SECTION 3. DISCUSSION AND RECOMMENDATIONS

In general, the type and severity of the distresses exhibited in the pavement areas would determine whether rehabilitation or reconstruction of the existing pavements should be performed from an engineering point-of-view. Existing pavements with minor distresses may be rehabilitated with an AC overlay with cold-planing. However, reconstruction of the existing pavements would be prudent for those areas where the observed distresses are likely caused by failures in the underlying base, subbase, and/or subgrade materials. Detailed information of the following areas would be required to provide input design parameters for the pavement design and analyses:

- Traffic Index
- Existing Pavement Section
- Condition of the Existing AC Layer
- Resistance (R) Value of the Subgrade Material

Our pavement condition survey conducted at the project site suggested that the majority of the pavements within the project limits appear to exist in fair to good condition. However, we believe that this observation is likely a result of the recent AC overlay performed on some of the severely distressed pavement areas, masking the deteriorated condition of the underlying pavements. Therefore, consideration should be given to reconstructing these pavement areas with a new pavement section similar to other pavement areas exhibiting moderate to severe distresses. Based on our evaluation, it is our opinion that pavement areas with minor distresses may be rehabilitated with an AC overlay consisting of cold-planing 4 inches of the existing AC surface and replacing with 4 inches of new AC overlay. Due to the poor bonding of the existing multiple AC overlays, a contingency fund should be allocated in the construction budget for extending the cold-planing thickness to the underlying intact asphaltic concrete.

Existing pavement areas with moderate to severe distresses have been identified and delineated by our office during the pavement condition survey. It is our opinion that these pavement areas should be reconstructed with new pavement section designed based on a 10-year pavement life in accordance with the guidelines provided in the pavement design manual prepared by HDOT. We believe that the majority of the pavement distresses may be attributed to the softening of the clayey subsurface soils anticipated at the pavement subgrade level resulting from moisture infiltration. Ideally, the distressed pavements should be completely removed (including the clayey subsurface soils) and should be replaced with select granular fill materials. However, complete removal and replacement would significantly increase the construction time required and may not be feasible nor practical due to the high traffic volumes of the highway. Therefore, we recommend replacing the existing weakened pavements with a new pavement structural section consisting of 4 inches of AC over 6 to 9.5 inches of ACB. The recommended new pavement sections have taken into account the contribution from the remaining existing pavement sections as well as constructability issues due to the limited time frame within a single work shift.

It should be noted that the existing AC and underlying base/subbase are relatively thin for the pavements towards Kamehameha Highway. Therefore, excavation for the pavement reconstruction may expose the clayey soils at the pavement subgrade level as encountered in our field exploration. If soft clayey soils are exposed at the pavement subgrade level, we recommend providing a stabilization layer in lieu of proof-rolling the soft subgrade, which may induce pumping condition. The stabilization layer should consist of 6 inches of aggregate base course over a layer of reinforcing geogrid (such as Tensar TriAx Grid, TX 7 or equivalent) underlain by a layer of permeable separator (such as Mirafi 140N or equivalent).

It is our opinion that other areas requiring reconstruction with new pavement sections may develop between the time construction plans are prepared and the actual commencement of the project construction. Therefore, we recommend re-surveying the highway prior to or re-evaluating during the project construction. In addition, a contingency fund should be allocated in the construction budget for these possible extra costs. Detailed discussion of these items and our geotechnical engineering design recommendations are presented in the following sections.

3.1 Methodology of Pavement Design

In general, the type and severity of the distresses exhibited in the pavement areas would determine whether rehabilitation or reconstruction of the existing pavements should be performed. Existing pavements with minor distresses are generally rehabilitated with an AC overlay with cold-planing. The procedures used in determining the new pavement section follow those described in Chapter 3 of the "Pavement Design Manual" dated March 2002. The pavement design manual was prepared by the State of Hawaii - Department of Transportation, Highways Division, Material Testing and Research Branch. The design procedures for flexible pavements are based on the Hveem Stabilometer method developed by the California Department of Transportation (Caltrans).

3.2 Design Traffic Loading Conditions/Traffic Index

Based on the guidelines provided by the State of Hawaii - Department of Transportation, Highways Division, Material Testing and Research Branch on similar projects in the past, reconstruction of the moderately and severely distressed pavement areas should be designed for a pavement life of 10 years. Design traffic loading conditions, including 24-hour truck traffic, were based on the information provided by the State of Hawaii - Department of Transportation, Highways Division, Planning Branch. A copy of the design traffic parameters is presented on Plate D-1.

