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3.13 CLIMATE CHANGE AND SEA LEVEL RISE

This chapter summarizes the anticipated long-term effects of climate change and sea level rise in the project area and how the No Build Alternative and Build Alternatives are set in the context of these changes. Each alternative is also evaluated for how it could alter localized conditions, building on the 2017 Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report's Sea Level Rise Exposure Area (SLR-XA). Appendix 3.13 presents a more detailed description of future conditions and the modeling results for the No Build Alternative and Build Alternatives.

The Federal Highway Administration (FHWA) and the Hawaiʻi Department of Transportation (HDOT) are committed to improving infrastructure resilience. Resilient and sustainable infrastructure improves public safety, reduces closures and maintenance costs, and facilitates the more efficient movement of people and goods. Particularly in coastal areas, climate change and sea level rise are key considerations and a principal component of the Honoapiʻilani Highway Improvements Project's (the Project's) purpose and need (Chapter 1, Introduction, Purpose and Need).

3.13.1 Regulatory Context

3.13.1.1 Federal

Executive Order 13653, Preparing the United States for the Impacts of Climate Change, encourages agencies to identify opportunities to support and encourage smarter, more climate-resilient investments.[1]

In January 2023, the Council on Environmental Quality issued interim National Environmental Policy Act Guidance on Greenhouse Gas Emissions and Climate Change. This guidance offers clarity on incorporating greenhouse gas (GHG) emissions and climate change considerations into project analyses. Key guidance includes using early planning processes to integrate GHG emissions and climate change into the development of alternatives and identifying potential mitigation and resilience measures.[2]

The 2014 FHWA Order 5520, Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events, makes resilience a part of FHWA policy and integrates climate change and the consideration of extreme weather risks into its planning, operations, policies, and programs in order to promote preparedness and resilience.[3]

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1 Executive Office of the President. (Nov. 1, 2013). *Preparing the United States for the Impacts of Climate Change* (Executive Order No. 13653). https://www.federalregister.gov/documents/2013/11/06/2013-26785/preparing-the-united-states-for-the-impacts-of-climate-change. Accessed September 2023.

2 Council on Environmental Quality. (Jan. 9, 2023). National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions and Climate Change. https://www.federalregister.gov/documents/2023/01/09/2023-00158/national-environmental-policy-act-guidance-on-consideration-of-greenhouse-gas-emissions-and-climate. Accessed September 2023.

3 Federal Highway Administration. (Dec. 15, 2014*). Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events* (Report No. 5520). https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm. Accessed September 2023.

3.13.1.2 State of Hawaiʻi

Former State of Hawaiʻi Governor David Ige identified "Climate Action" as one of several goals in the 2018 Executive Order 18-06, by recognizing the importance of "reducing human and economic loss caused by natural disasters" by "strengthening capacity to [sic] climate-related hazards and natural disasters; integrating climate change into policies and planning; improving information processes regarding climate change and natural disasters."

Hawaiʻi Revised Statutes (HRS), Chapter 226-65, establishes the *Hawaiʻi 2050 Sustainability Plan* as the State of Hawaiʻi's climate and sustainability and action plan, which defines the State's climate adaptation goals, principles, and policies. The intent is for this plan to guide future State actions.

By State law, all government actions trigger an environmental review in consultation with appropriate regulatory agencies, including socioeconomic and historic preservation considerations. All roadway projects, even emergency actions that are exempted from certain reviews and approvals, require some level of environmental review.

Effective July 2019, the State of Hawaiʻi required all new projects undergoing environmental review under the Hawaiʻi Environmental Policy Act (also known as HRS, Chapter 343) to consider whether the project is likely to have an adverse effect or be vulnerable to a SLR-XA, as defined by the 2017 Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report.

In May 2021, HDOT published the *Hawaii Highways Climate Adaptation Action Plan*. The plan assesses the effects of climate change on the National Highway System in the region and provides a roadmap for enhancing the resilience of Hawaiʻi's highways. The National Highway System refers to the Interstate Highway System as well as other roads that are important to the nation's economy, defense, and mobility.[4]

The action plan emphasizes developing a climate-resilient highway system with urgency, building institutional capacity, and using data-driven decision-making to prioritize resilient infrastructure investments.[5] Additionally, the plan seeks to complement and support climate-related policies, rules, and initiatives that guide the overall development of the State (and are therefore relevant to HDOT and the State Highway System). This includes consistency with the 2017 *Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report*, particularly in utilizing the SLR-XA as a standard for evaluating exposure of HDOT assets to coastal hazards.

In August 2019, HDOT developed the *Statewide Coastal Highway Program Report* to assess and rank the susceptibility of State coastal roads to hazards such as erosion and structural degradation from waves, currents, and sea level rise. The report includes a scientifically rigorous methodology for the Coastal Road Erosion Susceptibility Index (CRESI), which identified the 20 most critical road locations statewide in terms of their susceptibility to structural degradation. Additionally, the report addresses

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4 Federal Highway Administration. (June 29, 2017). National Highway System. https://www.fhwa.dot.gov/planning/national_highway_system/. Accessed December 2023.

5 Hawaiʻi Department of Transportation. (May 2021). Hawaii Highways Climate Adaptation Action Plan. HDOT Highways Division. https://hidot.hawaii.gov/wp-content/uploads/2021/07/HDOT-Climate-Resilience-Action-Plan-and-Appendices-May-2021.pdf. Accessed September 2023.

how climate change and ocean hazards can affect the NHS and provides decision-making guidance to minimize these effects and increase resiliency.[6]

Last updated in 1996, the *West Maui Community Plan* and its accompanying maps was updated in 2022. This update incorporates new components mandated by Maui County Code Chapter 2.80B and aligns with the *Countywide Policy Plan* and the *Maui Island Plan*. It includes a vision statement, objectives, policies, and action steps designed to steer development and conservation efforts in West Maui. The updated plan identifies strategies that would help West Maui adapt to climate change and build a more resilient and self-sustaining community.[7]

Each of the Build Alternatives was adapted from the County of Maui's 2005 *Pali to Puamana Parkway Master Plan*. And while this plan predates subsequent State plans, such as the 2021 *Hawaii Highways Climate Adaptation Action Plan*, they are consistent in focus and purpose. Both plans serve to enhance the resiliency of transportation assets to coastal hazards while committing to working with all stakeholders in addressing shared climate change and coastal hazard challenges.

3.13.2 Methodology

Climate change is interconnected with ecological systems and processes. The synergistic and additive effects of climate change influence a variety of factors including floodplain function, biodiversity, and natural hazards. For discussions on climates effects on floodplains, flora and fauna, and natural hazards, see Chapters 3.09, 3.10, and 3.11, respectively.

The 2017 *Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report* introduces an SLR-XA to illustrate regions within the state that are vulnerable to persistent flooding. By modeling annual high-wave flooding, coastal erosion, and passive flooding, the report presents multiple projections for sea level rise: 0.5-foot, 1.1-foot, 2.0-foot, and 3.2-foot. In Hawaiʻi, there is accepted guidance to use a 3.2-foot sea level rise as a planning target for 2100, with discussion of a 6-foot target in that time frame.[8] The 2013 Intergovernmental Panel on Climate Change (IPCC) *Fifth Assessment Report* was referenced for these guidelines. While there is a *Sixth Assessment Report*, the *Fifth Assessment Report* is still considered acceptable for planning purposes, and a 6-foot scenario is still appropriate for considering far-reaching potential effects (according to Sea Engineering, Inc. [2023]).

The most aggressive sea level rise curve, resulting from the highest warming scenario (RCP8.5), was used to project this sea level rise elevation (3.2 feet) in the year 2100. The 3.2-feet scenario is also approximately aligned with the Intermediate regional projection for Hawaii from the 2022 *Interagency Task Force Report*. The discussion for a 6-foot scenario as an additional safety factor was developed around the Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force Intermediate to High regional projection for Hawaiʻi, which projected approximately 6 feet of sea level

6 Francis, O., H. Brandes, G. Zhang, D. Ma, L. Yang, O. Doygun, H. Togia, C. Rossi, G. Costanzo (2019). State of Hawaii Statewide Coastal Highway Program Report. Prepared for the State of Hawai'i Department of Transportation, Project Number HWY-06-16, August 21, 2019.

7 County of Maui. (January 2022). West Maui Community Plan Update 2022. Long Range Planning. https://www.mauicounty.gov/2476/West-Maui-Community-Plan-Update-2022. Accessed September 2023.

8 Sea Engineering Inc. (September 2023). Sea Level Rise Wave Inundation Study – Honoapiʻilani. Prepared for WSP USA.

rise by 2100. The SLR-XA does not include effects from storm surge, tsunami, or other natural hazards. Analysis of these hazards can be found in Section 3.11, Geology, Soils and Natural Hazards. The SLR-XA consists of the three impact vulnerabilities: passive flooding, annual high-wave flooding, and coastal erosion TABLE 3.13-1).

