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10.1 General

The function of a foundation is to transfer the load from the superstructure to the subsurface soil and/or rock without objectionable lateral or vertical movement. Selection and design of the proper foundation is dependent on the materials at the site, interpretation of field data, results of laboratory tests and engineering judgment.

Substructure foundations are classified as two general types, namely shallow and deep, based on the depth at which the applied load is transferred to the bearing stratum. Shallow foundations are defined as foundation elements with an embedment depth of approximately 2 times the least dimension of the spread footing. Deep foundations transfer load to the bearing stratum at greater depth.

Generally shallow foundations are preferred over deep foundations due to economics and ease of construction. However, when surface soils do not have adequate bearing capacity or when excessive settlement is computed, the foundation must be carried down to more resisting layers. Depending on site conditions, this is accomplished by open excavation, by driving piles or with drilled shafts. Traditionally, bridge structures have generally utilized pile units to carry loads down to more resisting materials. Pile types most commonly used in Wisconsin are cast-in-place concrete piles or steel H-piles.

At many structure locations, the abutment rests on newly compacted fill. To preclude large movement at the abutments, it is recommended that piles penetrate into natural ground. When the fill material is in excess of 10 feet of height, preboring for a displacement type pile is generally required.

Consider scour potential at stream crossings when selecting the foundation type. To reduce loss of support due to scour, WisDOT prefers to support sill abutments with deep foundations that penetrate erodible soil to a minimum depth of 10 feet below streambed elevation. As an alternative, spread footings at stream crossings can be founded on a massive bedrock formation, such as granite, that is highly-resistant to scour. In general, the recommended penetration of any pile is not less than 10 feet in hard material. The recommended penetration when only soft material is available is not less than one-third the length of the pile nor less than 20 feet. For permanent foundations, do not terminate piling in a soft upper stratum when a hard layer exists below. The piling should penetrate the hard layer a sufficient distance to rigidly fix its end.

A change in spread footing elevations from plans on grade separation structures of 1 foot deeper or 3 feet shallower does not require redesign. The Bureau of Structures should be contacted whenever larger changes in spread footing elevations are anticipated. There may be structural or geotechnical concerns with these larger changes. All spread footing elevation changes from plans on stream crossings should be checked for scour conditions.



10.2 Soil Classification

The total weight of the bridge plus all of the forces imposed upon the bridge 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 - This wide variety of soils includes granular outwash, hard tills, bouldery areas and almost any combination of soil that glaciers can create.
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 that predominates behavior has the controlling name. For example, a soil composed of sand and clay is called sandy clay if the clayey fraction controls behavior.



10.3 Soils Exploration

The Geotechnical Section (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 CADD 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 stratum
- Soil texture, color, mottling and moisture content
- In-situ field tests to determine soil parameters
- Laboratory samples for determining soil parameters
- Water levels, 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. This is particularly true where rock is present. In some cases, borings should be made at each substructure unit to adequately define conditions. Where it is apparent the soil is uniform, fewer borings are needed. 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 bedrock is encountered, borings are advanced by diamond bit coring to determine rock quality.

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)

Laboratory Tests

- Moisture, density, consistency limits and unit weight
- Unconfined compression (cohesive soils)
- 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)
- pH corrosive resistivity (seldom used)

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 either 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 the FHWA Report No. FHWA-IF-02-034, Geotechnical Engineering Circular No. 5, *Evaluation of Soil and Rock Properties*. 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 study may be conducted to give such geological aspects as petrology, rock structure, stratigraphy, vegetation and erosion.

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

- The preferred type of substructure foundation (ie shallow or deep).
- The allowable bearing capacity versus settlement for 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 affect 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.



10.4 Site Investigation Report

The following is a sample of a Site Investigation Report. The subsurface exploration drawing is also submitted with the report.

CORRESPONDENCE/MEMORANDUM _____ State of Wisconsin

DATE: February 5, 2008

TO: Bill Niemi, P.E.
Southwest Region, Madison Office Soils and Materials Engineer

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

SUBJECT: **Site Investigation Report**
Project I.D. 1390-04-01
B-28-146/147
STH 26 over Crawfish River
Jefferson County

Attached is the Site Investigation Report for the above project.

Please call if you have any questions.

Attachments

cc: Southwest Region, Madison Office (via e-mail)
Bureau of Structures, Structures Design (via e-mail)
Tom Zalewski, Earth Tech (via e-mail)
Central Office Files
Geotechnical File (original)

**Site Investigation Report
Project I.D. 1390-04-01
Structure B-28-146/147
STH 26 over the Crawfish River
Jefferson County
February 5, 2008**

1. GENERAL

The project is located on STH 26 over the Crawfish River, west of the city of Jefferson, Jefferson County. The two new structures will each have three spans and are part of the Jefferson Bypass project. The proposed base of the south abutments will require approximately 7 feet of fill, the piers will require 2 feet to 12 feet of excavation and the north abutments will require approximately 8 feet to 11 feet of excavation. Topography near the proposed structure is the lowlands and the Crawfish River. The project will be constructed using LRFD design for pile-supported substructures. The plans are in English units.

The Southwest Region, Madison Office requested that the Geotechnical Unit evaluate the foundation support for the proposed bridges. The following report presents the results of the subsurface investigation, the design evaluation, the findings, the conclusions and the recommendations.

2. SUBSURFACE CONDITIONS

The Geotechnical Section drill crews completed eight borings near the proposed structure. Samples were collected in the borings with a method conforming to AASHTO T-206, Standard Penetration Test, in May and June 2007, using an automatic hammer. The purpose of the borings was to define subsurface soil conditions at this location. 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 structures. Attachment 2 presents the results of the soils laboratory tests. Attachment 3 presents figures that illustrate the boring locations and graphical representations of the boring logs. The original borings logs are available at the Central Office Geotechnical Unit and will be made available upon request.

