SECTION 2. SITE CHARACTERIZATION

Of interest to our geotechnical analysis are the subsurface materials encountered at the project site, the engineering properties of the materials encountered, and the variability of the subsurface conditions across the project site. Therefore, the following subsections provide a description of the geologic setting of the project site, the surface and subsurface conditions encountered at the site, and a discussion of the items needed for seismic design, such as seismicity, soil liquefaction, and the soil profile characteristics for seismic analysis.

2.1 Regional Geology

The Island of Oahu was built by the extrusion of basaltic lava from two shield volcanoes, Waianae and Koolau. The older volcano, Waianae, is estimated to be middle to late Pliocene in age, and younger shield, Koolau Volcano, is estimated to be late Pliocene to early Pleistocene in age. After a long period of volcanic inactivity, during which time erosion incised deep valleys into the Koolau shield, volcanic activity returned with a series of lava flows followed by cinder and tuff cone formations. These series are referred to as the Honolulu Volcanic Series. The project site is located at the southwestern flank of the Koolau Mountain Range.

During the Pleistocene Epoch (Ice Age), sea levels fluctuated in response to the cycles of continental glaciation. As the glaciers grew and advanced, less water was available to fill the oceanic basins such that sea levels fell below the present stands of the sea. When the glaciers melted and receded, an excess of water became available such that the sea levels rose to elevations above the present sea level.

The higher sea level stands caused the formation of deltas and fans of accumulated terrigenous sediments in the heads of old bays, accumulated reef deposits at correspondingly higher elevations, and lagoonal/marine sediments in the quiet waters protected by fringing reefs. The lower sea stands caused streams to carve valleys in the sediments and reef deposits. Subaerial exposure of the sediments and calcareous materials caused consolidation of the soft deltaic materials and lagoonal deposits and induration of the calcareous reef materials.

The project site lies on the North Shore Coastal Plain and the pediment of the northwestern end of the Koolau Mountain Range. The project area is straddling areas generally classified from a geological standpoint as “Qbd” for Quaternary Beach Deposits and ‘Qa’ for Quaternary Alluvium (Sinton, et.al.) deposited since the Pleistocene Epoch. Experience in the vicinity of the project site indicates that the project site is underlain by fill, beach deposits, alluvial deposits, and basalt rock formation.

2.2 Existing Site Conditions

The project site encompasses approximately 2,140 lineal feet of new roadway and a new bridge of about 102.5 feet long to be constructed on the mauka side of Kamehameha Highway in vicinity of Laniakea Beach in the North Shore neighborhood area of Waialua on the Island of Oahu, Hawaii. The busy Laniakea Beach is located on makai side of Kamehameha Highway within short walking distance and there are numerous vehicle parking on the mauka side of the highway.

The intermittent Lauhulu Stream crosses under Kamehameha Highway within the project limits. The streambed is mainly bare sand and is about 8 feet below Kamehameha Highway. It is our understanding that the upper reaches of Lauhulu Stream are generally dry except when heavy rains occur resulting in stream water flowing to the beach.

Based on the topographic survey map provided, the elevation of the existing ground surface within the project limits ranges from about +8 to +22 feet Mean Sea Level (MSL). The roadway elevation along the existing Kamehameha Highway ranges from about +16 to +21 feet MSL.

2.3 Subsurface Conditions

We explored the subsurface conditions at the project site by drilling and sampling eight borings, designated as Boring Nos. 1 through 8, extending to depths of about 5.1 to 71.5 feet below the existing ground surface. In addition, three bulk samples of the near-surface soils, designated as Bulk-1 through Bulk-3, were obtained to evaluate the pavement support characteristics of the near-surface soils. The approximate boring and bulk sample locations are shown on the Site Plan, Plate 2.

