Yeh and Associates, Inc.
Consulting Engineers & Scientists

Date: **September 13, 2012**

To: **Lee Kunselman, P.E. – Atkins**

From: **Tom Allen, P.E. – Yeh and Associates, Inc.** TA

Subject: **Final Geotechnical Evaluation Memorandum**
Sage Creek Road, WY PFH 26-1 (3) Final Design
YA Project: 211-218

This memorandum presents a summary of the geologic and subsurface conditions along the existing alignment of Sage Creek Road (Sections C, D, & E), south of Rawlings Wyoming and includes recommendations for grading and pavements. The purpose of this memo is to provide a summary of conditions encountered during the field investigation, a review of proposed pavement designs for Section C, recommendations for pavements in sections D and E and cut and fill slope recommendations.

Previous Investigation:

In May 2006 the Geotechnical and Pavement section of the Central Federal Lands Highway Division (CFLHD) of the Federal Highway Administration (FHWA) conducted a soil survey and subsurface investigation along Sage Creek Road in Sections B and C. The purpose of the study was to assess surface and subsurface soil and rock conditions, identify geologic hazards, drainage and erosion problems, and provide recommendations for pavement, and foundations of culverts and retaining structures. Pavement designs for Sections B and C were based on the results of this study.

Proposed Construction

Proposed grading includes cuts and fills to widen the roadway within the existing alignment. The proposed cuts and fills are shown at slope angles of 1 V to 1.5 H or flatter.

Section C

The 70% Plans for Section C show a typical pavement section of 8 inches of aggregate surface course that will be placed for this project and capped with 3.5 inches Hot Asphalt Concrete Pavement (HACP) as part of a future project. Proposed cut depths for Section C range from less than 1 foot to as much as 20 feet. The deepest proposed cuts are located between Sta. 2736+00 and Sta. 2785+50. Proposed fill depths in Section C range to as much as 12 feet with the deepest fill between Sta. 2723+50 and Sta. 2735+50. The proposed grading has been designed to reduce vertical curves throughout the section.

Section D

This section will receive improvements similar to those in section C. The proposed grading

consists of cuts with maximum depths of approximately 12 feet and fills of as much as 14 feet. The deepest proposed cut is located between Sta. 2984+00 and Sta. 2997+00. The deepest fill is proposed between Sta. 2822+00 and Sta. 2866+00.

Section E

Section E is located entirely within the Medicine Bow National Forest and is to remain a gravel surfaced road. The proposed 4R improvements will consist of minor grading with shallow cuts and fills. Drainage improvements and erosion control are also proposed for this section. The road will be widened to 24 feet and retaining structures will be required at several locations to support embankment fills of as much as 6.5 feet.

Geologic and Site Conditions

Sage Creek road extends south from Rawlins, Wyoming to State Highway 70 near the Colorado border. The alignment has been divided into five sections (A-E) with Section A beginning at the north end near Rawlins. Project WY PFH 26-1(2) (Section B) is currently under construction. Project WY PFH 26-1(3), including Sections C, D and E, begins about 26 miles south of Rawlins and ends at the junction with SH 70. Sections C and D have lengths of 10.85 miles and 6.34 miles, respectively and cross a mixture of private and public lands. Section E extends for 9.95 miles through the Medicine Bow National Forest and crosses some private in-holdings for short extents.

Along Sections C and D the terrain is open and sparsely vegetated with some rolling hills and rounded ridges characterized by alluvial features including arroyos, alluvial fans and outwash plains. The rocks in this area are relatively young, mostly Miocene age, sedimentary rocks consisting of soft sandstone, claystone and conglomerates. Near the south end of Section C the road crosses a formation of ancient Precambrian metamorphic granitic gneiss. Figure 1 is a photo of the Precambrian gneiss formation.