The following describes the subsurface conditions in the eight borings:

South Side Land Borings (B-1, B-3 and B-6)

1.5 feet to 5.0 feet of topsoil or black silt, overlying

4.5 feet to 9.5 feet of gray, soft, silt, trace clay, trace organics, overlying

2.5 feet to 8.5 feet of gray to brown, loose to firm, fine to medium, sand, overlying

52.0 feet to 65.0 feet of gray, medium hard, clay, some silt, overlying

Gray, firm to very dense, fine to coarse sand, some silt, some gravel and boulders (B-3 had a layer red silt at the base of the boring)

Water Borings (B-2, B-4 and B-5)

2.0 feet to 6.0 feet of water, overlying

0.0 feet to 6.0 feet of gray, very soft, silt, some sand, little organics, overlying

62.0 feet to 65.0 feet of gray, medium hard, clay, trace silt, overlying

Gray, firm to very dense, fine to course, sand, some silt, some gravel

North Side Land Borings (B-8 and B-7)

1.0 feet to 3.0 feet of topsoil or light brown sand or silt, overlying

12.0 feet to 14.0 feet of light brown to gray, loose, sand and silt, mottled, overlying

2.0 feet to 3.0 feet of light brown, firm, fine to medium, sand, overlying

12.0 feet to 15.5 feet of gray, soft, silt, little sand, overlying

55.0 feet to 59.5 feet of gray, medium hard, clay, trace silt, overlying

Gray, loose to very dense, sand, little silt, some gravel, trace boulders

The approximate water level at the time of drilling varied from elevation 773.5 feet to elevation 779.2 feet for the south side land borings, from elevation 777.0 feet to 778.0 feet in the Crawfish River and from 794.0 feet to 796.6 feet for the north side land borings. In addition, two of the borings (B-2 and B-4) experienced artesian conditions with a maximum water pressure of 7 feet above the level of the Crawfish River.

3. ANALYSIS ASSUMPTIONS

The foundation analyses are separated into a shallow foundation (spread footings) or a deep foundation (piling support). The analyses used the following assumptions:

Shallow Foundation (Allowable Stress Design)

1. The water level ranged from elevation 773.5 feet to elevation 796.6 feet.
2. The base of the foundations are at following elevations:

Substructure	B-28-146	B-52-147
South Abutment	790.7	792.5
Pier 1	771.0	771.2
Pier 2	769.2	768.6
North Abutment	786.9	788.9

3. The width of the footing is 6 feet.
4. The factor of safety is 3.0 for the allowable bearing capacity.

Deep Foundation (Load and Reduction Factor Design)

1. Soil pressures for displacement piles are based upon a 10 3/4-inch diameter cast-in-place pile.
2. The water level ranged from elevation 773.5 feet to elevation 796.6 feet.

3. Ultimate bearing capacity determined using the FHWA computer program DRIVEN.
4. The drivability evaluation used the computer program GRLWEAP.
5. The lateral capacities of the CIP piles are determined using the computer program LPILE.

Table 3 presents the design shear strength and unit weights used in the analysis. The values are based upon, empirical formulas for angle of internal friction using the Standard Penetration Test results and the effective overburden pressure and for cohesion using the pocket penetrometer tests results.

4. RESULTS OF ANALYSIS

Shallow Foundation

The estimated allowable bearing capacity at the base of the substructures (see Table 1) ranged from 1,700 psf for the fill at the south abutment with a 2H:1V end slope to 1,900 psf to 5,300 psf for the silt and clay below the piers and north abutment. Table 2 presents the results of the allowable bearing capacity for the soils at the base of the substructure footings.

Substructure	B-28-146	B-28-147
South Abutment	1,700 psf	1,700 psf
Pier 1	5,500 psf	1,900 psf
Pier 2	4,900 psf	5,300 psf
North Abutment	2,000 psf	3,000 psf

The estimated settlement from the bridge loads on the shallow foundations will be excessive at the substructures. The estimated settlement at the south abutment from the embankment load will range from 2 inches to 3 inches. The time for settlement would occur over several months in the fine-grained soils.

Deep Foundation

Table 3 shows the estimated skin friction and end bearing values.

Drivability

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 a 10 3/4-inch CIP pile should have the minimum pile thickness increased from 0.219-inches to 0.365-inches for the pile not to be overstressed during installation.

Lateral Pile Load Capacity

The lateral capacity of the 10 3/4-inch CIP piles is 8 kips for the front row and 12 kips at the back row at the south abutment and 14 kips for both rows of piles at the north abutment. The proposed abutment type is an A4.

Table 3: Soil Parameters and Foundation Capacities

Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)	Nominal Skin Friction ¹ (psf)	Nominal End Bearing ¹ (psf)
B-28-146 South Abutment (B-1)					
Fill, granular (replaces excavated 2' of topsoil) (Elevation 790.7 ft – 781.4 ft)	32	0	120	160	14,100
Silt, gray, trace clay, trace organics (Elevation 781.4 ft – 771.9 ft)	0	500	110	440	4,500
Sand, gray, fine to medium (Elevation 771.9 ft – 769.4 ft)	31	0	118	470	20,700
Silt, gray, trace silt (Elevation 769.4 ft – 755.4 ft)	0	2,000	120	1,510	18,000
Clay, gray, some silt (Elevation 755.4 ft – 723.4 ft)	0	2,250	123	1,570	20,200
Clay, gray, some silt (Elevation 723.4 ft – 704.4 ft)	0	2,500	125	1,520	22,500
Limestone Boulder (Elevation 704.4 ft – 703.4 ft)	NA	NA	NA	NA	NA
Sand, fine to medium, some silt, some gravel (Elevation 703.4 ft – 695.4 ft)	35	0	135	2,270	107,700
Boulder (Elevation 695.4 ft – 694.4 ft)	NA	NA	NA	NA	NA
Sand, gray, fine to medium, some silt, some gravel (Elevation 694.4 ft and below)	0	36,000	140	NA	Refusal
1. Skin friction and end bearings values are nominal values and have not been modified by a resistance factor. 2. NA - not applicable 3. Refusal, steel pile will obtain capacity in the very dense sand and silt layer.					

