Table of Contents

10.1 General

The purpose of the Geotechnical Investigation is to provide subsurface information for the plans and to develop recommendations for the construction of the structure at reasonable costs versus short and long term performance. The level of Geotechnical Investigation is a function of the type of the structure and the associated performance. For example, a box culvert under a low ADT roadway compared to a multi-span bridge on a major interstate would require a different level of Geotechnical Investigation. The challenge for the geotechnical engineer is to gather subsurface information that will allow for a reasonable assessment of the soil and rock properties compared to the cost of the investigation.

The geotechnical engineer and the structure engineer need to work collectively when evaluating the loads on the structures and the resistance of the soil and rock. The development of the geotechnical investigation and evaluation of the subsurface information requires a degree of engineering judgment. A guide for performing the Geotechnical Investigation is provided in WisDOT Geotechnical Bulletin No. 1, **LRFD [10.4]** and Geotechnical Engineering Circular #5 – Evaluation of Soil and Rock Properties (Sabatini, 2002).

The following structures will require a Geotechnical Investigation:

- Bridges
- Box Culverts
- Retaining Walls
- Non-Standard Sign Structures Foundations
- High Mast Lighting Foundations
- Noise Wall Foundations

10.2 Subsurface Exploration

The Geotechnical Engineering Unit (or geotechnical consultant) prepares the Site Investigation Report (SIR) and the Subsurface Exploration (SE) sheet. The SIR describes the subsurface investigation, laboratory testing, analyses, computations and recommendations for the structure. All data relative to the underground conditions which may affect the design of the proposed structure's foundation are reported. Further information describing this required investigation can be found in the Department's "Geotechnical Bulletin #1" document. The Subsurface Exploration sheet is a CADDS drawing that illustrates the soil boring locations and is a graphical representation of the driller's findings. This sheet is included in the structure plans. If the Department is not completing the geotechnical work on the project, the SIR and SE sheet(s) are the responsibility of the consultant.

The subsurface investigation is composed of two areas of investigation: the Surface Survey and the detailed Site Investigation.

Surface Surveys include studies of the site geology and air-photo review, and they can include geophysical methods of exploration. This work should include a review of any existing structure foundations and any existing geotechnical information. Surface Surveys provide valuable data indicating approximate soil conditions during the reconnaissance phase.

Based on the results of the Surface Survey information, the plans for a Detailed Site Investigation are made. The subsurface investigation needs to provide the following information:

- Depth, extent and thickness of each soil or rock stratum
- Soil texture, color, mottling and moisture content
- Rock type, color and condition
- In-situ field tests to determine soil and rock parameters
- Laboratory samples for determining soil or rock parameters
- Water levels, water loss during drilling, utilities and any other relevant information

The number and spacing of borings is controlled by the characteristics and sequence of subsurface strata and by the size and type of the proposed structure. Depending upon the timing of the Geotechnical Investigation the required information may not be available and the geotechnical engineer may have to develop a subsurface investigation plan based on the initial design. The Department understands that additional investigation may be required once the preliminary design is completed. The challenge for the Department and the consultant is to develop a geotechnical investigation budget without knowing the subsurface conditions that will be encountered. Existing subsurface information from previous work can help this situation, but the plans should be flexible to allow for some unforeseen subsurface conditions.

One particular subsurface condition is the presence of shallow rock. In some cases, borings should be made at a frequency of one per substructure unit to adequately define the subsurface conditions. However, with shallow rock two or more borings may be necessary to define the rock line below the foundation. Alternatively, where it is apparent the soil is uniform, fewer borings are needed. For example, a four span bridge with short (less than30 foot) spans at each end of a bridge may only require three borings versus the five borings (one per substructure).

Borings are typically advanced to a depth where the added stress due to the applied load is 10 percent of the existing stress due to overburden or extended beyond the expected pile penetration depths. Where rock is encountered, borings are advanced by diamond bit coring according to ASTM D2113 to determine rock quality according to ASTM D6032.

LRFD [Table 10.4.2-1] Minimum Number of Exploration Points and Depth of Exploration (modified after Sabatini et al., 2002) provides guidelines for an investigation of bridges (shallow foundations and deep foundations) and retaining walls. The following presents the typical subsurface investigation guidelines for the other structures:

- Box Culverts: The recommended spacing of the borings would be 1/every 200 feet of length of the box culvert with a minimum of two boring for a new box culvert. The borings should have 15 feet of continuous SPT samples below the base of the box culvert.

- Box Culvert Extensions: May require a boring depending upon the length of the extension and the available information from the existing box culvert. If a boring is recommended then it would follow the same procedures as for a new box culvert.

- Non-Standard Sign Structure Foundations: The recommended spacing would be one for each sign structure site. If the sign structure is a bridge with two foundations then one boring may still be adequate. The borings should have 20 feet of continuous SPT samples and a SPT sample at 25 feet and 30 feet below the ground surface at the sign structure site.

- High Mast Lighting Foundations: The recommended spacing would be one for each site. The borings should have 15 feet of continuous SPT samples and a SPT sample every 5 feet to a depth of 40 feet below the ground surface at the site.

- Noise Wall Foundations: The recommended spacing would be one for every 200 feet to 300 feet of wall. The borings should have 20 feet of continuous SPT samples below the ground surface.

The Department generally follows AASHTO laboratory testing procedures. Any or all of the following soil tests may be considered necessary or desirable at a given site:

In-situ (field) Tests

- Standard penetration
- Pocket penetrometer (cohesive soil)
- Vane shear (cohesive soil)
- Cone penetration (seldom used)
- Rock core recovery and Rock Quality Designation (RQD)

Laboratory Tests

- Moisture, density, consistency limits and unit weight
- Unconfined compression (cohesive soils and rock cores)
- Grain size analysis (water crossings) - This test is required for streambed sediments of multi-span structures over water to facilitate scour computations.
- One-dimensional consolidation (seldom used)
- Unconsolidated undrained triaxial compression (seldom used)
- Consolidated undrained triaxial compression with pore water pressure readings (seldom used)
- Corrosion Tests (pH, resistivity, sulfate, chloride and organic content)

One of the most widely used in-situ tests in the United States is the Standard Penetration Test (AASHTO T-206) as described in the *AASHTO Standard Specifications*. This test provides an indication of the relative density of cohesionless soils and, along with the pocket penetrometer readings, predicts the consistency and undrained shear strength of cohesive soils. Standard Penetration Tests (SPTs) generally consist of driving a 2-inch O.D. split barrel sampler into the ground with a 140-pound hammer falling over a height of 30 inches. The split-barrel sampler is driven in 6-inch increments for a total of 18-inches and the number of blows for each 6-inch increment is recorded. The field blow-count, SPT N-value, equals the number of blows that are required to drive the sampler the last 12-inches of penetration. Split-barrel samplers are typically driven with a conventional donut, safety or automatic-trip hammer. Hammer efficiencies, ER, are determined in accordance with ASTM D 4945. In lieu of a more detailed assessment, ER values of 45, 60 and 80 percent may be used to compute corrected blow counts, N_{60}, for conventional, safety and automatic-trip hammers, respectively, in accordance with **LRFD [10.4.6.2.4]**. Correlation between standard penetration values and the resulting soil bearing value approximations are available from many sources. Standard penetration values can be used by experienced Geotechnical Engineers to estimate pile shaft resistance values by also considering soil texture, moisture content, location of water table, depth below proposed footing and method of boring advance.

For example, DOT Geotechnical Engineers using DOT soil test information know that certain sand and clays in the northeastern part of Wisconsin have higher load-carrying capacities than tests indicate. This information is confirmed by comparing test pile data at the different sites to computed values. The increased capacities are realized by increasing the design point resistance and/or shaft resistance values in the Site Investigation Report.

Wisconsin currently uses most of the soil tests previously mentioned. The soil tests used for a given site are determined by the complexity of the site, size of the project and availability of funds for subsurface investigation. The scope and extent of the laboratory testing program should take into consideration available subsurface information obtained during the initial site reconnaissance and literature review, prior experience with similar subsurface conditions encountered in the project vicinity and potential risk to structure performance. Detailed information about how to develop a laboratory testing program and the type of tests required is presented in previous sited reference or refer to a soils textbook for a more detailed description of soil tests.

Laboratory tests of undisturbed samples provide a more accurate assessment of soil settlement and structural properties. Unconfined compression tests and other tests are employed to measure the undrained shear strength and to estimate pile shaft resistance in clay soils by assuming:

$$c = \frac{q_u}{2}$$

Where:

c = cohesion of soil

q_u = unconfined compression strength

It is worthy to note that pile shaft resistance is a function of multiple parameters, including but not limited to stress state, depth, soil type and foundation type.

In addition to the tests of subsurface materials, a geological and/or geophysical study may be conducted to give such geological aspects as petrology, rock structure, rock quality, stratigraphy, vegetation and erosion. This can include in-situ and laboratory testing of selected samples, as well as utilizing non-destructive geophysical techniques, such as seismic refraction, electromagnetic or ground penetrating radar (GPR)

Boring and testing data analysis, along with consideration of the geology and terrain, allow the geotechnical engineer to present the following in the bridge SIR:

- The preferred type of substructure foundation (i.e. shallow or deep).
- The factored bearing resistance for shallow foundations.
- The settlement for the shallow foundations.

- If piles are required, recommend the most suitable type and the support values (shaft resistance and point resistance) furnished by the different soil strata.

- A discussion of any geotechnical issues that may affect construction.

