Farrington Highway Corridor Study (Task 6)

Project No. STP-093-1(030)
Nānākuli to Mākaha
O'ahu, Hawai'i

FINAL Report

Produced for:
State of Hawaiʻi Department of Transportation
Highways Division

March 2021

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

List of Tables

List of Figures

Appendices

INTRODUCTION, PURPOSE AND BACKGROUND

The Farrington Highway (Route 93) Corridor Study [STP-093-1(030)] is an effort to assess existing conditions and evaluate needs on this highway which extends from the end of H-1 northwest towards Mākaha along the Leeward Coast of Oahu. The study corridor includes the communities of Nānākuli, Māʻili, Waiʻanae and Mākaha . The objective of the Corridor Study is to recommend measures to improve safety, reduce congestion, and improve resilience. There are long-term plans for widening Farrington Highway to six lanes by 2035. This Corridor Study is intended to identify interim measures to keep Farrington Highway functioning acceptably. The Corridor Study needs to be aligned with the Hawaiʻi State Department of Transportation's (HDOT) overall vision, mission, and goals and specifically with the following Departmental goals:

- Create and manage and integrated multi-modal transportation system that provides mobility and accessibility for people and goods.
- Enhance safety.
- Protect Hawaiʻi's unique environment and quality of life.
- Ensure the transportation system supports Hawaiʻi's economy.

The study was undertaken by the HDOT in order to create a long-term investment strategy for programming future improvement projects on Farrington Highway, including bicycle, sidewalk and transit projects. This study is meant to serve as a guide for HDOT Highways in setting their long-term direction and improvement program for Farrington Highway, a critical roadway on the Leeward Coast.

The study corridor is 18.5 miles long and extends from Kalaeloa Boulevard (Mile Post 0.0) to Mile Post 18.5 as shown in Figure 1. The corridor experiences varying levels of congestion throughout the day and week. A 4:00 to 6:00 PM contraflow lane from Piliokahi Avenue to Helelua Street was introduced in August 2016 to improve afternoon commute times. While numerous individual projects are identified in this report, they are each subject to the division's project justification process. This study can be used as a starting point to compare projects that address different objectives such as congestion relief, traffic safety, community resilience or assisting with freight movements.

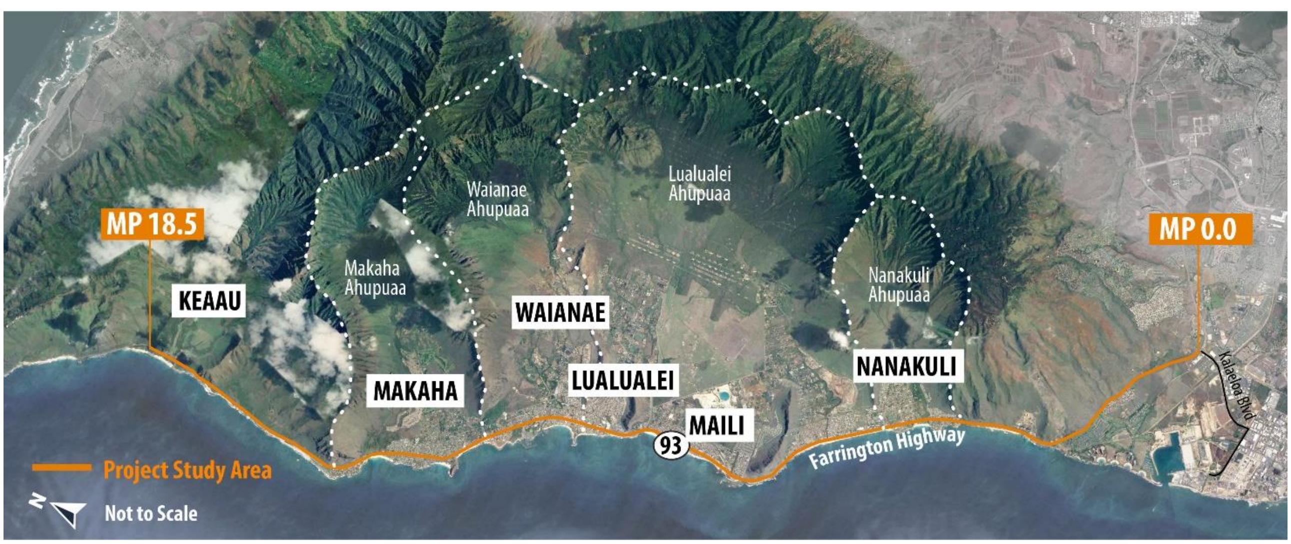

Figure 1: Farrington Highway is the sole public access to the Leeward Coast

Potential improvement projects include those that would provide congestion relief, such as intersection improvements or added lanes, safety, and spot improvements, such as improved lane delineation, signage or lighting, and efforts to improve resilience.

The study included four phases of work:

- Review of previous studies, identification of problems, and development of a preliminary list of candidate projects;
- Data collection, forecasting and analysis to identify problem areas and determine how each candidate project performs to improve traffic or safety or resilience, and elimination of those candidate projects with little or no benefit;
- Quantification of the transportation benefits of each remaining candidate project, including operational analysis; and
- Determination of the feasibility of each project, its environmental impacts, costs, and length of time to implement.

The Farrington Highway Corridor Study included two sub-reports:

The Second Access Assessment (Task 3), which reviews and summarizes previous studies that investigated potential routes to provide another access from the Leeward Coast to Kunia Road.

The Traffic Operations Assessment Technical Report (Task 4), which summarizes results from the traffic analysis, crash study, and access inventory. The recommendations in this report originated in the Traffic Operations Assessment Technical Report, which provides additional detail and documents the methodologies and findings.

Various recommendations from the Traffic Operations Assessment Technical Report were not included in the analysis that follows either because they are more geared toward simple operational or maintenance functions and can be implemented immediately and/or they have minor costs, because they involve City departments, or because they would be better to phase in over time. Those recommendations are summarized in Table 1.

Table 1: Recommendations from Traffic Operations Assessment Technical Report (Task 4) for Immediate Implementation, Cooperative projects with City, or Phased Implementation

Recommendation from Traffic Operations Assessment Technical Report (Task 4), not part of Task 6 Corridor Study analysis	Timing	Location in Traffic Operations Assessment Technical Report
Complete Waianae Coast Emergency Access Route (WCEAR) and improve communication plan (City)	Priority 1	Pages 6-7, 138
Improve crosswalks from Type A to Type B w raised medians: north of Maipalaoa Rd, at Maipela St., and Kaupuni St.	Priority 1	Page 20, Table 8
Restrict left in movements at Waiomea Street 6-9 am M-F	Priority 1	Page 130
Install “crosswalk ahead” warning sign before bus stop #523 (City)	Priority 1	Page 139
Move Bus stop #537 closer to Puhano St. (City)	Priority 1	Page 139
Remove bus stop #621 (City)	Priority 1	Page 139
Changing speed limits from 35 mph to 25 mph on segments MP 4.4-5.2, 5.9-6.8 and 8.1-9.1	Priority 2	Page 19, Table 7
Introduce pilot project: nontraversable median from Lualualei Naval Rd. to Helelua Street (median opening at Nanaikeola St.). If successful, introduce nontraversable medians on other segments: Kaukama Rd. to Hookele St, Maipalaoa Rd to St Johns Rd., Kaukamana St. to Leihoku St.	Priority 2	Pages 125, 143
Install left turn green arrow at Kaukamana St.	Priority 2	Community request
Implement TDM strategies by working with City and County of Honolulu	Priority 2	Page 143
HDOT to work with City and County of Honolulu to increase Transit Usage	Priority 2	Page 144
Limit driveways within the functional area of an intersection	Phase in with FH improvements and property improvements	Pages 122 and 143
Add colored paint to bike lanes, and bicycle markings through intersections at Nanakuli Ave., Haleakala Ave., Lualualei Naval Rd., Mailiili Rd., Lualualei Homestead Rd., Waianae Valley Rd., Plantation Rd., Makaha Valley Rd. and Kili Dr.	Phase in with FH improvements	Page 143
Expand bike lanes and shared use path to extend along the whole corridor	Phase in - Included in Oahu Bike Plan	Page 143
Add a right turn lane for northbound Farrington Highway at Haleakala Ave	Needed by 2040 or 6 lane FH	Page 143
Add a left turn lane for southbound Farrington Highway at Lualualei Naval Rd.	Needed by 2040 or 6 lane FH	Page 143
Work toward expanding street grid network for redundant paths by working with City and County of Honolulu	Phase in over time	Page 143

Another significant work effort that was part of the Corridor Study was a Community Engagement Task that included a pilot program reaching out to high school students to closely involve community members.

1 PHASE ONE: IDENTIFY PROBLEMS, MEASURES OF EFFECTIVENESS, AND CANDIDATE LIST OF PROJECTS

Phase 1 had three major Tasks:

1) Problems were identified along each roadway segment.
2) Evaluation criteria and Measures of Effectiveness (MOE) were researched and selected.
3) A preliminary set of candidate improvements was prepared which addressed the problems and needs.

The associated technical report for Phase 1 is:

Traffic Operations Assessment Report, Task 4.0 (SSFM, December 2020)

1.1 METHODOLOGIES USED

Phase 1 comprised an extensive gathering of documents and data. The sources of data used as part of the problem identification task included:

- Review of 20 previous studies
- Farrington Highway counts (2012-2016 historic and 2040 forecasted) for ten locations from the OahuMPO Travel Demand Model.
- HDOT tube counts giving 2012-2016 Average Annual Daily Traffic volumes (AADTs) from the HDOT historic annual database
- New tube counts in 2018 at three of the HDOT tube count locations
- 2018 Intersection turn movement counts at 39 intersections for 6-12 hours including AM and PM peak periods
- Farrington Highway counts at four locations in 2020 (during COVID-19 traffic reductions) in Nānākuli in the potential extension zone for the 5th lane
- Farrington Highway counts at eight locations in 2020 (during COVID-19 traffic reductions) to quantify pedestrian and bicycle activity
- Collision data (2013-2016) from the HDOT database

Synchro 10.0 software and Highway Capacity Manual (HCM) methodologies were utilized to analyze Levels of Service at the 39 study intersections.

Three rounds of community meetings at two locations were held with community leaders, members of the community and other stakeholders to identify and gather input on traffic and transportation issues.

1.2 PROBLEMS IDENTIFIED

The issues on Farrington Highway were grouped into those relating to Safety, Congestion and Resilience.

Safety

HDOT provided the project team with crash data for all crashes on Farrington Highway from 2013 through 2016. The data included 694 crashes. An in-depth crash study was conducted and summarized in the Task 4.0 Report: Traffic Operations Assessment. Safety issues included:

1. 64 crashes involving pedestrians, 11 fatal, (9 of them while dark)
2. 11 fatal crashes involving only motor vehicles
3. Overall crash rate of 86.3 crashes/100 million vehicle miles of travel, six study segments had a range of rates from 40.1 to 166.5.
4. 22 intersections with > or = 5 crashes
5. One intersection with 22 crashes and a crash rate 1.7x higher than the next highest intersection
6. 231 rear end crashes, over 4x the next highest crash type
7. 110 combined angle or broadside crashes, suggesting crashes between through traffic and entering or turning traffic

Figure 2: The study analyzed 694 crashes 2013 to 2016

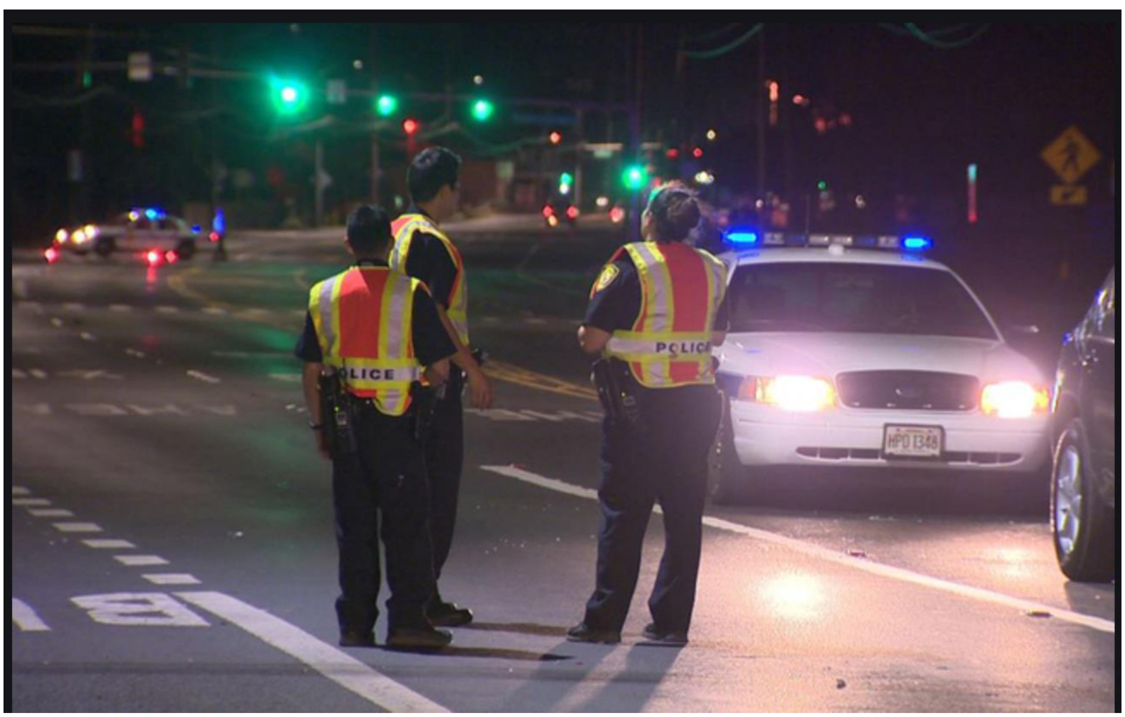

Photo Credit: Honolulu Star Advertiser

Congestion

Congestion is a daily occurrence on Farrington Highway, both in the morning and afternoon. Congestion occurs when the demand exceeds the capacity for a given period of time. Congestion is measured by the Level of Service and delay (in seconds). Outside of the peak periods, traffic demand is less than capacity and traffic may move at or above the speed limit. Capacity is a function of traffic signal timing, coordination and spacing, vehicle speed, how closely vehicles are spaced, sight distance, driver comfort with lane and shoulder widths, and other factors.

Various segments of Farrington Highway have insufficient mainline capacity in one or both directions during peak commute times. The congestion generally gets worse in the segment of Farrington Highway closer to M.P. 1.0 as it approaches H-1 and the traffic volumes are higher. The corridor lacks sufficient parallel facilities to allow alternative routes, which results in degraded operations. Segments of Farrington Highway that consistently operate at low levels of service in the AM peak include:

- Southbound (Honolulu bound) traffic near Laʻaloa Street and Waiomea Street traffic signals
- Southbound and northbound traffic near Haleakala Avenue traffic signal
- Southbound traffic near Lualualei Naval Road traffic signal

Afternoon peak periods also have significant congestion that can start as early as 2:00 PM. Segments that consistently operate at low levels of service in the PM peak (before 4-6 pm contraflow times) include:

- Northbound traffic near Laʻaloa Street and Waiomea Street traffic signals
- Southbound traffic near Lualualei Naval Road traffic signal

Figure 3: Bumper to bumper congestion on Farrington Highway can occur every day in peak periods

CINDY ELLEN RUSSELL / CRUSSELL@STARADVERTISER.COM

Resilience and Climate Change

Numerous reports have addressed resilience on the Leeward Coast. Appendix A summarizes past reports that investigate topics related to climate change and resilience for the Waiʻanae Coast. Excerpts of Appendix A are provided in this section. Previous studies have been completed for the Farrington Highway corridor that highlight the various coastal hazards and risks that pose a threat to the integrity of the highway and the Leeward communities that rely on the highway daily. Many of those studies have cited the vulnerability of Farrington Highway as being vital infrastructure that needs to be prioritized due to its proximity to the shoreline and the lack of alternate routes available in the area in the event of a natural disaster. Some of these studies have identified several sections of the Highway that are most at risk to be disrupted or cut off during a natural disaster.

Climate change is expected to impact Hawaiʻi's land, climate, and people in many ways over the coming decades. Impacts such as sea level rise, coastal erosion, and flooding are expected to impact major coastal areas such as the Waiʻanae Coast. Other impacts such as increased storms and wildfire hazards will have Statewide effects on Hawaiʻi's lands and critical infrastructure. The impacts of climate change have the potential to exacerbate current hazards to Farrington Highway, elevating the need for measures to protect the function of the highway as a lifeline and the promotion for an alternate access route.

The discussion below summarizes these impacts to the Waiʻanae Coast and the most relevant findings from past studies for Farrington Highway, and identifies recommendations that will improve the resilience of the highway for those Leeward Coast communities.

Findings:

Coastal Flooding and Erosion

Coastal flooding due to storm surge and seasonal high surf events have been a natural occurrence on Oʻahu, particularly along Kamehameha Highway from Kualoa to Kaʻaʻawa and along Farrington Highway fronting Mākaha Beach Park. Climate change is expected to increase the frequency and intensity of tropical storms in the Pacific, increasing the risk of storm impacts to the Hawaiian Islands. Given the area's low elevation and susceptibility to coastal flooding, the vulnerability of Farrington Highway to increased flooding and erosion events will increase in the future.

Figures 4, 5 and 6 show the AE and VE flood zones on Oʻahu's west coast.

AE zones are areas that present a 1% annual chance of flooding and a 26% chance over a 30-year period, according to FEMA. Approximately 2.8 miles of Farrington Highway are within AE Zones according to the FEMA maps.

VE Zones, are also known as the coastal high hazard areas. They are areas subject to high velocity water including waves; they are defined by the 1% annual chance (base) flood limits (also known as the 100-year flood) and wave effects 3 feet or greater. Approximately 2.1 miles of Farrington Highway are within VE Zones according to the FEMA maps.

A total of 4.9 miles of Farrington Highway are in either an AE or VE zone. The Base Flood Elevation in this area for Zone VE is 12-feet and 13-feet for Zone AE.

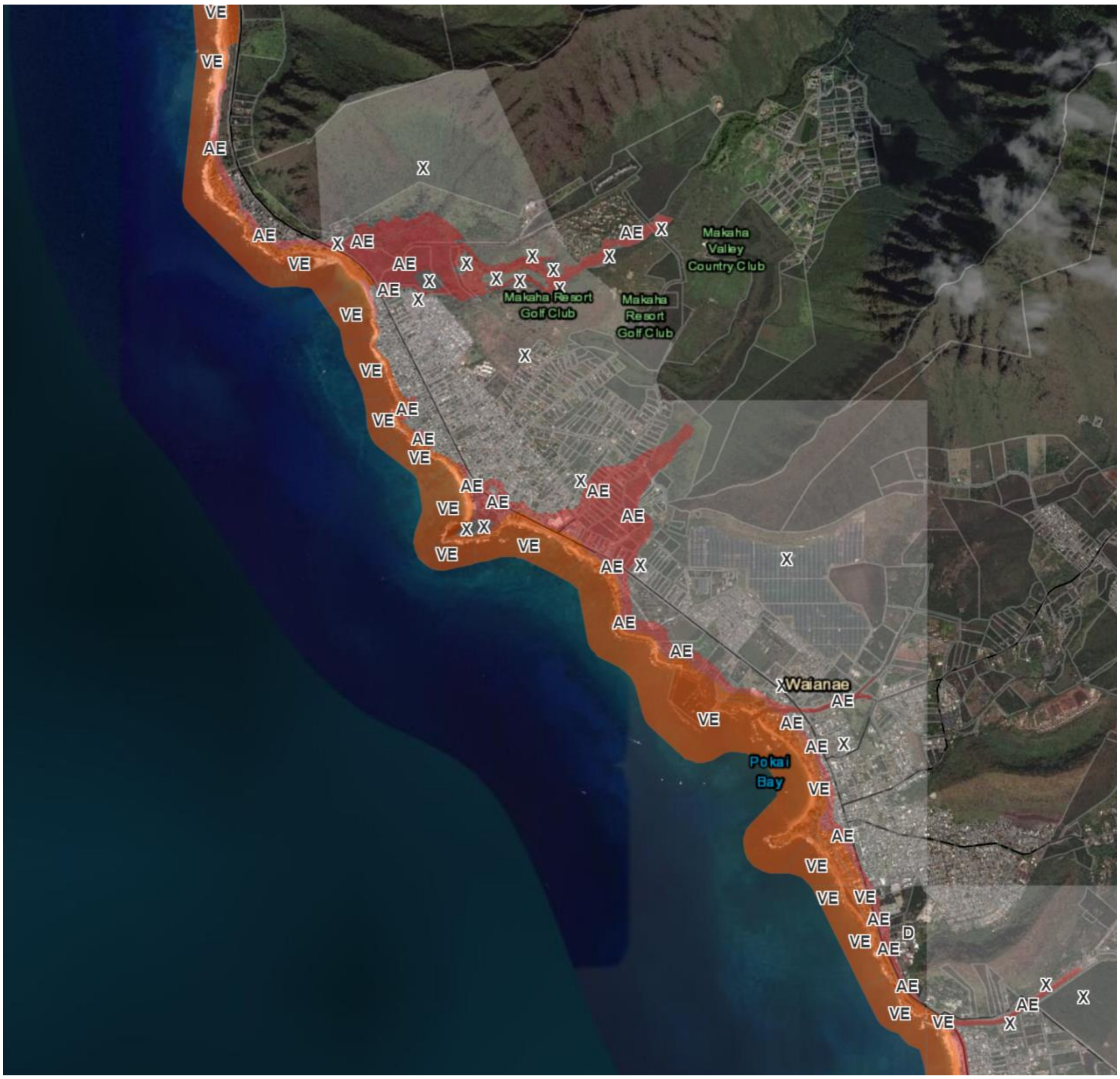

Figure 4: FEMA Flood Map for Mākaha

Figure 5: FEMA Flood Map for Māʻili

Figure 6: FEMA Flood Map for Nānākuli

<u>**Mākaha-Wai'anae**</u>

Mākaha Beach Park is highly vulnerable to high wave events, storm surges, and erosion. It has been documented in several past news reports and studies that Mākaha Beach Park, which abuts Farrington Highway, is highly vulnerable to flooding and erosion due to high wave and storm surge events. In 2018, a big south shore swell brought on by Hurricane Lane removed a 50-foot section of Mākaha Beach fronting a residential home located between Mākaha Beach and Farrington Highway, eroding away about half of the owner's backyard and exposing rock that had been buried in the sand for decades (HNN, 2018). Owners of the properties along this beach area have experienced flooding due to large storm surges in 1992 and 1982 when Hurricanes 'Iniki and 'Iwa, respectively, passed through Hawai'i. In an attempt to save a residential home, volunteers used bulldozers to try to move sand back to the area to protect the home. A 2010 Beach Management Guidelines report by the Department of Land and Natural Resources for Mākaha Beach Park had recommended that the city redistribute the sands from one end of the beach to the other before each winter to protect the shoreline from erosion (HNN, 2018).

The Oahu Metropolitan Planning Organization's (OMPO) Farrington Highway Realignment Study (2020) in the vicinity of Mākaha Beach has been conducted to assess the feasibility of realigning the stretch of Farrington Highway situated adjacent to Mākaha Beach. This study further confirmed the threats to this stretch of highway from seasonal beach erosion, wave overtopping during high surf, and greater and more frequent threats due to sea level rise (OMPO, 2020). The Study's Existing Conditions Report has found that periodic beach maintenance is needed to protect Farrington Highway and beach park facilities due the high seasonal transport of sand during winter northwest swells and summer southerly waves. Materials that have been installed under the sand at Mākaha Beach to protect the highway have been exposed during high wave events in recent years.

