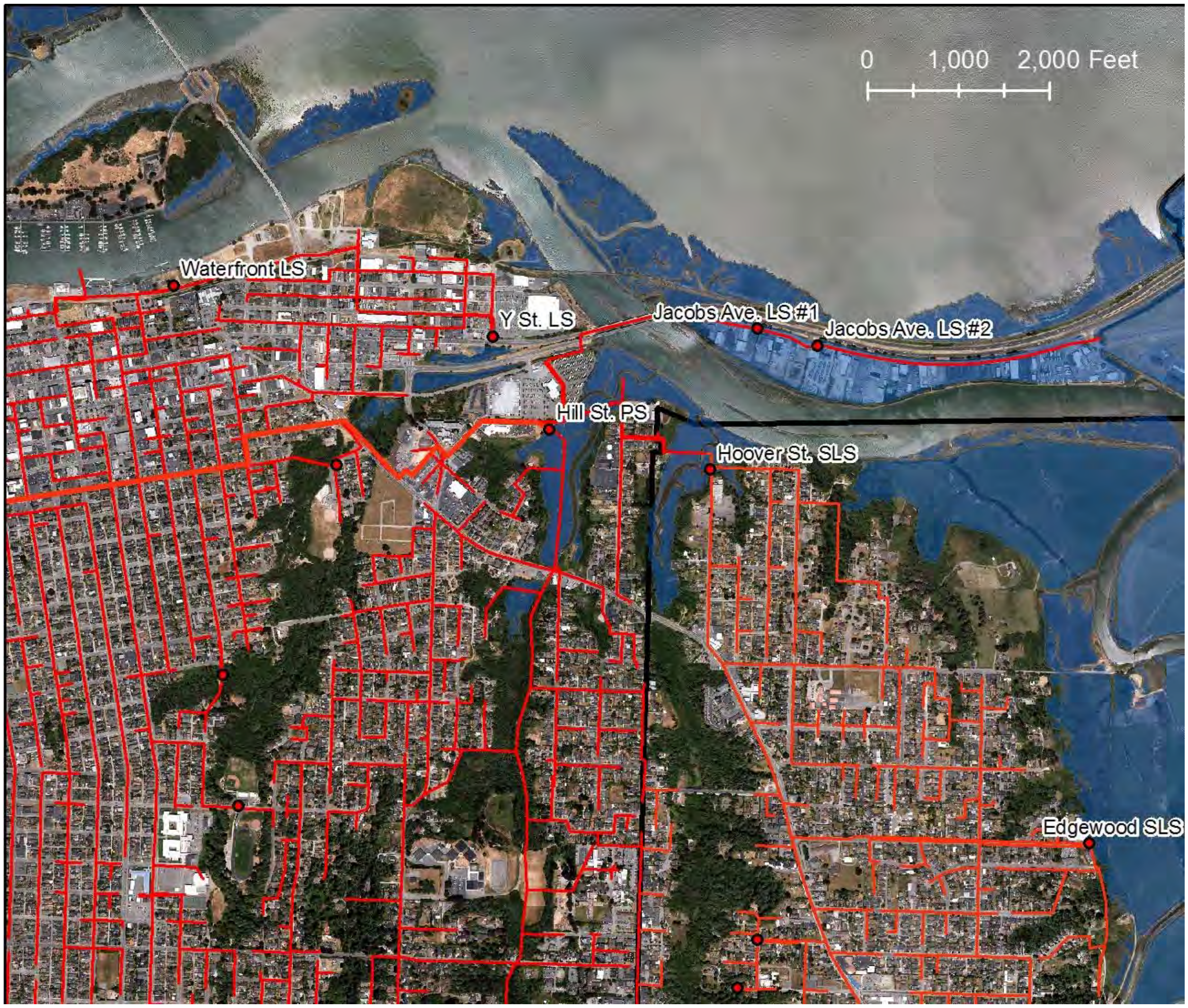

Figure 46. Sewer lift and pump stations in the HCSD: Hoover Street and Edgewood Road, and sewer mains and sewer interceptors (red lines) that potentially could be tidally inundated by the current MMMW inundation area of 7.7 feet.

The HCSD's collection system already has problems with I/I during storm and high tide events. Many of the communities in the HCSD that would be affected by sea level rise of 4.9 feet (1.5 M) contain wastewater collection infrastructure such as lift and pump stations, manholes, and a network of sewer pipes. Some of the lift stations and manholes are expected to experience regular tidal inundation (inflow). Groundwater elevations in and adjacent to these tidal inundation areas would also rise (infiltration). Both of these effects I/I would increase the amount of saltwater and brackish water entering the waste water collection system. This can, in turn, overwhelm the hydraulic and mechanical capacities of the system and upset the biological balance of the treatment plant digesters, causing mechanical failures that could result in the release of untreated wastewater into surface waters. Other sea level rise impacts include limited

access to collection pipes, lift and pump stations, and the WWTF for maintenance and operations. Infiltration would occur even outside the inundation areas due to elevated groundwater levels.

The following sections evaluate the impacts to specific components of a wastewater system.

➢ *Collection Pipe Network*

Much of King Salmon and Fields Landing was built on unconsolidated, porous fill materials that allow tidal waters to seep well inland from the edge of the bay. Surface water and groundwater also percolate into and through the fill and flow downhill, toward the bay. Groundwater saturates the fill and backs up against the seawater. The average elevation of groundwater on land adjacent to the shoreline is generally above MSL elevation of 3.4 ft. Groundwater elevations depend on surface elevations and would vary with stormwater runoff. Rising sea levels can cause a rise in groundwater elevations both seasonally and concurrent with the daily tidal cycle. The collection pipe networks in low-lying areas (King Salmon and Fields Landing) and on current tidelands (Second and Third Sloughs) are likely below the water table. In the HCSD, 3.1 miles of sewer line are vulnerable now, 3.6 miles by sea level rise of 0.9 feet (2030), 3.8 miles by sea level rise of 1.6 feet (0.5 M) and 7.5 miles by sea level rise of 4.9 feet (1.5 M). Between 2050 and 2100, the number of miles of sewer lines that could be tidally inundated approximately doubles from 3.8 to 7.5 miles in the HCSD.

The collection system throughout the tidal inundation areas is vulnerable and at risk from being flooded by rising groundwater levels. When groundwater is high, it can infiltrate into the gravel bedding and then into the pipes through cracks and leaking joints. Depending on the depth of the pipe and the porosity of the pipe bedding, trench fill materials and the surrounding ground, the infiltration can occur well outside of the tidal inundation area as groundwater is backed up by the rising tides or tidal waters infiltrate through the porous ground. This infiltration can be fresh and/or brackish water.

➢ *Lift/Pump Stations and Manholes*

The lift/pump stations and manholes in the tidal inundation areas are vulnerable and at risk from stormwater (freshwater) inflow entering into the collection system through the non-sealed lids and vent pipes. This can occur when stormwater backs up because it cannot discharge to the bay due to high tides or when tide gates are stuck open, allowing seawater to back up into the inundation area. This can also occur if the dikes breach. Other sources of inflow include roof drains and storm drains illegally connected to the wastewater collection network.

When lift/pump stations are exposed to tidal inundation, they have the potential to fill with sea water through non-sealed hatches and covers (inflow). This would not necessarily damage the lift station, but it would pump water that does not need to be

treated into the collection and treatment systems. This excess water could hydraulically overload the system, potentially resulting in discharge of untreated wastewater into surface water. The dilution of the wastewater with brackish water would also hinder the biological processes that treat the wastewater, resulting in a breakdown in the entire treatment process.

Additionally, the tidal inundation of the areas surrounding the lift station would limit access to the station for routine maintenance and emergency repairs. Tidal inundation may also damage exposed electrical components and controls and impact auxiliary emergency power (portable generator) functionality.

In the HCSD, seven sewer lift stations are potentially vulnerable and at risk of being tidally inundated by 1.6 ft. (0.5 M) of sea level rise. Eight lift stations are vulnerable from 4.9 ft. (1.5 M) of sea level rise. The Hoover Street pump station and Edgewood Road lift station are located east of Hill Street on Second Slough in the Myrtletown area (Figure 44). The Hoover Street pump station on Third Slough is located adjacent to inter-tidal wetland on Third Slough, a tributary to Eureka Slough, at 9.9 ft. This pump station is potentially vulnerable and at risk from tidal inundation by 1.6 ft. (0.5 M). The Edgewood Road lift station, on Freshwater Slough is at an elevation of 10.2 ft., is located at the current edge of the tidal inundation boundary should the dikes on Freshwater or Ryan Slough fail. This lift station is potentially vulnerable and at risk from tidal inundation by the current MAMW of 8.8 ft., and MMMW with sea level rise of 1.6 ft. (0.5 M). The Edgewood Road lift station pumps wastewater to the Hoover Street pump station. A loss of service at either station would impact the Myrtletown area.

In the HCSD, the Pine Hill Road lift station is also vulnerable and at risk from tidal inundation by MAMW of 9.7 feet in 2030 with 0.9 ft. of sea level rise, or MMMW tides of 9.6 ft. in 2050 with 1.6 ft. of sea level rise if the dikes on the north bank of Swain Slough are breached. Similarly, the Sea Avenue lift station at 10.0 ft. is vulnerable and at risk from tidal inundation by MAMW of 10.7 ft. projected for 2050 with 1.6 ft. of sea level rise, and MMMW tides of 10.9 ft. in 2070 with 3.3 ft. of sea level rise.

The South Broadway Street pump station (7.3 ft.) and Fields Landing lift station (7.9 ft.) are currently vulnerable and at risk from tidal inundation by MMMW of 7.7 ft. and MAMW of 8.8 ft. (Figure 47). In King Salmon, the King Salmon Avenue lift station (8.2 ft.) is currently vulnerable and at risk from the current MAMW of 8.8 ft. The Perch Street (9.5 ft.) lift station could potentially be at risk from MAMW of 9.7 ft. in 2030 and MMMW tides of 9.6 ft. by 2050, while the Buhne Street lift station (11.9 ft.) is vulnerable and at risk from MAMW of 12.0 ft. in 2070 and MMMW of 13.1 ft. in 2100.

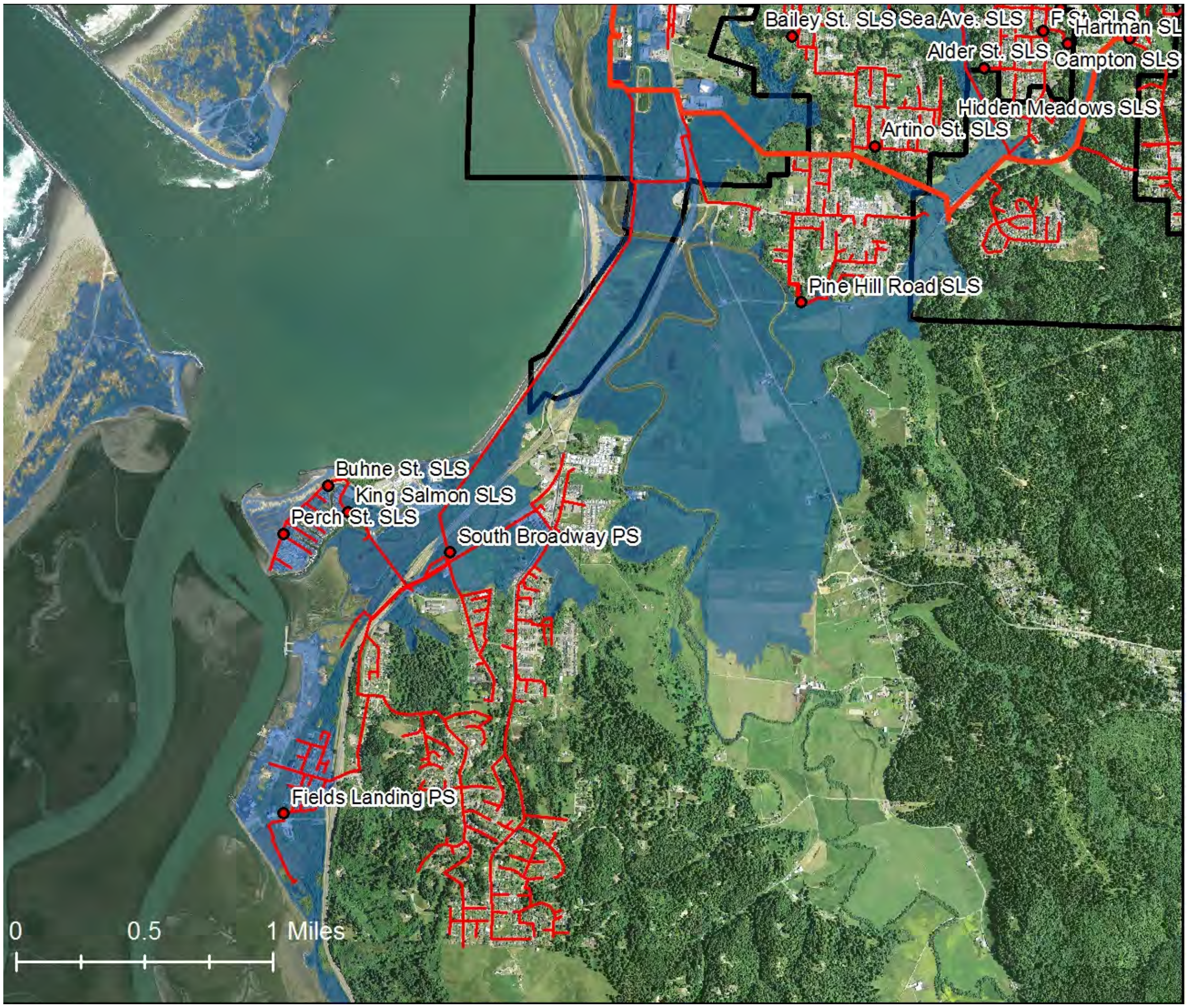

Figure 47. South Broadway pump station, Fields Landing, King Salmon, Perch Street, and Buhne Street lift stations, and sewer mains (red lines) that could potentially be tidally inundated by 2100 by the high projection for MMMW of 13.1 ft.

➢ *Sea Level Rise of 0.9 Feet*

There is only one residential parcel in the MCSD that could become tidally inundated by MAMW, that could possibly affect the collection system with salt water infiltration. This parcel is located at the end of Peninsula Drive.

In the HCSD, there is one pump station at South Broadway Street (7.3 ft.) and 3.1 miles of sewer lines potentially vulnerable and at risk now from tidal inundation by MMMW of 7.7 ft. There is also a Fields Landing pump station (7.9 ft.) and King Salmon Avenue lift station (8.2 ft.) and 3.6 miles of sewer lines that could be vulnerable to tidal inundation by 0.9 ft. of sea level rise (8.6 ft.) or our current MAMW of 8.8 ft. The Pine Hill Road lift station (9.2 ft.) on Martin Slough and the Perch Street lift station (9.5 ft.) in King Salmon

could also be vulnerable and at risk by the MAMW of 9.7 feet with 0.9 ft. of sea level rise.

➢ *Sea Level Rise of 1.6 Feet*

In the MCSD, in addition to the areas inundated by 0.9 ft. of sea level rise wastewater pipelines serving the industrial property on Mad River Slough, would be vulnerable to tidal inundation by 1.6 ft. (0.5 M) of sea level rise.

In the HCSD, the Pine Hill Road lift station (9.2 ft.) on Martin Slough and Perch Street lift station (9.5 ft.) in King Salmon could potentially be vulnerable and at risk from MMMW of 9.6 ft. Additionally, 3.8 miles of sewer lines are potentially vulnerable and at risk from tidal inundation. The Hoover Road pump station (9.9 ft.) and Edgewood Road lift station (10.2 ft.) near Third Slough and Freshwater/Ryan Sloughs, and Sea Avenue lift station (10.0 ft.) near Martin Slough may also be vulnerable and at risk from MAMW of 10.7 ft.

➢ *Sea Level Rise of 3.3 Feet*

In the MCSD, in addition to the areas inundated by 1.6 ft. of sea level rise wastewater pipelines serving residences on Vance Avenue, Vaissade Road, Young Lane and additional residences on Peninsula Drive, as well as a greater extent of the industrial property on Mad River Slough, would be vulnerable to tidal inundation by 3.3 ft. (1.0 M) of sea level rise.

The In the HCSD, there are three additional stations, including Hoover Road pump station (9.9 ft.), Sea Avenue lift station (10.0 ft.), and Edgewood Road lift station (10.2 ft.), potentially vulnerable and at risk from 3.3 ft (1.0 M) sea level rise and MMMW of 10.9 ft. The Buhne Drive lift station (11.9 ft.) may also be vulnerable and at risk from MAMW of 12.0 ft.

➢ *Sea Level Rise of 4.9 Feet*

In the MCSD, in addition to the areas inundated by 3.3 ft. of sea level rise, wastewater pipelines serving additional residences on Vance Avenue, Vaissade Road, Young Lane, and Peninsula Drive, and Midway Court as well as a greater extent of the industrial property on Mad River Slough, would be vulnerable to tidal inundation by 4.9 ft. (1.5 M) of sea level rise.

In the HCSD, one additional lift station at Buhne Drive (11.9 ft.) is potentially vulnerable and at risk from MMMW of 13.1 feet, and 7.5 miles of sewer lines are vulnerable and at risk from tidal inundation by 4.9 ft. (1.5 M) of sea level rise (Figure 45).

The WWTF at the College of the Redwoods would become partially inundated by 4.9 ft. (1.5 M) of sea level rise.

Susceptibility

With sea level rise, it is possible that increasingly long periods of ground saturation could result in settlement or movement and possibly floating of wastewater pipes, but in general, the wastewater collection system (including the lift stations) is fairly insensitive to flooding and tidal inundation. However, the lift stations and collection pipe networks exposed to tidal inundation could allow salt water into the collection and treatment system. This would hydraulically overload the collection and treatment system and cause a breakdown in the treatment process. If too much salt water is introduced into the treatment process, the biological system within the treatment plant would cease to function, resulting in a failure of the treatment process. The biological system would not able to cope with this sea level rise impact.

Electrical components of the lift stations are very susceptible to being tidally inundated or flooded. If the electric supply and control systems are exposed to salt water, they are likely to malfunction.

The biological treatment process of a wastewater treatment facility is very sensitive to saltwater, that could be introduced by I&I to a collection system that traverses areas subject to tidal inundation. The loss of functionality of a wastewater treatment plant, even if it is located in an area not vulnerable to direct tidal inundation by sea level rise, would be devastating to the entire community served by the facility. Future growth could also be impacted by loss of treatment capacity if the system has excessive I/I. If the treatment plant ceases to function, the impacts would be felt by all users in the MCSD and HCSD service areas.

3.4.3 Electrical

PG&E provides electrical service and natural gas service to the Humboldt Bay region, including within the HBAP planning area. PG&E owns the majority of electricity generation capacity, the electrical transmission towers (69 kV and 138 kV), and natural gas lines. Energy infrastructure assets include the Humboldt Bay Generating Stations (HBGS) which is a local natural gas-fired power plant in King Salmon, DG Fairhaven Biomass Power Plant on Samoa Peninsula, five electrical transmission substations with associated power lines, one major natural gas compressor station, and four natural gas regulating stations with associated pipelines. Also in the HBAP planning area is the former Humboldt Bay (Nuclear) Power Plant (HBPP), located next to the HBGS. The HBPP is currently being decommissioned. Also at the PG&E King Salmon property is an Independent Spent (nuclear) Fuel Storage Installation (ISFSI), which contains spent nuclear fuel rods from the former HBPP.

In the HBAP planning area, commercial generation of electricity is provided by two facilities located in King Salmon and Fairhaven. PG&E's HBGS is across from the entrance of Humboldt Bay (elevation 12 feet; Figure 48). The HBGS is the major

electrical generation station supplying power to Humboldt County through high voltage overhead transmission lines (69 kV and 138 kV) to sub-stations, and then through 12 kV distribution lines supported by numerous wooden distribution poles. HBGS is a 163 MW electric generation facility consisting of 10 Wartsila 18V50DF 16.3 megawatt (MW) reciprocating engine-generator sets and associated equipment suited to changes in demand and to the intermittent supply of renewable electricity.

There are three electrical substations in the HBAP planning area. The Humboldt Bay substation in King Salmon has a range of elevations from 9.6 to 10.9 ft. The Harris substation is located above 15.0 ft., which is above the projected tidal inundation elevation for 2100. The Humboldt substation on Mitchell Heights Drive is also above 15.0 ft.

The HBGS is supplied with natural gas via an underground onsite 10-inch-diameter, high-pressure, natural gas pipeline owned and operated by PG&E, which is critical to HBGS's continued operation. The HBGS uses approximately 2,400 gallons of water per day (2.7 acre-feet/year) on average for cooling or other industrial purposes. HBGS discharges industrial and sanitary wastewater into the HCSD wastewater system at an average rate of about 860 gallons per day. Untreated water for cooling, industrial processes and site landscape irrigation is supplied from PG&E's existing groundwater well via a direct connection to an onsite 6-inch-diameter water pipeline. Domestic water required for non-industrial uses is provided by a 4- to 6-inch-diameter on-site pipeline running 1,200 feet to a connection with the existing HCSD line that runs along King Salmon Avenue.