- The presence and effect of water, including discussion of dewatering impact and cut-slope impact under abutments.

When piles are recommended, suitable pile types, estimated length requirements, pile drivability and design loads are discussed. Adverse conditions existing at abutments due to approach fills being founded on compressible material are pointed out, and recommended solutions are proposed. Unfactored resistance values at various elevations are given for footing foundation supports. Problems associated with scour, tremie seals, cofferdams, settlement of structure or approach fill slopes and other conditions unique to a specific site are discussed as applicable.

10.3 Soil Classification

The total weight of the structure plus all of the forces imposed upon the structure is carried by the foundation soils. There are many ways to classify these soils for foundation purposes. An overall geological classification follows:

1. Bedrock - This is igneous rock such as granite; sedimentary rock such as limestone, sandstone and shale; and metamorphic rock such as quartzite or marble.

2. Glacial soils (Intermediate Geo Material- IGM) - This wide variety of soils includes granular outwash, hard tills, bouldery areas and almost any combination of soil that glaciers can create and are typically defined to have a SPT number greater than 50.

3. Alluvial soils - These are found in flood plains and deltas along creeks and rivers. In Wisconsin, these soils normally contain large amounts of sand and silt. They are highly stratified and generally loose. Pockets of clay are found in backwater areas.

4. Residual soils - These soils are formed as a product of weathering and invariably reflect the parent bedrock material. They may be sands, silts or clay.

5. Lacustrine soils - These soils are formed as sediment and are deposited in water environments. In Wisconsin, they tend to be clayey. One example of these soils is the red clay sediments around Lakes Superior and Michigan.

6. Gravel, cobbles and boulders - These are particles that have been dislodged from bedrock, then transported and rounded by abrasion. Some boulders may result from irregular weathering.

Regardless of how the materials are formed, for engineering purposes, they are generally broken into the categories of bedrock, gravel, sand, silt, clay or a combination of these. The behavioral characteristics of any soil are generally based on the properties of the major constituent(s). Listed below are some properties associated with each of these material types.

1. Sand - The behavior of sand depends on grain size, gradation, density and water conditions. Sand scours easily, so foundations on sand must be protected in areas subject to scour.

2. Silt - This is a relatively poor foundation material. It scours and erodes easily and causes large volume changes when subject to frost.

3. Clay - This material needs to be investigated very carefully for use as a bearing material. Long-term consolidation may be an issue.

4. Bedrock - This is generally the best foundation material. Wisconsin has shallow weathered rock in many areas of the state. Weathered granite and limestone become sands. Shale and sandstone tend to weather more on exposure.

5. Mixture of soils - This is the most common case. The soil type with predominant behavior has the controlling name. For example, a soil composed of sand and clay is called sandy clay if the clayey fraction controls behavior.

10.4 Site Investigation Report

The following is a sample of a Site Investigation Report for a two-span bridge and retaining wall. The subsurface exploration drawing is also submitted with the reports.

CORRESPONDENCE/MEMORANDUM ____________________State of Wisconsin

DATE: February 17, 2015

TO: Casey Wierzchowski, P.E.
Southeast Region Soils Engineer

FROM: Jeffrey D Horsfall, P.E.
Geotechnical Engineer

SUBJECT: **Site Investigation Report**
Project I.D. 1060-33-16
B-40-0880
Center Street over USH 45
Milwaukee County

Attached is the Site Investigation Report for the above project.

Please call if you have any questions.

Attachments

cc: Southeast Region (via e-mail)
Bureau of Structures, Structures Design (via e-submit)
Geotechnical File (original)

Site Investigation Report
Project I.D. 1060-33-16
Structure B-40-0880
Center Street over USH 45
Milwaukee County
February 17, 2015

1. GENERAL

The project is Center Street over USH 45, Milwaukee County. The proposed structure has two spans and will replace the existing structure with four spans (B-40-284). The existing structure is supported on spread footings with an allowable bearing capacity of 5,000 psf. The end slope in front of the abutments is to be supported with MSE walls with precast concrete panels. The current topography near the proposed structure is a rolling terrain in an urban area.

The Southeast Region requested that the Geotechnical Engineering Unit evaluate the foundation support for the proposed new structure. The following report presents results of the subsurface investigation, design evaluation, findings, conclusions, and recommendations.

2. SUBSURFACE CONDITIONS

Wisconsin Department of Transportation contracted with Gestra to completed one boring and PSI, Inc. to complete three borings near the proposed structure. Samples were collected in the borings with a method conforming to AASHTO T-206, Standard Penetration Test, in October and November 2014, using automatic hammers (with an efficiency ranging from 84 percent (Gestra) to 69 percent (PSI)). Attachment 1 presents tables showing the summary of subsurface conditions logged in the borings at this site and at the time of drilling for the structure. Attachment 2 presents a figure that illustrates the boring locations and graphical representations of the boring logs. The original borings logs are available at the Geotechnical Engineering Unit and will be made available upon request.

The following describes subsurface conditions in the four borings:

0.7 feet of topsoil or 1.0 feet to 2.0 feet of pavement structure, overlying
0.0 feet to 7.0 feet of brown, dense to very dense, fine to course, sand and gravel, overlying
20.0 feet to 43.0 feet of brown to gray, medium hard, clay, some silt, trace sand, overlying
0.0 feet to 8.0 feet of gray, loose to dense, fine sand, little silt, overlying
0.0 feet to 26.0 feet of gray, medium hard, clay, some silt, trace sand, overlying
Gray, very hard, clay and silt, some gravel

The observed groundwater elevation at the time of drilling ranged from 714 feet to 732 feet as determined by the drillers describing the samples as wet. However, not all of the borings encountered samples that were wet.

3. ANALYSIS ASSUMPTIONS

Foundation analyses are separated into shallow foundations (spread footings) and deep foundations (piling supports). The analyses used the following assumptions:

<u>Shallow Foundation</u>

1. The groundwater elevation ranged from 714 feet to 732 feet.
2. The base of the foundations are at the following elevations

Table 1: Foundation Elevations	
West Abutment	755.9 feet
Pier	733.3 feet
East Abutment	754.4 feet

3. The abutment end slopes are MSE Walls with precast panel facing.
4. The width of the pier footing is 10 feet and the width of the abutment footing is 6 feet.
5. The resistance factor of 0.55 for the factored bearing resistance.

<u>Pile Supported Deep Foundation</u>

1. Soil pressures for displacement piles are based upon a 10 3/4-inch diameter cast-in-place pile.
2. The groundwater elevation ranged from 714 feet to 732 feet.
3. Table 1 presents elevations at the base of the foundations.
4. Nominal soil pressures determined using the computer program APILE.
5. The drivability evaluation was performed using the computer program GRLWEAP.

The design shear strength, cohesion and unit weight for this analyses are presented latter in this report. The values are based upon empirical formulas for internal friction angles using blow counts from the AASHTO T-206 Standard Penetration Test results and the effective overburden pressure for the granular soils, the pocket penetrometer values for the cohesive soils and published values for the bedrock.

4. RESULTS OF ANALYSIS

<u>Shallow Foundation</u>

The results of the shallow foundation evaluation indicated that the factored bearing resistance was 6,000 psf for the west abutment and east abutment and 5,000 psf for the pier. The soils are relatively uniform. The estimated settlement from the bridge loads at the abutments and piers was excessive. The time for settlement would occur over a relatively long period of time.

<u>Deep Foundation</u>

Table 2 shows estimated nominal skin friction and end bearing values for deep foundation pilings.

<u>Drivability</u>

The drivability evaluation used a Delmag D 16-32 diesel hammer to determine if the pile would be overstressed during pile installation. The results of the evaluation indicated that 10 x 42 H-pile at the abutments and the 12 x 53 H-piles at the pier should not be overstressed.

<u>Lateral Earth Pressure</u>

The lateral earth pressure for the backfill material will exert 40 psf for sandy soils. The backfill material will be granular, free draining and locally available.

Table 2: Soil Parameters and Foundation Capacities

Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)	Skin Friction[1] (psf)	End Bearing[1] (psf)
B-40-0880 West Abutment (B-1)					
MSE Wall (Elevation 755.9 ft – 738.6 ft)	30	0	120	NA	NA
Clay, gray, trace gravel (Elevation 738.6 ft – 733.4 ft)	0	3,000	125	640	19,100
Clay, gray, trace gravel (Elevation 733.4 ft – 729.4 ft)	0	2,500	120	1,075	21,700
Clay, gray, trace gravel (Elevation 729.4 ft – 717.4 ft)	0	2,000	120	1,370	17,900
Clay and Silt, gray, trace sand and gravel (Elevation 717.4 ft – 705.4 ft)	0	4,500	135	1,210	40,500
Silt, gray, trace sand (Elevation 705.4 ft – 700.4 ft)	0	2,000	120	1,720	17,900
Silt, gray, some sand, trace gravel (Elevation 700.4 ft and below)	0	25,000	135	NA	Refusal
B-40-0880 Pier (B-1Gestra)					
Clay, brown to gray, trace sand, trace gravel (Elevation 733.3 ft – 731.7 ft)	0	2,000	120	340	15,800
Clay, gray, trace gravel (Elevation 731.7 ft – 715.7 ft)	0	3,000	125	930	27,000
Silt, gray, trace gravel (Elevation 715.7 ft – 698.7 ft)	0	3,500	130	495	31,600
Silt, gray, trace gravel (Elevation 698.7 ft – 694.2 ft)	40	0	135	470	417,800
Silt, Sand, Gravel, gray (Elevation 694.2 ft and below)	0	25,000	135	NA	Refusal