In general, our borings encountered a thin surface fill and/or alluvium about 0.5 to 4 feet thick underlain by beach deposit to depths of 11 to 19.5 feet. Below the beach deposit, alluvium, clinker and basalt rock formation were encountered, extending to the maximum depth explored of about 71.5 feet below the existing ground surface. The beach deposit was not encountered in three of the drilled borings. The surface fill layer consisted of about 7 and 8 inches of asphaltic concrete (AC) in paved areas and about 0.5 to 3 feet of medium dense to dense silty sand and sandy gravel and boulders. Beach deposit consisted of loose to medium dense poorly graded sand. The alluvium consisted of medium dense silty sand, stiff to hard silty clay and clayey silt with cobbles and boulders. Basalt formation encountered ranged from hard to very hard and moderately to slightly weathered. The clinker generally consisted of medium dense to very dense silty/sandy gravel and silty sand. An idealized subsurface cross-section across the proposed bridge is shown on the Generalized Geologic Cross-Section A-A', Plate 3.

We encountered groundwater in the drilled borings at depths of about 9.9 to 12.3 feet below the existing ground surface at the time of our field exploration. The groundwater levels measured generally correspond to about Elevations +0.7 to +2.2 feet MSL, respectively. Due to the proximity of the project site to the Pacific Ocean, groundwater levels can fluctuate depending on tidal fluctuations, storm surge conditions, seasonal precipitation, groundwater withdrawal and/or injection, and other factors.

Detailed descriptions of the materials encountered from our field exploration are presented on the Logs of Borings, Plates A-1 through A-8, in Appendix A. Results of the laboratory tests performed on selected samples obtained from our field exploration are presented in Appendix B. Photographs of the core samples retrieved from our field exploration are presented in Appendix C.

2.4 Seismic Design Considerations

Based on the LRFD Bridge Design Specifications, 9th Edition (2020), the project site may be subject to seismic activity, and seismic design considerations will need to be addressed. The following subsections provide discussions on the seismicity and the potential for liquefaction at the project site.

2.4.1 Earthquakes and Seismicity

In general, earthquakes that occur throughout the world are caused by shifts in the tectonic plates. In contrast, earthquake activity in Hawaii is linked primarily to volcanic activity. Therefore, earthquake activity in Hawaii generally occurs before or during volcanic eruptions. In addition, earthquakes may result from the underground movement of magma that comes close to the surface but does not erupt. The Island of Hawaii experiences thousands of earthquakes each year, but most are so small that only sensitive instruments can detect them. However, some of the earthquakes are strong enough to be felt, and a few cause minor to moderate damage.

In general, earthquakes associated with volcanic activity are most common on the Island of Hawaii. Earthquakes that are directly associated with the movement of magma are concentrated beneath the active Kilauea and Mauna Loa Volcanoes on the Island of Hawaii. Because the majority of the earthquakes in Hawaii (over 90 percent) are related to volcanic activity, the risk of high seismic activity and degree of ground shaking diminishes with increased distance from the Island of Hawaii. The Island of Hawaii has experienced numerous earthquakes greater than Magnitude 5 (M5+); however, earthquakes are not confined only to the Island of Hawaii.

To a lesser degree, the Island of Maui has experienced several earthquakes greater than Magnitude 5. Therefore, moderate to strong earthquakes have occurred in the County of Maui. The effects of earthquakes occurring on the Islands of Hawaii and Maui may be felt on the Island of Oahu. For example, several small landslides occurred on the Island of Oahu as a result of the Maui Earthquake of 1938 (M6.8). In addition, some houses on the Island of Oahu were reportedly damaged as a result of the Lanai Earthquake of 1871 (M7+).

Due to the relatively short period of documented earthquake monitoring in the State of Hawaii, information pertaining to earthquakes that were felt on the Island of Oahu may not be complete. In general, we are not aware of reported earthquakes greater than Magnitude 6 occurring on the Island of Oahu over the last 150 years of recorded history. Based on available information, we understand an earthquake of about Magnitude 5.6 occurred on June 28, 1948 in the vicinity of the Island of Oahu, possibly along the hypothesized and controversial Diamond Head Fault feature.