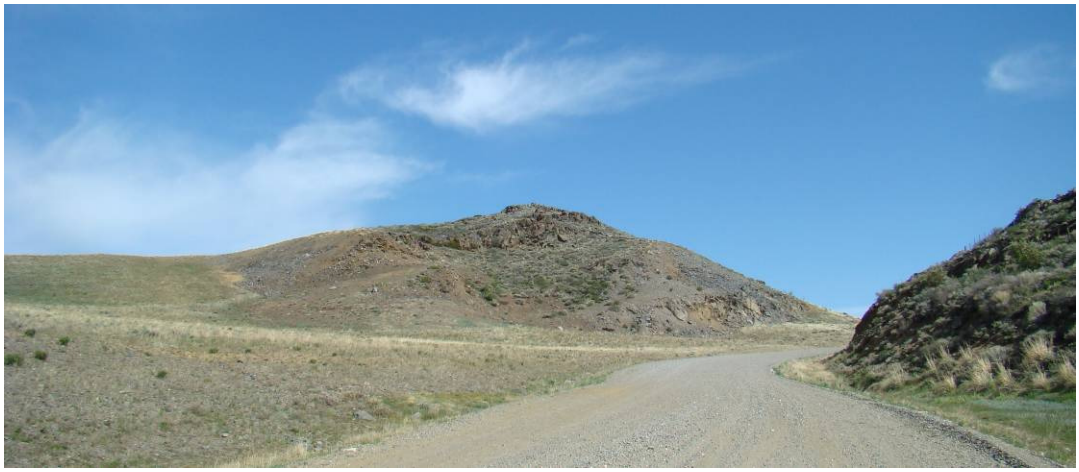

Figure 1: Precambrian Gneiss viewed from the south.

The lithology along Section E is similar to that in Sections C and D and is comprised predominantly of Miocene age sandstone and claystone. As the road heads south the terrain becomes mountainous and gains in elevation through the Medicine Bow National Forest. Near the forest boundary the vegetation abruptly changes from sagebrush and grass to mixed aspen and conifer forests with some low grasses and shrubs. The landscape in Section E includes deep canyons and ridges with steep slopes. The road crosses a series of three major creek valleys: Deep Creek, Big Sandstone Creek and Little Sandstone Creek. Where the road crosses Big Sandstone Creek a section of the Chugwater Formation is visible. The exposed bedrock is red siltstone and shale which contrasts sharply with surrounding gray sandstone. Figure 2 is a photo of the Chugwater Formation exposed at Big Sandstone Creek. As the road climbs out of the Little Sandstone Creek valley it travels along a heavily wooded ridge top where it reaches its maximum elevation 8,200 feet before it intersects with SH 70.

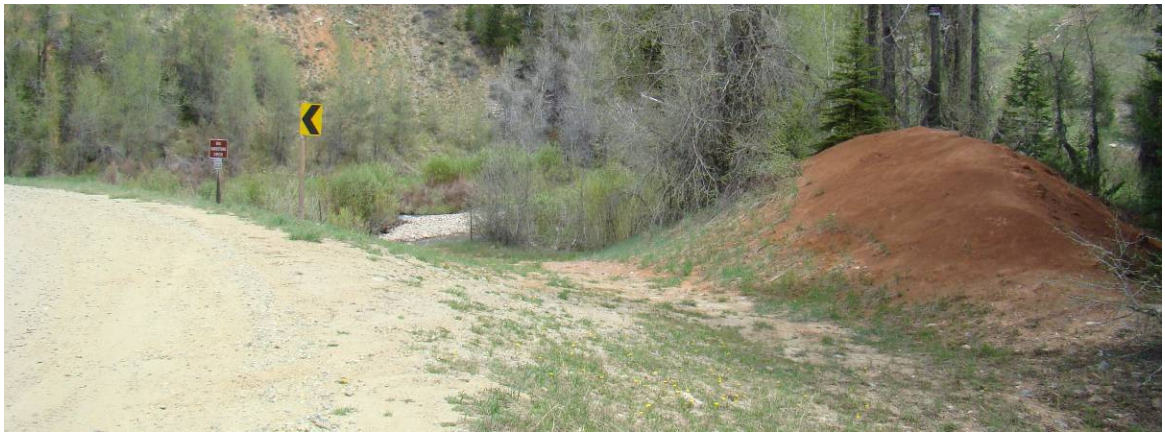

Figure 2: Chugwater Formation at Big Sandstone Creek

Geotechnical Investigation:

A geologic reconnaissance was performed along Sections D and E using the Preliminary 30% plans as a guide to the proposed construction. The reconnaissance was performed to identify geologic features that could impact construction.