Table 3: Soil Parameters and Foundation Capacities (Continued)

Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)	Nominal Skin Friction ¹ (psf)	Nominal End Bearing ¹ (psf)
B-28-147 South Abutment (B-3)					
Fill, granular (replaces excavated 1.5' of black silt) (Elevation 792.5 ft – 783.7 ft)	32	0	120	150	13,300
Silt, light brown (Elevation 783.7 ft – 779.2 ft)	0	1,000	115	820	9,000
Sand, gray to brown, fine to course (Elevation 779.2 ft – 770.7 ft)	31	0	118	460	20,700
Clay, gray to brown, trace silt (Elevation 770.7 ft – 750.2 ft)	0	1,000	115	950	9,000
Clay, gray to brown, trace silt (Elevation 750.2 ft – 730.2 ft)	0	1,500	118	1,290	13,500
Clay, gray to brown, trace silt (Elevation 730.2 ft – 705.7 ft)	0	1,750	118	1,430	15,800
Sand, gray, fine to course, some silt, little gravel (Elevation 705.7 ft – 699.7 ft)	30	0	115	1,320	13,300
Silt, gray, trace clay (Elevation 699.7 ft – 695.7 ft)	0	4,500	135	1,250	40,500
Sand, brown, fine to course, some silt, little gravel (Elevation 695.7 ft – 691.2 ft)	35	0	135	2,320	107,700
Sand, brown, fine to course, some silt, little gravel (Elevation 691.2 ft – 680.2 ft)	0	36,000	140	NA	Refusal
Silt, red, some gravel, little clay (Elevation 680.2 ft and below)	0	36,000	140	NA	Refusal
1. Skin friction and end bearings values are nominal values and have not been modified by a resistance factor. 2. NA - not applicable 3. Refusal, steel pile will obtain capacity in the very dense sand and silt layer.					

Table 3: Soil Parameters and Foundation Capacities (Continued)

Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)	Nominal Skin Friction ¹ (psf)	Nominal End Bearing ¹ (psf)
B-28-146 Pier 1 (B-2)					
Silt, gray, some sand, some organics (Elevation 771.0 ft – 770.0 ft)	28	0	105	10	300
Clay, gray, trace silt (Elevation 770.0 ft – 749.0 ft)	0	2,500	125	1,250	22,500
Clay, gray, trace silt (Elevation 749.0 ft – 729.0 ft)	0	2,500	125	1,520	22,500
Clay, gray, trace silt (Elevation 729.0 ft – 708.0 ft)	0	2,250	123	1,570	20,300
Sand, gray, fine to medium, some silt, little gravel (Elevation 708.0 ft – 700.5 ft)	38	0	135	2,170	268,700
Sand and Gravel, fine to course, some silt, boulders (Elevation 700.5 ft and below)	0	36,000	140	NA	Refusal
B-28-147 Pier 1 (B-6)					
Sand, fine to medium, trace shells (Elevation 771.2 ft – 768.5 ft)	30	0	110	10	1,100
Clay, gray (Elevation 768.5 ft – 743.0 ft)	0	2,000	120	1,410	18,000
Clay, gray (Elevation 743.0 ft – 728.0 ft)	0	2,000	120	1,510	18,000
Clay, gray (Elevation 728.0 ft – 708.0 ft)	0	2,250	123	1,570	20,300
Gravel (Elevation 708.0 ft – 704.0 ft)	38	0	135	1,990	268,700
Sand, brown, some silt, little gravel (Elevation 704.0 ft and below)	0	36,000	140	NA	Refusal
<ol style="list-style-type: none"> 1. Skin friction and end bearings values are nominal values and have not been modified by a resistance factor. 2. NA - not applicable 3. Refusal, steel pile will obtain capacity in the very dense sand and silt layer. 					

Table 3: Soil Parameters and Foundation Capacities (Continued)

Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)	Nominal Skin Friction ¹ (psf)	Nominal End Bearing ¹ (psf)
B-28-146 Pier 2 (B-4)					
Clay, gray, some silt (Elevation 769.2 ft – 753.0 ft)	0	2,500	125	1,140	22,500
Clay, gray, some silt (Elevation 753.0 ft – 733.0 ft)	0	2,500	125	1,520	22,500
Clay, gray, some silt (Elevation 733.0 ft – 709.0 ft)	0	2,250	123	1,570	20,300
Sand, gray, fine to medium, some silt, little gravel (Elevation 709.0 ft – 705.0 ft)	32	0	120	1,090	33,000
Gravel, fine to course, little sand (Elevation 705.0 ft – 701.0 ft)	38	0	135	2,130	268,700
Sand and Gravel, fine to course, some silt (Elevation 701.0 ft and below)	0	36,000	140	NA	Refusal
B-28-147 Pier 2 (B-5)					
Clay, gray, some silt (Elevation 768.6 ft – 753.0 ft)	0	2,750	128	1,010	24,800
Clay, gray, some silt (Elevation 753.0 ft – 733.0 ft)	0	2,500	125	1,520	22,500
Clay, gray, some silt (Elevation 733.0 ft – 707.5 ft)	0	2,500	125	1,520	22,500
Sand, gray, fine to course, some silt, some gravel (Elevation 707.5 ft – 703.5 ft)	34	0	130	1,360	73,600
Sand and Gravel, gray, fine to course, some silt (Elevation 703.5 ft – 695.0 ft)	40	0	138	2,790	417,800
Sand and Gravel, gray, fine to course, some silt (Elevation 695.0 ft – 689.0 ft)	32	0	120	1,400	33,000
Gravel, gray, fine to course, few boulders (Elevation 689.0 ft and below)	0	36,000	140	NA	Refusal
<ol style="list-style-type: none"> 1. Skin friction and end bearings values are nominal values and have not been modified by a resistance factor. 2. NA - not applicable 3. Refusal, steel pile will obtain capacity in the very dense sand and silt layer. 					

Table 3: Soil Parameters and Foundation Capacities (Continued)

Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)	Nominal Skin Friction ¹ (psf)	Nominal End Bearing ¹ (psf)
B-28-146 North Abutment (B-8)					
Silt, brown to gray, little sand, mottled (Elevation 786.9 ft – 782.6 ft)	0	1,000	110	800	9,000
Sand, light brown, fine to medium (Elevation 782.6 ft – 780.6 ft)	34	0	125	90	9,900
Silt, gray, little sand (Elevation 780.6 ft – 768.6 ft)	0	1,500	115	1,140	13,500
Clay, gray, little silt (Elevation 768.6 ft – 742.6 ft)	0	2,500	125	1,520	22,500
Clay, gray, little silt (Elevation 742.6 ft – 722.6 ft)	0	1,500	115	1,290	13,500
Clay, gray, little silt (Elevation 722.6 ft – 709.1 ft)	0	2,000	120	1,510	18,000
Sand, gray, some silt, little gravel, trace boulders (Elevation 709.1 ft and below)	0	36,000	140	NA	Refusal
1. Skin friction and end bearings values are nominal values and have not been modified by a resistance factor. 2. NA - not applicable 3. Refusal, steel pile will obtain capacity in the very dense sand and silt layer.					