1. Skin friction and end bearings vales are the nominal capacities
2. NA - not applicable

Table 2: Soil Parameters and Foundation Capacities

Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)	Skin Friction[1] (psf)	End Bearing[1] (psf)
B-40-0880 East Abutment (B-2 and B-3)					
MSE Wall (Elevation 754.4 ft – 741.5 ft)	30	0	120	NA	NA
Clay, gray, trace gravel (Elevation 741.5 ft – 732.5 ft)	0	2,500	125	920	22,500
Sand, gray, some silt (Elevation 732.5 ft – 730.5 ft)	36	0	130	620	45,900
Sand, gray, some silt (Elevation 730.5 ft – 728.5 ft)	30	0	115	340	19,700
Clay, gray, trace sand, trace gravel (Elevation 728.5 ft – 717.5 ft)	0	2,500	125	2,380	22,500
Clay, gray, trace sand, trace gravel (Elevation 717.5 ft – 711.0 ft)	0	2,000	120	1,830	17,900
Silt, gray, trace sand (Elevation 711.0 ft – 702.5 ft)	33	0	125	890	50,000
Clay, gray (Elevation 702.5 ft – 692.5 ft)	0	3,000	125	1,730	27,000
Clay and Gravel, gray, some silt (Elevation 692.5 ft and below)	0	25,000	135	NA	Refusal

1. Skin friction and end bearings vales are the nominal capacities
2. NA - not applicable

5. FINDING AND CONCLUSIONS

The following findings and conclusions are based upon the subsurface conditions and analysis:

1. The following describes the subsurface conditions in the four borings:

   0.7 feet of topsoil or 1.0 feet to 2.0 feet of pavement structure, overlying
   0.0 feet to 7.0 feet of brown, dense to very dense, fine to course, sand and gravel, overlying
   20.0 feet to 43.0 feet of brown to gray, medium hard, clay, some silt, trace sand, overlying
   0.0 feet to 8.0 feet of gray, loose to dense, fine sand, little silt, overlying
   0.0 feet to 26.0 feet of gray, medium hard, clay, some silt, trace sand, overlying
   Gray, very hard, clay and silt, some gravel

2. The observed groundwater elevation at the time of drilling ranged from 714 feet to 732 feet as determined by the drillers describing the samples as wet.

3. The results of the shallow foundation evaluation indicated that the factored bearing resistance was 6,000 psf for the west abutment and east abutment and 5,000 psf for the pier. The soils are relatively uniform. The calculations used a resistance factor of 0.55.

4. The estimated settlement from the bridge loads on the shallow foundations would be excessive. The time for settlement would occur over a long period of time.

5. If used the support of the piles will occur in the very hard clay and silt. The pile tip elevation will range from 692 feet to 700 feet. The driven pile lengths will depend upon the type of pile hammer used and actual subsurface conditions encountered.

6. RECOMMENDATIONS

The following recommendations are based upon the findings and conclusions:

1. The recommended support system for the abutments are 10 x 42 H-piles driven to a “Required Driving Resistance” of 180 tons and for the pier footings are 12 x 53 H-piles driven to a “Required Driving Resistance” of 220 tons. Table 3 presents the estimated pile tip elevation for the piles. The actual driven length may be shorter due to the very hard clay.

Table 3: Estimated H-Pile Tip Elevations

Substructure	Pile Type	Pile Tip Elevation
West Abutment	10 x 42 H-pile	700 feet
Pier	12 x 53 H-pile	694 feet
East Abutment	10 x 42 H-pile	692 feet

2. The field pile capacity should be determined by using the modified Gates dynamic formula. This method will use of a resistance factor of 0.50.

3. Pile points should be used to reduce the potential for damage during driving through the very hard clay and silts.

4. Shallow foundation should not be used based upon the anticipated settlement at the pier and the MSE walls at the abutments.

5. Granular 1 backfill should be used behind the abutments.

Attachment 1
Tables of Subsurface Conditions

Site Investigation Report
Structure B-40-0880
Attachment 1

B-40-0880 Subsurface Conditions							
B-1 Station 19+00.0 22.4 feet left of CE RL				**B-1Gestra Station 20+11.3 38.2 feet left of CE RL**			
Top of Soil Layer Elevation (feet)	**Soil Description**	**SPT Blow count**	**Corr. SPT Blow count[1]**	**Top of Soil Layer Elevation (feet)**	**Soil Description**	**SPT Blow count**	**Corr. SPT Blow count**
762.6	Pavement Structure			742.7	Pavement Structure	6	14
761.6	Clay, dark brown, trace sand and gravel (fill)	4	7	740.7	Clay, brown to gray, trace sand, trace gravel Qp=1.0 – 3.0	6,9, 9,13	12,17, 16,21
754.1	Clay, brown, some silt, trace sand and gravel Qp=3.0	18	25	731.7	Clay, gray, trace gravel Qp=3.0 – 4.0	9,10, 11,13, 14,12	14,15, 16,18, 19,15
749.6	Clay, gray, trace gravel Qp=1.75 – 3.5	15,13, 14	18,14, 15	715.7	Silt, gray, trace sand Qp=4.0	24,33, 31	27,36, 31
739.6	Clay, gray, trace gravel Qp=3.0 – 3.75	20,14, 18	21,14, 17	698.7	Silt, gray, with gravel Qp=4.5	50/6”	51/6”
733.6	Clay, gray, trace gravel Qp=2.0 – 2.5	23,29	22,26	694.2	Silt, Sand, Gravel, gray Qp=4.5	79, 50/2”	78, 48/2”
729.6	Clay, gray, trace gravel Qp=1.5 – 3.0	13,15, 24,17	12,13, 20,13	689.7	EOB		
717.6	Clay and Silt, gray, trace sand and gravel Qp=3.0 - 4.5+	66,67	49,47				
705.6	Silt, gray, trace sand Qp=1.5	28	18				
700.6	Silt, gray, some sand, trace gravel Qp=4.5+	78,42, 59, 60/4”	49,25, 34, 33/4”				
682.6	EOB						

1. Blow counts are corrected for SPT hammer efficiency and overburden pressure.
2. First elevation is the surface elevation for the boring
3. Qp = Unconfined compression strength as determined by a pocket penetrometer, tons/ft^2
4. EOB is the end of boring.

B-40-0880 Subsurface Conditions

B-3 Station 21+10.0 40.6 feet right of CE RL				B-2 Station 21+14.8 23.3 feet left of CE RL			
Top of Soil Layer Elevation (feet)	**Soil Description**	**SPT Blow count**	**Corr. SPT Blow count**	**Top of Soil Layer Elevation (feet)**	**Soil Description**	**SPT Blow count**	**Corr. SPT Blow count**
759.4	Topsoil			760.5	Pavement Structure		
758.7	Sand, light brown to brown, fine to course, trace silt and gravel	14,13	32,24	759.5	Sand and Gravel, brown	31	49
755.4	Clay, brown, some silt, trace sand and gravel Qp=4.5 – 4.5+	14,32, 16,50	23,48, 22,65	752.5	Clay and Silt, brown, trace gravel Qp=2.5 – 3.0	11,15	15,18
747.4	Clay, gray, trace sand and gravel Qp=2.5 – 3.25	32,13, 14,15	40,15, 15,15	742.5	Clay, gray, trace gravel Qp=1.75 – 4.5+	18,22, 24,15, 19	19,23, 24,15, 18
730.4	Sand, gray, fine, little silt	29	27	732.5	Sand, gray, some silt	38	35
726.4	Sand, gray, fine, little silt	9	8	730.5	Sand, gray, some silt	9	8
722.4	Silt, gray, little sand, trace clay Qp=3.0	15	13	728.5	Clay, gray, trace sand and gravel Qp=2.5 – 3.0	22,14, 17,20, 21	20,12, 15,17, 17
719.4	EOB			711.0	Silt, gray, trace sand Qp=1.0	38	30
				702.5	Clay, gray Qp=1.75 – 3.0	21,27	16,20
				692.5	Clay and Gravel, gray, some silt Qp=4.5+	117, 108, 60/2’	85, 76, 41/2”
				680.5	EOB		

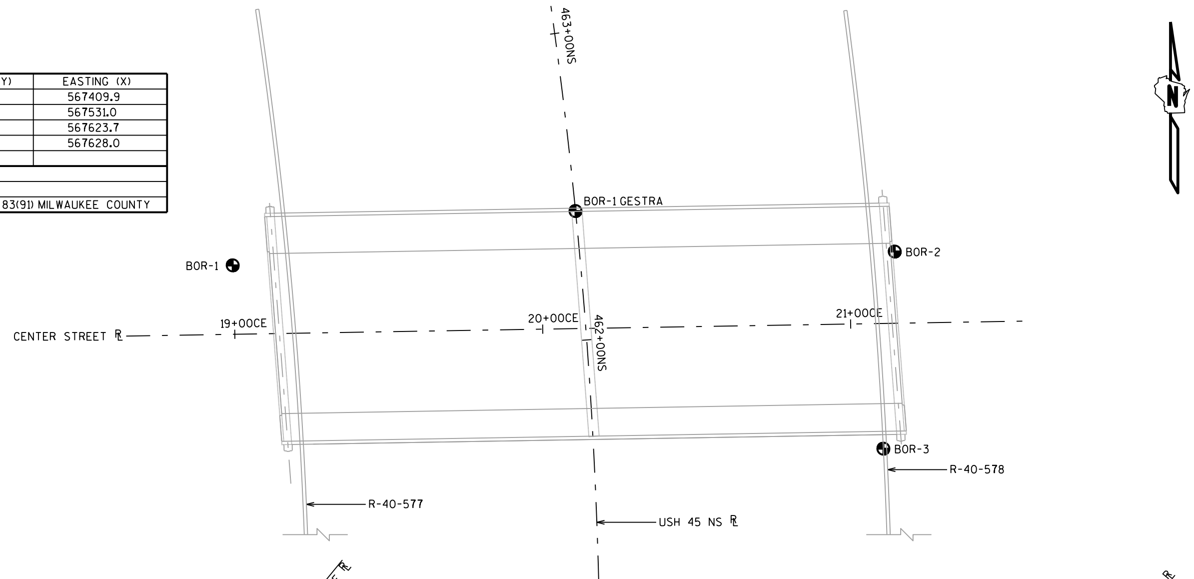
1. Blow counts are corrected for SPT hammer efficiency and overburden pressure.
2. First elevation is the surface elevation for the boring
3. Qp = Unconfined compression strength as determined by a pocket penetrometer, tons/ft^2
4. EOB is the end of boring.