Forty-four exploratory holes were excavated by hand to a maximum depth of 2 feet in Sections C, D and E of Sage Creek Road. The holes were located in the gravel surfaced roadway. Samples of the gravel surface material (aggregate base course) and subgrade soils were obtained from the exploratory holes. The depth of the aggregate base course (ABC) was measured and the subgrade soils were visually classified in the field. The samples of ABC and subgrade were returned to the Yeh and Associates laboratories in Durango and Denver, Colorado for testing. The classifications and relative quality of the subgrade with regard to pavement support are included in this memorandum. An applicable program of laboratory testing was developed to determine engineering properties of the subsurface materials. The results of the laboratory classifications were used to confirm or modify the field descriptions.

Laboratory tests performed included gradation (ASTM D 421, C 136 and AASHTO T 27), Atterberg limits (AASHTO T 89/T 90), moisture content (AASHTO T 265), R-value (ASTM D 2844), sulfate content (AASHTO T290), pH (ASTM D 972/AASHTO T 289) and resistivity (AASHTO T 288). Gradation and Atterberg limits test results were used to classify the soils in accordance with the AASHTO classification system and the USCS. Moisture content provides an estimate of the moisture conditions of the subgrade and underlying materials. Soil R-value is a measure of soil subgrade strength use for pavement design. Tests for soil sulfate content, pH and resistivity are used to evaluate the potential of the soil to be aggressive to concrete and to corrode buried metal. A summary of all laboratory test results is attached.

In Section C, eleven of the holes were located to supplement subsurface data from a previous report prepared by the Geotechnical and Pavement Sections of the Central Federal Lands Highway Division (CFLHD) of the Federal Highway Administration (FHWA), dated February 2009, for which borings were drilled at approximately one mile intervals. Three holes were located between Sta. 2525+50 and Sta. 2557+50 to better define an area suspected by CFLHD of having very poor subgrade soil conditions.

Subgrade materials encountered between Sta. 2525+50 and Sta. 2557+50 consisted of weathered sandstone with good pavement support characteristics. Figure 3 is a photo showing the sandstone outcrops in this area.

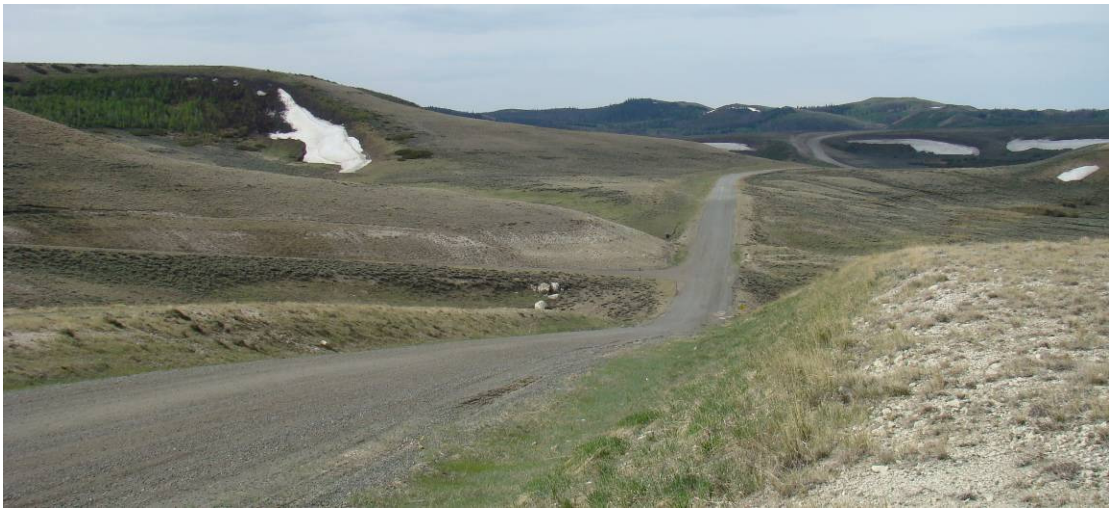

Figure 3: Sandstone exposed in cuts at approximate Sta. 2530+00 to Sta. 2558+00

The conditions encountered in the holes located within Section C are summarized on Table 1 below. The ABC thicknesses encountered ranged from 1 to 5 inches. Subgrade soils encountered below the gravel surface were generally gravelly with a silty sand matrix except at Sta. 2704+00 where silty, clayey sand was encountered.