LOCATION	**TRAFFIC VOLUME** (Average Daily Traffic)	
	Year 2013	Year 2023
Pali Highway (Waokanaka Street to Kamehameha Highway)	49,100	51,800

LOCATION	**TRAFFIC VOLUME** (ADT per Direction)		
	Design Distribution	Year 2013	Year 2023
Pali Highway (Waokanaka Street to Kamehameha Highway)	65/35	31,915	33,670

DESIGN TRAFFIC PARAMETERS	
24-Hour Truck Traffic	3%
Type of Axle	Truck Traffic Distribution
2-axle	84.50%
3-axle	5.23%
4-axle	4.39%
5-axle	4.80%
6-axle	0.89%
7-axle	0.20%

Based on the design period, traffic volume, and truck traffic distribution information provided, a Traffic Index (TI) of 10.0 has been determined for the Pali Highway (Waokanaka Street to Kamehameha Highway) project. Detailed analyses on the Traffic Index Determination are presented on Plate D-2 of this report.

3.3 Design Subgrade Conditions

Our field exploration program also consisted of collecting twelve (12) bulk samples, designated as Bulk-1 through Bulk-12, of the pavement subgrade soils. Each bulk sample consisted of soil cuttings of the pavement subgrade soils generated from Boring Nos. 2, 5 through 11, 14, 16, 19, and 20, respectively along the roadway alignment. Laboratory California Bearing Ratio (CBR) tests (ASTM D1883) were performed on the bulk samples to evaluate the swelling potential and pavement support characteristics of the pavement subgrade soils. The samples were remolded to near the optimum moisture content and saturated (Plates C-3 though C-14). In addition, R-value tests were also performed on selected bulk samples for additional information (Plates C-15 through C-22). The test results are summarized in the following table.

SUMMARY OF LABORATORY CBR AND R-VALUE TESTS					
Sample Number	**Location**	**Material**	**CBR Value**	**CBR Swell** (%)	**R-Value**
Bulk-1	B-2	Sandy Silt (ML)	13.2	0.15	70
Bulk-2	B-5	Silty Clay (CH)	24.5	0.39	36
Bulk-3	B-6	Silty Clay (CH)	29.4	1.46	-
Bulk-4	B-7	Clayey Silt (MH)	111.4	0.24	35
Bulk-5	B-8	Gravelly Clay (CL)	13.8	1.75	-
Bulk-6	B-9	Clayey Silt (MH)	27.5	0.44	31
Bulk-7	B-10	Silty Clay (CH)	3.4	5.32	15
Bulk-8	B-11	Silty Clay (CH)	3.9	4.38	-
Bulk-9	B-14	Clayey Silt (MH)	15.0	0.17	58
Bulk-10	B-16	Clayey Silt (MH)	26.6	0.11	68
Bulk-11	B-19	Silty Clay (CH)	9.6	2.97	24
Bulk-12	B-20	Clayey Silt (MH)	31.6	0.85	-

Based on our field exploration and laboratory test results, it appears that the pavement subgrade soils generally consist of stiff Silty Clay (CH) and Clayey Silt (MH) soils. Laboratory CBR tests suggest that these pavement subgrade soils exhibit CBR values ranging between 3.4 and 31.6 in a laboratory compacted condition. The corresponding R-value tests indicated these pavement subgrade soils generally exhibit an R-value ranging between about 15 and 36 at the existing moisture content.

Several authors have investigated relationships between the Dynamic Cone Penetrometer penetration index (PI) and California Bearing Ratio (CBR). Two types of equations have been considered for the correlation between the PI and CBR, which are log-log and inverse equations. The log-log and inverse equations for the relationship can be expressed as the following general forms:

log-log equation: $\log CBR = A - B (\log PI)^C$
inverse equation: $CBR = D (PI) E + F$

where CBR = California Bearing Ratio

PI = Penetration index obtained from DCP tests in units of mm/blow
A, B, C, D, E, and F = regression constants for the relationships

Based on statistical analysis of results from the log-log and inverse equations, Harison (1987) concluded that the log-log equation produces more reliable results while the inverse equation contains more errors and is not suitable to use. Considering the log-log equations, many authors have proposed different values of A, B, and C for use in the above equation. The typical log-log equations suggested by different authors for the CBR-PI correlation are summarized on Plates 5.1 through 5.3.