As a companion to the 2017 *Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report*, the State of Hawaiʻi Sea Level Rise Viewer was developed to offer map data illustrating future projections of hazard exposure and evaluate vulnerabilities stemming from sea level rise.[9] The State of Hawaiʻi Sea Level Rise Viewer uses a projection of 3.2 feet of global mean sea level rise, based on projections from the 2013 IPCC *Fifth Assessment Report*. It was developed by the Pacific Islands Ocean Observing System, the University of Hawaiʻi Sea Grant College Program, the Hawaiʻi Department of Land and Natural Resources (DLNR), and the State of Hawaiʻi Office of Planning and Sustainable Development (OPSD). Act 83 of the Session Laws of Hawaiʻi 2014 and Act 32 of Session Laws of Hawaiʻi 2017 mandated the 2017 *Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report* and developing the State of Hawaiʻi Sea Level Rise Viewer. Unless otherwise noted, any references to the SLR-XA boundary assumes the 3.2-foot sea level rise scenario.

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[9] Hawaiʻi Climate Change Mitigation and Adaptation Commission. 2021. State of Hawaiʻi Sea Level Rise Viewer. Version 1.11. Prepared by the Pacific Islands Ocean Observing System (PacIOOS) for the University of Hawaiʻi Sea Grant College Program and the State of Hawaiʻi Department of Land and Natural Resources, Office of Conservation and Coastal Lands, with funding from National Oceanic and Atmospheric Administration Office for Coastal Management Award No. NA16NOS4730016 and under the State of Hawaiʻi Department of Land and Natural Resources Contract No. 64064. http://hawaiisealevelriseviewer.org. Accessed July 2023.

TABLE 3.13-1. **SLR-XA Components**

COMPONENT	DESCRIPTION
Passive Flooding Area	The passive flooding area within the SLR-XA indicates lands that are projected to experience daily or more frequent flooding during high tide under specific sea level rise scenarios (for example, 3.2-foot rise). As sea levels rise, passive flooding resulting from sea level increase would also exacerbate the impact of less frequent flood events with a 1% annual chance depicted in Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps. This exacerbation occurs through higher water levels caused by direct marine inundation, rising groundwater, and impaired drainage. Notably, the passive flooding model does not explicitly account for the effects of rising groundwater tables, which can further contribute to the frequency and severity of flooding in many low-lying coastal areas. Nonetheless, the model serves as a useful initial assessment by identifying vulnerable low-lying areas where groundwater flooding is likely to occur.[10]
Annual High-Wave Flooding	The annual high-wave flooding area within the SLR-XA depicts lands that are projected to experience flooding at least once a year (or more frequently) due to high waves that wash over the shoreline. Within this hazard zone, lands at the seaward end would be subject to more frequent flooding, occurring multiple times per year, and with greater depth and velocity compared to lands toward the back of the zone. Unlike passive flooding, the annual high-wave flood zone poses additional risks to both land and structures. The exposure to wave velocity and currents within this zone can lead to scouring and damage, which effects the integrity of the land and structures.[11]
Coastal Erosion	The coastal erosion model indicates that areas landward of the boundary have an 80% probability of being safe from erosion at the specified sea level rise height (for example, 3.2 feet). The erosion model estimates shoreline change resulting from a combination of the historic erosion trends, and the modeled changes in beach profile with rising water levels. This model highlights areas that are susceptible to future land loss and would become unsuitable for construction, assuming that the shoreline is allowed to naturally retreat. However, in many instances, natural shoreline migration may not be permitted, which can have negative implications for the beach environment in the form of beach narrowing and loss.[12, 13]

10 Habel, S., Fletcher, C. H., Rotzoll, K., El-Kadi, A. I., & Oki, D. S. 2019. Comparison of a simple hydrostatic and a data-intensive 3D numerical modeling method of simulating sea-level rise induced groundwater inundation for Honolulu, Hawai'i, USA. Environmental Research Communications, 1(4), 041005.

11 Romine, B.M.; Habel, S.; Lemmo, S.J.; Pap, R.A.; Owens, T.M.; Lander, M.; Anderson, T.R. 2020. Guidance for Using the Sea Level Rise Exposure Area in Local Planning and Permitting Decisions. Prepared by the University of Hawaiʻi Sea Grant College Program with the Hawaiʻi Department of Land and Natural Resources - Office of Conservation and Coastal Lands for the Hawaiʻi Climate Change Mitigation and Adaptation Commission - Climate Ready Hawaiʻi Initiative. (Sea Grant Publication TT-20-01).

12 Fletcher, C.H., Romine, B.M., Genz, A.S., Barbee, M.M., Dyer, Matthew, Anderson, T.R., Lim, S.C., Vitousek, Sean, Bochicchio, Christopher, and Richmond, B.M., 2012, National assessment of shoreline change: Historical shoreline change in the Hawaiian Islands: U.S. Geological Survey Open-File Report 2011–1051, 55 p. (Also available at https://pubs.usgs.gov/of/2011/1051).

13 University of Hawaiʻi Coastal Geology Group. 2020, updated 2023. Sea Level Rise – Coastal Erosion. Version 2.1. https://planning.hawaii.gov/gis/download-gis-data-expanded/. Accessed [date]; University of Hawaiʻi Coastal Geology Group. 2017. Sea Level Rise – Vegetation Line. https://planning.hawaii.gov/gis/download-gis-data-expanded/. Accessed July 2023.

The *National Oceanic and Atmospheric Administration (NOAA) Technical Report NOS CO-OPS 083* (2017) emphasizes that coastal planners making critical decisions should weigh several factors when choosing which SLR scenario to use. These factors include the type of decision to be made, expected future performance, and overall risk tolerance.[14] For example, when designing a patio for a home or a bike path, a lower SLR scenario could be used for the design because it does not support any critical functions or may more easily adapt to rising water levels and therefore may have a higher-risk tolerance. In contrast, when designing a hospital or power plant with a low-risk tolerance and high criticality of the asset, a higher SLR scenario could be selected to design for future conditions. Scenarios help serve as a starting point for on-the-ground coastal preparedness planning and risk management processes needed to ensure that U.S. coastal communities remain vibrant and resilient to ongoing future changes in sea level.

Because Honoapiʻilani Highway is considered critical infrastructure, the risk tolerance is low; therefore, considerations of sea level rise hazards at and beyond the current 3.2-foot boundary are included in project evaluations to adhere to IPCC and NOAA planning recommendations. For this purpose, a passive flooding with 6-foot sea level rise projection prepared by NOAA is used in this evaluation in addition to the 3.2-foot boundary for considering far-reaching, potential effects. The description, assumptions, and limitations of a 6-foot sea level rise projection are the same as those above in the 3.2-foot passive flooding in that it does not explicitly account for the effects of rising groundwater tables, waves, or coastal erosion.[15,16] Current projections of sea level rise may underestimate inundation areas.

Sea Engineering Inc., was contracted to conduct a sea level rise and wave inundation study for the Project. Included in Appendix 3.13, Climate Change and Sea Level Rise, the 2023 *Sea Level Rise Wave Inundation Study, Honoapiʻilani Highway Realignment*, includes a comprehensive summary of the current sea level rise projections, a review of the Hawaiʻi SLR-XA, numerical modeling of wave-induced flooding for a future sea level of 3.2 feet for existing topography and each of the Build Alternatives, and a summary of project area FEMA flood hazard zones. The study used the XBeach nonhydrostatic numerical model, which includes the same annually recuring wave parameters as the SLR-XA (but it is two-dimensional and higher resolution).

TABLE 3.13-2 describes the various assessment parameters (3.2 feet and 6 feet). The No Build Alternative and the Build Alternatives are evaluated by modeling localized changes to SLR-XA core elements described above.

14 Hall, J.A., S. Gill, J. Obeysekera, W. Sweet, K. Knuuti, and J. Marburger (2016) Regional Sea Level Scenarios for Coastal Risk Management: Managing the Uncertainty of Future Sea Level Change and Extreme Water Levels for Department of Defense Coastal Sites Worldwide. U.S. Department of Defense, Strategic Environmental Research and Development Program. 224 pp.

15 Hawaiʻi Climate Change Mitigation and Adaptation Commission. 2021. State of Hawaiʻi Sea Level Rise Viewer. Version 1.11. Prepared by the Pacific Islands Ocean Observing System (PacIOOS) for the University of Hawaiʻi Sea Grant College Program and the State of Hawaiʻi Department of Land and Natural Resources, Office of Conservation and Coastal Lands, with funding from National Oceanic and Atmospheric Administration Office for Coastal Management Award No. NA16NOS4730016 and under the State of Hawaiʻi Department of Land and Natural Resources Contract No. 64064. http://hawaiisealevelriseviewer.org.