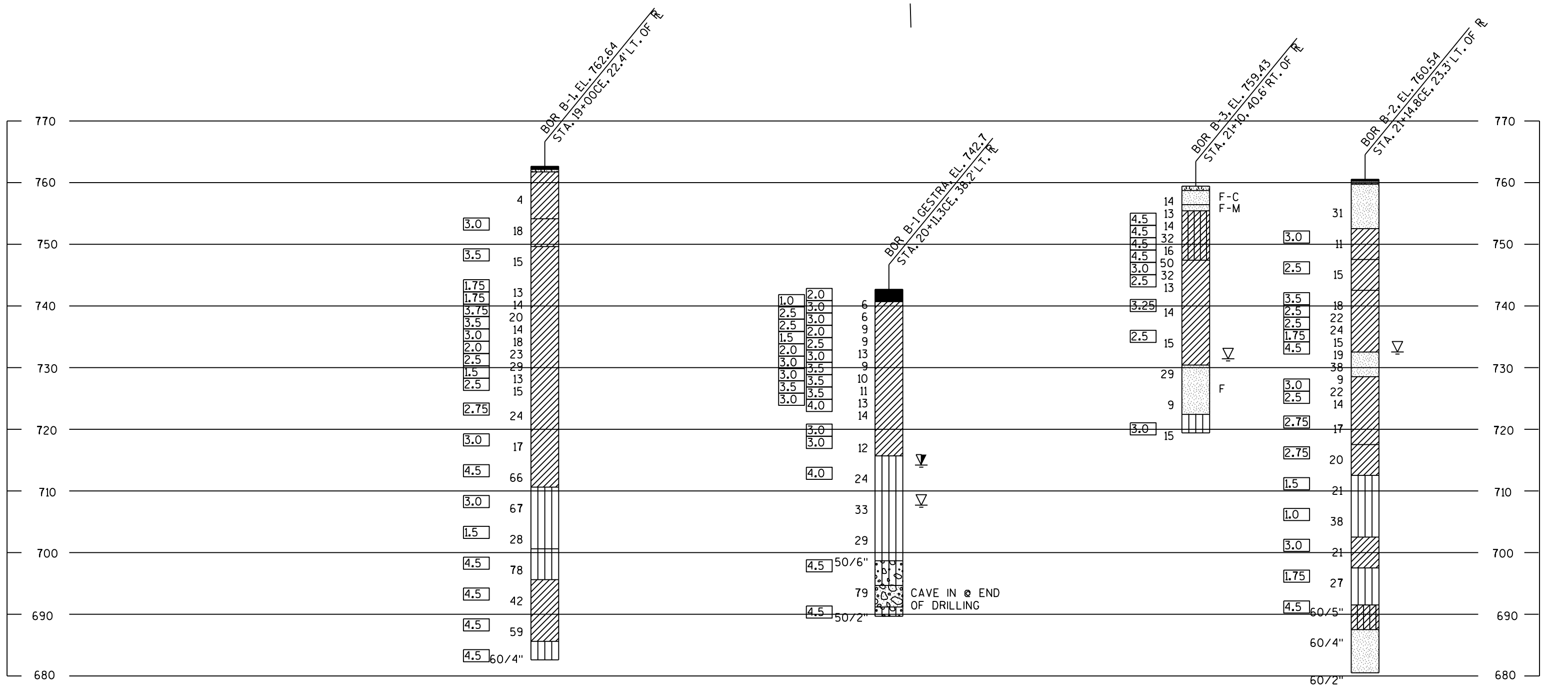
Attachment 2
Bridge Figure

ZOO INTERCHANGE, NORTH LEG
CENTER STREET OVER USH 45

BORING #	DATE COMPLETED	NORTHING (Y)	EASTING (X)
1	11/3/2014	310125.9	567409.9
GESTRA 1	10/16/2014	310131.3	567531.0
2	11/4/2014	310125.5	567623.7
3	11/5/2014	310040.4	567628.0

BORINGS COMPLETED BY: PSI/GESTRA
REPORT COMPLETED BY: WISDOT
ALL COORDINATES REFERENCED TO WCCS NAD 83(91) MILWAUKEE COUNTY

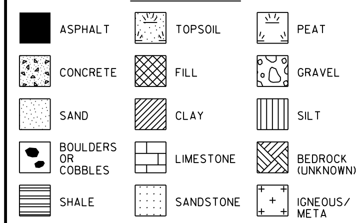




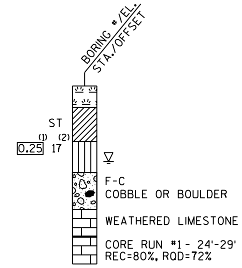
STATE PROJECT NUMBER

1060-33-16

MATERIAL SYMBOLS



LEGEND OF BORING



(1) UNCONFINED STRENGTH, AS DETERMINED BY A POCKET PENETROMETER (TSF)

(2) UNLESS OTHERWISE, SPECIFIED THE SPT 'N' VALUE IS BASED ON AASHTO T-206, STANDARD PENETRATION TEST. THE SPT 'N' VALUE PRESENTED HAS NOT BEEN CORRECTED FOR OVERBURDEN PRESSURE OR HAMMER EFFICIENCY.

GROUND WATER ELEVATION

- AT TIME OF DRILLING
- END OF DRILLING
- AFTER DRILLING

ABBREVIATIONS

F-FINE M-MEDIUM C-COARSE ST-SHELBY TUBE

SUBSURFACE EXPLORATION FOR FOUNDATION DESIGN AND BIDDERS INFORMATION

BORINGS WERE COMPLETED AT POINTS APPROXIMATELY AS INDICATED ON THIS DRAWING TO OBTAIN INFORMATION CONCERNING THE CHARACTER OF SUBSURFACE MATERIALS FOUND AT THE SITE. BECAUSE THE INVESTIGATED DEPTHS ARE LIMITED AND THE AREA OF THE BORINGS IS VERY SMALL IN RELATION TO THE ENTIRE SITE, THE WISCONSIN DEPARTMENT OF TRANSPORTATION DOES NOT WARRANT SIMILAR SUBSURFACE CONDITIONS BELOW, BETWEEN, OR BEYOND THESE BORINGS. VARIATIONS IN SOIL CONDITIONS SHOULD BE EXPECTED AND FLUCTUATIONS IN GROUNDWATER LEVELS MAY OCCUR.

NO.	DATE	REVISION	BY

STATE OF WISCONSIN
DEPARTMENT OF TRANSPORTATION
STRUCTURES DESIGN SECTION

STRUCTURE B-40-880

DRAWN BY PR | PLANS CK'D.

SUBSURFACE EXPLORATION

SHEET

SCALE =

8

WI Dept. of Transportation 3502 Kinsman Blvd. Madison, WI 53704	WISDOT PROJECT ID: 1060-33-16 WISDOT STRUCTURE ID: B-40-880-2		BORING ID: B-1 PAGE NO: 1 of 4	
WISDOT PROJECT NAME: Center Street over US Highway 45	CONSULTANT: Professional Service Industries, Inc.	CONSULTANT PROJECT NO: 0052853-7	LATITUDE: N43° 04.048'	LONGITUDE: W88° 03.229'
ROADWAY NAME: Center Street Over USH 45	DRILLING CONTRACTOR: PSI	DRILLING CONTRACTOR PROJECT NO: 0052853-7	NORTHING:	EASTING:
DATE STARTED: 11/03/14	CREW CHIEF: P. Rotaru	DRILL RIG: Freightliner	COORDINATE SYSTEM: Lat/Long	
DATE COMPLETED: 11/03/14	LOGGED BY: D. Zuydhoek	HOLE SIZE: 10 in	HORIZONTAL DATUM: WGS 1984	VERTICAL DATUM: MSL
COUNTY: Milwaukee	LOG QC BY:	HAMMER TYPE: Automatic	STREAMBED ELEVATION: NA	
STATION 462+35 / OFFSET 112.5' LT	TOWNSHIP: / RANGE: / SECTION:	1/4 SECTION: / 1/4 1/4 SECTION:	SURFACE ELEVATION: 762.64 ft	

