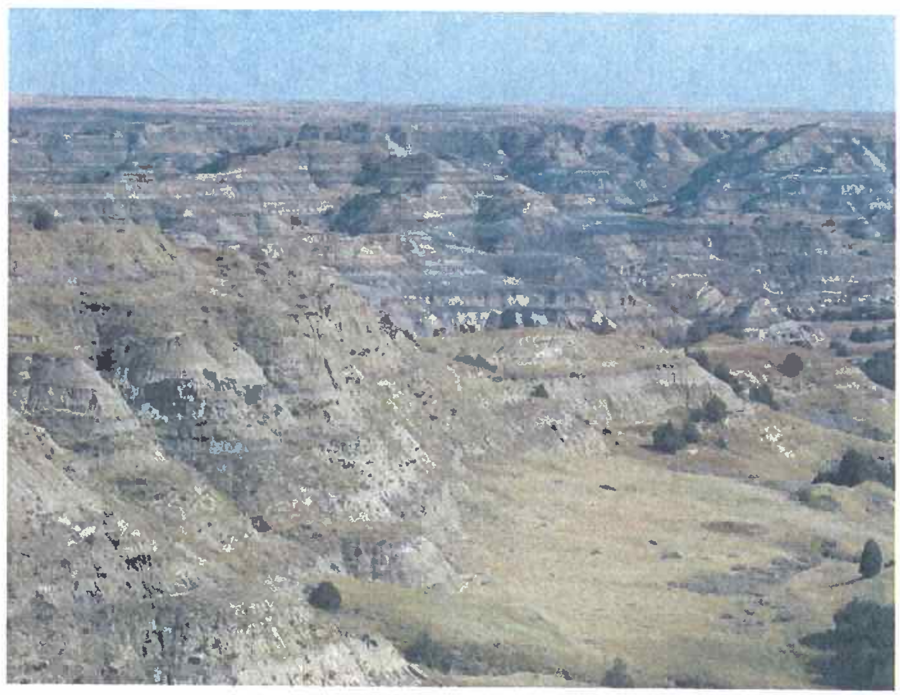
# THEODORE ROOSEVELT NATIONAL PARK – NORTH UNIT

*ND PRA THRO 10(3) & 10(4)*

## FINAL GEOTECHNICAL DESIGN REPORT

**Report # ND-PX-THRO-08-01**

**Geotechnical Services Branch**
**January 2008**



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**Distribution**

Project Management
Project Development (3)
Acquisition and Contracting
Construction
CFLHD, Central Files
Geotech (2)

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# THEODORE ROOSEVELT NATIONAL PARK
# NORTH UNIT
# MCKENZIE COUNTY, NORTH DAKOTA

## INTRODUCTION

### Project Description

This report presents the findings of a subsurface investigation and provides geotechnical recommendations for the repair and stabilization of select sites along Theodore Roosevelt National Park North Unit Scenic Drive. The entire 13.8 miles of the North Unit Scenic Drive will be rehabilitated under project ND PRA THRO 10(3) and three segments of the Drive will be reconstructed under project ND PRA THRO 10(4). The North Unit of Theodore Roosevelt National Park is located approximately 15 miles south of Watford City, North Dakota along US Highway 85. A Project Vicinity Map and Project Location Map are presented in Appendix A.

Specifically, the sites identified for stabilization are located between STA 378+73 (STA 1002+00) and STA 386+73 (STA 1010+00), between STA 424+38 (STA 1047+50) and STA 426+38 (STA 1049+50), and between STA 429+38 (STA 1052+50) and STA 432+38 (STA 1055+50) and are identified as Segments 1, 2, and 3, respectively. The station limits for each site on project ND PRA THRO 10(4) are denoted in parentheses. The Squaw Creek Bridge site is located at STA 269+00.

Each of these segments occur within the Cedar Canyon area and are evidenced by pavement distress due to the nature of the subgrade soils. From approximately STA 353+00 to STA 433+00 the roadway gains considerable elevation. As the roadway gains elevation it crosses several distinct clay layers, including a dark gray bentonitic, expansive clay layer. Roadway distress in this area range from deep ruts and heaving pavement to large slope failures. The movement of water through the soils has lead to several shallow failures and shoulder raveling that requires routine patching by the Park maintenance. Shallow movement of the subgrade has caused many "dips" in the pavement. Larger movements continuously cause fill slope failures and roadway failures.

Segment 1 is an 800-foot long section of roadway that has experienced severe pavement distress, as evidenced by extensive cracking and rolling, due to the expansive nature of the underlying bentonitic clay. Park maintenance staff recently placed an aggregate blade patch along the entire segment to allow public traffic to pass.

Segment 2 is a 200-foot long section of roadway that has experienced some cracking and shoulder distress due to creep of an adjacent, oversteepened fill slope. The fill slope was constructed at a very steep slope angle, approaching 1H:1V. On-site soils, generally consisting of plastic clays, are not able to support this high angle and begin to creep when saturated. This roadway segment has previously been repaired by Park maintenance.

Segment 3 is a 300-foot long section of roadway that has experienced shoulder distress similar to Segment 2. Segment 3 was also constructed adjacent to an oversteepened fill slope and has previously been repaired by Park maintenance.

Several culvert outlets along the length of the project have experienced distress due to the expansive and dispersive nature of on-site soils. The soils surrounding several of these culverts have also experienced sinkholes, due to piping or joint separation. The east abutment of the Squaw Creek Bridge, located at STA 270+00, has experienced some abutment and channel scour.

### Regional and Site Geology

The North Unit Scenic Drive lies primarily within the Sentinel Butte geologic formation. This formation generally consists of gray to brown colored, poorly lithified claystones, mudstones, and siltstones with subordinate amounts of fine-grained sandstones and lignite. A gray sandstone layer, that may attain a thickness of 100 feet, is present at the base of the Sentinel Butte Formation. The Sentinel Butte Formation can be over 700 feet thick in the North Unit. A widespread ash/bentonite clay deposit called Sentinel Butte ash, at times 25 feet thick, occurs within the Sentinel Butte Formation. Also, the Sentinel Butte Formation generally forms fairly steep weathering slopes. A geologic map is provided in Appendix A.

Several areas within the park have experienced fill failures, fill settlement, and/or severe erosion problems at culvert outlets. The cause of the problems is attributed to dispersive clays. Dispersive soils are fine-grained with a high content of pore-water sodium. The individual clay particles go into suspension in slow moving water (colloidal erosion) and form deep gullies and tunnels. This phenomenon can be seen throughout the park. Many deep gullies have formed at the outlet of culverts and rundowns. Sinkholes have also formed where pipe sections have separated or corrosion has deteriorated culvert sections.

## PROCEDURES AND RESULTS

### Exploratory Borings

A subsurface investigation program was managed by Central Federal Lands Highway Division (CFLHD) Geotechnical personnel, between May 10 and 11, 2006. The subsurface investigation program consisted of eight borings at selected sites along the route, varying in depth between 11.5 and 41.5 feet. Haz Tech Drilling, Billings, MT, provided the drilling services for this project. All borings were advanced through overburden soils using 8-inch-diameter hollow stem augers by a Longyear BK-81 truck mounted rig. Boring logs are presented in Appendix B.

### Sampling

Sampling of materials beneath the tip of hollow stem augers was performed as borings were advanced. Sampling was typically conducted at 5-foot intervals to the termination depth of the boring or auger refusal. Soil samples were recovered with a 2-inch outside diameter split-barrel sampler in accordance with AASHTO T200-87. Representative portions of recovered samples were preserved for laboratory testing. The sampling sequence for the borings is summarized on the bring logs in Appendix B.

**Field Tests and Measurements**

Field personnel performed the following field tests and measurements during the course of the subsurface exploration. Standard penetration tests (SPT) were performed and resistances were recorded during the recovery of each split barrel sample, in accordance with AASHTO T206-87. The sampler was driven into the soil using an automatic hammer. Sample recovery measurements were made and recorded for each sampling attempt. A field description by color and texture was made for each recovered sample by a CFLHD Geologist.

**Data Summary**

The results of field tests and measurements were recorded on field logs and appropriate data sheets at the time of the investigation. These data sheets and logs contain information concerning the boring methods; samples attempted and recovered; indications of the presence of various materials such as gravel, pebbles, organic matter, etc.; and observations of groundwater. They also contain interpretations by the field personnel of the conditions based on the performance of the drilling equipment and cuttings brought to the surface. Therefore, the field data represent both factual and interpretative information.

The boring logs, provided in Appendix B, represent a compilation of field and laboratory data and description of the soil samples by a geotechnical engineer. These records occasionally do not include all data recorded on field logs and data sheets, but do include all information considered relevant to the design and construction recommendations, as contained in this report.

Groundwater was encountered during and/or after drilling at select boring locations. Groundwater elevations are recorded on the applicable boring logs in Appendix B. Fluctuations in the ground water level due to seasonal and climatic effects should be expected.

**Laboratory Testing**

Laboratory tests were conducted on 12 soil samples recovered from completed borings. Laboratory tests on the samples included gradation (AASHTO T-27), Atterberg limits (AASHTO T-89, T-90), and classification (AASHTO T-317). Corrosion potential testing was also conducted on one sample from Boring B-2 and included tests for resistivity, pH, sulfate content, and chloride content. Test results indicated the presence of soils with high corrosion potential. Laboratory test results are represented in Appendix C and are summarized in Table 1.

*Table 1. Results of Laboratory Testing*

| Boring | Sample | Sample Depth (ft) | %-200 | LL(1) | PI(2) | Classification |
|---|---|---|---|---|---|---|
| B-1 | SPT 1,2,3 | 5.0-16.5 | 96 | 50 | 29 | A-7-6(31) |
| B-1 | SPT 4,5,6 | 20.0-31.5 | 99 | 59 | 41 | A-7-6(45) |
| B-2 | SPT 1,2,3,4 | 5.0-21.5 | 71 | 45 | 23 | A-7-6(15) |
| B-2 | SPT 5 | 25.0-26.5 | 83 | 49 | 31 | A-7-6(26) |
| B-3 | SPT 1,2,3 | 5.0-16.5 | 92 | 49 | 32 | A-7-6(31) |
| B-3 | SPT 4,5 | 20.0-26.5 | 100 | 79 | 59 | A-7-6(67) |
| B-4 | SPT 1 | 5.0-6.5 | 83 | 63 | 42 | A-7-6(37) |
| B-4 | SPT 2,3 | 10.0-16.5 | 96 | 29 | 5 | A-4(5) |
| B-4 | SPT 4 | 20.0-21.5 | 97 | 38 | 20 | A-6(20) |
| B-4 | SPT 6,7,8 | 30.0-41.5 | 96 | 76 | 45 | A-7-5(52) |
| B-5 | SPT 1 | 5.0-6.5 | 97 | 46 | 28 | A-7-6(29) |
| B-5 | SPT 4,5,6 | 20.0-31.5 | 99 | 42 | 22 | A-7-6(24) |
| B-6 | SPT 3 | 15.0-16.5 | 58 | * | * | * |
| B-7 | SPT 1,2 | 5.0-11.5 | 77 | 35 | 16 | A-6(11) |
| B-8 | SPT 1,2 | 5.0-11.5 | 70 | 40 | 22 | A-6(14) |

Notes: NP – Non-plastic
NV – No Value
NA – Not Applicable
* Insufficient amount of material to complete test

## Findings

Boring B-1 was advanced at STA 432+00, STA 1055+00 on the 10(4) project, approximately 7 feet left of the design centerline. Brown, moist, medium stiff clay was encountered to a depth of 18.0 feet below the asphalt pavement surface. Gray, slightly moist, medium stiff to stiff, silty clay was encountered beneath the brown clay layer to the borehole termination depth of 31.5 feet.

Boring B-2 was advanced at STA 425+70, STA 1048+70 on the 10(4) project, approximately 10.0 feet left of the design centerline. Brown, moist to wet, soft to medium dense clay was encountered to a depth of 30.5 feet below the asphalt pavement surface. Brown, stiff, moist silt and siltstone was encountered below the clay layer to the borehole termination depth of 41.5 feet.

Boring B-3 was advanced at STA 415+60, approximately 9.0 feet left of the design centerline. Brown, moist, medium stiff clay was encountered below the asphalt pavement surface to a depth of 20.0 feet. Yellow brown, moist, stiff, silty clay was encountered beneath the brown clay layer to the borehole termination depth of 26.5 feet.

Boring B-4 was advanced at STA 383+00, STA 1006+30 on the 10(4) project, approximately 10.0 feet left of the design centerline. Gray brown to yellow brown, moist, medium stiff clay was encountered below the asphalt pavement surface to a depth of 10.0 feet. Yellow brown to gray, moist to wet, clayey silt was encountered to a depth of 20.0 feet. Water was observed at a depth of 12.0 feet below the ground surface. Below the silt layer, gray, moist to wet, stiff, bentonitic clay was encountered to the borehole termination depth of 41.5 feet.

Boring B-5 was advanced at STA 381+60, STA 1004+90 on the 10(4) project, approximately 9.0 feet left of the design centerline. Yellow brown, moist to wet, soft silty clay was encountered below the asphalt pavement surface to a depth of 10.0 feet. Below the silty clay layer, siltstone and shale was encountered to a depth of 12.0 feet below the ground surface. Water was observed at a depth of 12.0 feet below the ground surface. Below the siltstone and shale, yellow brown silty clay with siltstone fragments was encountered to a depth of 16.5 feet below the ground surface. Below the silty clay, brown, moist, medium stiff clay was encountered to the borehole termination depth of 31.5 feet.

Boring B-6 was advanced at STA 375+80, approximately 10.0 feet left of the design centerline. Gray brown, moist, medium stiff to stiff clay was encountered below the asphalt pavement surface to a depth of 14.0 feet. Below the clay layer, gray, slightly moist, medium dense, fine sand was encountered to the borehole termination depth of 16.5 feet.

Boring B-7 was advanced at STA 367+90, approximately 7 feet right of the design centerline. Brown, moist, soft to medium stiff clay was encountered below the asphalt pavement surface to the borehole termination depth of 11.5 feet.

Boring B-8 was advanced at STA 77+00, approximately 12 feet right of the design centerline. Brown, moist, stiff, sandy clay was encountered below the asphalt pavement surface to the borehole termination depth of 11.5 feet.

## ANALYSIS

### Reinforced Soil Slopes

A reinforced soil slope (RSS) was evaluated as a potential repair solution for Segments 2 and 3 of the route. The potential for retreating the roadway alignment into the cutslope is not considered feasible because of existing horizontal alignment and curvature at the site. Traditional embankment reconstruction methods are not considered feasible at this site because of the quantity of material required to construct the embankment at reasonable slope ratios. The reinforced slope will also provide sufficient strength to the embankment to slow or even stop continued movement at the site.

Analysis of the reinforced slopes was performed using RESSA, a two dimensional, limit equilibrium computer program from ADAMA Engineering. The Simplified Bishop method of slices was used with isotropic soil and rock parameters. Based on the subsurface investigation the slope height will be limited to 9 feet below the current roadway elevation. Soft clay was encountered during the subsurface investigation at this depth. The clay will provide a suitable foundation for the reinforced embankment should subsurface water be kept from saturating the clay and the surface of the clay be scarified and recompacted before placing the reinforced embankment. Analyses were performed for this slope height to determine embedment length and tensile strength required for the geogrid reinforcement. For this analysis, a slope was evaluated using the data contained in Table 2.

***Table 2. Geogrid Reinforced Slope Properties***

| | |
|---|---|
| Slope Height | 9 ft |
| Slope Angle | 38.5° (1.25H:1V) |
| Reinforced Backfill Unit Weight | 120 pcf |
| Reinforced Backfill Cohesion | 100 psf |
| Reinforced Backfill Friction Angle | 32° |
| Surcharge | 250 psf |

A minimum global factor of safety of 1.30 was specified for the reinforced soil slopes, and primary geogrids were analyzed at various spacings. Analyses indicate that uniaxial (primary) geogrid layers with a minimum length of 10 feet, spaced at 3-foot vertical intervals will provide adequate stability and attain the required minimum factor of safety. See Appendix D for the geogrid slope design calculations.

**Deep Patches**

Deep patches were evaluated as potential repair solutions for Segment 1 of the route. Studies have shown deep patches as a cost effective technique for repairing and stabilizing areas of roadways damaged by subsidence or cracking. Deep patch analysis was performed in accordance with the guidelines described in the Deep Patch Road Embankment Repair Application Guide, developed by the US Forest Service.

Based on the preliminary analysis, a patch depth of 6 feet, with uniaxial geogrid layers spaced at 2.0 feet, will provide adequate stability to prevent or slow movement of the fill slope.

**Modular Gabion Gravity Wall**

A modular gabion gravity wall system was evaluated as a potential repair solution for the channel scour occurring adjacent to the Squaw Creek Bridge. The gabion wall system will armor the abutment slope and is an economical alternative in areas where large riprap is not readily available.

The analyses and recommendations for gabion gravity walls considered in this report follow the design methodology and guidelines in the AASHTO "Standard Specifications for Highway Bridges, "17th Edition (2002). Per AASHTO, the required minimum factors of safety for these walls are listed in Table 3.

*Table 3. Required Minimum Factors of Safety*

| Design Component | Minimum Factor of Safety |
|---|---|
| Bearing Capacity | 2.5 |
| Overturning | 2.0 |
| Sliding | 1.5 |
| Reinforcement Pullout | 1.5 |
| Global Stability (static) | 1.3 |

Gabion wall analysis was performed using general force and moment equilibrium calculations for the applicable design components discussed in Table 2. Slope stability analysis was performed using Slide, Version 5.0, a two dimensional, limit equilibrium computer program from RocScience. The Simplified Bishop method of slices was utilized with isotropic soil and rock parameters for the slope stability analysis. The proposed walls were evaluated based on the existing site conditions. The engineering properties of soils used in the analysis were based on conservative estimates. Cross sections were evaluated where the wall height was at its maximum. A water table was not considered in the analysis, as the wall systems is considered free draining. A seismic load was not considered in the global analysis, as the peak horizontal seismic acceleration for the project site is insignificant (listed at 0.01g by the USGS).

Based on the preliminary analysis, the proposed gabion gravity wall system will meet the minimum factors of safety as described in Table 3, with a maximum wall height of 9 feet and a minimum base width of 9 feet. A minimum setback width of 2.0 feet and a minimum embedment depth of 1.0 feet were used in the analysis. The gabion wall analysis is presented in Appendix D.

## RECOMMENDATIONS AND SUMMARY

### Reinforced Soil Slope Recommendations

It is recommended that the soft clay material at Segments 2 and 3 be excavated to a depth of 9 feet and 6 feet, respectively, and replaced with a geogrid reinforced slope as detailed in the typical section shown in Appendix E. It is recommended that the reinforced soil slope be constructed at a 1.25H:1V slope ratio. The uniaxial (primary) and biaxial (secondary) geogrid reinforcement should have a minimum, long-term design strength (allowable tensile strength) of 1,000 lb/ft and 500 lb/ft, respectively. Uniaxial reinforcement should be placed at a vertical 3-foot spacing and should be terminated at the slope face. It is recommended that the minimum uniaxial reinforcement embedment length be 10 feet. It is also recommended that the top two layers of uniaxial reinforcement be extended the entire width of the roadway. Biaxial (secondary) geogrid reinforcement layers should be equally spaced between layers of primary reinforcement, at 1.5 feet, vertically, and have a minimum embedment length of 4 feet. The biaxial reinforcement should be wrapped at the face of the slope, as show in the details. In addition, it is recommended that a type 4 erosion control mat be placed along the completed slope to assist with revegetation requirements. Detail drawings of the reinforced slope are contained in Appendix E.

### Deep Patch Recommendations

It is recommended that Segments 1 be reconstructed with the use of a deep patch, in which the existing soil fill material be subexcavated and replaced with unclassified borrow and uniaxial geogrid reinforcement layers. It is recommended that the deep patches be constructed to a depth of 6 feet, with layers of uniaxial geogrid reinforcement spaced every 2.0 feet. The uniaxial geogrid reinforcement should have a minimum length of 10 feet and a minimum, long term design strength (allowable tensile strength) of 1,000 lb/ft. Detail drawings of the deep patch are provided in Appendix E.

The deep patch repair along Segment 1 should be coupled with a deep, standard underdrain. The deep underdrain should be constructed within the inboard ditch and to a total depth of 15 feet below the ground surface. The underdrain should be backfilled with granular backfill meeting the requirements of Section 703 of the FP-03 and conforming to AASHTO M 6 specifications. The specified granular backfill will provide suitable filtration and migration control for the fine-grained native soils encountered at this site. It is also recommended that the perforated collector pipe be wrapped with a Type I-A geotextile. At this depth the underdrain should collect a majority of the subsurface water accounting for continued slope along this site.