Figure 48. PG&E's King Salmon facilities including the HBGS, HBPP, Humboldt Bay electrical substation, that could potentially be inundated by 2100 by mean monthly maximum tides of 13.1 ft. The surface elevation of the ISFI, an underground facility, is above the high projection for 2100 of 13.1 ft.

The DG Fairhaven Power Company's biomass plant is an 18 MW electric generation facility located on Samoa peninsula in the HBAP planning area. Since operations began in 1987, the power generated by this plant has been supplied to PG&E under a long-term power purchase agreement. The plant uses over 250,000 tons of various forms of wood waste from local sawmills and forest operations annually.

Humboldt County has two major connections to the larger state-wide electric grid. These connections are critical to communities and development in the HBAP planning area, as well as the cities of Eureka and Arcata. High voltage electrical transmission lines are shown in Figure 49, along with electrical substations and power plants. The

total electrical transmission capacity into Humboldt County through the existing transmission lines is approximately 70 MW, less than half of the county's current peak demand. Therefore, continued local generation of electricity is critical to meeting electrical demand of the HBAP and cities of Eureka and Arcata. In the HBAP planning area, in addition to the high voltage systems, stepped down-12 kV over-head and underground electrical transmission lines and pole-mounted and ground-mounted electrical transformers feed commercial, industrial, governmental, and residential customers on nearly every city block and extend out to the majority of rural properties.

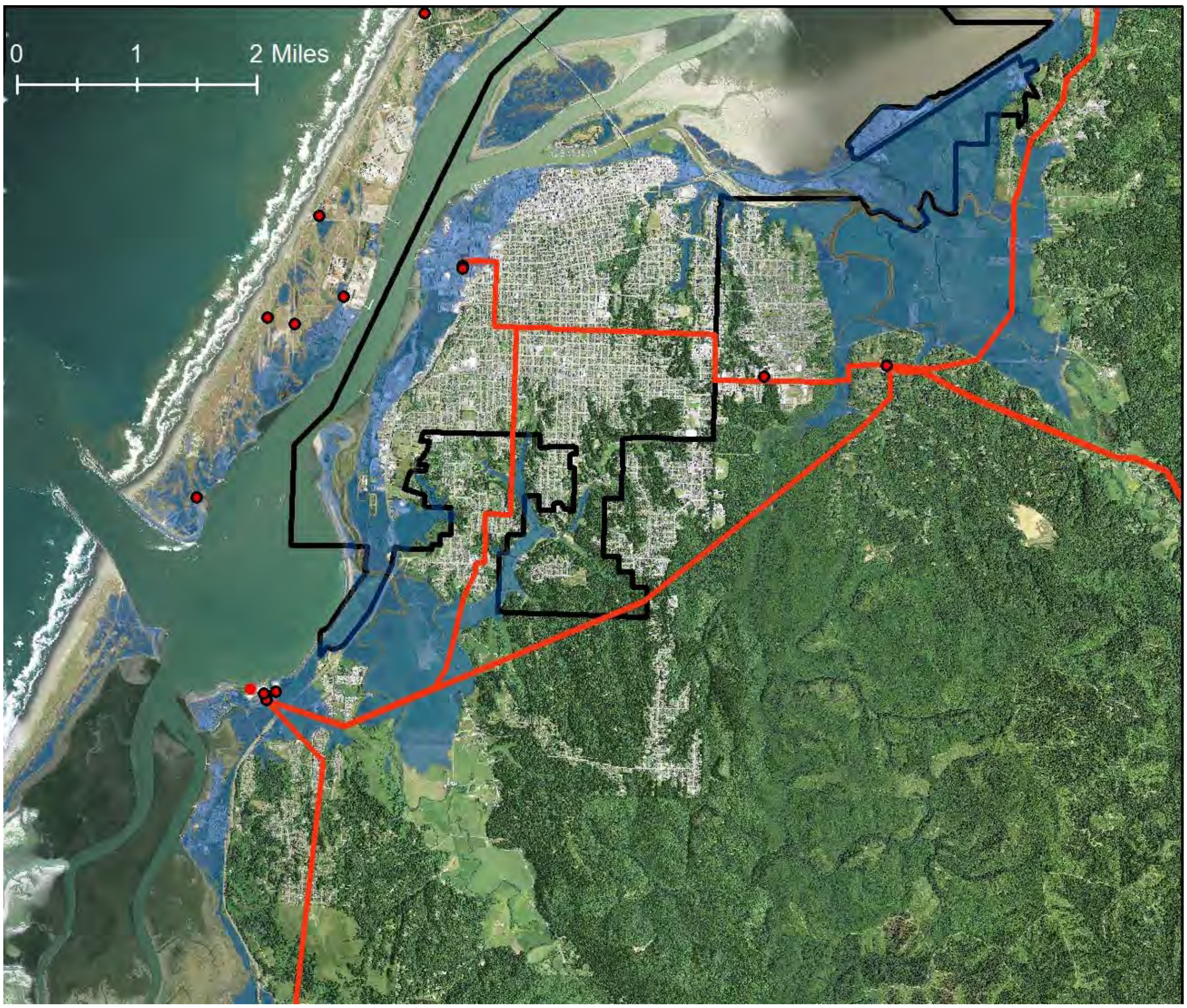

Figure 49. In the HBAP planning area, PG&E's power plants and electrical substations (red dots) and high voltage electrical transmission lines (red lines) that could potentially be tidally inundated by 4.9 ft. (1.5 M) of sea level rise.

There are high voltage electrical transmission towers (69 kV (yellow) and 138 kV (white) are in areas which are vulnerable to 4.9 ft. (1.5 M) of sea level rise (Figure 50). There is only one electrical substation in the HBAP planning area at King Salmon that is vulnerable to 4.9 ft. (1.5 M) of sea level rise.

Figure 50. PG&E'S HBGS (red), electrical transmission towers (white) and distribution poles (yellow) that could be affected by tidal inundation from 4.9 ft. (1.5 M) of sea level rise.

Exposure

In the potential MMMW inundation zone for 4.9 ft. (1.5 M) of sea level rise, there are electrical facilities, generating stations, and sub-stations that could be exposed to tidal inundation and flooding. Rising groundwater could also cause flooding of underground infrastructure. It is not known if the HBGS facility was designed to withstand the impacts of direct tidal inundation and whether emergency response procedures would be sufficient to safeguard employees from arc fault and additional hazards associated with high voltage electricity generation and exposure to water.

Electric transmission towers and distribution poles in low-lying areas could be destabilized by tidal inundation and rising groundwater. Pole-mounted electrical distribution lines, transformers, and service panels run throughout low-lying areas along the bay and sloughs. Diked former tide lands and other low-lying areas would be tidally inundated if the shoreline structures fail, resulting in loss of adequate support of poles and guy wires due to increased and continuous soil saturation, exposure of ground mounted transformers and electrical equipment to salt water and flooding, causing

burnout, and increased rates of equipment corrosion. Tidal inundation caused by dike failure or rising tide elevations may limit repair and maintenance access to electrical infrastructure during high tide and extreme weather events, leading to prolonged power outages. In some locations, access may be eliminated altogether.

In the HBAP planning area, commercial electrical generation facilities are located at Fairhaven on the Samoa Peninsula and in King Salmon. The Fairhaven facility is even above a high projection of 6.6 ft. (2.0 M) of sea level rise. The King Salmon electrical facilities (HBGS and Humboldt Bay substation) are less than 13.1 ft. and could potentially be tidally inundated by 4.9 ft. (1.5 M) of sea level rise (MMMW). The King Salmon electrical facilities are located in an area that is connected to Humboldt Bay via a former inlet canal to the south and protected from Humboldt Bay on the north by a fortified shoreline. The electrical generating infrastructure at King Salmon ranges in elevation between 11.0 and 14.3 ft. The King Salmon electrical facilities are vulnerable and at risk from tidal inundation beginning with 3.3 ft. (1.0 M) (MMMW of 10.9 ft.) of sea level rise and may be structurally compromised by rising groundwater levels and regular tidal inundation.

The HBPP, a former nuclear power site, is located at the King Salmon PG&E site in an area ranging in elevation between 9.6 to 10.9 ft. Tidal inundation of this site could potentially occur with 3.3 ft. (1.0 M) of sea level rise, should the shoreline of the former inlet canal be overtopped. Nuclear waste if contained on the site could be mobilized in the event of tidal inundation of the former HBPP. However, the amount of nuclear waste in storage, if any, is currently unknown, as decommissioning and remediation of the site has commenced. The ISFSI that contains the spent nuclear fuel rods of the HBPP is located above 14.3 ft., which is above the high projection for sea level rise by 2100; however, the high projection for the 100-year storm (1% probability of occurring any year) in 2100 is 15.2 ft.

- ***Sea Level Rise of 0.9 Feet***

In the HBAP planning area, major electrical transmission and distribution systems are located on diked former tidelands on Elk River Slough, Eureka Slough, Bayside/Gannon Slough, Butcher/McDaniel Slough, Arcata Bottom and Mad River Slough at elevations less than 7.7 ft. These diked lands are vulnerable and at risk now from MMMW tidal inundation if the shoreline structures are breached or overtopped. If these areas are tidally inundated, water depths could reach two to three feet during high tides. Tidal inundation could result in loss of adequate support of poles and guy wires due to increased and continuous soil saturation, exposure of ground mounted transformers and electrical equipment to salt water and flooding causing burnout, and increased rates of equipment corrosion. Tidal inundation caused by dike failure or rising tide elevations may limit repair and maintenance access to electrical infrastructure during high tide and extreme weather events, leading to prolonged power outages. It is possible that some access may be eliminated altogether.

With 0.9 ft. of sea level rise, if dikes are breached, water levels could be approximately two feet. deep This would impact 29 electrical 138 kV transmission towers and 112 electrical 69 kV transmission poles.

➢ *Sea Level Rise of 1.6 Feet*

In the HBAP planning area, many of the dikes are vulnerable and at risk of being overtopped by 1.6 ft. (0.5 M) of sea level rise (MMMW of 9.6 ft. by 2050). Indirect vulnerability of the HBGS to tidal inundation by 2050 stems from exposure of HCSD underground water and wastewater utilities that serve the King Salmon area. Lift stations that convey wastewater from HBGS to the WWTF may be susceptible to failures caused by I/I issues that are exacerbated by tidal inundation and rising groundwater levels, including longer pump run times, pipe and pump corrosion, and control equipment malfunction. PG&E and HCSD wells that serve the facility may experience salt water intrusion or be impaired by corrosion.

➢ *Sea Level Rise of 3.3 Feet*

In the HBAP planning area, with 3.3 ft. (1.0 M) of sea level rise, most of the hydrologic units with diked shorelines protecting major electrical transmission and distribution systems are vulnerable and at risk of being breached or overtopped by MMMW of 11.0 ft. Tidally inundated electrical infrastructure could include as many as 30 electrical 138 kV transmission towers and 113 electrical 69 kV transmission poles. Under existing road conditions, 3.3 ft. (1.0 M) of sea level rise would tidally inundate King Salmon Avenue by 2070. King Salmon Avenue is the only point of land-based ingress and egress to the HBGS and HBPP/ISFSI facilities. The Humboldt Bay substation and HBPP could also be tidally inundated from overbank flows via the former inlet canal to the south.

➢ *Sea Level Rise of 4.9 Feet*

The HBGS could potentially be tidally inundated by MMMW of 13.1 ft. Buhne Point and the ISFSI could become an island separated from the mainland. By 2100, nearly all of the dikes in the HBAP planning area could potentially be overtopped with 4.9 ft. (1.5 M) of sea level rise. As a result, the HBGS would be tidally inundated, as would 30 electrical 138 kV transmission towers and 115 electrical 69 kV transmission poles. The major electrical transmission towers and poles could be tidally inundated by up to 8.0 ft. of water. The electrical generation plant at Fairhaven, due to its high elevation, is not predicted to be tidally inundated in 2100.

Susceptibility

Electrical facilities are very susceptible to tidal inundation and flooding. In the HBAP planning area, electric transmission towers and distribution poles in diked low-lying

areas could become destabilized by tidal inundation and rising groundwater. Pole-mounted electrical distribution lines, transformers, and service panels run throughout low-lying areas along the bay. Diked former tide lands and other low-lying areas could potentially be tidally inundated if the shoreline structures fail, resulting in loss of adequate support of poles and guy wires due to increased and continuous soil saturation, exposure of ground mounted transformers and electrical equipment to salt water and flooding, causing burnout, and increased rates of equipment corrosion. Tidal inundation caused by dike failure or rising tide elevations may limit repair and maintenance access to electrical infrastructure during high tide and extreme weather events, leading to prolonged power outages. Access may be eliminated altogether. Areas protected by earthen dikes are vulnerable and at risk from tidal inundation now and increasingly vulnerable with high projections for sea level rise. Tidal inundation of these diked lands could significantly impact transmission and distribution support structures.

Electrical substations are very susceptible to tidal inundation and flooding. With 4.9 ft. (1.5 M) of sea level rise, one of PG&E substations in the HBAP at King Salmon may be tidally inundated. The electrical generation capacity and transmission from the HBGS may also be adversely impacted by saltwater inundation of electrical equipment. The impacts to facilities could be significant and may affect electrical transmission. Current access to the HBGS via King Salmon Avenue would also be tidally inundated, as would large portions of the King Salmon HBGS facility.

The sustainability of development in the HBAP planning area and cities of Eureka and Arcata is predicated on having secure and reliable electricity. The stability of the transmission towers and distribution poles are essential to delivering electricity to local communities. A loss of functionality or impairment of the HBGS from tidal inundation could reduce the overall electricity generating capacity of Humboldt County by approximately 80% (Laird 2016). The impacts to the electrical transmission and generating facilities would be significant to the communities in the HBAP planning area and beyond.

3.4.4 Natural Gas

In the HBAP planning area, PG&E has underground natural gas pipelines that traverse Eureka Slough parallel to U.S. Highway 101 and Old Arcata Road (Figure 51), and multiple crossings on Elk River Slough (Figure 52). The exact location of natural gas pipelines and stations are not known and unavailable due to PG&E’s security concerns, making it difficult to assess the vulnerability of this infrastructure to sea level rise.

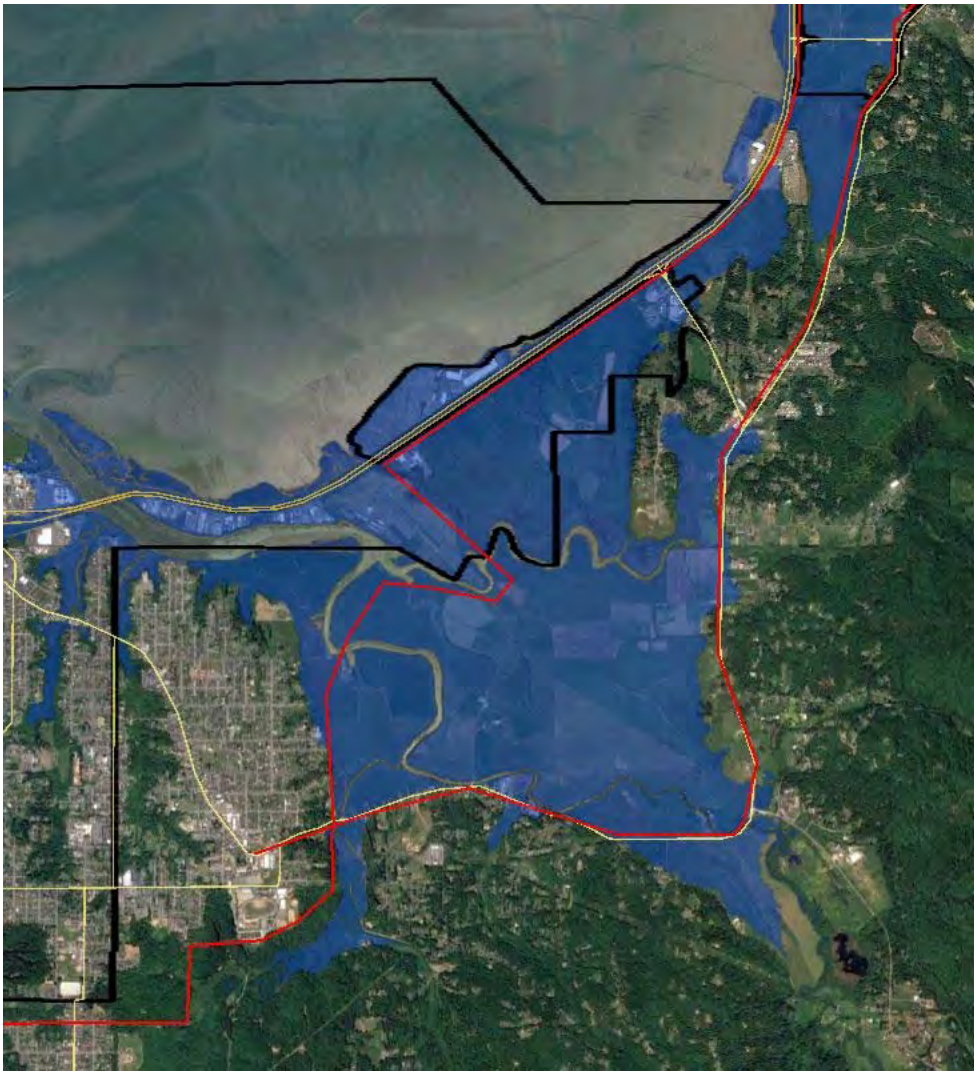

Figure 51. Approximate, location of PG&E natural gas transmission lines (red lines) in the HBAP and northern City of Eureka (black line) with respect to the 4.9 ft. (1.5 M) sea level rise tidal inundation area.

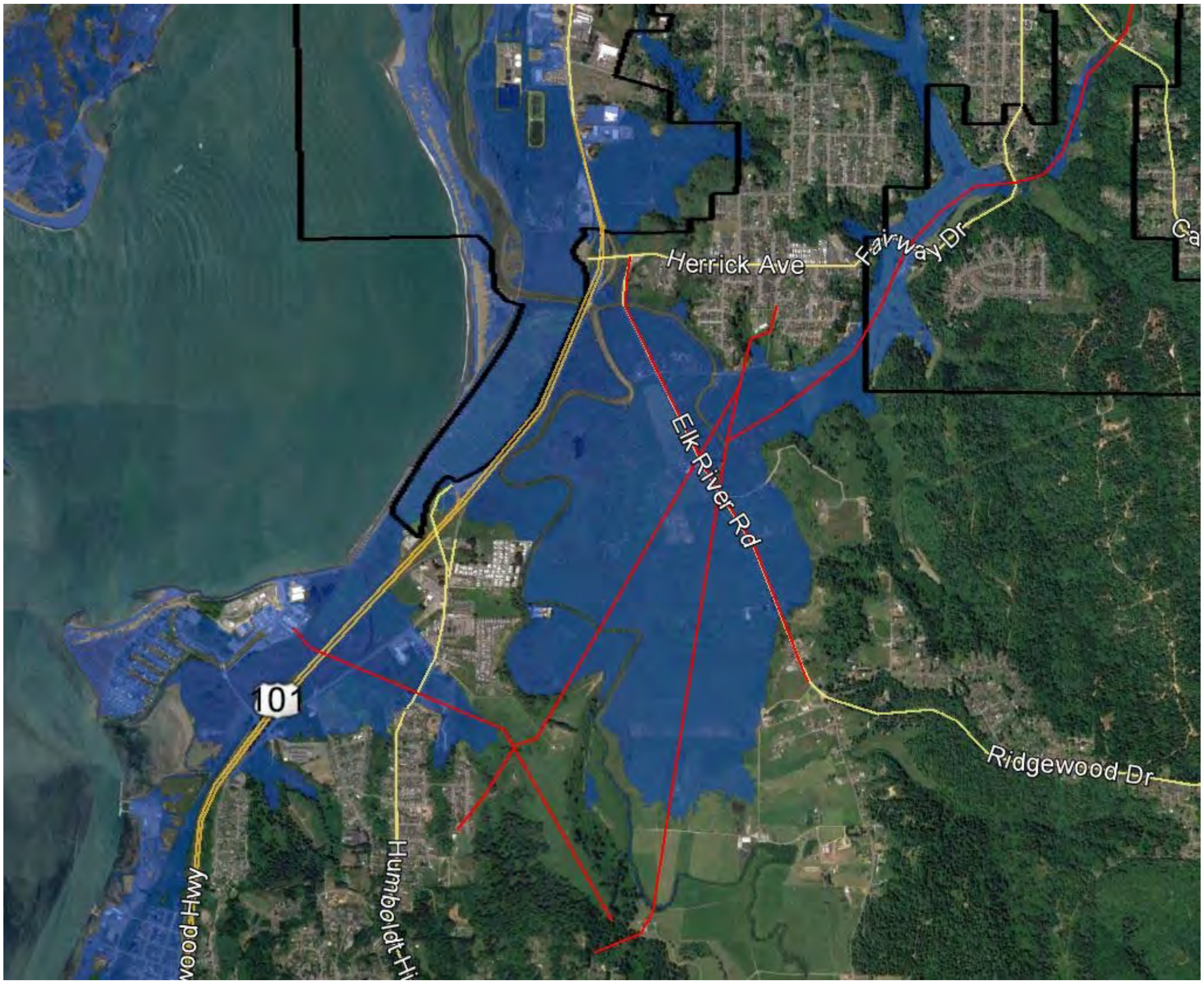

Figure 52. Approximate, location of PG&E natural gas transmission lines (red) in the HBAP and southern City of Eureka (black line) with respect to the 4.9 ft. (1.5 M) sea level rise tidal inundation area.