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
				0.5	ASPHALT, (5.5" Thick) — 762.1						HSA	
				0.9	BASE COURSE, (5" Thick) — 761.7	GPS						
					CLAY, Fill, Dark Brown, Soft, Trace Sand and Gravel	CL						
SPT 1	4	M	3-2-2-3 (4)	4								
				8.5	754.1							
SPT 2	24	M	5-6-12-17 (18)	9	CLAY, Brown, Very Stiff, Trace Sand and Gravel	CL	3.0					
				13.0	749.6							
SPT 3	24	M	8-8-7-11 (15)	14	CLAY, Gray, Very Stiff, Trace to Few Sand and Gravel	CL	3.5					
SPT 4	24	M	4-5-8-7 (13)	19			1.75					
SPT 5	24	M	4-6-8-8 (14)	21	Stiff		1.75					
SPT 6	24	M	6-9-11-10 (20)	23	Very Stiff		3.75					
SPT 7	24	M	6-6-8-11 (14)	25			3.5					
SPT 8	24	M	7-8-10-11 (18)	27			3.0					
SPT 9	24	M	11-11-12-12 (23)	29			2.0					

WATER LEVEL & CAVE-IN OBSERVATION DATA

WATER ENCOUNTERED DURING DRILLING: NE	CAVE - IN DEPTH AT COMPLETION: NMR (WET ☐ DRY ☐)
WATER LEVEL AT COMPLETION: NMR	CAVE - IN DEPTH AFTER 0 HOURS: NMR (WET ☐ DRY ☐)

NOTES: 1) Stratification lines between soil types represent the approximate boundary; gradual transition between in-situ soil layers should be expected.
2) NE = Not Encountered; NMR = No Measurement Recorded

P:\GINT\WISDOT GINT PROJECTS\GINT_40\B-40-880.GPJ Center Street over US Highway 45 2/11/15

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
						CLAY, Gray, Very Stiff, Trace to Few Sand and Gravel							
SPT 10	24	M	16-15-14-17 (29)	31				2.5					
				32		Stiff							
SPT 11	24	M	5-6-7-10 (13)	33				1.5					
				34									
SPT 12	24	M	4-7-8-11 (15)	35		Very Stiff		2.5					
				36									
				37									
				38									
SPT 13	24	M	10-12-12-15 (24)	39				2.75					
				40									
				41			CL						
				42									
				43									
SPT 14	24	M	6-7-10-13 (17)	44				3.0					
				45								MR	
				46									
				47									
				48									
SPT 15	24	M	17-33-33-51 (66)	49				4.5					
				50		Hard							
				51									
				52		52.0 — 710.6							
						SILT, Gray, Very Stiff, Trace Sand							
				53									
SPT 16	24	M	13-25-42-60 (67)	54				3.0					
				55									
				56									
				57			ML						
				58									
SPT 17	24	M	8-12-16-18 (28)	59				1.5					
				60		Stiff							
				61									
				62		62.0 — 700.6							
						SILT, Gray, Hard, Some Sand, Trace Gravel							
				63									
SPT 18	15	M	30-43-35-46 (78)	64				4.5					
				65			ML						
				66									
				67		67.0 — 695.6							
						CLAY, Gray, Hard, Little Sand, Trace Gravel							
				68			CL						
SPT			11-20-22-										

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
19	24	M	27 (42)	70		CLAY, Gray, Hard, Little Sand, Trace Gravel		4.5					
				71									
				72									
				73			CL						
SPT 20	24	M	15-23-36-31 (59)	74				4.5					
				75									
				76									
				77		77.0 685.6							
						SILT, Gray, Hard, Some Sand, Trace Gravel							
				78									
SPT 21	8	M	58-60/4"	79			ML	4.5					
				80		80.0 682.6							

End of Boring at 80.0 ft.

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes

WI Dept. of Transportation **3502 Kinsman Blvd.** **Madison, WI 53704**	WISDOT PROJECT ID: **1060-33-16** WISDOT STRUCTURE ID: **B-40-880**		**BORING ID: B-1 Gestra** PAGE NO: **1 of 2**
WISDOT PROJECT NAME: **Center Street over US Highway 45**	CONSULTANT: **Professional Service Industries, Inc.**	CONSULTANT PROJECT NO: **0052853-7**	LATITUDE: / LONGITUDE:
ROADWAY NAME: **Center Street Over USH 45**	DRILLING CONTRACTOR: **GESTRA**	DRILLING CONTRACTOR PROJECT NO:	NORTHING: / EASTING:
DATE STARTED: **10/16/14**	CREW CHIEF: **A. Woerpel**	DRILL RIG: **CME-75**	COORDINATE SYSTEM: **WCCS**
DATE COMPLETED: **10/16/14**	LOGGED BY: **A. Woerpel**	HOLE SIZE: **3.25 in**	HORIZONTAL DATUM: **WCCS Milwaukee** / VERTICAL DATUM: **MSL**
COUNTY: **Milwaukee**	LOG QC BY:	HAMMER TYPE: **Automatic**	STREAMBED ELEVATION: **NA**
STATION **462+42** / OFFSET **ON R/L**	TOWNSHIP: / RANGE: / SECTION:	1/4 SECTION: / 1/4 1/4 SECTION:	SURFACE ELEVATION: **742.7 ft**

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
SPT 1	5	M	3-3 (6)	0–2		Asphalt Concrete 2.0 — 740.7		2.0				HSA	3 1/4 Hollowstem Auger
SPT 2	10	M	2-3-3-4 (6)	2–4		Moist Brown Clay with Trace Gravel Trace Sand		1.0 3.0					
SPT 3	22	M	2-3-6-7 (9)	4–6		Color Change To Gray Moist Clay Trace Gravel		2.5 3.0					
SPT 4	24	M	3-4-5-6 (9)	6–8				2.5 2.0					
SPT 5	24	M	3-6-7-9 (13)	8–10				1.5 2.5					
SPT 6	24	M	2-3-6-7 (9)	10–12				2.0 3.0					
SPT 7	24	M	2-4-6-7 (10)	12–14				3.0 3.5					
SPT 8	24	M	2-5-6-8 (11)	14–16		Moist Gray Clay Trace Gravel		3.0 3.5					
SPT 9	24	M	2-5-8-10 (13)	16–18				3.5 3.5					
SPT 10	24	M	2-5-9-10 (14)	18–20				3.0 4.0					
				20–23.5		Wet Pockets							
SPT 11	18	M	3-5-7 (12)	23.5–25				3.0 3.0					
				25–28.5		27.0 — 715.7 Moist Gray Silt With Trace Sand							
SPT 12	18	M	5-10-14 (24)	28.5–30				4.0					

WATER LEVEL & CAVE-IN OBSERVATION DATA

WATER ENCOUNTERED DURING DRILLING:	NMR	CAVE - IN DEPTH AT COMPLETION:	NMR (WET / DRY)
WATER LEVEL AT COMPLETION:	NMR	CAVE - IN DEPTH AFTER 0 HOURS:	NMR (WET / DRY)

NOTES: 1) Stratification lines between soil types represent the approximate boundary; gradual transition between in-situ soil layers should be expected.
2) NE = Not Encountered; NMR = No Measurement Recorded

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
						Moist Gray Silt With Trace Sand							
				31									
				32									
				33									
SPT 13	18	M	10-14-19 (33)	34									
				35		Wet Silt And Sand Mix							
				36									
				37		Wet Gray Silt							
				38									
SPT 14	18	W	12-13-16 (29)	39									
				40									
				41									
				42									
				43		44.0 698.7							
SPT 15	12	M	20-50	44		Moist Silt With Gravel		4.5					
				45									
				46									
				47		48.0 694.7							
				48		Saturated Gray Sand & Gravel							
SPT 16	12	W	16-35-44 (79)	49									
				50									
				51		51.5 691.2							
				52		Moist Silt With Gravel							
						53.0 689.7							
SPT 17	2	M	50/2"	53		End of Boring at 53.0 ft.		4.5					

WI Dept. of Transportation 3502 Kinsman Blvd. Madison, WI 53704	WISDOT PROJECT ID: 1060-33-16 WISDOT STRUCTURE ID: B-40-880-3		BORING ID: B-2 PAGE NO: 1 of 4	
WISDOT PROJECT NAME: Center Street over US Highway 45	CONSULTANT: Professional Service Industries, Inc.	CONSULTANT PROJECT NO: 0052853-7	LATITUDE: N43° 04.048'	LONGITUDE: W88.03.181'
ROADWAY NAME: Center Street	DRILLING CONTRACTOR: PSI	DRILLING CONTRACTOR PROJECT NO: 0052853-4	NORTHING:	EASTING:
DATE STARTED: 11/04/14	CREW CHIEF: P. Rotaru	DRILL RIG: Freightliner	COORDINATE SYSTEM: Lat/Long	
DATE COMPLETED: 11/04/14	LOGGED BY: D. Zuydhoek	HOLE SIZE: 10 in	HORIZONTAL DATUM: WGS 1984	VERTICAL DATUM: MSL
COUNTY: Milwaukee	LOG QC BY:	HAMMER TYPE: Automatic	STREAMBED ELEVATION: NA	
STATION 462+20 / OFFSET 102' RT	TOWNSHIP: / RANGE: / SECTION: / 1/4 SECTION: / 1/4 1/4 SECTION:		SURFACE ELEVATION: 760.54 ft	

