Appendix D. Drilled Shaft Report Example

PLEASE NOTE
A sample foundations report is included here for reference. It is provided as an example of content, format, and organization representative of a typical Foundation Investigation and Recommendation Report for a drilled shaft foundation. As site conditions vary widely, the investigation means and methods, and report content (including recommendations), may differ for other projects. Note that the selection and inclusion of this report as a sample does not imply that it is guaranteed to be free of errors. Please contact the Foundations Unit with any questions when interpreting a geotechnical report issued by this office or if you have any questions with respect to preparing geotechnical reports for MnDOT. The information presented here is intended for use as a resource by geotechnical engineering professionals. MnDOT makes no warranty as to the suitability of engineering reports in the style of this sample report, for other geotechnical needs, purposes, clients, or projects.
Project Summary
This report provides for a preliminary foundation investigation, analysis and recommendations for replacing Bridge 5557 with Bridge 39008. The old three-span arch Bridge built in 1950, will be replaced with a new three-span structure. The new Bridge (39008) will use 63 inch prestressed concrete beams with a cast in place deck 40 feet wide by 247 feet long. The substructures are to be supported on drilled shaft foundations.

This report is preliminary in nature because of the iterative design process involved with drilled shaft foundations. A final report will be provided once the final structural loads (both axial and lateral) are determined. Load and Resistance Factor Design (LRFD) methods will be used for the analysis and design recommendations.

Field Investigation and Foundation Conditions
Four foundation borings were taken by STS, under a consultant contract for Mn/DOT, in June 2008. A copy of these borings is included with this report.

West Abutment & Pier
At the proposed west Abutment & Pier the foundation soils consist of a 10-15 ft. layer of sandy clay loam soil followed by bedrock. The bedrock at this site is a greenstone generally fresh with slight weathering. Unconfined compression tests were performed on selected representative rock core samples in order to determine the unconfined compressive strength and elastic modulus of the rock. The results of these tests are plotted on the individual boring logs and are shown in Table 1. Groundwater was not encountered during drilling.

East Abutment & Pier
At the proposed east Abutment & Pier the foundation soils consist of a 15-20 ft. layer of sandy loam soil followed by bedrock. The bedrock at this site is a greenstone generally fresh with slight weathering. Unconfined compressive tests were performed on selected representative rock core samples in order to determine the unconfined compressive strength and elastic modulus of the rock. The results of these tests
are plotted on the individual boring logs and are shown in Table 1. Groundwater was not encountered during drilling.

**West Abutment Samples**
Fig 1: Rock Core from 28.1 ft. to 28.4 ft.  
Fig 2: Rock Core from 40 ft. to 40.3 ft.

**East Abutment Samples**
Fig 3: Rock core from 18.2 ft. to 18.5 ft.  
Fig 4: Rock core from 26 ft. to 26.8 ft.
Table 1: Results of Lab Tests on Rock Core Samples

<table>
<thead>
<tr>
<th>Boring</th>
<th>Elevation</th>
<th>Rock Description</th>
<th>$q_u$ psi</th>
<th>$E$ psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>1065</td>
<td>Greenstone, slightly weathered</td>
<td>30,000*</td>
<td>3,064,000</td>
</tr>
<tr>
<td>B-2</td>
<td>895.3</td>
<td>Greenstone, slightly weathered to generally fresh</td>
<td>30,000*</td>
<td>2,893,100</td>
</tr>
<tr>
<td>B-3</td>
<td>897.7</td>
<td>Greenstone, slightly weathered to generally fresh</td>
<td>9,000**</td>
<td>1,825,400</td>
</tr>
<tr>
<td>B-4</td>
<td>899.1</td>
<td>Greenstone, slightly weathered to generally fresh</td>
<td>30,000*</td>
<td>3,438,500</td>
</tr>
</tbody>
</table>

* The rock core did not reach unconfined compressive strength
** The rock core did reach unconfined compressive strength

Please refer to the attached boring logs for a detailed description of the foundation soils and rock. Rock core is available for inspection in our lab. Please contact our office if you wish to see the core.

**Foundation Analysis**

Locations and elevations of existing and proposed substructures were determined from a bridge survey and a preliminary bridge plan provided by the Bridge Office. The existing three-span arch bridge was constructed in 1950 and is supported on spread footing foundations on the shallow bedrock.

**Scour**

At this site, no scour depth has been predicted by the Hydraulics Section.
**Drilled shaft Settlement**

For footings bearing on fair to very good rock, according to the Geomechanics Classification system, as defined in Article 10.4.6.4(AASHTO LRFD Bridge Design Specifications,2008 Interim Revisions), elastic settlements may generally be assumed to be less than 0.5 in.