Table 3: Soil Parameters and Foundation Capacities

Soil Description	Friction Angle (degrees)	Cohesion (psf)	Unit Weight (pcf)	Nominal Skin Friction ¹ (psf)	Nominal End Bearing ¹ (psf)
B-28-147 North Abutment (B-7)					
Silt, brown, trace sand, mottled (Elevation 788.9 ft – 782.0 ft)	0	1,500	115	1,060	13,500
Sand, brown, fine (Elevation 782.0 ft – 779.0 ft)	34	0	125	150	16,800
Silt, gray, trace sand (Elevation 779.0 ft – 763.5 ft)	0	2,000	120	1,380	18,000
Clay, gray, trace silt (Elevation 763.5 ft – 742.0 ft)	0	2,000	120	1,510	18,000
Clay, gray, trace silt (Elevation 742.0 ft – 722.0 ft)	0	2,000	120	1,510	18,000
Clay, gray, trace silt (Elevation 722.0 ft – 712.0 ft)	0	1,500	115	1,290	13,500
Silt, gray, little clay, trace sand and gravel (Elevation 712.0 ft – 708.5 ft)	0	1,000	110	940	9,000
Sand, gray, little silt and gravel (Elevation 708.5 ft – 700.0 ft)	29	0	110	1,010	13,300
Sand, gray, some gravel, little silt (Elevation 700.0 ft – 691.0 ft)	32	0	120	1,470	33,000
Sand, gray, little silt, some gravel (Elevation 691.0 ft and below)	0	36,000	140	NA	Refusal
1. Skin friction and end bearings values are nominal values and have not been modified by a resistance factor. 2. NA - not applicable 3. Refusal, steel pile will obtain capacity in the very dense sand and silt layer.					

Lateral Earth Pressure

The lateral earth pressure for the backfill material will exert 36 psf for sandy soils. The backfill material will be granular, free draining and locally available.

Scour

The bridge section will estimate the scour depth based on the soil types located in the riverbed.

5. FINDING 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 eight borings:

South Side Land Borings (B-1, B-3 and B-6)

1.5 feet to 5.0 feet of topsoil or black silt, overlying

4.5 feet to 9.5 feet of gray, soft, silt, trace clay, trace organics, overlying

2.5 feet to 8.5 feet of gray to brown, loose to firm, fine to medium, sand, overlying

52.0 feet to 65.0 feet of gray, medium hard, clay, some silt, overlying

Gray, firm to very dense, fine to course sand, some silt, some gravel and boulders (B-3 had a layer red silt at the base of the boring)

Water Borings (B-2, B-4 and B-5)

2.0 feet to 6.0 feet of water, overlying

0.0 feet to 6.0 feet of gray, very soft, silt, some sand, little organics, overlying

62.0 feet to 65.0 feet of gray, medium hard, clay, trace silt, overlying

Gray, firm to very dense, fine to course, sand, some silt, some gravel

North Side Land Borings (B-8 and B-7)

1.0 feet to 3.0 feet of topsoil or light brown sand or silt, overlying

12.0 feet to 14.0 feet of light brown to gray, loose, sand and silt, mottled, overlying

2.0 feet to 3.0 feet of light brown, firm, fine to medium, sand, overlying

12.0 feet to 15.5 feet of gray, soft, silt, little sand, overlying

55.0 feet to 59.5 feet of gray, medium hard, clay, trace silt, overlying

Gray, loose to very dense, sand, little silt, some gravel, trace boulders

2. The approximate water level at the time of drilling varied from elevation 773.5 feet to elevation 779.2 feet for the south side land borings, from elevation 777.0 feet to 778.0 feet in the Crawfish River and from 794.0 feet to 796.6 feet for the north side land borings. In addition, two of the borings (B-2 and B-4) experienced artesian conditions with a maximum water pressure of 7 feet above the level of the Crawfish River.
3. The estimated allowable bearing capacity at the base of the substructures (see Table 1) ranged from 1,700 psf for the fill at the south abutment with a 2H:1V end slope to 1,900 psf to 5,300 psf for the silt and clay below the piers and north abutment. Table 2 presents

the results of the allowable bearing capacity calculations. The calculation utilized a factor of safety of 3.

4. Support of the piles will occur in the very dense silt, weathered bedrock or bedrock. The pile tip elevation will range from 693 feet to 709 feet. The driven pile lengths will depend upon the type of pile hammer used and the actual subsurface conditions encountered.
5. 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 a 10 3/4-inch CIP pile should have the minimum pile thickness increased from 0.219-inches to 0.365-inches for the pile not to be overstressed during installation.
6. The lateral capacity of the 10 3/4-inch CIP piles is 8 kips for the front row and 12 kips at the back row at the south abutment and 14 kips for both rows of piles at the north abutment. The proposed abutment type is an A4.

6. RECOMMENDATIONS

The following recommendations are based upon the findings and conclusions:

1. The recommended support system for the abutments and piers are 10 3/4-inch diameter cast in place piles driven to a "Required Driving Resistance" of 186 tons using modified Gates dynamic formula. These values use a "Factored Axial Compression Resistance" of 74.5 tons and a Resistance Factor of 0.4 for the modified Gates dynamic formula.

Table 4 presents the estimated pile tip elevations for the substructures. The actual pile lengths compared to the design pile lengths maybe shorter, because the piles may achieve bearing in the dense sand or silt layers above the very dense sand and gravel layers.

Substructure	B-28-146	B-28-147
South Abutment	703 feet	693 feet
Pier 1	708 feet	708 feet
Pier 2	705 feet	703 feet
North Abutment	709 feet	694 feet

2. The drivability evaluation indicated that the driving stresses require the thickness of the 10 3/4-inch diameter CIP piles should be increased from 0.219-inches to 0.365-inches.
3. Flush mounted end plates should be used at the end of the 10 3/4-inch diameter cast in place pile to reduce the potential for loss of skin friction resistance because of the artesian conditions.