Table 1: Summary of Conditions Encountered in Section C

Station (from 30% plans)	ABC Thickness (in)	Subgrade Description	AASHTO and USCS Classifications	R-Value	Relative Subgrade Quality
2338+00, 12' L	4	silty Sand with some gravel & cobbles	A-1-b (0) (SM)		Good
2388+00, 13' R	2	silty Sand & Gravel	(GM)*		Good
2435+00, 10' L	3	silty Sand, some gravel	A-2-4 (0) (SM)		Good
2463+00, 12' R	3	clayey Sand & Gravel	(GC-GP)*		Good
2526+00, 14'L	5	silty Sand, some gravel,	A-2-4 (0) (SP-SM)		Good
2531+00, 12' R	5	silty Sand & Gravel	weathered sandstone fragments*		Good
2553+00, 10' L	3	silty Sand & Gravel	weathered sandstone fragments*		Good
2598+00, 15' R	2	silty Sand, some gravel / cobbles	A-1-b (0) (SP-SM)		Good
2652+00, 12' L	4	silty Sand, gravelly	(SM)*		Good
2704+00, 10' R	1	silty, clayey Sand, gravelly	A-2-4 (0) (SM-SC)		Good
2754+00, 13' L	4	silty Sand, gravelly	A-2-4 (0) (SM)	26	Good

*visual classification

Twelve holes were excavated through the gravel surface in Section D at approximately ½-mile intervals along the road alignment. A summary of the ABC and subgrade conditions is presented in Table 2. Gravel surface course thicknesses encountered ranged from 0 to 6 inches. Subgrade soil conditions ranged from good quality sandy gravel with cobbles to relatively poor quality sandy Clay.

Table 2: Summary of Conditions Encountered in Section D

Station (from 30% plans)	ABC Thickness (in)	Subgrade Description	AASHTO and USCS Classifications	R-Value	Relative Subgrade Quality
2845+00, 8' L	2	silty Sand, gravelly	A-2-4 (0) (SM)		Good
2871+00, 8' R	0	silty Sand, gravelly	A-2-4 (0) (SM)		Good
2897+00, 10' L	0	sandy Gravel with cobbles, clayey	(GC)*		Good
2924+00, 7' R	1	sandy Clay, some gravel	(CL)*		Fair
2953+00, 10' L	2	silty-clayey Sand	A-2-4 (0) (SM-SC)		Good
2977+00, 9' R	<1	silty Sand, some gravel,	A-2-4 (0) (SP-SM)		Good
3003+00, 10' L	6	silty Sand, gravelly	A-2-4 (0) (SM)	26	Good
3030+00, 6' R	2	Clayey Sand,	A-2-6 (0) (SC)		Fair
3056+00, 10' L	3	silty-clayey Sand, gravelly	(SM-SC)*		Fair
3083+00, 6' R	2	sandy Clay	A-6 (13) (CL)	12	Poor
3109+00, 10' L	3	Sand and Clay	A-6 (4) (CL)		Poor - Fair
3136+00, 7' R	2	sandy Clay	A-6 (11) (CL)	12	Poor

*visual classification

Twenty-one test holes were excavated in the roadway along Section E at approximately ½-mile spacing. The base course encountered consisted of sandy gravel with sufficient plastic fines to provide a cohesive and durable surface. Gravel surface thicknesses encountered generally ranged from 6 to 9 inches. The gravel surface thickness measured at Sta. 3163+00 was only 1 inch, possibly because the hole was located near the edge of the road where erosion had depleted the aggregate. Fair to poor sandy clay subgrade soils were encountered at several locations, but the road surface is in good condition and no areas of failure relating to poor subgrade conditions were observed. The base course and subgrade conditions are listed in Table 3.