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
						0.3 ASPHALT, (4" Thick) 760.2						HSA	
						0.6 CONCRETE, (3" Thick) 759.9	GPS						
						0.8 BASE COURSE, (3" Thick) 759.7							
				1–2		SAND, Brown, Dense, Some Gravel							
SPT 1	12	M	17-15-16-10 (31)	3–5			SP						
				6–7		8.0 752.5							
SPT 2	24	M	9-5-6-8 (11)	8–10		CLAY, Brown, Very Stiff, Trace Sand and Gravel	CL	3.0					
				11–12		13.0 747.5							
SPT 3	24	M	5-7-8-11 (15)	13–15		CLAY, Brown, Very Stiff, Trace Silt, Sand and Gravel	CL	2.5					
				16–17		18.0 742.5							
SPT 4	24	M	6-7-11-13 (18)	18–20		CLAY, Gray, Very Stiff, Trace Sand and Gravel	CL	3.5					
SPT 5	24	M	12-10-12-12 (22)	20–22				2.5					
SPT 6	24	M	11-13-11-12 (24)	22–24				2.5					
SPT 7	24	M	4-7-8-11 (15)	24–26		Stiff		1.75					
SPT 8	18	M	5-6-13-15 (19)	26–28		Hard 28.0 732.5		4.5					
SPT 9	24	W	19-22-16-16 (38)	28–30		SAND, Gray, Dense, Little Silt	SP						

WATER LEVEL & CAVE-IN OBSERVATION DATA

WATER ENCOUNTERED DURING DRILLING: NMR	CAVE - IN DEPTH AT COMPLETION: NMR	WET ☐ DRY ☐
WATER LEVEL AT COMPLETION: NMR	CAVE - IN DEPTH AFTER 0 HOURS: NMR	WET ☐ DRY ☐

NOTES: 1) Stratification lines between soil types represent the approximate boundary; gradual transition between in-situ soil layers should be expected.
2) NE = Not Encountered; NMR = No Measurement Recorded

P:\GINT\WISDOT GINT PROJECTS\GINT_40\B-40-880.GPJ Center Street over US Highway 45 2/11/15

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
SPT 10	24	W	2-3-6-9 (9)	31		SAND, Gray, Dense, Little Silt Loose 32.0 — 728.5	SP						
SPT 11	24	W	6-9-13-15 (22)	32–33		CLAY, Gray, Very Stiff, Trace Sand and Gravel		3.0					
SPT 12	24	W	4-6-8-8 (14)	34–35				2.5					
				36–37		Little Sand	CL						
SPT 13	24	W	5-6-11-12 (17)	38–39				2.75					
				40–42		43.0 — 717.5							
SPT 14	24	M	7-8-12-12 (20)	43–44		CLAY, Gray, Very Stiff, Trace Gravel		2.75					
				45–47		48.0 — 712.5	CL						
SPT 15	24	W	6-9-12-19 (21)	48–49		SILT, Gray, Stiff, Trace Sand		1.5					
				50–52								MR	
SPT 16	18	W	17-18-20-22 (38)	53–54			ML	1.0					
				55–57		58.0 — 702.5							
SPT 17	24	W	5-8-13-16 (21)	58–59		CLAY, Gray, Very Stiff, Trace Sand and Gravel		3.0					
				60–62		63.0 — 697.5	CL						
SPT 18	18	W	10-13-14-27 (27)	63–64		SILT, Gray, Stiff, Trace Sand		1.75					
				65–67			ML						
SPT	17	W	37-57-	68		69.0 — 691.5		4.5					

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
19			60/5"	70, 71, 72		SILTY CLAY, Gray, Hard, Trace Sand and Gravel	CL-ML						
				73		73.0 — 687.5							
SPT 20	12	W	53-48-60/4"	74, 75, 76, 77		SAND, Gray, Very Dense, Some Gravel, Trace Silt	SP						
SPT 21	2	W	60/2"	78, 79									
				80		80.0 — 680.5							

End of Boring at 80.0 ft.

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes

WI Dept. of Transportation 3502 Kinsman Blvd. Madison, WI 53704	WISDOT PROJECT ID: 1060-33-16 WISDOT STRUCTURE ID: R-40-578-3		**BORING ID: B-3** PAGE NO: 1 of 2	
WISDOT PROJECT NAME: Center Street over US Highway 45	CONSULTANT: Professional Service Industries, Inc.	CONSULTANT PROJECT NO: 0052853-7	LATITUDE: N43° 04.034'	LONGITUDE: W88° 03.180'
ROADWAY NAME: Center Street Over USH 45	DRILLING CONTRACTOR: PSI	DRILLING CONTRACTOR PROJECT NO: 0052853-4	NORTHING:	EASTING:
DATE STARTED: 11/05/14	CREW CHIEF: M. Ball	DRILL RIG: Diedrich D-50	COORDINATE SYSTEM: Lat/Long	
DATE COMPLETED: 11/05/14	LOGGED BY: D. Zuydhoek	HOLE SIZE: 10 in	HORIZONTAL DATUM: WGS 1984	VERTICAL DATUM: MSL
COUNTY: Milwaukee	LOG QC BY:	HAMMER TYPE: Automatic	STREAMBED ELEVATION: NA	
STATION: 461+60 / OFFSET: 94' RT	TOWNSHIP: / RANGE: / SECTION:	1/4 SECTION: / 1/4 1/4 SECTION:	SURFACE ELEVATION: 759.43 ft	

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
SPT 1	18	D	3-5-9-10 (14)	0.7	TOPSOIL, (8" Thick) — 758.7						HSA	
				1–3.0	SAND, Brown, Firm, Fine to Coarse, Trace Silt and Gravel — 756.4	SP						
SPT 2	24	D	12-7-6-6 (13)	3.0–4.0	SAND, Light Brown, Firm, Fine to Medium — 755.4	SP						
SPT 3	24	M	4-6-8-11 (14)	4.0–12.0	SILTY CLAY, Brown, Hard, Trace Sand and Gravel — 747.4	CL-ML	4.5					
SPT 4	12	M	7-12-20-18 (32)	7			4.5					
SPT 5	24	M	5-6-10-12 (16)	9			4.5					
SPT 6	24	M	12-25-25-23 (50)	11			4.5					
SPT 7	24	M	18-15-17-17 (32)	12.0–29.0	CLAY, Gray, Very Stiff, Trace Sand and Gravel — 730.4	CL	3.0					
SPT 8	24	M	4-6-7-7 (13)	15			2.5					
SPT 9	24	M	5-6-8-10 (14)	19			3.25					
SPT 10	24	M	9-7-8-8 (15)	24			2.5					
SPT 11	24	W	28-16-13-13 (29)	29.0	SAND, Gray, Firm, Fine, Little Silt	SP						

WATER LEVEL & CAVE-IN OBSERVATION DATA

WATER ENCOUNTERED DURING DRILLING: NMR	CAVE - IN DEPTH AT COMPLETION: NMR (WET ☐ DRY ☐)
WATER LEVEL AT COMPLETION: NMR	CAVE - IN DEPTH AFTER 0 HOURS: NMR (WET ☐ DRY ☐)

NOTES: 1) Stratification lines between soil types represent the approximate boundary; gradual transition between in-situ soil layers should be expected.
2) NE = Not Encountered; NMR = No Measurement Recorded

SAMPLE TYPE NUMBER	RECOVERY (in) (RQD)	Moisture	BLOW COUNTS (N VALUE)	Depth (ft)	Graphic	Soil / Rock Description and Geological Origin for Each Major Unit / Comments	USCS / AASHTO	Strength Qp (tsf)	Liquid Limit (%)	Plasticity Index (%)	Boulders	Drilling Method	Notes
				31		SAND, Gray, Firm, Fine, Little Silt	SP						
				32									
SPT 12	24	W	3-3-6-6 (9)	33–35									
				35–36		Loose							
				37		37.0 722.4							
				37		SILT, Gray, Very Stiff, Little Sand, Trace Clay	ML						
SPT 13	24	W	4-8-7-8 (15)	38–40		40.0 719.4		3.0					

End of Boring at 40.0 ft.

CORRESPONDENCE/MEMORANDUM ___________________State of Wisconsin

DATE: April 10, 2015

TO: Casey Wierzchowski, P.E.
Southeast Region Soils Engineer

FROM: Jeffrey D Horsfall, P.E.
Geotechnical Engineer

SUBJECT: **Site Investigation Report**
Project I.D. 1060-33-16
R-40-0577
Center Street over USH 45
(West Abutment B-40-0880)
Milwaukee County

Attached is the Site Investigation Report for the above project.

Please call if you have any questions.

Attachments

cc: Southeast Region (via e-mail)
Bureau of Structures, Structures Design (via e-submit)
Geotechnical File (original)

Site Investigation Report
Project I.D. 1060-33-16
Structure R-40-0577
Center Street over USH 45
(West Abutment B-40-0880)
Milwaukee County
April 10, 2015

1. GENERAL

The project is a retaining wall located along the west side of USH 45 near Center Street, Milwaukee County. A portion of the proposed retaining wall supports the West Abutment of B-40-0880. Table 1 presents the location of the wall compared to the wall stationing

Table 1: Wall Locations		
USH 45 Roadway Station	Wall Station	Description
457+75.0, 92.0' left	10+00.0	Beginning of Wall and supports side slope
463+22.0, 94.0' left	12+33.8	End of Wall and supports side slope

The maximum exposed height is 24.9 feet. The proposed wall type is a MSE wall with precast concrete panels. Aesthetics is a key item to consider in the evaluation of the wall. A portion of the wall is located within a cut section of the roadway. Topography in the general vicinity is urban with a bridge approach located near the wall.