Additionally, this section of Farrington Highway fronting Mākaha Beach is located between two FEMA flood zones (VE and AE). Due to the wetlands surrounding both Mākaha Stream and West Mākaha Stream, which flow under Farrington Highway and do not have permanent connections to the ocean, this section of the highway is very prone to flooding.

According to the OMPO Farrington Highway Realignment Study (2020), discussions regarding the possible realignment of Farrington Highway first surfaced in 1985, and since then, elected representatives and the public have periodically promoted realignment in this area and the replacement of Bridges 3 and 3A located above Mākaha and West Mākaha Stream.

A 2014 Environmental Assessment (EA) for the Mauna Lahilahi Beach Park – Rock Revetment located in Wai‘anae documented that this beach park and shoreline have been eroding for decades. Seasonal high wave events and hurricanes have eroded Mauna Lahilahi Beach Park and have threatened residential apartments near the south end of the beach park. As a result, a rock revetment fronting the apartments has been constructed to minimize erosion of the properties, while the northern section of Mauna Lahilahi Beach Park fronting Farrington Highway has been closed on occasion for erosion maintenance.

A 2011 USGS National Assessment of Shoreline Change documenting historical shoreline change in Hawai‘i found that areas of significant erosion rates in West Oahu include Mauna Lahilahi Beach, Pōkaī Beach, Nānākuli Beach, and Tracks Beach. A 2004 EA for the Mauna Lahilahi Beach Park Improvements by the City and County of Honolulu proposed that the bus shelter near the intersection of Mākaha Valley Road and Farrington Highway fronting the beach park be relocated due to the severely eroded shoreline fronting this portion of the beach as part of the master park improvements. The 2004 EA has noted that during heavy surf conditions, wave overtopping washes sand over the retaining wall that serves as the back wall of the existing bus stop, rendering the location unusable and potentially hazardous. Occasional maintenance of the bus stop had to be conducted over the years due to these events.

The HDOT Statewide Coastal Highway Program Report (2019) has assessed and ranked the susceptibility of State coastal roads along 302 mileposts to erosion and structural degradation due to coastal hazards such as waves, currents, tides, and sea level rise. Taking into account historical and future sea level rise rates, the Report created sea level rise inundation maps for each milepost to help understand the impacts of sea level rise to coastal roads including Farrington Highway, and to provide information for decisions about how to minimize impacts and increase asset and system resiliency.

The Report has found that no mileposts along Farrington Highway may be inundated due to sea level rise by 2050, however, multiple mileposts along Farrington Highway may likely be inundated due to sea level rise by the year 2100. These impacted mileposts are spread throughout portions of Farrington Highway including the sections from Depot Beach Park towards Ulehawa Beach Park fronting Nānākuli, along Māʻili Beach Park, and from Pōkaī Bay in Waiʻanae to Mākaha Beach Park. Additionally, the Report has found several sections of Farrington Highway that have a low to medium susceptibility to erosion, however, the only section of Farrington Highway that is identified as having a high susceptibility to erosion is fronting Mauna Lahilahi Beach Park in Waiʻanae (MP 12.6 to 13.1) (See Figure 7).

Figure 7: Susceptibility to Road Erosion from Lualualei to Mākaha (Source: HDOT Statewide Coastal Highway Program Report (2019))

Rainfall Flooding

The leeward side of O'ahu, particularly along the Wai'anae Coast, is typically drier than the windward side of the island. Nonetheless, the Wai'anae Coast has experienced drainage problems and flood damage as a result of severe storms. It has been documented that severe storms have brought extensive periods of rains that have lasted for a week or more on some occassions during high rain events. As a result, flooding of Farrington Highway and other major mauka-makai roads has caused major disruptions to many residents who are unable to travel to and from their homes, especially in Mākaha and Nānākuli.

Mākaha to Wai'anae

Mākaha has experienced numerous flooding events through the years contributing to significant damage to both roads and homes. The Mākaha Valley Flood Mitigation Study (2014) has documented multiple past flood events that resulted in flood waters up to a depth of three feet flowing onto Farrrington Highway, making the highway impassable for several hours.

The Mākaha Valley Flood Mitigation Study (2014) explained that the lack of an overall interconnected drainage system throughout Mākaha has contributed to intense flood events such as those that occur along Farrington Highway. Most of the stormwater runoff from these "piecemeal" drainage systems is conveyed toward Mākaha Stream and ʻEku Stream, both of which lack improvements to stream capacity. This has resulted in the streams overtopping their banks and causing widespread flooding. These flood problems along Farrington Highway have occurred most notably near Kili Drive and Mākaha Valley Road, which are within the Mākaha and ʻEku Stream floodplain (see Figure 8). The Mākaha Valley Flood Mitigation Study (2014) found that altered stream alignments, restrictions at the mouths of both Mākaha and ʻEku Streams, an "unimproved" stream channel at ʻEku Stream, the lack of maintenance programs, and damaged or clogged drainage infrastructure have all contributed to major flood problems and issues along Farrington Highway in Mākaha.

The 2008 Department of Hawaiʻian Homelands (DHHL) Regional Community Development Plan developed for Wai'anae and Lualualei identified several drainage problems and proposed recommendations to address flooding for these Leeward areas. The 2008 DHHL Plan showed that flooding is a problem where makai areas are higher in elevation than those mauka due to the deposition of sediment, which has caused a damming effect. The 2008 DHHL Plan explained that some areas of Farrington Highway were built up higher than the adjacent mauka areas which has restricted seaward runoff, causing localized flooding. Other causes of flooding identified in the Plan include the lack of adequate drainage facilities and clogged storm systems.

Māʻili to Nānākuli

Farrington Highway in Nānākuli has also experienced several flood events due to heavy periods of rain. The Lualualei Flood Study (2001) performed by the U.S. Army Corps of Engineers (USACE) and the U.S. Department of Agriculture (USDA) found insufficient drainage infrastructure in the Lualualei watershed that contributed to widespread flooding. The Study has identified several areas along Farrington Highway in Nānākuli and Māʻili that have been flooded in the past due to storm events. These areas include the area of Farrington Highway fronting Ulehawa Beach Park near Princess Kahanu Avenue and Hakimo Road, and Māʻili Beach Park (see Figure 9). In 2011, State crews pumped flood waters off Farrington Highway in Nānākuli due to a storm system that brought widespread flooding to Leeward Oʻahu (HNN, 2011). These floods disrupted access to the area and made Farrington Highway impassable, most notably at the Princess Kahanu Avenue intersection of Farrington Highway. State crews had pumped more than 20,000 gallons of rain water from the Princess Kahanu intersection of Farrington Highway alone during this one storm event.

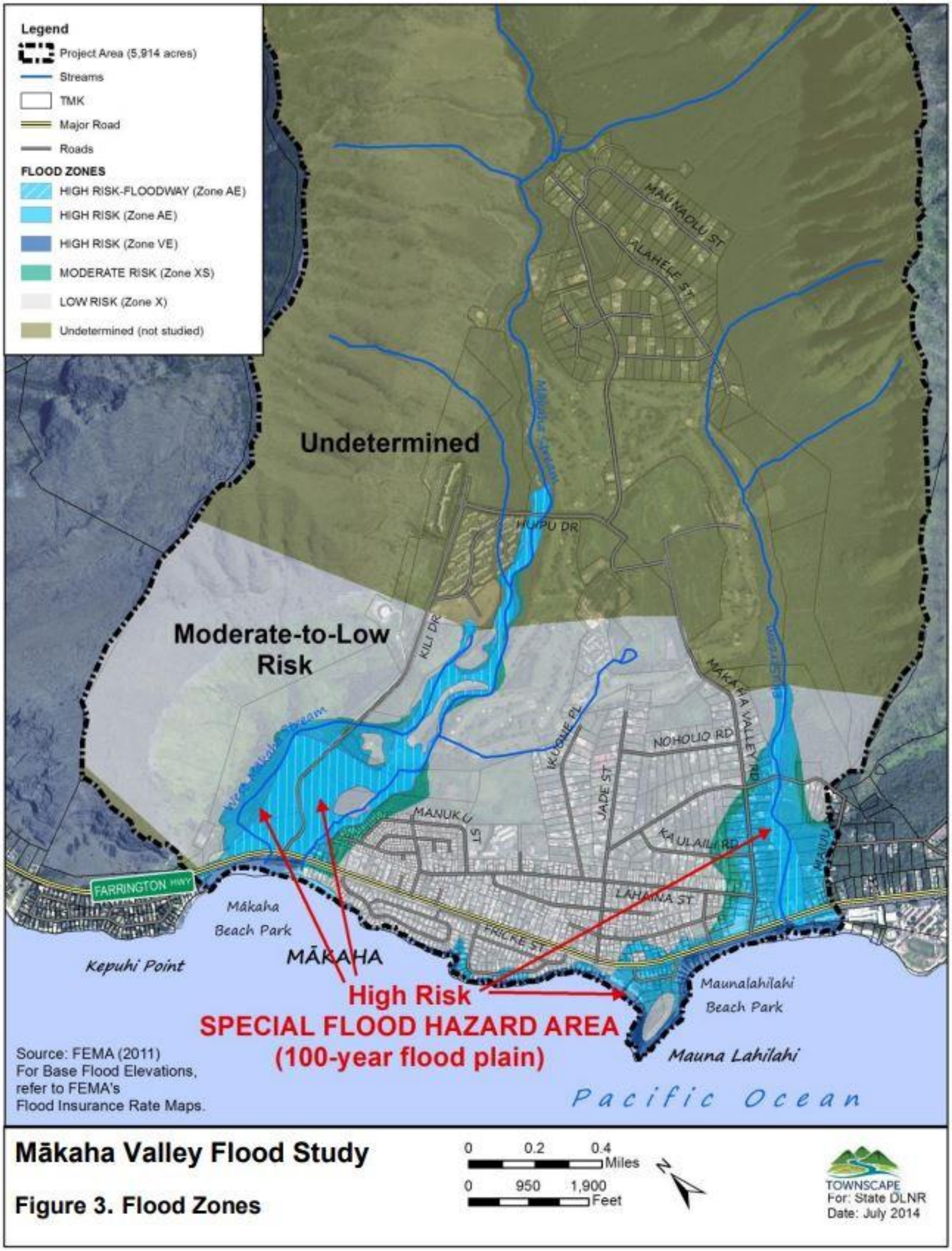

Figure 8: Areas of Flooding along Farrington Highway in Mākaha (Source: 2014 Mākaha Valley Flood Mitigation Study)

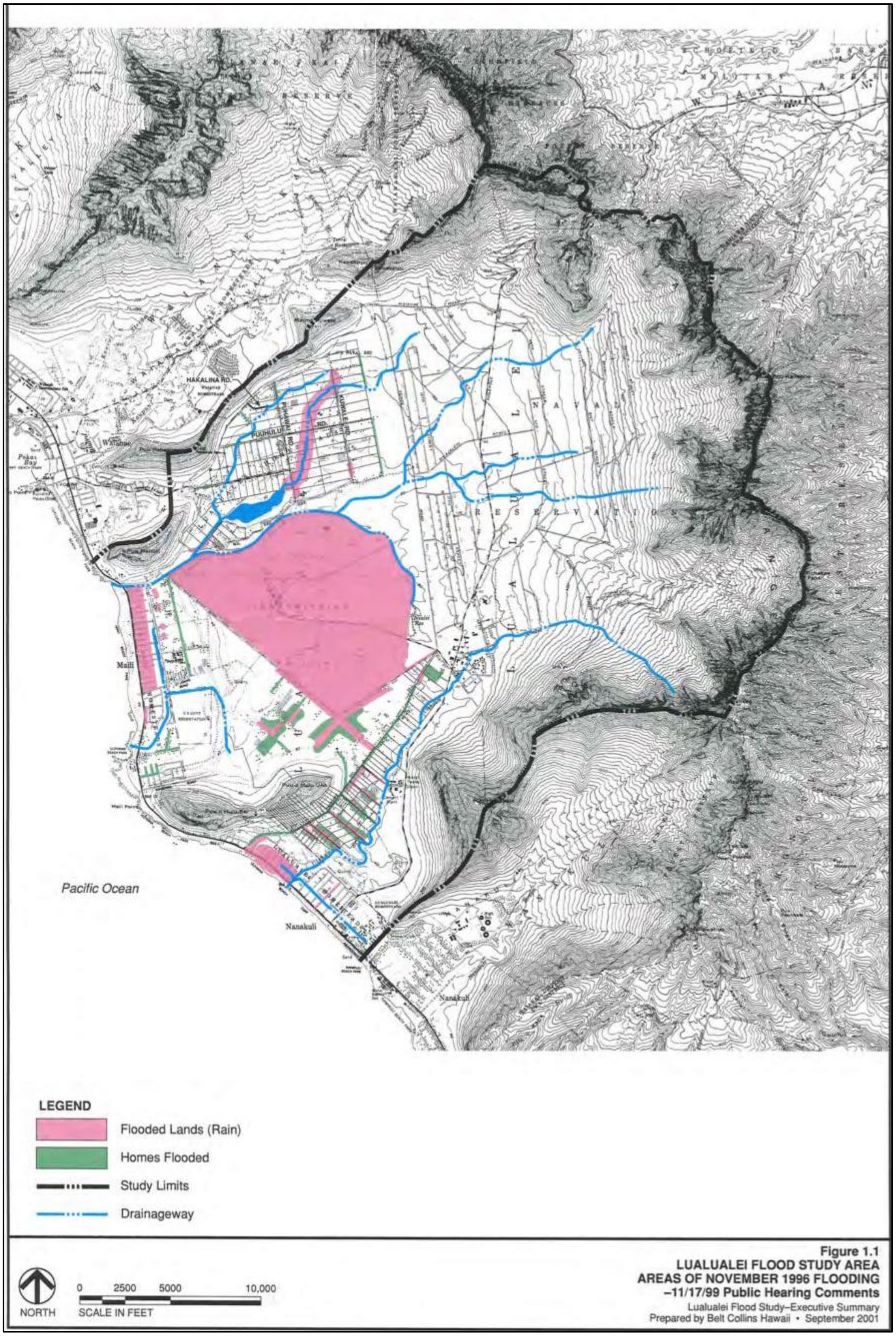

Figure 9: Areas of Flooding in Lualualei (Source: 2001 Lualualei Flood Study)

Recommendations:

The following recommendations have been identified from those past and current studies on the Wai’anae Coast as they pertain to Farrington Highway. The recommendations will improve the resilience of Farrington Highway from coastal and rainfall flooding, erosion, and sea level rise along the Waiʻanae Coast. Table 2 is a summary table displaying these recommendations.

Table 2: Summary of Past Recommendations for Farrington Highway and the Waiʻanae Coast

Current and Past Studies/Reports	Recommendations for Farrington Highway	Hazards Addressed
OMPO Farrington Highway Realignment Study (2020)	Possible realignment of Farrington Highway in front of Mākaha Beach Park	Addresses coastal flooding and erosion to the highway
	Replacement of Bridges 3 & 3A	Addresses potential hazard conditions due to coastal flooding and erosion
HDOT Statewide Coastal Highway Program Report (2019)	Construction of a seawall or revetment and future monitoring of sea level rise conditions for specific areas along Farrington Highway	Addresses coastal hazards at mileposts susceptible to future sea level rise
Mākaha Valley Flood Mitigation Study (2014)	Restore Mākaha Surfing Beach “Pond”	Improves stormwater drainage and debris catchment at Mākaha Beach Park
	New ʻEku Stream Bridge at Farrington Highway	Improve storm water drainage in Mākaha
	Implementation of other Mākaha Valley Flood Mitigation Projects and Programs	Improve stormwater drainage in Mākaha
DHHL Regional Community Development Plan (2008)	Comprehensive Study of Flooding and Drainage Problems in the Waiʻanae District	Analyze and Develop Solutions to Flooding in Waiʻanae
	Implementation of Flood Study Recommendations from the 2001 Lualualei Flood Study	Mitigate flooding and improve drainage in Nānākuli and Māʻili
	Develop Emergency and Secondary Access Roads through the Pōhākea and Kolokole Pass	Improve emergency and secondary access to the Waiʻanae Coast
Mauna Lahilahi Beach Park Improvements, Final EA (2004)	Relocation of Bus Stop on Farrington Highway fronting Mauna Lahilahi Beach Park near Mākaha Valley Road	Addresses potentially hazardous conditions due to heavy surf conditions and sand deposits

Mākaha to Nānākuli

Flooding in Mākaha, particularly along Farrington Highway, due to high rain and storm events has been a problem due to the lack of an overall interconnected drainage system as identified in the Mākaha Valley Flood Mitigation Study (2014). To mitigate flooding, the Mākaha Valley Flood Mitigation Study (2014) has proposed multiple structural and nonstructural flood mitigation projects and programs for Mākaha Valley (See Figure 10). The 2014 Study has grouped projects based on feasibility of implementation (See Figure 11). Projects with relatively low cost and implementation likelihood were categorized into Group 1, more complex and costly projects with large benefits into Group 2, and projects with high initial cost relative to benefits are listed in Group 3.

Projects recommended specifically for the Farrington Highway Corridor include the restoration of the Mākaha Surfing Beach "Pond" which flows under Farrington Highway and the construction of a new 'Eku Stream Bridge (est. cost bewtween $12M - $19M) at Farrington Highway. Community members have said that there used to be a natural "pond" that extended from the outlet of Mākaha Stream to the outlet of West Mākaha Stream which functioned as a natural debris basin and a catchment for stormwater. The 2014 Study noted that the City has mistakenly filled in most of the "pond" area during a 2008 beach reconstruction project which has resulted in debris and flood waters flowing onto Farrington Highway toward the ocean (DLNR, 2014). Construction of a new reinforced concrete bridge at Farrington Highway crossing 'Eku Stream is needed to reduce flooding on the highway and improve stream flow and disharge into the ocean as the current 'Eku Stream Bridge does not have adequate capacity to handle a 100-year storm (DLNR, 2014). The projects and programs in Mākaha, summarized in Figure 11, would help to mitigate flooding that may be conveyed towards Farrington Highway.

Structural Projects	Nonstructural Programs
1. Eku Stream Channel and Off-line Detention Basin 2. New Eku Stream Bridge at Farrington Highway 3. Repair the breach in the Mākaha Stream berm 4. Mākaha Stream Levee 5. Kili Drive Channel 6. Mauna 'Olu Estates Drainage Improvements 7. Noholio Road Drain Line 8. Restore Mākaha Surfing Beach "Pond" 9. In-stream Detention Basins for Mākaha Stream	1. Forest Restoration 2. Stream Channel Maintenance 3. Storm Drain Maintenance 4. Enforcement of existing legislation 5. Education on Best Management Practices for Watersheds 6. Special care in permitting future development

Figure 10: Proposed Flood Mitigation Projects and Programs for Mākaha Valley (Source: Mākaha Valley Flood Mitigation Study (2014))

Group 1	Group 2	Group 3
• Repair the breach in the Mākaha Stream berm • Restore Mākaha Surfing Beach "Pond"	• Eku Stream Channel and Off-line Detention Basin	• Kili Drive Channel • Mākaha Stream Levee • Noholio Road Drain Line • In-stream Detention Basins for Mākaha Stream • New Eku Stream Bridge at Farrington Highway

Figure 11: Proposed Flood Mitigation Projects and Programs for Mākaha Valley (Source: Mākaha Valley Flood Mitigation Study (2014))

The OMPO Farrington Highway Realignment Study (2020) is studying the feasibility of realigning a stretch of Farrington Highway adjacent to Mākaha Beach. The Study refers to the City and County of Honolulu's Department of Parks and Recreation (DPR) Mākaha Beach Park Master Plan Report (1998) that includes the realignment of Farrington Highway mauka as part of the Master Plan in the future (see Figure 12). Realignment of Farrington Highway includes the replacement of Bridges 3 and 3A located above Mākaha and West Mākaha Stream, which do not meet current State and Federal design standards. The replacement of the Mākaha Bridges 3 and 3A was funded for construction in 2020. In the 1998 Report, it is noted that should the highway be realigned inland in the future, the current proposed facilities for the Master Plan will be minimally affected. The Master Plan's recommended highway realignment stems from a 1985 USACE shore protection study for Mākaha Beach Park that concluded that Farrington Highway should be realigned further inland to protect the highway from future wave damage (DPR, 1998). The report notes that all attempts to have the highway realigned in the past have failed.

To address flooding and drainage issues for Wai'anae and Lualualei, the DHHL Regional Community Development Plan (2008) has proposed that a comprehenive study of flooding and drainage problems in the Wai'anae District be conducted and that recommendations in the USACE and USDA Lualualei Flood Study (2001) should be implemented. The comprehensive study of flooding and drainage problems in the Wai'anae District stems from the Wai'anae Sustainable Community Plan (DPP, 2000). Possible corrective measures may include removal of drainage barriers, cleaning of drainage channels and stream channels, re-grading areas to encourage positive drainage, and construction of new drainage channels, culverts, and other drainage structures (DHHL, 2008). The USACE and USDA Lualualei Flood Study (2001) found insuffient drainage infrastructure in Lualualei. Recommended flood mitigation projects along Farrington Highway identified include installation of specific drainage infrastructure fronting Ulehawa Beach Park in Nānākuli and Māʻili Beach Park in Māʻili.

The 2004 EA for the Mauna Lahilahi Beach Park Improvements project recommends relocation of the bus shelter near the intersection of Mākaha Valley Road and Farrington Highway fronting the beach park due to heavy surf conditions that have caused waves to overtop the retaining wall and deposit sand at the bus stop and along Farrington Highway. The 2004 EA has identified a new location for the proposed bus stop located further east where shoreline and more stable land areas buffer the bus stop from heavy surf and sand debris (CCH-DDC, 2004). The proposed location also provides a safer loading area as it is located further away from the intersection. The original bus shelter is proposed to be removed in favor of additional park space.