Table 3: Summary of Conditions Encountered in Section E

Station (from 30% plans)	ABC Thickness (in)	Subgrade Description	AASHTO and USCS Classifications	R-Value	Relative Subgrade Quality
3163+00, 10' L	1	sandy Clay	A-6 (7) (CL)		Poor
3190+00, 6' R	6	sandy Clay	A-6 (6) (CL)		Poor
3216+00, 7' L	9	sandy Clay	A-4 (3) (CL)		Poor - Fair
3244+00, 6' R	8	sandy Clay	(CL)*		Poor
3271+00, 6' L	7	silty Sand & Gravel / Cobbles,	A-1-a (0) (GP-GM)		Very Good
3297+00, 7' R	9	Sandstone boulder or bedrock			Very Good
3323+00, 7' L	8	clayey Sand,	A-6 (3) (SC)		Poor
3350+00, 6' R	9	clayey Sand & Gravel / Cobbles,	A-2-4 (0) (GC)		Very Good
3376+00, 8' L	8	clayey Sand & Gravel	(GC)*		Good
3402+00, 9' R	9	clayey Sand	A-2-6 (0) (SC)		Fair
3429+00, 6' R	9	clayey Sand	A-2-6 (0) (SC)		Fair
3455+00, 8' L	9	silty-clayey Sand,	A-4 (1) (SM-SC)		Poor-Fair
3482+00, 7' R	9	clayey Sand, gravel and cobbles	(SC)*		Good
3508+00, 9' L	7	silty Sand, sandstone at 14"	A-2-4 (0) (SM-SC)		Good
3534+00, 7' R	6	clayey Sand	A-6 (1) (SC)		Poor
3561+00, 9' L	6	clayey Sand	A-2-6 (0) (SC)		Fair
3587+00, 7' R	6	sandy Clay	(CL)*		Poor
3614+00, 9' L	6	sandy Clay	A-6 (2) (SC)	9	Poor
3640+00, 6’ R	8	clayey Sand , some gravel	A-2-4 (0) (SC)		Good
3667+00, 6’ L	7	clayey Sand	A-2-6 (0) (SC)		Fair

*visual classification

Potential Geologic Hazards:

Geologic hazards that could potentially affect the proposed construction include shallow groundwater, unstable slopes and landslides.

Seepage from the exposed bedrock surface was observed near Sta. 2853+00. The proposed cut in this area could encounter groundwater and installation of subsurface drains may be required to collect and divert groundwater from the subgrade. Poor surface drainage or groundwater has resulted in wet subgrade near Sta. 3060+00 and Sta. 3105+00. Improvements to surface drainage and/or subsurface drains are recommended at these locations.

The grading for Section E has created high and steep cut slopes where the road enters and exits the canyons of Deep Creek, Big Sandstone Creek and Little Sandstone Creek. These slopes appear to be stable in their current configuration, although some shallow surface slumping was observed. Grading that undercuts the toes and steepens these existing slopes could reduce their stability and should be avoided. Shallow cuts at the toes of the slopes to remove loose material that has accumulated at the edges of the road are not expected to adversely affect slope stability.

A tributary stream south of Big Sandstone Creek has cut into the roadway embankment between Sta. 3378+00 and Sta. 3384+00. Construction of hand-placed riprap or a rockery wall at this location will help stabilize the embankment and prevent further erosion. The riprap or rockery will have a height ranging from 5 to 7 feet for a length of about 120 feet. Large boulders suitable for riprap or rockery construction may be available from nearby cut slopes.

A small slope failure has blocked the ditch on the left side of the road near Sta. 3410+00. The failure appears to be caused by sand and gravel soils sliding on the shallow sandstone bedrock surface. The slope will likely continue to fail until the stable bedrock surface is exposed. Excavation to remove the sliding soil mass and create a stable slope will prevent a sudden landslide that could disrupt surface drainage and block the road.