16 NOAA Office for Coastal Management. Sea Level Rise Viewer. https://coast.noaa.gov/slr/. Accessed September 2023.

TABLE 3.13-2. **Sea Level Rise Assessment Overview**

ASSESSMENT METRIC	DESCRIPTION	PURPOSE	CONSISTENT WITH	SOURCE
SLR-XA (3.2 ft)	Overlay of three hazards: passive flooding, annual high-wave flooding, costal erosion modeled for a 3.2-foot sea level rise scenario.	Serves as the primary planning criteria for existing and future development.	• IPCC Fifth Assessment Report, IPCC Sixth Assessment Report • HDOT Climate Resilience Adaptation Action Plan • Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report • Honolulu Climate Change Commission's Sea Level Rise Guidance	Pacific Islands Ocean Observing System (PacIOOS)
XBeach Non-Hydrostatic Numerical Model (3.2 ft)	Modeling of wave induced flooding given 3.2 feet of sea level rise for existing topography and each of the four highway realignment alternatives.	Provides higher-resolution site-specific inundation modeling to better define the hazards associated with passive and annual high-wave flooding for 3.2 ft of sea level rise.	• IPCC Fifth Assessment Report, IPCC Sixth Assessment Report • HDOT Climate Resilience Adaptation Action Plan • Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report • Honolulu Climate Change Commission's Sea Level Rise Guidance	Sea Engineering Inc.
Passive Flooding 6-feet	A sea level rise projection of 6 feet above a local mean higher high water (MHHW).	Passive flooding with 6 feet of sea level rise is provided to support assessment of sea level rise hazards, particularly for critical infrastructure and for other development with low tolerance for risk.	• IPCC Fifth Assessment Report • Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force Intermediate-High Scenario • Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report • Honolulu Climate Change Commission's Sea Level Rise Guidance (Directive No. 18-02)	National Oceanic and Atmospheric Administration (NOAA)

3.13.3 Affected Environment

West Maui has a mild tropical climate that is characterized by abundant sunshine, persistent northeast trade winds, relatively constant temperatures, and moderate humidity. Severe storms have historically been infrequent in this region of Maui. Mean monthly temperatures range from mid-80 degrees Fahrenheit in the summer months, to low-70 degrees Fahrenheit during the winter. Annual average rainfall is less than 30 inches, with most of the rainfall occurring between October and March.

Hawaiʻi's geographical location in the Pacific Ocean makes the state particularly susceptible to adverse and extreme weather events. The rise in global temperatures and the associated rise in sea levels is primarily attributed to the emission of GHGs.[17] In Hawaiʻi, average air temperatures have risen approximately 1.1 degree Celsius (2 degrees Fahrenheit) since 1950, with a sharp increase in warming over the last decade.[18] Additionally, since the 1960s, the frequency of days per year with high-tide flooding in Honolulu has nearly doubled.[19] The United Nations Environment Programme *Emissions Gap Report 2022* points to a likely warming of 2.8 degrees Celsius (5 degrees Fahrenheit) by 2100.[20] As GHGs raise global surface temperatures, ice sheets melt and ocean heat uptake increases, contributing to long-term sea level rise. Section 3.15 includes additional discussion on potential project contributions to GHG emissions.

The changing climate patterns resulting from global warming pose various potential effects beyond sea level rise, including storm surges and heightened flooding risks. In the event of heavy rainfall, the water level in adjacent streams may rise rapidly. Sea level rise would also increase the severity of coastal flooding during less-frequent but more severe events such as extreme rainfall and storm surge.

Flood probability comes from a combination of historic events and projected future conditions. The Maui County *Hazard Mitigation Plan* lists West Maui as having a greater than 90% annual chance of an inland or coastal flooding event within any given year, based on historic data and projections from the NOAA National Center for Environmental Information database.[21] Official data on the frequency of flooding of Honoapiʻilani Highway does not exist, but West Maui residents report that the highway becomes flooded frequently with the seasonal high surf with south swells and king tides. Moderate storms often wash hazardous debris onto segments of the highway. And during severe storm events, the highway is closed to traffic to safeguard motorists. Moreover, as climate change progresses, the frequency and magnitude of flood events is expected to increase. This can be attributed to an increase in extreme weather phenomena associated with El Niño-Southern Oscillation, leading to a greater occurrence of heavy rainfall events, including hurricanes and Kona storms.[22]

Over the past 10 years, the portion of the highway that is proposed to be realigned has been repaired three times after storm and high-wave events undermined pavement sections and overtopped the roadway, rendering it impassable. Repairs include a project to address erosion where approximately 4,100 feet of highway fronting Ukumehame and approximately 1,000 feet of highway fronting Olowalu would be shifted 8 to 12 feet mauka within the existing roadway right-of-way. These projects are

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17 City and County of Honolulu Climate Change Commission. (March 31, 2023). Climate Change Brief. https://static1.squarespace.com/static/5e3885654a153a6ef84e6c9c/t/64374370c0631e3ac922692a/1681343347345/Climate+Change+Brief+2023.pdf. Accessed September 2023.

18 NOAA National Centers for Environmental Information (2022) State Climate Summaries 2022: Hawaiʻi.

19 Marra, J.J., and Kruk, M.C. (2017) State of Environmental Conditions in Hawaiʻi and the U.S. Affiliated Pacific Islands under a Changing Climate: https://coralreefwatch.noaa.gov/satellite/publications/state_of_the_environment_2017_hawaii-usapi_noaa-nesdis-ncei_oct2017.pdf.

20 United Nations Environment Programme (2022). Emissions Gap Report 2022: The Closing Window — Climate crisis calls for rapid transformation of societies. Nairobi. https://www.unep.org/emissions-gap-report-2022.

21 County of Maui. 2020. Maui County Multi-Hazard Mitigation Plan. August 2020. https://www.mauicounty.gov/1832/Multi-Hazard-Mitigation-Plan.

22 Chu, P., Y. R. Chen, and T. A. Schroeder, 2010: Changes in Precipitation Extremes in the Hawaiian Islands in a Warming Climate. J. Climate, 23, 4881–4900, https://doi.org/10.1175/2010JCLI3484.1.

short-term fixes because they address only the most severe locations where the road is already undermined.

3.13.3.1 Sea Level Rise Exposure Area Overview for Project Area

The hazards presented by sea level rise include a combination of passive flooding, annual high-wave flooding, and coastal erosion.

FIGURE 3.13-1 and FIGURE 3.13-2 show SLR-XA 3.2-foot results for Olowalu and Ukumehame, respectively, for each of the Build Alternatives.[23] It also shows the portions of the existing Honoapiʻilani Highway that are exposed to the SLR-XA.[24] The SLR-XA encroaches on approximately 4 miles out of the total 6 miles of the existing highway corridor. Of the roughly 2 miles outside of the SLR-XA, most of that occurs in Olowalu, while the Ukumehame area is largely within the SLR-XA. Overall, the project area is expected to experience direct effects of sea level rise associated with passive flooding, annual high-wave flooding, and coastal erosion into the future.[25,26,27]

Additionally, sea level rise may exceed the 3.2-foot projections, which requires considering a 6-foot projection as modeled by the NOAA Sea Level Rise Viewer (FIGURE 3.13-5).[28] This 6-foot projection only considers passive flooding, not wave action or coastal erosion. These omissions increase the likelihood that the extent of the flooded area is underestimated. Included in the 6-foot projection are high- and low-confidence areas of inundation. While high-confidence areas are those that may be correctly mapped as “inundated” more than 8 out of 10 times, low-confidence areas may be mapped correctly as “inundated” less than 8 out of 10 times.[29]

There are many unknowns when mapping future conditions, including natural evolution of the coastal landforms as well as the data used to predict changes. The presentation of confidence in FIGURE 3.13-5 only represents the known error in the elevation data and tidal corrections. It is important to include both areas of high and low mapping confidence to consider the full potential scale of a 6-foot passive flooding scenario, as areas that are potentially affected under the 6-foot passive flooding scenario are similar to those potentially affected by the SLR-XA. These areas include the

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23 Tetra Tech, Inc. and University of Hawaiʻi Coastal Geology Group. 2017. Sea Level Rise – Exposure Area. https://planning.hawaii.gov/gis/download-gis-data-expanded/. Accessed September 2023.

24 Tetra Tech, Inc. 2017. Sea Level Rise – Flooded Highways. https://planning.hawaii.gov/gis/download-gis-data-expanded/. Accessed September 2023.

25 University of Hawaiʻi Coastal Geology Group and Tetra Tech, Inc. 2017. Sea Level Rise – Passive Flooding. https://planning.hawaii.gov/gis/download-gis-data-expanded/. Accessed July 2023.