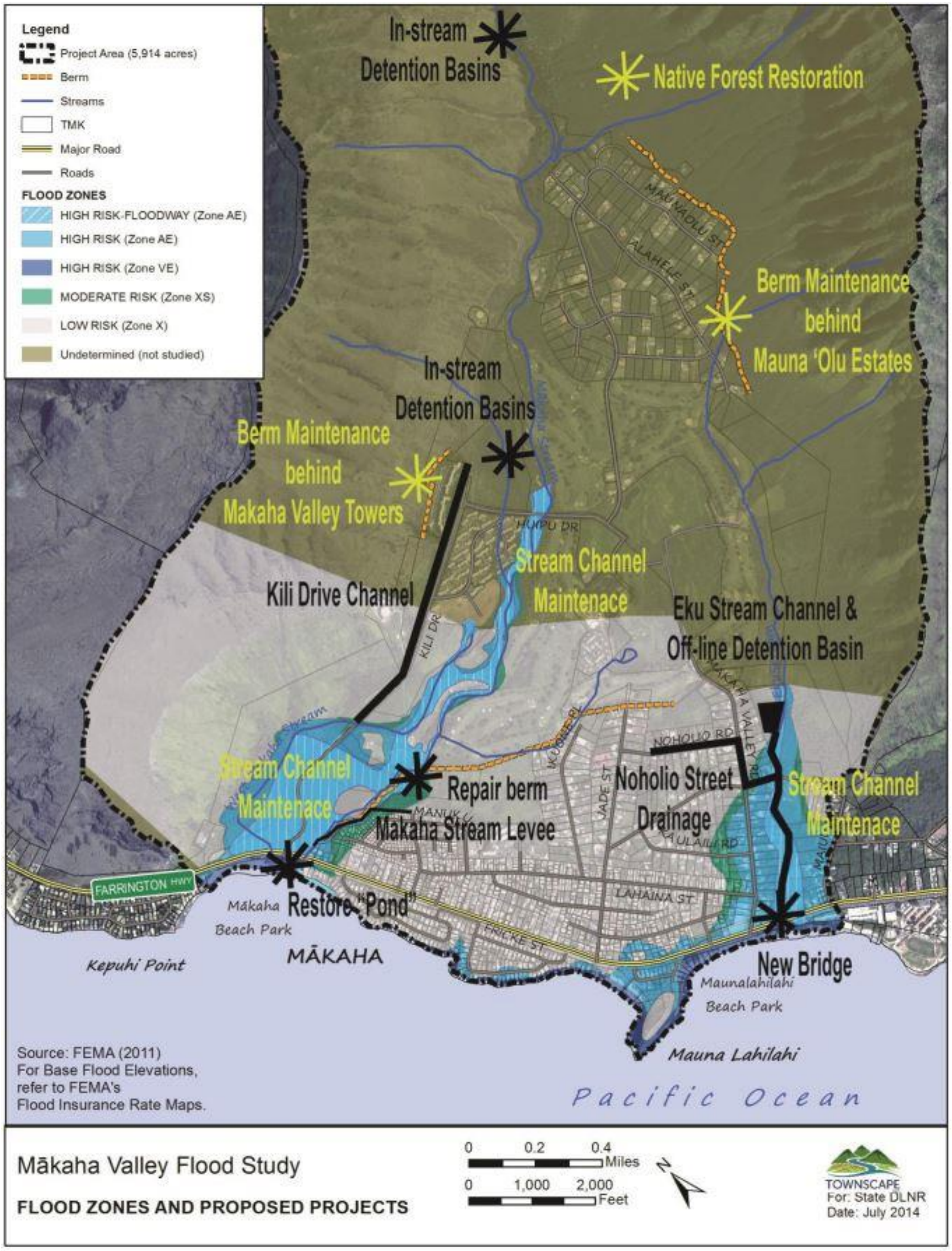

Figure 12: Proposed Flood Mitigation Projects in Mākaha Valley (Source: Mākaha Valley Flood Mitigation Study (2014))

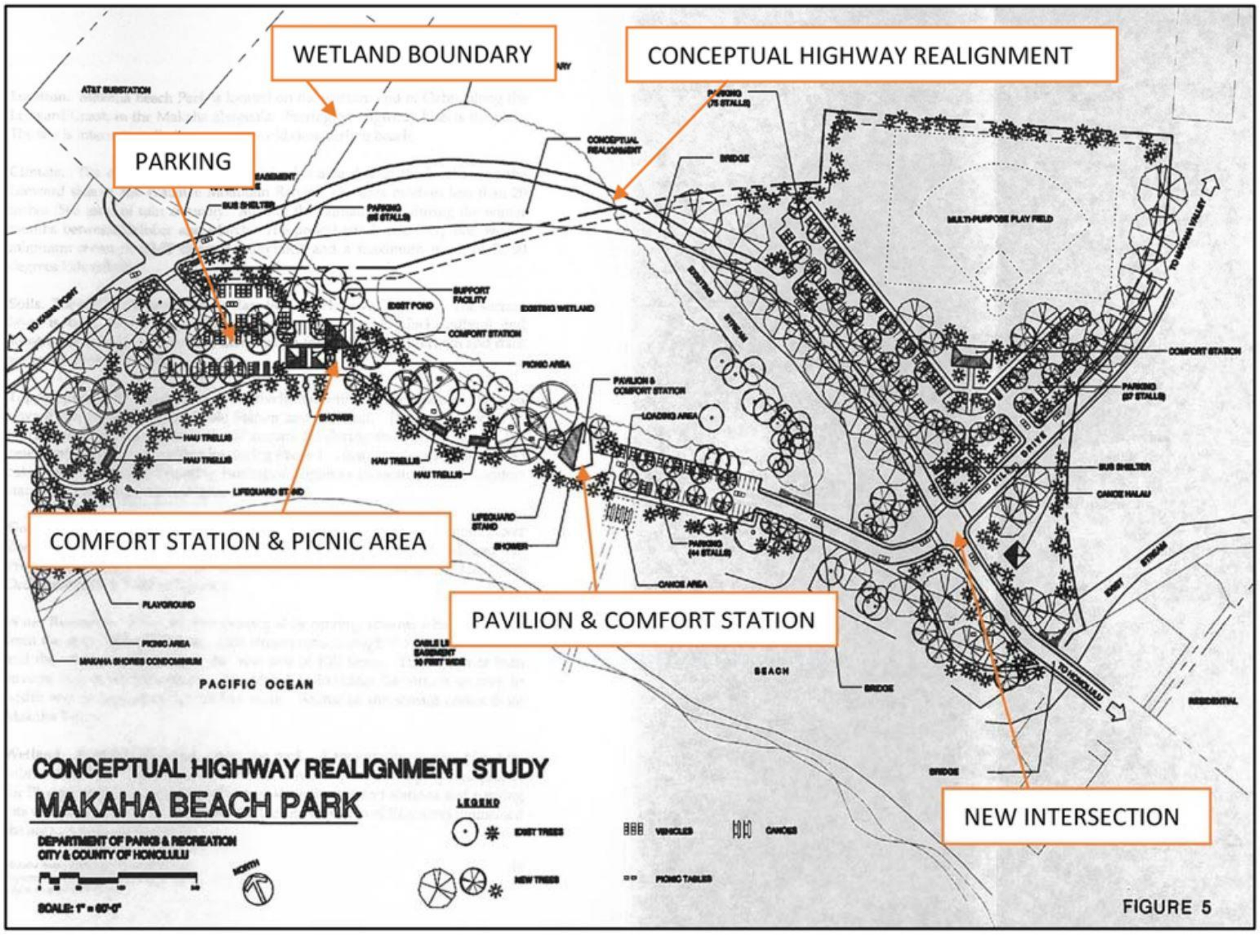

Figure 13: Mākaha Beach Park Master Plan Conceptual Highway Realignment (Source: Mākaha Beach Park Master Plan Report (1998)).

Sea Level Rise

The HDOT Statewide Coastal Highway Program Report (2019) has developed mid-term (9-15 years) and long-term (16-30 years) adaptation recommendations using location-specific ocean hazard data and a cost-benefit analysis for 302 mileposts of "susceptible" State of Hawaiʻi DOT coastal highways, including along Farrington Highway. The most common adaptation recommendations for Farrington Highway included either the construction of a seawall or revetment or to take no action, and that monitoring should take place. Hardening was recommended at certain areas due to one or more of the following reasons: failure of existing armoring; road susceptibility; sinkholes; and/or wave action, erosion, and storm surge (HDOT, 2019). A 'no action' or 'monitor' recommendation was chosen where ocean hazards are not present, the road is not susceptible, the shoreline is inaccessible (e.g., private property), and/or the milepost is just a marker (HDOT, 2019). See Figures 14-16 for adaptation recommendations for specific areas along Farrington Highway.

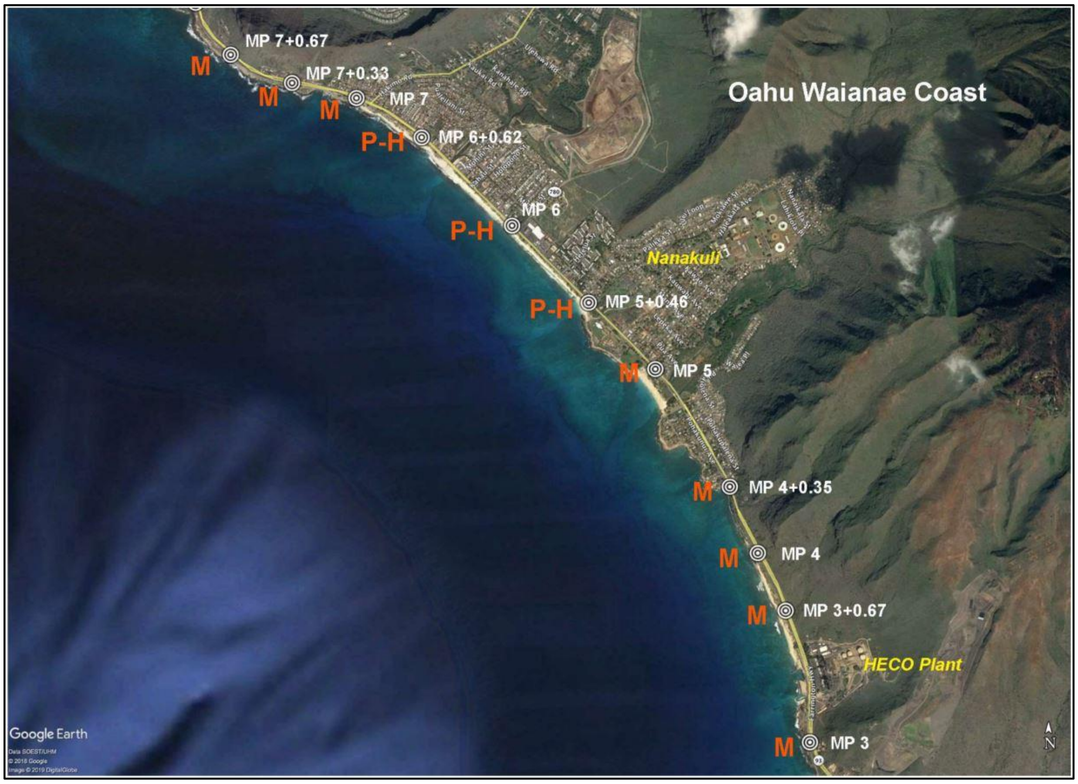

Figure 14: HECO Plant to Nānākuli adaptation recommendations for the State of Hawaiʻi Statewide Coastal Highway Program Report. P-H is hard protection; M is no action/monitor.

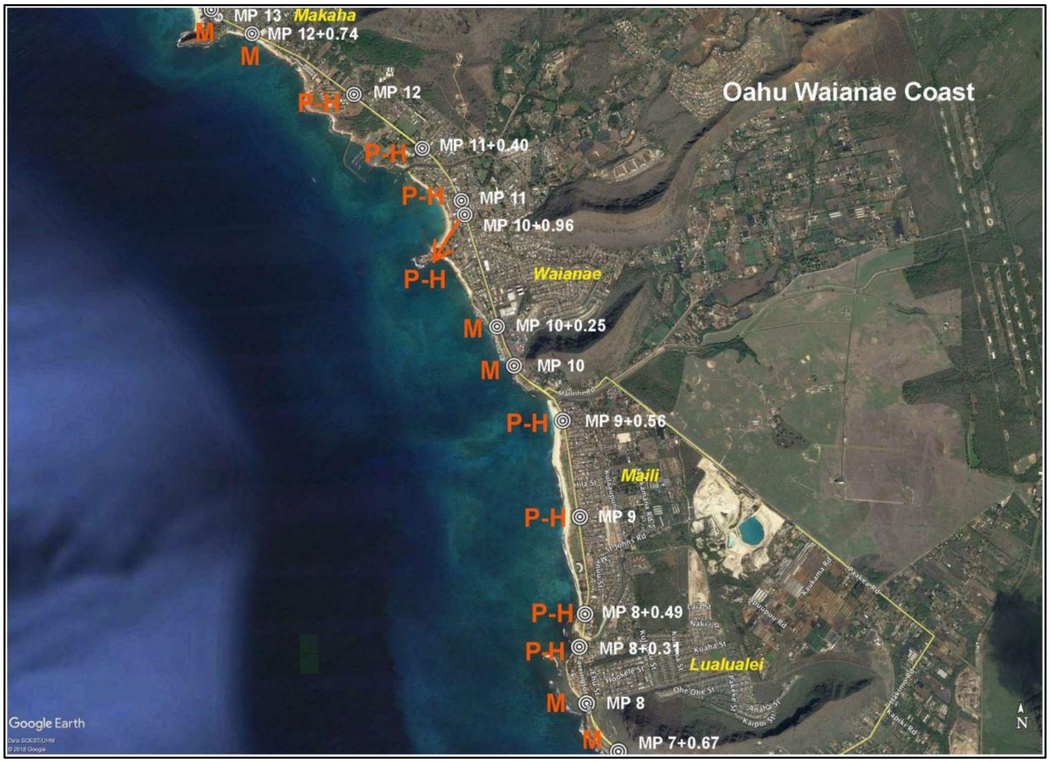

Figure 15: Lualualei to Mākaha adaptation recommendations for the State of Hawaiʻi Statewide Coastal Highway Program Report. P-H is hard protection; M is no action/monitor.

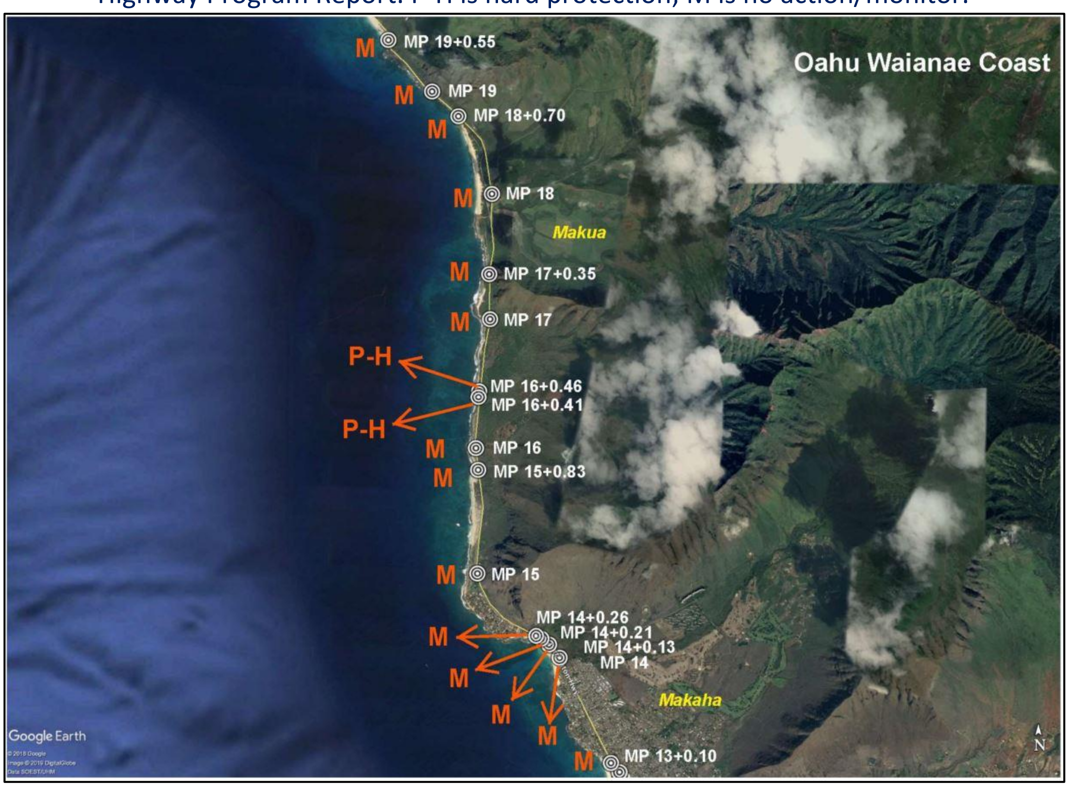

Figure 16: Mākaha to Makua adaptation recommendations for the State of Hawaiʻi Statewide Coastal Highway Program Report. P-H is hard protection; M is no action/monitor

Emergency Access

Many of the past studies have cited Farrington Highway as being a vital infrastructure that needs to be prioritized due to its proximity to the shoreline and the lack of alternate routes available in the area in the event of a natural disaster. Some of these studies have identified several sections of the Highway that are most at risk of having traffic flow disrupted or being cut off during a natural disaster. To improve resiliency, emergency access routes other than Farrington Highway have been discussed as a need for the Waiʻanae Coast.

The 2008 DHHL Regional Community Development Plan developed for Wai’anae and Lualualei identified developing emergency and secondary access roads to the area as being a priority project. The Plan discussed that for several decades the community has expressed their need for a second access road, both in times of emergency, as well as for carrying a significant volume of commuter traffic. Two main options had been developed based on studies of potential alignments and costs. Both access routes would go from Farrington Highway, up Lualualei Naval Road, over the Wai’anae Mountain Range, to Kunia Road. However, one access route would go through Pōhākea Pass (commuter road, est. $1 Billion), the other would go through Kolekole Pass, (emergency road, $30 Million to meet standards) (DHHL, 2008). The Plan suggested that the community would like to see the alignment through Kolekole Pass fixed first as an emergency access route, followed by a plan to open a commuter highway at Pōhākea Pass (DHHL, 2008). The effort to develop these routes would need funding and coordination by the City and County of Honolulu, Department of Transportation Services, State and Federal Department of Transportation, and the U.S. Army and Navy. According to the 2008 DHHL Regional Community Development Plan, there were no current plans to implement these emergency and secondary access routes at the time. Addtionally, the 2008 Plan calls for improvements in connecting the Wai’anae Coast Emergency Access Road (WCEAR) throughout the Wai’anae Coast.

None of the recommended projects fall completely within the HDOT right of way, complicating the implementation of planning and construction, and necessitating a concerted interagency effort to advance any of these projects.

The types of safety, congestion and resilience issues vary according to which segment of the highway is being examined. The study delineated six highway segments, as shown in Figure 17.

Table 3 shows the problems and issues by segment of Farrington Highway.

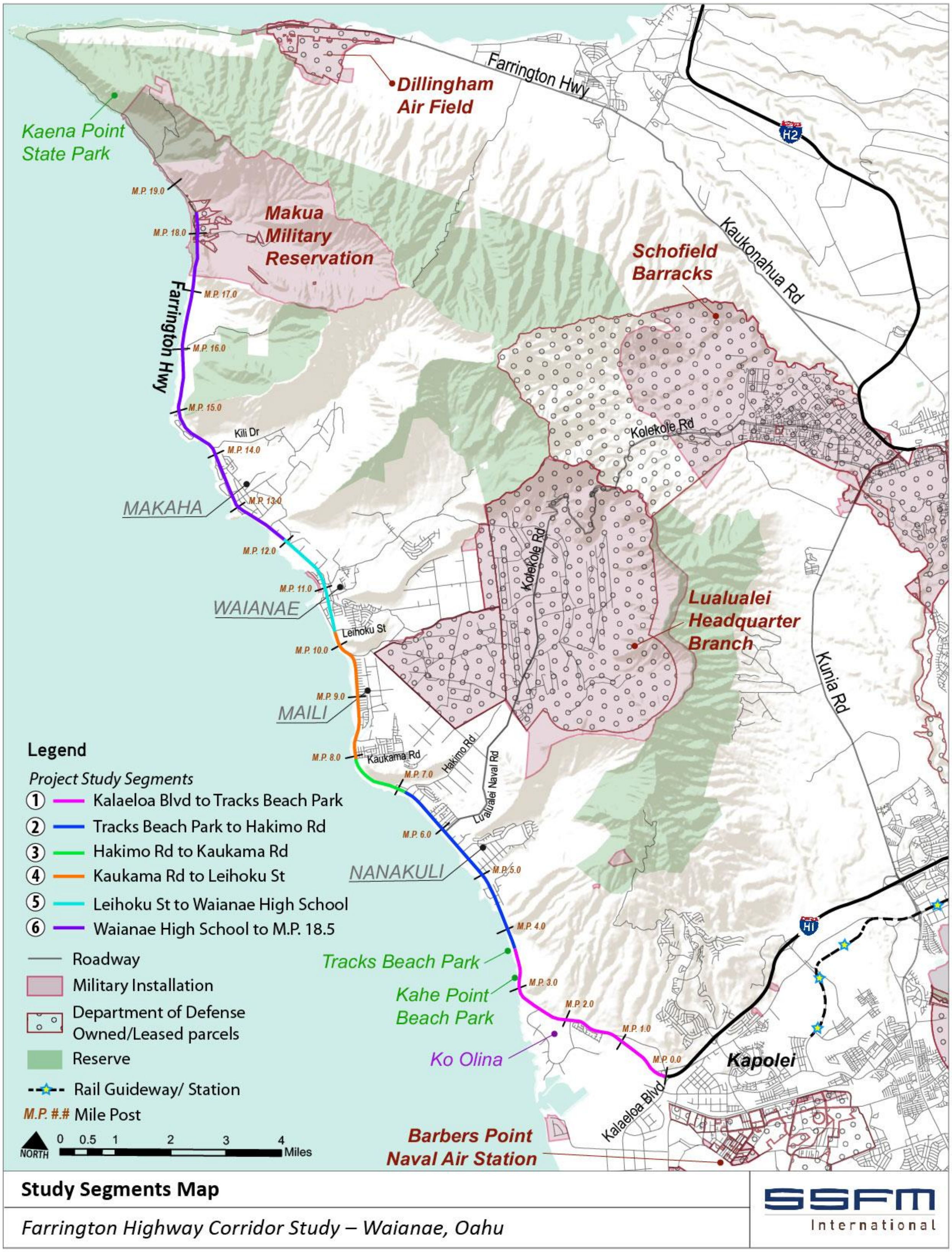

Figure 17: Study Segments Map

Table 3: Problems and Issues by Farrington Highway Segment

	Segment	2012 ADT	2040 ADT	Safety Concerns	Capacity Concerns	Resilience Concerns
Overall Corridor	Kalaeloa Boulevard to MP 18.5	4,832 to 54,852	2,137 to 66,559	See individual segments	See individual segments. In general, long commute times in AM and PM peak hours. Congestion at signalized intersections.	Waiʻanae Coast Emergency Access Route (WCEAR) is not connected in some places. Communication for activating WCEAR and unlocking gates is reportedly inconsistent and/or delayed. Farrington Highway is the sole access into and out of the Waiʻanae Coast.
1	Kalaeloa Boulevard to Tracks Park Beach 3.7 miles (20% of total length)	54,852 Oahu MPO model	66,559 Oahu MPO model	Crash rates are below averages for Farrington Highway corridor, but there were 7 fatal crashes in the 4 year study period.	Two traffic signals that cause delays on Farrington Highway. Peak AM and PM periods are congested.	None.
2	Tracks Beach Park to Hakimo Road 3.2 miles (17% of total length)	44,301 Oahu MPO model	55,075 Oahu MPO model	Crash rates are above averages for Farrington Highway corridor for overall, KAB[1], and Pedestrian crashes.	Eleven traffic signals that cause delays on Farrington Highway. Peak AM and PM periods are congested.	Flooding at Princess Kahanu Avenue intersection and vicinity

[1] Fatal (K), Incapacitating (A) and Non-incapacitating (B) injury

3	Hakimo Road to Ka'ukama Road 1.1 miles (6% of total length)	37,539 HDOT count	44,768 Oahu MPO model	Crash rates are below averages for Farrington Highway corridor.	None	Flooding between Mā'ili'ili Road and St. Johns Road
4	Ka'ukama Road to Leihoku Street 1.8 miles (10% of total length)	32,324 HDOT count	34,102 Oahu MPO model	Crash rates are above averages for Farrington Highway corridor for overall, KAB*, and pedestrian crashes.	Eight traffic signals that cause delays on Farrington Highway. Peak AM and PM periods are congested.	Flooding at Leihoku Street intersection and vicinity
5	Leihoku Street to Wai'anae High School. 2.3 miles (12% of total length)	24,747 Oahu MPO model	31,858 Oahu MPO model	Crash rates are above averages for Farrington Highway corridor for overall, KAB*, and pedestrian crashes.	Six traffic signals that cause delays on Farrington Highway. Peak AM and PM periods are congested.	Flooding at Wai'anae Valley Road intersection
6	Wai'anae High School to Mile Post 18.5 6.4 miles (35% of total length)	18,355 HDOT count (4,832 near Kili Drive)	15,028 Oahu MPO model 2,137 near Kili Drive)	Crash rates are below averages for Farrington Highway corridor for overall and KAB* crashes. However, pedestrian crash rate is above average for Farrington Highway.	None	Sand and wave over wash onto the sidewalk and Farrington Highway near Mākaha Valley Road. High Susceptibility to erosion of Farrington Highway M.P. 12.6 to 13.1

*KAB crashes include Fatal (K), Incapacitating (A) and Non-incapacitating (B) injury crashes

1.3 MEASURES OF EFFECTIVENESS

Measures of effectiveness (MOE) were reviewed to ensure they were consistent with HDOT Highways Goals, federal planning goals, the National Highway Performance Program and the goals of the OMPO.