Exposure

Natural gas transmission and distribution systems within the HBAP planning area are vulnerable and at risk from tidal inundation, as they are in low-lying areas and can experience loss of access by maintenance personnel during tidal inundation and stormwater-created flood events. Additional coordination with PG&E is necessary to be able to more fully evaluate the vulnerability of this infrastructure. Based on available information in the HBAP area, there are approximately 11.8 miles (6.84 miles east of Arcata Bay and Eureka Slough and 4.94 miles on Elk River Slough) that would be tidally inundated by 4.9 ft. (1.5 M) of sea level rise.

Susceptibility

Very little is known about the underground gas lines other than their approximate location. Tidal inundation is likely to infiltrate into the gravel bedding and potentially into the pipes through cracks and/or leaking joints. It is possible that increasingly long periods of ground saturation could result in settlement or movement of the pipes.

While saltwater may not affect underground gas lines significantly, tidal inundation and flooding could adversely affect access to these gas lines for emergency repairs and maintenance. A loss or interruption of access to natural gas would be a significant impairment to the provision of natural gas to local communities within the HBAP planning area.

3.5 Coastal Resources

Coastal resources refer to those resources addressed in Chapter 3 of the California Coastal Act, including beaches, wetlands, agricultural lands, and other coastal habitats; coastal development; public access and recreation opportunities; cultural, archaeological, and paleontological resources; and scenic and visual qualities. Examples of coastal resources can include harbor/port facilities, public trails and docks, aquaculture and fishing facilities or uses, ESHA, and archaeological or paleontological resources, including tribal cultural resources.

3.5.1 Humboldt Bay Harbor/Port Facilities

The entrance to Humboldt Bay is formed by two rock jetties, constructed and maintained by the U.S. Army Corps of Engineers (ACOE). The North Jetty is approximately 1.4 miles long, of which 0.5 miles extends out beyond the vegetated shoreline to the ocean. The South Jetty is approximately 1.6 miles long, with 0.8 miles waterward of the vegetated shoreline. The ACOE regularly dredges 2.1 miles of the bar and entrance channels (approximately 2,300 and 9,000 ft. in length, respectively) and

turning basin, as well as two main navigational channels to North Bay and Fields Landing (South Bay), and their respective turning basins (Figure 53).

Primary channels maintained in Humboldt Bay include:

- the entrance channel, which is maintained to a depth of 38 ft. for 0.9 miles;
- the Fields Landing Channel, which is 2.3 miles long and 26 ft. deep;
- the North Bay channel, which is approximately 4.3 miles (18,500 ft.) in length and is maintained to a depth of 38 ft.;
- the Samoa channel, which 1.5 miles in length and maintained to a depth of 38 ft.; and
- the Eureka channel, which is 2.01 miles in length. (Note - the Eureka channel is not located in the HBAP planning area.)

Both commercial fishing and recreational boating marinas are on the Eureka Channel (not in the HBAP planning area) in the City of Eureka, which include the Woodley Island Marina owned and maintained by the Harbor District, and the Eureka Public Marina owned and maintained by Eureka. Together the Harbor District and City are responsible for dredging the two public marinas.

Nearly all the industrial docks on Humboldt Bay are on the main North Bay channel, except for the non-functioning industrial dock on the Fields Landing channel. There are turning basins at the end of the Samoa and Fields Landing channels.

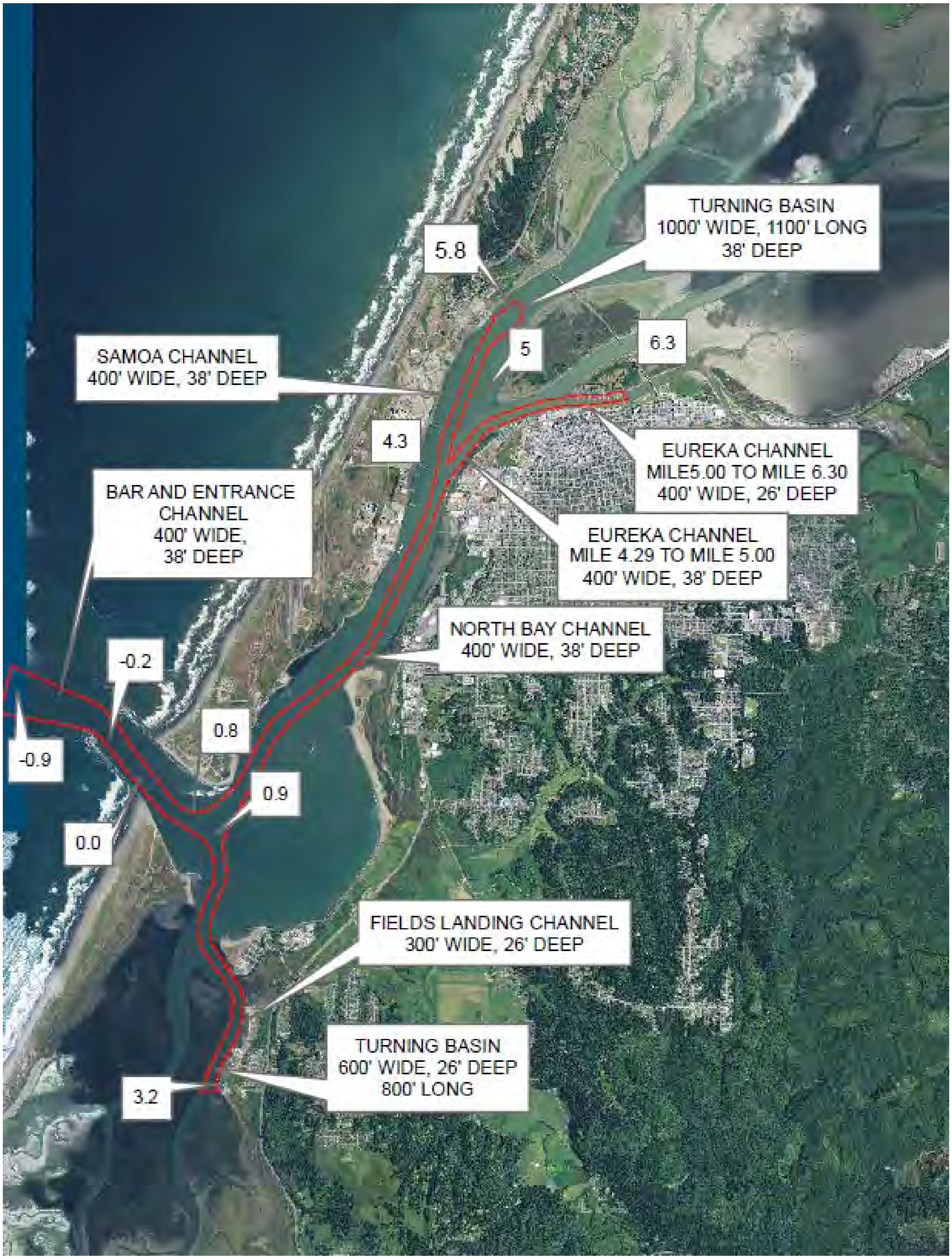

Figure 53. Humboldt Bay navigational channels maintained by U.S. Army Corps of Engineers.

Exposure

The 1997–1998 El Niño increased runoff from the Eel River, and elevated sea levels filled the bar and entrance channel with over a million cubic yards of sand. In 2000, the Harbor District and the ACOE completed a channel deepening project. Climate change could increase storm discharge magnitude in the Eel River, which combined with increased sea level elevations, could result in El Niño-like conditions off the coast of Humboldt Bay. If these conditions occur, they could increase the frequency of sediment filling the bar and entrance channel, requiring more frequent dredging to maintain the entrance to the harbor.

➢ *Tidal Inundation*

Rising sea levels and continued tectonic subsidence may affect the processes that maintain the morphology of the South Spit, which is relatively low in elevation (less than 20 ft.). Shoreline erosion and retreat could expose the South Spit to overtopping during extreme high tides and storm surge. This could lead to breaching, which is currently occurring on the spit south of the Eel River. Rising sea levels would inundate the existing jetties and associated access roads, if they are not raised in elevation. It is not known how submersion would affect the jetties' performance. However, submerged jetties could become a navigational hazard. Tidal inundation of access roads could impact the ability of vehicular equipment to reach the jetties for future repairs.

The diked former tidelands on Humboldt Bay are protected from tidal inundation by 41 miles of earthen dikes. If these dikes are breached, the former tidelands could become tidally inundated, which could expand the bay's footprint by as much as 9,846 acres (48%), increasing the tidal prism on Humboldt Bay. The effects of an increased tidal prism on conditions in the bar, entrance, and navigation channels is not known.

➢ *Sea Level Rise of 0.9 Feet*

The MMMW is projected to rise to 8.6 ft. with 0.9 ft. of sea level rise by 2030. Approximately 0.2 miles (790 ft.) of the North Spit jetty located in the bay could become submerged by 0.9 ft. of sea level rise.

➢ *Sea Level Rise of 1.6 Feet*

The high projection for sea level rise by 2050 is 1.9 ft., and MMMW would be 9.6 ft. Approximately 420 ft. of South Jetty Road, which provides vehicular access to the South Jetty, could be tidally inundated by 1.6 ft. (0.5 M) of sea level rise, and 475 ft. of New Navy Base Road that services the North Jetty could also be tidally inundated. Approximately 0.2 miles (1,214 ft.) of the North Jetty could also become submerged.

Sea Level Rise of 3.3. Feet

The high projection for sea level rise by 2070 is 3.2 ft. and MMMW would rise to 10.9 ft.. Approximately 0.3 miles (1,701 ft.) of South Jetty Road, which provides vehicular access to the South Jetty, could be tidally inundated by 3.3 ft. (1.0 M) of sea level rise. Additionally, 0.9 miles (4,858 ft.) of New Navy Base Road that services the North Jetty could also be tidally inundated. Approximately 867 ft. of the South Jetty and 1,214 ft. of the North Jetty could also become submerged.

Sea Level Rise of 4.9 Feet

The high projection for sea level rise by 2100 is 5.4 ft. and MMMW would rise to 13.1 ft.. Approximately 1.7 miles of New Navy Base Road and 1.1 miles of South Jetty Road could become tidally inundated by 4.9 ft. of sea level rise. Approximately 1.2 miles (87%) of North Jetty and approximately 0.9 miles (61%) of South Jetty could be submerged with the high projection of 13.1 ft. for MMMW by 2100.

Susceptibility

The impacts from sea level rise on the harbor related to sediment transport, channel scour or aggradation, dune/spit formation and maintenance, and jetty function are not currently known. Changes in these processes and functions may become more pronounced between 2050 and 2100, when the high projections for sea level rise could reach 1.9 ft. to 5.4 ft. Access to the jetties on South and North Spits may be affected by tidal inundation and shoreline erosion. The roadway accessing the jetties may need to be protected from sea level rise. It is not known if tidal inundation would impact the function of the jetties. However, expansion of the tidal prism by as much as 9,846 acres, should the diked shoreline fail, and ultimately by 14,524 acres after approximately 4.9 ft. (1.5 M) of sea level rise, could affect sediment supply, transport, and deposition in the navigation channels. Impacts could be significant.

Should the South Spit breach, it would likely have a significant effect on sediment transport and circulation in South Bay and the harbor entrance. If the bar and entrance channels aggrade significantly in response to sea level rise and changes in offshore sediment movement, the cost of maintaining the entrance and navigation channels would likely increase. Dredging the navigational channels is a major expense now for the Harbor District and may increase substantially.

In summary, the spits, jetties, entrance, and navigation channels are critical to Humboldt Bay in order to continue to provide a safe and functional harbor and port, and could be significantly impacted by future sea level rise.

3.5.2 Commercial Fishing-Aquaculture

In the HBAP planning area, there are four commercial fishing and two commercial aquaculture properties and facilities. On the Samoa Peninsula, the Harbor District's property and dock at Redwood Terminal 1 is proposed to be developed for commercial fishing fleet use, and Redwood Terminal 2 is now being used for aquaculture (Figure 54). Zerlang & Zerlang have a boatyard for repairs in Finn Town. Next to Zerlang is a commercial aquaculture dock at the end of Comet Street (Figure 54). A dock in Fields Landing is sometimes used for the commercial fishing, and the Harbor District's Fields Landing boatyard and property are actively used by commercial and recreational boats for repairs and to launch or remove boats (Figure 54). A functioning boatyard is critical to a working seaport.

Figure 54. Fields Landing commercial fishing facilities: (1) Private commercial fishing dock and property and (2) Humboldt Bay Harbor, Recreation and Conservation Harbor District's boatyard property.

Exposure

Rising sea levels would eventually cause boat berths and docks to float off their pilings during king tides or storm surges. The high projection for sea level rise is 1.9 ft. by 2050. MAMW could rise to 9.7 ft. by 2030, and may be 12.0 ft. with 3.3 ft. of sea level rise by 2070. When sea level rise overtops the shoreline, it would tidally inundate waterfront properties where commercial fishing and aquaculture facilities and docks are located, as well as streets that access these properties. Most of the properties that

support the commercial fishing fleet and aquaculture facilities have fortified shorelines that are not likely to erode, except for the Zerlang & Zerlang property on Samoa Peninsula.

The high projection for sea level rise by 2050 is 1.9 ft., and MMMW would be 9.6 ft. Approximately 420 ft. of South Jetty Road, which provides vehicular access to the South Jetty, could be tidally inundated by 1.6 ft. (0.5 M) of sea level rise,

- ***Sea Level Rise of 1.6 Feet***

The high projection for sea level rise by 2050 is 1.9 ft., and MMMW would be 9.6 ft. The commercial fisheries facility at Fields Landing could be partially inundated by 1.6 ft. (0.5 M) of sea level rise, as could the Harbor District's Fields Landing boatyard and the Zerlang & Zerlang boatyard on Samoa Peninsula.

- ***Sea Level Rise of 3.3 Feet***

The high projection for sea level rise by 2070 is 3.2 ft., and MMMW would be 10.9 ft. The two waterfront properties that supported commercial fishing facility at Fields Landing could be completely tidally inundated by 3.3 ft. (1.0 M) of sea level rise. On Samoa Peninsula, the two commercial fishing facilities at the Zerlang & Zerlang boatyard and the Harbor District's Redwood Terminal 1 properties could also be tidally inundated by 1.6 ft. (0.5 M) of sea level rise.

- ***Sea Level Rise of 4.9 Feet***

The high projection for sea level rise by 2100 is 5.4 ft., and MMMW would be 13.1 ft. All the commercial fishing properties in the HBAP planning area would be tidally inundated by 4.9 ft. (1.5 M) of sea level rise, as would the commercial aquaculture property at Comet Street on the Samoa peninsula. Only the commercial aquaculture facilities at Redwood Terminal 2 property would not be inundated.

Susceptibility

The commercial fishing and commercial aquaculture facilities and properties in Fields Landing and on the Samoa Peninsula, except for Redwood Terminal 2, are susceptible to a significant tidal inundation with 3.3 ft. (1.0 M) of sea level rise, which is projected to occur by 2070. Access to commercial fishing properties in Fields Landing with 3.3 ft. (1.0 M) of sea level rise would likely not be possible.

On the Samoa peninsula, access to commercial fishing and aquaculture properties would be possible if the waterfront facilities are moved inland with the shoreline. The loss of the boatyards at Fields Landing and Zerlang & Zerlang on Samoa Peninsula by

2070 could be a significant impact to the commercial fishing fleet in the Humboldt Bay region, if they had to utilize boat repair yards at other ports.

3.5.3 Public Access and Recreation

There are five boat launch areas that are accessible to the public within the HBAP planning area: one on Arcata Bay at Mad River Slough; one on Samoa Peninsula on Eureka Bay; and three on South Bay at Hookton Slough, Fields Landing and King Salmon. Coastal access locations accessible to the public within the HBAP planning area include approximately 10 on the open ocean, three on Arcata Bay, one on Eureka Bay, one on Elk River Slough, and 15 on South Bay.

In the HBAP planning area, recreational boating benefits from the safe harbor and port facilities provided by Humboldt Bay. The recreational boating community, in addition to using many of the public and private facilities that the commercial fleet uses, also uses facilities specifically for recreational boating in the HBAP planning area. There are six recreational boating facilities within the planning area: King Salmon (private fuel dock and bilge & sewage pump-out station, 80 boat berths, and EZ Landing boat launch ramp); Fields Landing (County boat ramp); HBNWR’s floating dock non-motorized boat launch at Hookton Slough; Samoa Peninsula (County boat ramp); and undeveloped non-motorized boat launches at Mad River Slough at the Samoa Bridge and the Northcoast Regional Land Trust property on Freshwater Slough. There are also several undeveloped non-motorized boat launch locations that provide public access to the Bay in the HBAP planning area on the bay shoreline of South Spit.

In the HBAP planning area, there are approximately 20 miles of undeveloped open ocean beach shoreline on the North and South Spits from the mouth of the Mad River to Table Bluff. There are approximately ten or more federal, state, and local entry points along the open ocean shoreline in the HBAP. Also in the HBAP, the HBNWR and Mad River Slough provide diverse recreational opportunities and access to the public, as do the Bureau of Land Management and DFW properties on South and North Spits, Arcata Bay, and Eureka and Elk River Sloughs. The cities of Eureka and Arcata both have a diverse array of public access facilities and recreational opportunities on Humboldt Bay.

Exposure and Tidal Inundation

The vulnerability of public recreational opportunities is discussed under the sections addressing shoreline conditions and land use (Figure 55).

Figure 55. Public coastal access (round dots) and boat launch sites (squares) in the HBAP planning area and 4.9 ft. (1.5 M) tidal inundation area.

➢ *2015 Tidal Inundation*

There are currently two developed recreational boating facilities described above in King Salmon and Fields Landing that are vulnerable and at risk from tidal inundation during MMMW (7.7 ft.) and MAMW (8.8 ft.). The boat launch facility at Hookton Slough is located behind dikes that, should they be breached, would tidally inundate the access road to the dock.

➢ *Sea Level Rise of 0.9 Feet*

The high projection for sea level rise by 2030 is 0.9 ft., and MMMW would rise to 8.6 ft. The private recreational boating facilities at EZ Landing property in King Salmon and the Humboldt County boat launch at Fields Landing could be tidally inundated when MMMW rises 0.9 ft. to 8.6 ft. and MAMW reaches 9.7 ft.

➢ *Sea Level Rise of 1.6 Feet*

The high projection for sea level rise by 2050 is 1.9 ft., and MMMW would be 9.6 ft. With 1.6 ft. (0.5 M) of sea level rise, the Humboldt County's Fields Landing boat launch ramp could become tidally inundated and the parking lot could partially flood. Recreational boating facilities in King Salmon could be tidally inundated, as would the access streets (Perch Street and Halibut Avenue), but not King Salmon Avenue and Buhne Drive. The dikes protecting the access road to the Hookton Slough boating facility could be overtopped by 1.6 ft. (0.5 M) of sea level rise.

- *Sea Level Rise of 3.3 Feet*

The high projection for sea level rise by 2070 is 3.2 ft., and MMMW would be 10.9 ft. Most of the County's Fields Landing boat launch ramp and parking lot and Railroad Avenue could be tidally inundated by 3.3 ft. (1.0 M) of sea level rise. A portion of the County's Samoa boat launch ramp and parking lot could also be tidally inundated. Most of the dikes protecting the access road to the Hookton Slough boating facility could be overtopped by 3.3 ft. (1.0 M) of sea level rise. Access to the Freshwater Slough boat launch would be tidally inundated.

- *Sea Level Rise of 4.9 Feet*

The high projection for sea level rise by 2100 is 5.4 ft., and MMMW would be 13.1 ft. All the recreational boating facilities and properties in the HBAP planning area are projected to be tidally inundated by 4.9 ft. (1.5 M) of sea level rise. Access streets to these recreational boating properties are also projected to be tidally inundated.

Susceptibility

The public's use of developed recreational boating facilities could be adversely impacted by tidal inundation of access roads, parking lots, and boat ramps as well as buildings. Extreme water elevations could cause floating docks at King Salmon and Hookton Slough to float off their pilings. Due to rising inundation of natural shorelines, non-developed boat launch sites on Mad River Slough and the South Spit would likely migrate inland if vehicular access was still possible to these sites. Vehicular access could become difficult with 3.3 ft. (1.0 M) of sea level rise at Mad River Slough and 4.9 ft. (1.5 M) of sea level rise at South Spit. Recreational boating facilities would likely have to retreat or abandon their present locations, but new launch locations may become available on the new shorelines with rising sea levels.

3.5.4 Environmentally Sensitive Habitat Areas

The California Coastal Act defines ESHA as "any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments" (Section 30107.5).