4. Pile spacing should be as great as possible to reduce the effect of densification of the soils during installation of cast in place piles within the cofferdam.
5. The settlement of the subsurface soils caused by the construction of the south abutment approach embankments will cause excessive down drag loads on the piles. Therefore, the plans should provide details for excavating the topsoil and silt and backfilling with granular fill prior to installation of the embankments and piling at the south abutments. The limits of the excavation should be based on a 1.5H:1V slope from the east and west subgrade shoulder points and from the front of the south abutments and the back of the approach slabs. The estimated depth of the excavation should range from 11 feet (east end) to 7 feet (west end).

An alternative option would be to surcharge the south abutment areas prior to construction of the bridges. The estimated time for the consolidation of the compressible materials would be approximately 6 months.

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

Site Investigation Report
Structure B-28-146/147
Attachment 1

Attachment 1
Tables of Subsurface Conditions

B-28-146/147 South Abutment							
B-1 Station 559+10 45.2 feet right of STH 26 NB RL				B-3 Station 559+19 105.3 feet left of STH 26 NB 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
783.4	Topsoil			785.2	Silt, black		
781.4	Silt, gray, trace clay, trace organics Qp=0.25	5	9	783.7	Silt, light brown Qp=1.0	7	13
771.9	Sand, gray, fine to medium	11	18	779.2	Sand, gray to brown, fine to course	9	16
769.4	Silt, gray, trace clay Qp=2.0 – 2.25	8,11, 11	12,16, 15	770.7	Clay, brown to gray, trace silt Qp=0.75 – 3.0	8,6,6, 11	13,9, 8,15
755.4	Clay, gray, some silt Qp=1.5 – 2.5	11,9, 13,11, 13,10	15,11, 16,13, 15,11	750.2	Clay, brown to gray, trace silt Qp=0.25 – 2.5	10,11, 8,12, 11	13,14, 9,14, 12
723.4	Clay, gray, some silt Qp=1.75 – 3.0	12,20, 19,20	13,20, 19,19	730.2	Clay, brown to gray, trace silt Qp=1.0 – 2.5	7,14, 14,15	7,14, 14,15
704.4	Limestone Boulder			705.7	Sand, gray, fine to course, some silt, little gravel	12	11
703.4	Sand, fine to medium, some silt, some gravel	51,35	47,31	699.7	Silt, gray, trace clay Qp=4.5	18	16
695.4	Boulder			695.7	Sand, brown, fine to course, some silt, little gravel	45	40
694.4	Sand, gray, fine to medium, some silt, some gravel	100/5” 100/5” 100/4”	81,84, 81	691.2	Sand, brown, fine to course, some silt, little gravel	94, 100/5” 72	81,83, 58
682.4	EOB			680.2	Silt, red, some gravel, little clay		
				679.2	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/ft²
4. EOB is the end of boring

Site Investigation Report
 Structure B-28-146/147
 Attachment 1

B-28-146/147 Pier 1							
B-2 Station 560+77 18 feet right of STH 26 NB RL				B-6 Station 560+54 79.1 feet left of STH 26 NB 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
779.0	Barge			783.0	Silt, black, trace clay		
778.0	Water			778.0	Silt, brown, trace sand, trace fibers Qp=0.5 – 1.0	4	8
776.0	Silt, gray, some sand, some organics	0,6,4	0,16,9	773.5	Sand, fine to medium, trace shells	5	8
770.0	Clay, gray, trace silt Qp=2.0 – 2.75	8,14, 8,12,8	17,28, 14,20, 12	768.5	Clay, gray Qp=0.5 – 2.75	8,9,7, 9,10,8	12,13, 9,12, 12,9
749.0	Clay, gray, trace silt Qp=1.75 – 2.5	10,13, 10,14	14,18, 13,18	743.0	Clay, gray Qp=1.25 – 2.25	12,10, 10	14,11, 11
729.0	Clay, gray, trace silt Qp=1.75 – 3.0	12,13, 18,16	14,15, 20,17	728.0	Clay, gray Qp=1.5 – 2.75	13,11, 13	13,11, 13
708.0	Sand, gray, fine to medium, some silt, little gravel	95,67	99,67	708.0	Gravel	100/5"	94
700.5	Sand and Gravel, fine to course, some silt, some boulders ARTESIAN	100/3" 100/2"	97,94	704.0	Sand, brown, some silt, little gravel	72, 100/2" 100/1" 100/1"	65,88, 85,82
694.0	EOB			688.9	EOB		

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4. EOB is the end of boring

B-28-146/147 Pier 2							
B-4 Station 562+23 19 feet right of STH 26 NB RL				B-5 Station 562+20 79 feet left of STH 26 NB 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
778.0	Barge			778.0	Barge		
777.0	Water			777.0	Water		
771.0	Clay, gray, some silt Qp=1.75 – 3.0	11,13, 12,13, 12,16	32,32, 26,27, 23,28	773.0	Clay, gray, some silt Qp=2.75 – 3.25	8,15, 11,14	47,34, 21,24
753.0	Clay, gray, some silt Qp=2.25 – 2.5	16,14, 17,15	26,21, 24,20	753.0	Clay, gray, some silt Qp=2.0 – 2.75	14,13, 13,13	22,20, 18,17
733.0	Clay, gray, some silt Qp=1.75 – 2.25	17,14, 16,14, 26	22,17, 19,18, 29	733.0	Clay, gray, some silt Qp=2.0 – 2.5	16,14, 17,18, 18	21,17, 20,20, 20
709.0	Sand, gray, fine to medium, some silt, little gravel	22	23	707.5	Sand, gray, fine to medium, some silt, some gravel	27	31
705.0	Gravel, fine to course, little sand	35	36	703.5	Sand and Gravel, gray, fine to course, some silt	106, 43	109, 42
701.0	Sand and Gravel, fine to course, some silt ARTESIAN	120, 134, 107	119, 129, 98	695.0	Sand, gray, fine to medium, some silt, some gravel	19	18
686.5	EOB			689.0	Gravel, gray, fine to course, few boulders	100/5” 100/5” 100/3”	93,89, 87
				678.0	EOB		

