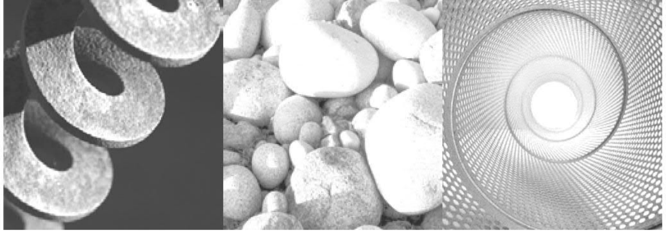


Consulting
Engineers and
Scientists

Geotechnical Report

McKnight Community Trail

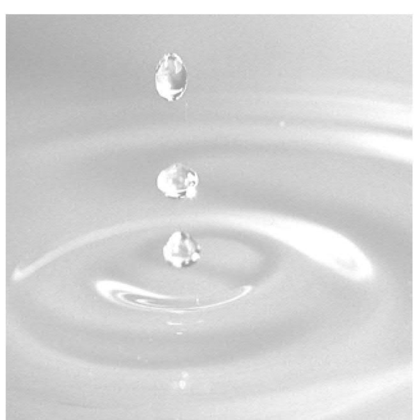
Springfield, Massachusetts

Submitted to:
BETA Group, Inc.
315 Norwood Park South
Norwood, MA 02062

Submitted by:
GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801
781-721-4000

April 2020

Project 1904391



Stephen J. Sarandis, P.E.
Project Manager

Richard F. Tobin, P.E.
Senior Project Manager

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Executive Summary

This report presents the results of the subsurface explorations and our geotechnical recommendations for the proposed McKnight Community Trail project in Springfield, Massachusetts.

We understand that the City of Springfield is planning on constructing a multi-use recreational trail on a historical railroad right-of-way on the northwest side of the McKnight Neighborhood in Springfield Massachusetts. The proposed trail will be about 3800 feet long and will extend from Armory Street northeastward up to St. James Avenue. The project includes the replacement of the superstructure of the existing Glen Road railroad bridge and the construction of two raised timber boardwalks to support a large section of the trail, which passes through an existing wetland.

Subsurface Conditions

Ten borings and six probes were performed in 2019 and 2020 by GEI. Twelve feet of stone abutment was cored in one of the probes at the west abutment.

The probes and abutment cores were performed to define the extents and bearing elevations of the existing bridge abutments.

The borings encountered 0.5 to 2 feet of topsoil, overlying interbedded layers Sand and Silt and Clay to a depth of approximately 96 feet below ground surface. Depth to groundwater measured in the borings ranged from at the ground surface to 9.3 feet.

Recommendations

Based on our evaluations, it appears the existing abutments of the Glen Road Bridge are founded on loose to medium dense Silt and Sand and will provide adequate bearing for the replacement structure. Curves of factored bearing resistance versus effective footing width are provided.

We understand that the raised boardwalks will be supported on helical piles to minimize impacts to the existing wetlands. We recommend that the helical piles installed to derive their support in the Upper Sand and Silt layer.

The helical piles should be designed and constructed in accordance with Section 1810.3 of the current edition of the Massachusetts State Building Code (which incorporates the 2015 International Building Code).

1. Introduction

1.1 Purpose

This report presents the results of the subsurface explorations and our geotechnical recommendations for the proposed McKnight Community Trail located in the McKnight neighborhood of Springfield, Massachusetts.

1.2 Scope

Our scope of work included:

- Conducted a site visit to observe site conditions and mark boring locations.
- Reviewed available published geologic data and available information on the existing Glen Road bridge and the proposed trail.
- Performed 10 borings to identify subsurface conditions, and 6 probes to explore the geometry of the abutments and their bearing materials. Provided full-time observation of the explorations.
- Performed laboratory grain-size tests on six soil samples collected from the explorations and six sediment soil samples collected for scour analysis.
- Performed two laboratory Atterberg Limits.
- Evaluated the soil conditions and developed geotechnical design and construction recommendations.
- Prepared this report.

1.3 Authorization

Mr. Mark R. Gershman, P.E. of BETA Group, Inc. authorized our work by a subconsultant agreement dated August 1, 2019.

1.4 Project Personnel

The following personnel at GEI were involved with the field explorations, evaluations, and preparation of this report:

Stephen J. Sarandis, P.E.	Project Manager
Rich F. Tobin, P.E.	In-House Reviewer
Hassan Ghiye	Geotechnical Engineer
Patrick Blessing	Staff Scientist

2. Site and Project Description

2.1 Site and Project Description

The site for the McKnight Community Trail is located along a historical railroad right-of-way on the northwest side of the McKnight neighborhood in Springfield Massachusetts (Figs. 1 and 2). The proposed trail will be about 3800 feet long and will extend from Armory Street northeastward up to St. James Avenue. A petroleum pipeline and easement owned by Buckeye Partners, L.P. extends along part of the project corridor.

Within the project limits there is an existing railroad bridge that crosses over an unnamed stream near the alignment of a paper street named Glen Road. The bridge is referred to as the Glen Road Bridge. Available information on this bridge compiled by previous consultants working on the project is presented in Appendix A. The bridge is a single span steel beam superstructure supported on stone abutments. The span of the bridge is 12 feet. There are no available drawings of the original construction of the bridge. We understand that the current plan is to replace the superstructure of the bridge and re-use the existing stone abutments. The unnamed stream that passes beneath the bridge drains wetlands located on and along the railroad right-of-way to the northeast of the bridge.

The ground surface within the project area slopes upward from a low of about El. 148 at the west end of the trail near Agnew Street up to about El. 191 towards the east end of the trail near St. James Avenue. The top of the Glen Road bridge is at about El. 161 and is about 10 feet above the unnamed stream and ground surface below.

The proposed trail will consist of a 12-foot wide paved hot mixed asphalt path with 2-foot wide gravel shoulders on each side. Northeast of the Glen Road Bridge there will be an 800-foot section of the proposed trail that will be supported on a raised timber boardwalk to carry it over wetland areas.

2.2 Project Design Basis

Our recommendations conform to the AASHTO 2017 LRFD Bridge Design Specifications, 8th Edition, and AASHTO 2011 Guide Specifications for LRFD Seismic Bridge Design, 2nd Edition, with interim revisions through 2015. Our recommendations are also based on the Massachusetts Department of Transportation (MassDOT) 2013 LRFD Bridge Manual (Bridge Manual).

2.3 Elevation Datum

Elevations in this report are in feet and are referenced to the 1988 North American Vertical Datum (NAVD 1988).

3. Subsurface Conditions

3.1 Site Geology

The surficial geology map of the Springfield South quadrangle indicates the soils in the project vicinity consist of clays, silts, sands, and gravel. Lake Deposits and Delta Outwash Plain deposits are shown on the map along the proposed alignment of the trail. The map indicates that the Lake Deposits were formed in historic glacial lake Hitchcock and may be as much as 230 feet thick. The Bedrock Geologic Map of Massachusetts indicates the bedrock in the project vicinity consists of reddish brown to gray arkose, siltstone and sandstone.

3.2 Subsurface Exploration Program

Northern Drill Service Inc. of Northborough, Massachusetts drilled ten borings (BB-1, BB-2 and BWB-1 through BWB-8), advanced six probes (P-1A through P-1C and P-2A through P-2C), and obtained 12 feet of abutment core between October 29, 2019 and March 16, 2020, using a Diedrich D-25 rig.

The locations of the borings and probes are shown in Figs. 2 and 3. A GEI engineer logged the explorations and collected samples. GEI logs for the borings, probes, and abutment cores are provided in Appendix B.

In addition, a GEI engineer collected six sediment samples near the Glen Road bridge for laboratory grain size analysis to support scour evaluation. The locations of the sediment samples collected are shown in Fig. 3.

The 2019 probes (P-1A through P-1C) were performed using the direct push method by advancing a 2 O.D. split spoon while the 2020 probes (P-2A through P-2C) were completed using driven flush joint 3-inch steel casing and rotary wash drilling techniques.

The borings were completed using driven flush joint 4-inch steel casing and rotary wash drilling techniques.

Standard Penetration Testing (SPT) with split-spoon sampling was performed using an automatic hammer at generally about 5-foot intervals in the explorations. Twelve feet of abutment core was obtained from probe P-2A.

The probes were advanced in the spaces between the wood ties and were performed to define the extents and depths of the existing bridge abutment foundations as follows:

- P-1A was advanced until refusal was encountered on probable stone abutment.

- P-2A was advanced until refusal was encountered on stone abutment. The abutment was then cored 12 feet using NX coring. One split spoon sample was taken below the bottom of the abutment to confirm the soil conditions.
- P-1B and P-2B were advanced until the split spoon encountered very hard material and collected stone fragments in the sample, indicating the presence of possible stone abutment. The probes were then drilled through the stone abutment foundations using drill rods and roller bits until the drill string broke through the underside of the last block. One to three split spoon samples were taken below the bottom of the abutment to confirm the soil conditions.
- P-1C and P-2C were advanced to depths of 21 and 20 feet below ground surface, respectively. No stone abutment was encountered in these probes.

Probe depths were measured from the top of the wooden railroad ties or adjacent ground surface, which were about the same elevation. Probe locations were referenced to the top front edge of the concrete cap structure. The results of the Glen Road bridge probes are shown on the cross section of Fig. 4.

Upon completion, borings and probes were backfilled with soil cuttings and topped off with gravel.

GEI's field engineer determined the as-drilled locations of the borings and probes by taping distances from known physical landmarks. Ground surface elevations at the boring and probe locations were estimated from the topographic plan of the site. Estimated ground surface elevations are reported on the exploration logs.

We also obtained six sediment samples, by hand, from the banks and channel of the unnamed stream upstream of the Glen Road Bridge (Fig. 2).

3.3 Laboratory Testing

We performed grain-size analyses on five soil samples obtained from the explorations and six sediment soil samples collected for scour evaluation. In addition, we performed liquid limit (LL), plastic limit (PL), and plasticity index (PI), aka Atterberg Limits, tests on two clay samples. The laboratory test results are presented in Appendix C. Grain-size tests and Atterberg Limits tests were performed in general accordance with ASTM D6913 and ASTM D4318, respectively.

3.4 Subsurface Conditions

The soil layers encountered in the borings are described below in order of increasing depth. The approximate layer boundary depths at the Glen Road bridge are shown in the subsurface profile in Fig. 5.

Topsoil – The borings encountered a 0.5 to 2 feet thickness of topsoil generally consisting of organic silt and sand, with trace to some gravel. Roots and organic fibers were present in the topsoil samples.

Upper Sand and Silt – A layer of Sand and Silt was encountered below the topsoil in the borings to depths ranging from 10 to 26 feet below the ground surface. The material generally consisted of fine to coarse sand with trace to some inorganic silt, ranging to inorganic silt with some fine to coarse sand, and trace fine to medium gravel.

- BB-1 and BB-2: SPT N-values corrected for hammer energy (N_{60}) in the Upper Sand and Silt generally ranged from 4 to 16 blows per foot with an average of 8 blows per foot in BB-1 and BB-2 at Glen Road bridge, indicating a loose soil.
- BWB-1 through BWB-8: SPT N-values corrected for hammer energy (N_{60}) in the Upper Sand and Silt from these borings generally ranged from 7 to 43 blows per foot with an average of 17 blows per foot, indicating a medium dense soil.

Clay – A layer of low plasticity Clay was encountered interbedded between the Sand and Silt in all borings except for BWB-8, which did not encounter Clay. The thickness of the Clay layer generally ranged from 20 to 30 feet, except for BWB-7 where a thinner Clay layer of 10 feet was encountered, indicating that Clay is less thick moving east towards St. James Avenue.

This layer consisted of low plasticity Clay with varying amounts of inorganic silt and trace fine to medium gravel. N_{60} values in the Clay ranged from Weight of Rod for 12 inches to 12 blows per foot with an average of 6 blows per foot, indicating medium stiff soil.

It should be noted that BB-1 and BB-2 encountered a second Clay layer beneath the Lower Sand and Silt layer at a depth of 74 feet below ground surface. BB-1 was terminated in this layer at a depth of 76 feet.

Lower Sand and Silt – A denser layer of Sand and Silt was encountered beneath the Clay in the borings, except for BWB-8, where there was a direct transition from the Upper Sand and Silt to the Lower Sand and Silt. All the borings except BB-1 were terminated in this layer at depths ranging from 36 to 96 feet. The Lower Sand and Silt generally consists of fine to coarse sand and inorganic silt to inorganic silt with some fine sand, with trace fine to medium gravel.