On Humboldt Bay, there are five general types of ESHA that are being assessed for impacts from sea level rise: open water, eel grass, mudflats, salt marsh, and seasonal freshwater wetlands on diked former tidelands. These ESHA types may undergo significant adjustments in response to changing shoreline conditions. Tidal habitats and seasonal freshwater wetlands are especially valuable habitats for a multitude of commercial and special status species.

Other significant ESHA on Humboldt Bay, above MHW (5.8 ft.) elevation not associated with diked former tidelands that are vulnerable to sea level rise, include:

- the coastal dune ecosystems on North and South Spits and Elk River Spit,
- forested wetlands between salt marsh and upland forest, limited to the west shore of Mad River Slough, and
- the south west corner of South Bay at Table Bluff.

One of the first surveys of Humboldt Bay depicts that it once occupied approximately 25,800 acres: 15,300 acres (59%) of open water, tidal channels, and mud flats, and 10,500 acres (41%) of inter-tidal wetlands (salt marsh and tidal channels) (USSG Township Plats 1854). Historically, seasonal freshwater wetlands (i.e. short-grass pasture that Aleutian geese currently use for grazing) did not exist. Today, Humboldt Bay occupies approximately 20,462 acres. Open water (5,776 acres) and mud flat (13,141 acres, including eel grass habitat) cover approximately 18,917 acres (92.5%), and salt marsh covers approximately 1,545 acres (7.5%) (NOAA 2009 Imagery).

Adjacent to the bay in the HABP planning area, there are approximately 15,459 acres of mostly agricultural pasture lands composed of alluvial deposits and diked former tidelands that also provide seasonal freshwater wetland habitat, and Aleutian geese grazing habitat. Historical shoreline alterations from diking, constructing railroad grades, and placing fill decreased Humboldt Bay in areal extent by 21% (5,338 acres).

On Humboldt Bay, there are approximately 7,000 acres of diked former tidelands that presently support seasonal freshwater wetlands, known as “farmed wetlands”, generally less than eight feet in elevation. This ESHA is predominately pasture that is used to graze livestock, and which significant numbers of Aleutian geese also use for grazing.

Humboldt Bay, as bound by the MHW shoreline, is 20,462 acres in extent and composed of open water (5,776 acres), eelgrass habitat (8,129 acres), mud flats (5,012 acres) and salt marsh (1,545 acres). This area below MHW generally constitutes the area within which the CCC’s retains jurisdiction for the issuance of coastal development permits. Therefore, this area within the unincorporated area of the County that is below MHW is not part of the HBAP official planning area in-so-far as the CCC is not required to implement the County’s HBAP policies. However, this report does address vulnerable assets within the CCC’s retained jurisdiction, even though the Commission is not legally bound to implement the County’s LCP policies and would use them only as guidance, including sea level rise policies.

Other significant ESHA in the HBAP planning area above MMMW elevation and not associated with inter-tidal wetlands, that are vulnerable to sea level rise are coastal dune ecosystems on North and South Spits (400 and 740 acres, respectively) and Elk River Spit (105 acres), although Elk River Spit is predominately in the City of Eureka’s LCP.

Exposure

Diked former tidelands, now pasture (waterfowl grazing habitat) and seasonal freshwater wetlands, (ESHA), are vulnerable to tidal inundation if barrier type shorelines are breached or overtopped. These lands and ESHA are also vulnerable to rising groundwater and salt water intrusion in response to sea level rise, even if the shorelines remain intact.

- ### *Tidal Inundation*

Eroding dike structures are at risk of breaching under our current tidal regime. The consequences of a dike breach could be significant, potentially tidally inundating ESHA throughout thousands of acres of former tidelands that are now pasture, seasonal freshwater wetlands, and Aleutian goose grazing habitat. The shoreline elevation profile for Humboldt Bay was in one-foot increments. Currently, there are 2.4 miles of diked shoreline that are vulnerable to being overtopped by MAMW of 8.8 ft. With 0.9 ft. of sea level rise, MAMW (9.7 ft.) could place 11.4 miles of dike at risk. With two feet of sea level rise, 23.4 miles would be at risk from MAMW of 10.7 ft.

If the diked shoreline were compromised, today, Humboldt Bay could expand to 30,308 acres, which is 4,508 acres (17.5%) greater than what was mapped in 1850. The additional acreage is comprised predominately of potential inundation areas associated with Elk River, Swain Slough and Martin Slough, that were not mapped as salt marsh in 1854 (USSG) or 1870 (USCS) as well because of the 18 inches of relative sea level rise that has occurred over the last century, on Humboldt Bay. Sea level rise of 1.6 ft. to 4.9 ft. (0.5 M to 1.5 M) would incrementally increase the bay from 32,279 acres up to 34,987 acres as the area subject to tidal inundation expands (Figure 56). Conversely, the 15,459 acres of mostly agricultural pasture land in the HBAP planning area would decrease 13% to 13,490 acres if the diked shoreline is breached because of the 18 inches of relative sea level rise that has occurred over the last century, on Humboldt Bay. With 4.9 ft. (1.5 M) of sea level rise, the decrease would be approximately 30% to 10,780 acres.

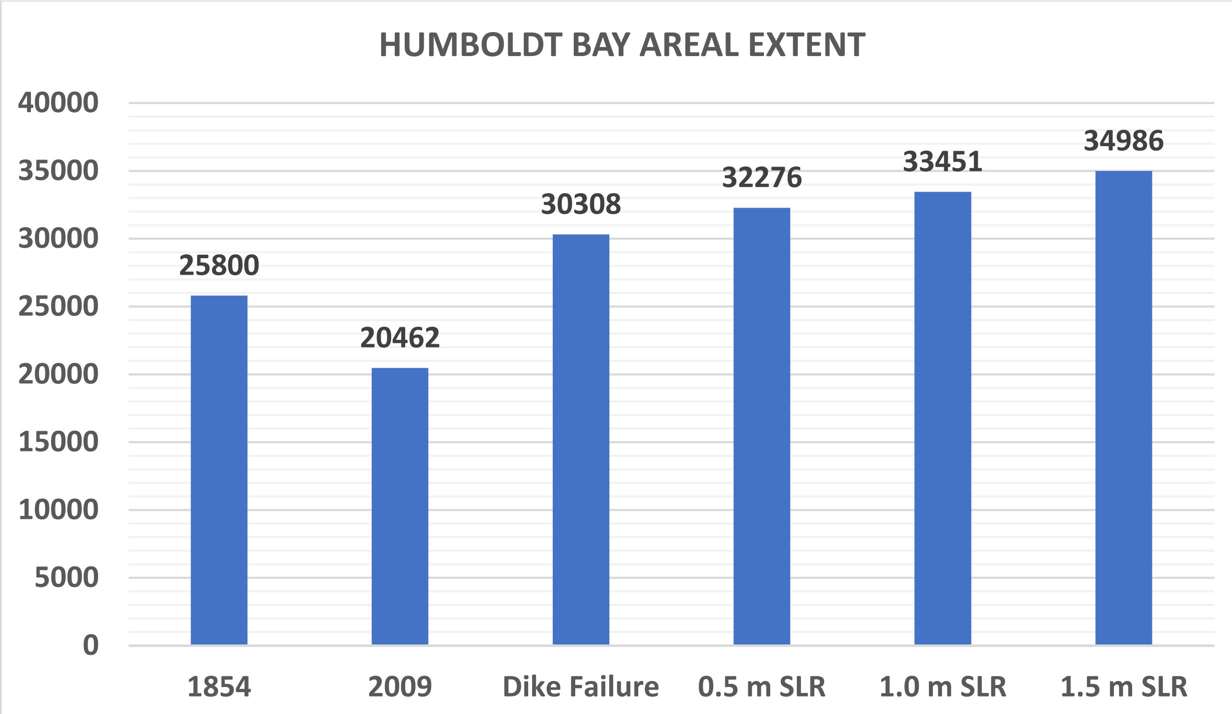

Figure 56. Areal extent (acres) of Humboldt Bay over time, if the diked shoreline is compromised, accounting for sea level rise projections ranging from 1.6 ft. to 4.9 ft. (0.5 M to 1.5 M).

Tidal habitat on Humboldt Bay can be segregated by maximum elevations for each type of habitat (Figure 57). With the addition of sea level rise, each habitat's maximum elevation increases, and its potential areal extent can be determined by surface elevations (Lidar). Due to a lack of data, estimates of areal extent of assume no sediment accretion.

Humboldt Bay's current habitat type distribution includes 5,776 acres of open water, 8,129 acres of eelgrass, 5,012 acres of mud flat, and 1,545 acres of salt marsh (Table 25). Under current tidal conditions if the diked shoreline on Humboldt Bay is compromised (breached or overtopped), the bay could expand 48%. Under this scenario, salt marsh, which is presently the rarest habitat on the bay, could expand by 294% (4,536 acres). The responses of each of the five habitats (open water, eel grass, mud flat, salt marsh, and pasture, which includes seasonal freshwater wetlands) to tidal inundation under existing tidal conditions and to sea level rise based on current (2010) surface elevations has been quantified.

Figure 57. Maximum surface elevations of Humboldt Bay habitat types with high projections for sea level rise of 0.9 ft. by 2030, 1.9 ft. by 2050, 3.2 ft. by 2070, and 5.4 ft. by 2100.

Table 25.Humboldt Bay habitat type areal extent (acres) under current conditions, if diked shoreline were to be compromised, and with sea level rise of 1.6 ft., 3.3 ft., and 4.9 ft. (0.5 M, 1.0 M, and 1.5 M).

Habitat	2009	Dike Failure	1.6 Ft.	3.3 Ft.	4.9 Ft.
Water	5,776	5,921	6,184	7,045	9,534
Eel Grass	8,129	8,501	9,928	10,917	12,573
Mud Flat	5,012	9,804	11,409	10,996	9,085
Salt Marsh	1,545	6,081	4,754	4,493	3,794
Total	**20,462**	**30,308**	**32,276**	**33,451**	**34,986**

With sea level rise, each habitat's maximum surface elevation increases, and its potential areal extent can be determined by surface elevations, utilizing 2009 Lidar surfaces. However, the most accurate depiction of the change in habitat distribution is the difference between intact diked shoreline and compromised diked shoreline because sediment accretion would not be a factor. Habitat distribution in response to sea level rise over time will need to account for sediment accretion, which for example would allow salt marsh habitat to rise in elevation in place; without sediment accretion, salt marsh would drown as sea levels rise.

Salt marsh habitat could expand from 1,545 acres to 6,081 acres if the diked shoreline is compromised. However, with 1.6 ft. (0.5 M) of sea level rise, salt marsh extent would actually decline to 4,754 acres, absent sediment accretion. Salt marsh habitat would continue to decline in areal extent with sea level rise, if sediment accretion cannot keep pace with sea level rise.

Similarly, mud flats would reach maximum coverage with 1.6 ft. (0.5 M) of sea level rise absent sediment accretion of salt marsh areas before declining in areal extent with additional sea level rise, if sediment accretion cannot keep pace with sea level rise.

Eelgrass habitat and, to a lesser extent, open water habitat, would increase in areal extent with sea level rise, through 4.9 ft. (1.5 M) of sea level rise. On Humboldt Bay, existing surface topography of the lands around the bay would limit the areal extent of sea level rise. As Humboldt Bay gets deeper, salt marsh and mudflats would be submerged. Ultimately, the historical salt marsh extent of 10,000 acres in 1854 would not be restored with sea level rise; salt marsh would remain the rarest of tidal ESHAs on Humboldt Bay.

Changes to each of the five habitats (open water, eel grass, mud flat, salt marsh, and pasture, which includes seasonal freshwater wetlands) to sea level rise based on current (2010) surface elevations is depicted in Figure 58 through Figure 77.

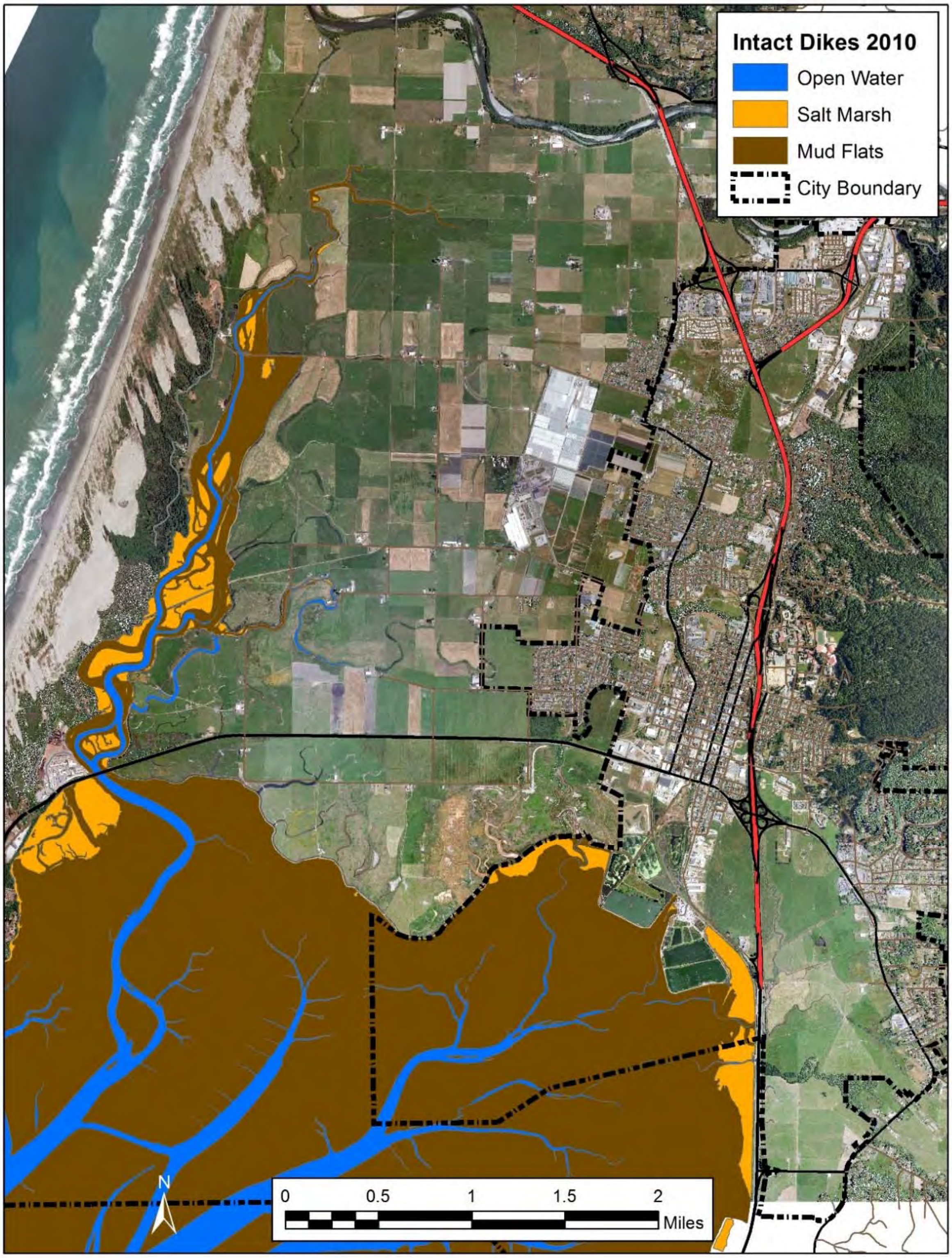

Figure 58. Mad River Slough-Mad River Bottom-Bayside habitat type distribution with diked shoreline intact (2009 Lidar).

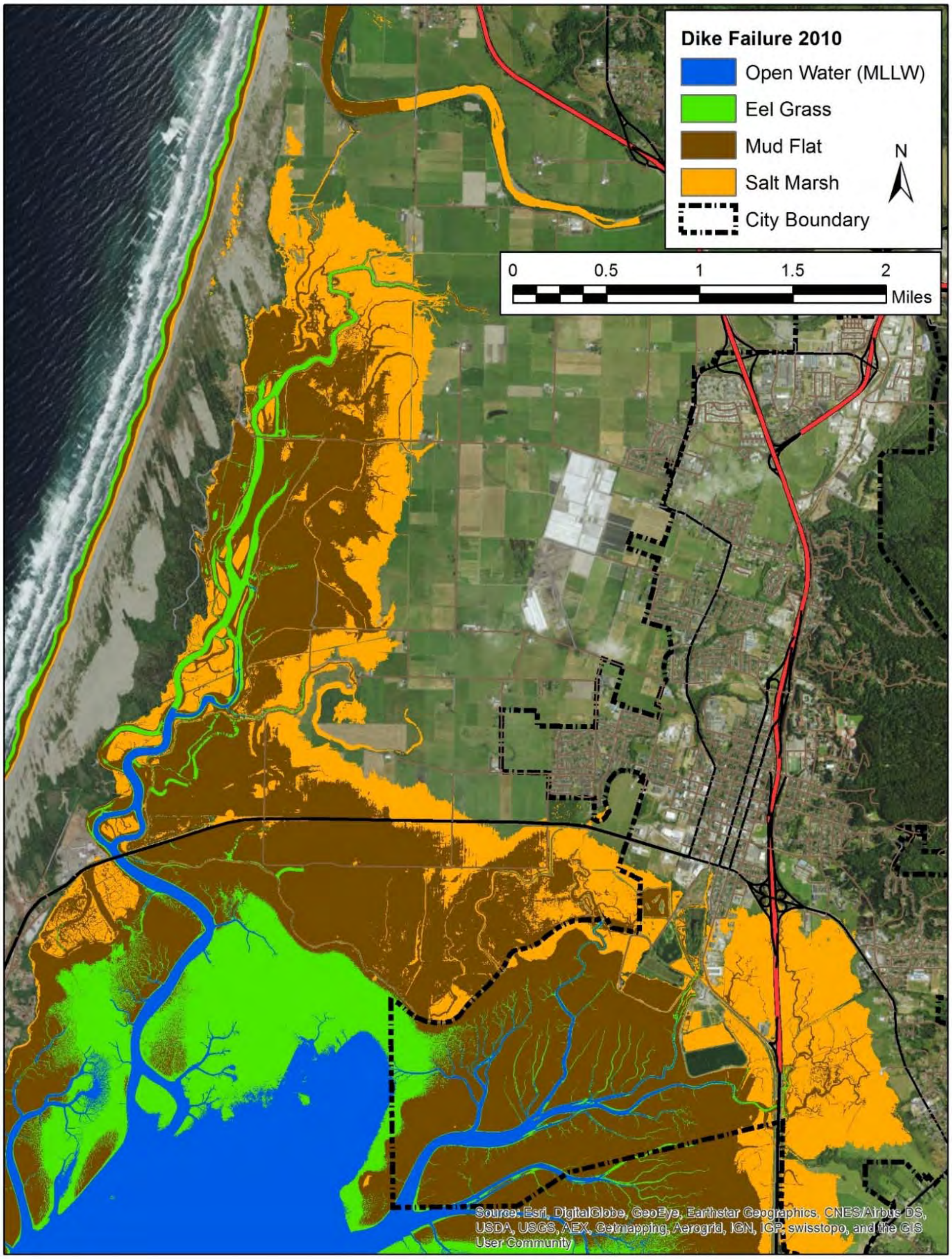

Figure 59. Mad River Slough-Mad River Bottom-Bayside habitat type distribution with diked shoreline compromised (2009 Lidar).