A large active landslide feature was observed between Sta. 3540+00 and Sta. 3560+00 on the slope above the road. Grading that undercuts the toe of this slide at the roadway could accelerate slide movement and should be avoided. The slide appears to extend several hundred feet up the hill above the east side of the road. Stabilization of this slide by methods such as retaining walls or anchored structures may not be feasible within the scope of this project.

Pavement Recommendations:

Traffic volumes on Sage Creek Road are low with a design Average Daily Traffic (ADT) of 145 for Section C (design year 2024) and 95 for Sections D and E (design year 2029). Sections C and D will ultimately have HACP surfacing with an aggregate surface in the interim. Section E is to have aggregate as the ultimate surface treatment.

Section C

The A-7-6 soil reported in the Final Geotechnical and Pavement Report by CFLHD is probably shale bedrock that was pulverized by the drill rig augers. It was reported by them to be below a depth of 4 feet at Sta. 2526+00. The subsurface materials in this area (Sta. 2525+00 to Sta. 2560+00) consist mainly of sandstone bedrock outcrops. The sandstone can have shale or claystone layers. If encountered in the cut near Sta. 2540+00, the claystone should be removed to a depth of 12 inches and replaced with aggregate base course.

The ultimate pavement section recommended in the CFLHD report for Section C is 3 inches HACP on 6 inches aggregate base course. The subgrade soils encountered in the supplemental exploratory holes are similar to those encountered by CFLHD. The recommended pavement section appears to be appropriate for the traffic and soil conditions in Section C. The recommended pavement section is the minimum recommended section based on environment and snowplowing requirements. The interim section should be 6 inches of base course and may need to be supplemented prior to paving.

Section D

The ultimate pavement section from Sta. 2817+57 to Sta. 3050+00 should be the same as Section C (3 inches HACP on 6 inches aggregate base course). From Sta. 3050+00 to Sta. 3152+20 the subgrade soils are not as good and the ultimate pavement should consist of 3.5 inches HACP on 8 inches base course (same as Section B). Place at least 6 inches of base course as the interim surface.

Section E

The aggregate surface for Section E was evaluated using the catalog method in accordance with the Aggregate Surfacing Design Standards and Guidance provided in the CFLHD Supplement 11.4.2-1 to Chapter 11 of the Project Development and Design Manual (PDDM). The relative subgrade soil quality in Section E ranges from Very Good to Poor with most of the locations having Very Good to Fair subgrade. Sage Creek Road is located in Climatic Region VI. The recommended aggregate surface thickness was determined from Exhibit 11.4.2.-A of the Supplement for low traffic volume and relative quality of the subgrade soil between Poor and Fair. Interpolation between Poor and Fair soil quality was used to determine the recommended aggregate surface thickness of 8 inches. The recommended thickness is similar to the existing aggregate thickness measured in the exploratory holes and should be used to reconstruct the aggregate surface in cut areas. Widening will require fill on the downhill sides of the road at some locations. A 7-inch aggregate surface thickness can be used in fill areas where the fill soils are good quality granular materials. The aggregate surface course should consist of well-graded, crushed gravel with 10 to 15 percent low plasticity fines. The fines will help bind the material, reduce dust and prevent loss of larger aggregate. The aggregate stockpile in the existing gravel pit near Sta. 3227+00 appears to be suitable for use as an aggregate surface course.

Retaining Structures:

Gabion basket-faced mechanically stabilized earth walls are proposed as retaining structures where fill will be placed for widening on the down-hill side Sage Creek Road in Section E. Wall heights will range from less than 3 feet to about 6.5 feet. Western Federal Lands Highway Division (WFLHD) design detail plan sheets that have been modified for this project will be used for the wall construction documents. The proposed walls should be constructed using welded wire fabric sheets as the reinforcement. The sheets should have a minimum length of 8 feet, measured from the face of the gabion baskets. The toes of the walls should have a minimum embedment of 2 feet. At least two layers of reinforcing fabric should be installed for each wall. The vertical spacing of the fabric layers should be 3 feet or less. The vertical spacing of the top layer can be adjusted to provide a minimum of 1 foot of cover over the fabric. Gabion basket construction and welded wire fabric connections should be in accordance with the WFLHD details. The recommendations for the retaining structures are based on visual observation of surface conditions at the sites and our experience with similar projects. Borings were not drilled at these locations at this stage of the geotechnical investigation. Per AASHTO guidelines, borings should be drilled to investigate subsurface conditions at each wall location. The recommendations provided are cursory because subsurface conditions were not investigated. The final design should be evaluated to determine if borings are necessary.