The Diamond Head Fault feature is believed to extend northeasterly away from the southeastern tip of the Island of Oahu. The Diamond Head Fault feature may be related to the widely documented Molokai Fracture Zone located on the sea floor in the vicinity of the Hawaiian Islands. Despite only the moderate tremor intensity, the resulting damage was reportedly widespread and included broken windows, ruptured masonry building walls, and a broken underground water main. In addition, some areas on the Island of Oahu, including the Tantalus, Iwilei, and Tripler areas, reported more intense ground shaking, severe enough to have cracked reinforced concrete.

2.4.2 Liquefaction Potential

Based on the AASHTO LRFD Bridge Design Specifications Ninth Edition, 2020, the project site may be subjected to seismic activity, and the potential for soil liquefaction at the project site will need to be evaluated.

Soil liquefaction is a condition where saturated cohesionless soils located near the ground surface undergo a substantial loss of strength due to the build-up of excess pore water pressures resulting from cyclic stress applications induced by earthquakes. In this process, when the loose saturated sand deposit is subjected to vibration (such as during an earthquake), the soil tends to densify and decrease in volume causing an increase in pore water pressure. If drainage is unable to occur rapidly enough to dissipate the build-up of pore water pressure, the effective stress (internal strength) of the soil is reduced. Under sustained vibrations, the pore water pressure build-up could equal the overburden pressure, essentially reducing the soil shear strength to zero and causing it to behave as a viscous fluid. During liquefaction, the soil acquires a mobility sufficient to permit both horizontal and vertical movements, and if not confined, will result in significant deformations.

Soils most susceptible to liquefaction are loose, uniformly graded, fine-grained sands and loose silts with little cohesion. The major factors affecting the liquefaction characteristics of a soil deposit are as follows.

FACTORS	LIQUEFACTION SUSCEPTIBILITY
Grain Size Distribution	Fine and uniform sands and silts are more susceptible to liquefaction than coarse or well-graded sands.
Initial Relative Density	Loose sands and silts are most susceptible to liquefaction. Liquefaction potential is inversely proportional to relative density.
Magnitude and Duration of Vibration	Liquefaction potential is directly proportional to the magnitude and duration of the earthquake.

Based on the subsurface conditions encountered, the phenomenon of soil liquefaction is not a design consideration for this project site. The risk for potential liquefaction is low based on the subsurface conditions encountered.

2.4.3 Soil Profile Type for Seismic Design

Based on the subsurface materials encountered at the project site, we believe the project site may be classified from a seismic analysis standpoint as being a “Stiff Soil” site corresponding to a Site Class D soil profile type based on AASHTO 2020 LRFD Bridge Design Specifications, 9th Edition.

Based on the AASHTO 2020 LRFD Bridge Design Specifications, the bridge structure will need to be designed based on an earthquake return period of 1,000 years. Based on a 1,000-year return period and the anticipated Site Class D, the following seismic design parameters were estimated and may be used for the seismic analysis of the bridge structure planned for the project.

SEISMIC DESIGN PARAMETERS AASHTO 2020 LRFD BRIDGE DESIGN SPECIFICATIONS 1,000-YEAR RETURN PERIOD (~7% PROBABILITY OF EXCEEDANCE IN 75 YEARS)	
Parameter	**Value**
Peak Bedrock Acceleration, PBA (Site Class B)	0.160g
Spectral Response Acceleration (Site Class B), S_S	0.363g
Spectral Response Acceleration (Site Class B), S_1	0.099g
Site Class	“D”
Site Coefficient, F_{pga}	1.48
Site Coefficient, F_a	1.51
Site Coefficient, F_v	2.40
Design Peak Ground Acceleration, PGA (Site Class D) or A_s	0.236g
Design Spectral Response Acceleration, S_{DS}	0.547g
Design Spectral Response Acceleration, S_{D1}	0.238g
Seismic Design Category	“B”

END OF SITE CHARACTERIZATION