### Modular Gabion Gravity Wall Recommendations

A modular gabion gravity wall system is recommended to repair and lessen the potential for abutment scour at the Squaw Creek Bridge. It is recommended that the gabion wall system be constructed to a maximum height of 9 feet (3 gabion lifts). The gabion baskets should be filled with rock meeting the requirements of Section 705 of the FP-03, with the maximum dimension ranging between 4 and 8 inches. It is further recommended that the bottom wall lift be constructed at a minimum base width of 9 feet, the middle lift at a minimum base width of 6 feet, and the top lift at a minimum base width of 3 feet. The recommended minimum embedment depth is 1 foot and the minimum setback distance is 2 feet. In no instance should the wall be constructed to a greater height than 9 feet without prior approval from CFLHD geotechnical personnel. The wall should be embedded sufficiently, as recommended by the CFLHD Hydraulics Group, to prevent scour from undermining the foundation of the wall. Wall details are presented in Appendix E.

Prior to backfilling the gabion baskets, a Type IV-C geotextile should be placed along the back face of the gabion wall to allow filtration between native soils and the gabion structure. In order to accommodate the proposed gabion structure the backslope will be excavated at a 1H:6V slope. Extreme caution should be used when excavating this slope and excavation should not proceed during periods of high precipitation. It is recommended that no more than a 50 foot length of slope be excavated prior to the placement of the gabion structure. In no instance should any portion of the excavation remain open for more than 2 days.

## Culvert Outlet Repairs

Due to the nature of the dispersive soils found along the length of the project, there are several culvert locations that have experienced sinkholes along the length of the pipe or have severe distress at outlet locations. It is recommended that the distress at the following culverts be repaired: STA 61+34, STA 99+29, and STA 226+92. It is recommended that the sinkholes be filled if the culvert is not scheduled for replacement and that suitable protection from outlet erosion be constructed. The sinkholes should be filled with properly compacted unclassified borrow. The gabion structure at the outlet of the culvert at STA 226+92 needs to be repaired. It is recommended that the existing gabions be removed and replaced with a suitable gabion structure. The existing gabion rock appears to be performing well and may be salvaged. The gabion structure should be anchored to the slope using 2 inch diameter galvanized pipe or 2.5 inch by 2.5 inch galvanized angle iron. All anchors should be a minimum of 6 feet long. It is recommended that anchors be placed in the center of baskets and spaced on 6 foot centers, longitudinally. In lieu of anchoring the baskets, the entire outlet protection system may be constructed of gabions, such that the outlet channel slopes and bottom are lined with gabion baskets.

## Subexcavation Recommendations

Severe pavement distress was noted along the shoulder and ditchline or the roadway between STA 70+00 and STA 80+00. It is recommended that the top 2 feet of soil be excavated and replaced with suitable borrow. Section 204 of the FP-03 specifications should be followed during borrow placement and compaction in subexcavation areas. It is further recommended that upon excavation the top of the subgrade be scarified and recompacted to a depth of 6 inches.

## Site Drainage Recommendations

For the above repair and reconstruction recommendations to function properly and remain stable, it is required that ditches and culvert inlets in the area of the failure sites be cleaned and reconditioned to prevent future roadway damage from large storm events. Many of the investigated culverts along the subject route exhibited severe distress from corrosion. It is recommended that all existing, corrugated metal pipe (CMP) culverts be thoroughly examined and replaced if conditions warrant. Culverts should be adequately sized to meet the hydraulic demands during storm events per recommendations from the CFLHD Hydraulics group.

## Shrink/Swell Factor Recommendations

On-site soils generally consist of loose plastic clays which will be excavated, wasted and generally not used as embankment fill for the proposed repairs. It is estimated that such soils will have a shrink percentage of 15 percent, corresponding to a shrink/swell factor of 0.87.

## Construction Considerations

*Specifications:* Sections 207 of the FP-03 should be followed during construction of the reinforced soil slopes and deep patches.

*Borrow Sources:* In general, on-site soils are not suitable for use as borrow because of their high plasticity and high fines content. Most likely, a source outside of the Park boundaries will have to be located for suitable borrow materials.

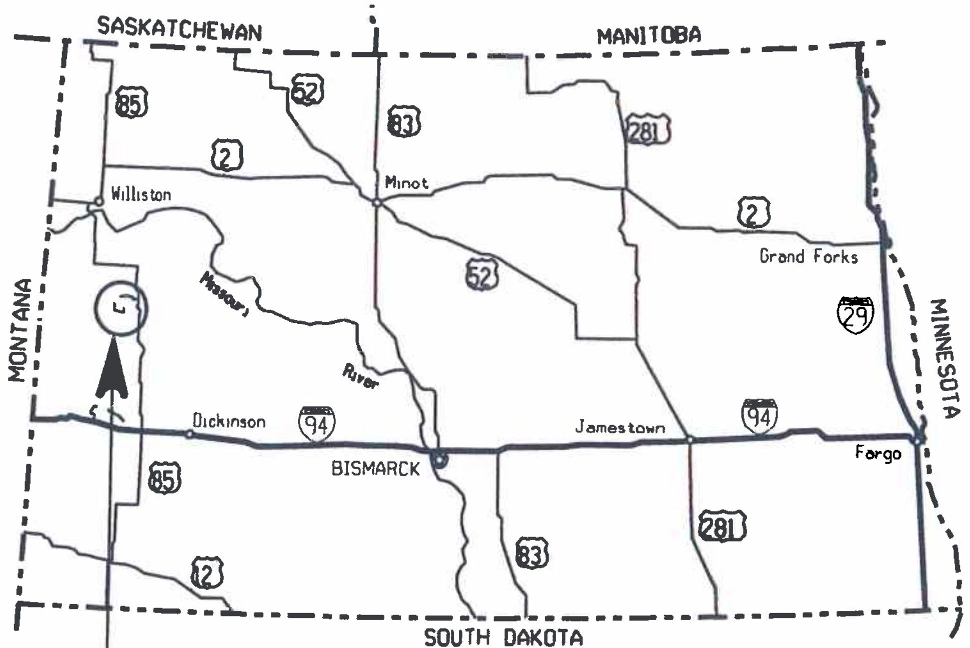
*Site Access:* Access plans for each site should be developed by the contractor and submitted to the CO for approval.

## DISCLAIMER/LIMITATIONS CLAUSE

The subsurface explorations and tests described in the section on Procedures and Results have been conducted in accordance with standard practices and procedures (except as specifically noted). The results of these explorations and tests represent conditions at the specific locations indicated. Subsurface conditions between these locations may vary. The Analysis section and the Recommendations section in this report include interpretations and recommendations developed by the Government in the process of preparing the design. These interpretations are not intended as a substitute for the personal investigation, independent interpretation, and judgment of the Contractor.

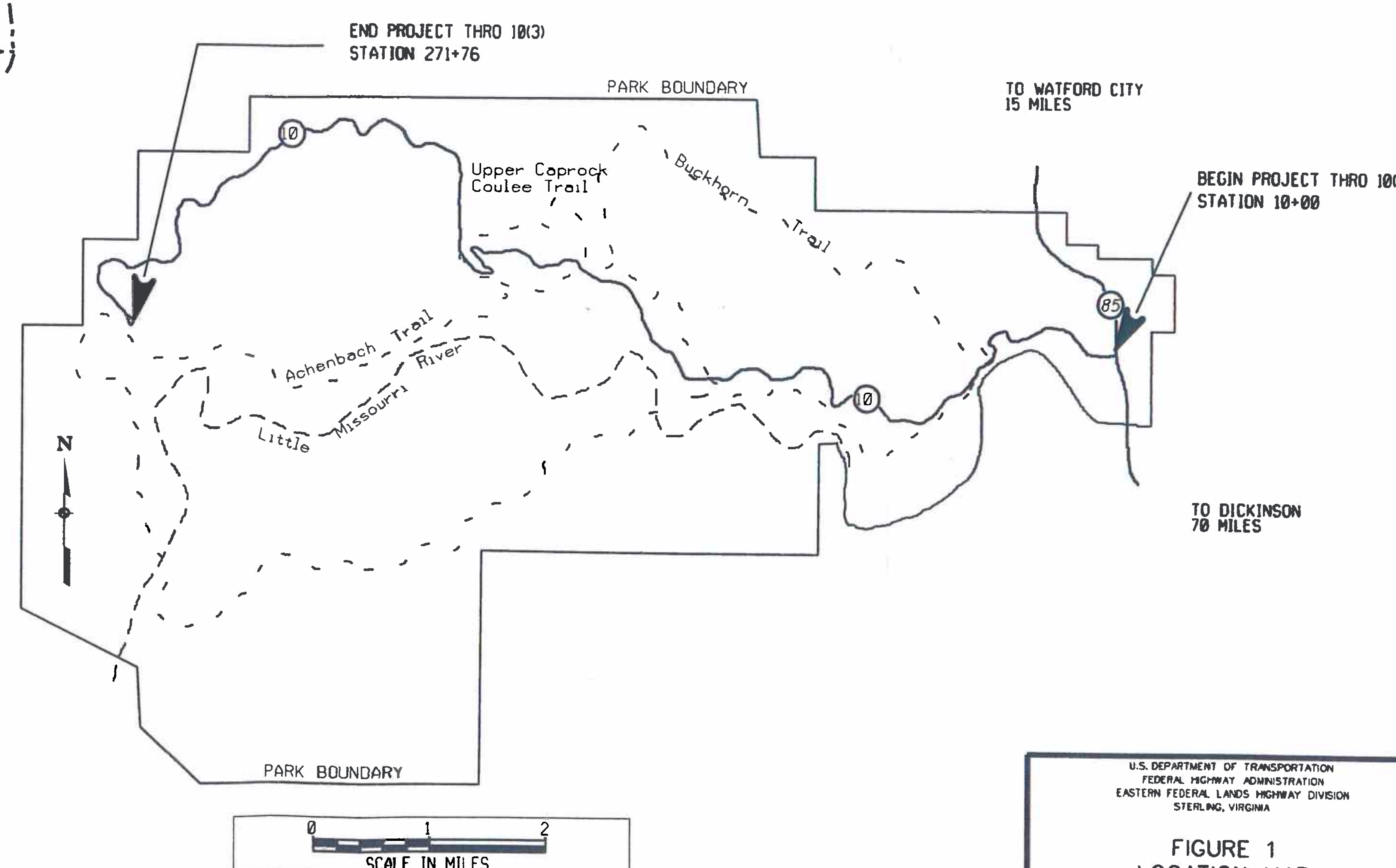
## APPENDIX A – Figures

| REG | STATE | PROJECT | SHEET NO. | TOTAL SHEETS |
|---|---|---|---|---|
| 16 | ND | THRO 10(3) & 10(4) | 1 | 1 |




## KEY MAP OF NORTH DAKOTA

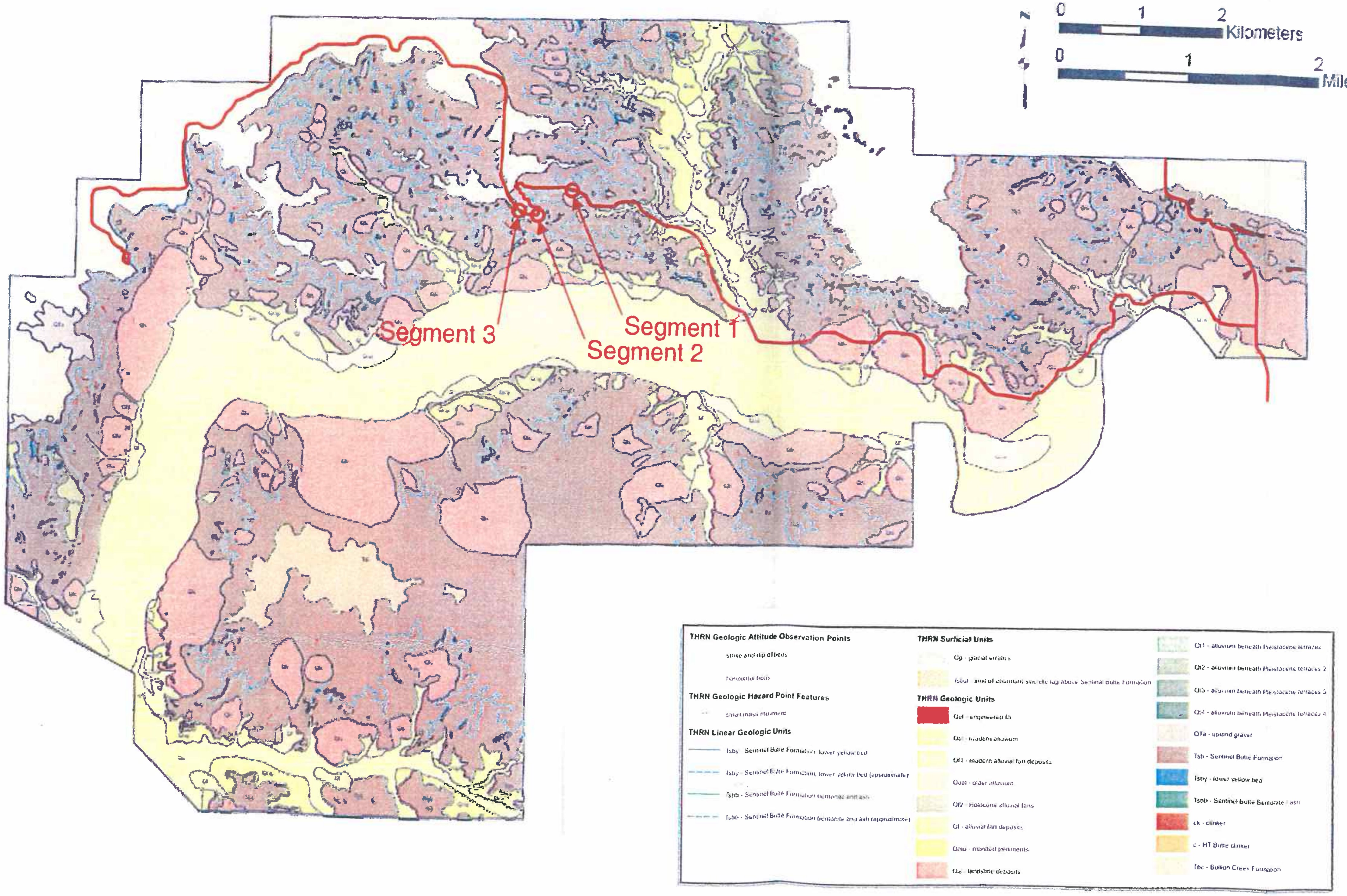
PROJECT LOCATION
ND THRO 10(3) & 10(4)
THEODORE ROOSEVELT
NATIONAL PARK NORTH UNIT




U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
EASTERN FEDERAL LANDS HIGHWAY DIVISION
STERLING, VIRGINIA

FIGURE 1
LOCATION MAP

| REG | STATE | PROJECT | SHEET NO. | TOTAL SHEETS |
| --- | --- | --- | --- | --- |
| 16 | ND | THRO 10(3) & 10(4) | 1 | 1 |

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FEDERAL HIGHWAY ADMINISTRATION
EASTERN FEDERAL LANDS HIGHWAY DIVISION
STERLING, VIRGINIA

FIGURE 2
GEOLOGIC MAP

# APPENDIX B – Boring Logs

# BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

| | | | |
|---|---|---|---|
| Project Name: North Unit, Theodore Roosevelt National Park | | Boring No. B-1 | Date: May 2006 / Sheet 1 of 1 |
| Boring Location: STA 432+00, 7 ft. LT | | Type of Boring: Auger | |
| Coordinates: | | Casing Used: HSA | Size: 4" I.D. |
| Drill: Longyear BK 81 | Driller: HazTech | Boring Began: 5/10/06 | Completed: 5/10/06 |
| Field Logged By: C. Martinez | | Ground Elev: ft. | Weather: Cloudy, windy |
| Revisions/Final By: C. Martinez | | Water Depth: | |
| | | Date: | |
| | | Time: | |

| Run/Samp No. | Depth (feet) | Graphic Log | U.S.C.S. | Length Recov. feet ----- % Rec. | RQD | SPT Blows per 6 in | Description: (Density, Color, Type, Moisture, Other) |
|---|---|---|---|---|---|---|---|
| AR 1 | 0.2<br>1 | | | | | | 0.0 - 0.2 ft. Asphalt Pavement<br>AR 1 Asphalt Pavement, base course and brown clay, moist.<br>0.2 - 1.0 ft. Base Course<br>1.0 - 18.0 ft. Brown CLAY |
| CAL SPT 1 | 5 | | CH | 0.83<br>55% | | 3/3/5 | CAL SPT 1 Rec. 0.83 ft. of brown clay, moist. |
| AR 2 | | | | | | | AR 2 brown clay, moist. |
| CAL SPT 2 | 10 | | CH | 0.83<br>55% | | 3/4/7 | CAL SPT 2 Rec. 0.83 ft. of brown clay, moist. |
| AR 3 | | | | | | | AR 3 brown clay, moist. |
| SPT 3 | 15 | | CH | 1.50<br>100% | | 3/4/6 | SPT 3 Rec. 1.5 ft. of brown clay, moist. |
| AR 4 | 18 | | | | | | AR 4 brown clay to 18', then stiffer gray clay, moist to slightly moist.<br>18.0 - 31.5 ft. Gray CLAY |
| SPT 4 | 20 | | CH | 1.50<br>100% | | 4/7/10 | SPT 4 Rec. 1.5 ft. of gray clay, slightly moist. |
| AR 5 | | | | | | | AR 5 gray clay, sl. moist. |
| SPT 5 | 25 | | CH | 1.50<br>100% | | 7/10/13 | SPT 5 Rec. 1.5 ft. of gray clay, sl. moist. |
| AR 6 | | | | | | | AR 6 gray clay, sl. moist. |
| SPT 6 | 30<br>31.5 | | CH | 1.50<br>100% | | 7/12/15 | SPT 6 Rec. 1.5 ft. of gray clay, sl. moist. |
| | 35 | | | | | | BHT at 31.5 ft. |

# BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

| | | | |
|---|---|---|---|
| Project Name: North Unit, Theodore Roosevelt National Park | Boring No. B-2 | Date: May 2006 | Sheet 1 of 1 |
| Boring Location: STA 425+70, 10 ft. LT | Type of Boring: Auger | | |
| Coordinates: | Casing Used: HSA | Size: 4" I.D. | |
| Drill: Longyear BK 81 / Driller: HazTech | Boring Began: 5/11/06 | Completed: 5/11/06 | |
| Field Logged By: C. Martinez | Ground Elev: ft. | Weather: Clear, cool | |
| Revisions/Final By: C. Martinez | Water Depth: | | |
| | Date: | | |
| | Time: | | |

| Run/Samp No. | Depth (feet) | Graphic Log | U.S.C.S. | Length Recov. feet ----- % Rec. | RQD | SPT Blows per 6 in | Description: (Density, Color, Type, Moisture, Other) |
|---|---|---|---|---|---|---|---|
| AR 1 | 0.2<br>1 | | | | | | 0.0 - 0.2 ft. Asphalt Pavement<br>AR 1 Asphalt Pavement, base course and brown clay, moist.<br>0.2 - 1.0 ft. Base Course<br>1.0 - 31.0 ft. Brown CLAY, some scoria fragments |
| SPT 1 | 5 | | CL | 1.10<br>73% | | 2/3/3 | SPT 1 Rec. 1.1 ft. of brown clay with some scoria fragments, moist. |
| AR 2 | | | | | | | AR 2 brown clay with some scoria fragments, moist. |
| SPT 2 | 10 | | CL | 0.50<br>33% | | 2/2/1 | SPT 2 Rec. 0.5 ft. of brown clay with some scoria fragments, slightly moist to dry. |
| AR 3 | | | | | | | AR 3 brown clay, sl. moist to dry. |
| SPT 3 | 15 | | CL | 0.50<br>33% | | 3/4/4 | SPT 3 Rec. 0.5 ft. of brown clay with some scoria fragments, slightly moist to dry. |
| AR 4 | | | | | | | AR 4 brown clay with some scoria fragments, slightly moist to dry. |
| SPT 4 | 20 | | CL | 0.58<br>39% | | 2/1/3 | SPT 4 Rec. 0.58 ft. of brown clay with some scoria fragments, moist. |
| AR 5 | | | | | | | AR 5 brown clay with some scoria fragments, moist. |
| SPT 5 | 25 | | CL | 1.50<br>100% | | 1/2/2 | SPT 5 Rec. 1.5 ft. of brown clay, moist to wet. |
| AR 6 | | | | | | | AR 6 brown clay, moist to wet. |
| SPT 6 | 30<br>31 | | | 1.50<br>100% | | 2/3/5 | SPT 6 Rec. 1.5 ft. of brown clay, moist (0.5') and gray clayey silt, moist.<br>31.0 - 41.5 ft. Gray clayey silt/siltstone |
| AR 7 | | | | | | | AR 7 gray clayey silt/siltstone, harder drilling with depth. |
| SPT 7 | 35 | | | 1.50<br>100% | | 8/12/16 | SPT 7 Rec. 1.5 ft. of gray clayey silt/siltstone. |
| AR 8 | | | | | | | AR 8 gray siltstone. |
| SPT 8 | 40<br>41.5 | | | 1.50<br>100% | | 8/15/21 | SPT 8 Rec. 1.5 ft. of gray siltstone. |
| | 45 | | | | | | BHT at 41.5 ft. |

# BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

| | | | |
|---|---|---|---|
| Project Name: North Unit, Theodore Roosevelt National Park | Boring No. B-3 | Date: May 2006 | Sheet 1 of 1 |
| Boring Location: STA 415+60, 9 ft. LT | Type of Boring: Auger | | |
| Coordinates: | Casing Used: HSA | Size: 4" I.D. | |
| Drill: Longyear BK 81 / Driller: HazTech | Boring Began: 5/11/06 | Completed: 5/11/06 | |
| Field Logged By: C. Martinez | Ground Elev: ft. | Weather: Clear, cool | |
| Revisions/Final By: C. Martinez | Water Depth: | | |
| | Date: | | |
| | Time: | | |

| Run/Samp No. | Depth (feet) | Graphic Log | U.S.C.S. | Length Recov. feet ----- % Rec. | RQD | SPT Blows per 6 in | Description: (Density, Color, Type, Moisture, Other) |
|---|---|---|---|---|---|---|---|
| AR 1 | 0.2, 1 | | | | | | 0.0 - 0.2 ft. Asphalt Pavement<br>AR 1 Asphalt Pavement, base course and brown clay, moist.<br>0.2 - 1.0 ft. Base Course<br>1.0 - 20.0 ft. Brown CLAY |
| SPT 1 | 5 | | CL | 1.00<br>67% | | 2/4/5 | SPT 1 Rec. 1 ft. of brown clay, sl. moist. |
| AR 2 | | | | | | | AR 2 brown clay, moist. |
| SPT 2 | 10 | | CL | 1.30<br>87% | | 2/1/3 | SPT 2 Rec. 1.3 ft. of brown clay, moist. |
| AR 3 | | | | | | | AR 3 brown clay, moist. |
| SPT 3 | 15 | | CL | 1.50<br>100% | | 2/4/4 | SPT 3 Rec. 1.5 ft. of brown clay, moist. |
| AR 4 | | | | | | | AR 4 brown clay, moist, coal seam from 18' to 18.5'. |
| SPT 4 | 20 | | CH | 1.50<br>100% | | 4/8/11 | 20.0 - 26.5 ft. Yellow brown to gray silty clay<br>SPT 4 Rec. 1.5 ft. of yellow brown clay, moist. |
| AR 5 | | | | | | | AR 5 yellow brown to gray silty clay, moist. |
| SPT 5 | 25, 26.5 | | CH | 1.50<br>100% | | 6/10/12 | SPT 5 Rec. 1.5 ft. of yellow brown to gray silty clay, sl. moist. |
| | 30 | | | | | | BHT at 26.5 ft. |

# BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

| | | | |
|---|---|---|---|
| Project Name: North Unit, Theodore Roosevelt National Park | Boring No. B-4 | Date: May 2006 | Sheet 1 of 1 |
| Boring Location: STA 383+00, 10 ft. LT | Type of Boring: Auger | | |
| Coordinates: | Casing Used: HSA | | Size: 4" I.D. |
| Drill: Longyear BK 81 — Driller: HazTech | Boring Began: 5/11/06 | Completed: 5/11/06 | |
| Field Logged By: C. Martinez | Ground Elev: ft. | Weather: Clear, cool | |
| Revisions/Final By: C. Martinez | Water Depth: 12ft. | | |
| | Date: 5/11/06 | | |
| | Time: ATD | | |

| Run/Samp No. | Depth (feet) | Graphic Log | U.S.C.S. | Length Recov. feet ----- % Rec. | RQD | SPT Blows per 6 in | Description: (Density, Color, Type, Moisture, Other) |
|---|---|---|---|---|---|---|---|
| AR 1 | 0.2<br>0.8 | | | | | | 0.0 - 0.3 ft. Asphalt Pavement<br>AR 1 Asphalt Pavement, base course and gray to brown clay, moist.<br>0.3 - 0.8 ft. Base Course<br>0.8 - 10.0 ft. Gray brown clay |
| SPT 1 | 5 | | CH | | | 1/1/3 | SPT 1 gray brown clay, moist. |
| AR 2 | | | | | | | AR 2 gray brown clay, moist. |
| SPT 2 | 10 | | ML | | | 2/3/2 | 10.0 - 20.0 ft. Yellow brown clayey silt<br>SPT 2 yellow brown clayey silt, moist. |
| AR 3 | ▽ | | | | | | AR 3 yellow brown clayey silt, soft, wet from 12' to 13'. |
| SPT 3 | 15 | | ML | | | 2/2/3 | SPT 3 yellow brown clayey silt, moist. |
| AR 4 | | | | | | | AR 4 yellow brown clayey silt, moist. |
| SPT 4 | 20 | | CL | | | 2/3/4 | 20.0 - 25.0 ft. Gray clay<br>SPT 4 gray clay, moist, coal at sampler shoe. |
| AR 5 | | | | | | | AR 5 gray clay, moist. |
| SPT 5 | 25 | | | | | 4/8/10 | 25.0 - 41.5 ft. Gray bentonitic clay<br>SPT 5 gray bentonitic clay, moist. |
| AR 6 | | | | | | | AR 6 gray bentonitic clay, moist. |
| SPT 6 | 30 | | CH | | | 5/5/7 | SPT 6 gray bentonitic clay, moist. |
| AR 7 | | | | | | | AR 7 gray bentonitic clay, moist. |
| SPT 7 | 35 | | CH | | | 4/5/8 | SPT 7 gray bentonitic clay, moist. |
| AR 8 | | | | | | | AR 8 gray bentonitic clay, moist. |
| SPT 8 | 40<br>41.5 | | CH | | | 7/8/11 | SPT 8 gray bentonitic clay, moist. |
| | 45 | | | | | | BHT at 41.5 ft. |

# BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

| | |
|---|---|
| Project Name: North Unit, Theodore Roosevelt National Park | Boring No. B-5 / Date: May 2006 / Sheet 1 of 1 |
| Boring Location: STA 381+60, 9 ft. LT | Type of Boring: Auger |
| Coordinates: | Casing Used: HSA / Size: 4" I.D. |
| Drill: Longyear BK 81 / Driller: HazTech | Boring Began: 5/11/06 / Completed: 5/11/06 |
| Field Logged By: C. Martinez | Ground Elev: ft. / Weather: Clear, cool |
| Revisions/Final By: C. Martinez | Water Depth: 12ft. |
| | Date: 5/11/06 |
| | Time: ATD |

| Run/Samp No. | Depth (feet) | U.S.C.S. | Length Recov. feet ----- % Rec. | RQD | SPT Blows per 6 in | Description: (Density, Color, Type, Moisture, Other) |
|---|---|---|---|---|---|---|
| AR 1 | 0.3<br>0.9 | | | | | 0.0 - 0.3 ft. Asphalt Pavement<br>AR 1 Asphalt Pavement, base course and yellow brown silty clay, soft, wet at 2.5'.<br>0.3 - 0.9 ft. Base Course<br>0.9 - 10.0 ft. Yellow brown silty silty clay |
| SPT 1 | 5 | CL | | | 1/1/1 | SPT 1 yellow brown silty clay, moist to wet. |
| AR 2 | | | | | | AR 2 yellow brown silty clay, moist. |
| SPT 2 | 10 | | | | 7/9/7 | 10.0 - 12.0 ft. Sandstone fragments<br>SPT 2 sandstone fragments, moist. |
| AR 3 | 12 ▽ | | | | | AR 3 sandstone fragments to 12', then brown gray silty clay, moist.<br>12.0 - 31.5 ft. Brown gray silty clay and claystone |
| SPT 3 | 15 | | | | 2/2/1 | SPT 3 brown gray silty clay, moist. |
| AR 4 | | | | | | AR 4 brown gray silty clay, moist. |
| SPT 4 | 20 | CL | | | 2/2/2 | SPT 4 brown gray silty clay, moist. |
| AR 5 | | | | | | AR 5 brown gray silty clay, moist. |
| SPT 5 | 25 | CL | | | 2/3/3 | SPT 5 brown gray silty clay, moist. |
| AR 6 | | | | | | AR 6 brown gray silty clay and claystone. |
| SPT 6 | 30<br>31.5 | CL | | | 6/11/14 | SPT 6 brown gray silty clay and claystone. |
| | 35 | | | | | BHT at 31.5 ft. |

# BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

| | |
|---|---|
| Project Name: North Unit, Theodore Roosevelt National Park | Boring No. B-6 / Date: May 2006 / Sheet 1 of 1 |
| Boring Location: STA 375+80, 10 ft. LT | Type of Boring: Auger |
| Coordinates: | Casing Used: HSA / Size: 4" I.D. |
| Drill: Longyear BK 81 / Driller: HazTech | Boring Began: 5/11/06 / Completed: 5/11/06 |
| Field Logged By: C. Martinez | Ground Elev: ft. / Weather: Clear, cool |
| Revisions/Final By: C. Martinez | Water Depth: |
| | Date: |
| | Time: |

| Run/Samp No. | Depth (feet) | Graphic Log | U.S.C.S. | Length Recov. feet ----- % Rec. | RQD | SPT Blows per 6 in | Description: (Density, Color, Type, Moisture, Other) |
|---|---|---|---|---|---|---|---|
| AR 1 | 0.2<br>1 | | | | | | 0.0 - 0.2 ft. Asphalt Pavement<br>AR 1 Asphalt Pavement, base course and gray brown clay, moist.<br>0.2 - 1.0 ft. Base Course<br>1.0 - 14.0 ft. Gray brown CLAY |
| SPT 1 | 5 | | | 0.50<br>33% | | 2/1/3 | SPT 1 Rec. 0.5 ft. of gray brown clay, moist. |
| AR 2 | | | | | | | AR 2 gray brown clay, moist, denser at 8'. |
| SPT 2 | 10 | | | 0.17<br>11% | | 5/4/5 | SPT 2 Rec. 0.17 ft. of fractured coal. |
| AR 3 | 14 | | | | | | AR 3 gray brown clay changing to sandy silt at 14'.<br>14.0 - 16.5 ft. Gray sandy silt |
| SPT 3 | 15<br>16.5 | | | 1.20<br>80% | | 3/4/4 | SPT 3 Rec. 1.2 ft. of gray sandy silt, sl. moist to dry. |
| | 20<br>25<br>30 | | | | | | BHT at 16.5 ft. |

BORING LOG TEDDY.GPJ FHWA_CO.GDT 10/10/07

# BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

| | | | |
|---|---|---|---|
| Project Name: North Unit, Theodore Roosevelt National Park | Boring No. B-7 | Date: May 2006 | Sheet 1 of 1 |
| Boring Location: STA 367+90, 7 ft. RT | Type of Boring: Auger | | |
| Coordinates: | Casing Used: HSA | Size: 4" I.D. | |
| Drill: Longyear BK 81 / Driller: HazTech | Boring Began: 5/11/06 | Completed: 5/11/06 | |
| Field Logged By: C. Martinez | Ground Elev: ft. | Weather: Clear, cool | |
| Revisions/Final By: C. Martinez | Water Depth: | | |
| | Date: | | |
| | Time: | | |

| Run/Samp No. | Depth (feet) | Graphic Log | U.S.C.S. | Length Recov. feet ----- % Rec. | RQD | SPT Blows per 6 in | Description: (Density, Color, Type, Moisture, Other) |
|---|---|---|---|---|---|---|---|
| AR 1 | 0.2<br>1 | | | | | | 0.0 - 0.2 ft. Asphalt Pavement<br>AR 1 Asphalt Pavement, base course and brown clay, sl. moist.<br>0.2 - 1.0 ft. Base Course<br>1.0 - 11.5 ft. Brown CLAY |
| SPT 1 | 5 | | CL | 0.83<br>55% | | 2/1/2 | SPT 1 Rec. 0.83 ft. of brown clay, sl. moist. |
| AR 2 | | | | | | | AR 2 brown clay, sl. moist. |
| SPT 2 | 10<br>11.5 | | CL | 1.50<br>100% | | 2/3/4 | SPT 2 Rec. 1.5 ft. of brown clay, sl. moist. |
| | 15<br>20<br>25<br>30 | | | | | | BHT at 11.5 ft. |

BORING LOG TEDDY.GPJ FHWA_CO.GDT 10/10/07

# BORING LOG

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

| | | | |
|---|---|---|---|
| Project Name: North Unit, Theodore Roosevelt National Park | Boring No. B-8 | Date: May 2006 | Sheet 1 of 1 |
| Boring Location: STA 77+00, 12 ft. RT | Type of Boring: Auger | | |
| Coordinates: | Casing Used: HSA | Size: 4" I.D. | |
| Drill: Longyear BK 81 / Driller: HazTech | Boring Began: 5/11/06 | Completed: 5/11/06 | |
| Field Logged By: C. Martinez | Ground Elev: ft. | Weather: Clear, cool | |
| Revisions/Final By: C. Martinez | Water Depth: | | |
| | Date: | | |
| | Time: | | |

| Run/Samp No. | Depth (feet) | Graphic Log | U.S.C.S. | Length Recov. feet ----- % Rec. | RQD | SPT Blows per 6 in | Description: (Density, Color, Type, Moisture, Other) |
|---|---|---|---|---|---|---|---|
| AR 1 | 0.2<br>1 | | | | | | 0.0 - 0.2 ft. Asphalt Pavement<br>AR 1 Asphalt Pavement, base course and brown clay, moist.<br>0.2 - 1.0 ft. Base Course<br>1.0 - 11.5 ft. Brown CLAY |
| SPT 1 | 5 | | CL | 1.50<br>100% | | 2/2/7 | SPT 1 Rec. 1.5 ft. of brown clay, moist. |
| AR 2 | | | | | | | AR 2 brown clay, moist, stiffer at 7'. |
| SPT 2 | 10<br>11.5 | | CL | 1.50<br>100% | | 7/11/14 | SPT 2 Rec. 1.5 ft. of brown clay, sl. moist. |
| | 15<br>20<br>25<br>30 | | | | | | BHT at 11.5 ft. |

**APPENDIX C – Laboratory Data**

U.S. Department of Transportation
Federal Highway Administration

# Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

## Report of Soil or Aggregate Tests

AASHTO R18 ISO/IEC 17025



**Project:** North Dakota PRA THRO 10 (3) North Unit Scenic Drive

**Submitted By:** Charlie Martinez

**Date Reported:** 6/19/2006

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample Number | Lab Number | | 06-465-SB | 06-466-SB | 06-467-T | 06-468-T | 06-469-SB |
| | Hole Number | | B-1 | B-1 | B-1 | B-1 | B-2 |
| | Field Number | | SPT 1,2,3 | SPT 4,5,6 | SPT 1 | SPT 2 | SPT 1,2,3,4 |
| Sample Location | Milepost | | 7.8 | 7.8 | 7.8 | 7.8 | 7.7 |
| | Offset | | Left | Left | Left | Left | Left |
| | Depth, Feet | | 5-16.5 | 20-31.5 | 6.0-6.5 | 11-11.5 | 5-21.5 |
| AASHTO T 11, T 27 & T 88 Washed Sieve Analysis % Passing | 3" | 75.0 mm | | | | | |
| | 1 1/2" | 37.5 mm | | | | | |
| | 1" | 25.0 mm | | | | | |
| | 3/4" | 19.0 mm | | | | | |
| | 1/2" | 12.5 mm | | | | | |
| | 3/8" | 9.5 mm | | | | | 100 |
| | #4 | 4.75 mm | | | | | 92 |
| | #8 | 2.36 mm | | | | | |
| | #10 | 2.00 mm | | | | | 85 |
| | #16 | 1.18 mm | | | | | 82 |
| | #30 | 600 µm | | | | | |
| | #40 | 425 µm | 100 | | | | 78 |
| | #50 | 300 µm | | | | | |
| | #100 | 150 µm | 99 | 100 | | | 75 |
| | #200 | 75 µm | 96 | 99 | | | 71 |
| | | 20 µm | | | | | |
| | | 2 µm | | | | | |
| | | 1 µm | | | | | |
| AASHTO T 255 | Moisture, % | | 26.3 | 22.9 | 27.5 | 28.6 | 20.9 |
| AASHTO T 89 & T 90 | Liquid Limit | | 50 | 59 | | | 45 |
| | Plasticity Index | | 29 | 41 | | | 23 |
| Soil Classification | AASHTO M 145 | | A-7-6 (31) | A-7-6 (45) | | | A-7-6 (15) |
| | ASTM D 2487 | | CH | CH | | | CL |
| AASHTO T 208 | Wet / Dry Density, pcf | | | | 108 / 85 | 108 / 84 | |
| AASHTO T 288 | Min. Resistivity, ohm-cm | | | | | | |
| AASHTO T 289 | pH | | | | | | |
| AASHTO Method | Optimum Moisture, % | | | | | | |
| | Maximum Dry Density, pcf | | | | | | |

**Distribution:**

| | |
|---|---|
| Laboratory | Num. / Project File |
| Geotechnical | Darrell Harding |
| Materials | Charlie Martinez |
| | 1 Copy |

**Remarks:**
Moisture contents and densities were the only tests requested on samples 06-467-SB & 06-468-SB.

Reported By:

Darrell Harding

U.S. Department of Transportation
Federal Highway Administration

# Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

## Report of Soil or Aggregate Tests

AASHTO R18 ISO/IEC 17025



**Project:** North Dakota PRA THRO 10 (3) North Unit Scenic Drive

**Submitted By:** Charlie Martinez

**Date Reported:** 6/19/2006

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample Number | Lab Number | | 06-470-SB | 06-471-SB | 06-472-SB | 06-473-SB | 06-474-SB |
| | Hole Number | | B-2 | B-2 | B-3 | B-3 | B-4 |
| | Field Number | | SPT 5 | SPT 6,7,8 | SPT 1,2,3 | SPT 4,5 | SPT 1 |
| Sample Location | Milepost | | 7.7 | 7.7 | 7.5 | 7.5 | 6.88 |
| | Offset | | Left | Left | Left | Left | Left |
| | Depth, Feet | | 25-26.5 | 30.5-41.5 | 5-16.5 | 20-26.5 | 5-6.5 |
| AASHTO T 11, T 27 & T 88 Washed Sieve Analysis % Passing | 3" | 75.0 mm | | | | | |
| | 1 1/2" | 37.5 mm | | | | | |
| | 1" | 25.0 mm | | | | | |
| | 3/4" | 19.0 mm | | | | | |
| | 1/2" | 12.5 mm | | | | | |
| | 3/8" | 9.5 mm | 100 | | | | |
| | #4 | 4.75 mm | 98 | | | | |
| | #8 | 2.36 mm | | | | | |
| | #10 | 2.00 mm | 94 | | | | |
| | #16 | 1.18 mm | 92 | | | | 100 |
| | #30 | 600 µm | | | | | |
| | #40 | 425 µm | 89 | | | | 99 |
| | #50 | 300 µm | | | | | |
| | #100 | 150 µm | 86 | | 100 | | 88 |
| | #200 | 75 µm | 83 | | 92 | 100 | 83 |
| | | 20 µm | | | | | |
| | | 2 µm | | | | | |
| | | 1 µm | | | | | |
| AASHTO T 255 | Moisture, % | | 31.7 | | 24.7 | 24.4 | 36.5 |
| AASHTO T 89 & T 90 | Liquid Limit | | 49 | | 49 | 79 | 63 |
| | Plasticity Index | | 31 | | 32 | 59 | 42 |
| Soil Classification | AASHTO M 145 | | A-7-6 (26) | | A-7-6 (31) | A-7-6 (67) | A-7-6 (37) |
| | ASTM D 2487 | | CL | | CL | CH | CH |
| AASHTO T 208 | Wet / Dry Density, pcf | | | | | | |
| AASHTO T 288 | Min. Resistivity, ohm-cm | | | 250 | | | |
| AASHTO T 289 | pH | | | 7.7 | | | |
| AASHTO T 290 | Sulfate Content, % / ppm | | | 0.369 / 3690 | | | |
| AASHTO T 291 | Chloride Content, % / ppm | | | <0.0001 / <1 | | | |

**Distribution:**

| | |
|---|---|
| Laboratory | Num. / Project File |
| | Darrell Harding |
| Geotechnical | Charlie Martinez |
| Materials | 1 Copy |

**Remarks:**
Resistivity and pH were the only tests requested on sample 06-471-SB. However, due to the low soil resistivity, both sulfate and chloride content tests were performed. An FHWA consultant, Colorado Analytical Laboratories, performed the sulfate content and chloride content testing.