26 University of Hawaiʻi Coastal Geology Group and Tetra Tech, Inc. 2017. Sea Level Rise – Annual High Wave Flooding. https://planning.hawaii.gov/gis/download-gis-data-expanded/. Accessed July 2023.

27 University of Hawaiʻi Coastal Geology Group. 2020, updated 2023. Sea Level Rise – Coastal Erosion. Version 2.1. https://planning.hawaii.gov/gis/download-gis-data-expanded/. Accessed July 2023; University of Hawaiʻi Coastal Geology Group. 2017. Sea Level Rise – Vegetation Line. https://planning.hawaii.gov/gis/download-gis-data-expanded/. Accessed July 2023.

28 NOAA Office for Coastal Management. Sea Level Rise Viewer. https://coast.noaa.gov/slr/. Accessed July 2023.

29 Schmid, K., Hadley, B., & Waters, K. (2014). Mapping and Portraying Inundation Uncertainty of Bathtub-Type Models. Journal of Coastal Research, 30(3), 548–561. https://doi.org/10.2112/JCOASTRES-D-13-00118.1.

southern portion of Olowalu through to Pāpalaua Wayside Park, with larger potentially affected areas just northwest of Ehehene Street after the common alignment, and the Ukumehame Firing Range.

The Sea Engineering Inc. XBeach non-hydrostatic numerical (XBeach) modeling of wave-induced flooding for a future sea level of 3.2 feet, which includes the same annually recuring wave parameters as the SLR-XA (but it is two-dimensional and higher resolution), was done for the existing topography in the project area and each of the Build Alternatives.

The model encompasses the existing topography and bathymetry of all Build Alternatives and proposed changes in ground elevation for all Build Alternatives that result from the construction of structures and embankments. For the existing ground results, drainage culverts and bridge/causeway areas within each alignment were not adjusted and left as the existing ground level to allow modeled flood waters to pass freely through these areas. Road and bridge deck elevations for these areas are not included in the model. The model topography uses a bare-earth digital elevation model where buildings and vegetation are not included. Ground elevations for these areas are interpolated using the surrounding ground levels. The model does not account for flooding/drainage through underground utilities or groundwater intrusion. Erosion is also not included in the model.

Sea Engineering Model results include existing ground flood extents and corresponding depths and elevations. Max flood depth refers to the depth of flood water above the ground elevation, while max flood elevation refers to the height of elevation above mean sea level (msl). Both are important to incorporate into highway design to avoid flooding. Notably, XBeach modeling results are representative of an annually occurring south swell wave event and does not account for mitigation, such as elevating the highway. Flooding may be more severe for less frequent but larger wave events combined with higher sea levels.

The results of this study show that due to the low-lying nature of this portion of the West Maui coastline, the Build Alternatives may be susceptible to future wave flooding with sea level rise. Appendix 3.13 provides more details about the modeling, and Section 3.13.4.2 provides key findings of the study.

FIGURE 3.13-1. **3.2-Foot Sea Level Rise Exposure Area (SLR-XA) in Olowalu Scenario**

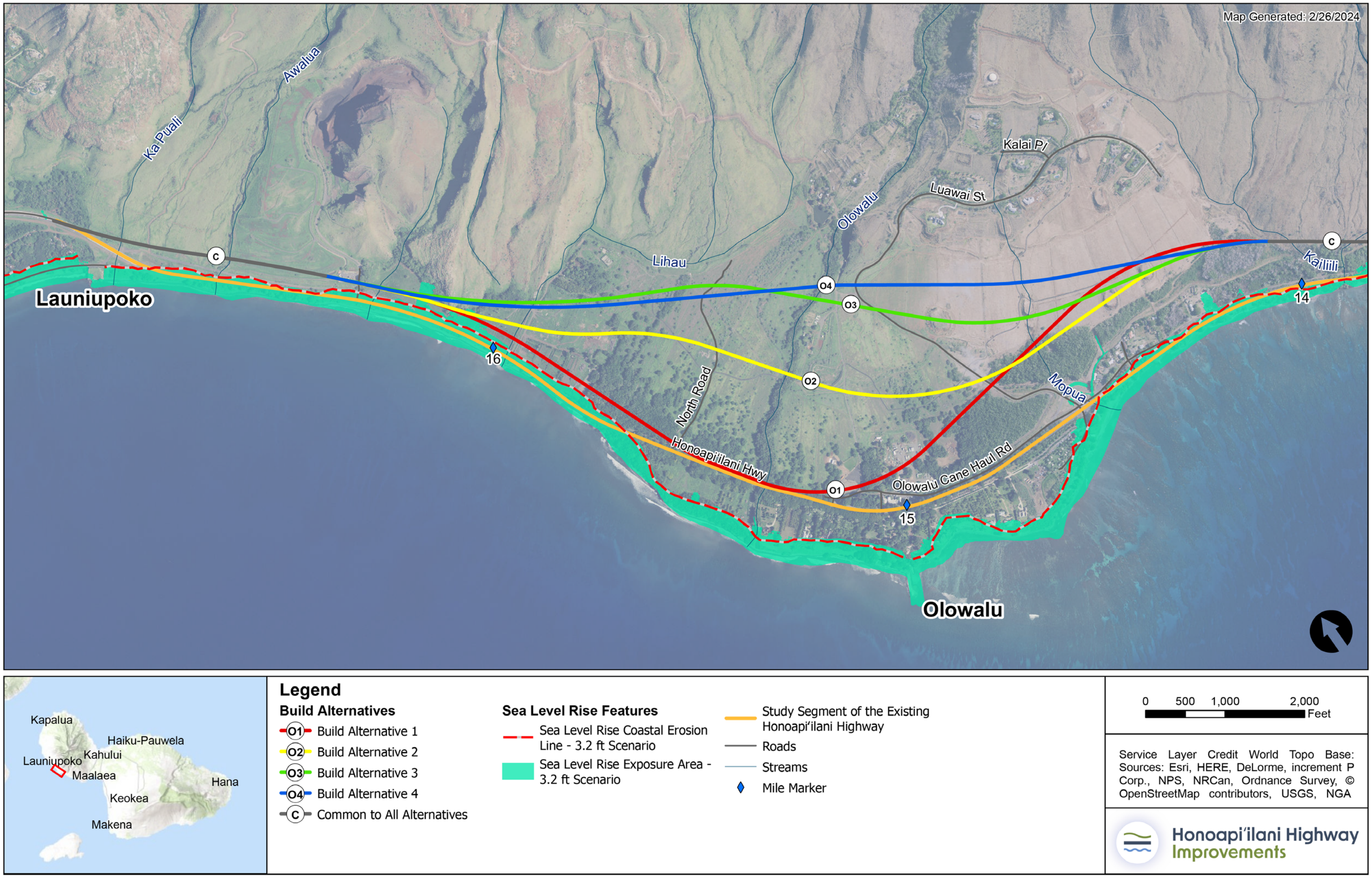


FIGURE 3.13-2. **3.2-Foot Sea Level Rise Exposure Area (SLR-XA) in Ukumehame Scenario**