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2. First elevation is the surface elevation for the boring
3. Qp = Unconfined compression strength as determined by a pocket penetrometer, tons/ft²
4. EOB is the end of boring

B-28-146/147 North Abutment							
B-8 Station 563+19 45.0 feet right of STH 26 NB RL				B-7 Station 563+19 105.0 feet left of STH 26 NB 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
797.6	Sand, light brown, some silt			797.0	Topsoil		
				796.0	Silt, light brown		
796.6	Silt, brown to gray, little sand, mottled Qp=1.25	7,6	13,9	794.0	Sand, light brown, some silt, mottled	9	16
				789.0	Silt, brown, tr. sand, mottled Qp=1.5	9	15
782.6	Sand, light brown, fine to medium	27	37	782.0	Sand, brown, fine	16	25
780.6	Silt, gray, little sand Qp=1.25 – 3.0	6,8	8,10	779.0	Silt, gray, trace sand Qp= 0.5 – 2.5	5,8,11	7,11, 15
768.6	Clay, gray, little silt Qp=1.5 – 2.75	11,10 10,9	13,12, 11,9	763.5	Clay, gray, trace silt Qp=1.75 – 2.25	13,12, 14,11	16,15, 16,12
742.6	Clay, gray, little silt Qp=1.25 – 2.2	9,10, 12,10	9,10, 11,9	742.0	Clay, gray, trace silt Qp=1.25 – 2.5	11,13, 11,11	12,14, 11,11
722.6	Clay, gray, little silt Qp=2.0 – 2.25	10,11, 16	9,10, 14	722.0	Clay, gray, trace silt Qp=1.75 – 2.0	11,11	11,10
709.1	Sand, gray, some silt, little gravel, trace boulders	92, 100/3” 100/4”	77,82, 79	712.0	Silt, gray, little clay, tr. sand and gravel Qp=0.75 – 1.2	10	9
697.1	EOB			708.5	Sand, gray, little silt and gravel	6,12	5,10
				700.0	Sand, gray, some gravel, little silt	32,21	27,17
				691.0	Sand, gray, some gravel, little silt	100/1” 100/0”	80,77
				683.0	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/ft²
4. EOB is the end of boring

Site Investigation Report
Structure B-28-146/147
Attachment 2

Attachment 2

Soils Laboratory Test Results

TEST NUMBER 230-6-07

MO.-DAY-YR.	PROJECT ID	TEST CODE	QUANTITY
6 12 07	1390-04-01	190 2	1 tube

County Jefferson	Project Name STH 26 over Crawfish River
Contractor	
Material Soil	
Source	
Tests Requested By Foundation & Pavements	
Submitted by: Jeff Horsfall	Date 6/4/07

BORING NUMBER	8	8	8		
SAMPLE NUMBER	bot	mid	top		
DEPTH, FT.	39.5-42.0	39.5-42.0	39.5-42.0		

MECHANICAL ANALYSIS (AASHTO T-88)					
Boulders (Ret. 3")					
Gravel (Pass 3" - Ret. #10)					
Coarse Sand (Pass #10 - Ret. #40)					
Fine Sand (Pass #40 - Ret. #200)		0			
Silt (Pass #200 - Ret. 0.002mm)		54			
Clay (Pass 0.002mm)		46			
LIQUID LIMIT (AASHTO T-89)		37			
PLASTICITY INDEX (AASHTO T-90)		20			
UNIFIED CLASSIFICATION (ASTM D 2487)		CL			
AASHTO CLASSIFICATION (AASHTO M-145)		A-6(21)			
LOSS ON IGNITION, % (AASHTO T-267)					
MOISTURE, % (AASHTO T-265)		21.4			
UNCONFINED COMPRESSION TEST (AASHTO T-208)					
MOISTURE CONTENT, %	23.0		23.2		
UNIT WEIGHT, PCF	104.7		104.9		
PENETRATION RESISTANCE, TSF	1.5	3.25	1.5		
UNCONFINED COMPRESSION, PSF	5506		5150		
CONSOLIDATION TEST (AASHTO T-216)					
MOISTURE BEFORE, %					
MOISTURE AFTER, %					
COMPRESSION INDEX					
DIRECT SHEAR TEST (AASHTO T-236)					
MOISTURE CONTENT, %					
ANGLE OF INTERNAL FRICTION, DEGREES					
COHESION, PSF					

