CONCLUSIONS AND RECOMMENDATIONS

Based on our exploratory borings, we expect that structural excavations for the proposed retaining walls will expose medium hard to hard basalt. Conventional wall footings founded directly on the medium hard to hard basalt may be used to support the retaining walls.

In the event that wall footing excavations expose the overlying gravel, we recommend the footing excavations extend through the gravel layer to expose the underlying medium hard to hard basalt. As an alternative to extending the footings down to basalt, the overexcavations should extend down to basalt and may be backfilled with lean concrete with a minimum compressive strength of 300 pounds per square inch. Wall footings may also bear directly on the lean concrete overlying the basalt.

Due to the potential for voids in the basalt stratum, a subsurface probing and grouting program is recommended as part of the site preparation work for foundations.

Conventional Retaining Wall

Foundations – Conventional wall footings founded directly on medium hard to hard basalt or lean concrete overlying medium hard to hard basalt may be used to support retaining walls. Lean concrete should have a minimum compressive strength of 300 pounds per square inch.

The following soil parameters may be used for design of retaining wall foundations.

Soil Type	Extreme Event Limit State	Strength Limit State	Service Limit State
Basalt	24,000 psf	10,800 psf	8,000 psf

Wall footings should be a minimum 24 inches in width, and embedded at least 12 inches below finish adjacent grade. Footings located on, or near the top of slopes, should be embedded such that a minimum horizontal distance of 5 feet is maintained between the bottom edge of footing and slope face.

The bottom of footing excavations should be cleaned of loose material prior to placement of reinforcing steel and concrete.

Drainage Fill Material - To prevent buildup of hydrostatic pressures, retaining walls should be well-drained. The standard of practice consists of placing an approximately 12-inch thick layer of free-draining gravel at the back of the wall. The gravel should extend from the base of the wall, around subdrains and/or weepholes, and up to within 12 inches of finish grade.

Alternatively, prefabricated drainage geocomposites, such as Miradrain or J-drain, may be used in lieu of the free-draining gravel. As with the free-draining gravel, the drainage geocomposites should be placed at the back of the wall, be connected with the weepholes and/or subdrains (in accordance with manufacturer's specifications), and extend to within 12 inches of finish grade. For freestanding walls, the drainage system should be covered by at least 12 inches of low permeability soil, such as material with a USCS classification of ML or MH. If the backfill is covered by pavement, the gravel fill should extend to the bottom of the pavement section.

Backfill Material - The remaining backfill placed behind conventional retaining walls may consist of the onsite gravels or imported granular structural fill. All rock fragments larger than 3 inches in maximum dimension should be removed from the onsite gravels prior to reuse. Pockets of volcanic ash should also be removed from the onsite gravels prior to reuse. See the *Site Grading* section of this report for imported granular structural fill recommendations.

Backfill should be placed in horizontal lifts restricted to 8 inches in loose thickness, and compacted to a minimum 95 percent compaction as determined by AASHTO

T-180 (ASTM D 1557). Overcompaction of the backfill material should be avoided.

Segmental Concrete Retaining Wall

We understand that alternatives to conventional retaining walls are being considered, such as segmental concrete retaining walls.

Foundations - Foundations for segmental concrete retaining walls should be founded on a base leveling pad consisting of a minimum 6 inches of imported granular structural fill. The granular structural fill should also extend a minimum 12 inches beyond the front and back faces of the units. Overexcavation of the basalt will be required for placement of the granular structural fill section. See the *Site Grading* section of this report for imported granular structural fill recommendations.

Unless covered by exterior concrete slabs or pavement, the granular structural fill section exposed to the environment should be capped by a minimum 12 inches of low permeability soil, such as material with a USCS classification of ML or MH.

Segmental concrete retaining wall foundations may be designed for an allowable bearing value of 8,000 pounds per square foot. The allowable bearing value is for the total of dead and frequently applied live loads, and may be increased by one-third for short duration loading which includes the effect of wind and seismic forces.

The initial lift of segmental wall units should be embedded a minimum depth of H/7, where H is the height of the wall, or 12 inches below finish adjacent grade, whichever is greater.