Lateral loads are not expected to control the drilled shaft design for this project. However, the lateral deflection will be checked once the final structural loads are made available.

The construction method to install the drilled shaft foundations is expected to utilize temporary casing and drilling slurry (water). The casing will first be sealed into competent rock and then the shaft will be drilled out to the design depth. Before placing the rebar cage, the bottom of the shaft will be cleaned out thoroughly.

**Abutment & Pier Foundations – Drilled Shaft Axial Capacity**

Since bedrock was found at a shallow depth during boring at the abutment and pier locations, drilled shafts foundation were analyzed. Diameters of 36, 42 and 48 in. were assumed for the drilled shaft.

The drilled shaft design follows the guidelines presented in the AASHTO LRFD BRIDGE DESIGN (2008 Interim Revisions). Because of the complexities and unknowns involved with load transfer in stratified rock, a conservative approach was used for design of the axial capacity of the shafts. This design assumes that the axial load will be resisted entirely by side resistance. In actual practice, some of the axial load is transferred to the base of the shaft, however, in lieu of static load testing, it is very difficult to determine how much.

The unit side resistance was first calculated for each material layer using the analysis method of Kulhawy and Phoon (1993).

\[
f_{\text{max},i} = 0.65 \alpha \cdot p \cdot \sqrt{\frac{q_{ui}}{p}}
\]

where

- \( p \) = atmospheric pressure
- \( q_{ui} \) = unconfined compressive strength of rock
- \( \alpha \) = reduction factor to account for jointing in rock

The total side resistance, \( R_s \), was then computed using the following equation:

\[
R_s = \phi_s \cdot \pi \cdot B \sum_{i=1}^{n} \Delta z_i \cdot f_{\text{max},i} \quad \text{where} \quad \phi_s = 0.55
\]

Because the final axial and lateral loads are unknown at this time, the factored side resistance is presented as a function of drilled shaft depth and diameter. The Structural Engineer should use this chart to select a preferred shaft diameter and depth and verify that the factored loads, \( \eta \Sigma y_i Q_i \), from the most critical design case (strength or extreme event), meet or exceed the factored resistances for the options shown.
Figure 1: Estimated Factored Geotechnical Side Resistance vs. Depth

![Graph showing estimated factored geotechnical side resistance vs. depth for Bridge 39008 East Abutment. The graph displays the relationship between factored side resistance and depth for drilled shafts of different diameters. The notes state that the resistance factor $\phi = 0.55$, and the top of the shaft is assumed at an elevation of 1085 ft.](image-url)
Figure 2: Estimated Factored Geotechnical Side Resistance vs. Depth

Notes:
- Resistance Factor $\phi = 0.55$
- Assumed Top of shaft elevation = 1068 ft.
Figure 3: Estimated Factored Geotechnical Side Resistance vs. Depth

Bridge 39008 West Abutment
Drilled Shaft Geotechnical Axial Capacity

Factored Side Resistance ($\phi Rs$) (tons)

Depth of Shaft (ft.)

Notes:

Resistance Factor $\phi = 0.55$

Assumed Top of shaft elevation = 1085 ft.
Figure 3: Estimated Factored Geotechnical Side Resistance vs. Depth

![Graph showing estimated factored side resistance vs depth for Bridge 39008 West Pier.]

Notes:
- Resistance Factor $\phi =$ 0.55
- Assumed Top of shaft elevation = 1068 ft.

**Preliminary Foundation Recommendations**

Based on the existing conditions along with an analysis of the project soils, we recommend that:

1. Topsoil and other organic material should be removed from areas where fill is to be placed.

2. The side slopes and end slopes be same as existing or flatter for stability.

3. The bridge abutments and piers should be supported with drilled shaft foundations. The drilled shaft diameter and depth will be finalized in the final Foundation Recommendation Report after the final structural loads are made available. Please provide the following loading values to our office when they become available:
a. Axial design load per column for most critical design case (strength or extreme event)
b. Lateral design load per column for most critical design case (strength or extreme event)

Attachments: Boring Logs B-1 – B-4 (Unique #70658-70661)
Boring Plan
Boring Profile

cc: G. Engstrom
    D. Dorgan
    T. Styrbicki
    A. Staples
    D. Robertson
    J. Bittman