As shown on Plates 4.1 through 4.3, the number of blows required to penetrate 1 inch (25.4 mm) of the in-situ pavement subgrade soils are generally on the order of about 1 to 3 blows, resulting in a penetration index ranging from about 25.4 to 8.5 mm/blow. These penetration index values were input into the various log-log equations as shown on Plates 5.1 through 5.3, and the corresponding CBR values obtained are shown on the same tables. Based on a penetration index of about 25.4 to 8.5 mm/blow, the average CBR values from the various correlations range from about 8.1 to 30.8. These CBR values obtained from the field DCP tests compared favorably with the laboratory CBR values ranging between 3.4 and 31.6 as mentioned above.

Based on our literature review, field exploration and laboratory test results, engineering analyses and evaluation, we believe that a design R value of 15 may be adopted for the in-situ pavement subgrade soils, consisting of stiff silty clays and clayey silts with relatively high in-situ moisture content, in the design of flexible pavements at Pali Highway.

3.4 Existing Pavement Sections

A site-specific field exploration program with borehole drilling through the existing AC pavements was conducted for this project. The thicknesses of the existing AC and underlying base/subbase are summarized in tabular form under the "Subsurface Conditions" of this report. As-built drawings and data for the original pavement construction and subsequent reconstruction and overlays along the various segments of the highway alignment were also provided by Wesley R. Segawa & Associates, Inc. and the State of Hawaii - Department of Transportation, Highways Division, Material Testing and Research Branch. These data have been reviewed in conjunction with our field exploration results and the existing pavement sections along the highway alignment were generalized as presented on Plate 6. Contribution from these existing pavement sections has been taken into consideration during our analyses to determine the new pavement structural sections for the reconstruction areas.

3.5 Rehabilitation of Existing Pavements

In general, the type and severity of the distresses exhibited in the pavement areas would determine whether rehabilitation or reconstruction of the existing pavements should be performed. Existing pavements with minor distresses are generally rehabilitated with an AC overlay with cold-planing. Based on our evaluation, it is our opinion that pavement areas with minor distresses may be rehabilitated with an AC overlay consisting of cold-planing 4 inches of the existing AC surface and replacing with 4 inches of new AC overlay. Due to the poor bonding of the existing multiple AC overlays, a contingency fund should be allocated in the construction budget for extending the cold-planing thickness to the underlying intact asphaltic concrete.

In general, the contractor should perform the cold-planing operation in accordance with Section 415 (Cold Planing of Existing Pavement) of the project special provisions and the Hawaii Standard Specifications for Road and Bridge Construction, 2005 (HSS). The cold-planed surfaces should also be cleaned in accordance with Section 310 (Brooming Off) of the HSS immediately after cold planing operations and prior to the overlay paving.

3.6 Rehabilitation of Bridge Deck Pavements

We understand that the Pali Highway within the project limits traverses existing gullies. Based on our evaluation and input from the State of Hawaii - Department of Transportation, Highways Division, Design Branch, we recommend cold-planing the existing AC surface course down to the top of the bridge deck elevation and overlaid with 2 inches of new AC.

3.7 Pavement Reconstruction

Based on the pavement condition survey conducted by our office, we believe the pavement areas exhibiting moderate to severe distresses within the project limits are likely caused by failures in the underlying base, subbase, and/or subgrade materials. In general, we recommend reconstructing these areas with a new pavement section in lieu of an AC overlay section.

Based on our evaluation, we believe that the majority of the pavement failures observed within the project limits could be attributed to the softening of the clayey subsurface soils anticipated at the pavement subgrade level resulting from moisture infiltration. The ideal solution would be to provide for complete removal of the clayey subsurface soils and replacement with select granular fill materials. However, this would significantly increase the construction time required and may not be feasible nor practical due to the high traffic volumes of the highway. Therefore, we recommend replacing the existing weakened pavements with a new pavement structural section consisting of 4 inches of AC over 6 to 9.5 inches of ACB as shown on Plate 6. Detailed calculations of the design pavement sections are presented on Plates D-3.1 through D-3.3 in Appendix D. The design pavement sections have already taken into account the contribution from the remaining existing pavement section below the new pavement section as well as constructability issues due to the limited time frame within a single work shift.

It should be noted that the existing AC and underlying base course/subbase are relatively thin for the pavements towards Kamehameha Highway. Therefore, excavation for the pavement reconstruction may expose the clayey soils at the pavement subgrade level as encountered in our field exploration. If soft clayey soils are exposed at the pavement subgrade level, we recommend providing a stabilization layer in lieu of proof-rolling the soft subgrade, which may induce pumping condition. The stabilization layer should consist of 6 inches of aggregate base course over a layer of reinforcing geogrid (such as Tensar TriAx Grid, TX 7 or equivalent) underlain by a layer of permeable separator (such as Mirafi 140N or equivalent) as shown on the Soft Subgrade Stabilization Detail, Plate 7.