HDOT Highways Statement of Goals (2020 Act 100 Report):

- Improve Safety
  - Reduce Fatalities and Serious Injuries on Hawaiʻi's roads and bridges
  - Reduce Fatalities and Serious Injuries of non-motorized modes
- Foster System Preservation
  - Improve pavement conditions
  - Improve bridge conditions
  - Preservation and improvement of other assets
- Improve System Efficiency
- Multi-Modal Integration
  - Improve Multimodal and Intermodal access and connections
  - Improve Non-Motorized facilities
- Encourage Economic Vitality
  - Improve travel time reliability for trucks
- Improve Resiliency
  - Improve Resiliency by incorporating design adaptation strategies
  - Increase redundancy in the Transportation System

These goals are very consistent with those of the OMPO:

- Improve the safety of the transportation system
- Support active and public transportation
- Promote an equitable transportation system
- Improve the resiliency of the transportation system
- Preserve and maintain the transportation system
- Support a reliable and efficient transportation system; and
- Improve air quality and protect environmental and cultural assets.

The HDOT goals are also aligned with the national Federal-aid Highway Program performance goals as established by Congress:

- **Safety** - To achieve a significant reduction in traffic fatalities and serious injuries on all public roads.
- **Infrastructure Condition** - To maintain the highway infrastructure asset system in a state of good repair

- **Congestion Reduction** - To achieve a significant reduction in congestion on the National Highway System
- **System Reliability** - To improve the efficiency of the surface transportation system
- **Freight Movement and Economic Vitality** - To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development.
- **Environmental Sustainability** - To enhance the performance of the transportation system while protecting and enhancing the natural environment.
- **Reduced Project Delivery Delays** - To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practice

Three categories of measures were identified. This yielded 24 separate measures.

- Safety measures (20 measures)
- Congestion Relief measures (3 measures)
- Resilience measures (1 measure)

Safety measures of effectiveness include: Crash Modification Factors (CMFs); number of crashes by intersection, number of crashes by type and those involving pedestrians or bicycles. The analysis also reviewed potential projects for their contribution to 16 relevant Performance Measures in the HDOT Statewide Pedestrian Master Plan

Congestion Relief measures of effectiveness include: Vehicle Delay in seconds; Level of Service, Volume/Capacity Ratios.

Resilience measure of effectiveness: the degree to which a project addresses recommendations in the HDOT Statewide Coastal Highway Program Report (2019).

Whenever possible, MOE were assigned a numerical measurement. Where there was no numerical measure, a qualitative measure was created with a scale or range for the degree to which the MOE is met.

1.4 PRELIMINARY PROJECT IDENTIFICATION

At this stage, three types of improvements were identified to create a preliminary list of projects. The three project types were: 1) safety improvements; 2) congestion relief; and 3) improvements for greater resilience.

The project team utilized a USDOT FHWA database with crash modification factors (CMFs) to identify potential safety improvements, traffic analysis and HDOT planned improvements to develop a list of potential congestion relief projects, and input from past resilience studies to identify potential projects for greater resilience on Farrington Highway. In some cases, public input was used to add improvements to the list of potential projects.

Safety Improvements included the following:

- Adding bright street lighting at both ends of crosswalks
- Adding sidewalks, shoulder bike lanes and multi-use paths
- Adding speed feedback signs in reduced speed zones
- Adding new Signing and Marking
- Adding High Visibility Crosswalks
- Restricting left turn movements
- Adding pedestrian countdown timers and leading pedestrian intervals at signals
- Adding a green left arrow
- Adding right turn lanes
- Verifying that yellow/red times are industry standard
- Implementing Safe Routes to Schools
- Adding pedestrian hybrid beacons and advanced stop markings
- Adding raised medians
- Converting an open median to left in only movement
- Adding left turn lane offsets

Congestion Relief projects included the following:

- Computerized Traffic Control Systems in Waiʻanae, Nānākuli and Māʻili
- Adding a center left turn lane in Māʻili
- Extending the 5th lane and contraflow in Nānākuli
- Adding short right turn lanes for side streets at 2 intersections
- Restricting left-in turns at Waiomea Street
- Implementing Transportation Demand Management program (Interagency Effort)

A review of past efforts to build a Second Access to Kunia Road was completed in the Task 3 report, but this project was not scoped to program a Second Access.

Improvements for greater Resilience included the following:

- Drainage studies for locations that experience flooding (Farrington Highway intersections at Princess Kahanu Avenue, Leihoku Avenue and Waiʻanae Valley Road)
- A project to alleviate sand and wave over wash near Mākaha Valley Road
- Projects to address the recommendations of the HDOT Statewide Coastal Highway Program Report (2019) in Nānākuli
- Projects to address the recommendations of the HDOT Statewide Coastal Highway Program Report (2019) in Māʻili and Waiʻanae
- Projects to address the recommendations of the HDOT Statewide Coastal Highway Program Report (2019) in Mākaha
- Complete Waiʻanae Coast Emergency Access Route (WCEAR) and upgrade communication/management of detours (Interagency Effort)

Each of these categories was applied to four areas of focus on Farrington Highway, Segments 2, 4, 5 and 6, as listed in Tables 4, 5 and 6.

Table 4: Potential Improvement Projects for Safety, Congestion Relief and Greater Resilience on Segment 2 (the Nānākuli Segment) of Farrington Highway

SAFETY

Intersection Improvements	Implement Safe Routes to School Program at Nānākuli Avenue intersection, includes raised median Install high-visibility yellow, continental type crosswalks at Nānākuli Ave (incl in SRTS)
	Install pedestrian countdown timers at Hakimo Rd, Lualualei Naval Rd, Helelua St, Nānākuli Ave and Piliokahi Ave
	Raised Median at Hakimo Rd, Lualualei Naval Rd, Helelua St, Nānākuli Ave and Piliokahi Ave intersections
	Verify traffic signal yellow and red times meet ITE Recommended Practice
	Implement a leading pedestrian interval at Hakimo Rd, Lualualei Naval Rd, Helelua St, Nānākuli Ave and Piliokahi Ave intersections
	Convert an open median to a left-in only median at Laumania Ave.
	Improve left-turn lane offset to create positive offset at Hakimo Rd and Piliokahi Ave.
	Implement systemic signing and marking improvements at Laumania Ave.
	Implement systemic signing and visibility improvements at Hakimo Rd, Lualualei Naval Rd, Helelua St, Nānākuli Ave, and Piliokahi Ave
	Increase retro reflectivity of STOP signs at Laumania Ave
	Increase illuminance from low (<0.2 fc) to Medium >0.2 fc and <1.1 fc) @ 13 crosswalks
	Install dynamic speed feedback sign for 2 lanes (in 2 locations)
	Convert bridge by Laumania to allow bike and pedestrian traffic.
	Upgrade and widen sidewalk from Pohakunui to Helelua along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides
	Upgrade and widen sidewalk from Helelua to Hakimo along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides. Add Shared Use Path on makai side.
	Build Shared Use Path from Nānākuli to Pohakunui (4,000 ft)
	Build Shared Use Path from Pohakunui to Ko Olina (9,900 ft), partnering with OMPO, C&C, DHHL, PPP, HBL, others

CONGESTION

Extension of 5th Lane and Contraflow (Helelua to as far as Hakimo) approx 6,900 ft, (to incl mauka sidewalk, shoulders, shared use path as listed in safety projects)
Computerized Traffic Control System Phase 15 - Nānākuli
Computerized Traffic Control System Phase 15 - Nānākuli, expand to include La'aloa St. and Waiomea St. intersections
Restripe to add short right turn lane at Haleakala Avenue from side street approach
Widen and restripe to add right turn lane at Lualualei Naval Road from side street approach

RESILIENCE

Focused Drainage Study - Improve drainage to alleviate flooding at Princess Kahanu
Projects to improve drainage, alleviate flooding and for coastal hardening in Nānākuli (Figure 14)

Table 5: Potential Improvement Projects for Safety, Congestion Relief and Greater Resilience on Segment 4 (the Māʻili Segment) of Farrington Highway

SAFETY

Intersection Improvements	Implement Safe Routes to School Program at Maliona Street, incl raised median Install high-visibility yellow, continental type crosswalks at Maliona Street (incl in SRTS)
	Install pedestrian countdown timers at Maliona Street, Hookele Street and Kaʻukama Road
	Raised Median at St Johns Road, Hoʻokele St and Kaʻukama Rd intersections
	Verify traffic signal yellow and red times meet ITE Recommended Practice
	Modify signal phasing (implement a leading pedestrian interval) at Maliona St, St Johns Rd, Hoʻokele St, and Kaʻukama Rd
	Improve left-turn lane offset to create positive offset at St Johns Rd, Hoʻokele St, and Kaʻukama Rd
	Implement systemic signing and visibility improvements at Maliona St, St Johns Rd, Hoʻokele St, and Kaʻukama Rd
	Increase illuminance from low (<0.2 fc) to Medium >0.2 fc and <1.1 fc) @ 9 crosswalks
	Install dynamic speed feedback sign for 2 lanes (in 2 locations)
	Add sidewalk and shoulder bike lanes along both sides of Farrington Highway from Kaʻukama to Māʻiliʻili, 9,500 ft
	Build Shared Use Path from Māʻiliʻili to Leihoku, 2,500 ft
	Build Shared Use Path from Kaʻukama to Hakimo, 5,600 ft

CONGESTION

Add Center Left Turn Lane (Mano to Māʻiliʻili), 1,250 ft
Computerized Traffic Control System - Māʻili, 7 signals

RESILIENCE

Focused Drainage Study - Improve drainage to alleviate flooding in Māʻili
Projects to improve drainage, alleviate flooding and for coastal hardening in Māʻili and Waiʻanae (Figure 15)

Table 6: Potential Improvement Projects for Safety, Congestion Relief and Greater Resilience on Segments 5 and 6 (the Mākaha/Waiʻanae Segments) of Farrington Highway

SAFETY

Intersection Improvements	Install pedestrian countdown timers at both Puhano crosswalks
	Install pedestrian RRFB with advanced yield or stop markings and signs at Army St
	Install more raised crosswalks
	Install ped refuge raised median island at Army St
	Raised Median at Puhano St.
	Verify traffic signal yellow and red times meet ITE Recommended Practice
	Modify signal phasing (implement a leading pedestrian interval)
	Implement systemic signing and marking improvements at Army St
	Implement systemic signing and visibility improvements at Puhano St
	Increase retro reflectivity of STOP signs at 7 Stop Controlled intersections
	Increase illuminance from low (<0.2 fc) to Medium >0.2 fc and <1.1 fc) @ 20 crosswalks
	Install dynamic speed feedback sign for 2 lanes (in 2 locations)

CONGESTION

Computerized Traffic Control System Phase 16 - Waiʻanae

RESILIENCE

Focused Drainage Study to propose solutions for flooding at Leihoku St
Focused Drainage Study to propose solutions for flooding at Waiʻanae Valley Road
Plan and build rock veneer wall 500 ft x 4 ft high to prevent sand and wave over wash in Mākaha
Projects to improve drainage, alleviate flooding and for coastal hardening in Mākaha (Figure 16)

Figure 18: Farrington Highway utilizes Contraflow Operations in Nānākuli on weekdays 4-6 pm (photo credit: Hawai'i News Now)

2 PHASE TWO: COMMUNITY ENGAGEMENT, DATA COLLECTION, AND ANALYSIS

Phase 2 gathered data on community concerns, traffic volumes, crash data, and future traffic volumes. Tasks include:

1) Engaging with the community to identify traffic-related concerns.
2) Data collection including traffic counts at 39 intersections and traffic counts and speed studies on 3 segments.
3) This data helped identify, for the candidate projects, what would be the impact with the improvement compared to a base case without the improvement.
4) This led to a refined list of projects for further consideration.

The associated technical report for Phase 2 is:

Traffic Operations Report, Task 4.0 (December 2020)

2.1 METHODOLOGIES USED

Measures of transportation performance that had been developed in Phase 1 were applied to the preliminary candidate projects. To do this, a data assembly and new data collection effort was undertaken. An assessment was made of which MOE and what data to support that MOE were needed for each preliminary project from Phase 1.

Historic HDOT counts from 2012-2016 were used for total traffic count data. These were supplemented by 2018 traffic counts on Farrington Highway at three locations throughout the day over a 48-hour period. In addition, data was derived from 12 count locations where Oceanit deployed AI sensors and cameras to quantify multimodal traffic. The study team also made its own field observations of traffic conditions.

Fehr and Peers studied the OMPO regional traffic model and completed 2040 forecasts for Farrington Highway and side streets that considered changes in projected employment and other factors by Transportation Analysis Zone (TAZ). These forecasts were utilized to predict the future Levels of Service at Farrington Highway intersections.

Generally speaking, future travel demand is expected to increase along almost all segments of Farrington Highway, with an expected increase in traffic of 21 or 22 percent (range 17-26 percent) from 2018 to 2040 on most segments[2]. On side streets, there is expected to be an increase in traffic of 12 percent in most places, higher at some intersections, and up to 47 percent at Māʻiliʻili

[2] Annual growth rates ranged from 0.71 percent to 1.05 percent.

Road, from 2018 to 2040. The OMPO model uses 762 traffic analysis zones (TAZ) in its analysis; the Farrington Highway corridor directly includes 34 of the TAZ.

Origin-destination patterns and future daily traffic levels were forecast using the regional model developed by the OMPO. The forecast year was 2040. The team tested the future land use assumptions, roadway assumptions and over origin-destination pairs. The model met three of four validation metrics (correct amount of traffic; low root mean squared error; and high correlation coefficient). The conclusion reached was that the model could be used for forecasting volumes.

2.2 COMMUNITY ENGAGEMENT

One vision and intention of the Farrington Highway Corridor Study was to implement a context-sensitive planning process that integrates technical knowledge and community intelligence to develop preferred solutions along the corridor. The goal of this study was to identify short- and long-term transportation-based improvements in the categories of safety, congestion, and resilience that reflect and uphold community priorities and address the needs of all modes and users.

The objectives of the community engagement effort were to:

1. Achieve broad community awareness and participation in the project.
2. Engage youth in gathering input from the West Side community to inform the development of solutions.
3. Align the project as much as possible with existing projects and planning efforts.
4. Utilize a variety of means to gather input, drawing from innovative approaches and best practices.
5. Apply an Environmental Justice lens to identify and engage vulnerable users in the project area.

The community outreach process included:

- **Coordination with Agencies and Elected officials** to identify community issues and stakeholders in the project area.
- **Stakeholder Identification & Consultation** with key stakeholders within each of the communities along the corridor.
- **Working with Area Students** to develop, deploy, and analyze data from an online survey and story map to identify transportation issues, opportunities, and behaviors.
- **A Series of Facilitated ʻĀina Meetings** to identify issues, solutions, priorities, and phasing appropriate to the communities and ahupuaʻa along the corridor. See photo in Figure 19.

Figure 19: Community Meeting in Waianae

Figure 20 provides some metrics on the scope and reach of the public engagement effort. Appendix B describes the outreach effort in greater detail.

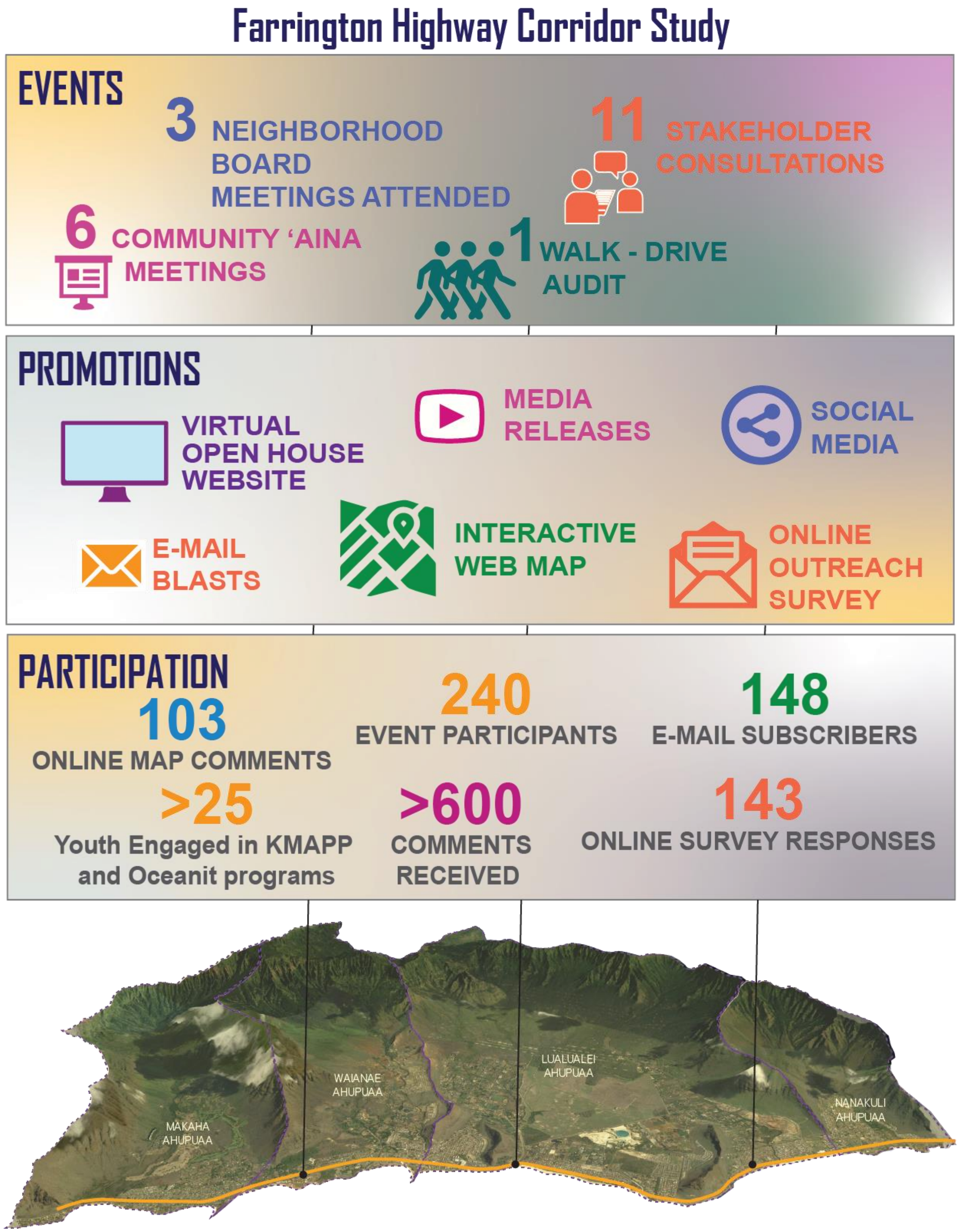

Figure 20: Community Engagement Summary

Community ʻĀina Meeting #1 – Transportation Issues and Behaviors

This Community ʻĀina meeting was the first of three rounds of meetings held in Waiʻanae and Nānākuli for the HDOT Farrington Highway Corridor Study. The purpose of the meeting was to introduce the project to both the Waiʻanae – Mākaha and the Nānākuli – Māʻili communities, gather input on critical transportation issues the community encountered as they move along the Waianae Coast, and to identify opportunities to improve conditions along Farrington Highway. The input provided went towards the development of recommendations for Farrington Highway that would meet the needs of the community into the future.

The first round of ʻĀina meetings for the Waiʻanae – Mākaha community was held on February 20, 2020, at the S&L Building in Waiʻanae. The Nānākuli – Māʻili community ʻĀina meeting was held on February 24, 2020, at the Nānākuli Public Library. A total of 68 attendees made up of community members and state, city, and local representatives were present for both meetings. At this community meeting, the project team shared a presentation of what has been done so far for the project, facilitated a breakout group discussion, conducted a question and answer session, and provided information on how the community can continue to participate and provide input for the project. Attendees received copies of the agenda, as well as copies of the presentation, project fact sheet, and comment sheets.

Several themes arose from the first round of community ʻĀina meetings related to safety, congestion, and resilience which include:

- **Safety:** We need to address pedestrian safety and reduce pedestrian-related deaths on the highway. The road feels unsafe for pedestrians and bicyclists especially at night, there are too many deaths and crashes due to speeding, the lack of lighting, and people parking on sidewalks affect this.
- **Congestion:** We need to make travel along the highway more efficient in order to reduce congestion. We spend too much of our lives in traffic – our time is valuable, and development here is still happening.
- **Resilience:** We need to improve major drainage issues along the highway, improve the existing emergency access road, and emphasize the need for a 2nd emergency access route to the Waianae Coast. The community is at risk of being cut off by disasters and the highway's proximity to the ocean is a concern for flooding and sea level rise.

An in-depth summary of all the input gathered from the first round of community ʻĀina meetings for both the Waiʻanae – Mākaha and the Nānākuli - Māʻili communities can be found in Appendix B.

Community ʻĀina Meeting #2 – Solutions for Safety, Congestion, and Resilience

This Community meeting was the second of three rounds of ʻĀina meetings held for the HDOT Farrington Highway Corridor Study. In lieu of in-person community meetings due to the State's COVID-19 Social Distancing Policy, this ʻĀina meeting was conducted through an online Open House website on HDOT's SpeakUp platform coupled with a virtual Question and Answer (Q&A) session with the project team through the Microsoft Teams video conference platform. The online Open House contained a recorded video presentation, materials, and information about the project. Through the Open House, the public was able to view the materials and provide comments in several ways – this included commenting directly on the file, filling out short voting polls, and filling out open-ended comment forms posted on the site. Email blasts, social media, and the HDOT project website were used to announce the online Open House and the dates and times of the live Q&A. The Q&A provided an opportunity for the people to ask questions of the project team that related to the Open House materials.

The purpose of this meeting was to continue collaborating with the community to develop solutions for Farrington Highway, to share the results from community input collected to date, present preliminary solutions for Farrington Highway based on community manaʻo and technical studies, and to continue collecting input on proposed solutions via the online Open House and virtual Q&A sessions. The Open House period was held from April 30 – May 14, 2020. Two one-hour virtual Q&A sessions were held for both the Waiʻanae – Mākaha and the Nānākuli – Māʻili communities on May 6 and 7, 2020. A total of eight (8) community members participated during both Q&A sessions.