File
TOP OF RAILING

ELEV. 1100

ELEV. 1101.610

V.P.L. 419+00.000

ELEV. 1030

ELEV. 1040

ELEV. 1050

ELEV. 1060

ELEV. 1070

ELEV. 1080

ELEV. 1090

ELEV. 1100

TOP OF RAILING

SILTY CLAY LOAM AT ROOTS, SOFT, DARK BROWN
CLAY LOAM, STIFF, BROWN
SILTY CLAY LOAM, STIFF WITH RUST LEACHING, WET
CLAY LOAM, LITTLE GRAVEL, STIFF TO VERY STIFF, GRAY TO GRAY-BROWN WITH RUST LEACHING
COARSE SAND, MEDIUM DENSE, BROWN AND WET
ELY GREENSTONE: TOP OF BEDROCK

END OF BORING AT 45 FEET. BORING BACKFILLED WITH NEAT CEMENT GROUT.
NZ DIAMOND BIT SERIES 5 BIT IS USED FOR ROCK CORING.

END OF BORING AT 60 FEET. BORING BACKFILLED WITH NEAT CEMENT GROUT.
NZ DIAMOND BIT SERIES 5 BIT IS USED FOR ROCK CORING.

WATER LEVEL 1068.975

EAST PIER

EAST ABUT.
**USER NOTES, ABBREVIATIONS AND DEFINITIONS** - Additional information available in Geotechnical Manual.

This boring was made by ordinary and conventional methods and with care deemed adequate for the Department's design purposes. Since this boring was not taken to gather information relating to the construction of the project, the data noted in the field and recorded may not necessarily be the same as that which a contractor would desire. While the Department believes that the information as to the condition of materials reported is accurate, it does not warrant that the information is necessarily complete. This information has been edited or abridged and may not reveal all the information which might be useful or of interest to the contractor. Consequently, the Department will make available at its offices, the field logs relating to this boring.

Since subsurface conditions outside each borehole are unknown, and soil, rock and water conditions cannot be relied upon to be consistent or uniform, no warrant is made that conditions adjacent to this boring will necessarily be the same as or similar to those shown on this log. Furthermore, the Department will not be responsible for any interpretations, assumptions, projections or interpolations made by contractors, or other users of this log.

Water levels recorded on this log should be used with discretion since the use of drilling fluids in borings may seriously distort the true field conditions. Also, water levels in cohesive soils often take extended periods of time to reach equilibrium and thus reflect their true field level. Water levels can be expected to vary both seasonally and yearly. The absence of notations on this log regarding water does not necessarily mean that this boring was dry or that the contractor will not encounter subsurface water during the course of construction.

**SOIL/CORE TESTS**

**SPT N**_60_ .......... ASTM D1586 Modified Blows per foot with 140 lb. hammer and a standard energy of 210 ft-lbs. This energy represents 60% of the potential energy of the system and is the average energy provided by a Rope & Cathead system.

**MC** .......... Moisture Content

**COH** .......... Cohesion

**Y** .......... Sample Density

**LL** .......... Liquid Limit

**PI** .......... Plasticity Index

**Φ** .......... Phi Angle

**REC** .......... Percent Core Recovered

**RQD** .......... Rock Quality Description

(Percent of total core interval consisting of unbroken pieces 4 inches or longer)

**ACL** .......... Average Core Length

(Average length of core that is greater than 4 inches long)