Reconstruction of weakened pavement areas should be performed in accordance with Section 414 (Reconstruction of Weakened Pavement Areas) of the HSS. Asphalt concrete base (ACB) material should consist of asphalt-treated basalt aggregate, placed in a layer not to exceed 6 inches in compacted thickness, and compacted to no less than 92 percent of the maximum theoretical specific gravity determined in accordance with AASHTO T-209. Asphalt concrete (AC) material should be constructed in accordance with Section 401 (Asphalt Concrete Pavement) of the HSS and its amendments.

It should be noted that additional areas requiring structural repairs with new pavement sections may develop between the time the construction plans are prepared and the actual commencement of the project construction. Therefore, we recommend re-surveying the highway to evaluate whether new distressed areas have developed that may require reconstruction with new pavement sections. In addition, a contingency fund should be allocated in the construction budget for these possible extra costs.

3.8 Light Pole Foundations

Based on the information provided, we understand that new light poles are planned along the median areas for the highway rehabilitation project. Based on the typical loading demands and anticipated subsurface soil conditions, we recommend supporting the new light poles on single cast-in-place drilled shaft foundations.

In order to develop the required bearing and lateral load resistances, the proposed new light pole structures may be supported by a foundation system consisting of cast-in-place concrete drilled shafts. Based on the subsurface conditions encountered in our field exploration, we believe the Standard Plan TE-47, Highway

Light Standard by the State of Hawaii – Department of Transportation, Highways Division may be used for the design of the proposed drilled shaft foundations to support the new light poles planned.

The cast-in-place concrete drilled shafts would derive vertical support principally from skin friction between the shafts and the surrounding soils. A net allowable compressive load capacity of up to 30 kips per shaft may be used for dead-plus-live loads and may be increased by one-third (1/3) for transient loads, such as wind or seismic forces.

Settlement of the drilled shaft foundation will result from elastic compression of the shaft and subgrade response of the foundation embedded in the soils encountered at the site. We anticipate that the total settlements of the drilled shafts are estimated to be less than 0.5 inch. We believe that a significant portion of the settlement will be elastic and should occur as the loads are applied.

Drilled shafts are desirable for the light pole foundations because of the significant increase in lateral and uplift load capacities when compared to shallow foundations. However, the performance of the drilled shafts will depend significantly upon the contractor's method of construction and construction procedures.

The load bearing capacities of drilled shafts depend, to a large extent, on the contact between the drilled shafts and the surrounding soils. Therefore, proper construction techniques are important. The contractor should exercise care in drilling the shaft holes and in placing concrete into the holes.

Drilling by methods utilizing drilling fluids is not recommended. Placement of concrete using a tremie pipe will be required due to the depth of the drilled shaft holes. The concrete should be placed in a suitable manner by starting at the bottom and continue in an upward fashion to the top of the shaft.

A low-shrink concrete mix with high slump (6 to 9-inch range) should be used for the concreting operation. The concrete should be placed in a suitable manner to reduce the potential for segregation of the aggregates from the concrete mix. If pre-cast concrete pole bases are used, the gap between the pole base and the surrounding soils should be backfilled with concrete or lean concrete.

3.9 Surface Drainage

One of the primary distress mechanisms in pavement structures is pumping due to saturation of the subbase and base course and/or subgrade soils. Therefore, the pavement surface should be sloped to drain and drainage gradients should be maintained to carry surface water off the pavement to appropriate drainage structures. Surface water ponding should not be allowed during or after construction. Development of good shoulder drainage along with a program to prevent obstructions in the drainage structures is strongly recommended to reduce the potential for pavement deterioration or premature failure of the pavements.

3.10 Design Review

Drawings and specifications for the project should be forwarded to Geolabs for review and written comments prior to bid advertisement. This review is necessary to evaluate conformance of the plans and specifications to the intent of the pavement and earthwork recommendations provided herein. If this review is not made, Geolabs cannot be responsible for misinterpretation of the recommendations presented.

3.11 Construction Monitoring

Geolabs should be retained to provide geotechnical engineering services during construction. The items of construction monitoring that are critical include observation of the excavation of the pavement reconstruction areas and subgrade preparation. This is to observe compliance with the design concepts, specifications, or recommendations and to expedite suggestions for design changes that may be required in the event that subsurface conditions differ from those anticipated at the time this report was prepared.

The recommendations provided herein are contingent upon such observations. If the actual exposed subsurface conditions encountered during construction are different from those assumed or considered in this report, then appropriate design modifications should be made.

END OF DISCUSSION AND RECOMMENDATIONS