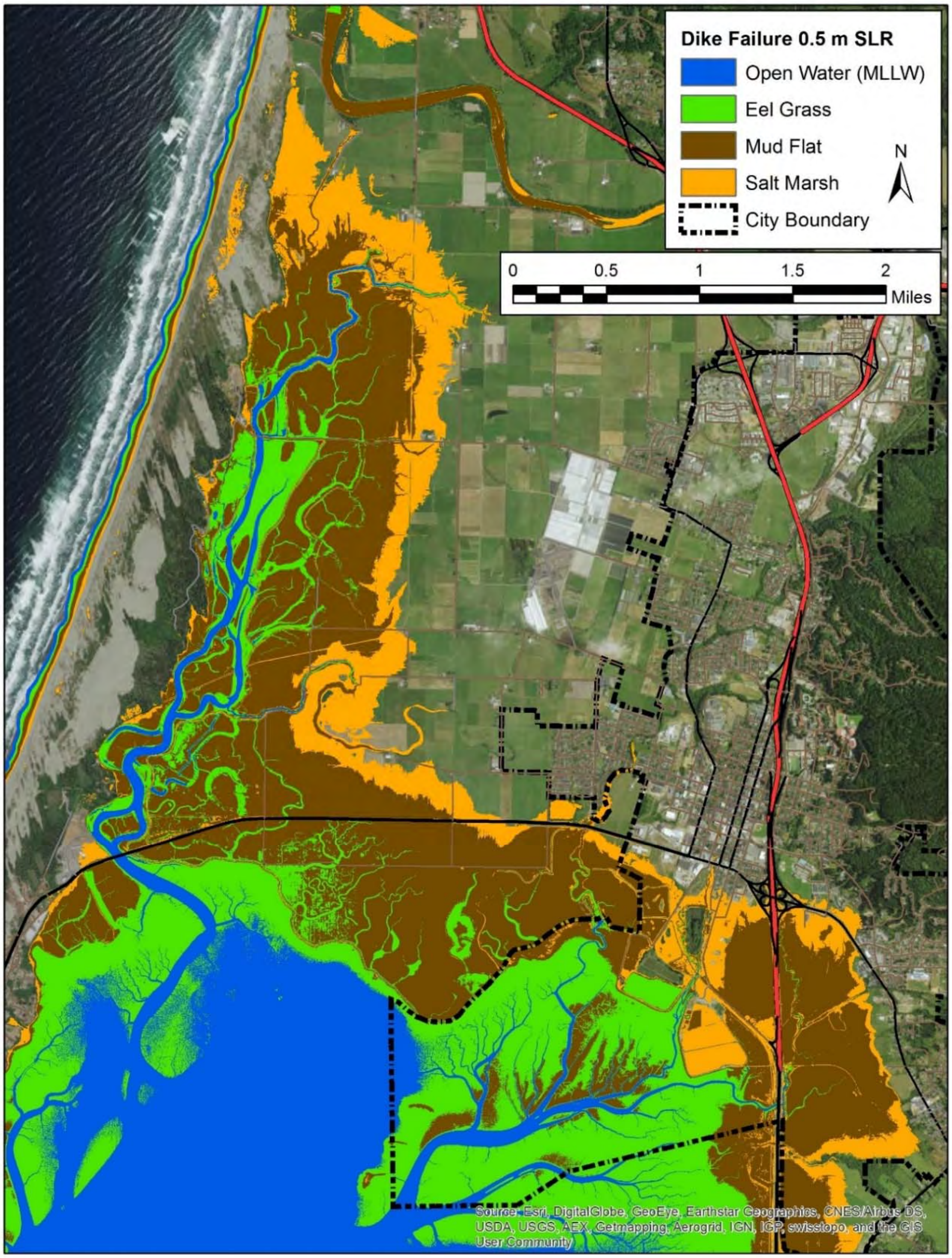

Figure 60. Mad River Slough-Mad River Bottom-Bayside habitat type distribution with diked shoreline compromised and 1.6 ft. (0.5 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

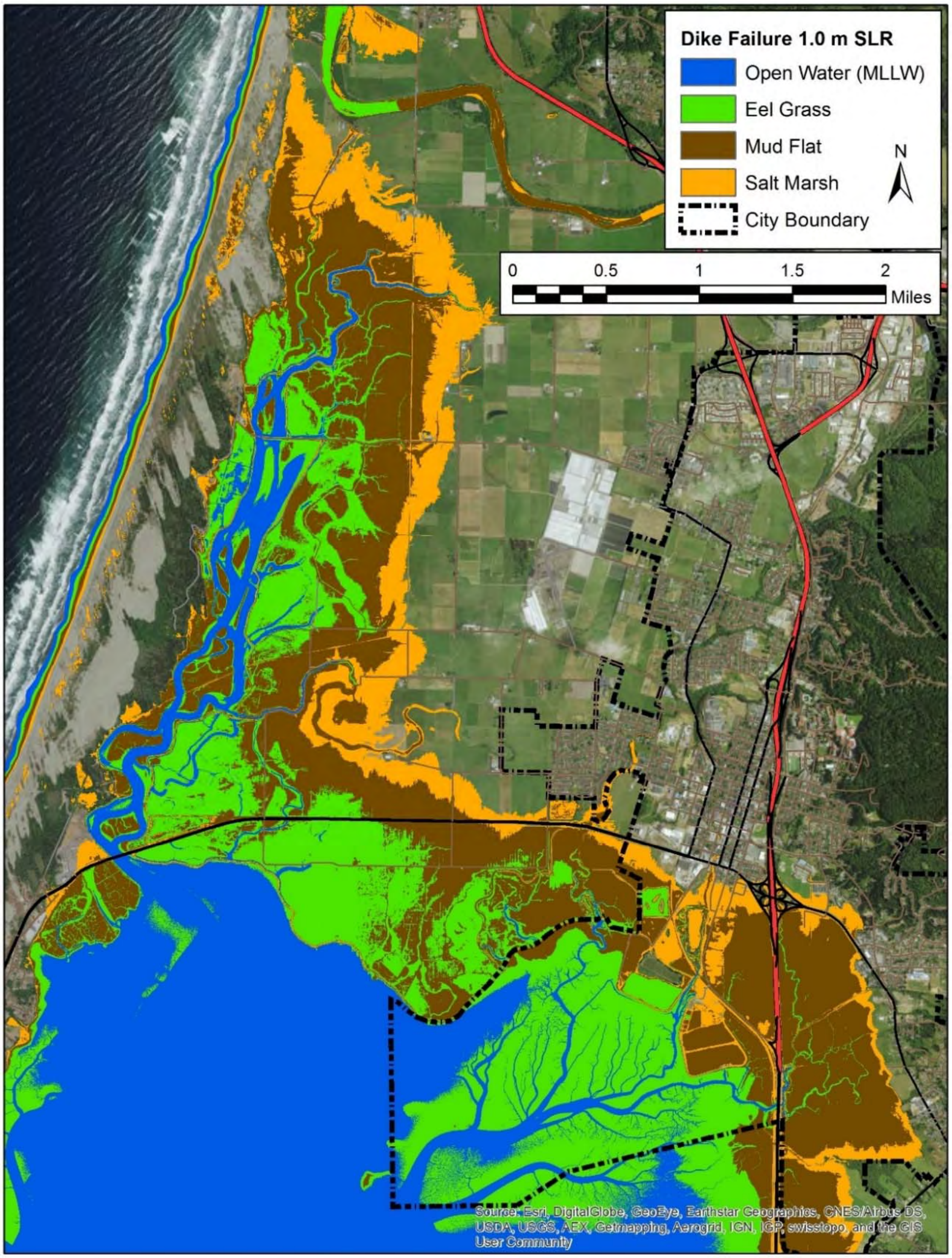

Figure 61. Mad River Slough-Mad River Bottom-Bayside habitat type distribution with diked shoreline compromised and 3.3 ft. (1.0 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

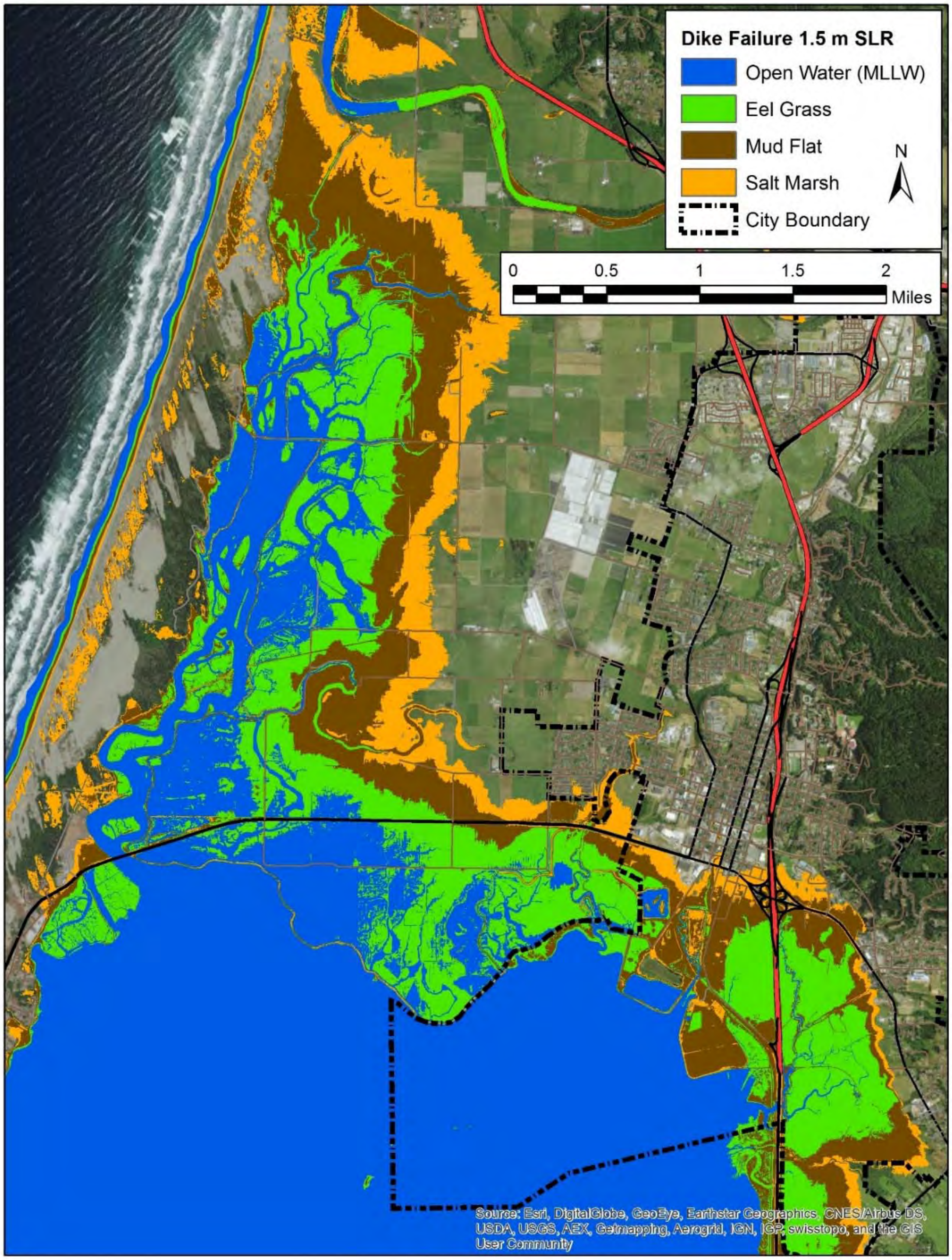

Figure 62. Mad River Slough-Mad River Bottom-Bayside habitat type distribution with diked shoreline compromised and 4.9 ft. (1.5 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

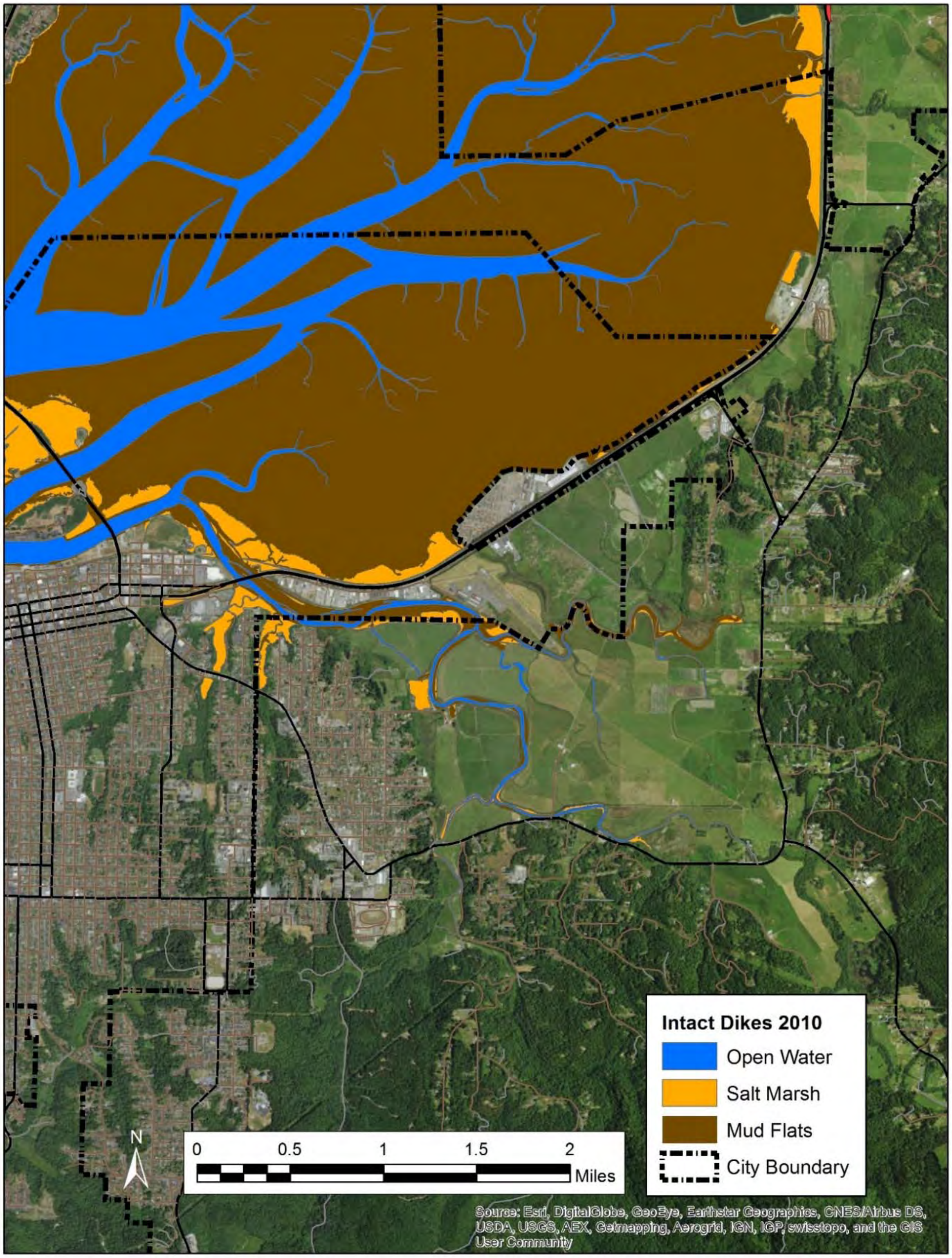

Figure 63. Eureka Slough-Bayside habitat type distribution with diked shoreline intact (2009 Lidar).

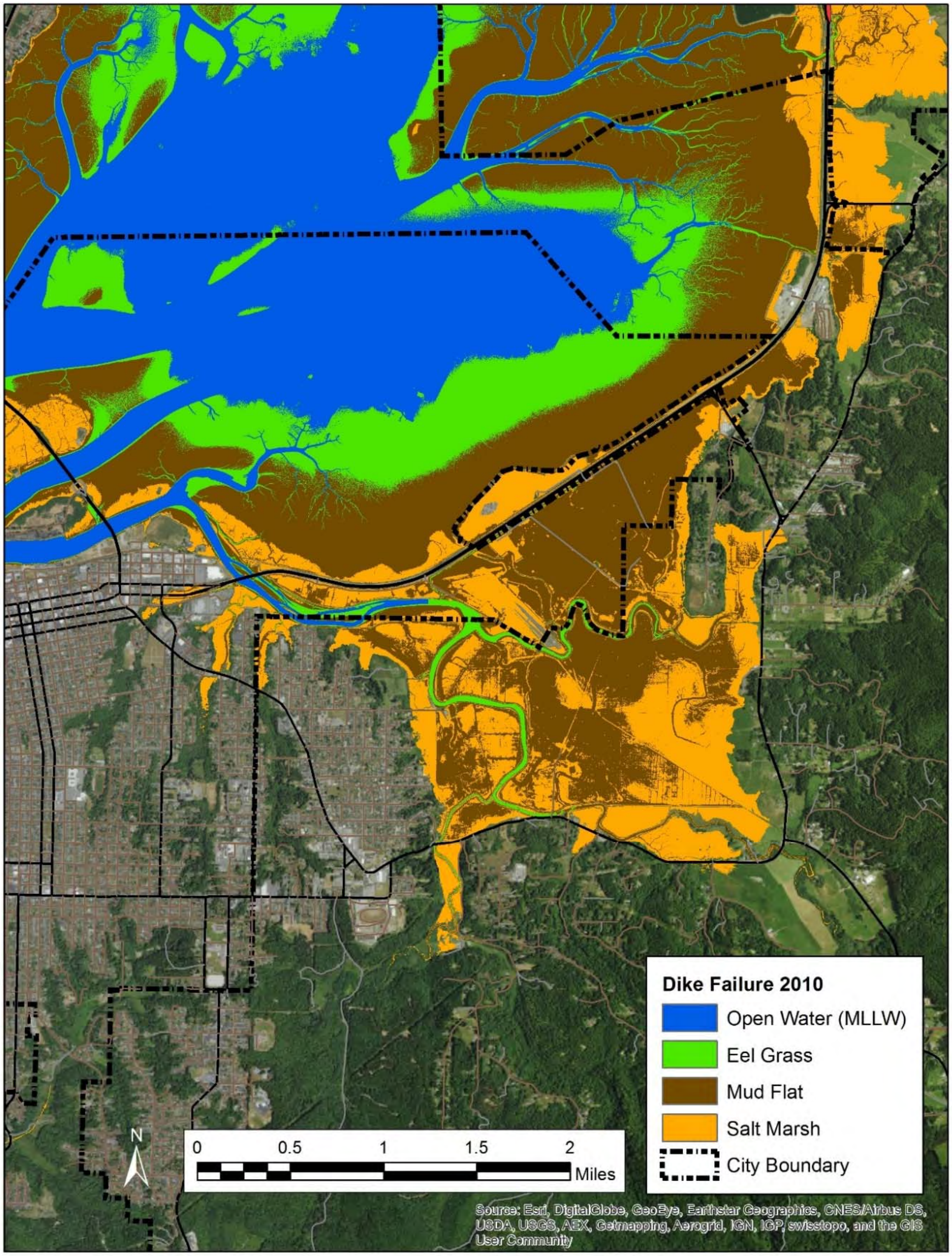

Figure 64. Eureka Slough-Bayside habitat type distribution with diked shoreline compromised (2009 Lidar).

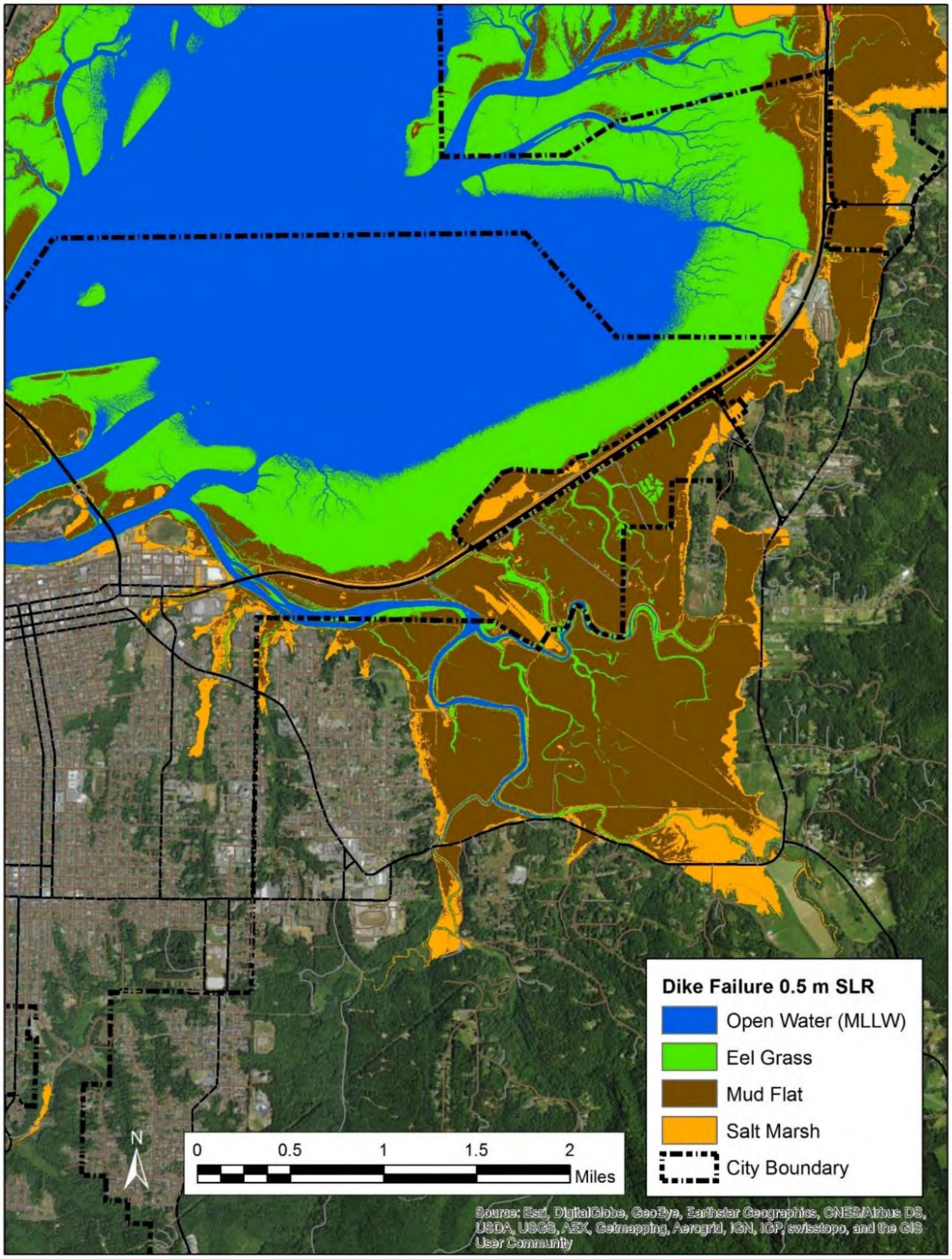

Figure 65. Eureka Slough-Bayside habitat type distribution with diked shoreline compromised and 1.9 ft. (0.5 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