Several specific takeaways for solutions were recorded from each Q&A session which include:

- **Congestion:**
    - Need for 5th lane extension to address Nānākuli bottlenecks; also, it will help alleviate illegal left turns.
    - Support for center turn lanes.
    - Interest in signal adjustments to alleviate congestion, but also need to allow people to turn off side streets and allow pedestrians to cross the street.
- **Safety:**
    - Desire for more shared-use paths for walking and biking – including extending from Mākaha to Kahe Point and to Kapolei for connectivity to the Honolulu Rail.
    - Agreement that the bridge at Nānākuli should be used for pedestrians.
    - Support for prohibiting right turns on red for safety.
    - Desire for more raised crosswalks (especially near schools), and to make existing ones more visible with colored/higher reflectivity paint.
    - Interest in learning more and seeing examples of pedestrian safety treatments.
    - Interest in looking at concrete barriers between Māʻiliʻili Road and Leihoku Street.
- **Resilience:**
    - Need for a second access to the Waiʻanae Coast.
- **Other Concerns:**
    - Questions regarding funding available for projects on the Westside.
    - That these needs are urgent, and interest in timing of when these solutions will all happen.

An in-depth summary of all the input gathered from the online Open House and both Q&A sessions from the second round of community ʻĀina meetings can be found in Appendix B.

Community ʻĀina Meeting #3 – Priorities and Phasing

This Community meeting was the third and final round of ʻĀina meetings held for the HDOT Farrington Highway Corridor Study. This final round of ʻĀina meetings was similar to the format of the 2nd round of community ʻĀina meetings due to the continuation of the State's COVID-19 Social Distancing Policy. This ʻĀina meeting was conducted through an online Open House website on HDOT's SpeakUp platform coupled with a virtual Q&A session to provide the public the opportunity to ask questions to the project team related to the new Open House materials. Email blasts, social media, flyer distribution, and the HDOT project website was used to announce the online Open House and the dates and times of the live Q&A.

The purpose of this meeting was to continue collaborating with the community to develop solutions for the highway and to present draft recommendations and to discuss priority improvements and the phasing of these improvements for Farrington Highway. The Open House's content and input-gathering mechanisms were customized to gather input on the priorities of proposed short and long-term solutions for the highway.

The Open House period was held from July 6 – 27, 2020. Two one-hour virtual Q&A sessions were held for both the Waiʻanae – Mākaha and the Nānākuli – Māʻili communities on July 16 and 24, 2020. A total of twelve (12) community members participated during both Q&A sessions.

Several discussion points were recorded from each Q&A session which include:

- Balance of projects that are oriented toward traffic control vs. resilience. Resilience improvements are few and long-term. The drainage improvements are fixing problems that already existing, not addressing future flooding issues.
- Need to bring together the disparate projects that are happening along Farrington Highway into a coherent program, not piecemeal. Corridor study should incorporate the existing projects as well as the proposed projects.
- Support for shared-use paths that separate pedestrian and bicycles from vehicular traffic. Need to tie into the Leeward Bikeway project (federally funded) to make it happen faster.

- Concern if revenue from the proposed car rental surcharge will still be available.
- Concern about the Mākaha Bridge project due to *iwi kupuna* (burials) located in the area.

An in-depth summary of all the input gathered from the online Open House and both Q&A sessions from the third round of community ʻĀina meetings can be found in Appendix B.

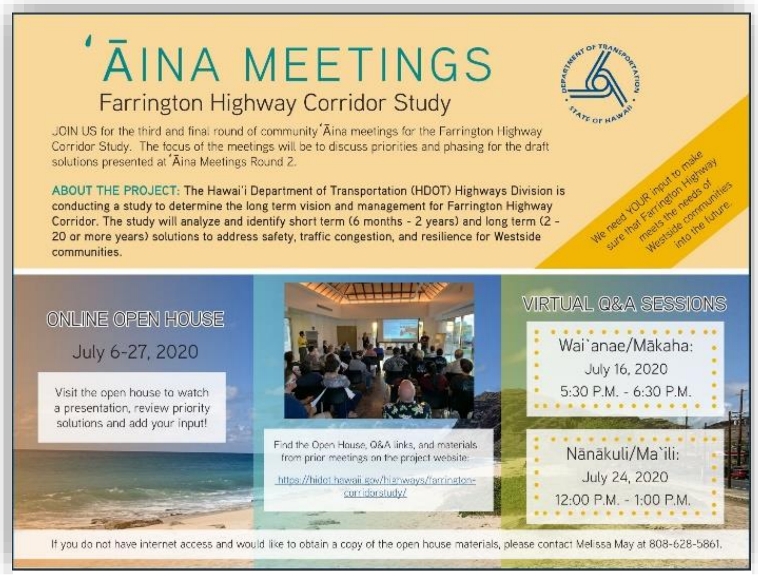

Figure 21: ʻĀina Meeting Flyer

Online Outreach Survey Notable Findings:

- Over 86% of respondents use their own personal car as their primary mode of transportation to move through or around the Project Area for work, school, or other activities. Over 40% have indicated using a household member's car as their secondary means of travel, next to walking (16.7%).
- More than 50% of respondents have viewed traveling along Farrington Highway as "Very Unsafe" for pedestrians of all ages during both day and night, especially for the youth (under age 13) and senior citizens (over age 65).
- Over 76% of respondents view bicycling at night as "Very Unsafe" on Farrington Highway versus over 41% during the day.
- Over 83% of respondents have said that reducing vehicle traffic congestion is the most important objective in the immediate and short-term period, next to providing a secondary access road to the community (82%) and reducing the number of vehicle crashes with pedestrians and bicyclists (74%).
- Similar to the top objectives for Farrington Highway in the short-term, over 83% of respondents have said that providing a secondary access road to the community is the most important objective in the long-term, next to reducing vehicle traffic congestion (78%), and reducing the number of vehicle crashes with pedestrians and bicyclists (74%).

3 PHASE THREE: ESTIMATING BENEFITS FOR CANDIDATE PROJECTS

Phase 3 concentrated on determining the benefits of the potential projects either alone or in combination.

3.1 METHODOLOGY

In Phase 3, multiple methods were used to determine benefits for a meaningful comparison of performance for the candidate projects.

For Safety projects, the analysis applied a factor that reflects the number of crashes prevented where data was available. Where those factors and data was not available, the analysis estimated the degree to which a project contributed to the Performance Measures of the Statewide Pedestrian Master Plan.

For Congestion Relief projects, the analysis used results of the Synchro analysis in the Traffic Operations report to calculate delay with and without the candidate project.

For Resilience projects, the analysis referenced a past study with benefit/cost calculations.

3.2 PHASE 3 ANALYSIS

The Federal Highway Administration (FHWA) provides guidance on conducting a Benefit/Cost Analysis for a given safety improvement or countermeasure.

> *"A benefit/cost analysis expresses benefits in monetary terms, which requires an estimate of the number of crashes avoided as a result of the countermeasure, and the monetary value of each avoided crash. When available, crash modification factors should be used to determine the expected reduction in crashes.[3]"*

A crash modification factor (CMF) is a number that, when multiplied by the expected number of crashes at a given site, will estimate the new number of crashes with a given countermeasure installed. For instance, if a given stretch of highway is expected to have 100 crashes/year based on historical data, and rumble strips are installed as a countermeasure, and installing rumble strips is determined (through data and case studies) to have a CMF of 0.9, the new expected number of crashes/year would be 90. CMFs can be found at www.cmfclearinghouse.org

[3] https://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/sec4.cfm

For each of the potential safety countermeasures, a calculation was applied to predict the expected number of crashes of a certain type with and without the countermeasure(s). The Benefit calculations are included in Appendix C, and the results are summarized in Tables 7, 8, 9 and 10.

Table 7: Recorded and Expected Crashes at Selected Study Intersections on Farrington Highway*

Farrington Highway Segment and locations of proposed Intersection Safety Improvements	PDO[4] $7,400[5]	C[6] $44,900	K/A/B[7] $158,200	Total
Segment 2: Tracks Beach Park to Hakimo Road (Piliokahi Ave., Laumania Ave., Nānākuli Ave., Helelua St., Lualualei Naval Rd., Hakimo Rd.)				
Recorded in 4 years	25	30	14	69
Expected in 10 years (no countermeasures)	63	75	35	173
Expected in 10 years (with countermeasures)	21	28	11	60
10 year Reduction	42	47	24	113
1 year Reduction	4.2	4.7	2.4	11.3
1 year Benefit	$31,080	$211,030	$379,680	$621,790
Segment 4: Kaʻukama Road to Leihoku Street (Kaʻukama Rd, Hoʻokele St, St Johns Rd and Maliona)				
Recorded in 4 years	10	4	8	22
Expected in 10 years (no countermeasures)	25	10	20	55
Expected in 10 years (with countermeasures)	8	1	6	15
10 year Reduction	17	9	14	40
1 year Reduction	1.7	0.9	1.4	4.0
1 year Benefit	$12,580	$40,410	$221,480	$274,470
Segment 5: Leihoku Street to Waiʻanae High School (Puhano St. and Army St.)				
Recorded in 4 years	5	3	2	10
Expected in 10 years (no countermeasures)	13	8	5	26
Expected in 10 years (with countermeasures)	5	2	1	8
10 year Reduction	8	6	4	18
1 year Reduction	0.8	0.6	0.4	1.8
1 year Benefit	$5,920	$26,940	$63,280	$96,140

*Only pedestrian, left turn, rear end and angle crashes are included, with crash type-specific CMFs applied. Refer to Appendix C for list of countermeasures and CMFs applied at study intersections.

[4] Property Damage Only (PDO) crashes
[5] Average cost for each type of crash obtained from FHWA website
[6] Possible injury (C) crashes
[7] Fatal (K), incapacitating injury (A) or non-incapacitating injury (B) crashes

Table 8: Recorded and Expected Nighttime Pedestrian Crashes (in crosswalks) on 3 segments of Farrington Highway*

	PDO $7,400	C $44,900	K/A/B $158,200	Total
Segment 2: 13 Crosswalks (Tracks Beach Park to Hakimo Road)				
Recorded in 4 years	1	4	6	11
Expected in 10 years (no countermeasure)	3	10	15	28
Expected in 10 years (with countermeasure)	1	5	7	13
10 year Reduction	2	5	8	15
1 year Reduction	0.2	0.5	0.8	1.5
1 year Benefit	$1,480	$22,450	$125,769	$149,699
Segment 4: 9 Crosswalks (Ka'ukama Road to Leihoku Street)				
Recorded in 4 years	1	4	3	8
Expected in 10 years (no countermeasure)	3	10	8	21
Expected in 10 years (with countermeasure)	1	5	4	10
10 year Reduction	2	5	4	11
1 year Reduction	0.2	0.5	0.4	1.1
1 year Benefit	$1,480	$22,450	$63,280	$87,210
Segment 5: 20 Crosswalks (Leihoku Street to Wai'anae High School)				
Recorded in 4 years	1	4	3	8
Expected in 10 years (no countermeasure)	3	10	8	21
Expected in 10 years (with countermeasure)	1	5	4	10
10 year Reduction	2	5	4	11
1 year Reduction	0.2	0.5	0.4	1.1
1 year Benefit	$1,480	$22,450	$63,280	$87,210

*Only nighttime pedestrian crashes within crosswalks are included. Countermeasure studied was increasing crosswalk street light illuminance from low (<0.2 fc) to medium (>0.2 fc). CMF = 0.47 for nighttime pedestrian crashes.

Table 9: Recorded and Expected Crashes on 3 Segments of Farrington Highway where Speed Feedback signs are a potential safety improvement*

	PDO $7,400	C $44,900	K/A/B $158,200	Total
Nānākuli Avenue – Helelua Street (in Segment 2)				
Recorded in 4 years	31	27	15	73
Expected in 10 years (no countermeasure)	78	68	38	184
Expected in 10 years (with countermeasure)	74	65	36	175
10 year Reduction	4	3	2	9
1 year Reduction	0.4	0.3	0.2	0.9
1 year Benefit	$2,960	$13,470	$31,640	$48,070
Kaʻukama Road - Maipalaoa Road (in Segment 4)				
Recorded in 4 years	20	18	18	56
Expected in 10 years (no countermeasure)	50	45	45	140
Expected in 10 years (with countermeasure)	48	43	43	134
10 year Reduction	2	2	2	6
1 year Reduction	0.2	0.2	0.2	0.6
1 year Benefit	$1,480	$8,980	$31,640	$42,100
Leihoku Street -Kili Drive (in Segment 5)				
Recorded in 4 years	48	57	38	143
Expected in 10 years (no countermeasure)	120	143	95	358
Expected in 10 years (with countermeasure)	114	136	90	340
10 year Reduction	6	7	5	18
1 year Reduction	0.6	0.7	0.5	1.8
1 year Benefit	$4,440	$31,430	$79,100	$114,970

*All crashes within potential speed feedback sign limits are included. Countermeasure studied was installing speed feedback signs. CMF = 0.95 for all crash types.

Table 10: Recorded and Expected Crashes in zone of potential addition of Center Left Turn Lane (Mana to Māʻiliʻili)*

	PDO $7,400	C $44,900	K/A/B $158,200	Total
Mana Street - Māʻiliʻili Road (in Segment 4)				
Recorded in 4 years	10	12	11	33
Expected in 10 years (no countermeasure)	25	30	28	83
Expected in 10 years (with countermeasure)	14	16	15	45
10 year Reduction	11	14	13	38
1 year Reduction	1.1	1.4	1.3	3.8
1 year Benefit	$8,140	$62,860	$205,660	$276,660

*All crashes within limits of potential addition of Center Left Turn Lane are included, with crash type-specific CMF applied. Countermeasure studied was 4 to 5 lane conversion. CMF = 0.54 for all crash types.

To convert the annual Benefit to a Present Value, guidance from the FHWA was used. With a uniform annual benefit, the Present Value of that benefit = PVB_v. In the analysis, five years was assumed for the service life of the countermeasures studied. Although the countermeasures' benefits are expected to last longer than 5 years, this simplified the analysis and gave a conservative B/C ratio.

*PVB_v = Total Annual Monetary Benefits * (P/A,i,n)*

Where:

PVB_v =	present value of the safety benefits for a specific site, v
(P/A,i,n) =	$[(1+i)^n - 1]/[i(1+i)^n]$
i =	minimum attractive rate of return of discount rate (i.e., if the discount rate is 4 percent, i = 0.04)
n =	years in the service life of the countermeasure(s). 5 years used for this study

(P/A,I,n) = $[(1+0.04)^5 - 1]/[0.04(1+0.04)^5]$ = 4.452

*PVB_v = Total Annual Monetary Benefits * 4.452*

Therefore, the Annual Monetary Benefits and the Present Values of the Benefits from the Potential Improvements are shown in Table 11. These values will be used in Section 4.6 to compute Benefit to Cost Ratios.

Table 11: Estimated Annual Monetary Benefits and Present Values of Various Potential Safety Improvements with CMFs

		Annual Monetary Benefits	PVB_v
SEGMENT 2			
	Intersection Improvements (6 intersections)	$ 621,970	$ 2,768,209
	Street Light Improvements (13 xwalks)	$ 149,699	$ 666,460
	Speed Feedback Signs	$ 48,070	$ 214,008
SEGMENT 4			
	Intersection Improvements (4 intersections)	$ 274,470	$ 1,221,940
	Street Light Improvements (9 xwalks)	$ 87,210	$ 388,259
	Speed Feedback Signs	$ 42,100	$ 187,429
	Add Center Left Turn Lane	$ 276,660	$ 1,231,690
SEGMENT 5			
	Intersection Improvements (2 intersections)	$ 96,140	$ 428,015
	Street Light Improvements (20 xwalks)	$ 87,210	$ 388,259
	Speed Feedback Signs	$ 114,970	$ 511,846

The Safety Projects without CMFs available, shown in Table 12 (repeated from Tables 4 and 5), relate to bicycle and pedestrian safety improvements. The projects that have been identified to enhance multimodal traffic involve adding sidewalk with curb and gutter to protect and separate pedestrians from vehicular traffic, to better accommodate persons with disabilities and to better fit into the high foot traffic neighborhoods. Completing the shared use path along Farrington Highway will also provide safe passage for pedestrians and bicyclists and will connect the communities along the Leeward Coast.

Table 12: Safety Projects without CMFs

SAFETY PROJECTS – SEGMENT 2 (NĀNĀKULI SEGMENT)
Convert bridge by Laumania to allow bike and pedestrian traffic.
Upgrade and widen sidewalk from Pohakunui to Helelua along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides
Upgrade and widen sidewalk from Helelua to Hakimo along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides. Add Shared Use Path on makai side.
Build Shared Use Path from Nānākuli to Pohakunui (4,000 ft)
Build Shared Use Path from Pohakunui to Ko Olina (9,900 ft), partnering with OMPO, C&C, DHHL, PPP, HBL, others
SAFETY PROJECTS – SEGMENT 4 (MĀʻILI SEGMENT)
Add sidewalk and shoulder bike lanes along both sides of Farrington Highway from Kaʻukama to Māʻiliʻili, 9,500 ft
Build Shared Use Path from Māʻiliʻili to Leihoku, 2,500 ft
Build Shared Use Path from Kaʻukama to Hakimo, 5,600 ft

These improvements are in response to community requests and priorities and they are consistent with multiple relevant planning, design and guidance documents, including:

- Hawaiʻi Statewide Transportation Plan
- Hawaiʻi Strategic Highway Safety Plan
- Hawaiʻi Pedestrian Master Plan and Pedestrian Toolbox
- Hawaiʻi Long-Range Land Transportation Plan (LRLTP) (2014)
- Oahu General Plan (2006)
- Oahu Regional Transportation Plan 2035 (2011)
- Oahu Bike Plan
- City and County of Honolulu Complete Streets ordinance and Design Manual
- Guidance on design to comply with ADA standards and best practice
- Oahu MPO Transportation Improvement Plan

Convert bridge by Laumania to allow bike and pedestrian traffic. This bridge is owned by the City and County of Honolulu. In the community engagement meetings, it was requested to open this gated, emergency use only vehicle bridge to bicycle and pedestrian traffic throughout the day. This is a low-cost way to provide safe transportation to bikes and pedestrians. This would require interagency discussions with the City and County of Honolulu for approval.

Upgrade and widen sidewalk from Pohakunui to Helelua along mauka side of Farrington Highway. Currently in this segment there is an asphalt curb separating an at grade 3-4-foot-wide paved pedestrian area from the vehicle lanes on the mauka side of Farrington Highway. In many locations, the pavement is degraded and uneven or missing, and has obstructions that prevent easy passage by wheelchairs, as shown in the following photos.

Figure 22: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google maps)

Figure 23: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google maps)

Figure 24: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google maps)

Figure 25: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google Maps)

Figure 26: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google Maps)

Figure 27: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google Maps)

Figure 28: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google Maps)

Figure 29: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google Maps)

Figure 30: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google Maps)

Figure 31: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google Maps)

Figure 32: Mauka Sidewalk along Farrington Highway between Pohakunui Avenue and Helelua Street (Google Maps)

Upgrade and widen sidewalk from Helelua to Hakimo along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides. Add Shared Use Path on makai side. Currently in this segment there is an asphalt curb separating an at grade 3-4-foot-wide paved pedestrian area from the vehicle lanes on the mauka side of Farrington Highway in some places, and no pavement or curb in other places. In many locations, the pavement is degraded and uneven or missing, and has obstructions that prevent easy passage by wheelchairs, as shown in the following photos.

Figure 33: Mauka Sidewalk along Farrington Highway between Helelua Street and Hakimo Road (Google Maps)

Figure 34: Mauka Sidewalk along Farrington Highway between Helelua Street and Hakimo Road (Google Maps)

Figure 35: Mauka Sidewalk along Farrington Highway between Helelua Street and Hakimo Road (Google Maps)

Figure 36: Mauka Sidewalk along Farrington Highway between Helelua Street and Hakimo Road (Google Maps)

Add sidewalk and shoulder bike lanes along both sides of Farrington Highway from Kaʻukama to Māʻiliʻili (9,500 ft). Similar to the walking path in Nānākuli, this area mauka of Farrington Highway is narrow and has many fire hydrants, utility poles, parked cars and signposts obstructing the walking area, preventing passage by wheelchairs, as shown in the following photos.

Figure 37: Mauka Sidewalk along Farrington Highway between Kaʻukama Road and Māʻiliʻili Road (Google Maps)

Figure 38: Mauka Sidewalk along Farrington Highway between Kaʻukama Road and Māʻiliʻili Road (Google Maps)

Figure 39: Mauka Sidewalk along Farrington Highway between Kaʻukama Road and Māʻiliʻili Road (Google Maps)

Build Shared Use Path from Nānākuli Avenue to Pohakunui Avenue (4,000 ft). This project will extend the current 0.5-mile shared use path that runs between Helelua Street and Nānākuli Avenue and could incorporate the use of the emergency use only bridge near Laumania Avenue.

Build Shared Use Path from Pohakunui Avenue to Ko Olina (9,900 ft). This project is described as the Leeward Bike Path Phase 2 and has been in the long-term plans for years.

Build Shared Use Path from Māʻiliʻili Road to Leihoku Street (2,500 ft). This project will provide connectivity between the communities of Māʻili and Waiʻanae and provide a walkway on a segment that has no sidewalk.

Build Shared Use Path from Kaʻukama Road to Hakimo Road (5,600 ft). This project will provide connectivity between the communities of Nānākuli and Māʻili and provide a walkway on a segment that has no sidewalk.

The bike lane and Shared Use Path projects together will provide continuous bicycle and pedestrian accommodations all the way from Ko Olina to Kili Drive.

Hawaiʻi DOT developed a Statewide Pedestrian Master Plan (PMP) in 2013. This document was used to evaluate and rank the projects for their value in addressing the Goals, Objectives and Performance Measures of the PMP. Figure 40 is taken from the PMP and the goals, objectives and performance measures that apply are highlighted.