N_{60} values ranged from 8 to 79 blows per foot with an average of 19 blows per foot, indicating a medium dense soil.

3.5 Results of Abutment Probes

As previously mentioned, probes were performed to estimate the shape and depth of the existing bridge abutment foundations. The results of the probes are shown on the abutment cross section in Fig. 4. Subsurface conditions encountered in the probes and borings at the bridge abutments are shown on the subsurface profile in Fig. 5.

Based on observations of refusals encountered in the probes, we estimate that the northeast abutment stone foundation extends back between about 3 and 4.5 feet from the front face of the concrete cap, and that the southwest abutment stone foundation extends back between approximately 2.2 to 3.8 feet from the front face of concrete cap.

Probes through the west abutment (P-2A, P-2B) encountered the bottom of the stone blocks at about El. 143 to El. 144. The one probe drilled though the east abutment foundation was advanced through difficult drilling down to about El. 141.5.

See the probe logs in Appendix B for detailed depths and probe offsets.

3.6 Groundwater Levels

The groundwater levels were measured in nearly all the 2020 explorations upon completion of drilling between March 4 and 16, 2020 and are recorded in Table 1. Water levels were not measured in the 2019 explorations. The groundwater level measurements represent conditions at the times and locations indicated. Significantly different groundwater levels may occur at other times and locations.

4. Design Recommendations

4.1 Soil Properties

Recommended soil properties for design are presented in Table 1. We selected these values based on published correlations to SPT N-values, our review of the soil descriptions, our laboratory testing, and our engineering judgment.

4.2 Foundation Design

Glen Road Bridge

Based on the result of our borings and probes, it appears that the existing abutments of the Glen Road bridge are founded on the Upper Sand and Silt at about El. 141.5 to El. 144.0. We reviewed the preliminary bridge loads provided by BETA, and it appears the Upper Sand and Silt layer should provide suitable bearing resistance. Also, it is likely that proposed loadings on the bridge abutments from the new trail crossing are significantly less than the loads imparted from the previous use of the bridge to carry trains.

Fig.6 presents curves of factored bearing resistance versus effective footing width for the bridge abutments for the Strength Limit, Extreme Limit and Service Limit (for 1-inch of settlement) states. For Strength and Extreme Limit cases, the applied bearing pressures should be computed based on the total expected loading. For the Service Limit case, the applied bearing pressures should be computed based only on the new loading from the superstructure.

Boardwalks

We understand that the raised boardwalks will be supported on helical piles to minimize disruption to the existing wetlands. We recommend that the helical piles be installed to derive their axial support in the Upper Sand and Silt Layer. We also understand that the raised boardwalk imparts a small lateral load component on the helical piles. Design considerations to resist lateral loads are provided below.

The helical piles should be designed and constructed in accordance with Section 1810.3 of the latest edition of the Massachusetts State Building Code (which incorporates the 2015 International Building Code). Helical piles are manufactured by several suppliers in a number of sizes and configurations used for different soil conditions and design loads. Generally, the specialty helical pile contractor designs the piles and submits the proposed design to the owner for review and approval.

Please clarify the plans state that the boardwalk is designed per AASHTO.

The contractor is responsible for providing a design that will satisfy a performance requirement based on the installation torque resistance. Field verification of helical pile capacity is typically performed by measuring the torque resistance during installation. Empirical correlations are used to relate the torque resistance to ultimate bearing capacity. The empirical data indicate that the relationship between torque and bearing capacity varies with the pile shaft diameter, so the required torque resistance is different for different pile designs. We recommend that the required torque resistance be determined using the following correlation (Perko, 2009):

$$Q_u = \frac{22T}{d^{0.92}}$$

Where,

Q_u = Ultimate bearing capacity
T = torque resistance
d = pile shaft diameter or diameter of a circle circumscribed around a square shaft (inch)

We recommend that helical piles be designed by a Massachusetts-registered Professional Engineer, obtaining all resistance in the Upper Sand and Silt (see boring logs in Appendix B for elevations of the top of Upper Sand and Silt). The helical piles should be designed in accordance with Section 1810.3.3.1.9.

We also recommend that the following items be noted on the construction drawings:

- Provide hot-dip galvanizing on all surfaces of the piles.
- Specify Round Shaft (RS) helical piles.
- Fill the inside of the shaft with grout.
- Install the helical piles in accordance with Section 1810.4.11 of the Building Code.
- Install the piles to a depth where all the helices bear in the Upper Sand and Silt.
- Maintain an installation tolerance of 1 inch for plan location and 5 degrees for verticality.
- Monitor the torque using equipment that has been calibrated within the previous 12 months.
- Maintain an adequate crowd force, sufficient that the pile advances into the ground a distance of at least 80 percent of the blade pitch per revolution during normal advancement.

Design Considerations for Lateral Loads:

Helical piles are primarily designed to resist axial loads, and they provide limited resistance to lateral loads. We recommend that the contractors engineer perform a lateral loading analysis on their helical pile using a program such as LPILE to verify it is adequate to resist the lateral loads. Based on the results of the analysis, it might be necessary to supplement the helical piles with enlarged shaft sections over the upper portion of the pile to increase the passive earth pressure resistance.

4.3 Lateral Earth Pressures and Sliding Resistance

Lateral earth pressures on the Glen Road bridge abutments should be calculated using the soil properties in Table 1. For sliding at the base of the footings, and since the stone abutment footings bear on the Upper Sand and Silt layer, we recommend an ultimate coefficient of friction of 0.45. We also recommend applicable resistance factors for sliding, as provided in Table 3.

4.4 Seismic Design Information

We understand that the Glen Road bridge is considered non-critical and non-essential. Based on the subsurface conditions observed in our borings, the site soil conditions satisfy the requirements of Site Class E. Site coefficients for peak ground acceleration [F_{PGA}], short-period range [F_A], and long-period range [F_v] are 2.5, 2.5, and 3.5, respectively.

Based on the maps in the AASHTO "Guide Specifications for LRFD Seismic Bridge Design," we recommend the following parameters for seismic design based on a 7 percent probability of exceedance in 75 years (approximately 1,000-year return period):

- Horizontal Peak Ground Coefficient (PGA) = 0.059
- Horizontal Response Spectral Coefficient (period = 0.2 sec) (S_s) = 0.130
- Horizontal Response Spectral Coefficient (period = 1.0 sec) (S_1) = 0.038

Application of the above site coefficients results in the following recommended coefficients for development of design response spectra:

- Response Spectral Acceleration, A_s = 0.148
- Design Spectral Acceleration Coefficient at 0.2 second period, S_{DS} = 0.325
- Design Spectral Acceleration Coefficient at 1.0 second period, S_{D1} = 0.133

This site falls into Seismic Design Category (SDC) A, based on the 1-second-period design spectral acceleration. The 2013 MassDOT "*LRFD Bridge Manual*" (Section 3.4) indicates that conventional bridges classified as SDC A, and single-span bridges regardless of SDC, do not require a detailed seismic analysis to determine the design earthquake loading. However, minimum design and detailing requirements do apply and are listed in Section 3.4.3.3 of the Bridge Manual.

We did not check liquefaction because the Guide Specifications (Section 6.8) state that liquefaction potential need not be evaluated for sites in SDC A.

5. Construction Recommendations

5.1 Preparation of Construction Subgrade

Topsoil, vegetation and pavement should be stripped and separated prior to any excavation within the limits of the proposed trail and paved areas. Topsoil may be reused as surface cover during final grading in landscaped areas.

5.2 Excavation and Dewatering

All excavations should be made in accordance with OSHA standards. Although no excavation support systems are anticipated to be needed, any necessary excavation support system should be designed by a Massachusetts-registered professional engineer experienced in excavation support design. The engineer should be engaged by the contractor and submit the designs for review before installation.

The groundwater level measured in the borings varies from the ground surface elevation in the wetland areas to about 9.8 feet at the Glen Road bridge. Even though we don't anticipate excavation for foundations below the groundwater levels, specifications for excavation should always require the contractor to maintain the groundwater level below the bottom of the excavation, in the event groundwater is encountered. Surface water should be diverted away from excavations.

5.3 Backfilling

In general, fill materials should be placed and compacted in accordance with MassDOT "*2020 Standard Specifications for Highway and Bridges*," Section 150. However, we recommend that compaction in areas too small for a smooth wheel vibratory compactor, or within 5 feet of walls, be performed using a vibratory walk-behind roller or plate compactor (weighing at least 200 lbs. imparting an impact load of at least 2.5 tons), with soil placed in maximum 6-inch-loose lifts.

5.4 Re-Use of Existing Materials

Grain-size tests performed on the granular soils indicate that some of them may meet the MassDOT requirements for Ordinary Borrow. Suitability for reuse should be confirmed by additional testing on samples obtained during construction. Some of the Sand and Silt materials have a high enough fines content that they are not free draining and may be difficult to compact in wet weather.

6. Limitations

Our recommendations are based on the project information provided to us at the time of this report and may require modification if there are any changes in the nature, design, or location of the proposed construction. We recommend that GEI be engaged to review the final plans and specifications to judge whether changes in the project affect the validity of our recommendations and whether our recommendations have been properly implemented in the design.

The recommendations in this report are based in part on the data obtained from the explorations. The nature and extent of variations between explorations may not become evident until construction. If variations from the anticipated conditions are encountered, it may be necessary to revise the recommendations in this report. Therefore, we recommend that GEI be engaged to make site visits during construction to ascertain that, in general, the geotechnical aspects of the work are being performed in compliance with the contract documents.

Our professional services for this project have been performed in accordance with generally accepted engineering practices; no warranty, express or implied, is made.

Tables

Table 1. Recommended Soil Properties
McKnight Community Trail
Springfield, Massachusetts

Layer/Soil Type	Unit Weight, γ (pcf) [1]	Friction Angle, ϕ (deg)	Undrained Shear Strength, c or Su (ksf)	Earth Pressure Coefficients[2,3]
Upper Sand and Silt (Glen Road Bridge)	120/130	30	--	Ka=0.3 Ko=0.5 Kp=4.8[3]
Upper Sand and Silt (Boardwalks)	125/130	34	--	Ka=0.26 Ko=0.44 Kp=6.5[3]
Clay	110/115	--	0.70	Ka=1.0[5] Ko=1.0 Kp=1.0[4][5]
Lower Sand and Silt	120/130	32	--	Ka=0.28 Ko=0.47 Kp=5.5[4]
Retained Backfill (Ordinary Borrow)	120/130	32	--	Ka=0.28 Ko=0.47 Kp=5.5([4])
Gravel Borrow	125/130	35	--	Ka=0.25 Ko=0.43 Kp=7.0[4]
Gravel Borrow for Bridge Foundations	130/135	37	--	Ka=0.23 Ko=0.40 Kp=8.2[4]

Notes:

1. The first value represents a moist condition above the water table; the second value represents a saturated condition below the water table.
2. Recommended active and passive earth pressure coefficients were calculated using the Coulomb and log spiral methods, respectively, for vertical wall face and horizontal backfill in front of and behind the walls and are in accordance with the recommendations in Subsection 3.1.6 of the MassDOT LRFD Bridge Design Manual. Values for sloping wall face should be calculated using the actual slope angle, with the interface friction angle assumed to be half the angle of internal friction of the backfill soil. See Article 3.11.5.3 of the AASHTO LRFD Bridge Design Specifications.
3. Seismic earth pressure coefficients are not included because the bridge is classified under Seismic Zone 1, and use of seismic earth pressures is not necessary per Sections 3.4.4.1 and 3.4.6 of the MassDOT LRFD Bridge Design Manual.
4. Passive pressure coefficients are intended for use in Support of Excavation design only.
5. Refer to Fig. 3.11.5.6-4 and Fig. 3.11.5.6-6 in Article 3.11.5.6 of the AASHTO LRFD Bridge Design Specifications for simplified earth pressure distributions for a cohesive soils.