Remarks

DISTRIBUTION: Geotechnical Unit
District

By WRK

Site Investigation Report
Structure B-28-146/147
Attachment 3

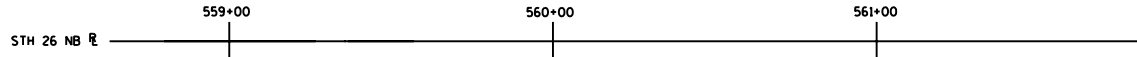
Attachment 3

Bridge Figures

STH 26 OVER CRAWFISH RIVER
JEFFERSON BYPASS

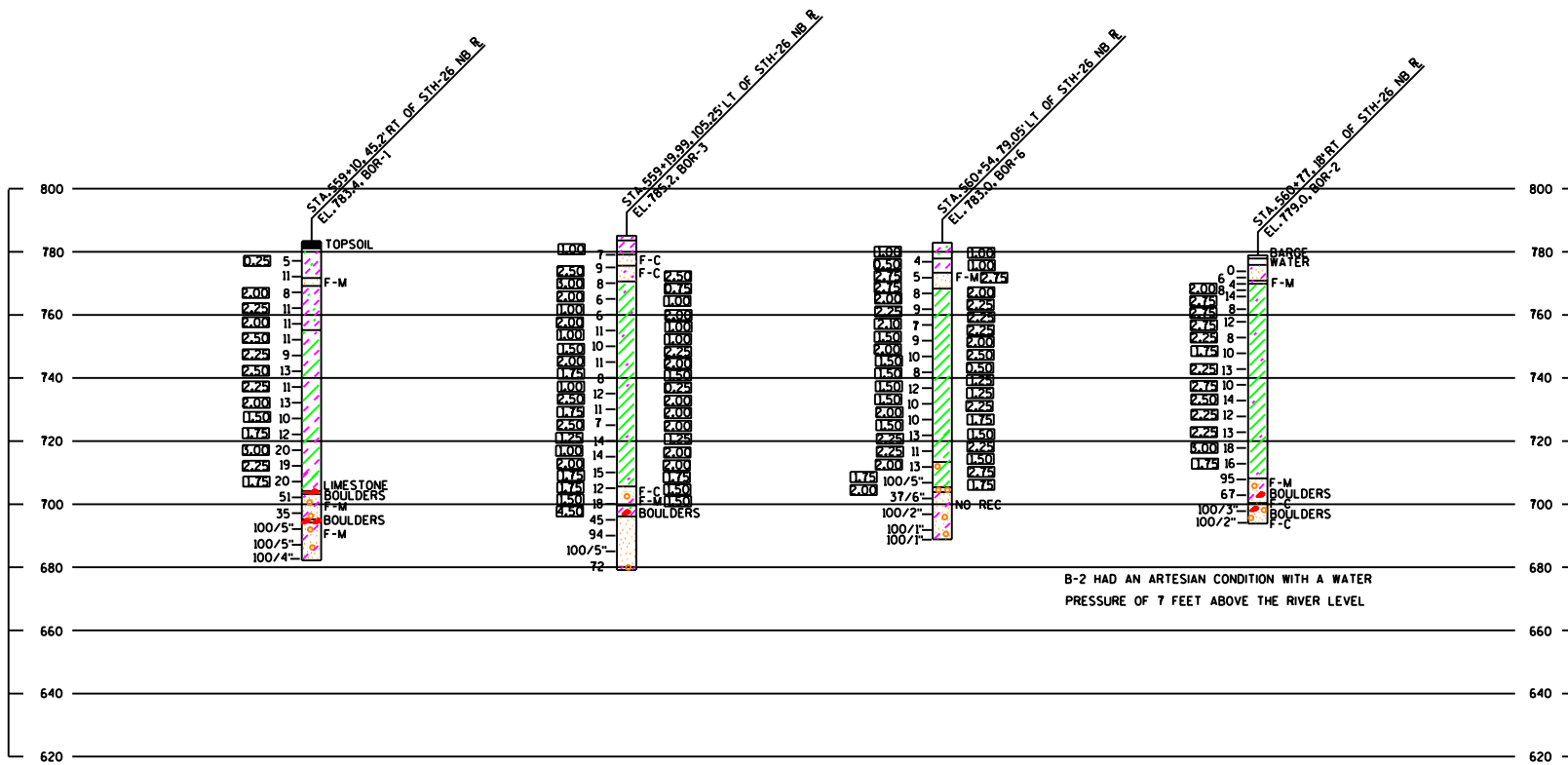
● BOR - 3

● BOR - 6



● BOR - 1

● BOR - 2



STATE PROJECT NUMBER



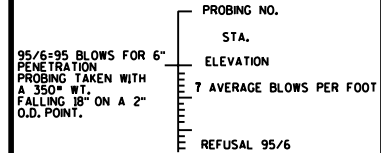
ABBREVIATIONS

F — FINE M — MEDIUM C — COARSE
WS — WEATHERED SO — SOUND

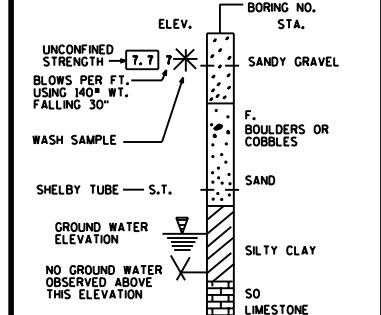
MATERIAL SYMBOLS



LEGEND OF PROBING



LEGEND OF BORING



UNLESS OTHERWISE SPECIFIED, THE BLOWS PER FOOT AT THE LOCATIONS INDICATED ARE BASED ON DRIVING A 2" O.D. X 1.4" I.D. SPLIT SPOON SAMPLER WITH A 140# HAMMER HAVING A FREE FALL OF 30". THE BLOW COUNT IS TAKEN IN UNDISTURBED SOIL IMMEDIATELY BELOW A CASED OR OPEN HOLE ELIMINATING SIDE FRICTION ON THE DRIVE PIPE.

SUBSURFACE EXPLORATION FOR FOUNDATION DESIGN AND BIDDERS INFORMATION

TO OBTAIN RELATIVE DATA CONCERNING THE CHARACTER OF MATERIAL IN AND UPON WHICH THE FOUNDATION MIGHT BE BUILT, BORINGS AND/OR SOUNDINGS WERE MADE AT POINTS APPROXIMATELY AS INDICATED ON THIS DRAWING. THE DATA PRESENTED HEREIN REPRESENTS THE FINDINGS OF THE SUBSURFACE EXPLORATIONS MADE. HOWEVER, BECAUSE THE DEPTHS INVESTIGATED ARE LIMITED AND THE AREA OF THE BORINGS AND/OR SOUNDINGS IS VERY SMALL IN RELATION TO THE ENTIRE AREA, THE WISCONSIN DEPARTMENT OF TRANSPORTATION DOES NOT WARRANT CONDITIONS BELOW THE DEPTHS INVESTIGATED OR THAT THE CLASSIFICATION OF MATERIAL ENCOUNTERED IN THESE INVESTIGATIONS IS NECESSARILY TYPICAL OF THE ENTIRE SITE.

NO.	DATE	REVISION	BY

STATE OF WISCONSIN
DEPARTMENT OF TRANSPORTATION
STRUCTURES DESIGN SECTION
STRUCTURE 8-20-146/147A

DRAWN BY: L.H. PLANS (C.D.)