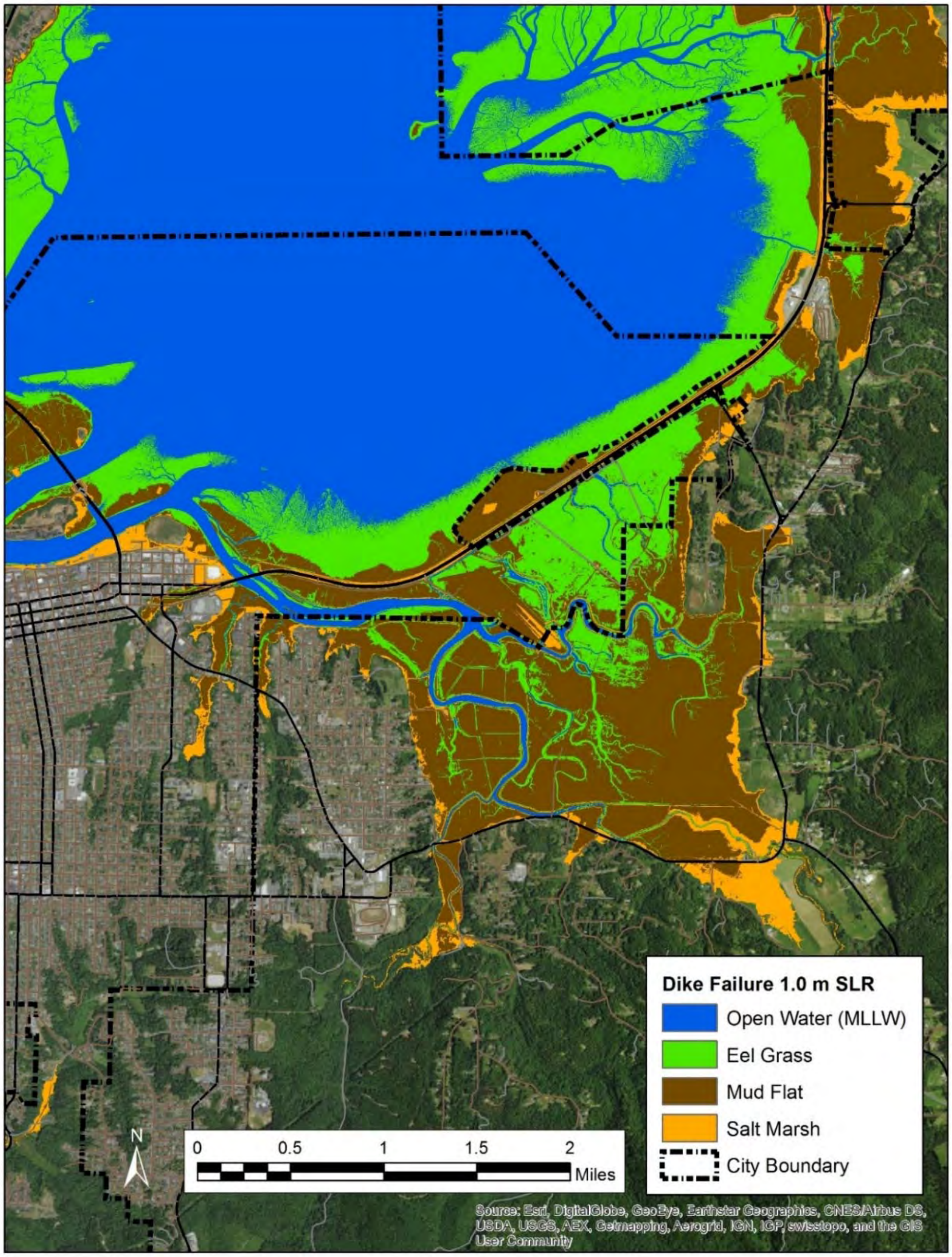

Figure 66. Eureka Slough-Bayside habitat type distribution with diked shoreline compromised and 3.3 ft. (1.0 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

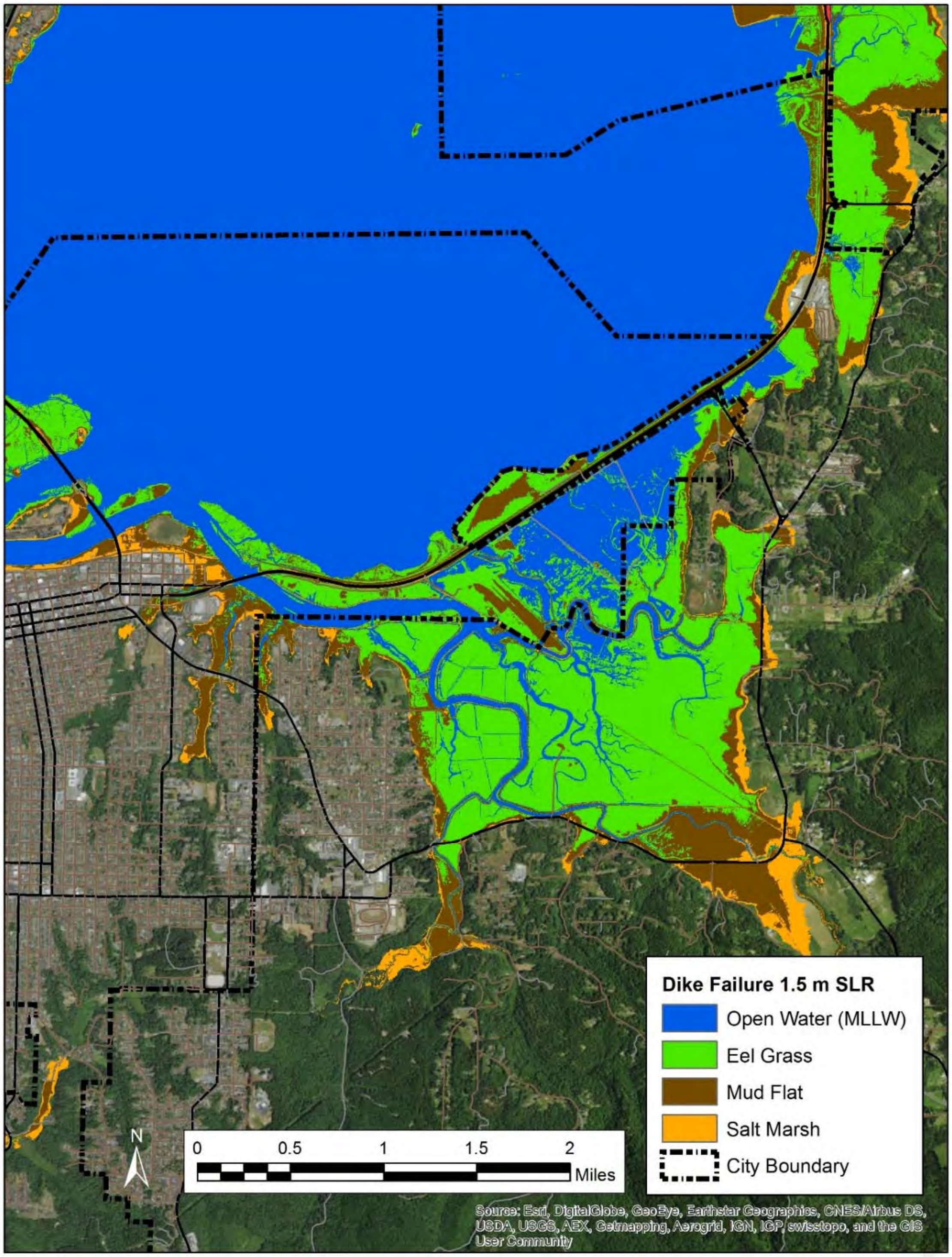

Figure 67. Eureka Slough-Bayside habitat type distribution with diked shoreline compromised and 4.9 ft. (1.5 M) of sea level rise (2009 Lidar).

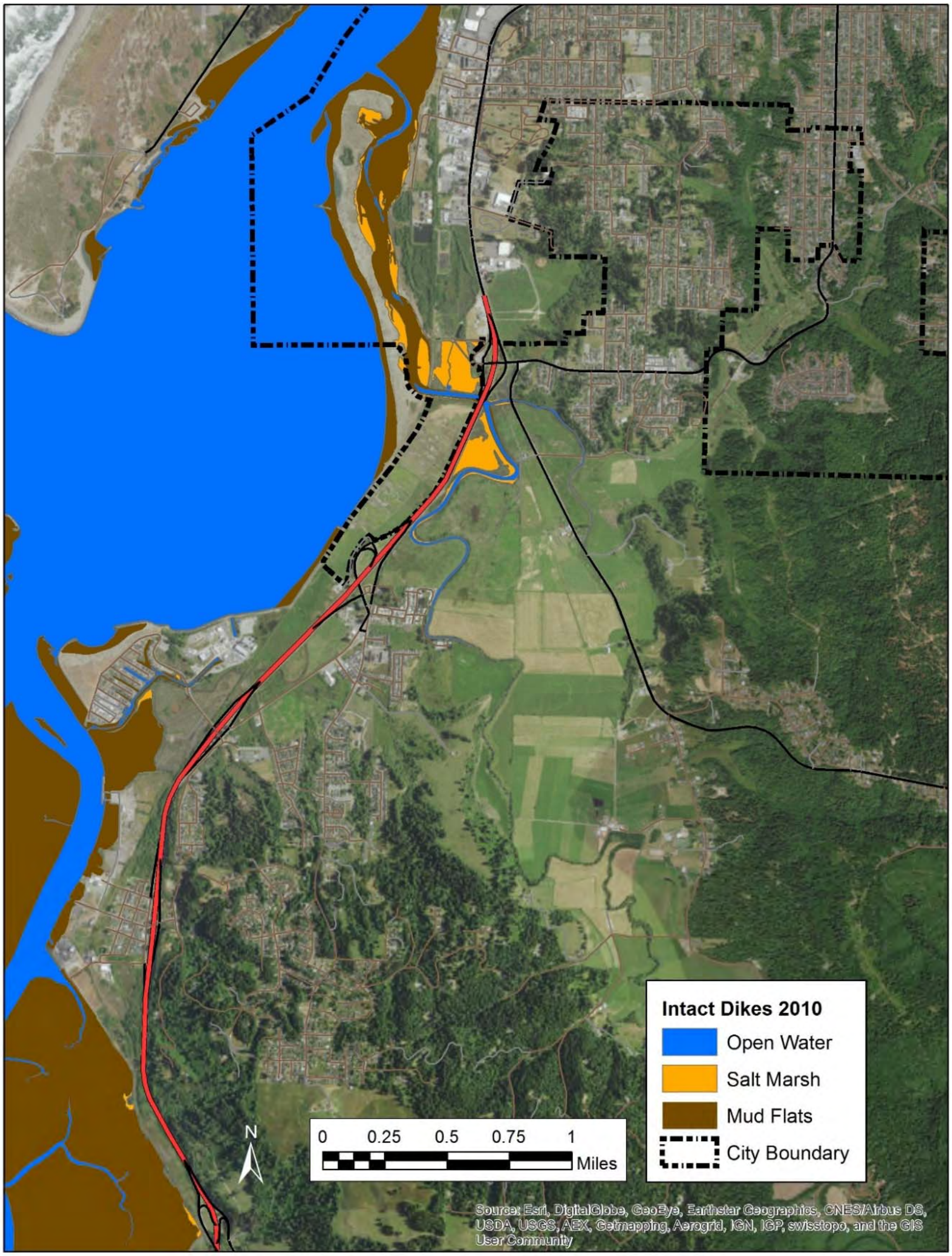

Figure 68. Elk River Slough habitat type distribution with diked shoreline intact (2009 Lidar).

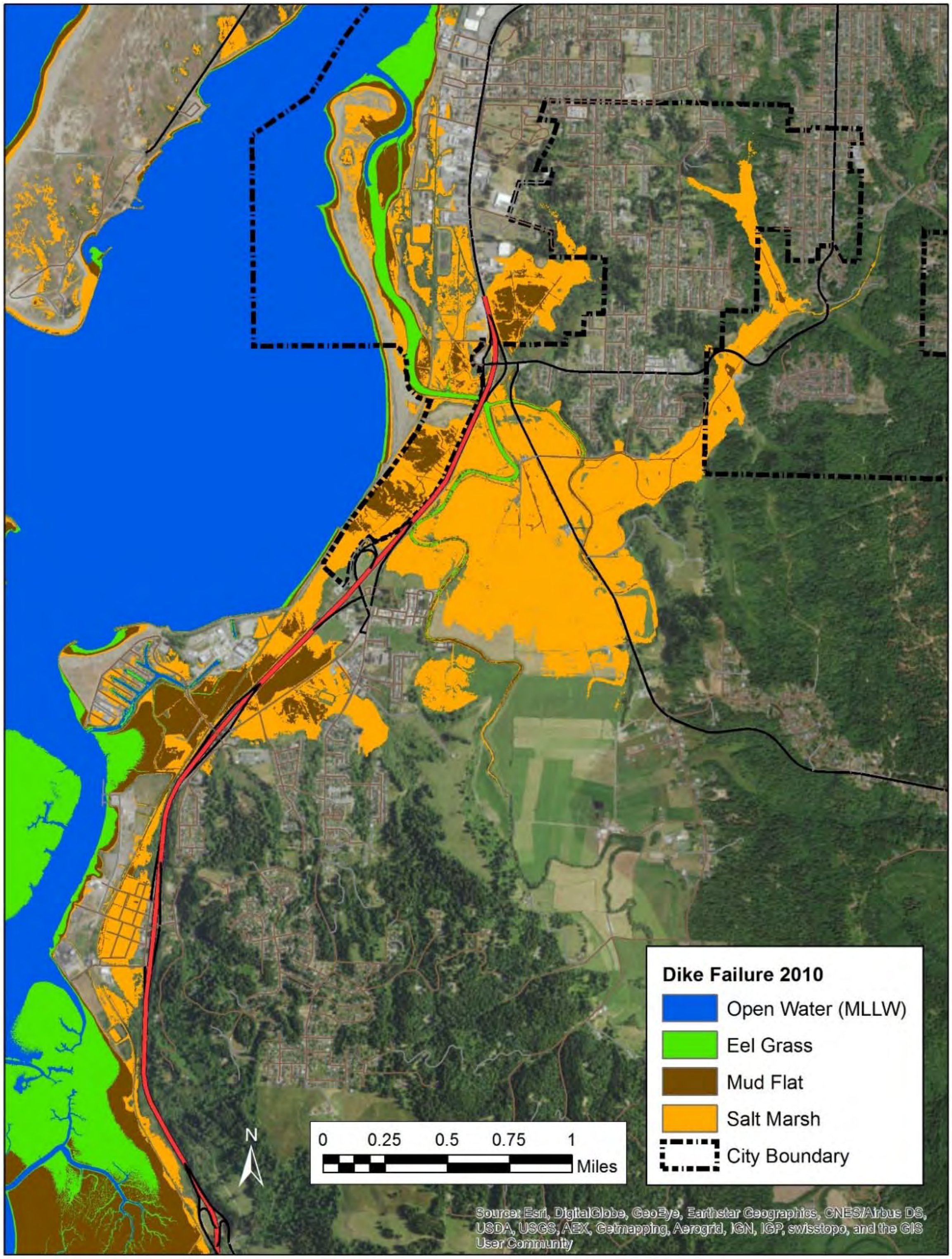

Figure 69. Elk River Slough habitat type distribution with diked shoreline compromised (2009 Lidar).

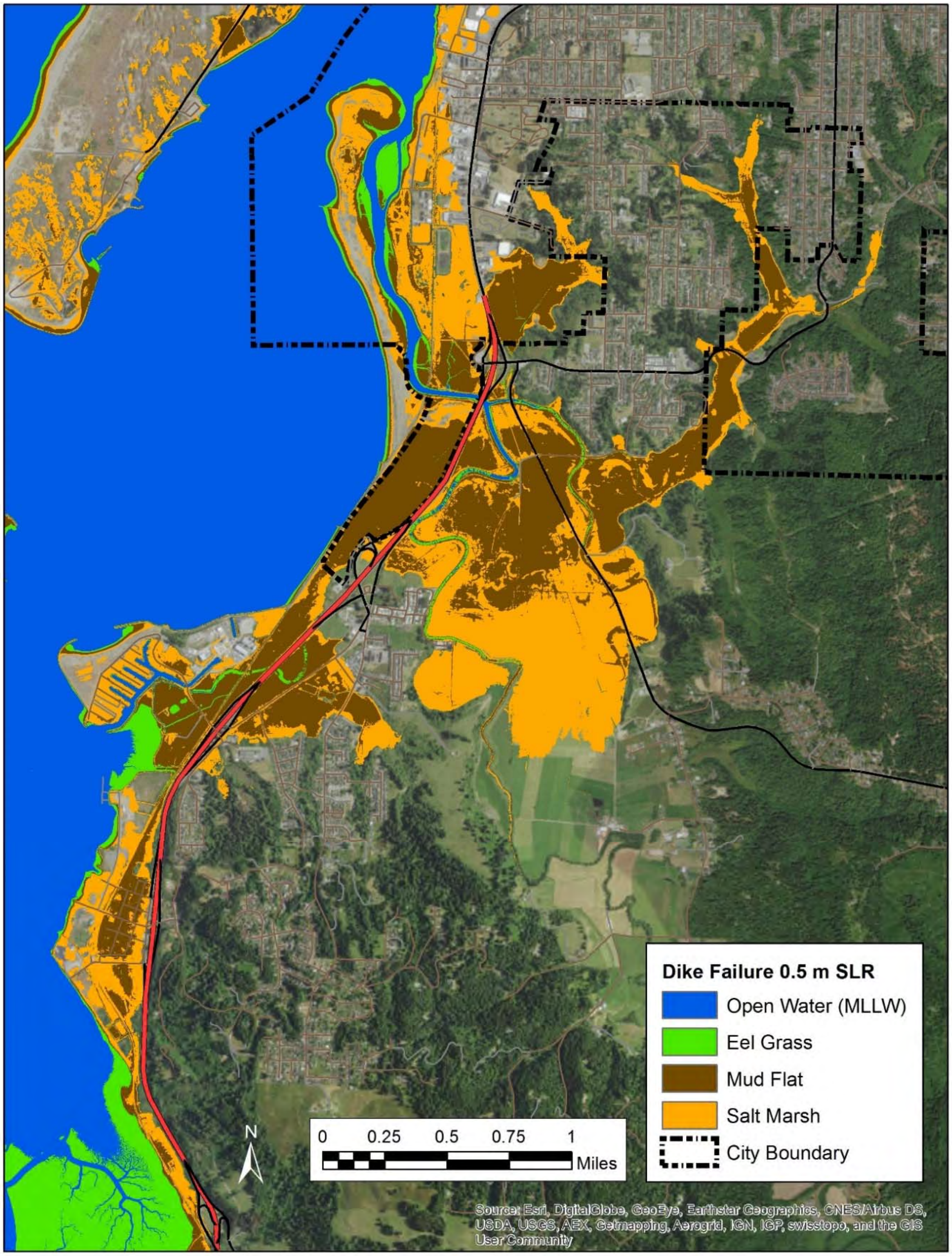

Figure 70. Elk River Slough habitat type distribution with diked shoreline compromised and 1.6 ft. (0.5 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