**Core Breaks** .......... Number of natural core breaks per 2-foot interval.

**DISCONTINUITY SPACING**

**Fractures**

**Distance**

**Bedding**

**Very Close** .......... 0-2 inches .......... Very Thin

**Close** .......... 2-12 inches .......... Thin

**Moderate** .......... 12-36 inches .......... Medium

**Wide** .......... >36 inches .......... Thick

**DRILLING SYMBOLS**

**Vane Shear Test**

**Washed Sample** (Collected during plug drilling)

**Augered**

**Plug Drilled**

**Split Tube Sample** (SPT No. 2 in. split tube with liners)

**Thin Wall Sample** (3 in. Shelby Tube)

**Core Drilled** (NV/Core Barrel unless otherwise noted)

**Continuous Soil**

**Sample**

**Augered & Jettied**

**Jettied**

**Augered & Plug Drilled**

**RELATIVE DENSITY**

**Compactness - Granular Soils**

**BPF**

**very loose** .......... 0-4

**loose** .......... 5-10

**medium dense** .......... 11-24

**dense** .......... 25-50

**very dense** .......... >50

**COLOR**

**blk** .......... Black

**wht** .......... White

**grn** .......... Green

**brn** .......... Brown

**orang** .......... Orange

**yel** .......... Yellow

**dk** .......... Dark

**lt** .......... Light

**IQS** .......... Iron Oxide Stained

**GRAIN SIZE /PLASTICITY**

**VF** .......... Very Fine

**pl** .......... Plastic

**F** .......... Fine

**spl** .......... Slightly

**Cr** .......... Coarse

**Sandy** .......... Slightly

**granular** .......... Granular

**GRANULAR Soils**

**Silt** .......... Silt

**silt** .......... Silt

**sand** .......... Sand

**sandy** .......... Sandy

**clay** .......... Clay

**clayey** .......... Clayey

**very soft** .......... 0-1

**soft** .......... 2-4

**firm** .......... 5-8

**stiff** .......... 9-15

**very stiff** .......... 16-30

**hard** .......... 31-60

**very hard** .......... >60

**SOIL/ROCK TERMS**

**C** .......... Clay

**L** .......... Loam

**S** .......... Sand

**Dol** .......... Dolomite

**Si** .......... Silt

**G** .......... Gravel (No. 10 Sieve to 3 inches)

**Bldr** .......... Boulder (over 3 inches)

**CL** .......... Clayey

**S** .......... Silt

**SCL** .......... Silt Clayey

**SST** .......... Siltstone

**Lmst** .......... Limestone

**Sst** .......... Sandstone

**Dolo** .......... Dolostone

**wx** .......... weathered

**Mn/DOT Triangular Textural Soil Classification System**

**% Sand**

**% Clay**

**% Silt**

**S**

**CL**

**SCL**

**SL**

**Si**

**SST**

**Lmst**

**Dolo**

**wx**

**S**

**CL**

**S**

**SCL**

**SL**

**Si**

**SST**

**Mn/DOT Triangular Textural Soil Classification System**
**UNIQUE NUMBER 70658**

**U.S. Customary Units**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Classification</th>
<th>Depth (Elev.)</th>
<th>Operation</th>
<th>SPT No.</th>
<th>MC (%)</th>
<th>COH (psf)</th>
<th>γ (pcf)</th>
<th>Soil Formation or Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Silty clay loam with roots, soft, dark brown</td>
<td>1089.0</td>
<td>REC</td>
<td>4</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.8</td>
<td>Clay loam, stiff, brown</td>
<td>1085.2</td>
<td>ROD</td>
<td>9</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.6</td>
<td>Silty loam, stiff, gray with rust leaching, wet</td>
<td>1081.4</td>
<td>ACL</td>
<td>10</td>
<td>22</td>
<td></td>
<td></td>
<td>Fine-grained, gray-green, unweathered</td>
</tr>
<tr>
<td>12.5</td>
<td>Clay loam, little gravel, stiff to very stiff, gray to gray-brown with rust leaching</td>
<td>1077.5</td>
<td>Core Breaks</td>
<td>PD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.9</td>
<td>Loamy sand, medium dense, brown and wet</td>
<td>1077.1</td>
<td></td>
<td>10</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ELY GREENSTONE: Top of Bedrock**

- SPT hammer cal. to 68%, 2005
- Groundwater not observed or measured while drilling

- Drill bit jammed at 27.3 feet
- Water loss approximately 35 gallons
- 8 min./foot
- 11 min./foot
- 10 min./foot
ELY GREENSTONE: Top of Bedrock (continued)

End of boring at 45 feet. Boring backfilled with neat cement grout.

NV2 diamond bit (Series 6 Bort) used for rock coring.
**MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION**

**LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION**

**UNIQUE NUMBER 70659**

U.S. Customary Units

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4</td>
<td>4” Bituminous pavement over FILL: sand, little gravel, loose, brown and moist</td>
</tr>
<tr>
<td>5</td>
<td>Silty clay loam, little organics, stiff to firm, gray-black</td>
</tr>
<tr>
<td>12.8</td>
<td>Silty clay loam, firm, gray and wet</td>
</tr>
<tr>
<td>18.6</td>
<td>Clay, stiff, brown</td>
</tr>
<tr>
<td>23.8</td>
<td>Fine to coarse sand and gravel, very dense, gray-black and wet</td>
</tr>
<tr>
<td>28.0</td>
<td>Weathered rock (possible boulder)</td>
</tr>
<tr>
<td>28.7</td>
<td>Sandy loam with gravel, very dense, brown and wet</td>
</tr>
<tr>
<td>30</td>
<td>ELY GREENSTONE: Top of Bedrock</td>
</tr>
</tbody>
</table>

**Location**
Lake of the Woods/North Zone Co. Coordinate: X=608850 Y=218860

**Drilling Operation**

- **SPT N60**: 8 5 9 9 12 24 7 29 7 6 12 23
- **MC (pct)**: 8 7 9 24 7 5 26 5 33 50 50/42 6 7
- **COH (psf)**: 750 127
- **γ (pcf)**: 609.0