Reported By:

Darrell Harding

# Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

US Department of Transportation
Federal Highway Administration

## Report of Soil or Aggregate Tests

AASHTO R18 ISO/IEC 17025



**Project:** North Dakota PRA THRO 10 (3) North Unit Scenic Drive
**Submitted By:** Charlie Martinez

**Date Reported:** 6/19/2006

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample Number | Lab Number | | 06-475-SB | 06-476-SB | 06-477-SB | 06-478-T | 06-479-T |
| | Hole Number | | B-4 | B-4 | B-4 | B-4 | B-4 |
| | Field Number | | SPT 2,3 | SPT 4 | SPT 6,7,8 | SPT 4 | SPT 5 |
| Sample Location | Milepost | | 6.88 | 6.88 | 6.88 | 6.88 | 6.88 |
| | Offset | | Left | Left | Left | Left | Left |
| | Depth, Feet | | 10-16.5 | 20-21.5 | 30-41.5 | 25.5-26 | 26.0-26.5 |
| AASHTO T 11, T 27 & T 88 Washed Sieve Analysis % Passing | 3" | 75.0 mm | | | | | |
| | 1 1/2" | 37.5 mm | | | | | |
| | 1" | 25.0 mm | | | | | |
| | 3/4" | 19.0 mm | | | | | |
| | 1/2" | 12.5 mm | | | | | |
| | 3/8" | 9.5 mm | | 100 | | | |
| | #4 | 4.75 mm | | 98 | | | |
| | #8 | 2.36 mm | | | | | |
| | #10 | 2.00 mm | | 98 | | | |
| | #16 | 1.18 mm | | 98 | | | |
| | #30 | 600 µm | | | | | |
| | #40 | 425 µm | | 97 | 100 | | |
| | #50 | 300 µm | | | | | |
| | #100 | 150 µm | 100 | 97 | 98 | | |
| | #200 | 75 µm | 96 | 97 | 96 | | |
| | | 20 µm | | | | | |
| | | 2 µm | | | | | |
| | | 1 µm | | | | | |
| AASHTO T 255 | Moisture, % | | 28.2 | 26.9 | 41.8 | 33.3 | 29.8 |
| AASHTO T 89 & T 90 | Liquid Limit | | 29 | 38 | 76 | | |
| | Plasticity Index | | 5 | 20 | 45 | | |
| Soil Classification | AASHTO M 145 | | A-4 (5) | A-6 (20) | A-7-5 (52) | | |
| | ASTM D 2487 | | ML | CL | CH | | |
| AASHTO T 208 | Wet / Dry Density, pcf | | | | | 106 / 80 | 109 / 84 |
| AASHTO T 288 | Min. Resistivity, ohm-cm | | | | | | |
| AASHTO T 289 | pH | | | | | | |
| AASHTO Method | Optimum Moisture, % | | | | | | |
| | Maximum Dry Density, pcf | | | | | | |

**Distribution:**

| | |
|---|---|
| Laboratory | Num. / Project File |
| | Darrell Harding |
| Geotechnical | Charlie Martinez |
| Materials | 1 Copy |

**Remarks:**
Moisture contents and densities were the only tests requested on samples 06-478-T & 06-479-T.

Reported By:

Darrell Harding

U.S. Department of Transportation
Federal Highway Administration

# Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

AASHTO R18 ISO/IEC 17025

## Report of Soil or Aggregate Tests



**Project:** North Dakota PRA THRO 10 (3) North Unit Scenic Drive

**Submitted By:** Charlie Martinez

**Date Reported:** 6/19/2006

| | | | 06-480-SB | 06-481-SB | 06-482-SB | 06-483-SB | 06-484-SB |
|---|---|---|---|---|---|---|---|
| Sample Number | Lab Number | | 06-480-SB | 06-481-SB | 06-482-SB | 06-483-SB | 06-484-SB |
| | Hole Number | | B-5 | B-5 | B-6 | B-7 | B-8 |
| | Field Number | | SPT 1 | SPT 4,5,6 | SPT 3 | SPT 1,2 | SPT 1,2 |
| Sample Location | Milepost | | 6.86 | 6.86 | 6.75 | 6.6 | 1.2 |
| | Offset | | Left | Left | Left | Right | Right |
| | Depth, Feet | | 5-6.5 | 20-31.5 | 15-16.5 | 5-11.5 | 5-11.5 |
| AASHTO T 11, T 27 & T 88 Washed Sieve Analysis % Passing | 3" | 75.0 mm | | | | | |
| | 1 1/2" | 37.5 mm | | | | | |
| | 1" | 25.0 mm | | | | | |
| | 3/4" | 19.0 mm | | | | | |
| | 1/2" | 12.5 mm | | | | | 100 |
| | 3/8" | 9.5 mm | | | | | 99 |
| | #4 | 4.75 mm | | | | 100 | 97 |
| | #8 | 2.36 mm | | | | | |
| | #10 | 2.00 mm | 100 | | | 98 | 94 |
| | #16 | 1.18 mm | 99 | | | 98 | 92 |
| | #30 | 600 µm | | | | | |
| | #40 | 425 µm | 99 | 100 | 100 | 97 | 88 |
| | #50 | 300 µm | | | | | |
| | #100 | 150 µm | 99 | 99 | 84 | 90 | 81 |
| | #200 | 75 µm | 97 | 99 | 58 | 77 | 70 |
| | | 20 µm | | | | | |
| | | 2 µm | | | | | |
| | | 1 µm | | | | | |
| AASHTO T 255 | Moisture, % | | 32.9 | 33.7 | 12.4 | 22.5 | 18.0 |
| AASHTO T 89 & T 90 | Liquid Limit | | 46 | 42 | * | 35 | 40 |
| | Plasticity Index | | 28 | 22 | * | 16 | 22 |
| Soil Classification | AASHTO M 145 | | A-7-6 (29) | A-7-6 (24) | | A-6 (11) | A-6 (14) |
| | ASTM D 2487 | | CL | CL | | CL | CL |
| AASHTO T 208 | Wet / Dry Density, pcf | | | | | | |
| AASHTO T 288 | Min. Resistivity, ohm-cm | | | | | | |
| AASHTO T 289 | pH | | | | | | |
| AASHTO Method | Optimum Moisture, % | | | | | | |
| | Maximum Dry Density, pcf | | | | | | |

**Distribution:**

| | |
|---|---|
| Laboratory | Num. / Project File |
| | Darrell Harding |
| Geotechnical | Charlie Martinez |
| Materials | 1 Copy |

**Remarks:**
* An insufficient amount of material was furnished to perform plasticity index testing.

Reported By:
Darrell Harding

# APPENDIX D – Analysis

**PROJECT IDENTIFICATION**

Title:
Project Number: -
Client:
Designer: JTH
Station Number:

**Description:** RSS Design for Segment 2 of ND PRA THRO 10(4)

**Company's information:**

Name:
Street:
,
Telephone #:
Fax #:
E-Mail:

**Original file path and name:** N:\ND\thro10(4)\Geotech\5_Analysis\ReSSA2.MSE
**Original date and time of creating this file:** Tue Sep 11 06:40:44 2007

**PROGRAM MODE:** ANALYSIS of a Simple Slope using GEOSYNTHETIC as reinforcing material.

## INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

### SOIL DATA

| ========== Soil Layer #: ========== | Unit weight, γ [lb/ft ³] | Internal angle of friction, ϕ [deg.] | Cohesion, c [lb/ft ²] |
|---|---|---|---|
| REINFORCED SOIL.......................................... | 120.0 | 32.0 | 100.0 |
| RETAINED SOIL............................................ | 115.0 | 28.0 | 200.0 |
| FOUNDATION SOIL...................................... | 115.0 | 28.0 | 200.0 |

### REINFORCEMENT

| Reinforcement Type # | Geosynthetic Designated Name | Ultimate Strength, Tult [lb/ft] | Reduction Factor for Installation Damage, Rfid | Reduction Factor for Durability, RFd | Reduction Factor for Creep, RFc | Coverage Ratio, Rc |
|---|---|---|---|---|---|---|
| 1 | Geosynthetic type #1 | 3150.00 | 1.10 | 1.10 | 2.48 | 1.00 |

| Interaction Parameters Type # | Geosynthetic Designated Name | == Direct Sliding == Cds-phi | Cds-c | ==== Pullout ==== Ci | Alpha |
|---|---|---|---|---|---|
| 1 | Geosynthetic type #1 | 0.80 | 0.00 | 0.80 | 0.80 |

Relative Orientation of Reinforcement Force, ROR = 0.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50

### WATER

Water is not present

### SEISMICITY

Not Applicable

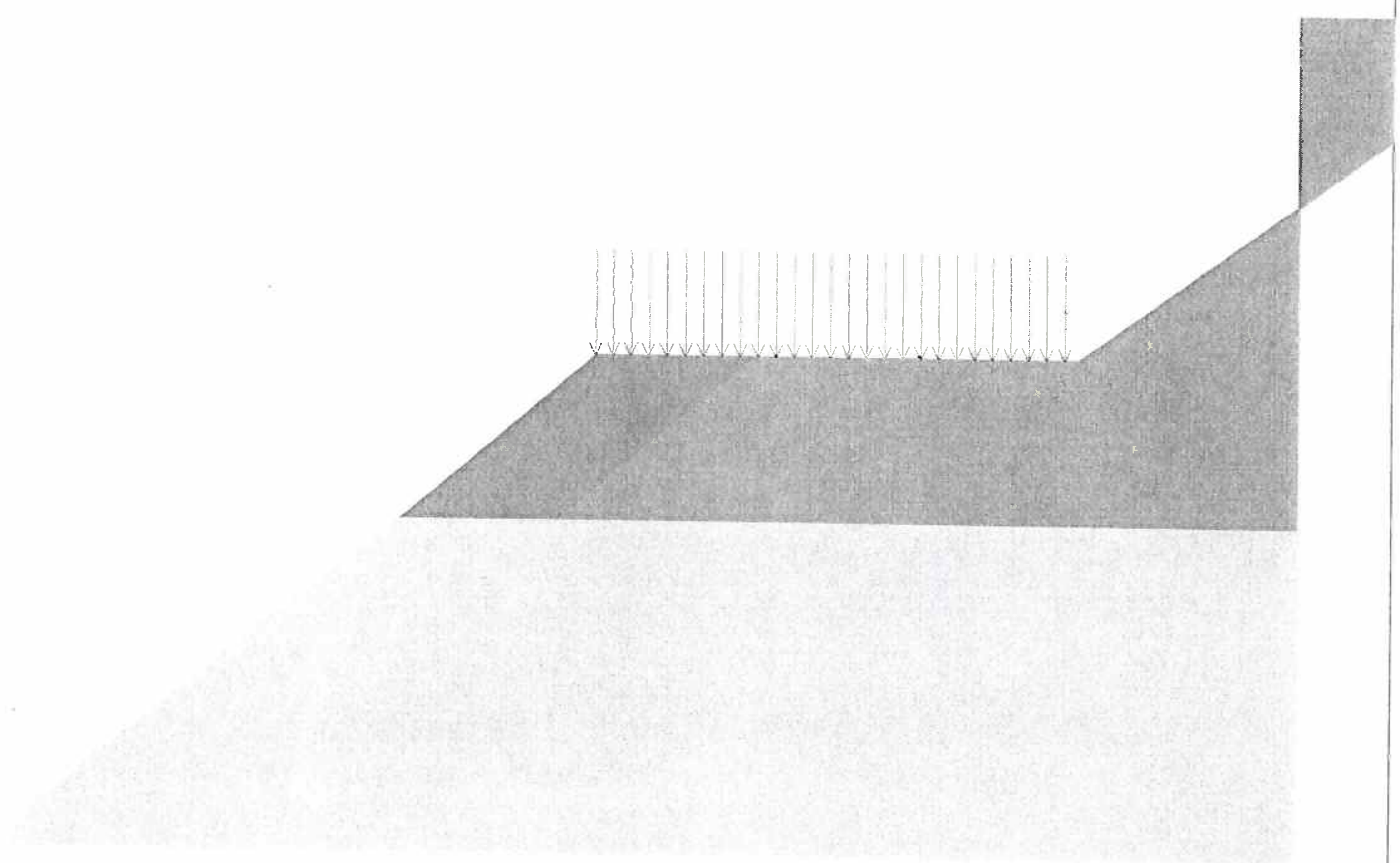
## DRAWING OF SPECIFIED GEOMETRY - SIMPLE

### GEOMETRY

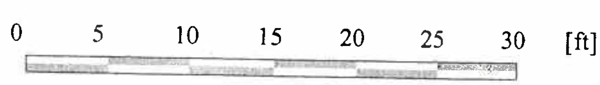
| | | |
|---|---|---|
| Height of slope, H | 10.00 | [ft] |
| Slope angle, i | 39.00 | [deg.] |
| Horizontal crest length, A | 30.00 | [ft] |
| Horizontal crest length, B | 30.00 | [ft] |
| Backslope angle, β | 35.00 | [deg.] |
| Sloping angle, α | 38.00 | [deg.] |

### UNIFORM SURCHARGE

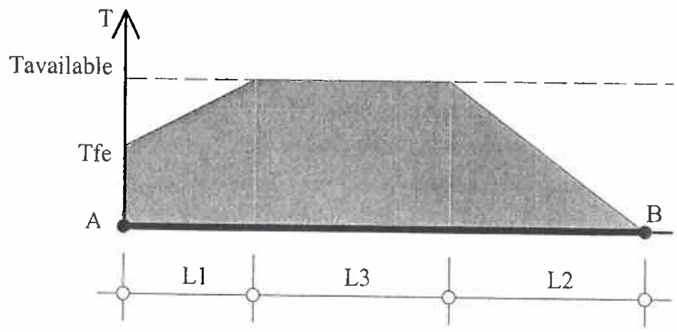
| | | |
|---|---|---|
| Surcharge load over A, Q1 | 250.00 | [lb/ft²] |
| Surcharge load over backslope B, Q2 | 0.00 | [lb/ft²] |
| Surcharge load away from backslope, Q3 | 0.00 | [lb/ft²] |



SCALE:



## DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER




A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

| Reinforcement Layer # | Designated Name | Height Relative to Toe [ft] | L [ft] | L1 [ft] | L2 [ft] | L3 [ft] | Tfe [lb/ft] | Tavailable [lb/ft] |
|---|---|---|---|---|---|---|---|---|
| 1 | Geosynthetic type #1 | 0.00 | 10.00 | 0.00 | 2.07 | 7.93 | 1049.72 | 1049.72 |
| 2 | Geosynthetic type #1 | 2.00 | 10.00 | 0.00 | 1.90 | 8.10 | 1049.72 | 1049.72 |
| 3 | Geosynthetic type #1 | 4.00 | 10.00 | 0.00 | 2.26 | 7.74 | 1049.72 | 1049.72 |
| 4 | Geosynthetic type #1 | 6.00 | 10.00 | 0.00 | 3.08 | 6.92 | 1049.72 | 1049.72 |
| 5 | Geosynthetic type #1 | 8.00 | 10.00 | 0.00 | 4.92 | 5.08 | 1049.72 | 1049.72 |

## RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

**Critical circles for each entry point (considering all specified exit points)**

| Entry Point # | Entry Point (X, Y) [ft] | | Exit Point (X, Y) [ft] | | Critical Circle (Xc, Yc, R) [ft] | | | Fs | STATUS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 10.00 | 8.10 | -10.27 | -7.75 | -6.56 | 8.39 | 16.56 | 2.52 | |
| 2 | 12.00 | 9.72 | -10.29 | -7.75 | -6.21 | 10.01 | 18.22 | 2.28 | |
| 3 | 14.00 | 10.00 | -10.20 | -7.75 | -4.81 | 10.28 | 18.82 | 1.90 | |
| 4 | 16.00 | 10.00 | -10.30 | -7.74 | -5.18 | 13.04 | 21.40 | 1.75 | |
| 5 | 18.00 | 10.00 | -10.12 | -7.80 | -7.62 | 19.37 | 27.28 | 1.62 | |
| 6 | 20.00 | 10.00 | -10.00 | -7.81 | -10.00 | 26.36 | 34.17 | 1.55 | OK |
| 7 | 22.00 | 10.00 | -10.14 | -7.82 | -11.40 | 32.36 | 40.20 | 1.57 | |
| 8 | 24.00 | 10.00 | -10.28 | -7.82 | -10.75 | 34.97 | 42.79 | 1.62 | |
| 9 | 26.00 | 10.00 | -10.07 | -7.81 | -10.82 | 39.13 | 46.95 | 1.67 | |
| 10 | 28.00 | 10.00 | -10.29 | -7.82 | -10.90 | 43.54 | 51.36 | 1.72 | |
| 11 | 30.00 | 10.00 | -10.09 | -7.81 | -10.98 | 48.20 | 56.02 | 1.78 | |

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

*************************

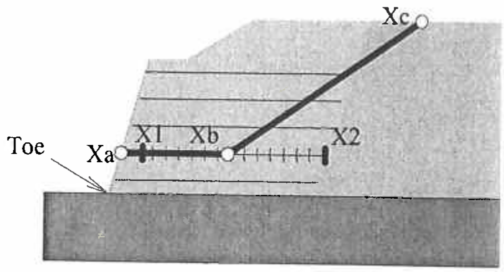
Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

**Critical circles for each exit point (considering all specified entry points)**

| Exit Point # | Exit Point (X, Y) [ft] | | Entry Point (X, Y) [ft] | | Critical Circle (Xc, Yc, R) [ft] | | | Fs | STATUS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -10.00 | -7.81 | 20.00 | 10.00 | -10.00 | 26.36 | 34.17 | 1.55 | On extreme X-exit |
| 2 | -8.78 | -6.63 | 20.00 | 10.00 | -7.95 | 25.14 | 31.78 | 1.59 | |
| 3 | -7.19 | -5.46 | 20.00 | 10.00 | -5.97 | 24.03 | 29.52 | 1.63 | |
| 4 | -5.60 | -4.29 | 20.00 | 10.00 | -4.07 | 23.04 | 27.37 | 1.68 | |
| 5 | -4.21 | -3.11 | 20.00 | 10.00 | -1.85 | 21.45 | 24.67 | 1.74 | |
| 6 | -2.66 | -1.93 | 20.00 | 10.00 | 0.52 | 19.52 | 21.69 | 1.82 | |
| 7 | -1.25 | -0.72 | 20.00 | 10.00 | 3.34 | 16.62 | 17.93 | 1.94 | |
| 8 | 0.30 | 0.45 | 20.00 | 10.00 | 4.15 | 17.59 | 17.57 | 1.93 | |
| 9 | 1.98 | 1.63 | 20.00 | 10.00 | 6.81 | 14.82 | 14.05 | 2.11 | |
| 10 | 3.41 | 2.87 | 20.00 | 10.00 | 7.97 | 15.12 | 13.07 | 2.26 | |
| 11 | 4.98 | 4.06 | 20.00 | 10.00 | 9.97 | 13.40 | 10.59 | 2.64 | |

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

## RESULTS OF TRANSLATIONAL ANALYSIS




Results in the table below represent critical two-part wedges identified between specified starting (X1) and ending (X2) search points. Wedges along all reinforcement layers and at elevation zero are reported. The critical two-part wedge, one for each predetermined elevation, is defined by Xa, Xb and Xc where Xa is the front end of the passive wedge (slope face), Xb is where the passive wedge ends and the active one starts, and Xc is the X-ordinate at which the active wedge starts.

**Critical two-part wedge along each interface:**

| Interface | Height Relative to Toe [ft] | ( Xa, Ya ) [ft] | | ( Xb, Yb ) [ft] | | ( Xc, Yc ) [ft] | | Fs | STATUS |
|---|---|---|---|---|---|---|---|---|---|
| At toe elevation | 0.00 | 0.00 | 0.00 | 9.89 | 0.00 | 22.24 | 10.00 | 1.53 | OK |
| Reinf. Layer #1 | 0.00 | 0.00 | 0.00 | 9.89 | 0.00 | 22.24 | 10.00 | 1.53 | Minimum on Edge |
| Reinf. Layer #2 | 2.00 | 2.47 | 2.00 | 12.39 | 2.00 | 22.27 | 10.00 | 1.76 | Minimum on Edge |
| Reinf. Layer #3 | 4.00 | 4.94 | 4.00 | 14.79 | 4.00 | 22.20 | 10.00 | 2.23 | Minimum on Edge |
| Reinf. Layer #4 | 6.00 | 7.41 | 6.00 | 17.29 | 6.00 | 22.23 | 10.00 | 2.96 | Minimum on Edge |
| Reinf. Layer #5 | 8.00 | 9.88 | 8.00 | 12.04 | 8.00 | 14.04 | 10.00 | 3.14 | OK |

Note: In the 'Status' column, OK means the critical two part-wedge was identified within the specified search domain. 'Minimum on Edge' means the critical result corresponds to a minimum on the edge of the search domain; i.e., either on X1 or X2 or the internally preset limits on Xc.

## CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

### Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.55

Critical Circle: Xc = -10.00[ft], Yc = 26.36[ft], R = 34.17[ft]. (Number of slices used = 55 )

### Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

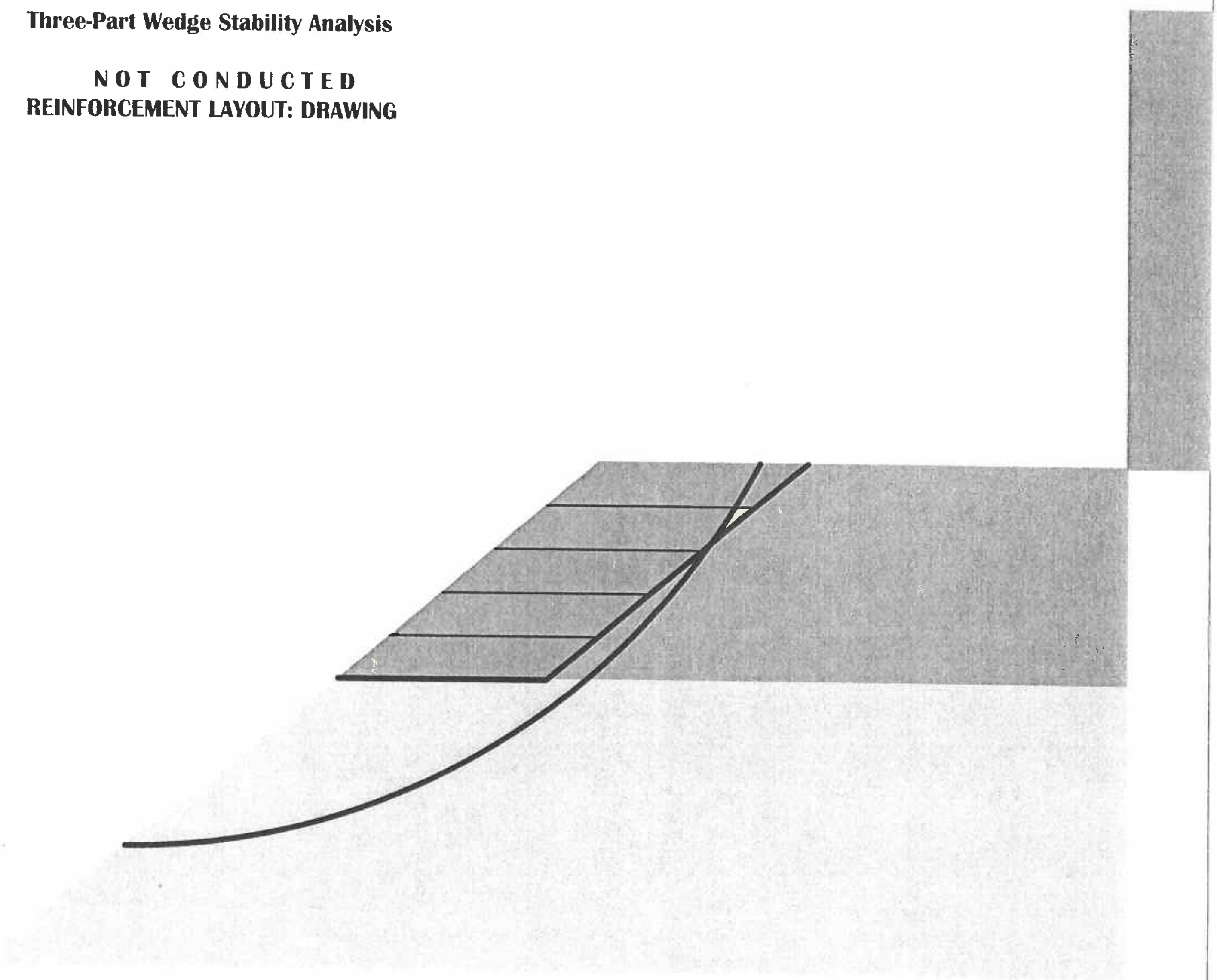
Minimum Factor of Safety = 1.53

Critical Two-Part Wedge: (Xa = 0.00, Ya = 0.00) [ft]
(Xb = 9.89, Yb = 0.00) [ft]
(Xc = 22.24, Yc = 10.00) [ft]
(Number of slices used = 30 )
Interslice resultant force inclination = 25.00 [degrees]

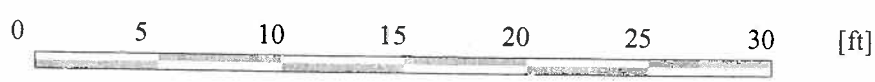
### Three-Part Wedge Stability Analysis

NOT CONDUCTED

### REINFORCEMENT LAYOUT: DRAWING



**SCALE:**

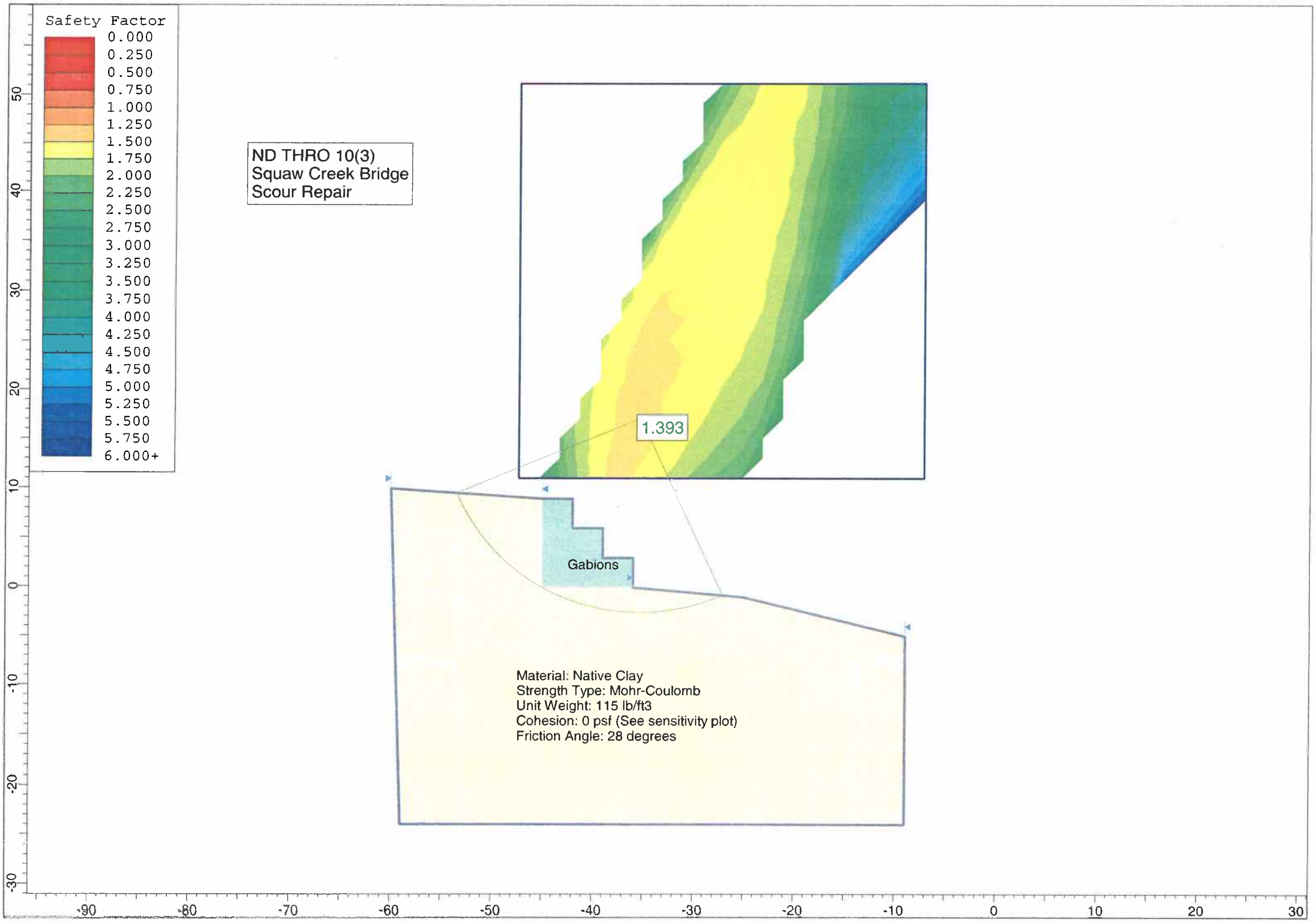


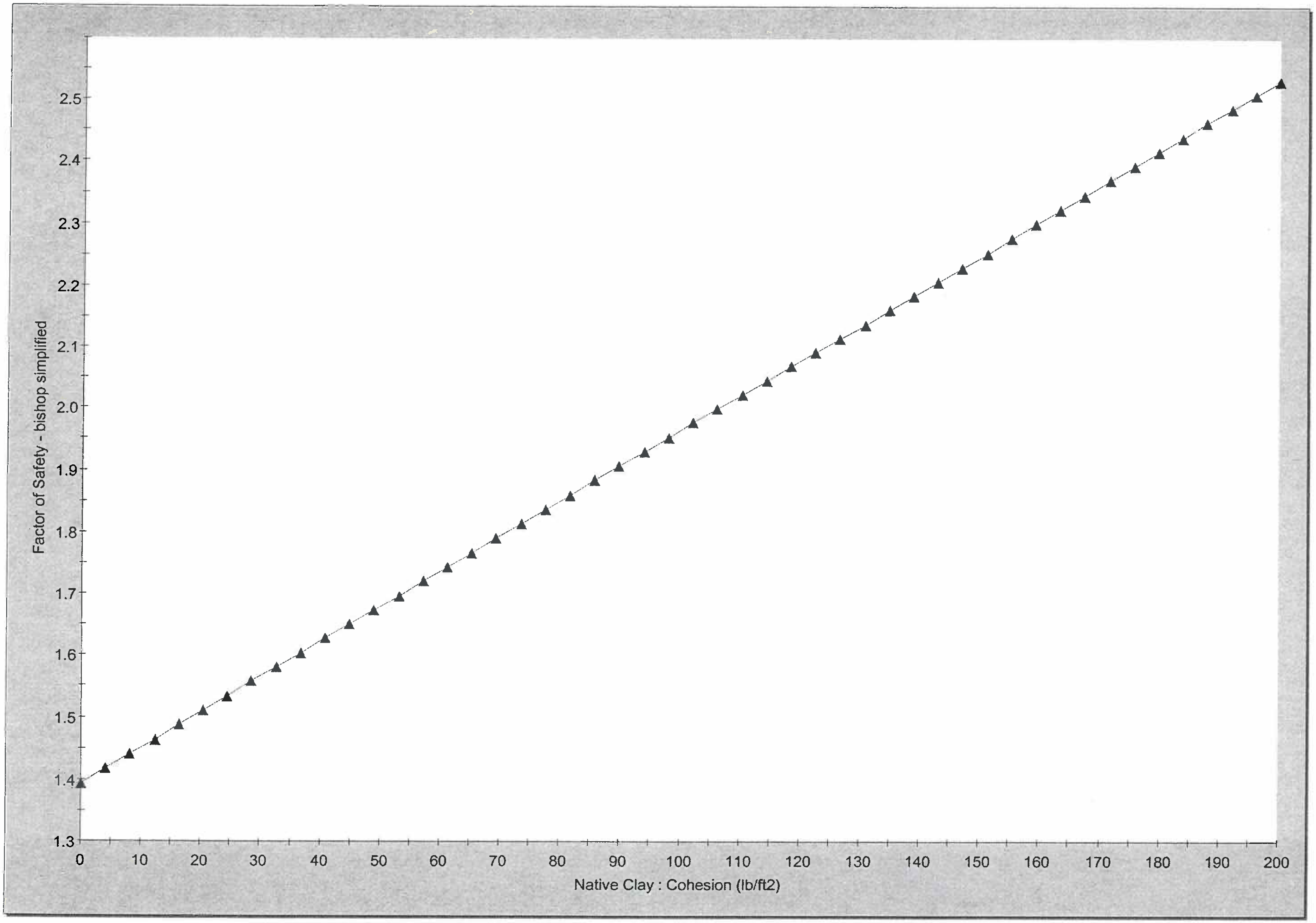
## REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

| Layer # | Reinf. Type # | Geosynthetic Designated Name | Height Relative to Toe [ft] | Embedded Length [ft] | Covergae Ratio, Rc | ( X, Y ) front [ft] | | ( X, Y ) rear [ft] | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Geosynthetic type #1 | 0.00 | 10.00 | 1.00 | 0.00 | 0.00 | 10.00 | 0.00 |
| 2 | 1 | Geosynthetic type #1 | 2.00 | 10.00 | 1.00 | 2.47 | 2.00 | 12.47 | 2.00 |
| 3 | 1 | Geosynthetic type #1 | 4.00 | 10.00 | 1.00 | 4.94 | 4.00 | 14.94 | 4.00 |
| 4 | 1 | Geosynthetic type #1 | 6.00 | 10.00 | 1.00 | 7.41 | 6.00 | 17.41 | 6.00 |
| 5 | 1 | Geosynthetic type #1 | 8.00 | 10.00 | 1.00 | 9.88 | 8.00 | 19.88 | 8.00 |

## QUANTITIES

| Reinf. Type # | Designated Name | Coverage Ratio | Area of reinforcemnt [ft²] / length of slope [ft] |
|---|---|---|---|
| 1 | Geosynthetic type #1 | 1.00 | 50.00 |


Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
ND THRO 10(3)
Squaw Creek Bridge
Scour Repair
1.393
Gabions
Material: Native Clay
Strength Type: Mohr-Coulomb
Unit Weight: 115 lb/ft3
Cohesion: 0 psf (See sensitivity plot)
Friction Angle: 28 degrees
50
40
30
20
10
0
-10
-20
-30
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30

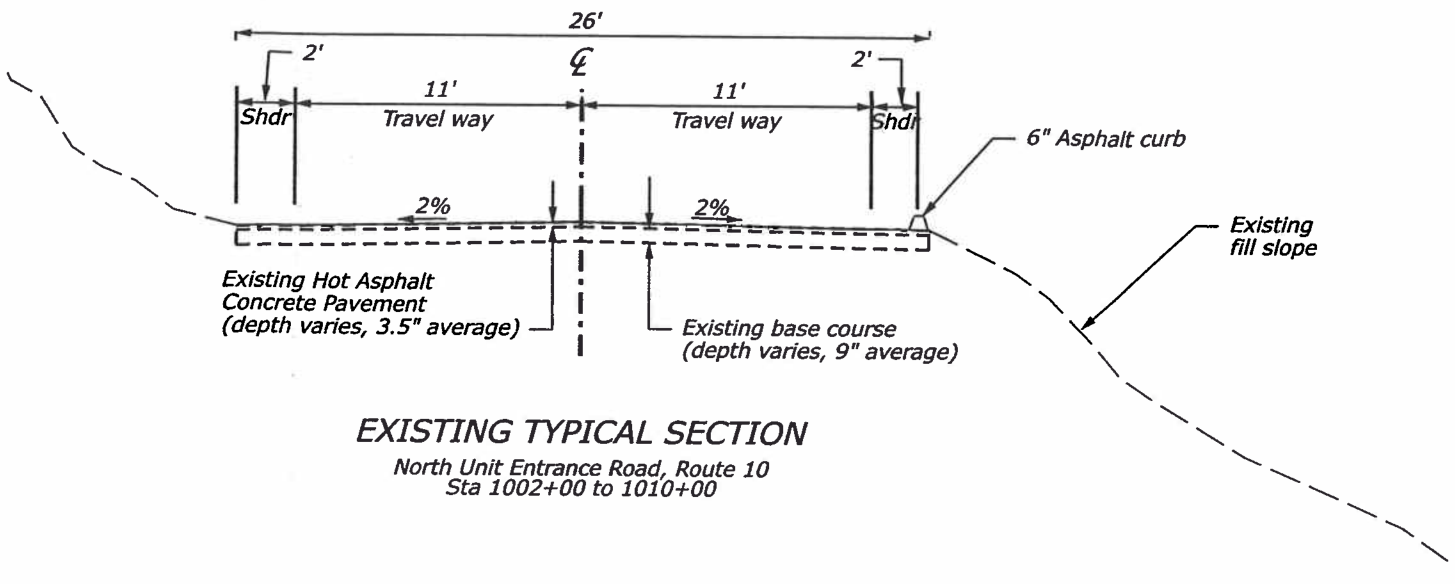

Factor of Safety - bishop simplified
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Native Clay : Cohesion (lb/ft2)

| REG | STATE | PROJECT | SHEET NO. | TOTAL SHEETS |
|---|---|---|---|---|
| 16 | ND | TEDDY ROOSEVELT THRO 10(4) | A7 | A9 |

## NOTE:

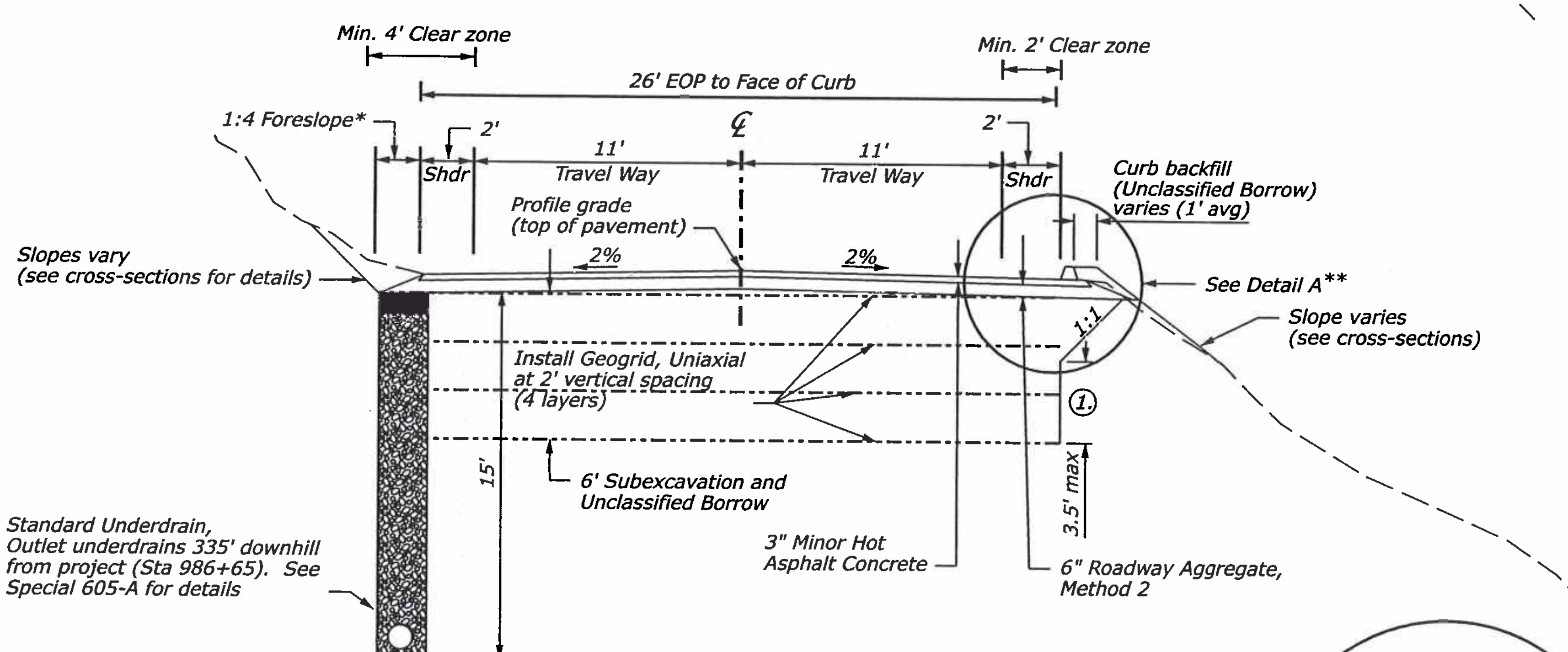
1. Maximum vertical face for subexcavation is 3.5 ft. Beyond 3.5 ft, cut at a 1:1 slope as shown in the cross-sections.
2. Full depth excavation occurs from 1003+50 to 1008+50. Taper from zero subexcavation at 1002+00 to full depth subexcavation at 1003+50. At the end, taper from full depth subexcavation at 1008+50 to zero excavation at 1010+00.
3. Clearing limits extend 5 ft beyond the outer limit of slope rounding for cuts and 5 ft beyond the toe of fill.