Performance Measure by Goal and Objective

Goal 1: Improve Pedestrian Mobility and Accessibility		
Objective	**Performance Measures**	**Tier**
a. Increase pedestrian activity	Adoption of statewide and county Complete Streets policies	1
	Pedestrian mode split (percentage of trips by foot)	2
b. Encourage use of the Hawaii Pedestrian Toolbox	Provide training for agency staff and consultants on the Hawaii Pedestrian Toolbox	1
c. Implement projects along state highways to enhance pedestrian mobility and accessibility	Percentage of roadway projects completed that include improvements to pedestrian facilities	1
d. Improve maintenance of pedestrian facilities	Dollar amount spent on sidewalk repairs.	2
Goal 2: Improve Pedestrian Safety		
Objective	**Performance Measures**	**Tier**
a. Reduce the number of crashes and fatalities involving pedestrians	Number of annual pedestrian crashes and fatalities	1
b. Increase driver and pedestrian knowledge of laws, legal requirements, rights, and responsibilities	Dollar amount spent on pedestrian safety educational programs sponsored or co-sponsored by the HDOT	1
	Number of public awareness campaigns related to pedestrian safety implemented each year	1
	Hours of or number of pedestrian-related law enforcement stings implemented each year	1
	Number of the HDOT bike/pedestrian staff per million people	2
c. Modify driver and pedestrian behaviors to improve pedestrian safety	Existence of laws protecting pedestrian right-of-way in crosswalks	1
	Number of driver's test questions on pedestrians and information on pedestrians in the Hawaii Driver's Manual	1
	Number of police citations for pedestrian-related violations	2
d. Use best practices for design and operation of all pedestrian crossings	Provide training for agency staff and consultants on the Hawaii Pedestrian Toolbox (Same performance measure as Goal 1, Objective b)	1
	Percentage of projects that include pedestrian crossing safety treatments	1
	Number of pedestrian countdown timers installed at signalized intersections	2
Goal 3: Improve Connectivity of the Pedestrian Network		
Objective	**Performance Measures**	**Tier**
a. Support development of seamless and continuous pedestrian networks along state highways with connections to paths, walkways, trails, transit centers, and other pedestrian facilities	Miles of new sidewalks and shared use paths along state highways	1
	Percentage of transportation improvement projects that have been reviewed for consideration of pedestrians	2
b. Encourage pedestrian connectivity across jurisdictions	Adoption of Complete Streets Policy (Same performance measure as Goal 1, Objective a)	1
	Provide training for agency staff and consultants on the Hawaii Pedestrian Toolbox (Same performance measure as Goal 1, Objective b)	1
c. Support programs to encourage more students to walk to and from school	Presence and number of Walk/Bike to School Day programs	2
Goal 4: Promote Environmental Benefits of Walking		
Objective	**Performance Measures**	**Tier**
a. Broaden public awareness about the environmental benefits of pedestrian travel	Number of the HDOT bike/pedestrian staff per million people (same performance measure as Goal 2, Objective b)	2
b. Reduce overall vehicle miles traveled through increased pedestrian trips	Pedestrian mode split (same performance measure as Goal 1, Objective a)	2

STATEWIDE PEDESTRIAN MASTER PLAN

Figure 40: Hawai'i DOT's Statewide Pedestrian Master Plan Performance Measures, Goals and Objectives

Objective	Performance Measures	Tier
c. Increase the use of other modes of transportation to reduce the use of fossil fuels.	Percentage increase of bike ridership to work	2
	Percentage increase of annual transit ridership	2
d. Integrate pedestrian facility design with the natural environment to the greatest extent possible	Provide training for agency staff and consultants on the Hawaii Pedestrian Toolbox (same performance measure as Goal 1, Objective b)	1
Goal 5: Encourage Walking to Foster Healthy Lifestyles		
Objective	**Performance Measures**	**Tier**
a. Broaden public awareness about the health benefits of walking/pedestrian travel	Number of public awareness campaigns related to pedestrian safety implemented each year (same performance measure as Goal 2, Objective b)	1
	Dollar amount of pedestrian safety educational programs sponsored or co-sponsored by the HDOT (same performance measure as Goal 2, Objective b)	1
	Number of the HDOT bike/pedestrian staff per million people (same performance measure as Goal 2, Objective b)	2
b. Improve public health through encouragement of walking	Percentage of state centerline miles with sidewalks in urban areas	1
	Percentage of overall population and of youth (ages 10 to 17) who are obese or overweight	2
	Incidences of diabetes or asthma per million people and physical activity levels	2
c. Support community-based events such as fun runs, walks, parades, and other pedestrian-based activities that encourage walking for daily exercise and socialization	Number of community-based events endorsed by the HDOT	2
Goal 6: Enhance Communities and Economic Development By Creating Pedestrian-Oriented Areas and Positive Pedestrian Experiences		
Objective	**Performance Measures**	**Tier**
a. Encourage priority pedestrian infrastructure investment in communities that are in high-density residential, visitor/tourist locations, and/or that have higher pedestrian-oriented populations (seniors, youth, low-income, or households with no access to vehicles)	Consider the locations of pedestrian-oriented populations and visitor/tourist locations when preparing General Plans, Community Development Plans, or Sustainable Community Plans. Include the need for pedestrian facilities in developments in these areas and high-density residential areas.	1
b. Encourage reference to and use of the Hawaii Pedestrian Toolbox to create pedestrian-friendly settings that provide a positive pedestrian experience and attract high levels of activity	Provide training for agency staff and consultants on the Hawaii Pedestrian Toolbox (same performance measure as Goal 1, Objective b)	1
c. Require development projects to include pedestrian infrastructure, for the appropriate land use and facility	Number and/or percentage of encroachment permits that include pedestrian infrastructure on state facilities	2
Goal 7: Promote and Support Walking as an Important Transportation Mode That Reduces Overall Energy Use		
Objective	**Performance Measures**	**Tier**
a. Strengthen public awareness about the energy conservation benefits of walking	Number of public awareness campaigns related to pedestrian safety implemented each year (same performance measure as Goal 2, Objective b)	1
	Number of the HDOT bike/pedestrian staff per million people (same performance measure as Goal 2, Objective b)	2
b. Increase the use of other modes of transportation that reduce the use of fossil fuels.	Percentage increase of annual transit ridership (same performance measure as Goal 4, Objective c) Percentage Increase of bike ridership to work (same performance measure as Goal 4, Objective c)	2
c. Reduce resident and visitor motor vehicle fuel demand to help meet 2030 targets for energy efficiency	Air quality levels	2
d. Encourage Smart Growth development with coordinated land use and transportation planning	Implementation of priorities established in transporation planning documents, such as the Statewide and Regional LRLTPs, Bike Plan Hawaii, and Statewide Pedestrian Master Plan	2

STATEWIDE PEDESTRIAN MASTER PLAN

To compare the benefits of these safety projects and to help prioritize their construction, a summary table (Table 13) was created that lists the estimated pedestrian and bicycle activity. Furthermore, the table summarizes how each project contributes to the goals, objectives and performance measures (PM) of the HDOT Pedestrian Master Plan (PMP) and to what degree. [1=theoretical or very minor contribution, 2=minor contribution, 3=significant contribution]

Table 13: Project Benefits and Rankings by Contribution to Pedestrian Master Plan Performance Measures

	Convert Emergency Bridge to Allow Bikes and Pedestrians [S11]	Sidewalk [S12]	Sidewalk, shoulder bike lanes and shared use path [S13]	Shared Use Path [S14]	Shared Use Path [S15]	Sidewalk and shoulder bike lanes [S16]	Shared Use Path [S17]	Shared Use Path [S18]
From	~Laumania	Pohakunui	Helelua	Nānākuli	Pohakunui	Kaʻukama	Māʻiliʻili	Kaʻukama
To	~Nānākuli	Helelua	Hakimo	Pohakunui	Ko Olina	Māʻiliʻili	Leihoku	Hakimo
Segment Avg. # of peds traveling parallel to Farrington Highway in 12 hr count	34	65	97	34	54[8]	83	51	40
Segment Avg. # of bikes traveling parallel to Farrington Highway in 12 hr count	13	N/A	36	11	24[9]	54	67	28
PMP Goal 1 - Objective a PM2 % trips by foot	3	2	3	3	2	2	2	2
PMP Goal 1 - Objective c PM % projects with pedestrian improvements	3	3	3	3	3	3	3	3
PMP Goal 1 - Objective d PM $ spent on sidewalk repairs	0	3	3	2	1	3	1	1
PMP Goal 2 - Objective a PM # ped crashes	1	2	2	1	1	2	1	1

[8] To estimate the # of pedestrians using this path, the number of pedestrians at Piliokahi Ave. travelling parallel to Farrington Highway was doubled.
[9] To estimate the # of bikes using this path, the number of bikes at Piliokahi Ave. travelling parallel to Farrington Highway was tripled.

PMP Goal 2 - Objective d PM1 % projects that include ped crossing safety treatments, PM2 # of ped countdown timers installed	0 0	3 3	3 3	1 1	0 0	2 *2*	0 0	0 0
PMP Goal 3 - Objective a PM1 miles of new sidewalks and shared use paths along state highways, PM2 % transportation projects w consideration of pedestrians	1 3	3 3	3 3	3 3	3 3	3 *3*	3 3	3 3
PMP Goal 4 - Objective b PM pedestrian mode split	1	2	2	2	1	2	2	2
PMP Goal 4 - Objective c PM1 % increase in bike ridership to work, PM2 % increase in annual transit ridership	1	1	2	2	2	2	2	2
PMP Goal 5 - Objective b PM1 % of state centerline miles w sidewalks in urban areas	1	3	3	2	1	3	2	2
PMP Goal 6 - Objective a PM consider locations of ped-oriented populations when preparing general plans, etc.	3	3	3	3	2	3	2	2
PMP Goal 6 - Objective c PM # or % of encroachment permits that include pedestrian infrastructure on state facilities	0	1	1	1	1	1	1	1
PMP Goal 7 - Objective b PM % increase of transit ridership and bike ridership to work	1	1	2	2	2	2	2	2
PMP Goal 7 - Objective c PM air quality levels	0	1	1	1	1	1	1	1
PMP Goal 7 - Objective d PM implementation of priorities in LRLTPs, bike plans, PMP	3	3	3	3	3	3	3	3
Sum of Points earned for contributing to Performance Measures of the PMP	21	37	40	33	26	37	28	28
Sum of Points * (# peds + # bikes) to benefit	987	2405	5320	1485	2028	5069	3304	1904
Rank	8	4	1	7	5	2	3	6

The Congestion Relief Projects in Table 14 (repeated from Tables 4, 5 and 6) relate to reducing delays and relieving congestion. An analysis follows to estimate the benefits of each project.

Table 14: Congestion Projects for Consideration

CONGESTION RELIEF PROJECTS – SEGMENT 2 (NĀNĀKULI SEGMENT)
Extension of 5th Lane and Contraflow (Helelua to as far as Hakimo) approx 6,900 ft, incl mauka sidewalk, shoulders, shared use path
Restripe to add short right turn lane at Haleakala from side street approach
Widen pavement and restripe to add right turn lane at Lualualei Naval Road from side street approach
Computerized Traffic Control System Phase 15 - Nānākuli
Computerized Traffic Control System Phase 15 - Nānākuli, expand to include Laʻaloa St. and Waiomea St. intersections
CONGESTION RELIEF PROJECTS – SEGMENT 4 (MĀʻILI SEGMENT)
Computerized Traffic Control System - Māʻili, 7 signals
CONGESTION RELIEF PROJECTS – SEGMENT 5 (WAIʻANAE SEGMENT)
Computerized Traffic Control System Phase 16 - Waiʻanae

Extension of 5th Lane and Contraflow (Helelua to as far as Hakimo Road) approximately 6,900 ft, including mauka sidewalk, shoulders, shared use path. The traffic operations report calculated delays at each signalized intersection in the potential 5th Lane extension zone with and without the extended contraflow. The results of that analysis are summarized in Table 15.

Table 15: Estimated PM Peak Hour Congestion Relief Benefits from Extended Contraflow Lane in Nānākuli

Intersection	NO Extended Contraflow, Avg. Delay/veh (sec)	Extended Contraflow Avg. Delay/veh (sec)	Avg. Time Savings/ veh (sec)	PM Peak Hour Volume	PM Peak Hour Time Savings/ day (hrs)
Lualualei Naval Road and Farrington Highway	23.0	19.8	3.2	3,706	3.3
Auyong Homestead Road and Farrington Highway	6.0	5.6	0.4	3,083	0.3
Mohihi Street and Farrington Highway	5.3	4.0	1.3	3,061	1.1
Princess Kahanu Avenue and Farrington Highway	8.5	6.5	2.0	3,045	1.7
Hakimo Road and Farrington Highway	12.1	11.0	1.1	2,935	0.9
Aggregate Time saved (hrs) for segment during PM Peak Hour					7.3
Benefits to Community assuming $15/hr					$109.50
Benefits in both contraflow hours 4-6 PM					$219.00
Benefits per year (weekdays only)					$56,940.00

Although the 5th Lane project was introduced as a congestion relief project, it has extensive safety benefits as well, whose monetary benefits are summarized in Table 16.

Table 16: Recorded and Expected Crashes in zone of potential Extended Contraflow Lane and Safety Benefits from Extended Contraflow Lane in Nānākuli*

	PDO $7,400	C $44,900	K/A/B $158,200	Total
Extend 5th Lane and Contraflow from Helelua to Hakimo in Nānākuli				
Recorded in 4 years	40	47	31	118
Expected in 10 years (no countermeasure)	100	118	78	296
Expected in 10 years (with countermeasure)	54	64	42	160
10 year Reduction	46	54	36	136
1 year Reduction	4.6	5.4	3.6	13.6
1 year Benefit	$34,040	$242,460	$569,520	$846,020

*All crashes within limits of potential addition of 5th Lane and Contraflow operation are included, with crash type-specific CMF applied. Countermeasure studied was 4-to-5-lane-conversion. CMF = 0.54 for all crash types.

Restripe and widen to add short right turn lanes at Haleakala Avenue and Lualualei Naval Road from side street approaches. These projects address low LOS at Haleakala Avenue and Lualualei Naval Road intersections. By adding a better defined right turn lane for the side street approach, capacity is increased, and delays decrease, as shown in Tables 17 and 18.

Table 17: Delay, v/c and LOS at Haleakala Ave and Lualualei Naval Rd. Under Existing Conditions

	Intersection		Control Type	AM			PM		
	Approach	Movement		Delay (s)	v/c	LOS	Delay (s)	v/c	LOS
HCM 6th	**Haleakala Avenue and Farrington Highway**			**79.9**	**-**	**E**	**27.7**	**-**	**C**
	Westbound	LR	Signal	120.8	1.05	F	131.1	0.96	F
	Northbound	T		88.9	0.91	F	23.4	0.74	C
		TR		88.4	0.91	F	23.4	0.74	C
	Southbound	L		115.6	0.96	F	43.8	0.75	D
		T		50.9	0.88	D	11.8	0.56	B
HCM 2000	**Lualualei Naval Road and Farrington Highway**			**37.2**	**1.04**	**F**	**55.5**	**1.12**	**E**
	Westbound	LR	Signal	175.3	1.03	F	188.3	1.13	F
	Northbound	TR		3.5	0.49	A	7.9	0.62	A
	Southbound	LT		46.2	1.01	F	76.4	1.09	E

Table 18: Delay, v/c and LOS at Haleakala Ave and Lualualei Naval Rd. with Added Right Turn Lanes

	Intersection		Control Type	AM			PM		
	Approach	Movement		Delay (s)	v/c	LOS	Delay (s)	v/c	LOS
HCM 6th	**Haleakala Avenue and Farrington Highway**			**49.4**	**-**	**D**	**22.0**	**-**	**C**
	Westbound	L	Signal	65.3	0.38	E	89.3	0.23	F
		Added R		104.1	0.96	F	127.1	0.93	F
	Northbound	T		45.1	0.66	D	17.4	0.70	B
		TR		45.0	0.66	D	17.3	0.70	B
	Southbound	L		73.6	0.95	E	32.1	0.70	C
		T		31.0	0.76	C	8.5	0.53	A
HCM 2000	**Lualualei Naval Road and Farrington Highway**			**27.6**	**0.99**	**C**	**29.6**	**0.98**	**C**
	Westbound	L	Signal	134.3	0.85	F	125.4	0.82	F
		Added R		98.9	0.27	F	113.2	0.72	F
	Northbound	TR		3.2	0.48	A	4.1	0.57	A
	Southbound	LT		34.6	0.99	C	36.6	0.98	D

To convert time savings to a monetary benefit number, the number of vehicles entering the intersection in each peak hour is multiplied by the reduced delay, and the time savings is multiplied by a $ value/hr.

Haleakala Avenue and Farrington Highway intersection:

3,488 veh[10] in AM peak hour, 30.5 seconds reduced delay/veh = 29.6 hours saved

3,292 veh in PM peak hour, 5.7 seconds reduced delay/veh = 5.2 hours saved

If only the time savings during the AM and PM peak hours are considered, 34.8 hrs are saved, multiplied by $15/hr = $522/day. Assuming the other 22 hours of the day will at least double the savings, *the addition of a right turn lane on Haleakala Avenue will benefit the community $1,044/day, or $271,440/year only including weekdays.*

Lualualei Naval Road and Farrington Highway intersection:

3,206 veh in AM peak hour, 9.6 seconds reduced delay/veh = 8.5 hours saved

3,276 veh in PM peak hour, 25.6 seconds reduced delay/veh = 23.3 hours saved

If only the time savings during the AM and PM peak hours are considered, 31.8 hrs are saved, multiplied by $15/hr = $477/day. Assuming the other 22 hours of the day will at least double the savings, *the addition of a right turn lane on Lualualei Naval Road will benefit the community $954/day, or $248,040/year only including weekdays.*

[10] Volumes from Traffic Operations report Figure 60

Computerized Traffic Control Systems

HDOT has been converting its traffic signals to be computerized and controlled centrally, which will allow better coordination, optimization and synchronization of traffic signals in series. The following analysis in Tables 19, 20 and 21 assume a 10% decrease in travel times at each intersection is attainable. The anticipated time savings at each signal are multiplied by the vehicles entering the intersection for each peak hour and the time savings are added up for the segment. To convert time savings to a monetary benefit, the total saved time is multiplied by $15/hr and converted to an annual benefit. This process is applied to each of the three signal series (Nānākuli, Māʻili, Waiʻanae). Avg. Delay and Volume numbers used were obtained from the traffic operations report.

Table 19: Estimated Benefits from Computerized Traffic Control System, Phase 15 – Nānākuli, Expanded to Include Laʻaloa Street and Waiomea Street

Nānākuli Intersection	AM				PM			
	Avg. Delay/ veh (sec)	10% reduction (sec/veh)	AM Peak Hr Volume	Time Saved (hrs)	Avg. Delay/ veh (sec)	10% reduction (sec/veh)	PM Peak Hr Volume	Time Saved (hrs)
Laʻaloa Street and Farrington Highway	36.0	3.60	3855	3.86	37.8	3.78	4549	4.78
Waiomea Street and Farrington Highway	36.6	3.66	3922	3.99	58	5.8	4488	7.23
Piliokahi Avenue and Farrington Highway	14.3	1.43	3133	1.24	27.3	2.73	3472	2.63
Nānākuli Avenue and Farrington Highway	17.9	1.79	3398	1.69	22.2	2.22	3569	2.20
Haleakala Avenue and Farrington Highway	79.9	7.99	3488	7.74	27.7	2.77	3292	2.53
Helelua Street and Farrington Highway	11.9	1.19	3404	1.13	7.1	0.71	3278	0.65
Nanaikeola Street and Farrington Highway	1.7	0.17	3193	0.15	3.4	0.34	3214	0.30
Lualualei Naval Road and Farrington Highway	37.2	3.72	3206	3.31	55.5	5.55	3276	5.05
Auyong Homestead Road and Farrington Highway	13.7	1.37	3002	1.14	4.0	0.4	3083	0.34
Mohihi Street and Farrington Highway	3.8	0.38	2909	0.31	5.6	0.56	3061	0.48
Princess Kahanu Avenue and Farrington Highway	9.8	0.98	2878	0.78	7.5	0.75	3045	0.63
Hakimo Road and Farrington Highway	11.2	1.12	2737	0.85	9.6	0.96	2935	0.78
Aggregate time savings in peak hour				26.19				27.61
Benefits/hr assuming $15/hr				$392.87				$414.15
AM+PM savings x 3 (assuming benefits triple from other 22 hrs of the day)				$807.02 x 3 = $2421.06/day				
Benefits/year, weekdays only				$629,475.60				

Table 20: Estimated Benefits from Computerized Traffic Control System - Māʻili

Māʻili Intersection	AM				PM			
	Avg. Delay/ veh (sec)	10% reduction (sec/veh)	AM Peak Hr Volume	Time Saved (hrs)	Avg. Delay/ veh (sec)	10% reduction (sec/veh)	PM Peak Hr Volume	Time Saved (hrs)
Kaʻukama Road and Farrington Highway	14.7	1.47	2574	1.05	10.7	1.07	2726	0.81
Hoʻokele Street and Farrington Highway	14.6	1.46	2392	0.97	10.4	1.04	2567	0.74
Maipalaoa Road and Farrington Highway	6.0	0.60	2466	0.41	4.0	0.40	2508	0.28
St Johns Road and Farrington Highway	14.5	1.45	2687	1.08	11.2	1.12	2537	0.79
Maliona Street and Farrington Highway	2.4	0.24	2469	0.16	1.8	0.18	2374	0.12
Kaʻukamana Street and Farrington Highway	5.2	0.52	2748	0.40	3.6	0.36	2518	0.25
Māʻiliʻili Road and Farrington Highway	16.9	1.69	2948	1.38	14.4	1.44	2637	1.05
Aggregate time savings in peak hour				5.46				4.05
Benefits/hr assuming $15/hr				$81.90				$60.68
AM+PM savings x 3 (assuming benefits triple from other 22 hrs of the day)				$142.57 x 3 = $427.71/day				
Benefits/year, weekdays only				$111,204.60				

Table 21: Estimated Benefits from Computerized Traffic Control System – Phase 16, Waiʻanae

Waiʻanae or Mākaha Intersection	AM				PM			
	Avg. Delay/ veh (sec)	10% reduction (sec/veh)	AM Peak Hr Volume	Time Saved (hrs)	Avg. Delay/ veh (sec)	10% reduction (sec/veh)	PM Peak Hr Volume	Time Saved (hrs)
Leihoku Street and Farrington Highway	9.1	0.91	2744	0.69	7.4	0.74	2556	0.53
Waiʻanae Mall and Farrington Highway	5.0	0.50	2331	0.32	6.4	0.64	2277	0.40
Puhano Street and Farrington Highway	7.6	0.76	2387	0.50	7.7	0.77	2308	0.49
Lualualei Homestead Road and Farrington Highway	8.6	0.86	2498	0.60	6.6	0.66	2307	0.42
Waiʻanae Valley Road and Farrington Highway	10.7	1.07	1676	0.50	11.9	1.19	2160	0.71
Old Government Road and Farrington Highway	10.0	1.00	1592	0.44	9.5	0.95	1964	0.52
Intermediate School Driveway and Farrington Highway	1.6	0.16	1369	0.06	20.0	2.00	1762	0.98
Ala Akau and Farrington Highway	27.3	2.73	1441	1.09	30.4	3.04	1700	1.44
Waiʻanae High School Entrance and Farrington Highway	1.3	0.13	1038	0.04	1.5	0.15	2441	0.10
Mākaha Valley Road and Farrington Highway	21.2	2.12	966	0.57	25.8	2.58	1299	0.93
Aggregate time savings in peak hour				4.82				6.53
Benefits/hr assuming $15/hr				$72.28				$97.89
AM+PM savings x 3 (assuming benefits triple from other 22 hrs of the day)				$170.17 x 3 = $510.51/day				
Benefits/year, weekdays only				$132,732.60				

The Resilience Projects in Table 22 (repeated from Tables 4, 5 and 6) relate to improving drainage and protecting the vulnerable shoreline area near Mākaha Valley Road.

Table 22: Resilience Projects for Consideration

RESILIENCE PROJECT – NĀNĀKULI
Focused Drainage Study - Improve drainage to alleviate flooding at Princess Kahanu
Projects to improve drainage, alleviate flooding and for coastal hardening in Nānākuli (Figure 14)
RESILIENCE PROJECTS – MĀʻILI/WAIʻANAE
Focused Drainage Study to propose solutions for flooding in Maili
Focused Drainage Study to propose solutions for flooding at Leihoku St
Focused Drainage Study to propose solutions for flooding at Waiʻanae Valley Road
Projects to improve drainage, alleviate flooding and for coastal hardening in Māʻili/Waiʻanae (Figure 15)
RESILIENCE PROJECTS – MĀKAHA
Plan and build rock veneer wall 500 ft x 4 ft high to prevent sand and wave over wash in Mākaha
Projects to improve drainage, alleviate flooding and for coastal hardening in Mākaha (Figures 15 and 16)

Focused Drainage Studies at:

Princess Kahanu
Maili
Leihoku Street
Waiʻanae Valley Road

All four of these recommendations match those included in the 2008 DHHL Regional Community Development Plan.