The Southeast Region requested that the Geotechnical Unit evaluate a MSE wall with precast concrete panels. The following report presents the results of the subsurface investigation, the design evaluation, the findings, the conclusions and the recommendations.

2. SUBSURFACE CONDITIONS

Wisconsin Department of Transportation contracted with PSI to completed three borings near the proposed wall. Samples were collected with a method conforming to AASHTO T-206, Standard Penetration Test, using an automatic hammer. The purpose of the borings was to define subsurface soil conditions at this site. Soil textures in the boring logs were field identified by the drillers. Attachment 1 presents tables showing the summaries of subsurface conditions logged in the borings at this site and at the time of drilling for the retaining wall. Attachment 2 presents a figure that illustrates the boring locations and graphical representations of the boring logs. The original borings logs are available at the Central Office Geotechnical Engineering Unit and will be made available upon request.

The following describes the subsurface conditions in the three borings:

0.0 feet to 1.0 foot of pavement structure, overlying
0.0 feet to 7.5 feet of dark brown, soft, clay, trace sand and gravel (fill, B-1), overlying
3.0 feet to 36.5 feet of brown, medium hard to hard, clay, trace sand and gravel, overlying
5.0 feet to 25.0 feet of brown to gray, fine to medium, firm to very dense, sand or silt, trace gravel, overlying
Gray, very hard, silt and clay, little sand, trace gravel

Generally, groundwater was not encountered in the borings at the time of drilling.

3. ANALYSIS ASSUMPTIONS

Chapter 14 of the WisDOT Bridge Manual describe ten different types of retaining structures: reinforced cantilever, gabion, post and panel, sheet pile, modular block gravity, mechanically stabilized earth (MSE) with 4 types of facings, and modular bin and crib walls. Geotechnical Engineering Unit procedures require that the wall alternatives requested by the region be evaluated to determine the feasibility at a particular location, from a geotechnical standpoint.

Table 2 presents the design soil parameters utilized for the analyses, which approximate the conditions at B-7, B-6 and B-1.

Table 2: Soil Parameters

Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)
Granular Backfill Within the wall in the reinforcing zone	30	0	120
Fill Behind and below the reinforcing zone	31	0	120
B-7, 11+00			
Silt, gray, trace sand and gravel (Elevation 745.9 ft – 741.4 ft)	0	4,500	135
Sand, gray, fine to medium (Elevation 741.4 ft – 737.4 ft)	36	0	135
Silt, gray, trace sand, trace clay (Elevation 737.4 ft – 723.4 ft)	0	2,500	125
Silt, gray, trace sand, trace clay (Elevation 723.4 ft – 716.4 ft)	0	4,500	135
B-6, 12+00			
Silt, gray, trace clay, trace sand, trace gravel (Elevation 743.4 ft – 738.4 ft)	0	4,500	135
Sand, gray, fine to medium (Elevation 738.4 ft – 732.4 ft)	32	0	120
Clay, gray, little silt, trace sand, trace gravel (Elevation 732.4 ft – 710.4 ft)	0	3,000	128
Clay, gray, little silt, trace sand, trace gravel (Elevation 710.4 ft – 709.4 ft)	0	4,500	135
B-1, 14+60			
Clay, gray, trace gravel (Elevation 738.6 ft – 733.6 ft)	0	3,000	125
Clay, gray, trace gravel (Elevation 733.6 ft – 729.6 ft)	0	2,500	120
Clay, gray, trace gravel (Elevation 729.6 ft – 717.6 ft)	0	2,000	120
Clay and Silt, gray, trace sand and gravel (Elevation 717.6 ft – 705.6 ft)	0	4,500	135

Table 2: Soil Parameters			
Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)
B-1, 14+60 (continued)			
Clay, gray, trace sand (Elevation 705.6 ft – 700.6 ft)	0	2,000	120
Silt, gray, some sand, trace gravel (Elevation 700.6 ft and below)	0	25,000	135

The typical wall section used in the analyses had an **exposed** height that varies from 8.7 feet to 24.9 feet. The following assumptions are also included in the analyses:

1. The slope in front and behind the wall is horizontal.
2. Groundwater was not used in the analyses.
3. The granular backfill is free draining and will not become saturated.
4. The minimum embedment depth is 1.5 feet.
5. A surcharge load of 240 psf is included to model pedestrian and lightweight construction equipment.
6. An additional surcharge load equivalent to the weight of the soil behind the abutment is also included in the design.
7. Global stability factor of safety was determined by the computer program STABLPRO.
8. Bearing resistance is determined by Terzaghi's bearing capacity equation.
9. Settlement of the foundation on cohesionless and cohesive soil is based upon methods described in the FHWA Soils and Foundations Manual.

4. RESULTS OF ANALYSIS

The Geotechnical Unit evaluated a MSE wall with precast concrete facing for the project. The wall was evaluated for sliding, overturning, bearing resistance, global stability and settlement.

Table 3 presents the results of the evaluation and the Capacity to Demand Ratio (CDR).
The exposed wall height examined varied from 8.7 feet to 24.9 feet. The length of reinforcement for the wall is determined by meeting the eccentricity requirements (B/4>e) and a minimum embedment length of 8 feet.

The results of the evaluation indicated that if the sliding and bearing resistance requirements are met, then the eccentricity is also met. The global stability of the wall at the critical location was stable with a CDR of greater than 1.0.

The settlement of the foundation was estimated to be less than 1 inches and should occur within years of loading of the wall. The subsurface soils are relatively uniform; therefore, differential settlement should not be an issue.

Table 3: Results of MSE Wall External Stability Evaluation				
Dimensions				
Wall Height (feet)[1]	10.2	13.2	18.8	26.4
Exposed Wall Height (feet)	8.7	11.7	17.3	24.9
Length of Reinforcement (feet)[3]	8.0	9.2	17.4	18.5
Length of Rein. / Wall Height	NA	0.70	0.93	0.70
Wall Station	11+00.0	12+00.0	14+50.0	14+67.2
Boring Used	B-7	B-6	B-1	B-1
Capacity to Demand Ratio (CDR)[4]				
Sliding (CDR > 1.0)	1.4	1.3	1.0	1.5
Eccentricity (CDR > 1.0)	1.5	1.2	1.0	1.3
Global Stability (CDR > 1.0)	NA	NA	2.1	NA
Bearing Resistance (CDR > 1.0)	2.4	1.8	1.1	1.1
Required Bearing Resistance (psf)	6,000	6,000	7,000	7,000

1. The wall height includes an embedment of 1.5 feet.
2. The wall stability evaluation included a surcharge load that was equal to the weight of the soil behind the abutment.
3. The length of reinforcement is the minimum required length.
4. CDR requirements and load and resistance factors are presented in Chapter 14 of the Bridge Manual.
5. NA not applicable, global slope stability was evaluated at the critical wall location.

5. FINDINGS AND CONCLUSIONS

The following findings and conclusions are based upon the subsurface conditions and the analysis:

1. The following describes the subsurface conditions in the three borings:

   0.0 feet to 1.0 foot of pavement structure, overlying
   0.0 feet to 7.5 feet of dark brown, soft, clay, trace sand and gravel (fill, B-1), overlying
   3.0 feet to 36.5 feet of brown, medium hard to hard, clay, trace sand and gravel, overlying
   5.0 feet to 25.0 feet of brown to gray, fine to medium, firm to very dense, sand or silt, trace gravel, overlying
   Gray, very hard, silt and clay, little sand, trace gravel

2. The groundwater was not encountered in the investigation.

3. Table 3 presents the results of the external stability evaluation and shows that if the sliding and bearing resistance requirements are satisfied, then the eccentricity and global stability will also be satisfied.

4. Settlement of the foundation was estimated to be less than 2 inches and should occur within months of loading of the wall. The subsurface soils are relatively uniform; therefore, differential settlement should not be an issue.

6. RECOMMENDATIONS

The following recommendations are based upon the findings and conclusions:

1. The MSE wall with precast concrete panels will achieve the external stability factors of safety if the sliding and bearing resistance requirements are met. Table 3 presents the minimum length of the reinforcement at the locations evaluated. In the area of the wall that supports the abutment, the ratio of length of reinforcement to total height of wall should be increased from 0.70 to 0.93.

2. The contractor should remove 6-inches of topsoil and silt and clay below the reinforcing zone and replace with granular fill in the areas that the topsoil and silt and clay are encountered.

3. The backfill behind the MSE wall with precast concrete facing should be granular and free draining.

4. The Southeast Region soils engineer should review the fill subsurface conditions prior to construction of the wall.

Attachment 1
Tables of Subsurface Conditions

Site Investigation Report
Structure R-40-0577
Attachment 1

Subsurface Conditions: R-40-0577							
B-7 Station 458+75 85.5 feet left of USH 45 RL				**B-6 Station 459+75 85.5 feet left of USH 45 RL**			
Estimated Top of Soil Layer Elevation (feet)	**Soil Description**	**SPT Blow count**	**Corr. SPT Blow count**	**Estimated Top of Soil Layer Elevation (feet)**	**Soil Description**	**SPT Blow count**	**Corr. SPT Blow count**
751.4	Clay, brown, trace sand and gravel Qp=3.5	9	20	749.4	Clay, brown, trace sand and gravel Qp=2.25 – 2.5	7,12, 8	16,22, 13
748.4	Sand, brown, fine to medium, trace clay	18	33	743.9	Silt, gray, trace clay, trace sand, trace gravel Qp=4.5 – 4.5+	42,26	63,36
747.4	Silt, gray, trace sand and gravel Qp=3.0 – 4.5+	36,56, 62	58,82, 85	738.4	Sand, gray, fine to medium	12,31, 26	16,39, 31
741.4	Sand, gray, fine to medium	55,47	71,57	732.4	Clay, gray, little silt, trace sand, trace gravel Qp=3.25 – 4.5	23,17, 15,18	25,17, 14,16
737.4	Silt, gray, trace sand, trace clay Qp=2.5 – 4.5+	18,25, 18	21,27, 18	710.4	Clay, gray, little silt, trace sand, trace gravel Qp=3.5	43	35
723.4	Silt, gray, trace sand, trace clay Qp=3.5	108, 60/4”	100, 51/4”	709.4	EOB		
716.4	EOB						

1. Blow counts are corrected for SPT hammer efficiency and overburden pressure.
2. First elevation is the surface elevation for the boring.
3. Qp = Unconfined compression strength as determined by a pocket penetrometer, tons/ft^2.
4. EOB is the end of boring.