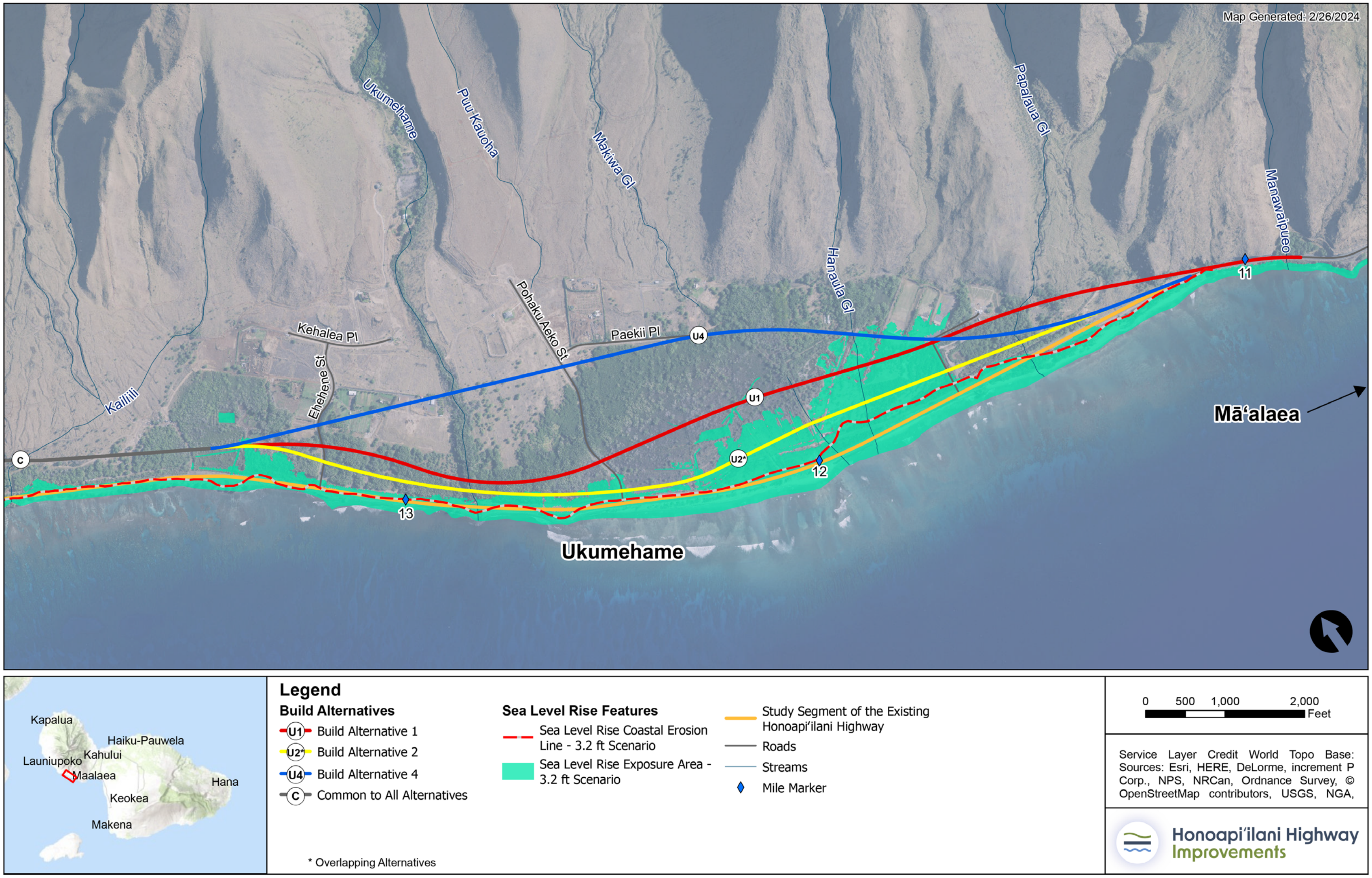


FIGURE 3.13-3. **6-Foot Passive Flooding Scenario in Olowalu**

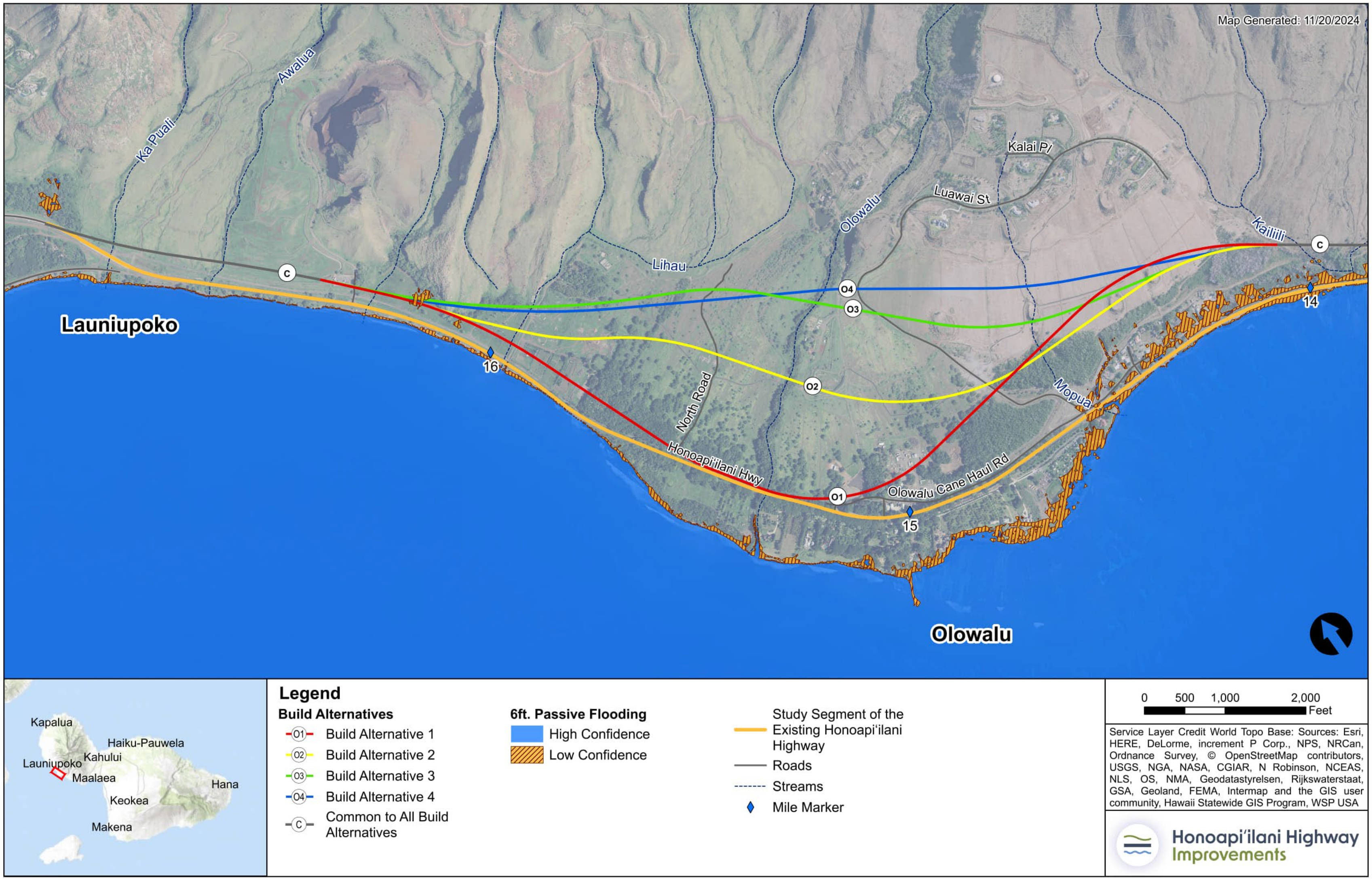
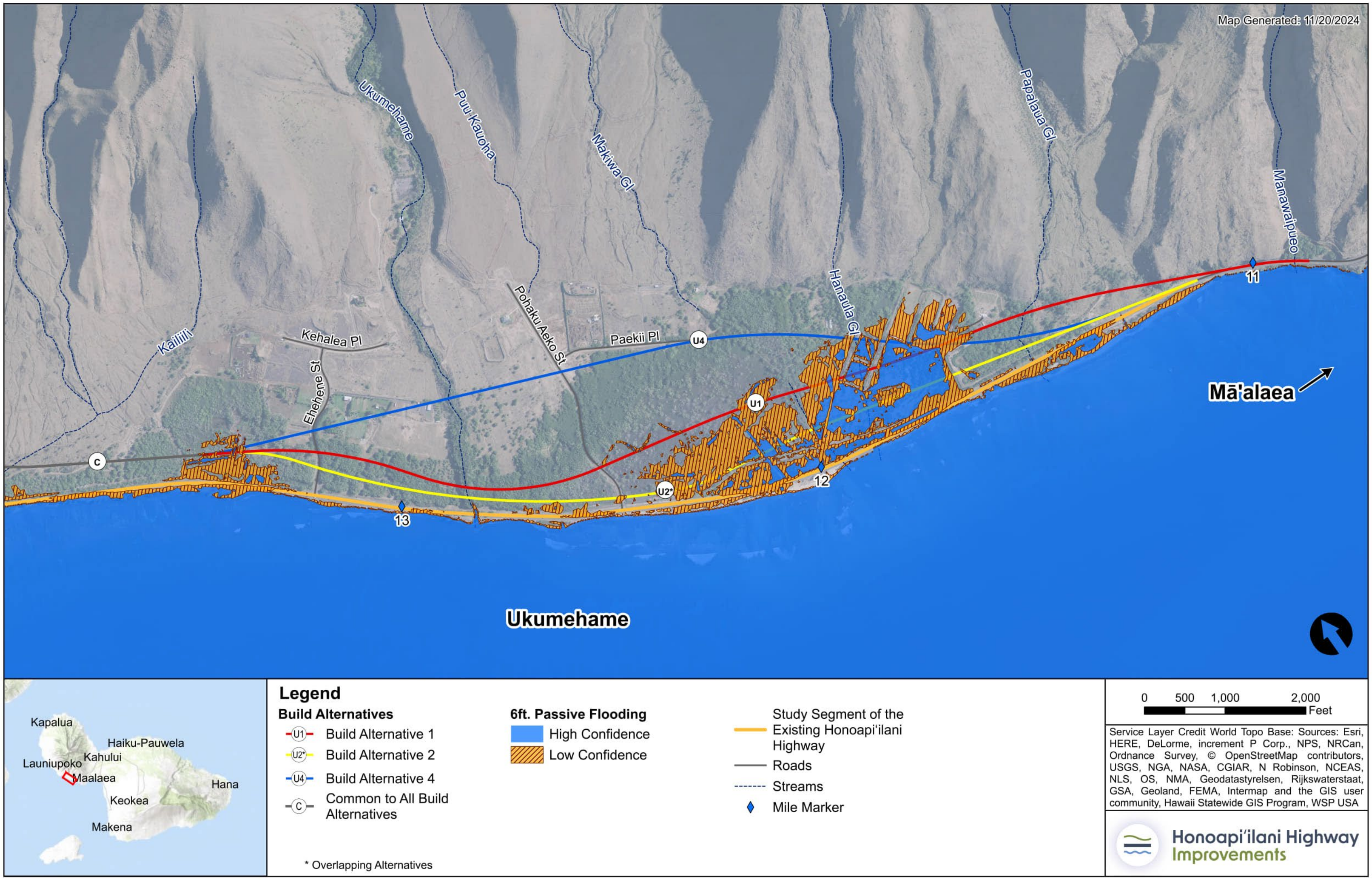