Projects to improve drainage, alleviate flooding and for coastal hardening in Nānākuli, Māʻili/Waiʻanae and Mākaha. This is to provide funding for projects that are recommended by the focused drainage studies, and to construct P-H (Hard Protection) at the locations recommended in the 2019 HDOT Statewide Coastal Highway Program Report and shown in Figures 14, 15 and 16.

Plan and build rock veneer wall 500 ft x 4 ft high to prevent sand and wave over wash in Mākaha. This is consistent with the recommendations in the 2019 HDOT Statewide Coastal Highway Program Report, which calls for P-H (Hard Protection) in that location. That project completed a Benefit and Costs analysis as shown in Table 23.

Table 23: Benefit and Cost Analysis of Hard Protection - Revetment, Seawall Repair/New (Source: 2019 HDOT Statewide Coastal Highway Program Report)

State of Hawaii
Statewide Coastal Highway Program Report (Version 2 (Final)) August 21, 2019
Chapter 4
Adaptation Recommendations

Table 4.1. (continued)

Type	Action	Legend	Protect - P								
			Soft Protection - Beach nourishment (SB)			**Soft Protection - Living dunes (SD)**			**Hard Protection - Revetment, Seawall Repair/New (H)**		
			Alternative P-SB			**Alternative P-SD**			**Alternative P-H**		
			Hazards: Storm surge			**Hazards:** Storm surge			**Hazards:** Storm surge		
			Cost: 1,000[1,3] USD / LF			Cost: 2,000[1,3] USD / LF			Cost:$4,000[1,2] /$10,000[3] USD / LF		
			O&M: Replace every few years			O&M: Replace every few years			O&M: Monitor every few years		
			B[5]	C[1,3]	B/C	B[5]	C[1,3]	B/C	B[5,6,7]	C[1,2,3]	B/C
Social	Will the action lead to an increased in social resilience?	S1	4	1	4	4	1	4	2	3	0.7
	Is the action equitable?	S2	4	4	1	4	4	1	3	3	1
Technical	Can the action be implemented from a technical point of view?	T1	5	1	5	5	1	5	3	4	0.8
	Can the action handle a range of climate change impacts?	T2	2	4	0.5	2	4	0.5	5	3	1.7
Administrative	Does your agency/organization have the operational control to implement this action?	A1	5	2	2.5	5	2	2.5	5	4	1.3
Political	Can this action be implemented in a timely manner?	P1	4	2	2	4	2	2	3	4	0.8
	Does this action have political support?	P2	5	1	5	5	1	5	3	4	0.8
Economic	Is it cost effective? Does the benefit exceed the cost?	E1	4	3	1.3	4	3	1.3	4	4	1
	Does funding exisit or can it be acquired to finance the action?	E2	5	1	5	5	1	5	3	4	0.8
Environmental	Will the action increase the resilience of the natural environment?	EN1	2	4	0.5	2	4	0.5	3	3	1
	Are there any positive side effects on the environment of the action?	EN2	3	5	0.6	3	5	0.6	2	4	0.5

(B: Benefit, C: Cost, B/C: Benefit to Cost ratio, the ranking goes as 1 (lowest) to 5 (highest))

4 PHASE FOUR: FEASIBILITY AND FINAL LIST OF PROJECTS

Phase 4 included only those projects which are physically located on Farrington Highway. The objective of this phase of work was to develop a feasible program of improvements, with an emphasis on understanding their benefits and challenges, and to identify possible approaches to phasing. This set of studies will assist with better informed decision making and prioritization of efforts.

4.1 METHODOLOGIES

Phase 4 had the most varied methodologies for evaluation. Among them were Feasibility, Environmental Issues, and Cost and Benefits. The Phase 4 work identifies program funding and recommends various approaches to prioritization of available funding in the short, mid, and long term.

4.2 PROJECTS ANALYZED

In Phase 4, a total of 31 projects, all directly on Farrington Highway were analyzed. This included 18 Safety projects, 6 Congestion Relief projects and 7 Resilience projects, summarized in Table 24.

Table 24: Projects Included in Phase 4

	Project	Name of Package or Project
I. Farrington Highway Safety Projects		
Safety	S1	Nānākuli – Segment 2 - Intersection Improvements
	S2	Nānākuli – Segment 2 - Streetlight Improvements
	S3	Nānākuli – Segment 2 - Speed Feedback signs
	S4	Māʻili – Segment 4 - Intersection Improvements
	S5	Māʻili – Segment 4 - Streetlight Improvements
	S6	Māʻili – Segment 4 – Speed Feedback signs
	S7	Māʻili – Segment 4 – Add Center Left Turn Lane
	S8	Waiʻanae/Mākaha – Segment 5 - Intersection Improvements
	S9	Waiʻanae/Mākaha – Segment 5 - Streetlight Improvements
	S10	Waiʻanae/Mākaha – Segment 5 - Speed Feedback signs
	S11	Segment 2 - Convert bridge by Laumania to allow bike and pedestrian traffic.
	S12	Segment 2 - Upgrade and widen sidewalk from Pohakunui to Helelua along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides
	S13	Segment 2 - Upgrade and widen sidewalk from Helelua to Hakimo along mauka side of FH. Add C&G (mauka) & 6' shoulders both sides. Add Shared Use Path on makai side.
	S14	Segment 2 - Build Shared Use Path from Nānākuli to Pohakunui (4,000 ft)
	S15	Segments 1 and 2 - Build Shared Use Path from Pohakunui to Ko Olina (9,900 ft), partnering with OMPO, C&C, DHHL, PPP, HBL, others
	S16	Segment 4 - Add sidewalk and shoulder bike lanes along both sides of Farrington Highway from Kaʻukama to Māʻiliʻili, 9,500 ft
	S17	Segment 5 - Build Shared Use Path from Māʻiliʻili to Leihoku, 2,500 ft
	S18	Segment 3 - Build Shared Use Path from Kaʻukama to Hakimo, 5,600 ft
II. Farrington Highway Congestion Relief Projects		
Congestion Relief	C1	Segment 2 - Extension of 5th Lane and Contraflow (Helelua to as far as Hakimo) approx 6,900 ft, incl mauka sidewalk, shoulders, shared use path
	C2	Segment 2 - Restripe to add short right turn lane at Haleakala from side street approach
	C3	Segment 2 - Widen pavement and restripe to add right turn lane at Lualualei Naval Road from side street approach
	C4	Segments 1 and 2 - Computerized Traffic Control System Phase 15 - Nānākuli, expanded to include Laʻaloa St. and Waiomea St. intersections
	C5	Segment 4 - Computerized Traffic Control System - Māʻili, 7 signals
	C6	Segment 5 - Computerized Traffic Control System Phase 16 - Waiʻanae
III. Farrington Highway Resilience Projects		
Resilience	R1	Segment 2 - Focused Drainage Study - Improve drainage to alleviate flooding at Princess Kahanu
	R2	Segment 4 - Focused Drainage Study to propose solutions for flooding in Maili
	R3	Segment 5 - Focused Drainage Study to propose solutions for flooding at Leihoku St
	R4	Segment 5 - Focused Drainage Study to propose solutions for flooding at Waiʻanae Valley Road
	R5	Segment 6 - Plan and build rock veneer wall 500 ft x 4 ft high to prevent sand and wave over wash in Mākaha
	R6	Segment 2 - Nānākuli: Hard Protection locations from Figure 14, Projects identified in Drainage Study
	R7	Segments 4 and 5 - Māʻili/Waiʻanae: Hard Protection locations from Figure 15, Projects identified in Drainage Study
	R8	Segment 6 - Mākaha: Hard Protection locations from Figure 16, Projects identified in Drainage Study

4.3 FEASIBILITY ANALYSES

Feasibility is an important concept for understanding whether a project can be built given constraints. Feasibility considers how reasonable are the disruptions or impacts of undertaking such a project both in the short-term construction period and the permanent impacts. While theoretically, anything is possible, the resources required for project delivery (both human and financial resources) are limited, and prudency calls for selecting those that can be advanced with the least amount of friction or difficulty. Certain challenges, such as the level of environmental review required, can shift a project from short-term to mid- or long-term feasibility.

Farrington Highway Corridor Study projects were examined for their likely environmental impacts, takings (ROW and/or structures), and ease of implementation. These are the most common reasons for a project to take additional time. The feasibility information is presented in summary or tabular form according to the degree of difficulty and the analysis for each project is presented in Tables 25 and 26.

Environmental issues were assessed and described in Table 25. Environmental compliance is an important part of any undertaking that uses Federal or State resources. Of the 31 projects, 18 Farrington Highway Corridor Projects were determined to likely be a categorical exemption under NEPA. Thirteen (13) Farrington Highway Corridor Projects are expected to require either an EA or an EIS under NEPA. If the initial environmental review results in a Finding of No Significant Impact, then an EA would suffice. If there are impacts, then the project proceeds to the more detailed EIS level documentation. If significant impacts are anticipated, the project can head straight into the EIS process. An EA can take up to 2 years to prepare and circulate for review before a Finding of No Significant Impact (FONSI) can be issued. An EIS can take longer.

Among the issues that can require added time in the environmental review process are Section 7 of the Endangered Species Act, Section 106 Historic Preservation review, cultural impact analysis, consistency determination with the Coastal Zone Management Act, and review of the impact on Sole Source Aquifer (drinking water impacts).

Land takings are required by some projects, especially widenings where additional land would need to be acquired beyond the current right of way. Fourteen (14) of the projects would require taking some amount of land, however, most of these would require less than one acre. None of the projects are expected to take commercial or residential properties.

Construction challenges include the difficulty in creating a safe work zone, places to store equipment near the construction zone, and requirements to keep traffic moving through a construction area. Unavoidable construction impacts such as noise, dust, impacts to traffic, and impacts to nearby businesses and residents all enter into the complexity of planning for construction. For the Farrington Highway Corridor projects, the most complex projects are those in communities, which will require phasing to reduce impacts from work on projects occurring simultaneously.

The net result of the feasibility studies was to categorize projects according to short-term, mid-term and long-term. Short-term projects can be cleared environmentally in a short time, have minimal or no land takings and little or no construction impacts. Eighteen (18) projects were identified for the short term. Mid-term projects likely require an EA, will require some takings and have some construction challenges. There are 11 mid-term projects.

Long-term projects have long environmental lead times, would have many ROW takings, and are generally of a higher cost, which indicates they may require alternate sources of funding than are available currently. There are two long-term projects identified for Farrington Highway Corridor.

The scoring system for project feasibility in Table 25 was developed to quantify project complexity and assess the anticipated timeline for each project. The results of the feasibility assessment are summarized in Table 26.

Table 25: Scoring Matrix for Project Feasibility

Score	Environmental Issues	Land Takings	Construction Challenges
0	No Env. Impacts	No takings	No Construction Challenges
1	Potential Minor Impacts	1-2 Minor easement or encroachment issues expected	Minor Isolated Construction Challenges possible
2	CatEx	3-5 Minor easement or encroachment issues expected	Minor Isolated Construction Challenges likely
3	More likely CatEx than EA	1-2 strip acquisitions expected	Consistent minor Construction challenges
4	More likely EA than CatEx	3-5 strip acquisitions expected	consistent moderate construction challenges
5	EA	Strip acquisitions with at least 1 structure	1 or 2 spot locations with involved construction challenges
6	More likely EA than EIS	Consistent strip acquisition 1 side, <=6 ft	3 or 4 spot locations with involved construction challenges
7	More likely EIS than EA	Consistent strip acquisition 1 side, >6 ft	Complicated Construction, including challenges with 1 of the following soils, drainage, utility relocations
8	Small to Medium EIS	Consistent strip acquisition both sides <=6 ft ea	Complicated Construction, including challenges with 2 of the following: soils, drainage, utility relocations
9	Medium EIS	Consistent strip acquisition both sides >6 ft ea	Complicated Construction, including challenges with soils, drainage, utility relocations, sensitive areas
10	Very involved EIS	Consistent strip acquisition both sides >6 ft ea + >1 structure	Complicated Construction, including challenges with soils, drainage, utility relocations, sensitive areas, bridges

Table 26: Feasibility Scoring for Candidate Projects

	Project		Environmental Issues	Land Takings	Construction Challenges	Total Score	Timeline	Cost
Safety	S1	Nānākuli – Segment 2 - Intersection Improvements	0	0	2	2	Short term	$ 502,300
	S2	Nānākuli – Segment 2 - Streetlight Improvements	1	0	3	4	Short term	$ 463,800
	S3	Nānākuli – Segment 2 - Speed Feedback signs	1	0	1	2	Short term	$ 44,000
	S4	Mā'ili – Segment 4 - Intersection Improvements	0	0	2	2	Short term	$ 347,200
	S5	Mā'ili – Segment 4 - Streetlight Improvements	1	0	3	4	Short term	$ 321,100
	S6	Mā'ili – Segment 4 – Speed Feedback signs	1	0	1	2	Short term	$ 33,000
	S7	Mā'ili – Segment 4 – Add Center Left Turn Lane	5	8	6	19	Mid term	$ 820,200
	S8	Wai'anae/Mākaha – Segment 5 - Intersection Improvements	0	0	2	2	Short term	$ 121,000
	S9	Wai'anae/Mākaha – Segment 5 - Streetlight Improvements	1	0	3	4	Short term	$ 713,400
	S10	Wai'anae/Mākaha – Segment 5 - Speed Feedback signs	1	0	1	2	Short term	$ 33,000
	S11	Segment 2 - Convert bridge by Laumania to allow bike and pedestrian traffic.	3	0	1	4	Short term	$ 32,000
	S12	Segment 2 - Upgrade and widen sidewalk from Pohakunui to Helelua along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides	4	8	8	20	Mid term	$ 10,171,700
	S13	Segment 2 - Upgrade and widen sidewalk from Helelua to Hakimo along mauka side of FH. Add C&G (mauka) & 6' shoulders both sides. Add Shared Use Path on makai side.	4	9	8	21	Mid term	$ 10,000,000
	S14	Segment 2 - Build Shared Use Path from Nānākuli to Pohakunui (4,000 ft)	4	7	7	18	Mid term	$ 1,625,300
	S15	Segments 1 and 2 - Build Shared Use Path from Pohakunui to Ko Olina (9,900 ft), partnering with OMPO, C&C, DHHL, PPP, HBL, others	9	7	10	26	Long term	$ 18,604,000

	S16	Segment 4 - Add sidewalk and shoulder bike lanes along both sides of Farrington Highway from Kaʻukama to Māʻiliʻili, 9,500 ft	6	8	8	22	Mid term	$ 13,887,300
	S17	Segment 5 - Build Shared Use Path from Māʻiliʻili to Leihoku, 2,500 ft	5	7	7	19	Mid term	$ 1,002,100
	S18	Segment 3 - Build Shared Use Path from Kaʻukama to Hakimo, 5,600 ft	5	7	7	19	Mid term	$ 2,245,000
Congestion Relief	C1	Segment 2 - Extension of 5th Lane and Contraflow (Helelua to as far as Hakimo) approx 6,900 ft, incl mauka sidewalk, shoulders, shared use path	9	9	8	26	Long term	$ 22,000,000
	C2	Segment 2 - Restripe to add short right turn lane at Haleakala from side street approach	0	0	0	0	Short term	$ 6,500
	C3	Segment 2 - Widen pavement and restripe to add right turn lane at Lualualei Naval Road from side street approach	1	3	2	6	Short term	$ 50,000
	C4	Segments 1 and 2 - Computerized Traffic Control System Phase 15 - Nānākuli, expanded to include Laʻaloa St. and Waiomea St. intersections	0	0	4	4	Short term	$ 3,800,000
	C5	Segment 4 - Computerized Traffic Control System - Māʻili, 7 signals	0	0	4	4	Short term	$ 2,660,000
	C6	Segment 5 - Computerized Traffic Control System Phase 16 - Waiʻanae	0	0	4	4	Short term	$ 3,800,000
Resilience	R1	Segment 2 - Focused Drainage Study - Improve drainage to alleviate flooding at Princess Kahanu	0	0	0	0	Short term	$ 65,000
	R2	Segment 4 - Focused Drainage Study to propose solutions for flooding in Maili	0	0	0	0	Short term	$ 65,000
	R3	Segment 5 - Focused Drainage Study to propose solutions for flooding at Leihoku St	0	0	0	0	Short term	$ 112,000
	R4	Segment 5 - Focused Drainage Study to propose solutions for flooding at Waiʻanae Valley Road	0	0	0	0	Short term	$ 134,000
	R5	Segment 6 - Plan and build rock veneer wall 500 ft x 4 ft high to prevent sand and wave over wash in Mākaha	7	7	8	22	Mid term	$ 1,390,000

	R6	Segment 2 - Nānākuli: Hard Protection locations from Figure 14, Projects identified in Drainage Study	6	4	7	17	Mid term	$ 5,000,000
	R7	Segments 4 and 5 - Māʻili/Waiʻanae: Hard Protection locations from Figure 15, Projects identified in Drainage Study	6	4	7	17	Mid term	$ 5,000,000
	R8	Segment 6 - Mākaha: Hard Protection locations from Figure 16, Projects identified in Drainage Study	6	4	7	17	Mid term	$ 5,000,000

Projects scoring 0 to 6 are expected to be uncomplicated, without significant environmental issues, little to no right-of-way acquisition and few or no construction challenges. These are projects that can be implemented in a short-term time frame, 0-2 years.

Projects scoring 7 to 22 are expected to be of average complications, most likely needing an EA or some environmental documentation, needing some right of way acquisition, and moderate construction challenges. These are projects that can be implemented in a mid-range time frame, >2 years to 5 years.

Projects scoring over 22 are expected to be complicated, with significant environmental issues and likely needing an EA or EIS, consistent right of way acquisition and/or notable construction challenges. These are projects that are expected to take 5-10 years or more to implement.

4.4 PRIORITIZATION BY MEASURES OF EFFECTIVENESS

The projects were rated by their quantitative or qualitative measures of effectiveness. For the Safety Improvement projects, purely using crash prevention $ benefits/year as measures, the overall ranking is as follows: [Short-term, Mid-Term, Long Term]

1. Intersection Improvements on Segment 2 [S1] $621,790 savings/year
2. Add Center Left Turn Lane in Segment 4 [S7] $276,660 savings/year
3. Intersection Improvements on Segment 4 [S4] $274,470 savings/year
4. Streetlight Improvements on Segment 2 [S2] $149,699 savings/year
5. Speed Feedback Signs in Segment 5 [S10] $114,970 savings/year
6. Intersection Improvements on Segment 5 [S8] $ 96,140 savings/year
7. Streetlight Improvements on Segment 4 [S5] $ 87,210 savings/year
8. Streetlight Improvements on Segment 5 (tied) [S9] $ 87,210 savings/year
9. Speed Feedback Signs on Segment 2 [S3] $ 48,070 savings/year
10. Speed Feedback Signs on Segment 4 [S6] $ 42,100 savings/year

For the Safety Improvement projects, purely using their contribution to the Pedestrian Master Plan Performance Measures as a basis of ranking, the overall results are as follows:

1. Upgrade and widen sidewalk from Helelua to Hakimo along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides. Add Shared Use Path on makai side. [S13]
2. Add sidewalk and shoulder bike lanes along both sides of Farrington Highway from Kaʻukama to Māʻiliʻili, 9,500 ft [S16]
3. Build Shared Use Path from Māʻiliʻili to Leihoku, 2,500 ft [S17]
4. Upgrade and widen sidewalk from Pohakunui to Helelua along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides [S12]
5. Build Shared Use Path from Pohakunui to Ko Olina (9,900 ft), partnering with OMPO, C&C, DHHL, PPP, HBL [S15]
6. Build Shared Use Path from Kaʻukama to Hakimo, 5,600 ft [S18]
7. Build Shared Use Path from Nānākuli to Pohakunui (4,000 ft) [S14]
8. Convert bridge by Laumania to allow bike and pedestrian traffic [S11]

For the Congestion Relief projects, purely using their time savings $ benefits/year as a measure, the overall ranking is as follows:

1. Nānākuli Computerized Traffic Signal Improvements [C4] $629,476 savings/year
2. Adding right turn lane at Haleakala Avenue [C2] $271,440 savings/year
3. Adding right turn lane at Lualualei Naval Road [C3] $248,040 savings/year
4. Waiʻanae/Mākaha Computerized Traffic Signal Improvements [C6] $132,733 savings/year
5. Maili Computerized Traffic Signal Improvements [C5] $111,205 savings/year
6. Nānākuli Extension of 5th Lane [C1] $ 56,940 savings/year

However, if the safety benefits of the 4 to 5 lane conversion are factored into the Nānākuli Extension of 5th Lane, the overall ranking is as follows:

1. Nānākuli Extension of 5th Lane [C1] $902,960 savings/year
2. Nānākuli Computerized Traffic Signal Improvements [C4] $629,476 savings/year
3. Adding right turn lane at Haleakala Avenue [C2] $271,440 savings/year
4. Adding right turn lane at Lualualei Naval Road [C3] $248,040 savings/year
5. Waiʻanae/Mākaha Computerized Traffic Signal Improvements [C6] $132,733 savings/year
6. Maili Computerized Traffic Signal Improvements [C5] $111,205 savings/year

4.5 COSTS

Order of magnitude cost estimates for each project were developed using historical cost-based estimating techniques from construction data for Hawaiʻi. They are displayed by community in Tables 27, 28, and 29. Cost calculations can be found in Appendix C. If all projects were completed using these estimates, the total amount would come to $110,048,900. This does not account for future year inflation.