Drainage Fill Material - To prevent buildup of hydrostatic pressures, the segmental retaining wall should be well-drained. Unit drainage fill, consisting of crushed rock or clean, well-draining granular fill, should be placed at the back of the wall, in accordance with the manufacturer's specifications. The width of the unit drainage fill should be approximately 24 inches, measured from the wall face. The unit drainage fill should extend from the base of the wall, and up to within 12 inches of finish grade. The drainage system should be covered by at least 12 inches of low permeability soil, such as material with a USCS classification of ML or MH. If the drainage system is covered by exterior concrete slabs or pavement, the unit drainage fill should extend to the bottom of slab cushion or base course elevation.

Reinforced Fill Material - The onsite gravel will be acceptable for reuse in the reinforced soil zone for geosynthetic reinforcement of the segmental concrete retaining wall. All rock fragments larger than 3 inches in maximum dimension should be removed from the onsite gravels prior to reuse. Pockets of volcanic ash should also be removed from the onsite gravels prior to reuse. As an alternative, imported granular structural fill, generated from a quarry, may be used as backfill in the reinforced soil zone.

To reduce the potential for surface water to infiltrate the reinforced soil zone, the upper 12 inches of the reinforced fill should consist of relatively impermeable soil, such as material with a USCS classification of ML or MH.

The following geotechnical parameters may be used for the reinforced fill material in designing the segmental concrete retaining wall.

Angle of internal friction	34 degrees
Moist unit weight	130 pcf
Cohesion	0 psf

The reinforced fill should be placed in horizontal lifts restricted to 8 inches in loose thickness and compacted to a minimum 95 percent compaction as determined by AASHTO T-180 (ASTM D 1557).

Probing and Grouting

Although subsurface cavities in the basalt stratum were not encountered in our exploratory borings, our past experience in the general Keaau and Pahoa areas indicates that occasional cavities/voids can be expected in the basalt stratum. Therefore, a probing and grouting program is recommended during construction.

All footing excavations should be probed with a drill or air-track hammer. As a general guideline for cost estimating purposes, we recommend that one probe hole be drilled at about 10 feet on centers along wall footings. The probe holes should be a minimum 2 inches in diameter and extend to depths of at least twice the footing width or a minimum 10 feet below the bottom of footings. When available, the foundation plans should be provided to our office for review, and to provide further recommendations for the probing and grouting plan, including quantity and depths of probe holes.

All probe holes should be filled with pumped sand-cement grout through a grout pipe starting at the bottom of the probe hole. The grout should consist of a sand-cement mixture consisting of about one part cement to three parts sand. Placement of thin wall plastic pipes in probe holes may be necessary to prevent holes from caving. Areas encountering cavities or voids that consume large quantities of grout may require additional probe holes. Voids exposed at the bottom of foundation excavations should be opened and filled with lean concrete.

Seismic Design

Based on the borings drilled as part of this study and our knowledge of the deep soil conditions in the area, the subsurface soils can be characterized as a rock profile. Therefore, based on the 7TH Edition of the AASHTO LRFD Bridge Design Specifications, Site Class B is recommended for this site.

Lateral Design

Resistance to lateral loading may be provided by friction acting at the base of wall foundations, and by passive earth pressure acting on the buried portions of foundations. The following coefficients of friction may be used with dead load forces.

Soil Type	Extreme Event Limit State	Strength Limit State
Base Leveling Pad	0.58	0.46
Basalt	0.70	0.60

For passive earth pressure considerations, the following equivalent fluid pressures may be used. Unless covered by pavement or concrete slabs, the upper 12 inches of soil should not be considered in computing lateral resistance.

Soil Type	Extreme Event Limit State	Strength Limit State
Gravel	750 pcf	375 pcf
Basalt	1,200 pcf	600 pcf

For active earth pressure considerations, equivalent fluid pressures of 35 and 50 pounds per cubic foot may be used for freestanding and restrained or at-rest conditions, respectively.

Surcharge stresses due to traffic loads within a horizontal distance equal to the depth of the retained height should also be considered in the design of retaining walls. For uniform surcharge stresses, a rectangular distribution with a uniform pressure equal to 28 percent of the vertical surcharge pressure acting on the entire height of the wall may be used for freestanding conditions.

For dynamic lateral earth pressure considerations, a dynamic lateral force of $37H^2$ pounds per lineal foot of wall length may be used for level backfill conditions where the walls are free to move laterally up to 1 to 2 inches or rotate in the event of an earthquake. H is the height of the retained soil or backfill in feet. The dynamic lateral force may be assumed to act through the mid-height of the wall. The dynamic lateral earth pressures are in addition to the static earth pressures.