FIGURE 3.13-4. **6-Foot Passive Flooding Scenario in Ukumehame**

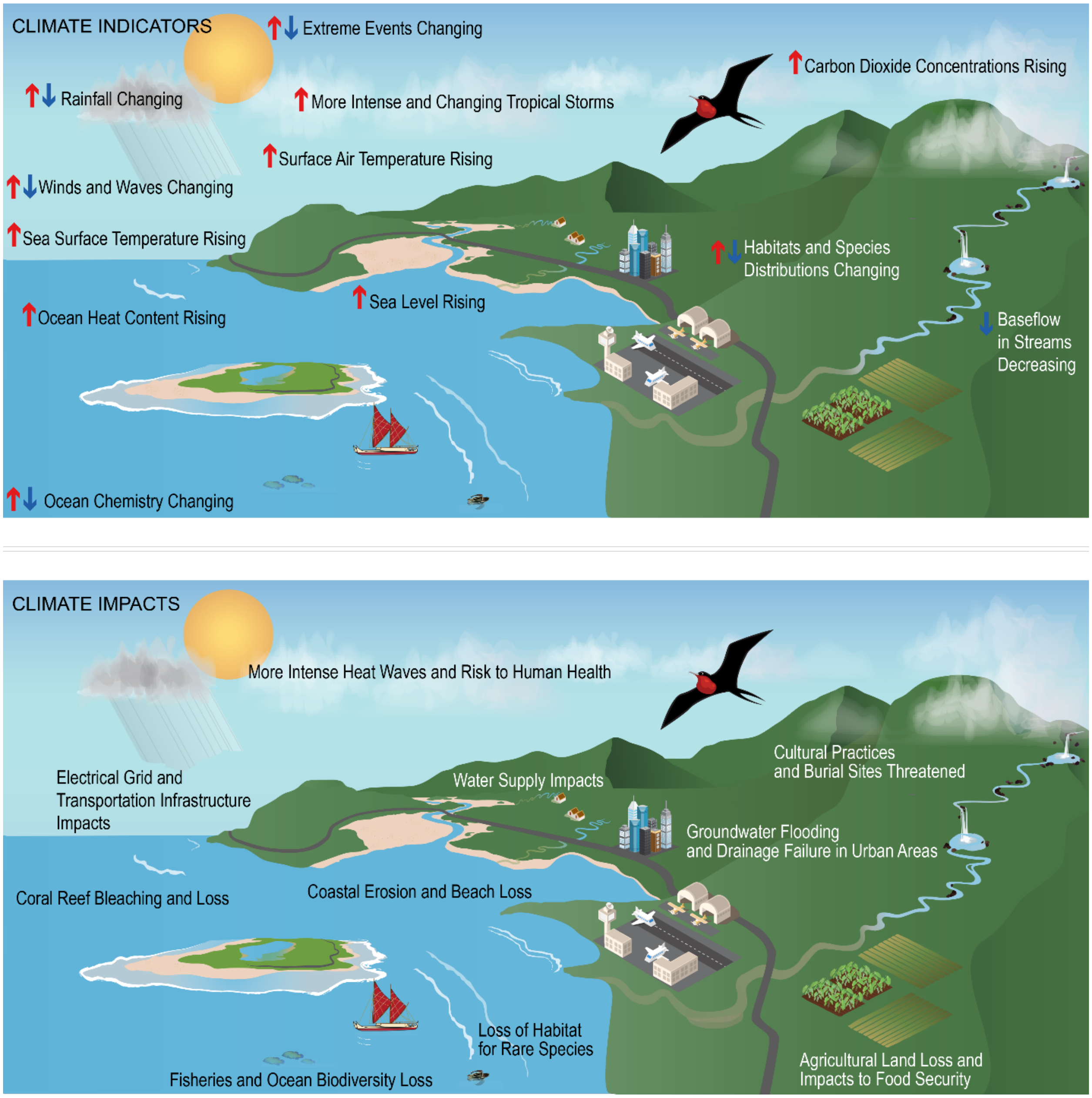


3.13.4 Environmental Consequences

Climate change and sea level rise have a cascading effect that can affect all elements within the project area. They affect water quality, through increased wildfires and storms, and people through increased heat waves, droughts, floods, and storms. TABLE 3.13-5 describes some of these interconnected effects resulting from climate hazards from the 2018 *Fourth National Climate Assessment*.[30] While these effects are synergistic and additive, most of them are not directly related to the Project. The Build Alternatives and appropriate mitigation measures can improve the resilience of Hawaiʻi's transportation system to such effects, primarily those associated with the SLR-XA. See Section 3.15, Air Quality and Energy, for additional discussion on potential project contributions to GHG emissions.

30 U.S. Global Change Research Program. (2018). Fourth National Climate Assessment. Ch. 27 – Hawaii and U.S.-affiliated Pacific Islands. https://nca2018.globalchange.gov/chapter/27/.

FIGURE 3.13-5. **Climate Hazards Cascading Effects**



Source: Fourth National Climate Assessment – Ch. 27: Hawaii and U.S.-Affiliated Pacific Islands (2018)

3.13.4.1 No Build Alternative

As TABLE 3.13-1 shows, the No Build Alternative (that is, no changes to existing conditions) faces a greater threat from sea level rise than any of the Build Alternatives. The 3.2-foot SLR-XA encroaches on roughly 4 out of the total 6 miles of the existing highway in the study area. Of the roughly 2 miles outside of the SLR-XA, most of that section occurs in Olowalu just south of the Maui Paintball facility extending to Luawai Street (FIGURE 3.13-1). Service disruptions (such as closures) and the need for emergency repairs are expected to increase as the frequency and magnitude of these flood occurrences are exacerbated by climate change and sea level rise.

Nature-based solutions, revetments and seawalls, or a combination of those protections combined with elevating the road are short- to mid-term fixes that are assumed with the No Build Alternative due to the current state of the road and chronic effects from coastal hazards.

3.13.4.2 Build Alternatives

Common to All Build Alternatives in both Olowalu and Ukumehame

Based on the limitations of alignment options at each end of the project area, a portion of all Build Alternatives in Olowalu as well as in Ukumehame are likely to remain within the SLR-XA (TABLE 3.13-3, TABLE 3.13-4). If the Build Alternatives were constructed at the existing ground level elevation, they would be within the horizontal plane of the SLR-XA in certain areas. But elevating the vertical profile would minimize adverse effects from sea level rise.

As all the Build Alternatives cross flood hazards areas, freeboard would be required. Freeboard is an additional amount of height above Base Flood Elevation where a structure must be elevated or floodproofed to comply with floodplain management regulations.[31] Freeboard height would be determined in final design.

Max flood depth and max flood elevations for each Build Alternative in each region are listed in TABLE 3.13-5 and TABLE 3.13-6. For each Build Alternative, flood depths and elevations may vary at different points along the alignment. To account for this, the greatest max flood depths and max flood elevations are presented to identify the high end of alignment elevation needed to avoid flooding. Appendix 3.13 provides more detailed information.

31 FEMA. (July 8, 2020). Freeboard. https://www.fema.gov/glossary/freeboard#:~:text=Freeboard-,a..or%20community%20floodplain%20management%20regulations. Accessed December 2023.