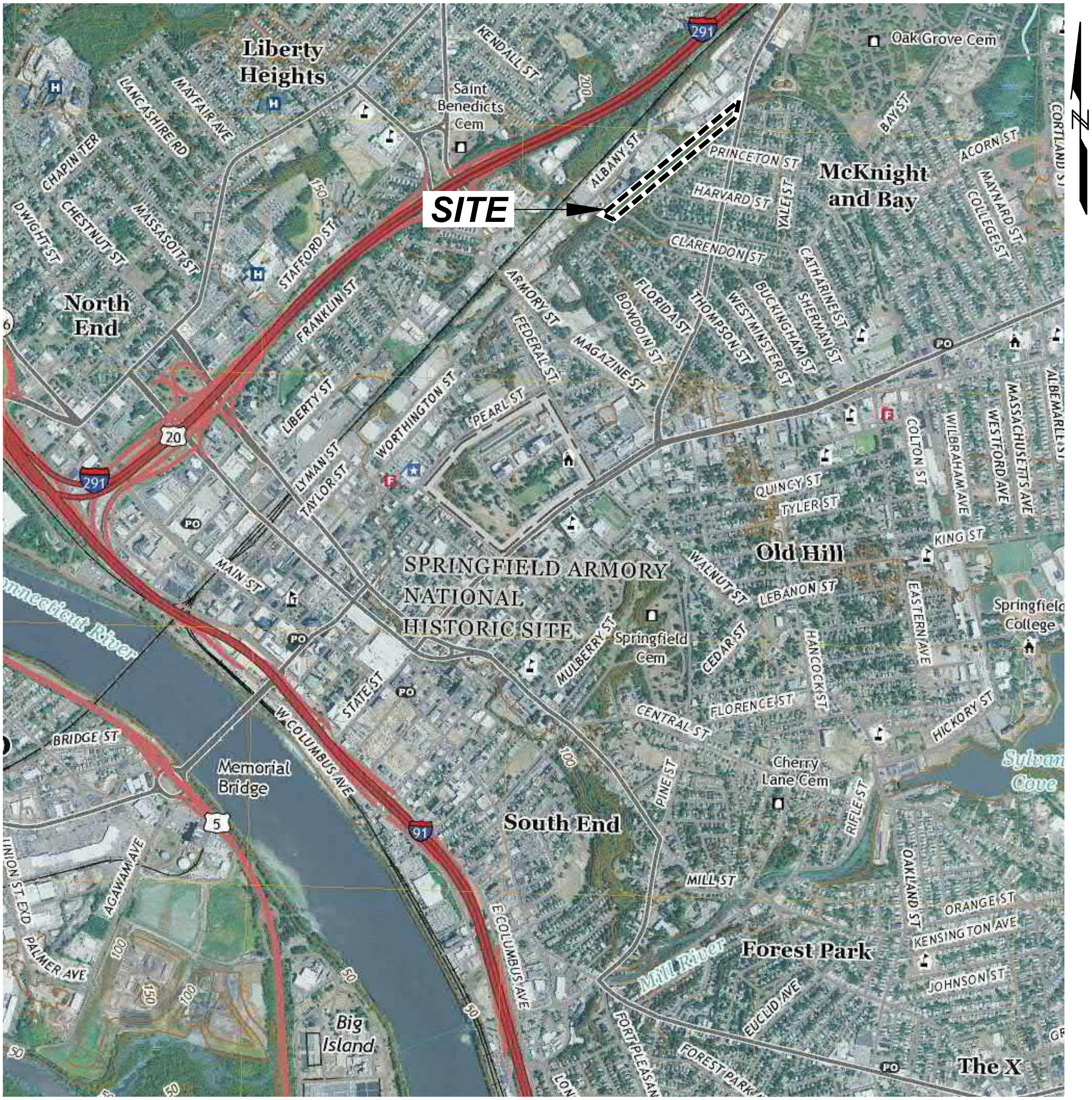
Table 2. Resistance Factors
McKnight Community Trail
Springfield, Massachusetts

Load Case	Strength Limit State(2)	Service Limit State(3)	Extreme Limit State(4)
Glenn Road Bridge - Foundations (Abutments)			
Bearing resistance of shallow foundations	0.45	1.0	1.0
Sliding - Cast-in-place/Pre-cast concrete on granular soil	0.8/0.9	1.0	1.0
Global Stability(5)	--	0.75/0.65(6)	NA

General Notes:

1. Resistance factors above were obtained from the 2017 AASHTO LRFD Bridge Design Specifications (AASHTO).
2. The strength limit state resistance factors for bearing and sliding of shallow foundations were obtained from AASHTO Table 10.5.5.2.2-1.
3. Both AASHTO Sections 10.5.5.1 indicate that a resistance factor of 1.0 should be used for bearing resistance and sliding at the service limit state. The resistance factor for global stability at the service limit state was obtained from Section 11.6.2.3.
4. AASHTO Sections 10.5.5.3 provide resistance factors for the Extreme Limit State.
5. Global stability analysis at the Strength Limit State is not required, per AASHTO 11.6.2.3. Global stability analysis is not required for the Extreme Event Limit State because a seismic analysis of this wall is not necessary per Section 3.4 of the MassDOT LRFD Bridge Design Manual.

Figures



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SCALE, FEET

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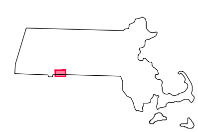
Springfield South, MA-CT Quadrangle, 2018.
Datum is North American Vertical Datum of 1988 (NAVD88).
Contour Interval is 10 Feet.



MASSACHUSETTS
QUADRANGLE LOCATION

McKnight Community Trail Springfield, Massachusetts	GEI Consultants	SITE LOCATION MAP
BETA Group, Inc. Norwood, Massachusetts	Project 1904391	April 2020 Fig. 1

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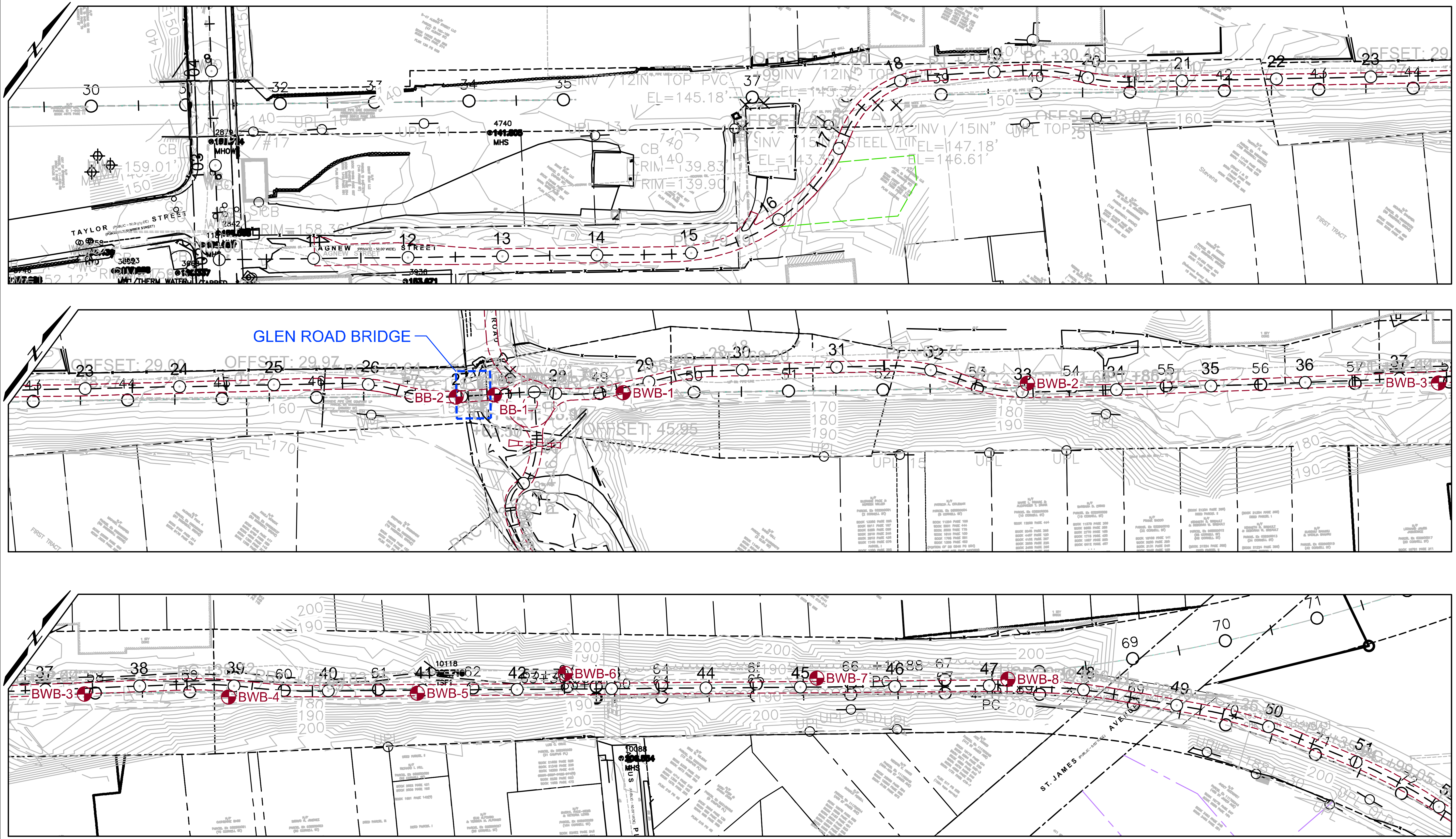

LEGEND:

BORING, GEI 2019, 2020

SOURCE:

1. BASE PLAN PROVIDED BY BETA GROUP, INC. MARCH 2020.

0 100 200

SCALE: 1" = 100'

McKnight Community Trail Springfield, Massachusetts	GEI Consultants	BORING LOCATION PLAN
BETA Group, Inc. Norwood, Massachusetts	Project 1904391	April 2020 Fig. 2

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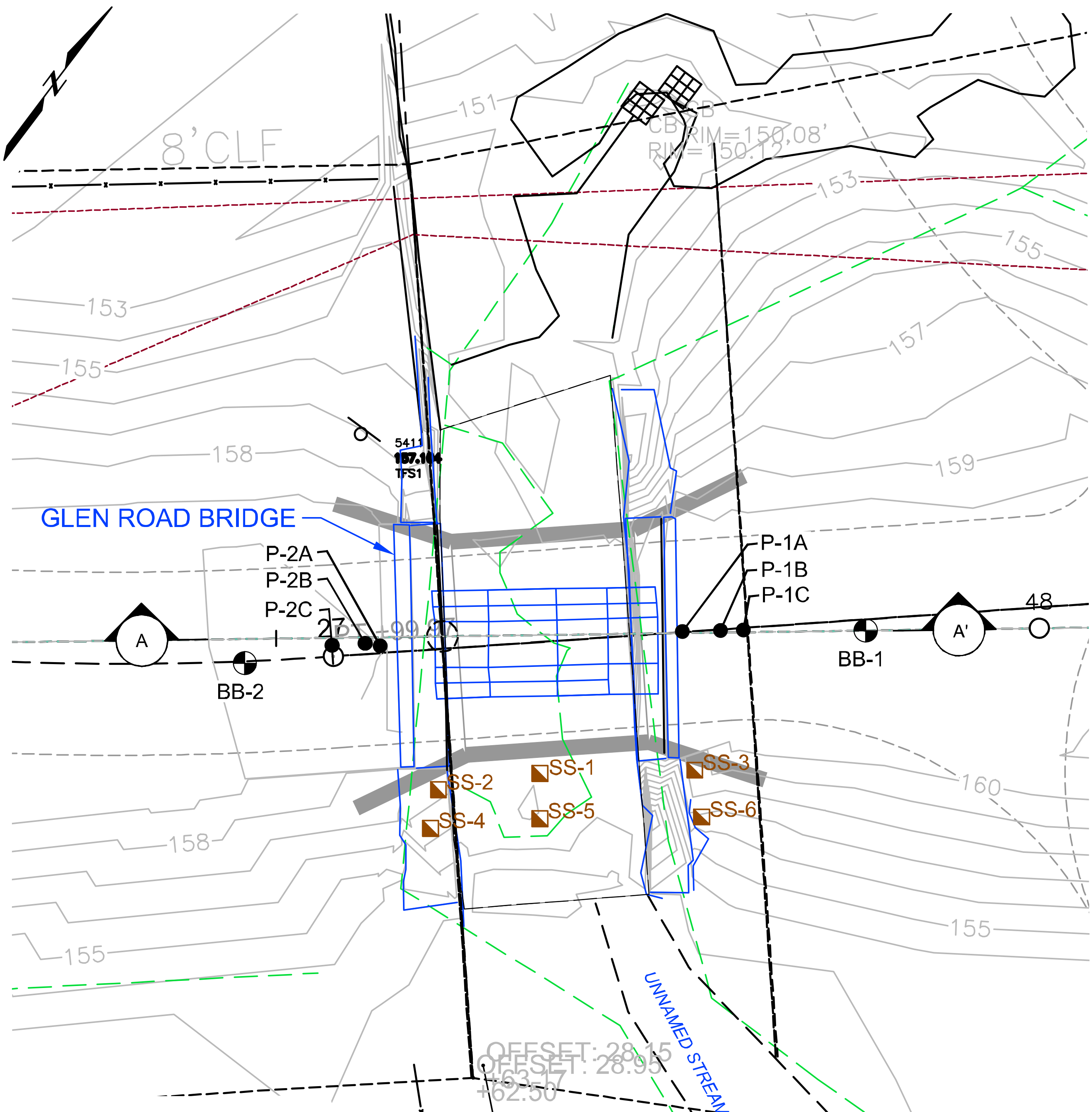