Foundation Settlement

Neither excessive total nor differential settlement is expected for foundations bearing on medium hard to hard basalt or lean concrete overlying basalt

Pavement Design

Our pavement design calculations were based on procedures in the Hawaii DOT-Highways Pavement Design Manual (2002). Design of the pavement sections were based on vehicular classification counts provided by the Hawaii Department of Transportation, and are summarized below. The 50-year traffic information was linearly extrapolated from the traffic information provided.

	Shower Dr. to Ainaloa Blvd.
ADT (2018)	28,300
ADT (2028)	33,800
ADT (2068)	*55,800*
Percent Trucks (T24)	3.5%
Design D	75/25
2-Axle (% of T24)	63.03%
3-Axle (% of T24)	16.33%
4-Axle (% of T24)	11.22%
5-Axle (% of T24)	7.54%
6-Axle (% of T24)	1.88%

	Ainaloa Blvd. to Kahakai Blvd.
ADT (2011)	20,300
ADT (2031)	23,100
ADT (2018)	*21,280*
ADT (2068)	*28,280*
Percent Trucks (T24)	3.0%
Design D	65/35
2-Axle (% of T24)	60.79%
3-Axle (% of T24)	17.91%
4-Axle (% of T24)	10.42%
5-Axle (% of T24)	9.40%
6-Axle (% of T24)	1.48%

A 50-year design life based on a high volume urban road was used to evaluate pavement sections.

Pavement subgrades are expected to consist of dense onsite gravels or new compacted granular fill. Pockets of volcanic ash, such as encountered in our bulk sample near boring B6, indicated by pumping conditions, should be removed from the pavement subgrade.

R-value tests performed on the onsite gravels resulted in R-values ranging from about 75 to 84. The Pavement Design Manual indicates that any soil having an R-value greater than 55 shall be limited to an R-value of 55. In fill areas, we recommend that imported granular fill with a minimum R-value of 55 be used as fill material. Therefore, an R-value of 55 was used for design of the pavement section.

Our pavement design analyses resulted in the following flexible pavement sections for the proposed roadway widening. Design calculations for flexible pavement are shown on Plates C1.1 through C4.3.

Shower Drive to Ainaloa Boulevard - Alternative #1

4.0"	Asphaltic Concrete
8.0"	Asphalt Concrete Base (ACB)
12.0"	Total Thickness

Shower Drive to Ainaloa Boulevard - Alternative #2

7.5"	Asphaltic Concrete
10.0"	Aggregate Base (AB)
17.5"	Total Thickness

Southeast of Ainaloa Boulevard - Alternative #1

4.0"	Asphaltic Concrete
7.0"	Asphalt Concrete Base (ACB)
11.0"	Total Thickness

Southeast of Ainaloa Boulevard - Alternative #2

7.0"	Asphaltic Concrete
9.0"	Aggregate Base (AB)
16.0"	Total Thickness

Prior to the placement of asphalt concrete base or aggregate base, the exposed subgrade should be scarified to a minimum depth of 6 inches, moisture conditioned to about 2 percent above optimum moisture content, and compacted to a minimum 95 percent compaction as determined by AASHTO T-180 (ASTM D 1557). The aggregate base should also be compacted in lifts to a minimum 95 percent compaction as determined by AASHTO T-180 (ASTM D 1557).

Site Grading

Site Preparation - The project site should be cleared of all vegetation, including large tree roots, AC pavement, and other deleterious material. Prior to placement of fill, the exposed subgrade should be scarified to a minimum depth of 6 inches, moisture conditioned to about 2 percent above optimum moisture content, and compacted to a minimum 95 percent compaction as determined by AASHTO T-180 (ASTM D 1557). Where basalt is encountered or exposed, scarification may be terminated prior to the minimum 6-inch depth.

If encountered, pockets of volcanic ash indicated by pumping conditions should be removed down to competent material and replaced with either approved onsite soil or imported fill compacted in lifts to the recommended minimum standard as indicated in the *Compaction* section below.

Structural Excavations - Based on our exploratory borings, we believe that excavations into the surface gravels can generally be accomplished using conventional excavating equipment. Excavations into medium hard to hard basalt will require hydraulic equipment.

Shallow temporary cuts into the near surface gravels should be stable at slope gradients of 1H:1V or flatter. Temporary cuts into the moderately to slightly weathered basalt should stand at a near vertical gradient. However, it should be the Contractor's responsibility to conform to all OSHA safety standards for excavations.