| LENGTH OF PROJECT | | | |
|---|---|---|---|
| Station to station | Description | Length (feet) | Length (miles) |
| | Slope Improvements Near Visitor Center | 725 | 0.137 |
| 1002+00 to 1010+00 | Segment 1, Entrance Road | 800 | 0.152 |
| 1047+50 to 1049+50 | Segment 2, Entrance Road | 200 | 0.038 |
| 1052+50 to 1055+50 | Segment 3, Entrance Road | 300 | 0.057 |
| | TOTAL | | 0.384 |



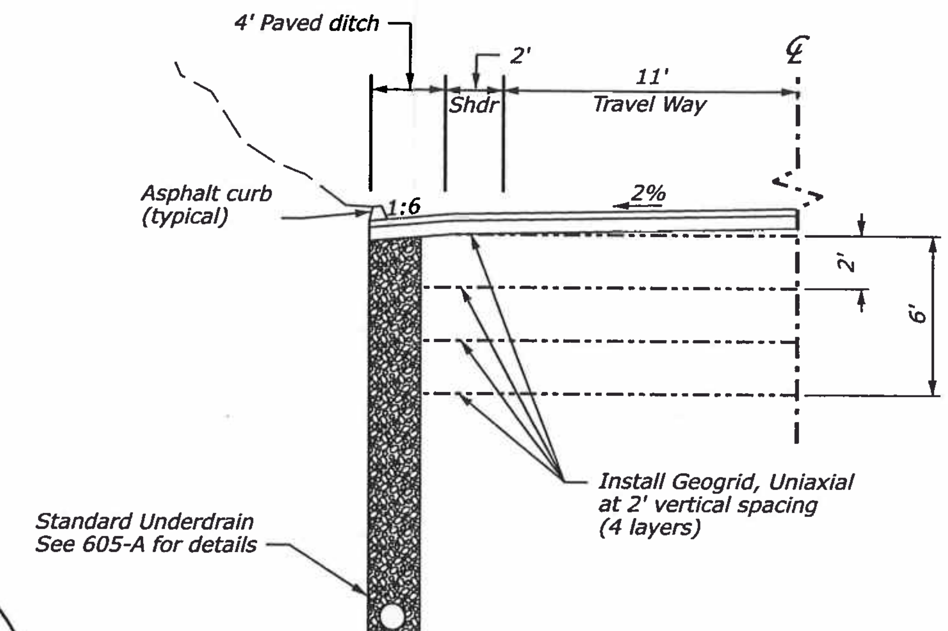

## EXISTING TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1002+00 to 1010+00



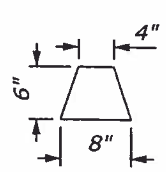

## PROPOSED TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1002+00 to 1010+00*
* See Paved Ditch Typical Section Also

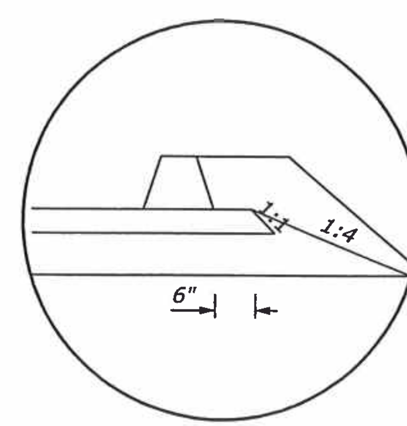



## PAVED DITCH TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1002+00 to 1004+30 and
1004+70 to 1007+75




## 6" ASPHALT CURB DETAILS




## DETAIL A

** CURB, ASPHALT, 6-INCH DEPTH
Sta 1002+00 to 1004+50, rt

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

## TYPICAL SECTIONS SEGMENT 1

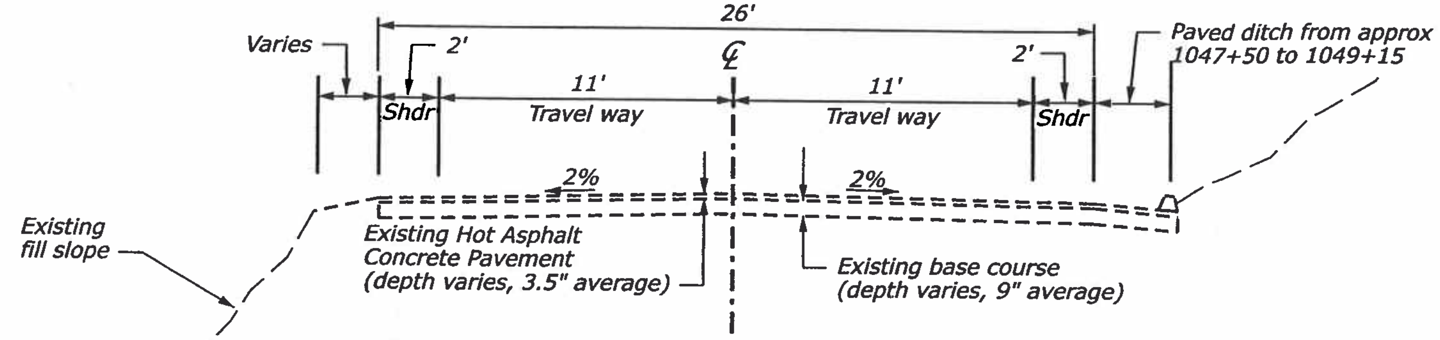
SHEET 1 OF 3

NPS PMIS NO.: 127543

$$$DATE$$$$ $TIME$ $$$DGN$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

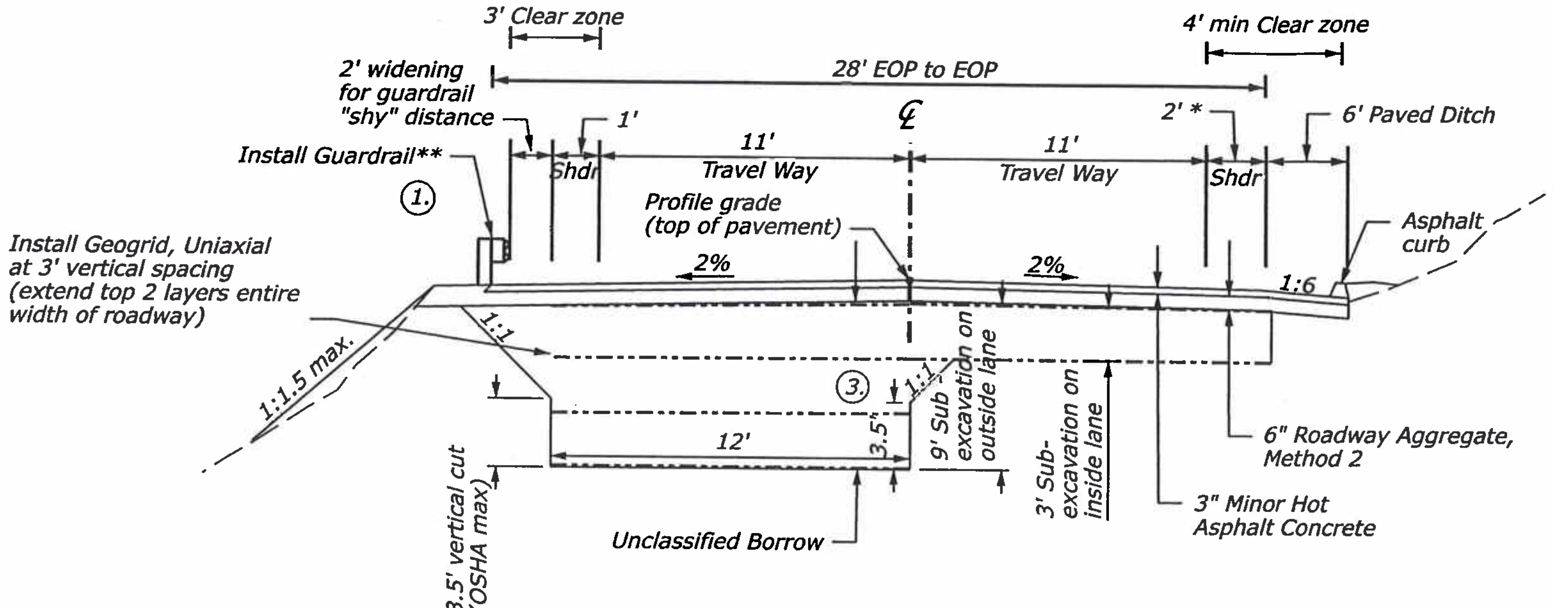
...\sheets\A-Gen_sht\TYP_149_1.dgn 12/27/2007 10:52:15 AM

| REG | STATE | PROJECT | SHEET NO. | TOTAL SHEETS |
|---|---|---|---|---|
| 16 | ND | TEDDY ROOSEVELT THRO 10(4) | A8 | A9 |



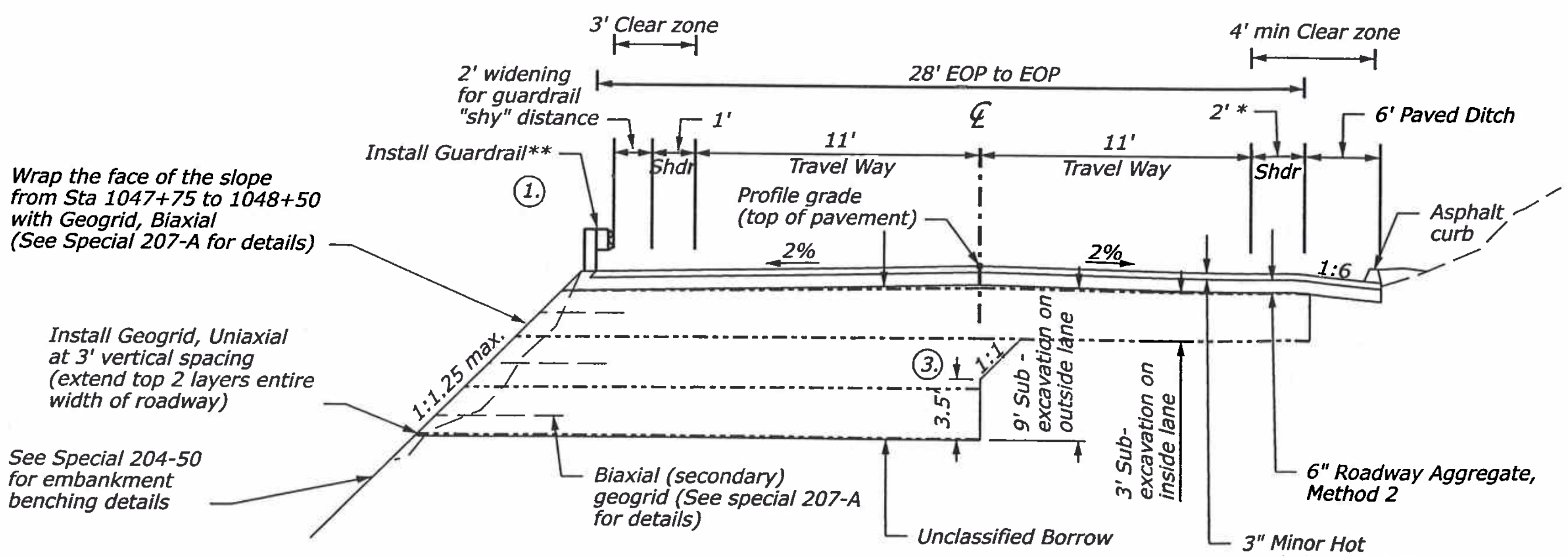

## EXISTING TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1047+50 TO 1049+50




## PROPOSED TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1047+50 to 1047+75 and 1048+55 to 1049+50
* See cross-sections for curve widening
** Guardrail from Sta 1047+05 to 1050+30

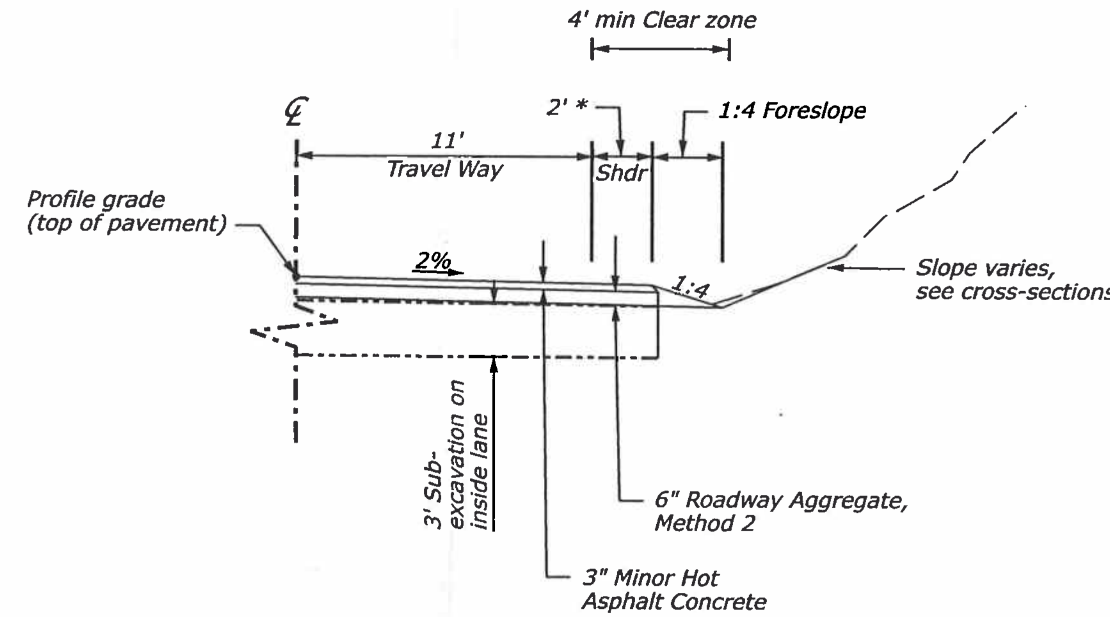



## PROPOSED TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1047+75 to 1048+50
* See cross-sections for curve widening
** Guardrail from Sta 1047+05 to 1050+30

NOTE:

1. Where it is not possible to maintain a 24-inch distance between the back of the post and the top of a 1:2 or steeper slope, increase the standard guardrail post by 12 inches.
2. Full depth subexcavation occurs from Sta 1047+75 to 1048+40. Taper from zero subexcavation at 1047+50 to full depth subexcavation at Sta 1047+75. At the end, taper from full depth subexcavation at 1048+50 to 3' subexcavation on both lanes at Sta 1048+75. Carry 3' subexcavation to the end of Segment 2.
3. Maximum vertical face for subexcavation is 3.5 ft. Beyond 3.5 ft, cut at a 1:1 slope as shown in the cross-sections.
4. Extend subexcavation to the slope face and wrap slope from Sta 1047+75 to 1048+50. See Special 207-A for details.
5. Clearing limits extend 5 ft beyond the outer limit of slope rounding for cuts and 5 ft beyond the toe of fill.




## PROPOSED TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1049+15 to 1049+50
* See cross-sections for curve widening
** Guardrail from Sta 1047+05 to 1050+30

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

TYPICAL SECTIONS
SEGMENT 2

SHEET 2 OF 3

$$$$DGN$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $TIME$ $$$$DATE$$$$

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| REG | STATE | PROJECT | SHEET NO. | TOTAL SHEETS |
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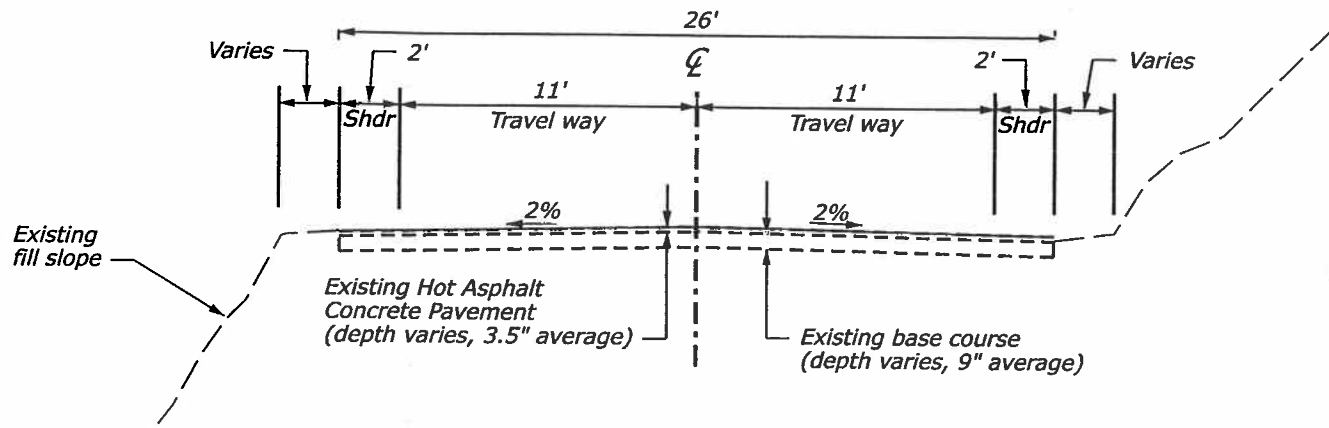
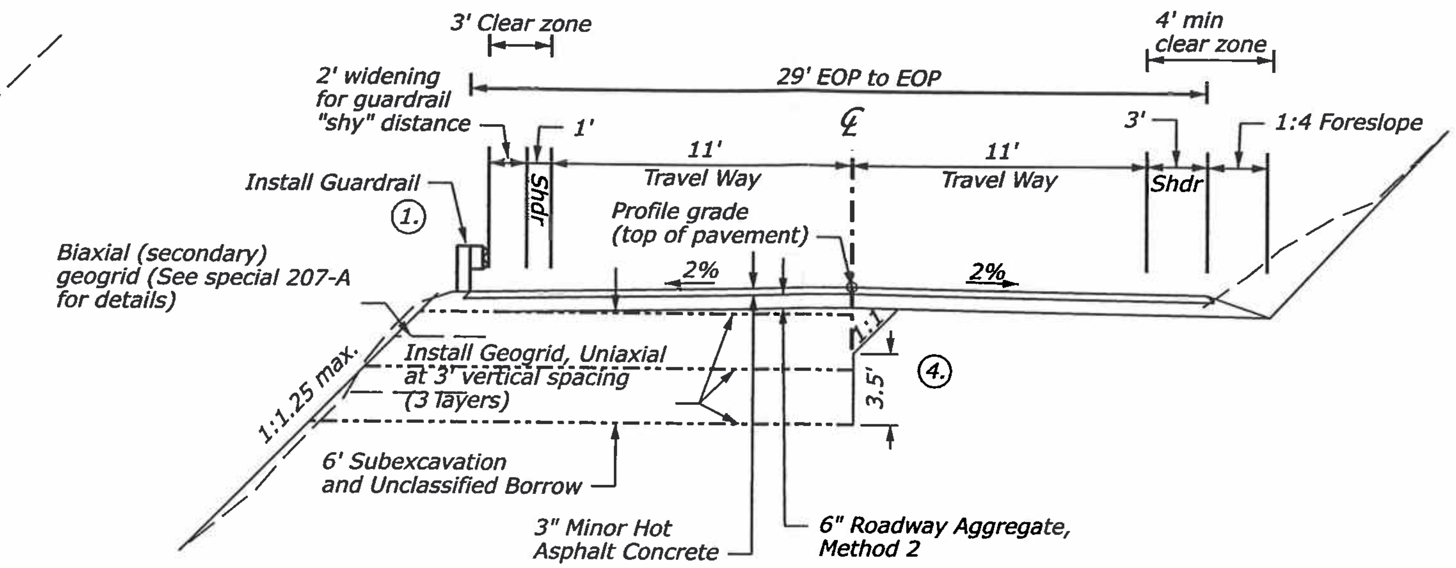
| 16 | ND | TEDDY ROOSEVELT THRO 10(4) | A9 | A9 |