Table 27: Improvement Projects for Segment 2 (Nānākuli segment) of Farrington Highway

SAFETY

Implement Safe Routes to School Program at Nānākuli Avenue intersection, includes raised median Install high-visibility yellow, continental type crosswalks at Nānākuli Ave (incl in SRTS) [S1]	$60,500
Install pedestrian countdown timers at Hakimo Rd, Lualualei Naval Rd, Helelua St, Nānākuli Ave and Piliokahi Ave [S1]	$67,900
Raised Median at Hakimo Rd, Lualualei Naval Rd, Helelua St, Nānākuli Ave and Piliokahi Ave intersections [S1]	$214,300
Verify traffic signal yellow and red times meet ITE Recommended Practice [S1]	HDOT/C&C
Implement a leading pedestrian interval at Hakimo Rd, Lualualei Naval Rd, Helelua St, Nānākuli Ave and Piliokahi Ave intersections [S1]	$1,900
Convert an open median to a left-in only median at Laumania Ave. [S1]	$47,600
Improve left-turn lane offset to create positive offset at Hakimo Rd and Piliokahi Ave. [S1]	$66,900
Implement systemic signing and marking improvements at Laumania Ave. [S1]	$7,000
Implement systemic signing and visibility improvements at Hakimo Rd, Lualualei Naval Rd, Helelua St, Nānākuli Ave, and Piliokahi Ave [S1]	$34,800
Increase retro reflectivity of STOP signs at Laumania Ave [S1]	$1,400
Increase illuminance from low (<0.2 fc) to Medium >0.2 fc and <1.1 fc) @ 13 crosswalks [S2]	$463,800
Install dynamic speed feedback signs at both ends of 25 mph zone [S3]	$44,000
Convert bridge by Laumania to allow bike and pedestrian traffic. [S11]	$32,000
Upgrade and widen sidewalk from Pohakunui to Helelua along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides [S12]	$10,171,700
Upgrade and widen sidewalk from Helelua to Hakimo along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides. Add Shared Use Path on makai side. [S13]	$10,000,000
Build Shared Use Path from Nānākuli to Pohakunui (4,000 ft) [S14]	$1,625,300
Build Shared Use Path from Pohakunui to Ko Olina (9,900 ft, includes Segment 1), partnering with OMPO, C&C, DHHL, PPP, HBL, others [S15]	$18,604,000

CONGESTION

Extension of 5th Lane and Contraflow (Helelua to as far as Hakimo) approx 6,900 ft, incl mauka sidewalk, shoulders, shared use path [C1]	$22,000,000
Computerized Traffic Control System Phase 15 – Nānākuli, expand to include Laʻaloa St. and Waiomea St. [C4]	$3,800,000
Widen and restripe to add short right turn lane at Lualualei Naval Road from side street approach [C3]	$50,000
Restripe to add short right turn lane at Haleakala from side street approach [C2]	$6,500

RESILIENCE

Focused Drainage Study - Improve drainage to alleviate flooding at Princess Kahanu [R1]	$65,000
Projects to improve drainage, alleviate flooding and for coastal hardening in Nānākuli (Figure 14) [R6]	$5,000,000

Table 28: Improvements Projects for Segment 4 (Māʻili segment) of Farrington Highway

SAFETY

Implement Safe Routes to School Program at Maliona Street, incl raised median Install high-visibility yellow, continental type crosswalks at Maliona Street (incl in SRTS) [S4]	$57,300
Install pedestrian countdown timers at Maliona Street, Hookele Street and Kaʻukama Road [S4]	$31,400
Raised Median at St Johns Road, Hoʻokele St and Kaʻukama Rd intersections [S4]	$128,700
Verify traffic signal yellow and red times meet ITE Recommended Practice [S4]	HDOT/C&C
Modify signal phasing (implement a leading pedestrian interval) at Maliona St, St Johns Rd, Hoʻokele St, and Kaʻukama Rd [S4]	$1,500
Improve left-turn lane offset to create positive offset at St Johns Rd, Hoʻokele St, and Kaʻukama Rd [S4]	$100,400
Implement systemic signing and visibility improvements at Maliona St, St Johns Rd, Hookele St, and Kaʻukama Rd [S4]	$27,900
Increase illuminance from low (<0.2 fc) to Medium >0.2 fc and <1.1 fc) @ 9 crosswalks [S5]	$321,100
Install dynamic speed feedback sign for 2 lanes (in 2 locations) [S6]	$33,000
Add sidewalk and shoulder bike lanes along both sides of Farrington Highway from Kaʻukama to Māʻiliʻili, 9,500 ft [S16]	$13,887,300
Build Shared Use Path from Māʻiliʻili to Leihoku, 2,500 ft [S17]	$1,002,100
Build Shared Use Path from Kaʻukama to Hakimo, 5,600 ft (includes Segment 3) [S18]	$2,245,000

CONGESTION

Add Center Left Turn Lane (Mana to Māʻiliʻili), 1,250 ft [S7]	$820,200
Computerized Traffic Control System - Māʻili, 7 signals [C5]	$2,660,000

RESILIENCE

Focused Drainage Study to propose solutions for flooding at Maili	$65,000
Projects to improve drainage, alleviate flooding and for coastal hardening in Māʻili (Fig 15) [R7]	$5,000,000

Table 29: Improvement Projects for Segments 5 and 6 (Mākaha/Waiʻanae) segment of Farrington Highway

SAFETY

Install pedestrian countdown timers at both Puhano crosswalks [S8]	$10,500
Install pedestrian RRFB with advanced yield or stop markings and signs at Army St [S8]	$17,400
Install ped refuge raised median island at Army St [S8]	$26,500
Raised Median at Puhano St. [S8]	$43,000
Verify traffic signal yellow and red times meet ITE Recommended Practice [S8]	HDOT/C&C
Modify signal phasing (implement a leading pedestrian interval) [S8]	$400
Implement systemic signing and marking improvements at Army St [S8]	$7,000
Implement systemic signing and visibility improvements at Puhano St [S8]	$7,000
Increase retroreflectivity of STOP signs at 7 Stop Controlled intersections [S8]	$9,200
Increase illuminance from low (<0.2 fc) to Medium >0.2 fc and <1.1 fc) @ 20 crosswalks [S9]	$713,400
Install dynamic speed feedback sign for 2 lanes (in 2 locations) [S10]	$33,000

CONGESTION

Computerized Traffic Control System Phase 16 - Waiʻanae [C6]	$3,800,000

RESILIENCE

Focused Drainage Study to propose solutions for flooding at Leihoku St [R3]	$112,000
Focused Drainage Study to propose solutions for flooding at Waiʻanae Valley Road [R4]	$134,000
Plan and build rock veneer wall 500 ft x 4 ft high to prevent sand and wave over wash in Mākaha [R5]	$1,390,000

Projects to improve drainage, alleviate flooding and for coastal hardening in Mākaha/Waiʻanae (Fig 16) [R8]	$5,000,000

The sum of all candidate projects is $109,983,900. The costs are broken down by Safety, Congestion Relief and Resilience, and by Short Term, Mid Term and Long Term in Table 30.

Table 30: Overall cost for all projects by type.

Type of Project	Preliminary Total
Safety	$50,146,200
Congestion Relief	$43,136,700
Resilience	$16,766,000
PRELIM TOTAL OF ALL PROJECTS	**$110,048,900**
Short Term	**$13,303,300**
Mid-Range	**$56,141,700**
Long Term	**$40,603,900**

4.6 BENEFIT COST REVIEW

A cost/benefit analysis compared the cost of each project to its safety and congestion relief benefits. The highest ranking projects were restriping to add a right turn lane at Haleakala Avenue and widening/restriping to add a right turn lane at Lualualei Naval Road, Speed Feedback signs in Waiʻanae and Māʻili, and Intersection Improvements in Nānākuli. The rankings for top five projects by Benefit/Cost ratios are shown in Table 31.

Benefit Cost Analysis can be used as a framework for considering a range of benefits and costs in monetary terms. Some benefits are difficult to monetize so B/C is rarely used as the sole tool in decision-making, but it is helpful for making comparisons among many projects.

Table 31: Top five projects with the best Benefit/Cost ratios along the corridor.

Project #	Project Name	B/C Ratio
C2	Restripe to add right turn lane on Haleakala Avenue from side street approach	338.7
C3	Widen and restripe to add right turn lane on Lualualei Naval Road from side street approach	40.2
S10	Speed Feedback Signs (in Waiʻanae)	15.5
S6	Speed Feedback Signs (in Māʻili)	5.7
S1	Intersection Improvements (in Nānākuli)	5.5

The full list of B/C ratios for candidate projects is shown in Tables 32 and 33.

Table 32: Benefit Cost Analysis for Intersection Improvements, Street Light Improvements, Speed Feedback Signs and Center Left Turn Lane

SEGMENT 2	**Annual Monetary Benefits**	**5 Year PVB$_v$**	**Costs[11]**	**B/C Ratio**
S1 **Intersection Improvements (6 intersections)**	$ 621,970	$ 2,768,209	$ 502,300	5.5
S2 **Street Light Improvements (13 xwalks)**	$ 149,699	$ 666,460	$ 463,800	1.4
S3 **Speed Feedback Signs**	$ 48,070	$ 214,008	$ 44,000	4.9
SEGMENT 4				
S4 **Intersection Improvements (4 intersections)**	$ 274,470	$ 1,221,940	$ 347,200	3.5
S5 **Street Light Improvements (9 xwalks)**	$ 87,210	$ 388,259	$ 321,100	1.2
S6 **Speed Feedback Signs**	$ 42,100	$ 187,429	$ 33,000	5.7
S7 **Add Center Left Turn Lane**	$ 276,660	$ 1,231,690	$ 820,200	1.5
SEGMENT 5				
S8 **Intersection Improvements (2 intersections)**	$ 96,140	$ 428,015	$ 121,000	3.5
S9 **Street Light Improvements (20 xwalks)**	$ 87,210	$ 388,259	$ 713,400	0.5
S10 **Speed Feedback Signs**	$ 114,970	$ 511,846	$ 33,000	15.5

[11] Refer to Appendix C

Table 33: Benefit Cost Analysis for Potential Congestion Relief Projects

	Annual Monetary Benefits	10 Year PVB_v	Costs[12]	B/C Ratio
C1 Extension of 5th Lane and Contraflow	$ 56,940	$ 461,834	$22,000,000	0.0
C2 Restripe to add Right Turn Lane on Haleakala Ave.	$ 271,440	$ 2,201,622	$ 6,500	338.7
C3 Widen and Restripe to add Right turn Lane on Lualualei Naval Rd.	$ 248,040	$ 2,011,827	$ 50,000	40.2
C4 Nānākuli Computerized Traffic Control System	$ 629,476	$ 5,105,614	$ 3,800,000	1.3
C5 Māʻili Computerized Traffic Control System	$ 111,205	$ 901,972	$ 2,660,000	0.3
C6 Waiʻanae/Mākaha Computerized Traffic Control System	$ 132,733	$ 1,076,584	$ 3,800,000	0.3

[12] Refer to Appendix C

4.8 OBSTACLES TO IMPLEMENTATION

The research into past studies on Farrington Highway revealed some persistent obstacles to completing the projects that have been identified over the years. Table 34 summarizes some of the obstacles that have prevented the construction of a Second Access in the past (but may also affect the long term projects identified in Table 26) and potential solutions for overcoming them.

Table 34: Obstacles to Implementation and Potential Solutions

Obstacle	Potential Solutions
Finding adequate funding	• Pre-plan the funding of projects using the Long Range Transportation Plan. • Pool funds from multiple agencies • Research and apply for grants that target specific types of improvements • Utilize funds from rental car surcharge
Not having a clear and concise Master Plan for the very finite area within the Leeward Coast communities. Potentially relocating Farrington Highway in the future will need to consider the wishes of the communities and what areas should or should not be developed, what areas should be preserved, how to zone them for protection, where to plan schools, parks, commercial areas, etc.	• Update the Wai‘anae Sustainable Communities Plan (DPP 2012) or develop a comprehensive Master Plan for the Leeward Coast. • Define and secure areas for preservation or development and create/approve zoning rules to enforce long term adherence to the intention of the Master Plan
Jurisdictional ambiguity – the Resilience and Second Access projects identified over the decades span numerous territories and rights of way, and no one agency or official has the authority to push a project through.	• Form Task Force that includes: HDOT, OMPO, DHHL, City and County of Honolulu DTS, DPP, Army Corps of Engineers, FEMA, military, DLNR, and other stakeholder agencies. Formulate common goals and objectives for identifying and completing projects • Include elected officials from City Councils and Hawai‘i and US senators and representatives.
Lack of agreement on how to approach a Second Access. Many residents strongly feel it is needed to relieve traffic congestion and to provide an evacuation route in the event of a natural disaster. Many residents strongly feel that unwanted development and bringing traffic through school zones and quiet neighborhoods will follow and degrade their communities and quality of life. These issues need to be resolved before moving ahead with a Second Access.	• See Task Force formation above. • Begin the lengthy EIS process so various alternatives can be thoroughly explored and vetted
Lack of topographic survey on and around Farrington Highway right of way and for the areas through which the Second Access may pass. This limits the identification and planning of alternatives and makes cost estimates unreliable.	• Develop a 5-year plan for collecting topographic survey for Farrington Highway right of way plus 20 – 50 feet outside R/W, and 30-50-foot strip for shared use path corridor. • Develop a 5-10-year plan for collecting topographic survey for potential Second Access routes

5 Program Funding

A review of the funding environment at both the federal and state levels is summarized in Table 35. While all the projects are eligible for federal formula funds as well as for state CIP, there is competition for these dollars with other state and county projects. Working with HDOT managers of the Statewide Transportation Improvement Program (STIP) a working estimate was made of the starting funds that could reasonably be assumed to be available for all Oahu projects as shown in Table 35.

Table 35: Federal Funds available for Oahu projects.

	Federal	State	Total for Term
Single Year (for reference)	$67-76 M	$20-22 M State CIP $36 M SMP	$123-134 M
Short Term (<= 2 years) 2021-2022	$134-152 M	$40-44 M State CIP $72 M SMP	$246-268 M
Mid Term (>2 to 5 Years) 2023-2025	$201-228 M	$60-66 M State CIP $108 M SMP	$369-402 M
Long Term (5-10+ years) 2026-2030)	$335-380 M	$100-110 M State CIP $180 M SMP	$615-670 M

These dollar totals are shown for a single year (for reference), for the short-term (<= two year period from 2021-2022), the mid-term (>two to five year period 2023-2025) and the long-term (five to ten year period from 2026-2030).

If there is no change in funding available for Farrington Highway projects, then the most that can be expected is to undertake projects for Safety and System Preservation (also called Tier I projects). The projects for addressing congestion and capacity increase (Tier II projects) will require new sources of revenue. Tier I and II totals are summarized in Table 36. HDOT has established that the 5th Lane Extension project would be funded by the rental car surcharge.

Table 36: Farrington Highway Proposed Projects by Tier and Category

Category	Cost
Tier I - Mandated, Safety, and System Preservation Projects (All “S” and “R” projects)	$77,732,500
Tier II Congestion Relief, Modernization and Capacity Increase Projects (All “C” projects)	$32,316,500
Total Cost	**$110,048,900**

Considering how projects could be funded over time helps to pace their expenditures and make their implementation more manageable. Their costs can be aligned with available funding for a given time period. Projects were classified as Short Term, Mid-Term, or Long Term in Table 26, and the relative share of the Oahu transportation funding for each time period is given below.

- Short term List (those which can be undertaken within the next 2 years subject to availability of funding and prioritization) contains 18 projects whose costs total $13,238,300, which is about 4.9 to 5.4% of the Oahu funding available in a 2-year period.
- Mid-term List (those which have a >2 to 5-year timeline) may require an EA or EIS, right of way acquisition and have construction complications) contains 11 projects, whose costs total $56,141,700, which is about 14.0-15.2% of the Oahu funding in a 3-year period.
- Long Term List (those which have a 5-10-year timeline) will likely require an EA or EIS, may require extensive right of way acquisitions and have complicated construction, contains two projects whose costs total $40,603,900, which is about 6.1-6.6% of the Oahu funding in a five year period.

The value of sorting the projects according to their benefits and their ability to be undertaken in the short, mid or long term is that it can set a direction for HDOT action. Once priorities have been agreed upon, the top short term projects can begin to be programmed.

The top mid-term and long term projects can begin their environmental studies, and then where required, land acquisition can be started (following completion of environmental clearance). This will take 3-7 years, so these projects should be started as early as possible.

Farrington Highway will take major investments for safety improvements, congestion relief and resilience. The combined federal and state funds currently available on Oahu is $123 – 134 million/year. New sources of revenue will be necessary to fund the congestion relief projects. The rental car surcharge is being designated for the 5th Lane Extension, but the 2020 significant decrease in tourism has made these funds unrealistic for the short term. As the department and state administration continue their quest for increasing the state highway fund revenues, it is hoped that this report will provide valuable data driven analysis and information for making hard choices.

Project	Description	B/C	Tier I Costs	Tier II Costs
Short Term Projects				
C2	Segment 2 - Restripe to add short right turn lane at Haleakala from side street approach	338.7		$ 6,500
C3	Segment 2 - Widen pavement and restripe to add right turn lane at Lualualei Naval Road from side street approach	40.2		$ 50,000
S10	Waiʻanae/Mākaha – Segment 5 - Speed Feedback signs	15.5	$ 33,000	
S6	Māʻili – Segment 4 – Speed Feedback signs	5.7	$ 33,000	
S1	Nānākuli – Segment 2 - Intersection Improvements	5.5	$ 502,300	
S3	Nānākuli – Segment 2 - Speed Feedback signs	4.9	$ 44,000	
S4	Māʻili – Segment 4 - Intersection Improvements	3.5	$ 347,200	
S8	Waiʻanae/Mākaha – Segment 5 - Intersection Improvements	3.5	$ 121,000	
S2	Nānākuli – Segment 2 - Streetlight Improvements	1.4	$ 463,800	
C4	Segments 1 and 2 - Computerized Traffic Control System Phase 15 - Nānākuli, expanded to include Laʻaloa St. and Waiomea St. intersections	1.3		$ 3,800,000
S5	Māʻili – Segment 4 - Streetlight Improvements	1.2	$ 321,100	
S11	Segment 2 - Convert bridge by Laumania to allow bike and pedestrian traffic.	Ranked 8[13]	$ 32,000	
R1	Segment 2 - Focused Drainage Study - Improve drainage to alleviate flooding at Princess Kahanu	N/A	$ 65,000	
R2	Segment 4 - Focused Drainage Study to propose solutions for flooding in Maili	N/A	$ 65,000	
R3	Segment 5 - Focused Drainage Study to propose solutions for flooding at Leihoku St	N/A	$ 112,000	
R4	Segment 5 - Focused Drainage Study to propose solutions for flooding at Waiʻanae Valley Road	N/A	$ 134,000	
S9	Waiʻanae/Mākaha – Segment 5 - Streetlight Improvements	0.5	$ 713,400	
C5	Segment 4 - Computerized Traffic Control System - Māʻili, 7 signals	0.3		$ 2,660,000
C6	Segment 5 - Computerized Traffic Control System Phase 16 - Waiʻanae	0.3		$ 3,800,000
	Short Term Project Totals		$ 2,986,800	$ 10,316,500

[13] Ranked and N/A were assumed to have B/C ~1

Mid-Term Projects				
S7	Māʻili – Segment 4 – Add Center Left Turn Lane	1.5	$ 820,200	
S13	Segment 2 - Upgrade and widen sidewalk from Helelua to Hakimo along mauka side of FH. Add C&G (mauka) & 6' shoulders both sides. Add Shared Use Path on makai side.	Ranked 1	$ 10,000,000	
S16	Segment 4 - Add sidewalk and shoulder bike lanes along both sides of Farrington Highway from Kaʻukama to Māʻiliʻili, 9,500 ft	Ranked 2	$ 13,887,300	
S17	Segment 5 - Build Shared Use Path from Māʻiliʻili to Leihoku, 2,500 ft	Ranked 3	$ 1,002,100	
S12	Segment 2 - Upgrade and widen sidewalk from Pohakunui to Helelua along mauka side of Farrington Highway. Add C&G (mauka) & 6' shoulders both sides	Ranked 4	$ 10,171,700	
S18	Segment 3 - Build Shared Use Path from Kaʻukama to Hakimo, 5,600 ft	Ranked 6	$ 2,245,000	
S14	Segment 2 - Build Shared Use Path from Nānākuli to Pohakunui (4,000 ft)	Ranked 7	$ 1,625,300	
R5	Segment 6 - Plan and build rock veneer wall 500 ft x 4 ft high to prevent sand and wave over wash in Mākaha	N/A	$ 1,390,000	
R6	Segment 2 - Nānākuli: Hard Protection locations from Figure 14, Projects identified in Drainage Study	0.95[14]	$ 5,000,000	
R7	Segments 4 and 5 - Māʻili/Waiʻanae: Hard Protection locations from Figure 15, Projects identified in Drainage Study	0.95	$ 5,000,000	
R8	Segment 6 - Mākaha: Hard Protection locations from Figure 16, Projects identified in Drainage Study	0.95	$ 5,000,000	
	Mid-Term Project Totals		$ 56,141,600	

Long Term Projects				
S15	Segments 1 and 2 - Build Shared Use Path from Pohakunui to Ko Olina (9,900 ft), partnering with OMPO, C&C, DHHL, PPP, HBL, others	Ranked 5	$ 18,604,000	
C1	Segment 2 - Extension of 5th Lane and Contraflow (Helelua to as far as Hakimo) approx 6,900 ft, incl mauka sidewalk, shoulders, shared use path	0		$ 22,000,000
	Long Term Project Totals		$ 18,604,000	$ 22,000,000

[14] Composite B/C score from Table 23

THIS PAGE INTENTIONALLY LEFT BLANK

REFERENCES

City and County of Honolulu Department of Design and Construction (CCH -DDC). 2004. *Final Environmental Assessment: Mauna Lahilahi Beach Park Improvements.* Available online at: http://oeqc2.doh.Hawaiʻi.gov/EA_EIS_Library/2004-05-DD-OA-FEA-Mauna-Lahilahi-Beach-Park-Improvements.pdf

City and County of Honolulu Department of Parks and Recreation (DPR). 1998. *Mākaha Beach Park Master Plan Report.* Available online at: https://www.Oʻahumpo.org/wp-content/uploads/2016/04/Mākaha-Beach-Park-Master-Plan-Report-1998.pdf

City and County of Honolulu Department of Planning and Permitting (DPP). 2000. *Waiʻanae Sustainable Communities Plan.* Available online at: http://206.195.188.174/docushare/dsweb/Get/Document-258/AR00047097.pdf

Department of Hawaii Home Lands (DHHL). 2008. *Waiʻanae and Lualualei Regional Community Development Plan.* Available online at: https://www.Oʻahumpo.org/wp-content/uploads/2015/12/Wai'anae-Regional-Plan-January-2008.pdf

Department of Land and Natural Resources Engineering Division (DLNR). 2014. *Mākaha Valley Flood Mitigation Study.* Available online at: http://dlnreng.Hawaiʻi.gov/fcds/wp-content/uploads/sites/21/2014/09/Public-DRAFT-Mākaha-Flood-Report.pdf

Department of Land and Natural Resources Office of Conservation and Coastal Lands (DLNR-OCCL). 2010. *Beach Management Guidelines: Mākaha Beach Park.* Available online at: https://21maile.files.wordpress.com/2013/04/Mākaha-beach-sand-pushing-guidelines_2010.pdf

Hawaii News Now (HNN). 2018. *Erosion at a Mākaha Shoreline is gobbling up the beach and threatening homes.* Available online at: https://www.Hawaiʻinewsnow.com/story/39025590/Mākaha-resident-battle-beach-erosion/

Hawaii News Now (HNN). 2011. *Leeward Oahu drenched by storm.* Available online at: https://www.Hawaiʻinewsnow.com/story/13841799/leeward-Oʻahu-drenched-by-storm/

Oahu Metropolitan Planning Organization (OMPO). 2020. *Farrington Highway Realignment in Vicinity of Mākaha Beach: Existing Conditions Report Summary.*

Oahu Metropolitan Planning Organization (OMPO). 2011. *Transportation Asset Climate Change Risk Assessment Project.*

SSFM International. December 2020. Farrington Highway Operations Assessment, Farrington Highway (Route 93) Corridor Study (Task 4.0)

SSFM International. December 2019. Second Access Assessment, Farrington Highway (Route 93) Corridor Study (Task 3.0)

State of Hawaii Department of Transportation Highways Division (HDOT). 2019. *State of Hawaii Statewide Coastal Highway Program Report*. Available online at: https://hidot.Hawaiʻi.gov/highways/files/2019/09/State-of-Hawaiʻi-Statewide-Coastal-Highway-Program-Report_Final_2019.pdf

United States Army Corps of Engineers. (USACE). 2001. *Lualualei Flood Study Executive Summary.* Available online at: https://21maile.files.wordpress.com/2011/12/lualualeifloodstudyexecutivesummary_Wai'anae_sep2001.pdf

United States Geological Survey (USGS). 2011. *National Assessment of Shoreline Change: Historical Change in the Hawaiian Islands.* Available online at: https://pubs.usgs.gov/of/2011/1051/pdf/ofr2011-1051_report_508_rev052512.pdf