Earthwork:

Sandstone and shale bedrock will be encountered in the proposed cuts in several locations. This bedrock is relatively soft and should be rippable with bulldozers and hydraulic excavators. Non-shale materials recovered from the cuts are suitable for re-use as fill. The proposed cuts in Section C will likely encounter very hard granitic gneiss bedrock. Excavation for these cuts will require blasting. The gneiss bedrock materials removed from these areas may be crushed for use as aggregates and riprap.

Cut slopes in soil should be graded at 1V:1.5H or flatter. Cut slope in the sandstone bedrock can be graded at 1V:1H or flatter. The proposed cuts in the granitic gneiss bedrock can be as steep as 4V:1H if loose fragments are removed by scaling and appropriate rockfall mitigation measures are used. Unreinforced fill slopes should be graded at 1V:2H or flatter. Fill placement and compaction should be in accordance with the Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (FP-03).

Rockfall Mitigation:

The proposed rock cut between Sta. 2738+00 and Sta. 2784+00 will be in granitic gneiss and will be graded at 4V:1H with a 5-foot wide ditch. The cut will have a maximum height of 23 feet. The slope from the shoulder of the road to the flowline of the ditch has been designed at 1V:3H in the lower portion and 1V:4H adjacent to the road. Rockfall Catchment Area Design Charts are published in the Rockfall

Catchment Area Design Guide, Report No. FHWA-OR-RD-02-04, dated November, 2001. The charts for 4V:1H cut slopes that are 40 feet high indicate that an approximate 10 foot catchment ditch is necessary to retain 95% of the rockfall. The report indicates a 5-foot wide catchment that is sloped at 1V:4H will likely contain less than 90 % of the rockfall and will retain approximately 70% of the rockfall from a 40 foot high rock slope. Either a steeper (1V:3H) catchment ditch grade or a ditch greater than 8 feet in width should be considered to provide greater than 70% containment of rockfall at this site.

Soil Corrosivity:

The soils encountered in the exploratory holes have near neutral pH, low water soluble sulfates content and low concentration of Chloride ions. Some of the fine-grained clay samples tested had low laboratory resistivity, indicating a potential to be aggressive toward unprotected buried metal. Steel culvert pipes should be 18-gauge Aluminized Type 2 to resist corrosion.

Limitations

This study has been conducted in accordance with generally accepted geotechnical engineering practices in this area for use by the client for design purposes. The conclusions and recommendations submitted in this report are based upon the data obtained from shallow, hand-excavated exploratory holes, laboratory testing, field reconnaissance, and our understanding of the proposed type of construction. The nature and extent of subsurface variations across the site may not become evident until excavation is performed. If during construction, fill, soil, or water conditions appear to be different from those described herein, this office should be advised at once so reevaluation of the recommendations may be made. We recommend on-site observation of excavations, the exposed face of the final rock slopes, and foundation bearing strata, by a representative of the geotechnical engineer.

Undisturbed and disturbed slope rating and evaluation methods have a certain degree of variability and subjectivity that is inherent to the rating systems. An accurate geologic assessment of proposed cut slopes may not be possible prior to completion of the excavation. Difficult access conditions and vegetation or other obstacles that obscure the terrain can limit the geologic assessment of undisturbed natural outcrops and slopes. These factors increase the uncertainty of rating and evaluation methods.

It should be noted that rockfall and rockfall events are sporadic and unpredictable. This report does not attempt to predict the average recurrence interval, magnitude, or location of a rockfall event. These factors cannot be predicted with rating systems. Consequently, neither the rockfall hazard in terms of probability of a rockfall at any specific location, nor the risk to people or facilities due to such events, are assessed in this memorandum.