LEGEND:

- BORING, GEI 2019, 2020
- PROBE, GEI 2019, 2020
- SEDIMENT SAMPLE COLLECTED IN MARCH 2020
- A — A' SUBSURFACE PROFILE LOCATION, SEE FIG. 4

0 10 20

SCALE: 1" = 10'

SOURCE:

1. BASE PLAN PROVIDED BY BETA GROUP, INC. MARCH 2020.

McKnight Community Trail Springfield, Massachusetts	GEI Consultants	SUBSURFACE LOCATIONS PLAN GLEN ROAD BRIDGE
BETA Group, Inc. Norwood, Massachusetts	Project 1904391	April 2020 Fig. 3

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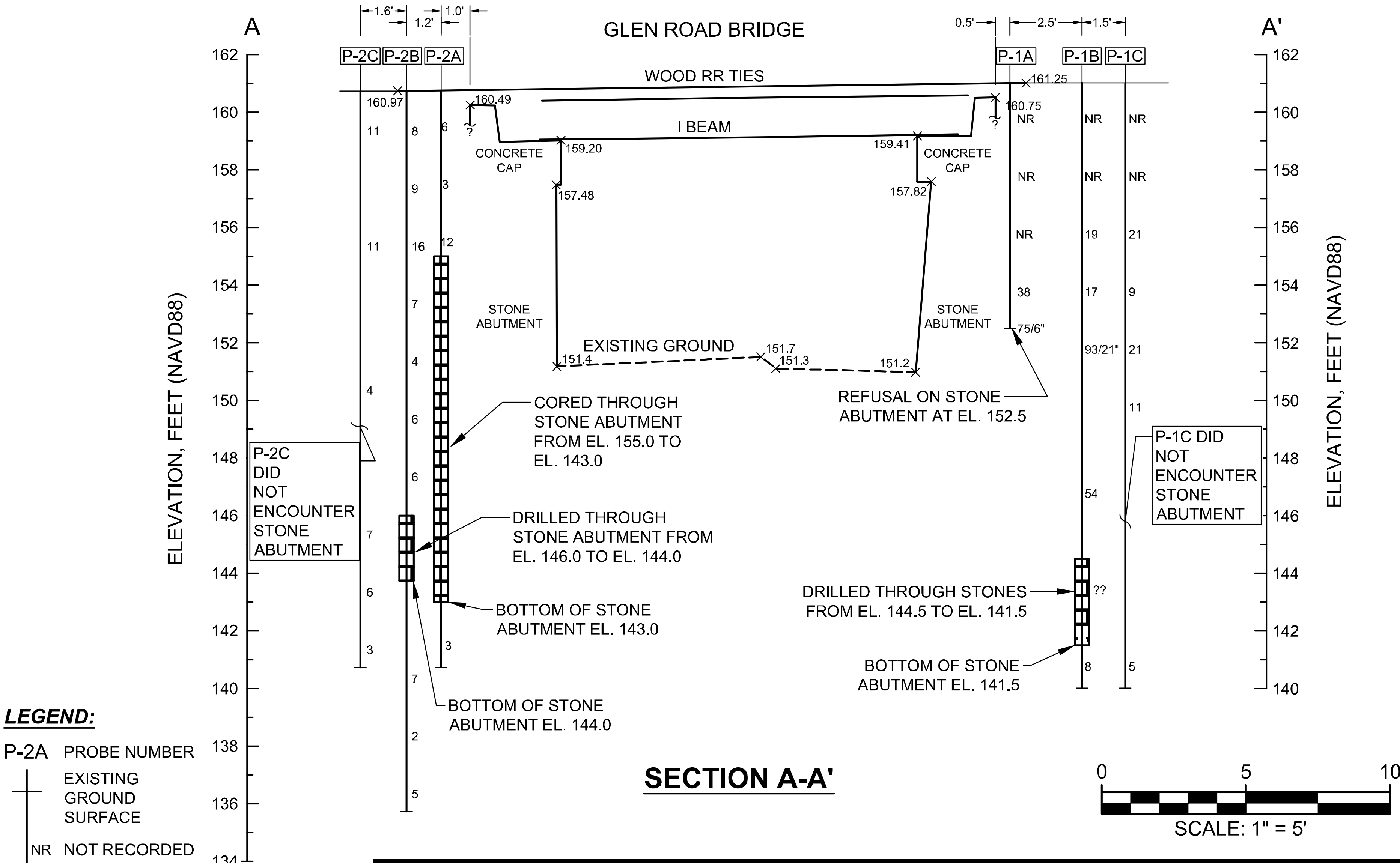

McKnight Community Trail Springfield, Massachusetts	GEI Consultants	ABUTMENT CROSS SECTION
BETA Group, Inc. Norwood, Massachusetts	Project 1904391	April 2020 Fig. 4

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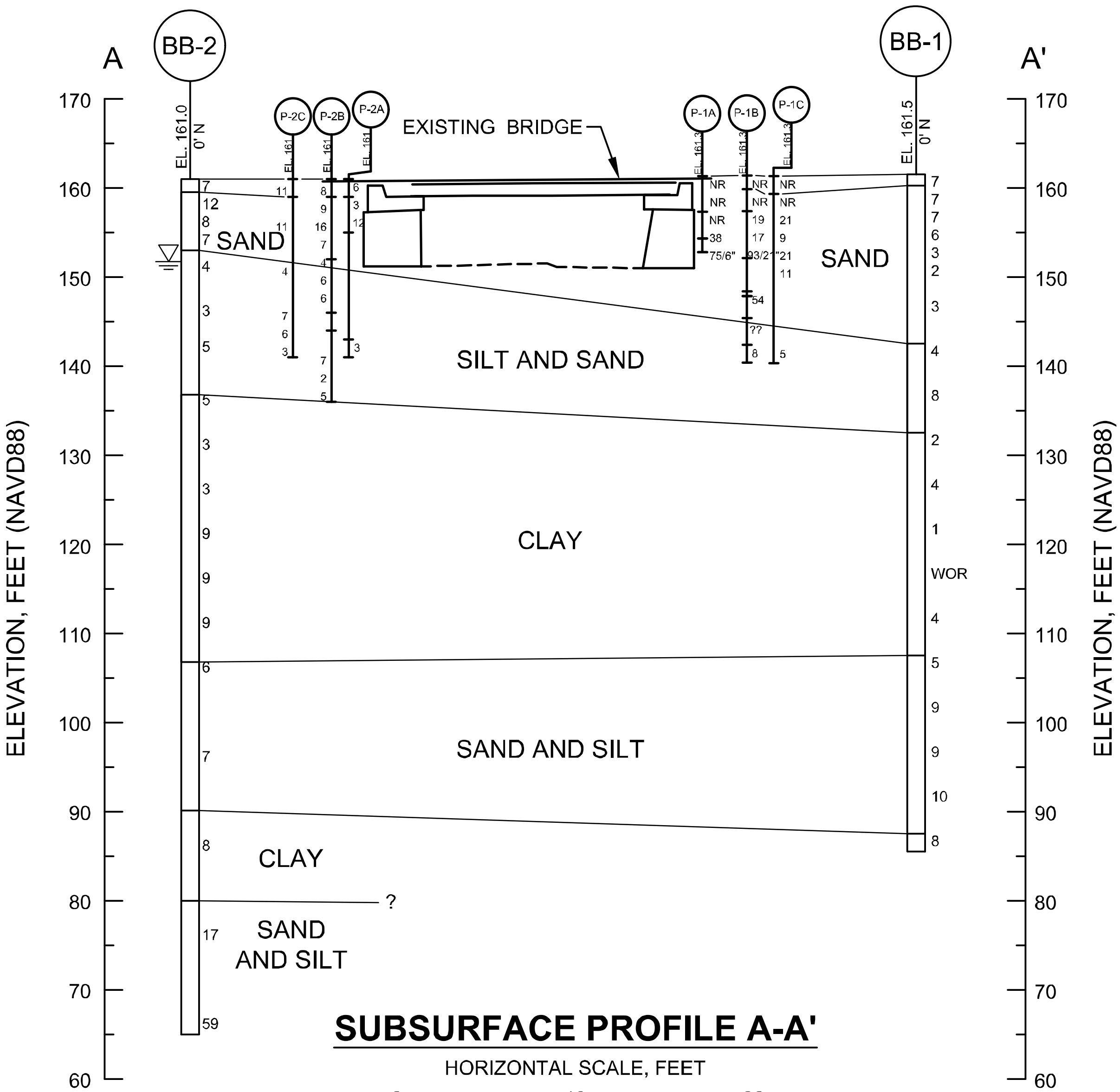


SUBSURFACE PROFILE A-A'

HORIZONTAL SCALE, FEET

0 10 20

0 20 40

VERTICAL SCALE, FEET

NOTE: 2x HORIZONTAL EXAGGERATION

LEGEND:

BB-2 — BORING NUMBER

EL. 161.0 / 10' E — ELEVATION OF GROUND SURFACE AND OFFSET OF BORING FROM PROFILE LINE

EXISTING GROUND SURFACE

STRATUM BOUNDARY

GROUNDWATER LEVEL MEASURED AT COMPLETION OF DRILLING

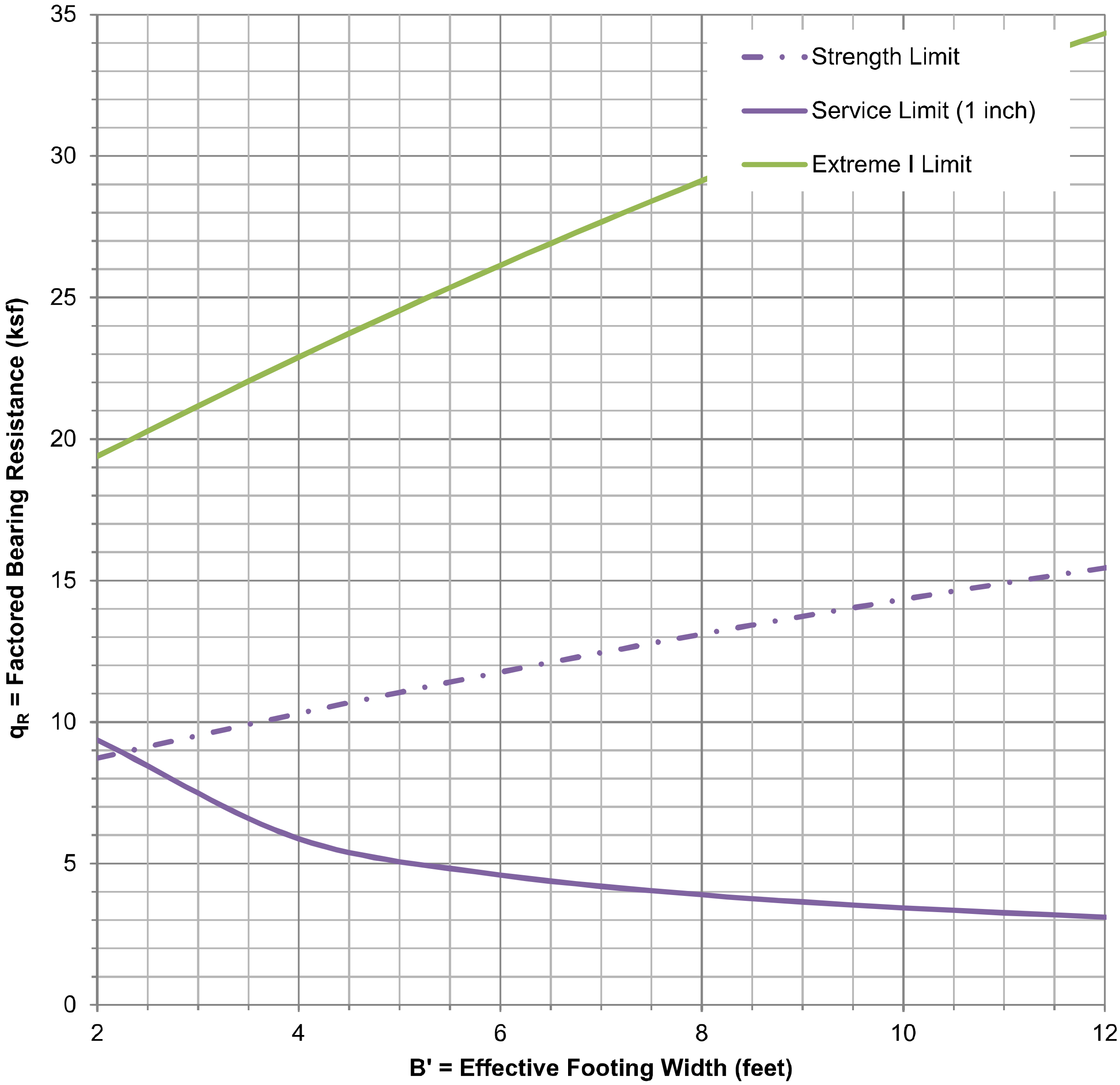
DRILLED THROUGH OBSTRUCTION

107 — N-VALUE FROM STANDARD PENETRATION TEST, BLOWS PER FOOT

NOTES:

1. PROFILES AND BORING LOCATIONS ARE SHOWN IN FIG. 3.
2. THE BOUNDARIES BETWEEN SOIL STRATA MAY BE TRANSITIONAL. THE STRATA BOUNDARIES BETWEEN BORINGS MAY VARY SIGNIFICANTLY FROM THE INTERPOLATIONS SHOWN.