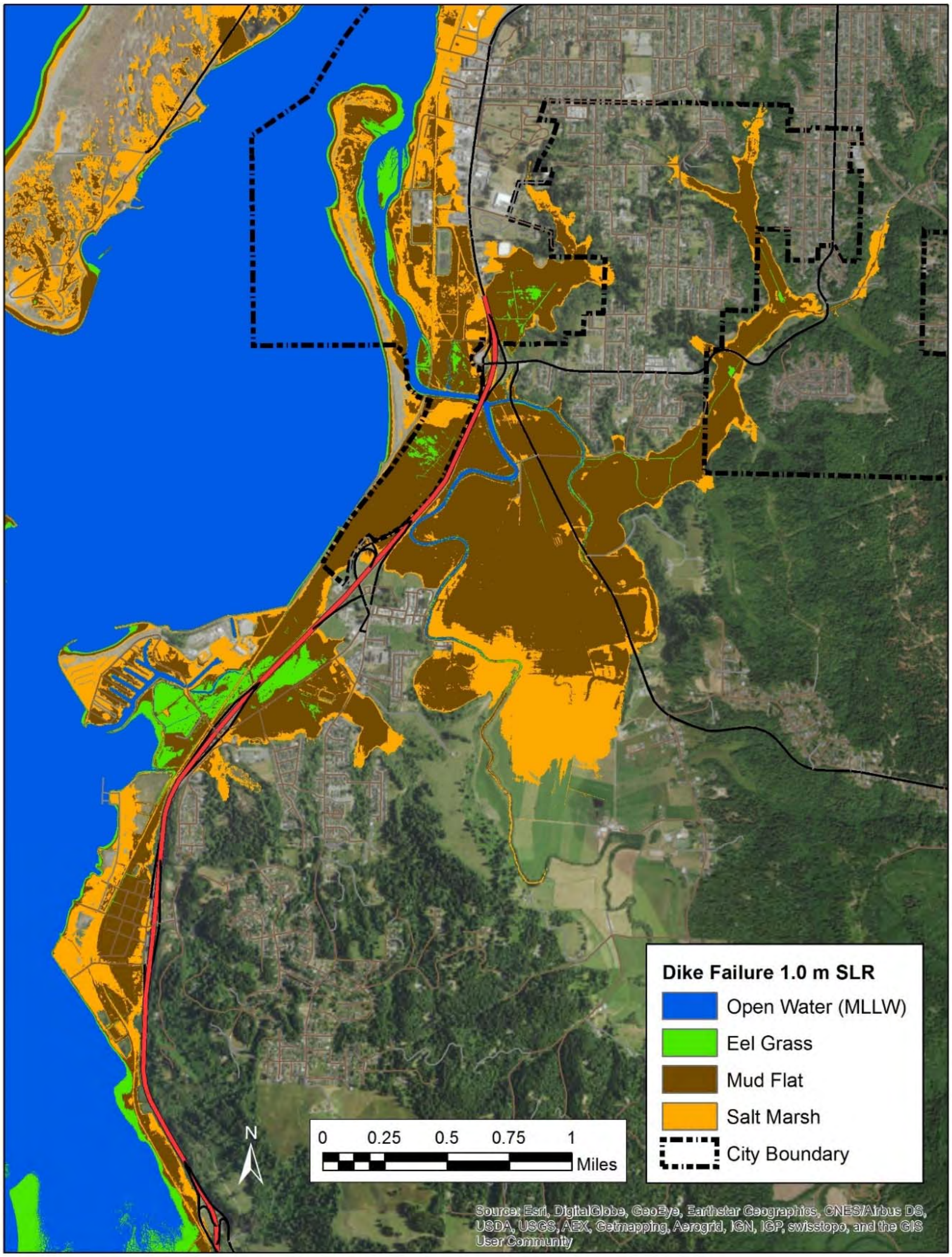

Figure 71. Elk River Slough habitat type distribution with diked shoreline compromised and 3.3 ft. (1.0 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

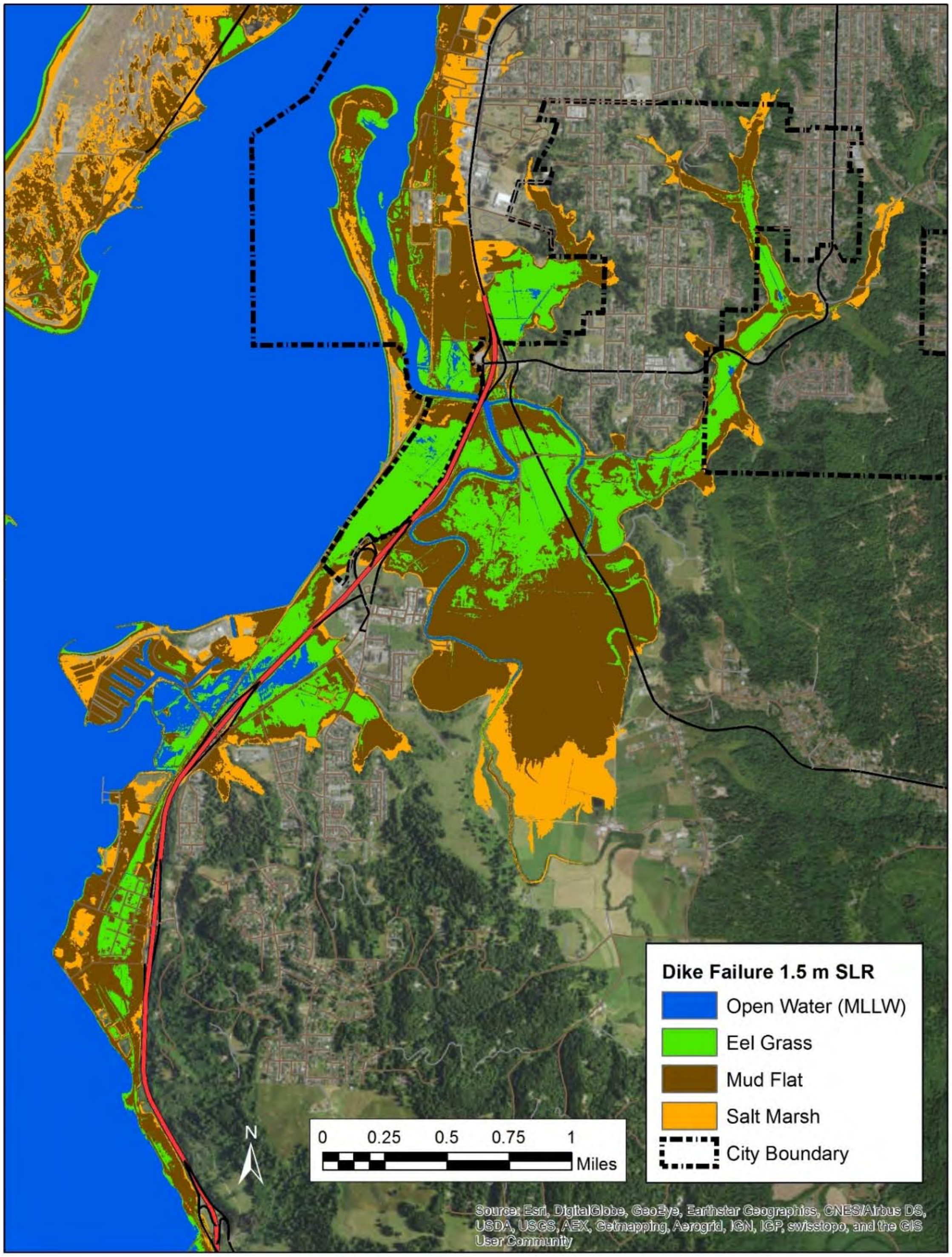

Figure 72. Elk River Slough habitat type distribution with diked shoreline compromised and 4.9 ft. (1.5 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

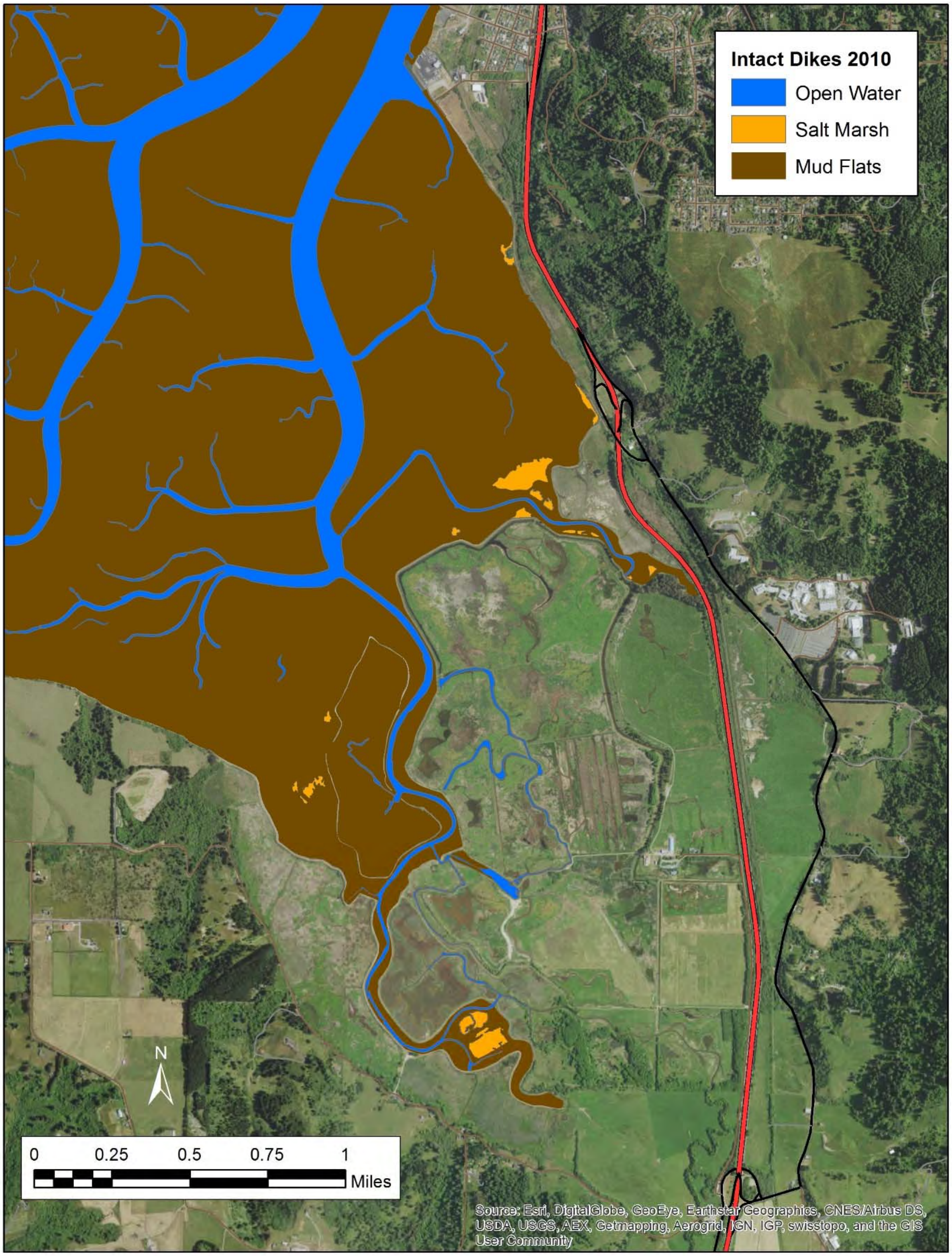

Figure 73. South Bay habitat type distribution with diked shoreline intact (2009 Lidar).

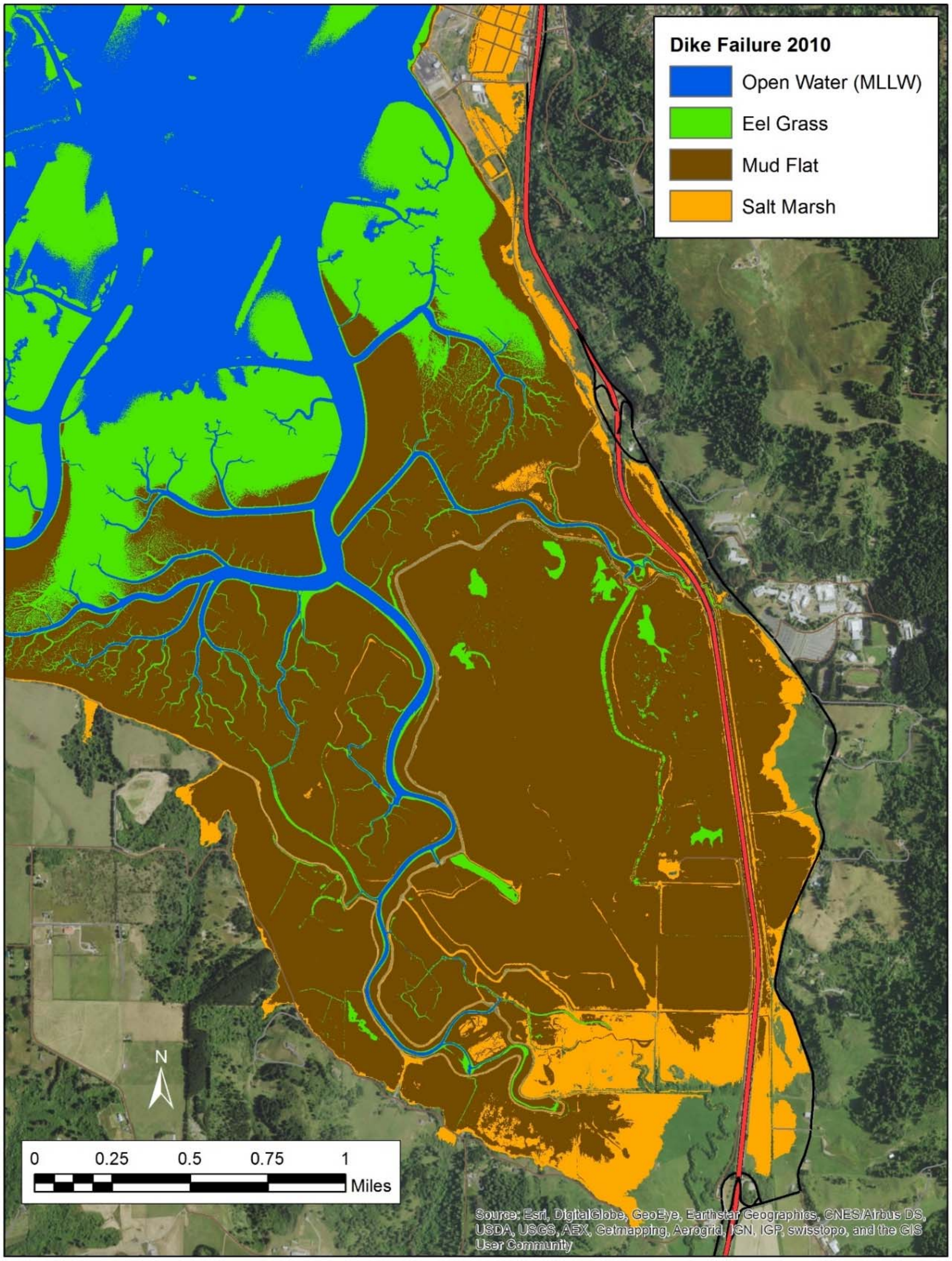

Figure 74. South Bay habitat type distribution with diked shoreline compromised (2009 Lidar).

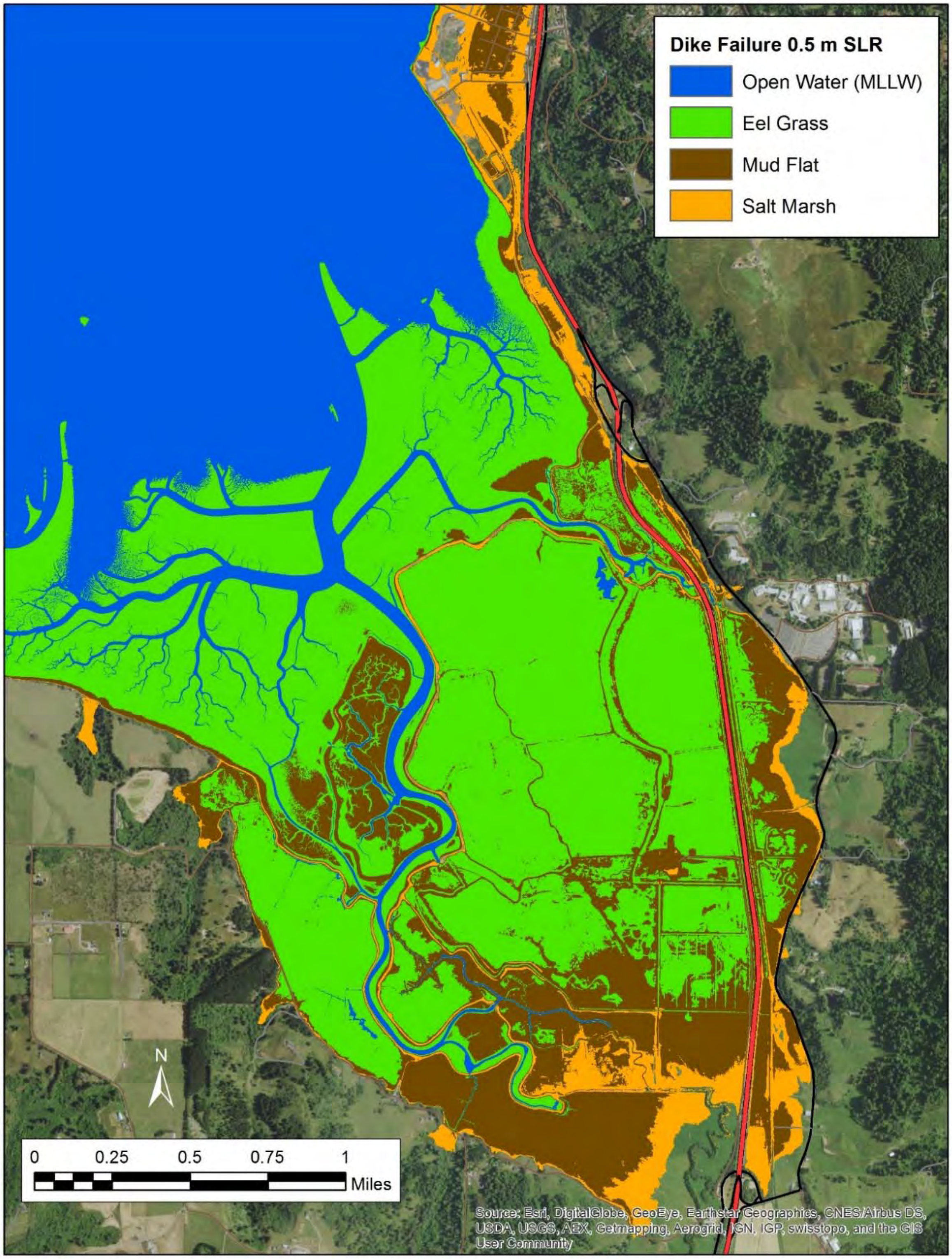

Figure 75. South Bay habitat type distribution with diked shoreline compromised and 1.6 ft. (0.5 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

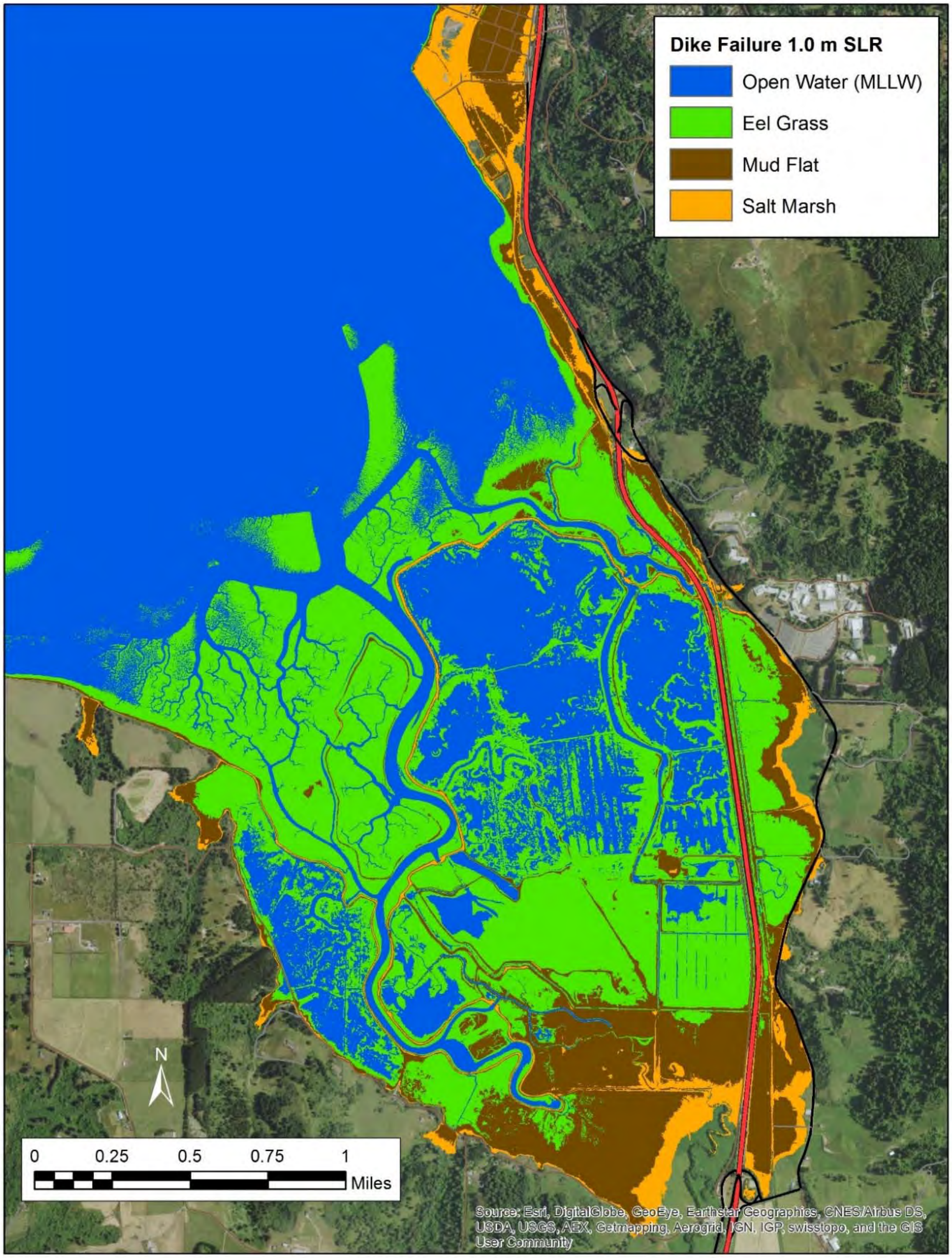

Figure 76. South Bay habitat type distribution with diked shoreline compromised and 3.3 ft. (1.0 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