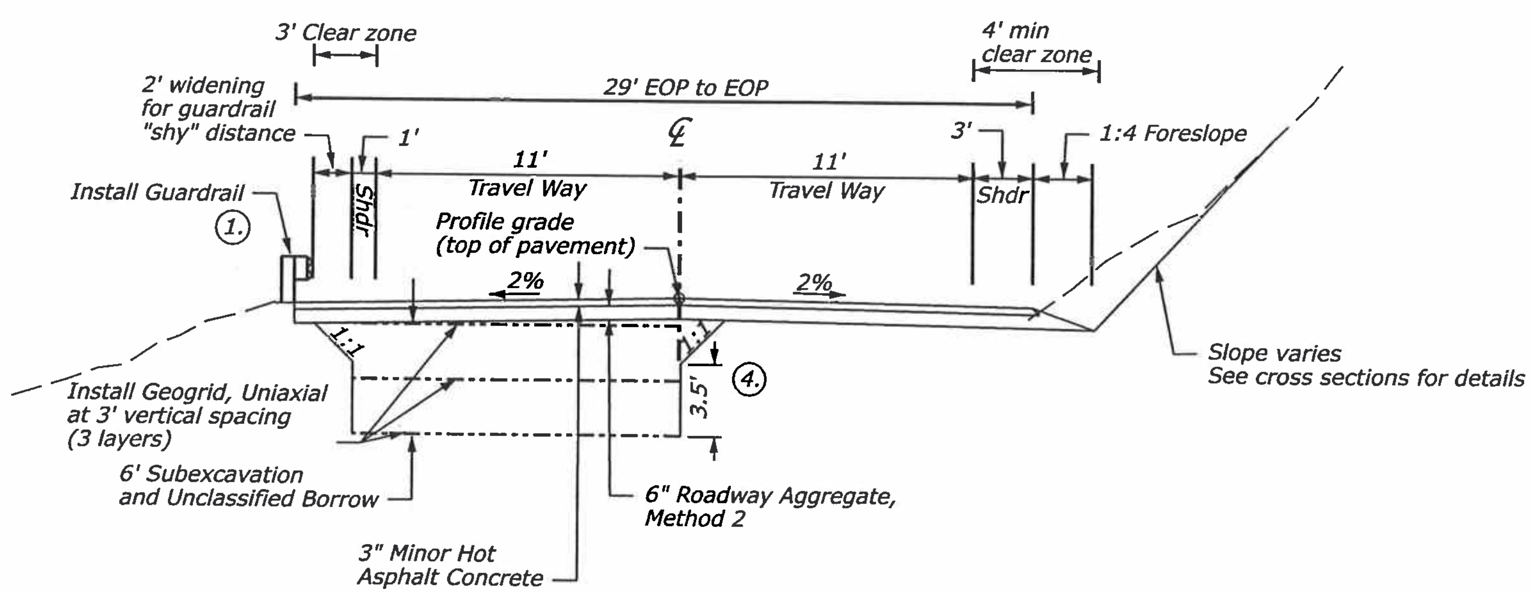

## EXISTING TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1052+50 TO 1055+50




## PROPOSED TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1052+50 to 1055+50




## PROPOSED TYPICAL SECTION

North Unit Entrance Road, Route 10
Sta 1052+50 to 1055+50

NOTE:

1. Where it is not possible to maintain a 24-inch distance between the back of the post and the top of a 1:2 or steeper slope, increase the standard guardrail post by 12 inches.
2. Full depth subexcavation occurs from Sta 1052+75 to 1055+25. Taper from zero subexcavation at Sta 1052+50 to full depth subexcavation at 1052+75. At the end, taper from full depth subexcavation at 1055+25 to zero subexcavation at 1055+50.
3. Extend subexcavation to the slope face and wrap slope from sta 1054+60 to 1055+40. See Special 207-A for details.
4. Maximum vertical face for subexcavation is 3.5 ft. Beyond 3.5 ft, cut at a 1:1 slope as shown in the cross-sections.
5. Clearing limits extend 5 ft beyond the outer limit of slope rounding for cuts and 5 ft beyond the toe of fill.

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

# TYPICAL SECTIONS SEGMENT 3

SHEET 3 OF 3

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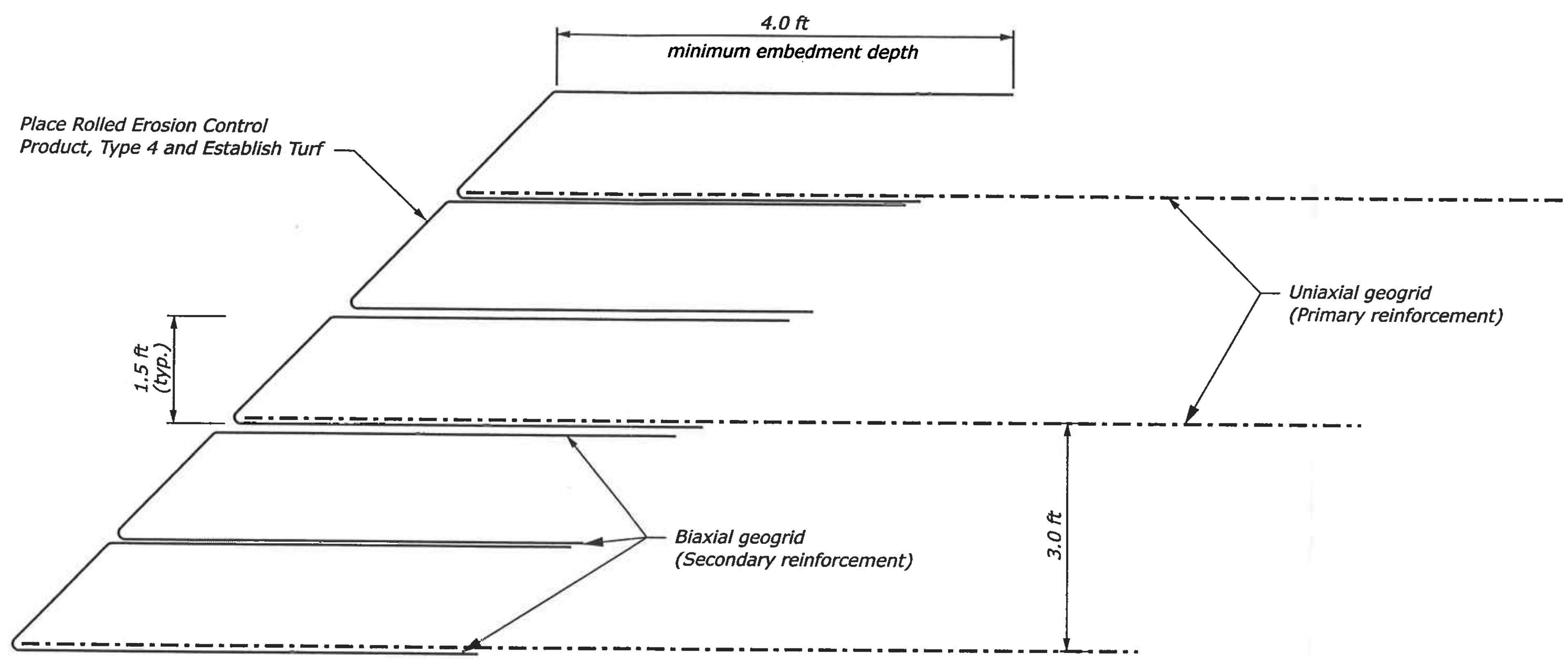


GEOGRID INSTALLATION
ON WRAPPED SLOPE FACES
(TYPICAL SECTION)

$$$$DGN$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $TIME$ $$$$DATE$$$$

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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

U.S. CUSTOMARY SPECIAL

REINFORCED STABILIZED SLOPE

SPECIAL
207-A

| REG | STATE | PROJECT | SHEET NO. | TOTAL SHEETS |
|---|---|---|---|---|
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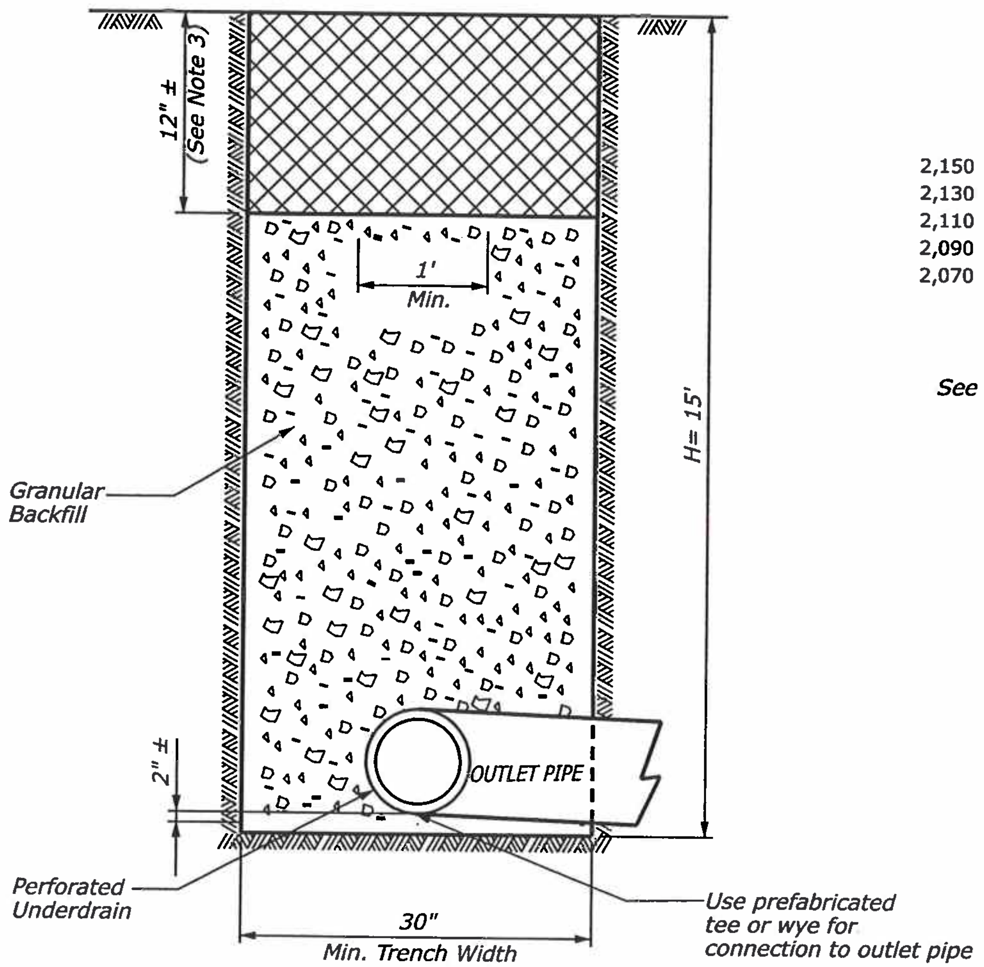
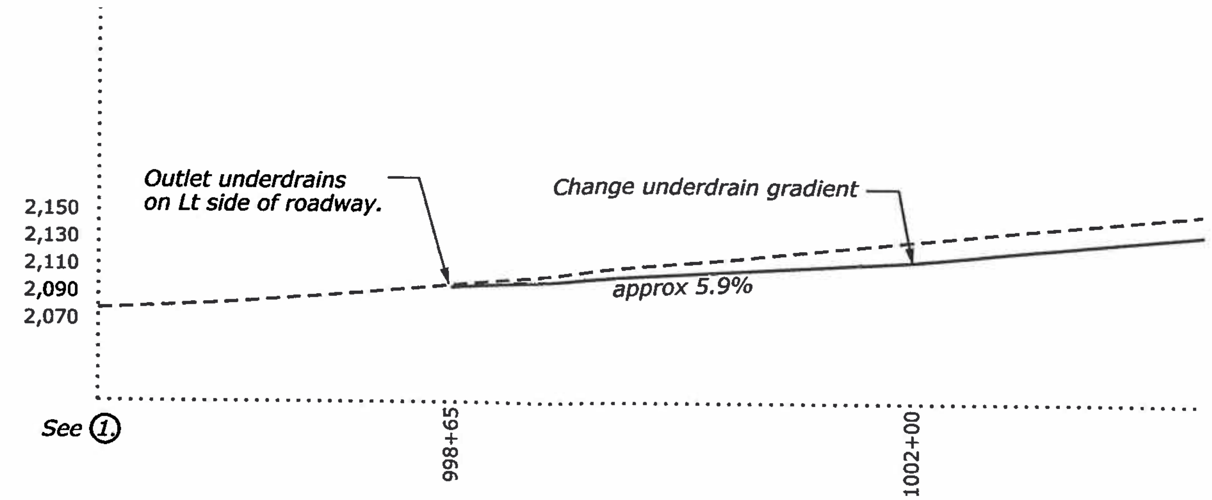


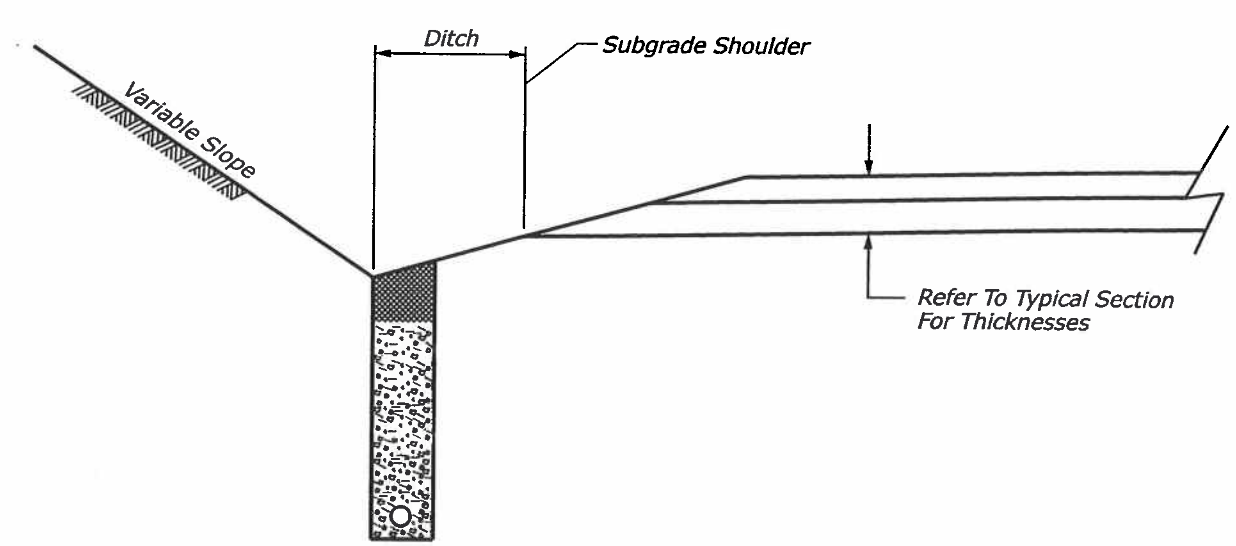

STANDARD UNDERDRAIN



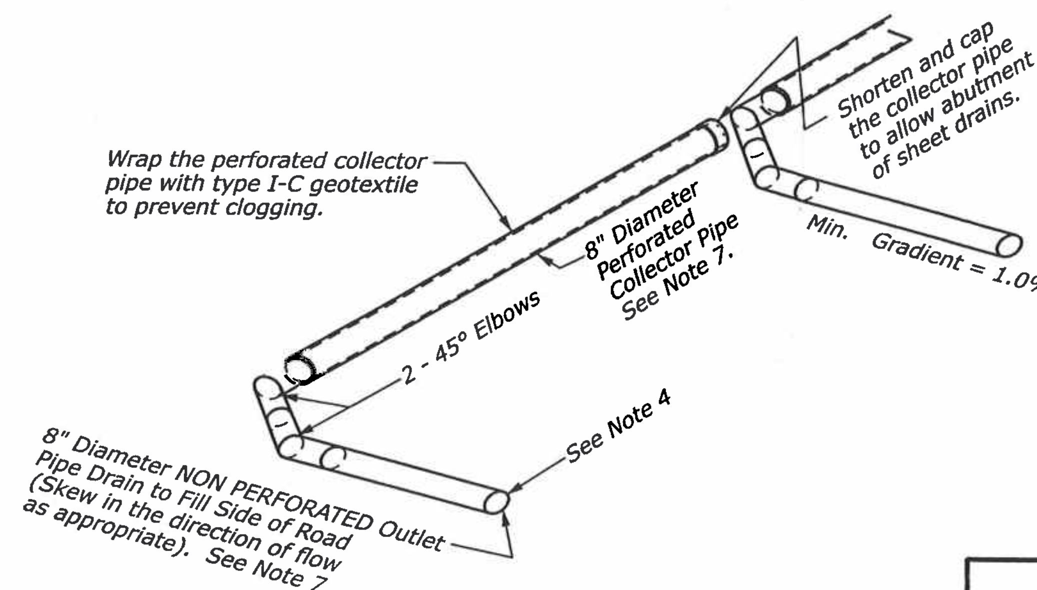

Profile of Existing Ground and Approx Profile of Underdrains

## NOTE:

1. Install underdrain at a 15' depth. Construct the flowline gradient parallel to the roadway from Sta 1002+00 to 1010+00. At Sta 1002+00 change the gradient to outlet the underdrain at approx Sta 986+65. Maintain a minimum cover of 12" under the roadway at the outlet.
2. Use the minimum width required for installation.
3. Fill and compact the top 12" of the 5' underdrain trench with impermeable material (A4-A7 soil), except when underdrains are under the paved ditch. Use granular material for the top 12" when under the paved ditch.
4. Cover the end of the outlet pipe with screen according to Subsection 605.03.Hold the screen securely in place with standard coupling bands or by other approved means.
5. Mark the outlet of the underdrain with a delineator post or other suitable marker (subsidiary to underdrain).
6. Furnish geocomposite sheet drain meeting requirements of subsection 714.02.
7. Furnish collector pipe, outlet pipe & fittings meeting the requirements of subsection 706.08(d).
8. The location of the Standard Underdrain will vary in relation to the ditch. The underdrain shall be installed at the face of the subexcavation as shown in the typical sections as directed by the CO.
9. Remove and replace 4' paved ditch to install the underdrains from Sta 998+65 to 1002+00. Payment will be made under 60908-1000.