McKnight Community Trail Springfield, Massachusetts	GEI Consultants	SUBSURFACE PROFILE A-A'
BETA Group, Inc. Norwood, Massachusetts	Project 1904391	April 2020 — Fig. 5



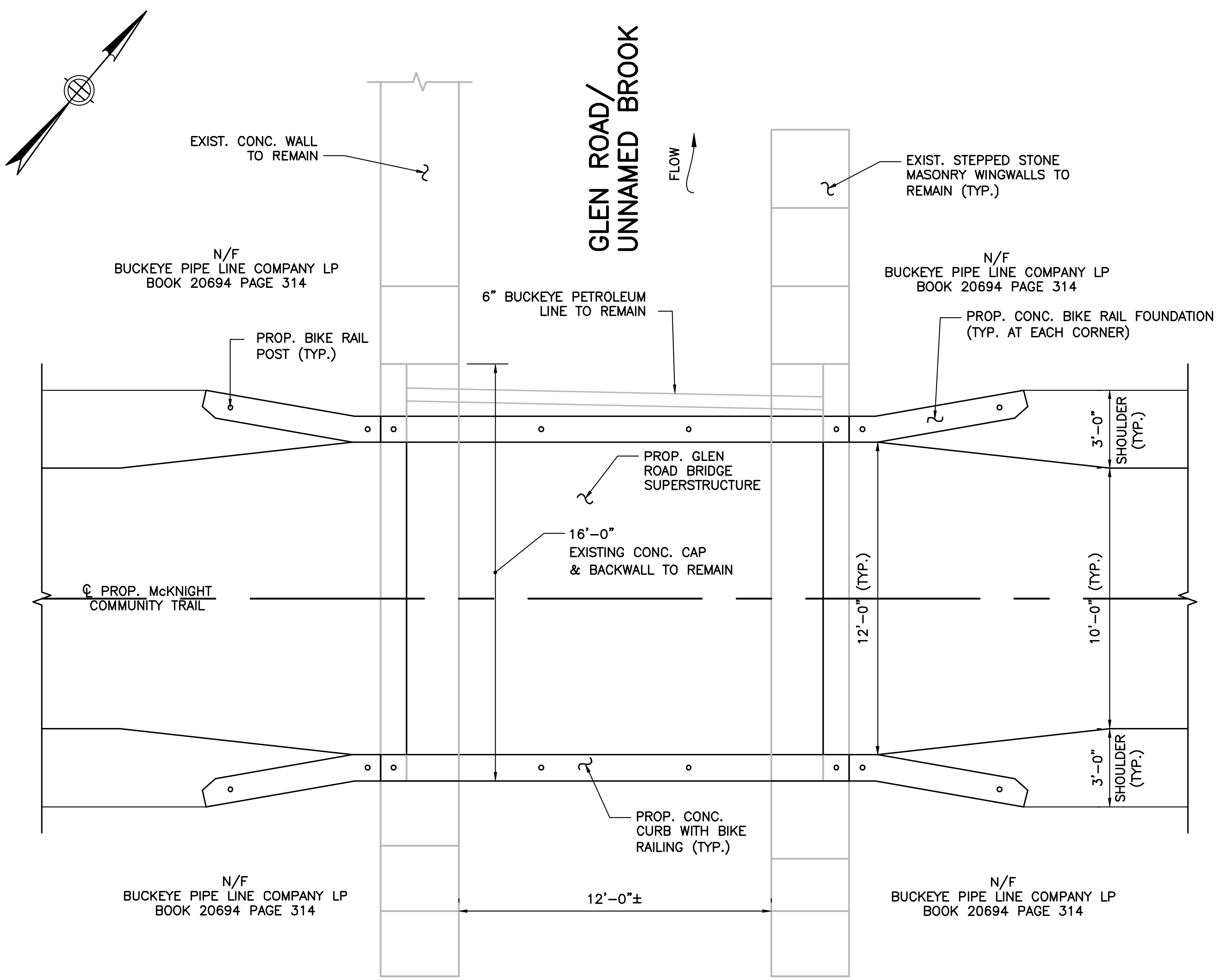
Notes:

1. B' represents the smallest dimension (i.e. effective footing width).
2. Groundwater was conservatively measured to be 9.3 ft (~El. 151.7).
3. The strength limit values are based on a resistance factor of 0.45 for the abutment footing, and the extreme limit values are based on a resistance factor of 1.0.
4. Based on results of the probes, an embedment depth of 8.5 ft (bottom of footing at El. +142.5) was assumed.
5. Level ground in front and behind the abutment was assumed (i.e., no sloping ground).

McKnight Community Trail Springfield, Massachusetts	GEI Consultants	FACTORED BEARING RESISTANCE VERSUS EFFECTIVE FOOTING WIDTH - GLEN ROAD BRIDGE
BETA Group, Inc. Norwood, Massachusetts	Project 1904391	April 2020 Fig. 6

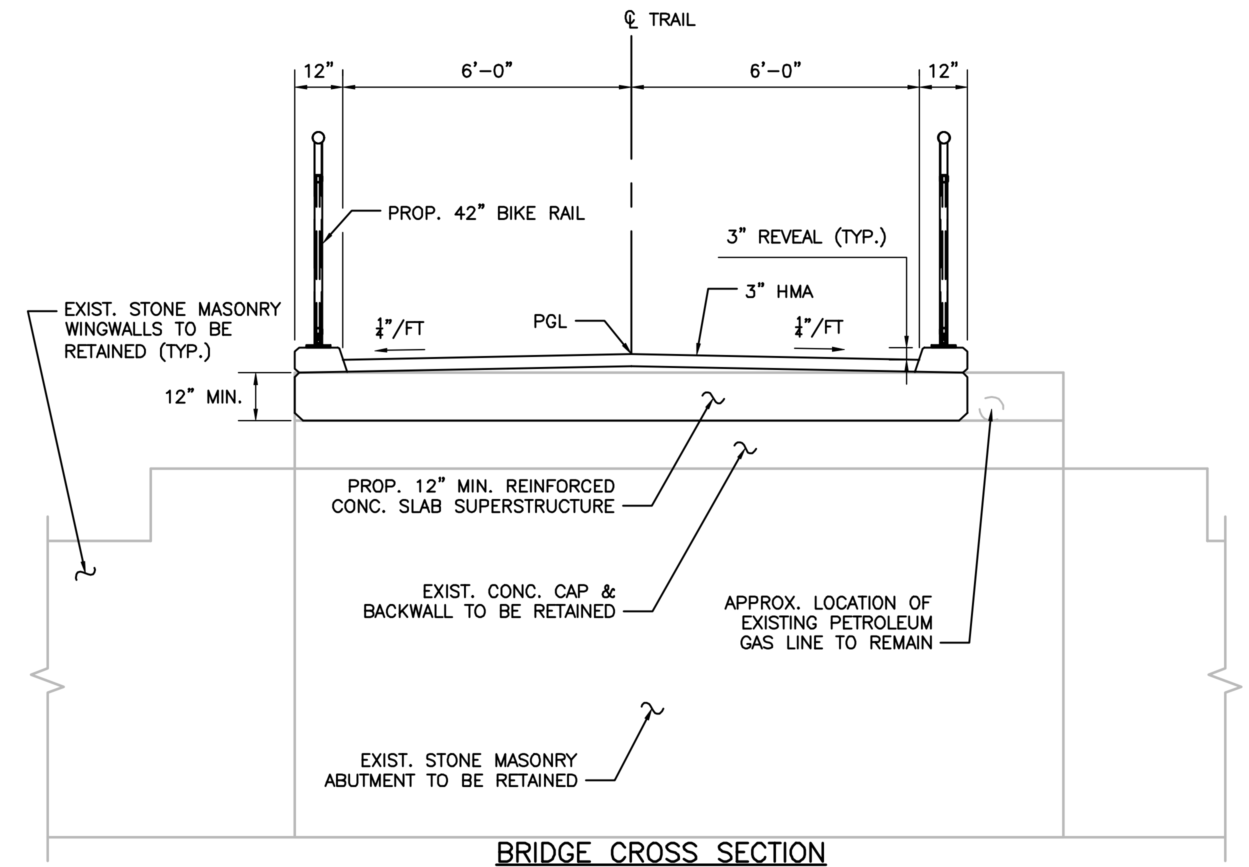
Appendix A

Glen Road Bridge Drawings



GENERAL PLAN VIEW

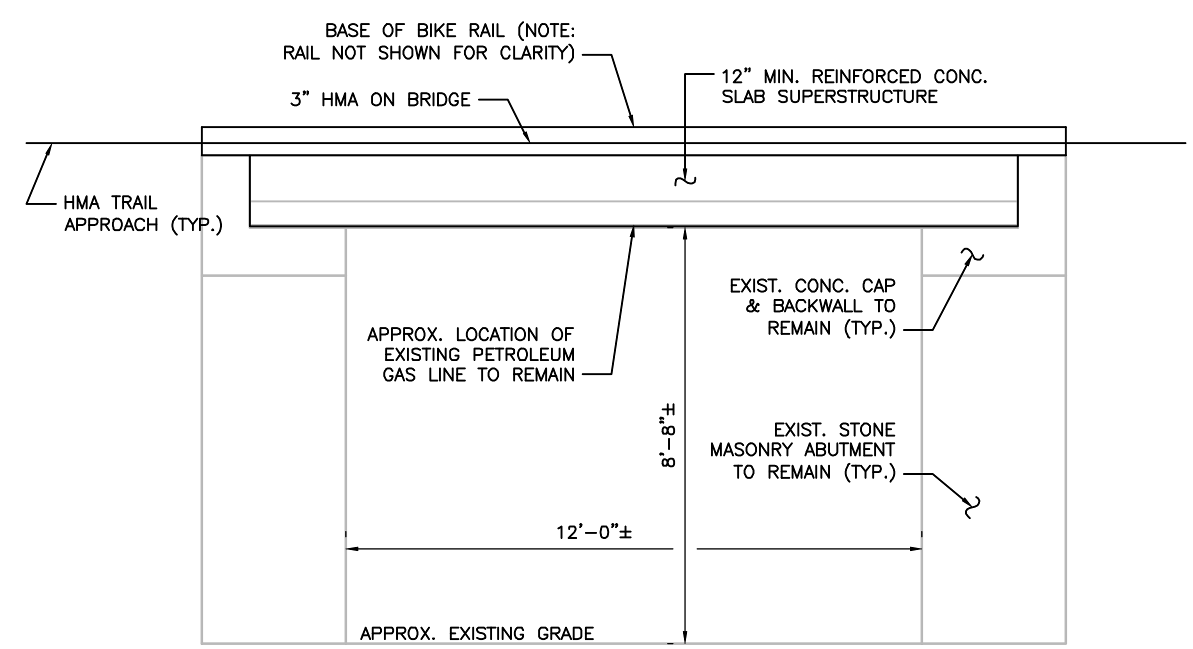
SCALE: 3/16" = 1'-0"