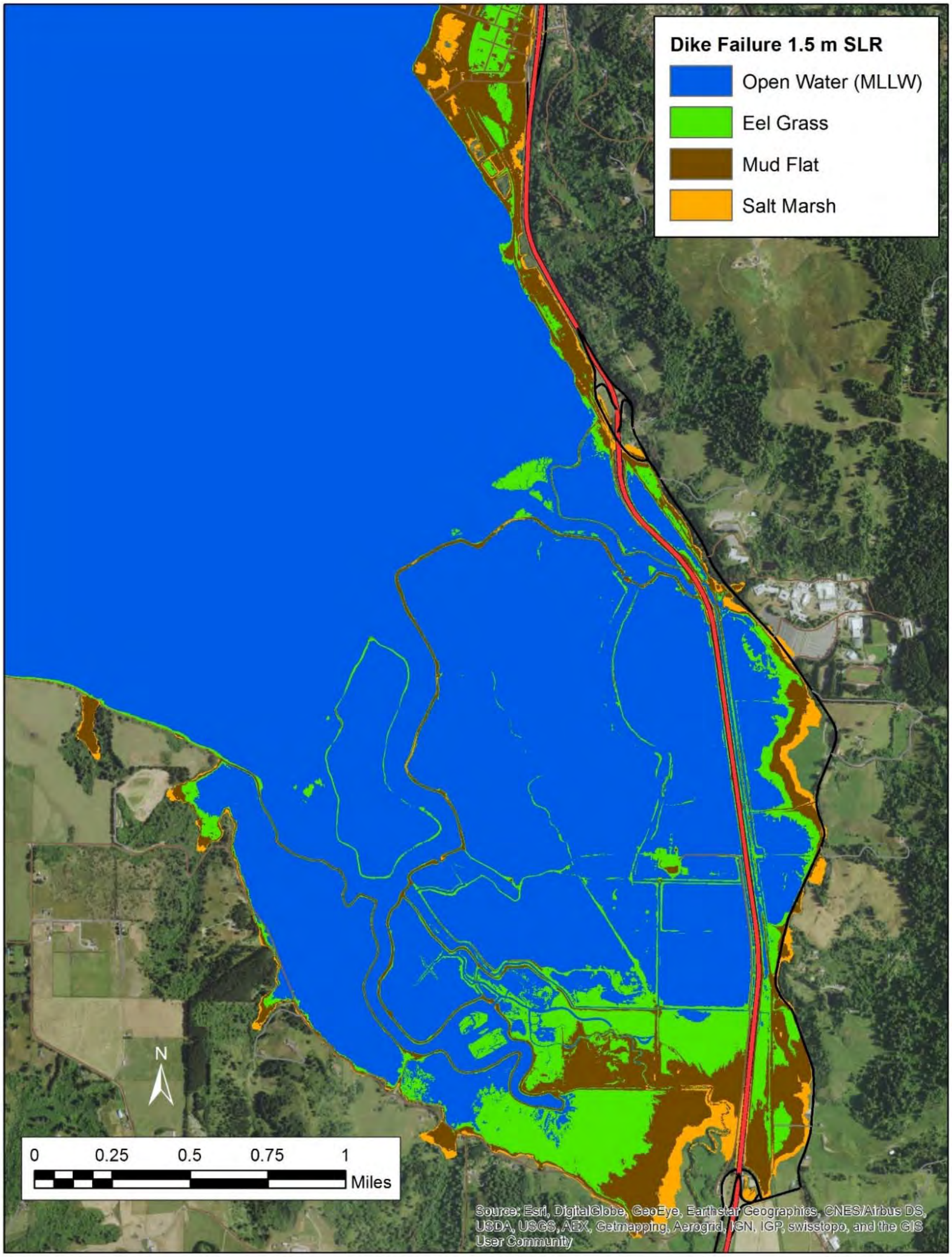

Figure 77. South Bay habitat type distribution with diked shoreline compromised and 4.9 ft. (1.5 M) of sea level rise (2009 Lidar), assuming no sediment accretion.

➢ *Flooding*

Flooding or overtopping of artificial shoreline structures can occur infrequently from extreme storm events (10 to 100-year flood). Flooding during a 100-year event (1% probability of occurring any year) could rise to 10.2 ft., and overtop more than 20.9 miles of artificial shoreline structures that are less than or equal to 9.7 ft. elevation, two feet above MMMW elevation.

The 100-year flood would likely affect the same diked former tidelands that are vulnerable to 3.3 ft. (1.0 M) of sea level rise (MMMW of 11.0 ft.) potentially putting 6,600 acres of seasonal freshwater wetlands and Aleutian goose grazing habitat at risk of tidal inundation in those areas where protective dikes are breached or overtopped.

Flooding of low-lying lands behind barrier type shorelines can also occur during heavy rainfall as drainage to the bay is impaired, resulting in backwater ponding. Flooding and ponding of water behind dikes by stormwater runoff from interior watersheds can also result in erosion and/or slumping of earthen dike slopes, as fortification of dike slopes is generally limited to the bay side of the dikes.

Likewise, flooding can occur in the short-term when rising groundwater emerges onto the ground surface in low-lying areas in response to winter storms, king tides or from rising sea levels. Regardless of protective shoreline structure, its fortification or elevation, low-lying areas behind these structures such as diked former tidelands and seasonal freshwater wetlands, including Aleutian grazing habitats, are vulnerable to flooding from rising groundwater. Ultimately, if the land surface elevation is not increased emerging groundwater would inundate these low-lying areas and they would become first emergent and then submergent wetlands.

The average elevation of groundwater on land adjacent to the shoreline is generally above MSL elevation of 3.4 ft. On Humboldt Bay, diked former tidelands are generally equal to or less than 6.5 ft. (MHHW) in elevation. Groundwater, depending on surface elevations and the season, can fluctuate from the ground surface down to 3 ft. (Hoover 2015). As sea level rises, the denser saltwater would push groundwater to higher elevations, eventually emerging and flooding the ground surface. With sea level rise, this type of flooding would likely begin as nuisance flooding during the winter and increase in duration over time until it becomes chronic flooding and eventually permanent inundation. King tides that equal or exceed MAMW elevation of 8.8 ft. occur now approximately four times a year. With 1.6 ft. (0.5 M) of sea level rise, tides would reach 8.8 ft. 125 days a year, constituting chronic flooding (NHE 2017).

On Humboldt Bay, rising groundwater during winter and spring months creates seasonal freshwater wetlands on diked former tidelands. If not tidally inundated, rising groundwater in response to sea level rise would likely form emergent and submergent freshwater wetlands and eventually open water habitat. Once barrier type shorelines are breached or overtopped, daily tidal inundation would convert freshwater wetlands to

inter-tidal wetlands, and with sea level rise, inter-tidal wetlands would become submerged or open water.

- ### *Salt Water Intrusion*

Salt water intrusion and rising groundwater flooding are linked, as fresh groundwater floats on higher-density seawater. Salt water intrusion, like tidal inundation, can lead to significant vegetative conversions from salt intolerant species to salt tolerant species, or to mudflats if the area is inundated for extended periods of time. A significant portion of diked lands on Humboldt Bay have surface elevations from three to six feet, and are vulnerable to salt water intrusion. On Humboldt Bay, the conversion of current freshwater ESHA, such as seasonal freshwater wetlands and Aleutian goose grazing habitat (pasture) would lead to significant changes in wildlife composition, distribution, and abundance.

Not all diked area surface elevations are in the three to six feet range. On Elk River Slough, the diked lands surface elevations mostly range between six and nine feet. Therefore, salt water intrusion may be less severe in the Elk River Slough area (Figure 78).

Once barrier type shorelines are breached or overtopped, tidal inundation would convert freshwater wetlands. As a result, there would be no effect on inter-tidal wetlands from salt water intrusion under this scenario.

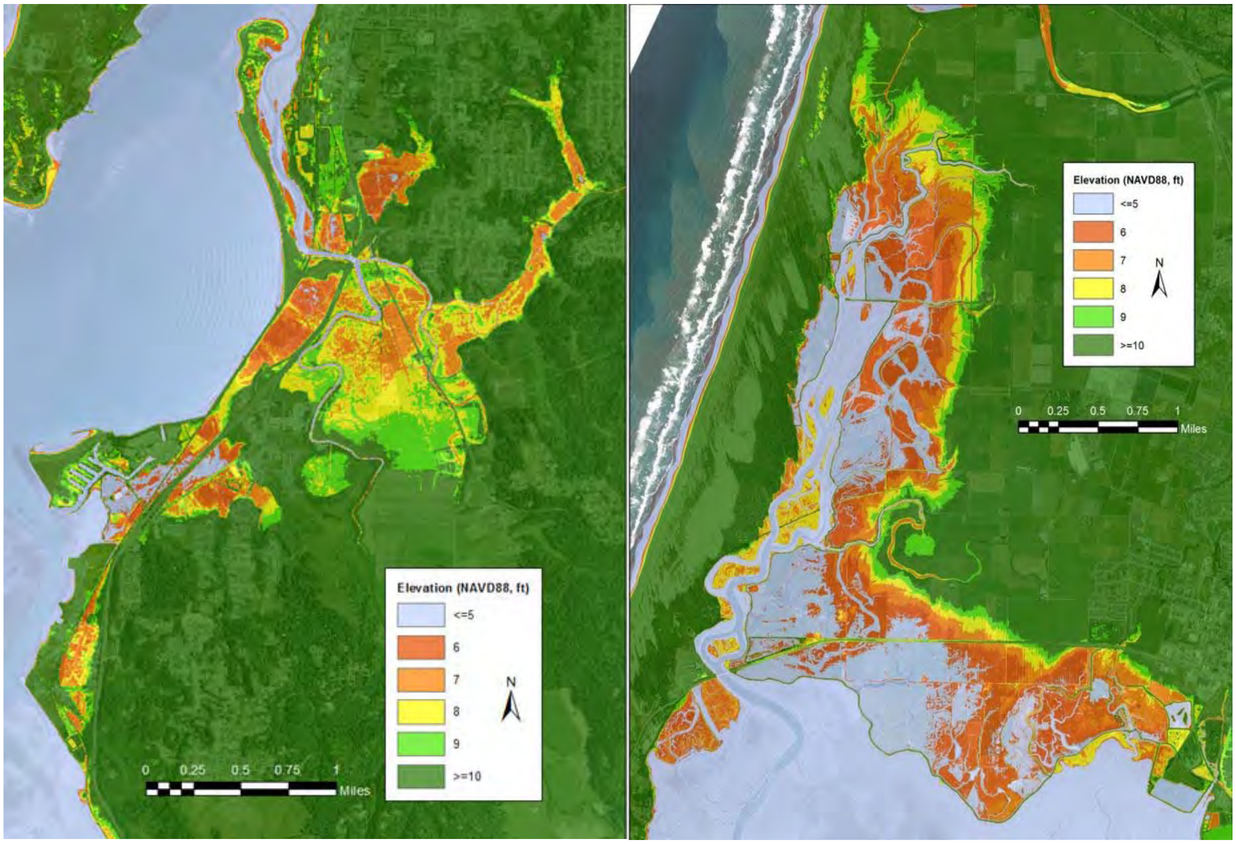

Figure 78. Surface elevations on Elk River Slough are much higher compared to Mad River Slough. Impacts from saltwater intrusion may be more significant in the Mad River Slough area, given the lower surface elevations.

Susceptibility

The freshwater ESHA habitats in the HBAP planning area that are vulnerable to tidal inundation, flooding, and salt water intrusion are located on low-lying diked former tidelands. Approximately 50% of the agricultural lands in the HBAP planning area are vulnerable to 4.9 ft. (1.5 M) of sea level rise.

Current agricultural uses are based on raising forage for livestock grazing. Saltwater inundation, even for short durations, can have a significant impact on non-saltwater tolerant plants such as forage. Agricultural practices are very susceptible to tidal inundation. Frequent or chronic flooding with salt water would likely result in a vegetative conversion to salt tolerant plant species, and the collapse of agricultural endeavors. Flooding from extreme storm events is infrequent, and current agricultural uses can recover from such flooding. Backwater flooding in the winter and spring months can seasonally restrict agricultural lands uses. Without improved drainage in

response to rising sea levels, such flooding may lead to pastures converting to freshwater or brackish water wetlands. Emerging groundwater may also result in the conversion of forage to wetland vegetation, which would be a significant impediment to continuing agricultural uses. Saltwater intrusion of shallow wells would impact irrigated agricultural lands significantly. Saltwater intrusion of groundwater would lead to vegetative conversions to salt tolerant species and a reduction or elimination of livestock grazing.

3.5.5 Wiyot Cultural Resources

Humboldt Bay, or Wigi, is home to the Wiyot people. In 1918, L.L. Loud published his ethnographic report on the Wiyot, which included a map of 103 cultural sites on Humboldt Bay. A copy of his 1913 field map was used to delineate the location of cultural sites. Loud's field map did not cover all the area and sites contained in his published ethnographic report. Consultation with a Wiyot Tribal Historic Preservation Officer (THPO) enabled additional sites to be added in areas beyond Loud's field map, and enabled revisions to the location of several of Loud's field map site locations. Consultation with the THPO confirmed the status (whether the presence of the site has been field verified) of all sites, locations and their uses. Of the 103 sites on Humboldt Bay identified by Loud, 75 are within Humboldt County's HBAP planning area, 15 are in the City of Eureka's LCP jurisdiction, 6 are in the City of Arcata's LCP jurisdiction, and 4 are in the unincorporated area of the County but inland of the HBAP planning area.

Number and Distribution of the 103 Loud Cultural Sites:

- 11 sites on Mad River Slough
- 24 sites on Arcata Bay
- 12 sites on Eureka Slough
- 21 sites on Eureka Bay
- 1 site on Elk River Slough
- 34 sites on South Bay

Exposure

When sea levels rise, wave action could erode unfortified shorelines, exposing cultural sites to erosion, or in low-lying areas generally consisting of diked former tidelands, to tidal inundation. The vulnerability of diked former tidelands to tidal inundation is dependent on the integrity of the entire shoreline of the hydrologic unit within which they are located. Therefore, those sites below 12.6 ft. elevation that are located behind diked

shorelines could experience erosion and become tidally inundated if any segment along the shoreline (not just the segment in front of the site) of the hydrologic unit is breached or overtopped. Shoreline erosion could expose and destroy Wiyot artifacts, burials, and the structure of shell middens at these sites. In 2006, the Wiyot Tribe installed composite fiberglass sheet piling protection at Tuluwat on Indian Island to prevent further shoreline erosion of the site. Rising groundwater and salt water intrusion, could also lead to acidification and calcification of buried artifacts from sea level rise would also likely affect the archaeological integrity of Wiyot sites characterized as shell middens.

There are 103 Wiyot sites on Humboldt Bay, 51 sites appear to be located above 12.6 ft. elevation (40 in the HBAP, 6 in City of Eureka LCP, and 5 in City of Arcata LCP) and therefore not vulnerable tidal inundation by 4.9 ft. (1.5 M) of sea level rise. The remaining 52 sites (42 in the HBAP, 8 in the City of Eureka LCP, and 2 in the City of Arcata LCP) on Humboldt Bay are vulnerable to 4.9 ft. (12.6 ft.) of sea level rise. The location of 12 of these sites have been confirmed, 38 have not, and the two sites located on Daby Island in the City of Eureka are simply place names (Table 26).

Table 26. Wiyot settlement sites on Humboldt Bay potentially inundated by 0.9 ft. (MAMW), 1.6 ft. (0.5 M), 3.3 ft. (1.0 M), and 4.9 ft. (1.5 M) of sea level rise, and total number of sites potentially exposed. Confirmed site - yes (12) versus no (40) designated by Y/N. There are 50 settlement sites, 3 are also ceremonial sites (C), plus two that are just place names (P) on Daby Island.

0.9 Ft.	1.6 Ft.	3.3 Ft.	4.9 Ft.
19 5Y/1C/14N	**5** 1Y/4N	**13** 4Y/2C/9/N	**15** 2Y/13N
Total: 19	**Total: 24**	**Total: 37**	**Total: 52**

In the HBAP planning area on the south shore of South Bay, there are also a series of four sites that are located above 12.9 ft. but are near a bluff face and potentially vulnerable to bluff retreat in response to shoreline erosion from extreme tides or storm surge now and to rising sea levels and storm waves.

With 0.9 ft. of sea level rise, essentially equal to our current MAMW elevation (8.8 ft.), 19 sites including five confirmed sites, one of which is a ceremonial site could be exposed to shoreline erosion and tidal inundation. With approximately 1.6 ft. (0.5 M) of sea level rise (9.3 ft.), another five sites, one of which is confirmed, would be vulnerable to erosion and tidal inundation. Sea level rise of approximately 3.3 ft. (1.0 M) (11.0 ft.) could expose an additional 13 sites, four that are confirmed and two of which are ceremonial sites to tidal inundation. With 4.9 ft. (1.5 M) of sea level rise (12.6 ft.),

another 15 sites, two that are confirmed would be exposed to tidal inundation and resulting shoreline erosion. In summary, based on sea level rise of 4.9 ft. (1.5 M), there could be as many as 56 Wiyot sites exposed to erosion (4 sites) or tidal inundation (52).

Number and Distribution of Vulnerable Sites to 4.9 ft. of Sea Level Rise:

- 5 sites on Mad River Slough
- 12 sites on Arcata Bay
- 9 sites on Eureka Slough
- 13 sites on Eureka Bay
- 13 sites on South Bay

Approximately 18 of the 52 sites vulnerable to 4.9 ft. of sea level rise may be located on public lands. The remaining 34 sites appear to be located on private property.

Susceptibility

On Humboldt Bay, there are potentially 52 Wiyot sites that are likely to be physically damaged due to tidal inundation from sea level rise, and four sites could be damaged by shoreline erosion and bluff retreat. Permanent tidal inundation would prevent access and use of these sites. Shoreline erosion due to rising sea levels or extreme storm events could physically damage or even eliminate sites. The cultural and archaeological significance of sites actively eroded or destroyed would be diminished or lost. Impacts from sea level rise on these sites to the Wiyot people would be significant.

4 References

California Coastal Commission. 2015. Sea Level Rise Policy Guidance: interpretive guidelines for addressing sea level rise in local coastal programs and coastal development permits.

Griggs, G., J. Árvai, D. Cayan, R. DeConto, J. Fox, H.A. Fricker, R.E. Kopp, C. Tebaldi, and E.A. Whiteman (California Ocean Protection Council Science Advisory Team Working Group). 2017. Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust.

Hoover, David, J. 2015. Sea-Level Rise and Coastal Groundwater Inundation and Shoaling at Select Sites in California, USA. Journal of Hydrology: Reg. Stud.

Laird, Aldaron, Brian Powell. 2013. Humboldt Bay shoreline inventory, mapping, and sea level rise vulnerability assessment, with an Addendum: Shoreline Vulnerability Ratings. Prepared for the California State Coastal Conservancy.

Laird, Aldaron. 2015. Humboldt Bay sea level rise adaptation planning project: Phase II report. Prepared for the California State Coastal Conservancy and Coastal Ecosystems Institute of Northern California.

Laird, Aldaron. 2016. City of Eureka Sea Level Rise Assets Vulnerability and Risk Assessment. Prepared for the Ocean Protection Council and City of Eureka.

National Oceanic and Atmospheric Administration. 2001. Tidal Datums and Their Applications. NOAA Special Publication NOS CO-OPS 1. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services, Silver Spring, MD.

National Research Council. 2012. Sea-Level rise for the Coasts of California, Oregon, and Washington. National Academies Press, Washington, DC.

Northern Hydrology and Engineering. 2014a. Estimates of local or relative sea level rise for Humboldt Bay region. Prepared for the California State Coastal Conservancy and Coastal Ecosystems Institute of Northern California.

Northern Hydrology and Engineering. 2014b. Data release for the Humboldt Bay sea level rise vulnerability assessment: Humboldt Bay sea level rise inundation mapping. Prepared for the California State Coastal Conservancy.

Northern Hydrology and Engineering. 2015. Humboldt Bay Sea Level Rise Hydrodynamic Modeling and Inundation Vulnerability Mapping. Prepared for the California State Coastal Conservancy.

Northern Hydrology and Engineering. 2017. North Spit Predicted Tide Level Daily Exceedance Analysis for Mean Annual Maximum Water, Results from Sea Level Rise Modeling.

Patton, J.R., T.B. Williams, J.K. Anderson, and T.H. Leroy. 2017. Tectonic land level changes and their contribution to sea-level rise, Humboldt Bay region, Northern California: 2017 Final Report. Prepared for U.S. Fish and Wildlife Service Coastal Program. Cascadia GeoSciences, McKinleyville, CA.

Russell, Nicole, Gary Griggs. 2012. Adapting to Sea Level Rise: A Guide for California's Coastal Communities. University of California, Santa Cruz.

Schultz, Jonathan. 2017. Irrigated agricultural lands of Humboldt Bay. USDA-Natural Resource Conservation Service, Eureka, CA.

Willis, Robert. 2014. Conceptual Groundwater Model of Sea Level Rise in the Humboldt Bay Eureka-Arcata Coastal Plain. Prepared for the California State Coastal Conservancy and Coastal Ecosystems Institute of Northern California.