**Other Tests**
- SPT hammer cal. to 68%, 2005
- Groundwater not observed or measured while drilling
- No recovery at 22.5 to 23.5 feet
- Set NX casing to 23.4 feet
- Pulled NX, reamed hole with 3 7/8”, reset NX to 28.7 feet
- ELY GREENSTONE, fine-grained, gray-green, unweathered
- 6 min./foot
- No voids, no water loss

**Soil Class:** MM
**Rock Class:** DH

This boring was taken by STS Limited, Inc. under a consultant contract for Mn/DOT.
ELY GREENSTONE: Top of Bedrock (continued)

End of boring at 60 feet. Boring backfilled with neat cement grout.

NV2 diamond bit (Series 6 Bort) used for rock coring.
This boring was taken by STS Limited, Inc. under a consultant contract for Mn/DOT.

**Location**
Lake of the Woods/North Zone Co. Coordinate: X=608620    Y=218807

**State Project** 3902-21  **Bridge No. or Job Desc.**  5557  **Trunk Highway/Location** MN Trunk Highway 11  **Boring No.** B-3  **Ground Elevation** 1095.0(DTM)

**Drilling Machine** CME-750  **Hammer** CME Automatic  **Completed** 6/4/08  **Drilling Machine** CME Automatic

<table>
<thead>
<tr>
<th>Depth (ft.)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>6&quot; Bituminous pavement over FILL: Sand, little gravel, loose, brown and moist</td>
</tr>
<tr>
<td>3.5</td>
<td>Silty clay loam, trace organics, stiff, gray-brown, trace black</td>
</tr>
<tr>
<td>5.0</td>
<td>Sandy clay loam, stiff, gray-brown</td>
</tr>
<tr>
<td>9.0</td>
<td>Sandy clay loam and organic silt, very dense, brown and black</td>
</tr>
<tr>
<td>21.0</td>
<td>ELY GREENSTONE: Top of Bedrock</td>
</tr>
</tbody>
</table>

**End of boring at 21 feet. Boring backfilled with neat cement grout.**

NV2 diamond bit (Series 6 Bort) used for rock coring.
**MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION**

**LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION**

**UNIQUE NUMBER 70661**

U.S. Customary Units

<table>
<thead>
<tr>
<th>State Project</th>
<th>Bridge No. or Job Desc.</th>
<th>Trunk Highway/Location</th>
<th>Boring No.</th>
<th>Ground Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3902-21</td>
<td>5557</td>
<td>MN Trunk Highway 11</td>
<td>B-4</td>
<td>1093.5 (Auto Level)</td>
</tr>
</tbody>
</table>

**Location**
- Lake of the Woods/North Zone Co. Coordinate: X=608606 Y=218832
- Latitude (North)=
- Longitude (West)=

**Drill Machine** CME-750

**Hammer** CME Automatic

**Drilling Completed** 6/10/08

**Ground Elevation**
- ELY GREENSTONE: Top of Bedrock
  - 10 min./foot, no water loss
  - 3 min./foot, no water loss
  - 4 min./foot, 15% water loss
  - 4 min./foot, 15% water loss
  - 4 min./foot, 16% water loss
  - 4 min./foot, no water loss

**SPT hammer cal. to 68%, 2005**

Groundwater not observed or measured while drilling

**Classification**
- 4 1/4" bituminous pavement over FILL: loamy sand, trace gravel, brown and moist
- Clay loam, trace gravel, firm, gray-brown
- Organic silt loam, loose, black and dark gray, moist
- Sandy clay loam, brown and wet

**Other Tests Or Remarks**
- Soil Class: MM
- Rock Class: DH

**SPT Nø**
- 8
- 6
- 7
- 3
- 9
- 100

**MC (%)**
- 8
- 24
- 44
- 50
- 65
- 87

**COH (psf)**
- 130
- 500
- 50

**γ (pcf)**
- 3
- 4
- 5
- 6
- 7

**Soil Core Breaks**
- 4

**Soil or Member**
- ELY GREENSTONE, fine-grained, gray-green, unweathered

**Edit: Date:** 9/30/08

This boring was taken by STS Limited, Inc. under a consultant contract for Mn/DOT.
ELY GREENSTONE: Top of Bedrock (continued)

End of boring at 46.8 feet. Boring backfilled with neat cement grout.

NV2 diamond bit (Series 6 Bort) used for rock coring.

1046.7