BRIDGE CROSS SECTION

(LOOKING NORTH)

SCALE: 1/4" = 1'-0"



LONGITUDINAL SECTION

SCALE: 1/4" = 1'-0"

benesch

GLEN ROAD BRIDGE
SPRINGFIELD, MA

DATE: 10/19/2018

SCALE: AS NOTED

EXHIBIT 3 OF 3

7. – Looking East Across Bridge Decking

8. – Looking West Across Bridge Decking

9. – South Elevation Looking Northerly

10. – North Elevation Looking Southerly

11. – Elevation West Abutment Looking Southerly

12. – Elevation West Abutment Looking Northerly

Appendix B

Exploration Logs

- Boring logs
- Probe and abutment core logs

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~161.5 **DATE START/END:** 10/29/2019 - 10/30/2019

VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 76.0 **DRILLER NAME:** Zac Nader

LOGGED BY: Patrick Blessing **RIG TYPE:** Track Mounted Diedrich D-25

BORING BB-1

DRILLING INFORMATION

HAMMER TYPE: Automatic **CASING I.D./O.D.:** NA/ NA **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA **DRILL ROD O.D.:** 2.625 inch **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): Not Measured

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample Information: Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/18	3-4-3-4		TOPSOIL	S1 (0"-15"): Dry to Moist, loose, black, FINE - COARSE SAND, trace to some Fines, trace to some fine - medium coarse Gravel. Slag and Coal fragments present (Topsoil).
							SAND	S1 (15"-24"): Dry to Moist, loose, brown, FINE - COARSE SAND, trace to some fine - medium coarse Gravel, trace inorganic Fines.
		S2	2 to 4	24/21	3-4-3-4			S2: Similar to S1B (15"-24").
	5	S3	4 to 6	24/22	4-3-4-5			S3: Dry to Moist, loose, light grayish brown, FINE SAND, trace to some inorganic Fines. Root fragments present.
		S4	6 to 8	24/24	2-3-3-4			S4: Dry to Moist, loose, brown to light brown, FINE - COARSE SAND, trace inorganic Fines. Most sand is fine.
		S5	8 to 10	24/9	1-2-1-1			S5: Wet, very loose, brown, FINE - COARSE SAND, trave fine - medium coarse Gravel.
	10	S6	10 to 12	24/12	1-1-1-1			S6: Wet, very loose, brown, FINE - COARSE SAND, trace to some inorganic Fines, trace fine - medium coarse Gravel.
	15	S7	14 to 16	24/12	1-2-1-1			S7: Wet, very loose, brown, FINE - COARSE SAND, trace to some inorganic Fines.
	20	S8	19 to 21	24/18	1-2-2-5		SAND & SILT	S8: Wet, very loose to loose, gray to dark brown, FINE - COARSE SAND AND SILT, some Fines. Peat and deteriorated wood fragments present.

NOTES:

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	25	S9	24 to 26	24/12	6-3-5-5			S9: Wet, loose, gray, FINE SAND AND CLAY, some inorganic Fines.
	30	S10	29 to 31	24/24	1-1-1-1		CLAY	S10: Wet, very soft to soft, gray, CLAY, trace fine Sand.
	35	S11	34 to 36	24/19	3-2-2-2		CLAY	S11: Wet, soft to medium stiff, gray, CLAY, trace to some fine - coarse Sand.
	40	S12	39 to 41	24/24	1-WOR-1-WOR		CLAY	S12: Wet, very loose, gray, FINE - COARSE SAND AND CLAY, trace fine - coarse Gravel.
	45	S13	44 to 46	24/21	WOR-WOR-WOR-3		CLAY	S13: Wet, very soft, gray, CLAY, some fine Sand.
	50	S14	49 to 51	24/21	2-2-2-3		CLAY	S14: Wet, soft to medium soft, gray, CLAY, some fine Sand.
	55	S15	54 to 56	24/21	5-3-2-4		SAND	S15: Wet, loose, gray, FINE SAND.

NOTES:

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	60	S16	59 to 61	24/15	3-1-8-5		SAND	S16: Similar to S15 but FINE - COARSE SAND.
	65	S17	64 to 66	24/24	2-5-4-4		SAND	S17: Wet, loose, gray, FINE SAND AND CLAY, some inorganic Fines.
	70	S18	69 to 71	24/24	2-4-6-10		SAND	S18: Wet, loose to medium dense, SAND.
	75	S19	74 to 76	24/23	3-4-4-4		CLAY	S19: Wet, medium stiff to stiff, gray, CLAY, some fine Sand.
								Bottom of borehole at 76'
	80							
	85							

NOTES:

BORING INFORMATION

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~161
DATE START/END: 3/4/2020 - 3/5/2020
VERTICAL DATUM: NAVD 88
DRILLING COMPANY: Northern Drill Service, Inc.
TOTAL DEPTH (ft): 96.0
DRILLER NAME: Zac Nader
LOGGED BY: H. Ghiye
RIG TYPE: Track Mounted Diedrich D-25

BORING BB-2

DRILLING INFORMATION

HAMMER TYPE: Automatic
CASING I.D./O.D.: 4 inch/ 4.5 inch
CORE BARREL TYPE:
AUGER I.D./O.D.: NA / NA
DRILL ROD O.D.: 2.625 inch
CORE BARREL I.D./O.D. NA / NA
DRILLING METHOD: Driven casing and washed with rotary tooling.
WATER LEVEL DEPTHS (ft): ∇ 8.5 3/5/2020 2:10 pm ▼ 9.3 3/6/2020 9:25 am

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/18	7-4-3-4		TOPSOIL	S1 (0"-18"): Moist, medium stiff, black, ORGANIC SILT AND PEAT, some fine sand. Roots and organic fibers present (Topsoil).
							SAND	S1 (18"-24"): Moist, loose, blackish brown, FINE - COARSE SAND, some inorganic Silt.
		S2	2 to 4	24/12	1-5-7-7		SAND	S2: Moist, medium dense, brown, FINE - COARSE SAND, trace inorganic Silt.
	5	S3	4 to 6	24/12	4-3-5-5		SAND	S3: Moist, loose, light brown, FINE - COARSE SAND, some inorganic Silt.
		S4	6 to 8	24/12	3-3-4-5		SAND	S4: Similar to S3.
		S5	8 to 10	24/14	3-2-2-4		SILT	S5: Wet, soft to medium stiff, grayish brown, INORGANIC SILT, trace Clay, trace fine Sand.
	10						SILT	
	15	S6	14 to 16	24/14	1-2-1-3		SILT	S6: Wet, soft, gray, INORGANIC SILT, trace Clay, trace fine Sand.
		S7	18 to 20	24/22	WOR-2-3-2		SILT	S7 (0"-6"): Wet, loose, black, INORGANIC SILT, trace - some fine Sand. S7 (6"-24"): Wet, loose, black, INORGANIC SILT, trace fine Sand, trace to some organic fibers. Some Wood pieces present.
	20						SILT	

NOTES:
Stopped drilling for the day at ~ 20 ft (3/4/2020; 14:30). Resumed drilling (3/5/2020; 07:45).

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA			**BORING**
GROUND SURFACE EL. (ft): ~161	**DATE START/END:** 3/4/2020 - 3/5/2020		**BB-2**
VERTICAL DATUM: NAVD 88	**DRILLING COMPANY:** Northern Drill Service, Inc.		

Elev. (ft)	Depth (ft)	Sample Information				Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD			
	25	S8	24 to 26	24/16	2-2-3-4		CLAY	S8: Wet, medium stiff, gray, CLAY, some inorganic Silt.
	30	S9	29 to 31	24/16	2-1-2-2			S9: Wet, soft, gray, CLAY, trace inorganic Silt.
	35	S10	34 to 36	24/20	1-1-2-3			S10: Wet, soft, gray, CLAY, some inorganic Silt.
	40	S11	39 to 41	24/18	2-4-5-4			S11: Wet, stiff, gray, CLAY, some inorganic Silt.
	45	S12	44 to 46	24/18	5-5-4-5			S12 (0"-12"): Wet, stiff, gray, CLAY AND INORGANIC SILT. S12 (12"-24"): Similar to S11.
	50	S13	49 to 51	24/0	7-4-5-5	No Recovery		S13: No Recovery.
	55	S14	54 to 56	24/16	3-2-4-8		SILT	S14: Wet, loose, gray, INORGANIC SILT, some fine Sand, trace Clay.

NOTES:
Stopped drilling for the day at ~ 20 ft (3/4/2020; 14:30). Resumed drilling (3/5/2020; 07:45).

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~161 **DATE START/END:** 3/4/2020 - 3/5/2020
VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

BORING BB-2

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
						Opened split-spoon sampling to 10-foot interval in open hole.		
	60							
	65	S15	64 to 66	24/20	4-4-3-3		SILT	S15: Wet, loose, INORGANIC SILT, some fine Sand, trace to some Clay.
	70							
	75	S16	74 to 76	24/22	3-3-5-6		CLAY	S16: Wet, medium stiff to stiff, gray, CLAY, some inorganic Silt.
	80							
	85	S17	84 to 86	24/18	10-9-8-7		FINE SAND & SILT	S17 (0"-18"): Wet, medium dense, gray, FINE SAND, some inorganic Silt. S17 (18"-24"): Wet, medium dense, gray, INORGANIC SILT, some fine Sand.

NOTES:
Stopped drilling for the day at ~ 20 ft (3/4/2020; 14:30). Resumed drilling (3/5/2020; 07:45).

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~161 **DATE START/END:** 3/4/2020 - 3/5/2020
VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

BORING BB-2

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	90						FINE SAND & SILT	
	95	S18	94 to 96	24/20	17-27-32-34			S18: Wet, very dense, FINE SAND, some inorganic Silt, trace to some fine Gravel.
								Bottom of borehole at 96' Backfilled with soil cuttings and all-purpose gravel (3/6/2020).
	100							
	105							
	110							
	115							

NOTES:
Stopped drilling for the day at ~ 20 ft (3/4/2020; 14:30). Resumed drilling (3/5/2020; 07:45).

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

BORING INFORMATION		BORING
LOCATION: Springfield, MA		BWB-1
GROUND SURFACE EL. (ft): ~162.5	DATE START/END: 3/9/2020 - 3/10/2020	PAGE 1 of 2
VERTICAL DATUM: NAVD 88	DRILLING COMPANY: Northern Drill Service, Inc.	
TOTAL DEPTH (ft): 46.0	DRILLER NAME: Zac Nader	
LOGGED BY: H. Ghiye	RIG TYPE: Track Mounted Diedrich D-25	

DRILLING INFORMATION

HAMMER TYPE: Automatic	CASING I.D./O.D.: 4 inch/ 4.5 inch	CORE BARREL TYPE:
AUGER I.D./O.D.: NA / NA	DRILL ROD O.D.: 2.625 inch	CORE BARREL I.D./O.D. NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): ∇ 3.0 3/10/2020 7:15 am ▼ 3.7 3/10/2020 8:09 am ▼ 3.5 3/10/2020 8:16 am Before resuming drilling.

ABBREVIATIONS:

Pen. = Penetration Length	S = Split Spoon Sample	Qp = Pocket Penetrometer Strength	NA, NM = Not Applicable, Not Measured
Rec. = Recovery Length	C = Core Sample	Sv = Pocket Torvane Shear Strength	Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%	U = Undisturbed Sample	LL = Liquid Limit	
	SC = Sonic Core	PI = Plasticity Index	
WOR = Weight of Rods	DP = Direct Push Sample	PID = Photoionization Detector	
WOH = Weight of Hammer	HSA = Hollow-Stem Auger	I.D./O.D. = Inside Diameter/Outside Diameter	

Elev. (ft)	Depth (ft)	Sample Information				Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD			
		S1	0 to 2	24/18	2-3-3-7		TOPSOIL	S1: Moist, loose, black, FINE - COARSE AND ORGANIC SILT, trace fine - coarse Gravel. Roots present (Topsoil).
		S2	2 to 4	24/20	5-5-5-9		SILT	S2: Moist, loose to medium dense, grayish brown, INORGANIC SILT, some fine Sand, trace Gravel.
	5	S3	4 to 6	24/18	8-9-7-7			S3: Moist, medium dense, grayish brown, INORGANIC SILT, some fine Sand.
		S4	6 to 8	24/20	5-5-7-6			S4: Wet, medium dense, brownish gray, INORGANIC SILT, some fine Sand, trace Clay, trace fine - medium Gravel.
		S5	8 to 10	24/18	4-3-3-3			S5: Wet, loose, gray, INORGANIC SILT, some fine Sand, trace fine Gravel.
	10	S6	10 to 12	24/20	1-2-3-4		CLAY	S6: Wet, medium stiff, gray, CLAY. some inorganic Silt, trace fine Sand, trace fine - medium Gravel.
		S7	12 to 14	24/22	3-3-3-3			S7: Wet, medium stiff, gray, CLAY, some inorganic Silt, trace fine - medium Gravel.
	15	S8	14 to 16	24/24	1-2-2-3			S8: Similar to S7.
		S9	16 to 18	24/24	1-2-2-3			S9: Similar to S7 and S8.
	20	S10	19 to 21	24/22	1-2-1-2			S10: Wet, soft, gray, CLAY, some inorganic Silt, trace fine - medium Gravel.