Slope Gradients - The following permanent slope gradients may be used for design purposes.

Soil Type	Gradient
Permanent fill slopes	2H:1V or flatter
Cuts in gravels	2H:1V or flatter
Cuts in basalt	1H:1V or flatter

All slopes should be planted as soon as practical upon completion of grading to reduce the effects of erosion and weathering.

Fill slopes should be constructed from the bottom up. The fill should be continually benched into existing slopes as the fill is brought up in lifts. The benches should extend into competent material and be wide enough for compaction equipment to work effectively. Fill slopes should be constructed by overfilling and cutting back to the design slope gradient to obtain a well-compacted slope face.

Onsite Fill Material – The onsite gravels will be acceptable for reuse in structural fills and backfills provided all rock fragments larger than 3 inches in maximum dimension are removed prior to reuse. Pockets of volcanic ash should also be removed from the onsite gravels prior to reuse. Excavated basalt will also be acceptable for reuse in structural fills and backfills provided the material is crushed to a well-graded consistency with a maximum particle size of 3 inches.

Imported Fill Material - Imported structural fill should be well-graded, non-expansive granular material. Specifications for imported granular structural fill should indicate a maximum particle size of 3 inches, and state that between 8 and 20 percent of soil by weight shall pass the #200 sieve. In addition, the plasticity index (P.I.) of that portion of the soil passing the #40 sieve shall not be greater than 10. Imported structural fill should have a CBR expansion value no greater than 1.0 percent and a minimum CBR value of 15 percent, when tested in accordance with AASHTO T-193 (ASTM D 1883).

Compaction - Structural fill and backfill should be placed in horizontal lifts restricted to 8 inches in loose thickness and compacted to a minimum 95 percent compaction as determined by AASHTO T-180 (ASTM D 1557).

Fill placed in areas which slope steeper than 5H:1V should be continually benched as the fill is brought up in lifts. Fill placed on slopes should be keyed and benched into the existing slope to provide stability for the new fill against sliding. Filling the slope with sliver fills should be avoided.

ADDITIONAL SERVICES

We recommend that we perform a general review of the final design plans and specifications. This will allow us to verify that the foundation design and earthwork recommendations have been properly interpreted and implemented in the design plans and construction specifications.

For continuity, we recommend that we be retained during construction to (1) observe all probing and grouting operations, (2) perform compaction testing on the pavement subgrade, as well as the base materials, (3) observe footing excavations prior to placement of the base leveling pad, or reinforcing steel and concrete, (4) review and/or perform laboratory testing on import borrow to determine its acceptability for use in compacted fills, (5) observe structural fill placement and perform compaction testing, and (6) provide geotechnical consultation as required.

Our services during construction will allow us to verify that our recommendations are properly interpreted and included in construction, and if necessary, to make modifications to those recommendations, thereby reducing construction delays in the event subsurface conditions differ from those anticipated.

LIMITATIONS

The boring logs indicate the approximate subsurface soil conditions encountered only at those times and locations where our borings were made, and may not represent conditions at other times and locations.

This report was prepared specifically for SSFM International, Inc. and their sub-consultants for design of the proposed improvements to Keaau-Pahoa Road, from near its intersections with Shower Drive to Ainaloa Boulevard, in Keaau to Pahoa, Hawaii. The boring logs, laboratory test results, and recommendations presented in this report are for design purposes only, and are not intended for use in developing cost estimates by the contractor.

During construction, should subsurface conditions differ from those encountered in our borings, we should be advised immediately in order to re-evaluate our recommendations, and to revise or verify them in writing before proceeding with construction.

Our recommendations and conclusions are based upon the site materials observed, the preliminary design information made available, the data obtained from our site exploration, our engineering analyses, and our experience and engineering judgment. The conclusions and recommendations in this report are professional opinions which we have strived to develop in a manner consistent with that level of care, skill, and competence ordinarily exercised by members of the profession in good standing, currently practicing under similar conditions in the same locality. We will be responsible for those recommendations and conclusions, but will not be responsible for the interpretation by others of the information developed. No warranty is made regarding the services performed, either expressed or implied.

Respectfully submitted,

HIRATA & ASSOCIATES, INC.

Nathan K. Tanaka, Project Engineer

NATHAN K. TANAKA
LICENSED PROFESSIONAL ENGINEER
No. 15005-C
HAWAII, U.S.A.

This work was prepared by
me or under my supervision.
Expiration Date of License:
April 30, 2020