FIGURE 3.13-6. **XBeach-NH Modeled Maximum Flood Extent**

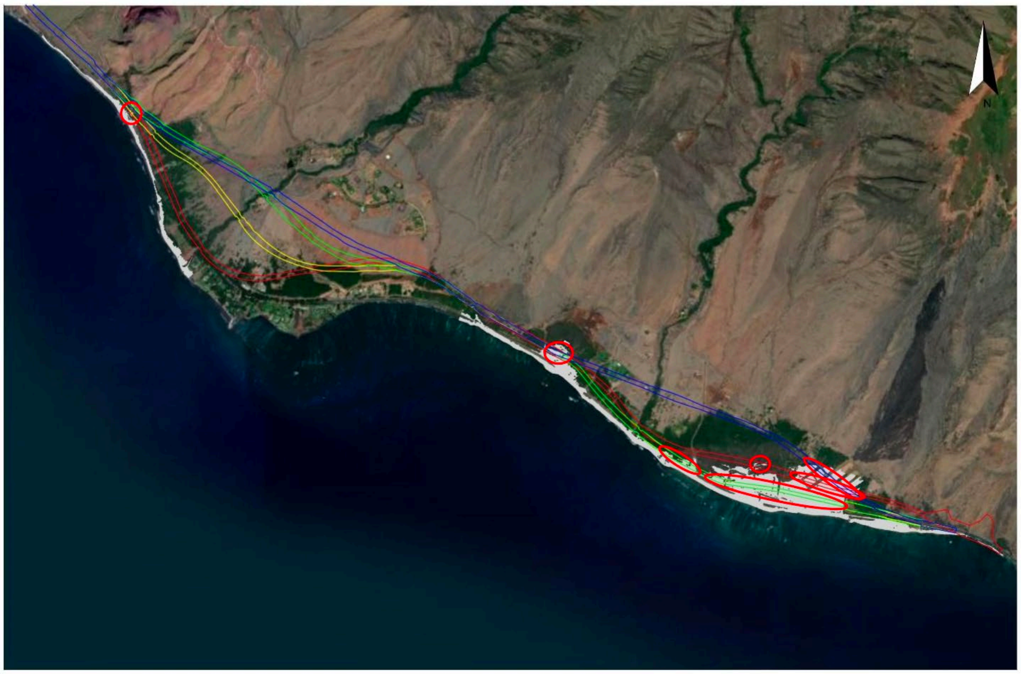


Figure 5-5. XBeach-NH modeled maximum flood extent (gray) for existing ground relative to alternatives 1 (red), 2 (yellow/green), 3 (green), and 4 (blue) alignments. Overlapping flooded areas are outlined in red.

Olowalu

Common to All Build Alternatives in Olowalu

In Olowalu, XBeach modeled flooding of the Build Alternatives at existing ground elevation is only present for Build Alternatives 1 and 2, at the alignment divergence point in the northern portion of the project area (FIGURE 3.13-6). All Build Alternatives are within the SLR-XA at this location just south of the Olowalu Recycling and Refuse Convenience Center. In this location, SLR-XA covers a larger area than XBeach modeled flooding, incorporating parts of Build Alternative 3 and Build Alternative 4. FIGURE 3.13-7 depicts where XBeach modeling identifies areas at existing ground elevation that are susceptible to potential flooding for a 3.2-foot sea level rise scenario in Olowalu.

All Build Alternatives share approximately the same area within the low-confidence area of passive flooding with 6 feet of sea level rise. This is a small area just south of the recycling center. No portions of the Build Alternatives in Olowalu are within the high-confidence area of passive flooding with 6 feet of sea level rise (TABLE 3.13-3).

Build Alternative 1

Build Alternative 1 is the largest area within the SLR-XA in Olowalu. XBeach modeling indicates flooding in the same general area as within the SLR-XA, just south of the Olowalu Recycling and Refuse Convenience Center (Appendix 3.13, Figure 5-5). To avoid flooding, Build Alternative 1 needs to be raised 1.0 foot above ground elevation and 6.7 feet above msl with freeboard (TABLE 3.13-5).

Build Alternative 2

Build Alternative 2 is the second largest area within the SLR-XA in Olowalu. XBeach modeling indicates flooding in the same general area as within the SLR-XA, just south of the Olowalu Recycling and Refuse Convenience Center (Appendix 3.13, Figure 5-5). To avoid flooding, Build Alternative 2 needs to be raised 0.8 feet above ground elevation and 6.7 feet above msl with freeboard (TABLE 3.13-5).

Build Alternative 3 and Build Alternative 4

Build Alternative 3 and 4 are tied for the smallest area within the SLR-XA in Olowalu. XBeach modeling indicates no flooding for Build Alternatives 3 and 4 in Olowalu (Appendix 3.13).

FIGURE 3.13-7. **XBeach-NH Modeled Maximum Flood Extent - Olowalu**

Source: Sea Engineering Inc. (December 2023). Sea Level Rise Wave Inundation Study Honoapiʻilani Highway Realignment.

Ukumehame

Common to all Build Alternatives in Ukumehame

In Ukumehame, all Build Alternatives traverse flood prone areas identified by SLR-XA, XBeach modeling at existing ground elevation, and both high- and low-confidence areas of passive flooding with 6-feet of sea level rise, largely on viaduct.[32] There is slightly greater coverage of low-confidence areas of

[32] As described in Chapter 2, an at-grade embankment was evaluated as an alternative to a viaduct through Ukumehame around the firing range and would have greater environmental effects for all the Build Alternatives.

passive flooding with 6-feet of sea level rise than high confidence for all Build Alternatives in Ukumehame (TABLE 3.13-4).

Common flood prone areas for all Build Alternatives include at the southern end of the common alignment, through the Ukumehame Firing Range, and at the Pali.

Build Alternative 1

Build Alternative 1 has the third largest area within SLR-XA, as well as third largest area within both high- and low-confidence areas of passive flooding with 6-feet of sea level rise in Ukumehame (TABLE 3.13-4). This overlap occurs, generally, just northwest of Ehehene Street at the southern end of the common alignment, then just before the Ukumehame Firing Range, and a third portion through the Ukumehame Firing Range. XBeach modeling indicates flooding in same general areas as within the SLR-XA, with a greater area facing flooding at the southern end of the common alignment (Appendix 3.13, Figure 5-6). To avoid XBeach modeled flooding, Build Alternative 1 needs to be raised 4.7 feet above ground elevation and 7.1 feet above msl with freeboard (TABLE 3.13-6).

Build Alternatives 2 and 3

Build Alternatives 2 and 3 have the largest area within SLR-XA, as well as largest area within both high- and low-confidence areas of passive flooding with 6-feet of sea level rise in Ukumehame (TABLE 3.13-4). This overlap occurs, generally, just northwest of Ehehene Street at the southern end of the common alignment, makai of Build Alternative 1 extending north of Pōhaku ʻAeko Street, then through to the Ukumehame Firing Range driveway. XBeach modeling indicates flooding for Build Alternative 2 in the same general areas as within the SLR-XA in Ukumehame (Appendix 3.13, Figures 5-8 and 5-10). To avoid XBeach modeled flooding, Build Alternative 2 needs to be raised 4.7 feet above ground elevation and 7.1 feet above msl with freeboard (TABLE 3.13-6).

Build Alternative 4

Build Alternative 4 has the smallest area within SLR-XA, as well as least area within both high- and low-confidence areas of passive flooding with 6-feet of sea level rise in Ukumehame (TABLE 3.13-4). Generally, this overlap occurs just northwest of Ehehene Street at the southern end of the common alignment, and the most mauka portion of the Ukumehame Firing Range. XBeach modeling indicates flooding in the same general areas as within the SLR-XA in Ukumehame (Appendix 3.13, Figure 5-12). To avoid flooding, Build Alternative 4 needs to be raised 3.0 feet above ground elevation and 6.8 feet above msl with freeboard (TABLE 3.13-6).

FIGURE 3.13-8. **XBeach-NH Modeled Maximum Flood Extent - Ukumehame**

Source: Sea Engineering Inc. (December 2023). Sea Level Rise Wave Inundation Study Honoapiʻilani Highway Realignment.

3.13.5 Construction Effects

Highway service disruptions are expected to increase as climate change and sea level rise increase the frequency and magnitude of flood occurrences. There are no anticipated direct adverse construction effects of the Build Alternatives on climate change and sea level rise. However, the No Build Alternative would result in a future condition where the vulnerabilities from climate change, sea level rise, and coastal erosion remain a threat to Honoapiʻilani Highway's reliability as a critical highway link to and from West Maui.

For the No Build Alternative and the Build Alternatives within the SLR-XA, it is likely that steady interventions and repairs would be required to maintain the existing highway. Soft protections such as nature-based solutions, hard protections such as revetments and seawalls, or a combination of protections are only short- to mid-term fixes and would be continually needed to address the chronic effects from coastal hazards. Over the long term, the costs of these short- to mid-term fixes would increase and design accommodations to elevate portions of alignments above the SLR-XA would be required.

3.13.6 Indirect Effects

Shoreline hardening associated with the No Build and Build Alternatives within the SLR-XA can lead to scouring effects that hasten erosion on the seaward side of revetments and seawalls.