SHEET _3

SUBSURFACE EXPLORATION

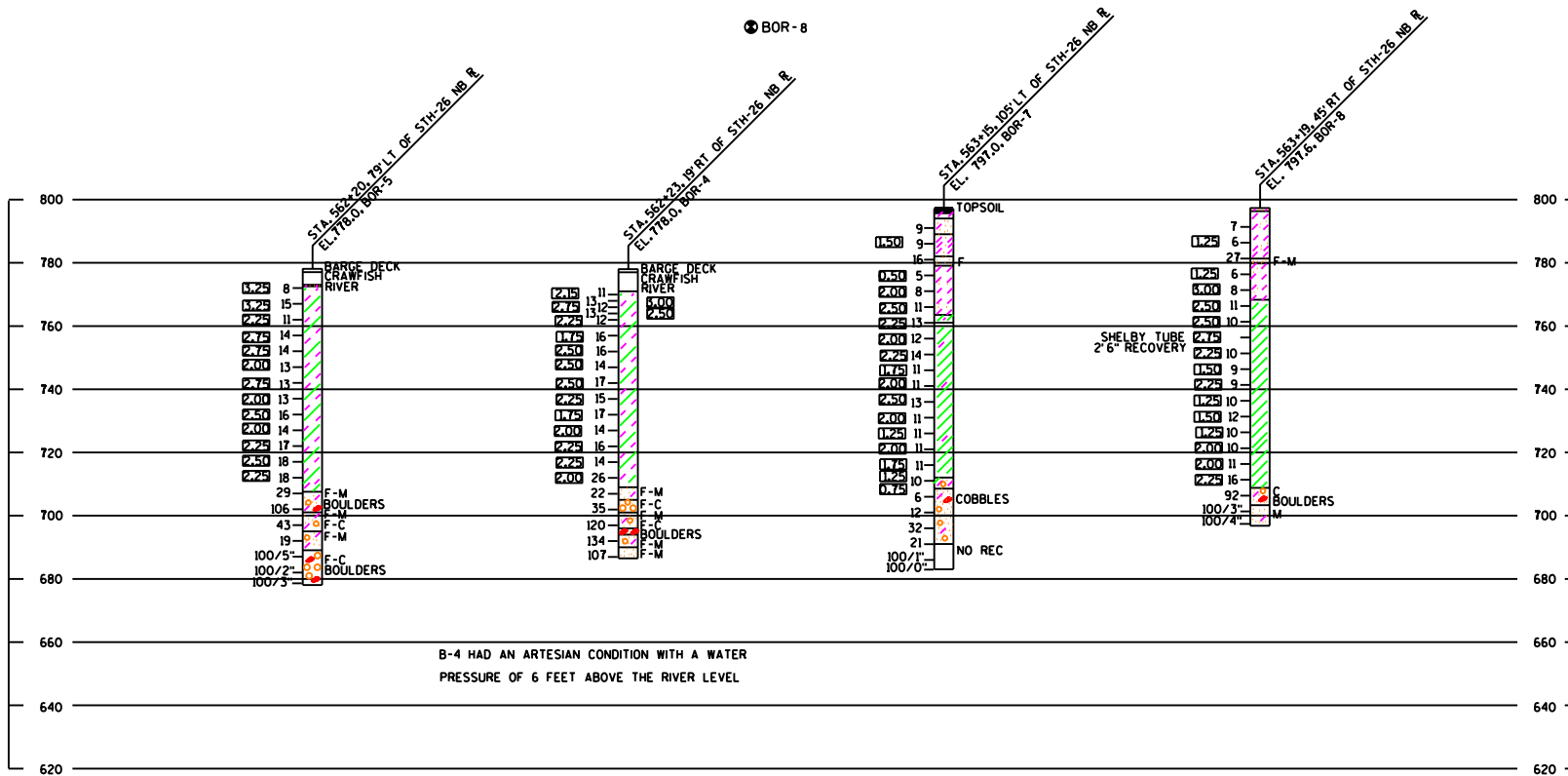
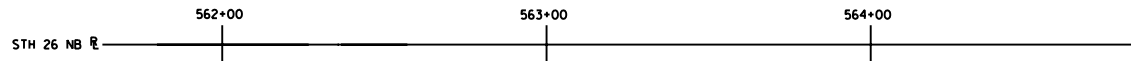
STH 26 OVER CRAWFISH RIVER
JEFFERSON BYPASS

BOR - 7

BOR - 5

BOR - 4

BOR - 8



STATE PROJECT NUMBER



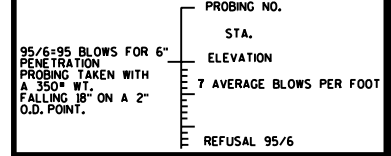
ABBREVIATIONS

F — FINE M — MEDIUM C — COARSE
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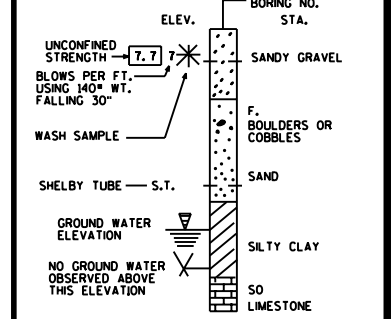
MATERIAL SYMBOLS



LEGEND OF PROBING



LEGEND OF BORING



SUBSURFACE EXPLORATION FOR FOUNDATION DESIGN AND BIDDERS INFORMATION

TO OBTAIN RELATIVE DATA CONCERNING THE CHARACTER OF MATERIAL IN AND UPON WHICH THE FOUNDATION MIGHT BE BUILT, BORINGS AND/OR SOUNDINGS WERE MADE AT POINTS APPROXIMATELY AS INDICATED ON THIS DRAWING. THE DATA PRESENTED HEREIN REPRESENTS THE FINDINGS OF THE SUBSURFACE EXPLORATIONS MADE. HOWEVER, BECAUSE THE DEPTHS INVESTIGATED ARE LIMITED AND THE AREA OF THE BORINGS AND/OR SOUNDINGS IS VERY SMALL IN RELATION TO THE ENTIRE AREA, THE WISCONSIN DEPARTMENT OF TRANSPORTATION DOES NOT WARRANT CONDITIONS BELOW THE DEPTHS INVESTIGATED OR THAT THE CLASSIFICATION OF MATERIAL ENCOUNTERED IN THESE INVESTIGATIONS IS NECESSARILY TYPICAL OF THE ENTIRE SITE.

NO.	DATE	REVISION	BY
STATE OF WISCONSIN DEPARTMENT OF TRANSPORTATION STRUCTURE DESIGN SECTION			
STRUCTURE 0-20-146/147B			
DRAWN BY		PLANS	
L.H.		G.S.	
SUBSURFACE EXPLORATION			SHEET 3