NOTES:
Stopped drilling for the day at ~ 41 ft (3/9/2020; 14:30). Resumed drilling (3/10/2020; 07:15).

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~162.5 **DATE START/END:** 3/9/2020 - 3/10/2020
VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

BORING BWB-1

Elev. (ft)	Depth (ft)	Sample Information				Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD			
	25	S11	24 to 26	24/22	1-2-1-2		CLAY	S11: Similar to S10.
	30	S12	29 to 31	24	1-2-2-3		CLAY	S12: Wet, soft to medium stiff, gray, CLAY, some inorganic Silt, trace fine Gravel.
	35	S13	34 to 36	24/24	1-2-3-4		CLAY	S13: Wet, medium stiff, gray, CLAY, trace inorganic Silt, trace fine Gravel.
	40	S14	39 to 41	24/24	2-4-3-3		SILT & FINE SAND	S14: Wet, loose, gray, INORGANIC SILT, some fine Sand, some Clay, trace fine Gravel.
	45	S15	44 to 46	24/18	4-4-5-6		SILT & FINE SAND	S15: Wet, stiff, gray, INORGANIC SILT, some Clay, trace fine - medium Gravel.
								Bottom of borehole at 46' Backfilled with soil cuttings.
	50							
	55							

NOTES:
Stopped drilling for the day at ~ 41 ft (3/9/2020; 14:30). Resumed drilling (3/10/2020; 07:15).

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~169.5 **DATE START/END:** 3/6/2020 - 3/9/2020

VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 61.0 **DRILLER NAME:** Zac Nader

LOGGED BY: H. Ghiye **RIG TYPE:** Track Mounted Diedrich D-25

BORING BWB-2

DRILLING INFORMATION

HAMMER TYPE: Automatic **CASING I.D./O.D.:** 4 inch/ 4.5 inch **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA **DRILL ROD O.D.:** 2.625 inch **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): ▼ 9.3 3/10/2020 8:09 am ▼ 5.7 3/9/2020 7:45 am

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/20	1-2-3-3		TOPSOIL	S1 (0"-6"): Moist, medium stiff, black, ORGANIC SILT, trace fine Sand. Roots and wood present (Topsoil).
							SAND	S1 (6"-24"): Moist, loose, light brown, FINE SAND, some inorganic Silt.
		S2	4 to 6	24/18	2-3-4-6		SAND	S2 (0"-12"): Moist, loose, light brown, FINE - COARSE SAND, some inorganic Silt, trace fine - coarse Gravel.
	5						SILT	S2 (12"-24"): Moist, loose, grayish brown, INORGANIC SILT, trace fine Sand.
		S3	6 to 8	24/16	6-4-4-7		SILT	S3: Moist, loose, brown, INORGANIC SILT, some fine - coarse Sand, trace fine - coarse Gravel.
		S4	8 to 10	24/18	2-3-3-4		SILT	S4: Wet, loose, brownish gray, INORGANIC SILT, trace fine Sand.
	10	S5	10 to 12	24/22	3-3-3-5		SILT	S5: Wet, loose, brownish gray, INORGANIC SILT, trace fine Sand, trace coarse Gravel.
		S6	12 to 14	24/18	4-4-5-7		SILT	S6: Wet, loose, brownish gray, INORGANIC SILT, trace fine Sand.
	15	S7	14 to 16	24/16	2-3-3-4		SILT	S7: Similar to S6.
		S8	16 to 18	24/16	3-4-3-4		SILT	S8: Similar to S7 and S6.
		S9	18 to 20	24/20	1-3-2-3		CLAY	S9: Wet, medium stiff, gray, CLAY.
	20	S10	20 to 22	24/22	1-2-2-3		CLAY	S10: Similar to S9.
		S11	22 to 24	24/20	WOH-2-3-3		CLAY	S11: Wet, medium stiff, gray, CLAY, some inorganic Silt, trace fine - medium Gravel.

NOTES:
Stopped drilling for the day at ~ 14 ft (3/6/2020; 14:05). Resumed drilling (3/9/2020; 07:50).

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~169.5
VERTICAL DATUM: NAVD 88
DATE START/END: 3/6/2020 - 3/9/2020
DRILLING COMPANY: Northern Drill Service, Inc.

BORING BWB-2

Elev. (ft)	Depth (ft)	Sample Information: Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	25	S12	24 to 26	24/22	1-2-2-3		CLAY	S12: Wet, soft to medium stiff, gray, CLAY, some inorganic Silt, trace fine Sand, trace Gravel.
		S13	26 to 28	24/22	2-3-3-4			S13: Wet, medium stiff, gray, CLAY, trace inorganic Silt, trace fine Gravel.
	30	S14	29 to 31	24/20	1-2-2-3			S14: Similar to S12.
	35	S15	34 to 36	24/22	2-2-2-3			S15: Similar to S12 and S14.
	40	S16	39 to 41	24/22	2-4-5-4			S16: Wet, stiff, gray, CLAY, some inorganic Silt, trace fine - medium Gravel.
	45	S17	44 to 46	24/18	7-7-8-10		SILT & FINE SAND	S17: Wet, medium dense, gray, INORGANIC SILT, some fine Sand, trace fine - medium Gravel.
	50	S18	49 to 51	24/18	2-3-3-4			S18: Wet, loose, gray, INORGANIC SILT AND FINE SAND, trace fine Gravel.
	55	S19	54 to 56	24/18	3-7-8-8			S19: Wet, medium dense, gray, INORGANIC SILT AND FINE SAND, trace Clay.

NOTES:
Stopped drilling for the day at ~ 14 ft (3/6/2020; 14:05). Resumed drilling (3/9/2020; 07:50).

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	60	S20	59 to 61	24/18	7-8-9-9		SILT & FINE SAND	S20: Wet, medium dense, gray, FINE SAND, some inorganic Silt, trace fine Gravel.
	65							Bottom of borehole at 61' Backfilled with soil cuttings.
	70							
	75							
	80							
	85							

NOTES:
Stopped drilling for the day at ~ 14 ft (3/6/2020; 14:05). Resumed drilling (3/9/2020; 07:50).

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~175.5 **DATE START/END:** 3/16/2020 - 3/16/2020

VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 71.0 **DRILLER NAME:** Justin Stevens

LOGGED BY: H. Ghiye **RIG TYPE:** Track Mounted Diedrich D-25

BORING BWB-3

DRILLING INFORMATION

HAMMER TYPE: Automatic **CASING I.D./O.D.:** 4 inch/ 4.5 inch **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA **DRILL ROD O.D.:** 2.625 inch **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): Not Measured

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/22	2-5-8-8		TOPSOIL	S1 (0"-12"): Moist, medium dense, black, FINE - COARSE SAND, some organic Silt, trace Gravel. Roots and glass present (Topsoil).
							SILT & SAND	S1 (12"-24"): Moist, medium dense, brown, FINE - COARSE SAND, some inorganic Silt, trace fine Gravel.
		S2	2 to 4	24/20	4-5-7-9			S2: Wet, medium dense, brown to blackish brown, FINE - COARSE SAND AND FINE - MEDIUM GRAVEL, some inorganic Silt.
	5	S3	4 to 6	24/16	8-8-7-7			S3 (0"-12"): Wet, medium dense, brown, FINE - COARSE SAND, some inorganic Silt, some fine - medium Gravel. S3 (12"-24"): Wet, medium dense, grayish brown, INORGANIC SILT, some fine Sand, trace fine - coarse Gravel.
		S4	6 to 8	24/18	5-7-8-9			S4: Wet, medium dense, brown, FINE - COARSE SAND AND INORGANIC SILT, trace fine - medium Gravel.
		S5	8 to 10	24/18	4-8-6-6			S5: Wet, medium dense, grayish brown, FINE SAND, some inorganic Silt, trace fine Gravel.
	10	S6	10 to 12	24/20	5-6-8-8			S6 (0"-12"): Wet, medium dense, brown, FINE SAND, some inorganic Silt, trace fine - medium Gravel. S6 (12"-24"): Wet, medium dense, grayish brown, INORGANIC SILT, some fine Sand, trace fine Gravel.
	15	S7	14 to 16	24/22	1-2-2-2		CLAY	S7: Wet, soft to medium stiff gray, CLAY, some inorganic Silt, trace fine - mediun Gravel.
	20	S8	19 to 21	24/22	1-2-2-2			S8: Similar to S7.

NOTES:
No GW level was measured due to malfunction in the water level indicator on this day.

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~175.5
VERTICAL DATUM: NAVD 88
DATE START/END: 3/16/2020 - 3/16/2020
DRILLING COMPANY: Northern Drill Service, Inc.

BORING BWB-3

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	25	S9	24 to 26	24/24	3-2-3-3		CLAY	S9: Similar to S7 and S8.
	30	S10	29 to 31	24/22	1-2-2-2		CLAY	S10: Similar to S7 through S9.
	35	S11	34 to 36	24/22	1-2-3-3		CLAY	S11: Wet , medium stiff, gray, CLAY, some inorganic Silt, trace fine Gravel.
	40	S12	39 to 41	24/18	3-4-6-5		SILT & SAND	S12: Wet, medium dense, gray, INORGANIC SILT, some fine Sand, trace Clay, trace fine Gravel.
	45	S13	44 to 46	24/18	2-3-3-4		SILT & SAND	S13:Similar to S12 but loose.
	50	S14	49 to 51	24/16	7-8-10-12		SILT & SAND	S14: Wet, medium dense, gray, FINE SAND, some inorganic Silt, trace fine - medium Gravel.
	55							

NOTES:
No GW level was measured due to malfunction in the water level indicator on this day.

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

Elev. (ft)	Depth (ft)	Sample Information				Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD			
	60	S15	59 to 61	24/16	6-9-11-13		SILT & SAND	S15: Wet, medium dense, gray, FINE SAND, some inorganic Silt, trace Clay, trace fine - medium Gravel.
	65							
	70	S16	69 to 71	24/16	6-6-10-15			S16: Similar to S15.
								Bottom of borehole at 71' Backfilled with soil cuttings and all-purpose gravel.
	75							
	80							
	85							

NOTES:
No GW level was measured due to malfunction in the water level indicator on this day.

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~178 **DATE START/END:** 3/13/2020 - 3/13/2020

VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 51.0 **DRILLER NAME:** Zac Nader

LOGGED BY: H. Ghiye **RIG TYPE:** Track Mounted Diedrich D-25

BORING BWB-4

DRILLING INFORMATION

HAMMER TYPE: Automatic **CASING I.D./O.D.:** 4 inch/ 4.5 inch **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA **DRILL ROD O.D.:** 2.625 inch **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): Not Measured

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/14	5-7-9-10		TOPSOIL	S1 (0"-12"): Wet, stiff, black, ORGANIC SILT AND FINE TO COARSE SAND, some fine to medium coarse gravel. Roots present (Topsoil).
							SILT & SAND	S1 (12"-24"): Wet, medium dense, brown, FINE - COARSE SAND, some fine - medium Gravel, some inorganic Silt.
		S2	2 to 4	24/22	10-10-8-8			S2: Similar to S1 (12"-24").
	5	S3	4 to 6	24/16	4-5-6-5			S3: Wet, medium dense, brownish gray, INIRGANIC SILT, some fine Sand, trace fine - medium Gravel.
		S4	6 to 8	24/18	4-6-8-10			S4: Similar to S3.
		S5	8 to 10	24/16	3-3-4-4			S5: Wet, loose, brownish gray, FINE - COARSE SAND, some inorganic Silt, trace fine - medium Gravel.
	10	S6	10 to 12	24/18	3-5-6-9			S6 (0"-18"): Similar to S5. S6 (18"-24"): Wet, medium dense, brownish gray, INORGANIC SILT, some fine Sand.
	15	S7	14 to 16	24/18	2-2-2-3		CLAY	S7: Wet, medium stiff, gray, CLAY, some inorganic Silt.
	20	S8	19 to 21	24/22	1-2-2-3			S8: Wet, medium stiff, gray, CLAY, some inorganic Silt, trace fine Gravel.