3.13.7 Mitigation

The Build Alternatives would provide an opportunity to reduce the highway's exposure to the SLR-XA and to storm surge and other event-based coastal effects. As portions of the highway are anticipated to remain within the SLR-XA based on limitations of alignment options at each end of the project area, these sections would require mitigation in the form of designs to elevate the roadway above the SLR-XA. Without this mitigation, the highway would be a less reliable transportation asset with anticipated closures and restrictions to the full use of the roadway. Strengthening and reinforcing the highway's reliability would improve the efficiency of not only the critical daily travel demands of Maui residents, businesses, and visitors, but also of critical emergency response services.

As noted in Section 2.3, Build Alternatives, there are two areas (both less than 0.5 acre) in Olowalu that cannot avoid SLR-XA. Located just south of the Olowalu Recycling and Refuse Convenience Center (Figure 2.7), these areas would require armoring to protect future shorelines from wave-runup.

According to The Nature Conservancy (2017), natural climate solutions can be used to further mitigate climate change effects through several pathways. Additional carbon sequestration can be achieved through the integration of trees into landscaping in woodland, grassland, and shrubland communities. Other natural climate solutions include avoiding the degradation and loss of wetlands and forest conversion, which in turn avoids emissions of aboveground and belowground biomass and soil carbon.[33]

In accordance with the *West Maui Greenway Plan*, mitigation opportunities for effects of climate change and sea level rise include utilizing the existing highway as a bicycle and pedestrian path. Green infrastructure, along with enhanced alternative transportation options, can reduce emissions, provide native habitat being lost to climate change, more effectively manage runoff and flooding through climate-ready design elements, and offer opportunities for a healthier lifestyle.[34]

To follow recommended actions for highways outlined in the 2021 *Hawaii Highways Climate Adaptation Action Plan*, technical studies produced for this Project can be used to mitigate the effects of climate change in future HDOT projects. Because hazards such as coastal erosion are site-specific, they require field visits. These visits would be important in the validation of areas identified in this current work as being exposed to coastal erosion.

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33 Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., Schlesinger, W. H., Shoch, D., Siikamäki, J. V., Smith, P., Woodbury, P., Zganjar, C., Blackman, A., Campari, J., Conant, R. T., Delgado, C., Elias, P., Gopalakrishna, T., Hamsik, M. R., ... Fargione, J. (2017). Natural climate solutions. Proceedings of the National Academy of Sciences - PNAS, 114(44), 11645–11650. https://doi.org/10.1073/pnas.1710465114

34 Maui County. (September 2022). West Maui Greenway. https://issuu.com/mauimpo/docs/220920_wmg_final_report?fr=sNGIwNTMwNzgwNTg. Accessed September 2023.

3.13.8 Build Alternatives Comparative Assessment

TABLE 3.13-3 and TABLE 3.13-4 provide a comparative overview of approximate Build Alternative percentages within the SLR-XA, both high- and low-confidence areas of passive flooding with 6 feet of sea level rise, and a breakdown for each hazard contributing to SLR-XA in Olowalu and Ukumehame, respectively. TABLE 3.13-5 and TABLE 3.13-6 provide max flood depths and max flood elevations for each Build Alternative in Olowalu and Ukumehame, respectively, resulting from XBeach modeling. Additionally, TABLE 3.13-7 and TABLE 3.13-8 provide overall results of XBeach modeling for the length of highway impacted by modeled flooding for each Build Alternative in Olowalu and Ukumehame, respectively.

TABLE 3.13-3. **Build Alternatives Coastal Hazard Exposure Compared to the No Build Alternative - Olowalu**

TOPIC	NO BUILD ALTERNATIVE	BUILD ALTERNATIVE 1	BUILD ALTERNATIVE 2	BUILD ALTERNATIVE 3	BUILD ALTERNATIVE 4
Percentage within SLR-XA (3.2 ft)	51%	3%	2%	1%	1%
Percentage makai of Coastal Erosion Line	38%	0%	0%	0%	0%
Percentage within Annual High-Wave Flooding Area	29%	3%	2%	1%	1%
Percentage within Passive Flooding Area	5%	0%	0%	0%	0%
Percentage within 6-foot Passive Flooding Scenario (High Confidence)[35]	5%	0%	0%	0%	0%
Percentage within 6-foot Passive Flooding Scenario (Low Confidence) [36]	9%	1%	1%	1%	1%

TABLE 3.13-4. **Build Alternatives Coastal Hazard Exposure Compared to the No Build Alternative - Ukumehame**

TOPIC	NO BUILD ALTERNATIVE	BUILD ALTERNATIVE 1	BUILD ALTERNATIVE 2	BUILD ALTERNATIVE 3	BUILD ALTERNATIVE 4
Percentage within SLR-XA (3.2 ft)	73%	12%	35%	35%	8%

35 NOAA Office for Coastal Management. Sea Level Rise Viewer. https://coast.noaa.gov/slr/#/layer/cof/0/17429880.518077355/2368286.2582530957/14/satellite/128/0.8/2050/interHigh/midAccretion. Accessed October 2023.

36 NOAA Office for Coastal Management. Sea Level Rise Viewer. https://coast.noaa.gov/slr/#/layer/cof/0/17429880.518077355/2368286.2582530957/14/satellite/128/0.8/2050/interHigh/midAccretion. Accessed October 2023.

TOPIC	NO BUILD ALTERNATIVE	BUILD ALTERNATIVE 1	BUILD ALTERNATIVE 2	BUILD ALTERNATIVE 3	BUILD ALTERNATIVE 4
Percentage makai of Coastal Erosion Line	42%	0%	1%	1%	1%
Percentage within Annual High-Wave Flooding Area	62%	9%	32%	32%	6%
Percentage within Passive Flooding Area	14%	9%	24%	24%	5%
Percentage within 6-foot Passive Flooding Scenario (High Confidence) [37]	11%	8%	13%	13%	3%
Percentage within 6-foot Passive Flooding Scenario (Low Confidence) [38]	27%	12%	17%	17%	9%

TABLE 3.13-5. **Build Alternatives Max Flood Depth and Max Flood Elevation - Olowalu[39]**

TOPIC	BUILD ALTERNATIVE 1	BUILD ALTERNATIVE 2	BUILD ALTERNATIVE 3	BUILD ALTERNATIVE 4
Max Flood Depth (ft above ground elevation)	1.0 ft	0.8 ft	0 ft	0 ft
Max Flood Elevation (ft above msl)	6.7 ft	6.7 ft	0 ft	0 ft

TABLE 3.13-6. **Build Alternatives Max Flood Depth and Max Flood Elevation - Ukumehame[40]**

TOPIC	BUILD ALTERNATIVE 1	BUILD ALTERNATIVE 2	BUILD ALTERNATIVE 3	BUILD ALTERNATIVE 4
Max Flood Depth (ft above ground elevation)	4.7 ft	4.7 ft	4.7 ft	3.0 ft
Max Flood Elevation (ft above msl)	7.1 ft	7.1 ft	7.1 ft	6.8 ft

37 NOAA Office for Coastal Management. Sea Level Rise Viewer. https://coast.noaa.gov/slr/#/layer/cof/0/17429880.518077355/2368286.2582530957/14/satellite/128/0.8/2050/interHigh/midAccretion. Accessed October 2023.

38 NOAA Office for Coastal Management. Sea Level Rise Viewer. https://coast.noaa.gov/slr/#/layer/cof/0/17429880.518077355/2368286.2582530957/14/satellite/128/0.8/2050/interHigh/midAccretion. Accessed October 2023.

39 Sea Engineering Inc. (December 2023). Sea Level Rise Wave Inundation Study Honoapiʻilani Highway Realignment.

40 Sea Engineering Inc. (December 2023). Sea Level Rise Wave Inundation Study Honoapiʻilani Highway Realignment.

TABLE 3.13-7. **Comparison of Build Alternatives based on XBeach Model Results - Olowalu[41]**

Highway Alignment	BUILD ALTERNATIVE 1	BUILD ALTERNATIVE 2	BUILD ALTERNATIVE 3	BUILD ALTERNATIVE 4
Length of Highway Impacted by Modeled Flooding	148 ft	142ft	0 ft	0 ft

TABLE 3.13-8. **Comparison of Build Alternatives based on XBeach Model Results - Ukumehame[42]**

Highway Alignment	BUILD ALTERNATIVE 1	BUILD ALTERNATIVE 2	BUILD ALTERNATIVE 3	BUILD ALTERNATIVE 4
Length of Highway Impacted by Modeled Flooding	1,291 ft	2,741 ft	2,715 ft	745 ft

[41] Sea Engineering Inc. (December 2023). Sea Level Rise Wave Inundation Study Honoapiʻilani Highway Realignment.

[42] Sea Engineering Inc. (December 2023). Sea Level Rise Wave Inundation Study Honoapiʻilani Highway Realignment.