STANDARD UNDERDRAIN LOCATION
(See Note 8)




OUTLET PIPE DETAIL

NO SCALE

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FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

U.S. CUSTOMARY SPECIAL

STANDARD UNDERDRAINS

SPECIAL 605-A

$$$$DGN$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ $TIME$ $$$$DATE$$$$

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| REG | STATE | PROJECT | SHEET NO. | TOTAL SHEETS |
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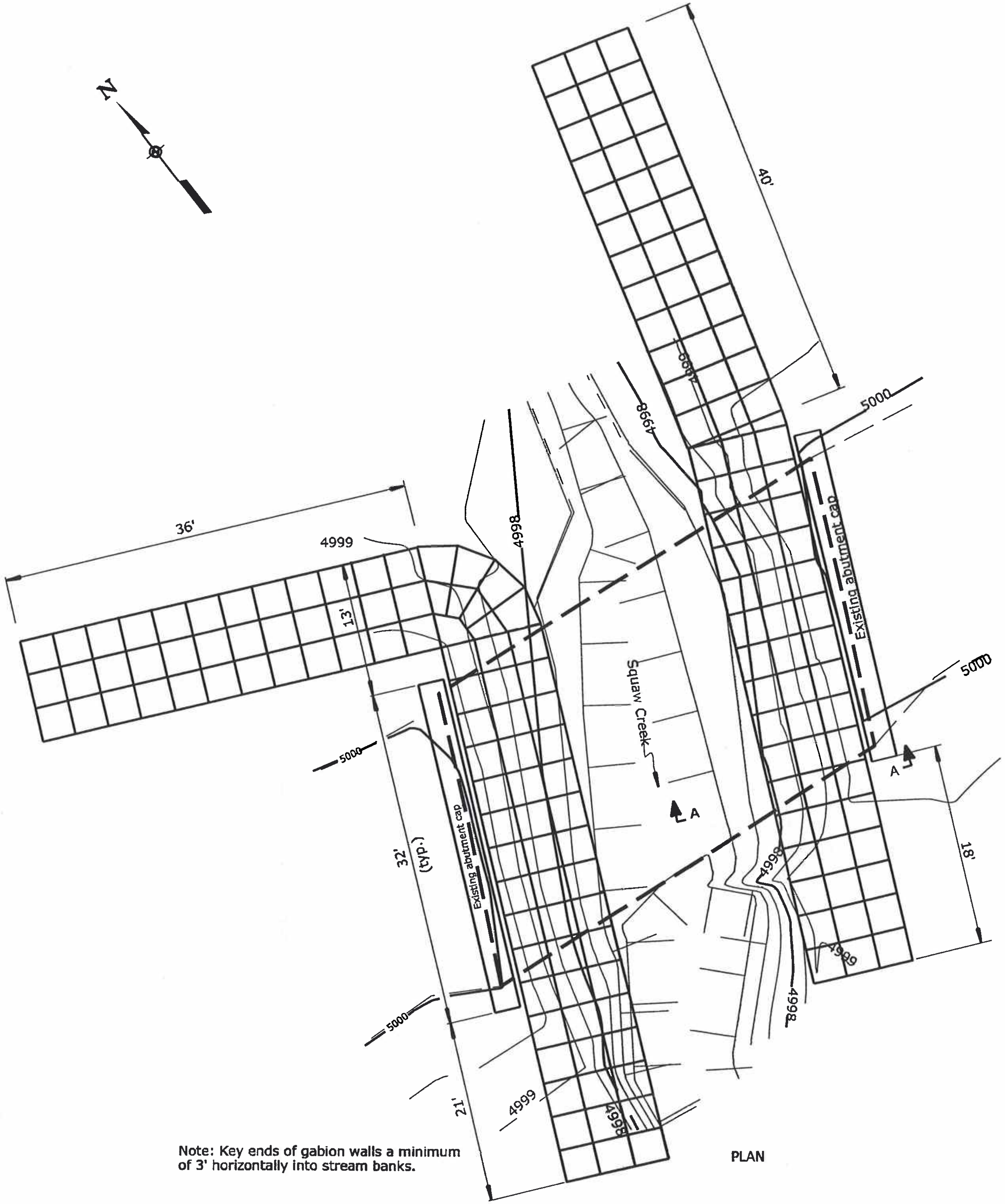
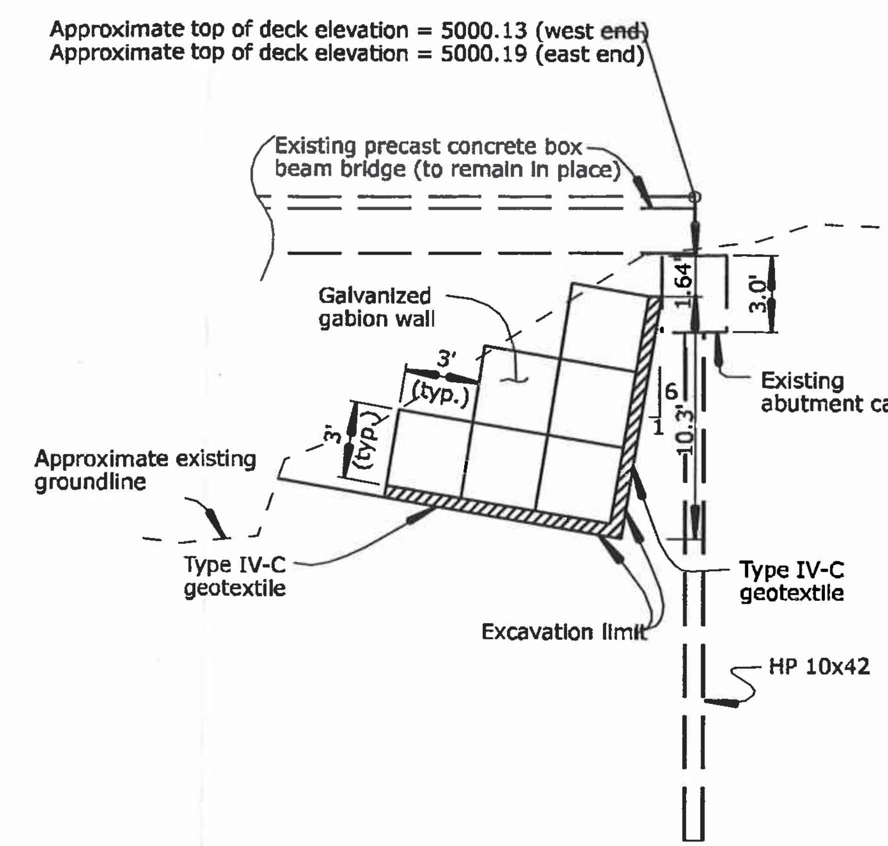


PLAN



SECTION A-A

Notes:

1. Construct gabion walls in accordance with Section 253 of the FP03.
2. Care shall be taken not to excavate beyond the limits specified.
3. Place Type IV-C geotextile material over gabions in areas where the ends of the gabions are turned back into the stream bank before backfilling.
4. Dimensions and elevations for the existing bridge are approximate and shall be verified as needed.
5. Place Geotextile, Type IV-C according to Section 714.
6. Repair damage done to the existing bridge during construction.

Drawing not to scale

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

SQUAW CREEK BRIDGE
SCOUR PROTECTION

$$$$DATE$$$$ $TIME$ $$$$DGN$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

NPS PMIS NO. 63939

# APPENDIX F – Special Contract Requirements

## Section 207. — EARTHWORK GEOTEXTILES

Delete the text of this section and add the following:

### Description

**207.01** This work consists of furnishing and placing a geotextile as a permeable separator, stabilizer, or permanent erosion control measure.

This work also consists of furnishing and placing a geogrid as a soil reinforcement element.

Geotextile types are designated as shown in Subsection 714.01.

### Material

**207.02** Conform to the following Subsection:

| | |
|---|---|
| Geotextile | 714.01 |
| Geogrid | 714.03 |

### Construction Requirements

**207.02 General.** Submit test results to the CO verifying the proposed products meet the criteria as outlined in Section 714.

Where placing a geotextile on native ground, cut the trees and shrubs flush with the ground surface. Do not remove the topsoil and vegetation mat. Remove all sharp objects and large rocks. Fill depressions or holes with suitable material to provide a firm foundation.

Replace or repair all geotextile or geogrid that is torn, punctured, or muddy. Remove the damaged area and place a patch of the same type of geotextile or geogrid by overlapping 3 feet beyond the damaged area.

Furnish geogrid packaged in a sheathing or container suitable to protect the geogrid from damage due to ultraviolet light during storage and handling. Store, handle, protect, and haul all the materials in accordance with the manufacturer's specifications and as directed by the CO. Furnish geogrid that is visibly labeled with the name of the manufacturer, identification of the geogrid product, date of manufacture, lot number, length, width, and quantity.

**207.04 Separation and Stabilization Applications.** Where placing a geotextile on a subgrade, prepare the subgrade according to Subsections 204.13(c) and (d).

Place the geotextile smooth and free of tension, stress, or wrinkles. Fold or cut the geotextile to conform to curves. Overlap in the direction of construction. Overlap the geotextile a minimum of 2 feet at the ends and sides of adjoining sheets, or sew the geotextile joints according to the manufacturer's recommendations. Do not place longitudinal overlaps below anticipated wheel loads. Hold the geotextile in place with pins, staples, or piles of cover material.

End dump the cover material onto the geotextile from the edge of the geo-textile or from previously placed cover material. Do not operate equipment directly on the geotextile. Spread the end-dumped pile of cover material maintaining a minimum lift thickness of 12 inches. Compact the cover material with rubber-tired or nonvibratory smooth drum rollers. Avoid sudden stops, starts, or turns of the construction equipment. Fill all ruts from construction equipment with additional cover material. Do not regrade ruts with placement equipment.

Place subsequent lifts of cover material in the same manner. Vibratory compactors may be used for compacting subsequent lifts. If foundation failures occur, repair the damaged areas and revert to the use of nonvibratory compaction equipment.

**207.05 Permanent Erosion Control Applications.** Place and anchor the geotextile on an approved smooth-graded surface. For slope or wave protection, place the long dimension of the geotextile down the slope. For stream bank protection, place the long dimension of the geotextile parallel to the centerline of the channel.

Overlap the geotextile a minimum of 12 inches at the ends and sides of adjoining sheets or sew the geotextile joints according to the manufacturer's recommendations. Overlap the uphill or upstream sheet over the downhill or downstream sheet. Offset end joints of adjacent sheets a minimum of 5 feet. Pins may be used to hold the geotextile sheets in place. Space pins along the overlaps at approximately 3-foot centers.

Place aggregate, slope protection, or riprap on the geotextile starting at the toe of the slope and proceed upward. Place riprap onto the geotextile from a height of less than 12 inches. Place slope protection rock or aggregate backfill onto the geotextile from a height less than 3 feet. In underwater applications, place the geotextile and cover material in the same day.

**207.06 Soil Reinforcement Applications.** Install the geogrid reinforcement according to the manufacturer's recommendations. Place the geogrid reinforcement at the elevations and to the extent shown on the plans. Place the geogrid reinforcement in continuous longitudinal strips such that the principle strength (highest strength) axis is perpendicular to the slope or wall face. If unable to complete the required length with a single continuous length of geogrid, a joint may be made with the CO's approval. Only one joint per length of geogrid will be allowed. Construct this joint for the full width of the strip using a similar material, conforming to the requirements of Subsection 714.03(a), and following the manufacturer's recommendations. Pull and hold taut joints in geogrid reinforcement during fill placement. Lay flat and pull taut the geogrid reinforcement prior to backfilling. After a layer of geogrid reinforcement has been placed, use suitable means, such as pins or small piles of soil, to hold the geogrid reinforcement in position until the subsequent layer of backfill can be placed. Do not operate track-mounted equipment on the geogrid reinforcement until at least 6 inches of soil has been placed over the geogrid. Keep equipment turning to a minimum to prevent displacement of embankment and damage to the geogrid reinforcement. If approved by the CO, rubber tired equipment may pass over the geogrid reinforcement at speeds less than 10 miles per hour. If during embankment placement waves, wrinkles, or slack develop in the geogrid, remove the embankment and pull geogrid taut to remove slack.

Place only that amount of geogrid reinforcement required for immediately pending work to prevent undue damage. During construction, the surface of the fill should be kept approximately horizontal. Place geogrid reinforcements within 3 inches of the design elevations and extend to the length as shown in the plans unless otherwise directed by the CO. Place uniaxial (primary) and biaxial (secondary) geogrid reinforcement as shown on the plans or as directed by the CO. Place and compact embankment soils according to Subsections 204.10 and 204.11. Do not place sharp or angular rock and rock larger than 4 inches in diameter within 6 inches of the geogrid reinforcement. After the specified soil layer has been placed, install the next layer of geogrid reinforcement. Repeat the process for each subsequent layer until final grade is reached.

**207.06 Acceptance.** Material for earthwork geotextile will be evaluated under Subsections 106.02, 106.03, and 714.01. Material for the geogrid will be evaluated under Subsections 106.02, 106.03, and 714.03.

Earthwork geotextile installation will be evaluated under Subsections 106.02 and 106.04.

## Measurement

**207.07** Measure the Section 207 items listed in the bid schedule according to Subsection 109.02 and the following as applicable.

## Payment

**207.08** The accepted quantities will be paid at the contract price per unit of measurement for the Section 207 pay item listed in the bid schedule. Payment will be full compensation for the work prescribed in this Section. See Subsection 109.05.

## Section 703 – AGGREGATE

**703.03 Granular Backfill.** Delete the text and substitute the following:

Furnish granular backfill conforming to AASHTO M 6, except soundness test is not required.

## Section 704. – SOIL

**704.06 Unclassified Borrow.** Delete line (a), and substitute the following:

(a) Maximum particle size 6 inches

## Section 714.--GEOTEXTILE AND GEOCOMPOSITE DRAIN MATERIAL

**714.01(a) Physical requirements.** Add the following:

| | |
|---|---|
| (7) Uniaxial Geogrid | Table 714-7 |
| (8) Biaxial Geogrid | Table 714-7 |

The following is added after Subsection 714.02:

**714.03 Geogrid.** Furnish geogrid reinforcement with a regular network of integral connected polymer tensile elements having an aperture geometry and junction strength to sufficiently permit significant mechanical interlock with the surrounding soil or rock. Provide geogrid with a structure dimensionally stable and able to retain its geometry under manufacture, transport, installation, ultraviolet degradation, and all forms of chemical and biological degradation encountered in the soil being reinforced.

**(a) Physical requirements.** Provide geogrids composed of fibers or ribs that are at least 85% by weight polyethelene, polypropylene or polyester. Form a network of fibers that will retain dimensional stability. Calculate long-term tensile strength "$T_{al}$" and pullout capacity of geogrids according to FHWA publication No. FHWA-NHI-00-043, entitled "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines." The long-term tensile strength "$T_{al}$" must take into account reduction factors "RF" for creep ($RF_{CR}$), durability ($RF_D$), and installation damage ($RF_{ID}$) as defined in FHWA-00-043. Conform to the physical requirements in Table 714-7.

**Table 714-7**
**Geogrid Physical Requirements**

| Property | Test Method | Minimum Acceptable Values | |
|---|---|---|---|
| | | Uniaxial Geogrid | Biaxial Geogrid |
| Wide width tensile strength (ultimate), lb/ft | ASTM D 4595 | 3,000/1,000$^{(1)}$ | 1,100/1,100$^{(1)}$ |
| Aperture size, inches | ---------------- | 0.5/0.5$^{(1)}$ | 0.5/0.5$^{(1)}$ |
| Long Term Design Strength, lb/ft | GRI:GG4 | 1,000$^{(2)}$ | 500$^{(2)}$ |

(1) Machine Direction/Cross Machine Direction
(2) Principle strength (highest strength) direction

Identify, store, and handle geogrid according to ASTM D 4873-88 and manufacturer's recommendations. Limit geogrid exposure to ultraviolet radiation to less than 10 days.

**(b) Evaluation procedures.** Geogrid will be evaluated under Subsection 106.03. Furnish to the CO three copies of a commercial certification that the geogrid supplied meets the respective index criteria, measured in full accordance with all test methods and standards set forth in these specifications. State on the commercial certification the name of the manufacturer, product name, style number, chemical composition of the filaments, ribs, or yarns, and other pertinent information to fully describe the geogrid. Attest the certification by a person having legal authority to bond the manufacturer. In case of dispute over validity of values, the CO can require the contractor to supply test data from an agency approved laboratory to support the certified values submitted. Also, include the calculation of the long term design strength, with assumed reduction factors.

When samples are required, remove a 3-foot long, full-width sample from beyond the first outer wrap of the roll. Label the sample with the lot and batch number, date of sampling, project number, item number, manufacturer, and product name.

**Manufacturing Quality Control:** The manufacturer is responsible for establishing and maintaining a quality control program to ensure compliance with the requirements of this specification.

Perform conformance testing as part of the manufacturing process, testing may vary for each type of product. Consider the Table 714-8 for applicable index tests as a minimum for an acceptable QA/QC program.

**Table 714-8**
**Minimum Index Tests for QA/QC**

| Property | Test Method | Minimum Conformance Requirement |
|---|---|---|
| Specific Gravity (HDPE only) | ASTM D-1505 | To be provided by the material supplier of specialty company |
| Wide Width Tensile | ASTM D-4595 | |
| Melt Flow (HDPE and PP only) | ASTM D-1238 | |
| Intrinsic Viscosity (PET only) | ASTM D-4603 | |
| Carboxyl End Group (PET only) | ASTM D-2455 | |
| Single Rib Tensile (geogrids) | GRI:GG1 | |

**APPENDIX G – Photos**

Segment 1

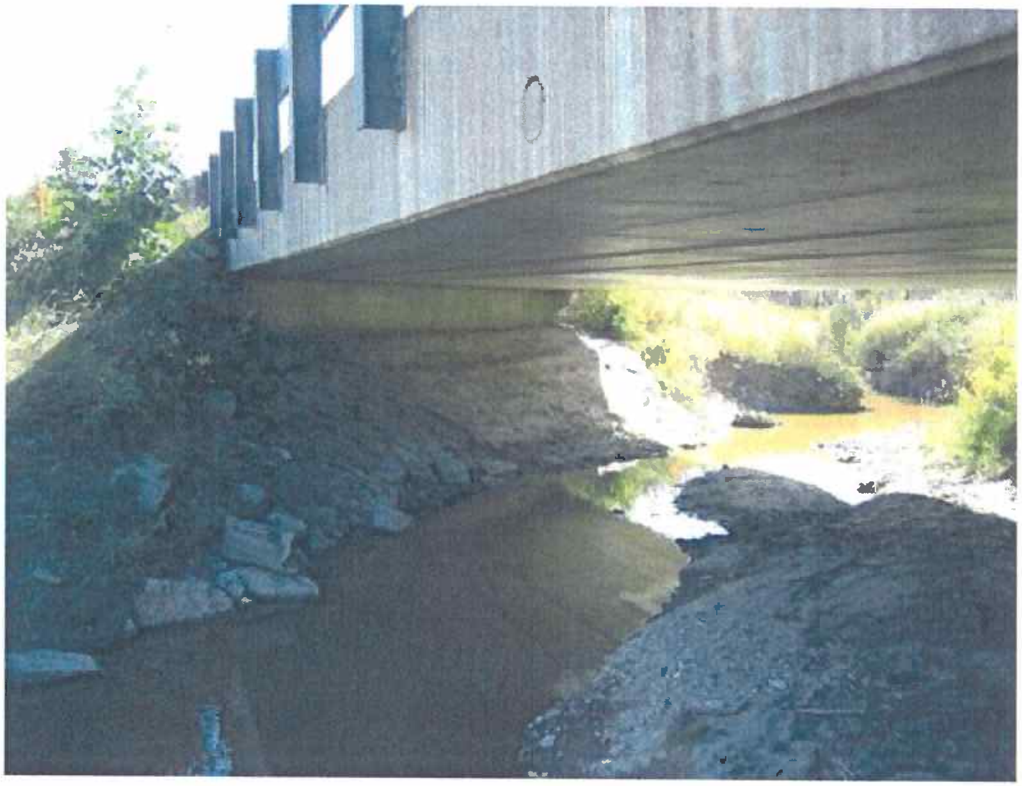
Segment 1

Segment 1 prior to blade patch

Segment 2

Segment 2

Segment 3



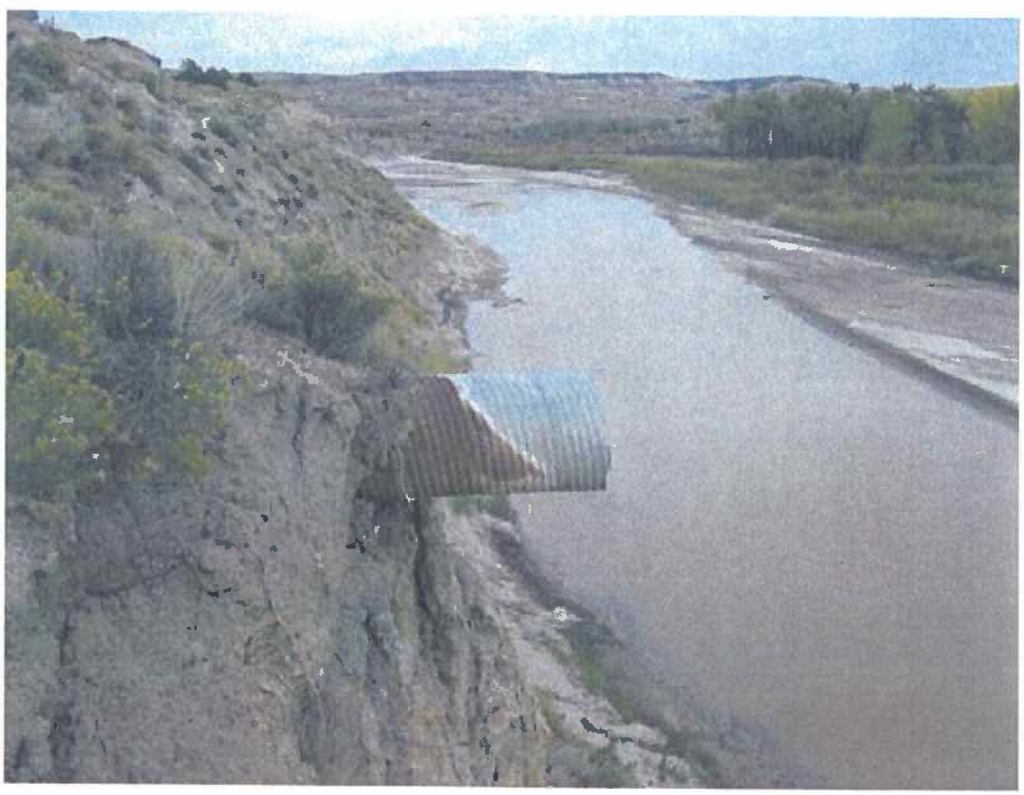
West Abutment of Squaw Creek Bridge

West Abutment of Squaw Creek Bridge

Culvert at STA 61+34

Shoulder Distress near STA 70+00

Culvert sinkhole at STA 99+29



Culvert at STA 99+29

Culvert outlet at STA 226+92

Culvert outlet at STA 226+92