Subsurface Conditions: R-40-0577			
B-1 Station 462+35.0 112.5 feet left of USH 45 RL			
Estimated Top of Soil Layer Elevation (feet)	**Soil Description**	**SPT Blow count**	**Corr. SPT Blow count**
762.6	Pavement Structure		
761.6	Clay, dark brown, trace sand and gravel (fill)	4	7
754.1	Clay, brown, some silt, trace sand and gravel Qp=3.0	18	25
749.6	Clay, gray, trace gravel Qp=1.75 – 3.5	15,13,14	18,14,15
739.6	Clay, gray, trace gravel Qp=3.0 – 3.75	20,14,18	21,14,17
733.6	Clay, gray, trace gravel Qp=2.0 – 2.5	23,29	22,26
729.6	Clay, gray, trace gravel Qp=1.5 – 3.0	13,15,24,17	12,13,20,13
717.6	Clay and Silt, gray, trace sand and gravel Qp=3.0 - 4.5+	66,67	49,47
705.6	Silt, gray, trace sand Qp=1.5	28	18
700.6	Silt, gray, some sand, trace gravel Qp=4.5+	78,42,59, 60/4”	49,25,34, 33/4”
682.6	EOB		

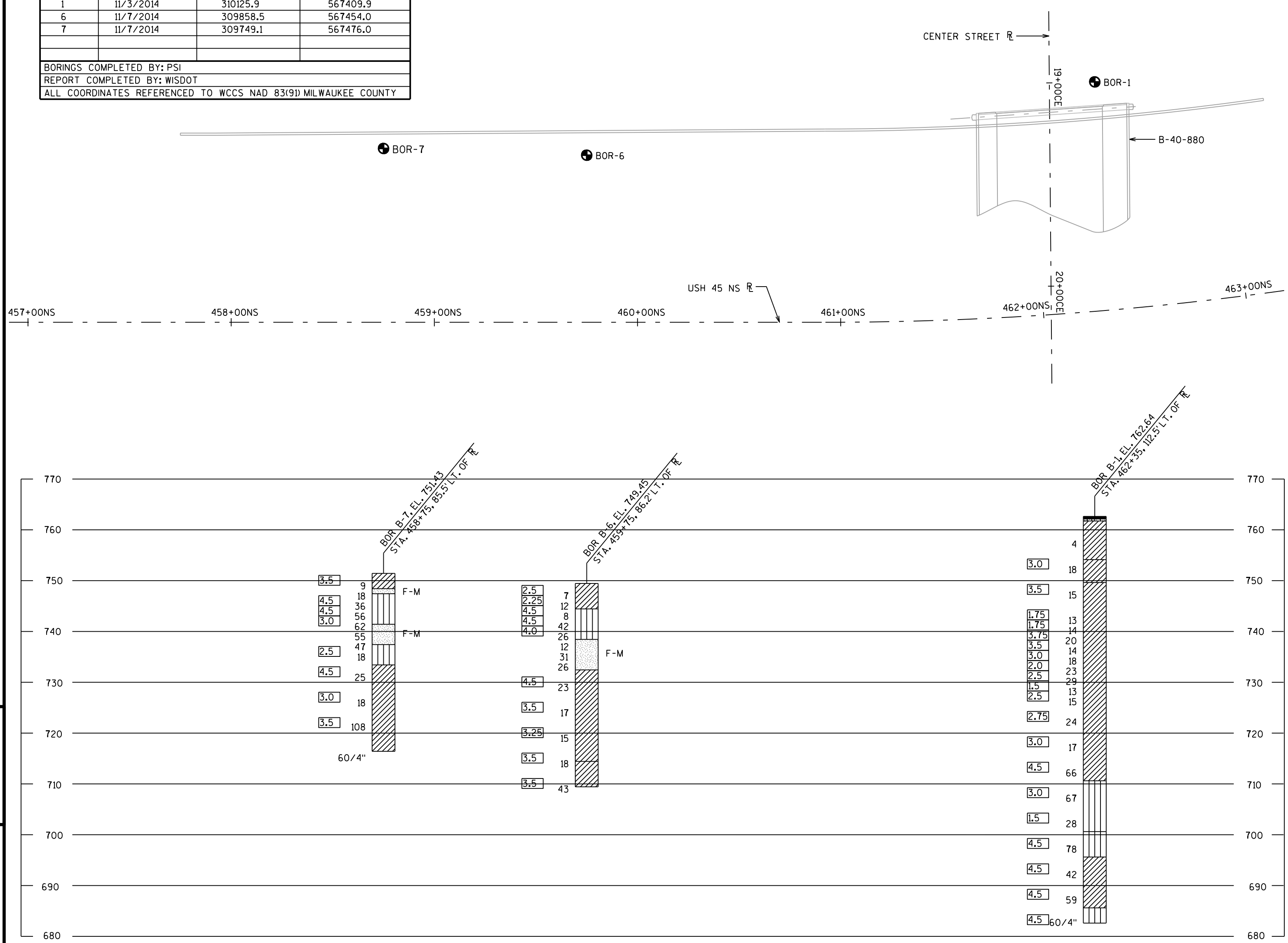
1. Blow counts are corrected for SPT hammer efficiency and overburden pressure.
2. First elevation is the surface elevation for the boring.
3. Qp = Unconfined compression strength as determined by a pocket penetrometer, tons/ft^2.
4. EOB is the end of boring.

Attachment 2
Wall Figure

ZOO INTERCHANGE, NORTH LEG
CENTER STREET OVER USH 45

BORING #	DATE COMPLETED	NORTHING (Y)	EASTING (X)
1	11/3/2014	310125.9	567409.9
6	11/7/2014	309858.5	567454.0
7	11/7/2014	309749.1	567476.0

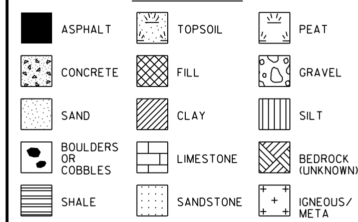
BORINGS COMPLETED BY: PSI
REPORT COMPLETED BY: WISDOT
ALL COORDINATES REFERENCED TO WCCS NAD 83(91) MILWAUKEE COUNTY



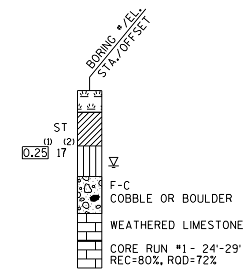
STATE PROJECT NUMBER

1060-33-16

MATERIAL SYMBOLS



LEGEND OF BORING



(1) UNCONFINED STRENGTH, AS DETERMINED BY A POCKET PENETROMETER (TSF)

(2) UNLESS OTHERWISE, SPECIFIED THE SPT 'N' VALUE IS BASED ON AASHTO T-206, STANDARD PENETRATION TEST. THE SPT 'N' VALUE PRESENTED HAS NOT BEEN CORRECTED FOR OVERBURDEN PRESSURE OR HAMMER EFFICIENCY.

GROUND WATER ELEVATION

- AT TIME OF DRILLING
- END OF DRILLING
- AFTER DRILLING

ABBREVIATIONS

F-FINE M-MEDIUM C-COARSE ST-SHELBY TUBE

SUBSURFACE EXPLORATION FOR FOUNDATION DESIGN AND BIDDERS INFORMATION

BORINGS WERE COMPLETED AT POINTS APPROXIMATELY AS INDICATED ON THIS DRAWING TO OBTAIN INFORMATION CONCERNING THE CHARACTER OF SUBSURFACE MATERIALS FOUND AT THE SITE. BECAUSE THE INVESTIGATED DEPTHS ARE LIMITED AND THE AREA OF THE BORINGS IS VERY SMALL IN RELATION TO THE ENTIRE SITE, THE WISCONSIN DEPARTMENT OF TRANSPORTATION DOES NOT WARRANT SIMILAR SUBSURFACE CONDITIONS BELOW, BETWEEN, OR BEYOND THESE BORINGS. VARIATIONS IN SOIL CONDITIONS SHOULD BE EXPECTED AND FLUCTUATIONS IN GROUNDWATER LEVELS MAY OCCUR.

NO.	DATE	REVISION	BY

STATE OF WISCONSIN
DEPARTMENT OF TRANSPORTATION
STRUCTURES DESIGN SECTION

STRUCTURE R-40-577

DRAWN BY PR | PLANS CK'D.

SUBSURFACE EXPLORATION

SHEET

8

8

SCALE =

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