NOTES:
No GW level was measured due to malfunction in the water level indicator on this day.

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~178
VERTICAL DATUM: NAVD 88
DATE START/END: 3/13/2020 - 3/13/2020
DRILLING COMPANY: Northern Drill Service, Inc.

BORING BWB-4

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	25	S9	24 to 26	24/24	1-2-2-3		CLAY	S9: Similar to S8.
	30	S10	29 to 31	24/24	2-2-2-2		CLAY	S10: Wet, medium stiff, gray, CLAY, some inorganic Silt, trace fine Gravel.
	35	S11	34 to 36	24/24	1-2-3-4		CLAY	S11: Wet, medium stiff, gray, CLAY, some inorganic Silt, trace fine Gravel.
	40	S12	39 to 41	24/18	4-6-6-6		SILT & SAND	S12: Wet, medium dense, gray, INORGANIC SILT, some fine Sand, some fine Gravel.
	45	S13	44 to 46	24/18	6-6-7-11		SILT & SAND	S13: Similar to S12.
	50	S14	49 to 51	24/12	8-12-12-15		SILT & SAND	S14: Wet, medium dense, gray, FINE - COARSE SAND, some inorganic Silt, trace fine Gravel.
	55							Bottom of borehole at 51' Backfilled with soil cuttings.

NOTES:
No GW level was measured due to malfunction in the water level indicator on this day.

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

BORING INFORMATION		**BORING**
LOCATION: Springfield, MA		**BWB-5**
GROUND SURFACE EL. (ft): ~180.5	**DATE START/END:** 3/12/2020 - 3/13/2020	**PAGE 1 of 2**
VERTICAL DATUM: NAVD 88	**DRILLING COMPANY:** Northern Drill Service, Inc.	
TOTAL DEPTH (ft): 36.0	**DRILLER NAME:** Zac Nader	
LOGGED BY: H. Ghiye	**RIG TYPE:** Track Mounted Diedrich D-25	

DRILLING INFORMATION

HAMMER TYPE: Automatic **CASING I.D./O.D.:** 4 inch/ 4.5 inch **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA **DRILL ROD O.D.:** 2.625 inch **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): ▼ 1.0 3/13/2020 7:45 am ▼ 0.0 3/13/2020 10:00 am

ABBREVIATIONS:

Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer

S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger

Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter

NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample Information: Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/20	1-2-7-10		TOPSOIL	S1 (0"-18"): Moist, loose, black, ORGANIC SILT AND FINE - COARSE SAND, some fine to coarse gravel. Roots and organic fibers present (Topsoil).
							SAND &SILT	S1 (18"-24"): Moist, loose, brown, fine - coarse SAND, some inorganic Silt, trace fine - medium Gravel.
		S2	2 to 4	24/22	8-10-12-12			S2: Similar to S1 (18"-24") but wet and medium dense.
	5	S3	4 to 6	24/16	5-9-14-15			S3: Wet, medium dense brown, FINE - COARSE SAND, trace inorganic Silt, some fine - coarse Gravel.
		S4	6 to 8	24/22	9-13-14-14			S4: Wet, medium dense brown, FINE - COARSE SAND, trace inorganic Silt, some fine - medium Gravel.
		S5	8 to 10	24/16	8-11-12-11			S5: Wet, medium dense, brown, FINE SAND AND INORGANIC SILT, trace fine Gravel.
	10	S6	10 to 12	24/18	4-6-8-8			S6: Wet, medium dense, grayish brown, INORGANIC SILT, some fine Sand, trace fine Gravel.
	15	S7	14 to 16	24/22	2-2-3-4		CLAY	S7: Wet, medium stiff, gray, CLAY, some inorganic Silt, trace fine - medium Gravel.
	20	S8	19 to 21	24/29	2-2-3-2			S8: Similar to S7.

NOTES:
Stopped drilling for the day at ~ 16 ft (3/12/2020; 14:15). Resumed drilling (3/13/2020; 07:45).

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~180.5 **DATE START/END:** 3/12/2020 - 3/13/2020
VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	25	S9	24 to 26	24/22	2-2-3-3		CLAY	S9 (0"-6"): Wet, loose gray, FINE TO COARSE GRAVEL, some fine - coarse Sand, some Clay. S9 (6"-24"): Wet, medium stiff, gray, CLAY, some inorganic Silt, trace fine Gravel.
	30	S10	29 to 31	24/22	1-2-2-3		CLAY	S10: Wet, medium stiff, CLAY, some inorganic Silt, some fine - medium Gravel.
	35	S11	34 to 36	24/20	2-4-3-4		SAND, SILT & GRAVEL	S11 (0"-6"): Wet, loose, gray, FINE - COARSE GRAVEL AND FINE - COARSE SAND, some inorganic Silt. S11 (6"-24"): Wet, loose, gray, INORGANIC SILT, some fine Sand, trace fine Gravel.
						Could not advance the boring more than 36 feet due to ~15 ft of sand blowing in at the bottom of the hole and into the drilling rods.		Bottom of borehole at 36' Backfilled with soil cuttings.
	40							
	45							
	50							
	55							

NOTES:
Stopped drilling for the day at ~ 16 ft (3/12/2020; 14:15). Resumed drilling (3/13/2020; 07:45).

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~184 **DATE START/END:** 3/12/2020 - 3/12/2020

VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 41.0 **DRILLER NAME:** Zac Nader

LOGGED BY: H. Ghiye **RIG TYPE:** Track Mounted Diedrich D-25

BORING BWB-6

DRILLING INFORMATION

HAMMER TYPE: Automatic **CASING I.D./O.D.:** 4 inch/ 4.5 inch **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA **DRILL ROD O.D.:** 2.625 inch **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): ▼ 4.3 3/12/2020 10:33 am ▼ 0.6 3/12/2020 10:41 am

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/16	9-7-8-10		TOPSOIL	S1 (0"-12"): Wet, medium dense, black, ORGANIC SILT AND FINE - COARSE SAND, some fine - coarse Gravel. Roots and organic Fibers present (Topsoil).
							SAND & SILT	S1: (12"-24"): Moist, medium dense, brown, FINE - COARSE SAND, some inorganic Silt, some fine - medium coarse gravel.
		S2	2 to 4	24/20	5-9-10-11			S2: Similar to S1 (12"-24").
	5	S3	4 to 6	24/18	5-7-10-16			S3: Wet, medium dense, brown, FINE - COARSE SAND, some fine - coarse Gravel, trace inorganic Silt.
		S4	6 to 8	24/22	11-15-17-14			S4 (0"-12"): Similar to S3. S4 (12"-24"): Wet, dense, grayish brown, INORGANIC SILT AND FINE SAND, trace fine - medium Gravel.
		S5	8 to 10	24/18	9-10-10-8			S5: Wet, medium dense, orange-brown, INORGANIC SILT, some fine Sand, trace fine - medium Gravel.
	10	S6	10 to 12	24/20	4-5-6-7			S6 (0"-18"): Similar to S5 but some fine - medium coarse Gravel. S6 (18"-24"): Wet, medium dense, gray, INORGANIC SILT, trace fine Sand, trace Clay.
	15	S7	14 to 16	24/22	1-2-3-3		CLAY	S7: Wet, medium stiff, gray, CLAY, some inorganic Silt, trace fine Gravel.
	20	S8	19 to 21	24/18	2-4-4-4			S8: Wet, medium stiff to stiff, gray, CLAY, some fine Sand, trace fine Gravel.

NOTES:

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~184
VERTICAL DATUM: NAVD 88
DATE START/END: 3/12/2020 - 3/12/2020
DRILLING COMPANY: Northern Drill Service, Inc.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	25	S9	24 to 26	24/24	2-2-3-3		CLAY	S9: Wet, medium stiff, gray, CLAY, some inorganic Silt, trace fine Gravel.
	30	S10	29 to 31	24/24	1-2-2-2		CLAY	S10: Similar to S9.
	35	S11	34 to 36	24/16	5-6-7-7		CLAY / SAND & SILT	S11 (0"-6"): Wet, stiff, gray, CLAY, some inorganic Silt, trace fine Gravel. S11 (6"-24"): Wet, medium dense, gray, INORGANIC SILT, some fine Sand, trace fine Gravel.
	40	S12	39 to 41	24/16	5-6-7-7		SAND & SILT	S12: Wet, medium dense, gray, FINE SAND, some inorganic Silt, trace fine Gravel.
								Bottom of borehole at 41' Backfilled with soil cuttings.
	45							
	50							
	55							

NOTES:

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

GEI WOBURN STD 1-LOCATION-LAYER NAME 1904391 - MCKNIGHT COMMUNITY TRAIL - GEI 2020 EXPLORATIONS.GPJ GEI DATA TEMPLATE 2011.GDT 4/22/20

BORING BWB-7

BORING INFORMATION

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~187.5
VERTICAL DATUM: NAVD 88
TOTAL DEPTH (ft): 41.0
LOGGED BY: H. Ghiye
DATE START/END: 3/11/2020 - 3/11/2020
DRILLING COMPANY: Northern Drill Service, Inc.
DRILLER NAME: Zac Nader
RIG TYPE: Track Mounted Diedrich D-25

DRILLING INFORMATION

HAMMER TYPE: Automatic
AUGER I.D./O.D.: NA / NA
CASING I.D./O.D.: 4 inch/ 4.5 inch
DRILL ROD O.D.: 2.625 inch
CORE BARREL TYPE:
CORE BARREL I.D./O.D. NA / NA
DRILLING METHOD: Driven casing and washed with rotary tooling.
WATER LEVEL DEPTHS (ft): ▼ 6.1 3/11/2020 2:17 pm ▼ 0.8 3/11/2020 2:27 pm

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/18	1-4-5-6		TOPSOIL	S1 (0"-12"): Moist, stiff, black, ORGANIC SILT AND SAND, trace fine - coarse gravel. Roots, fibers and wood chips present (Topsoil).
							SAND & SILT	S1 (12"-24"): Moist, loose, blackish brown, FINE - COARSE SAND, some inorganic Silt, some fine - medium coarse gravel.
		S2	2 to 4	24/22	1-4-7-7			S2: Wet, medium dense, brown, FINE - COARSE SAND, some fine - medium Gravel, trace inorganic Silt.
	5	S3	4 to 6	24/18	5-7-3-5			S3: Similar to S2.
		S4	6 to 8	24/20	5-6-4-4			S4: Wet, medium dense, brown, FINE - COARSE SAND, trace fine Gravel, trace inorganic Silt.
		S5	8 to 10	24/10	1-2-5-6			S5: Wet, loose, brown, FINE - COARSE SAND, trace inorganic Silt, trace fine Gravel.
	10	S6	10 to 12	24/22	1-4-5-7			S6: Similar to S5.
	15	S7	14 to 16	24/20	4-5-7-7			S7: Wet, stiff, gray, INORGANIC SILT, some Clay, trace fine Gravel.
	20	S8	19 to 21	24/22	2-3-4-5		CLAY	S8: Wet, medium stiff, gray, CLAY, some inorganic Silt.

NOTES:

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA	**BORING BWB-7**
GROUND SURFACE EL. (ft): ~187.5 **DATE START/END:** 3/11/2020 - 3/11/2020	**PAGE 2 of 2**
VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.	

Elev. (ft)	Depth (ft)	Sample Information				Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD			
	25	S9	24 to 26	24/18	1-2-5-6		CLAY	S9: Similar to S8.
	30	S10	29 to 31	24/18	4-6-7-9		SAND & SILT	S10: Wet, medium dense, interbedded gray FINE SAND, some brown inorganic Silt, trace fine Gravel.
	35	S11	34 to 36	24/16	5-7-7-8			S11: Wet, medium dense, brownish gray, INORGANIC SILT AND FINE SAND, trace fine Gravel.
	40	S12	39 to 41	24/14	6-6-9-8			S12: Wet, medium dense, gray, FINE SAND AND INORGANIC SILT, trace fine - coarse gravel.
								Bottom of borehole at 41' Backfilled with soil cuttings.
	45							
	50							
	55							

NOTES:

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~191 | **DATE START/END:** 3/10/2020 - 3/11/2020

VERTICAL DATUM: NAVD 88 | **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 76.0 | **DRILLER NAME:** Zac Nader

LOGGED BY: H. Ghiye | **RIG TYPE:** Track Mounted Diedrich D-25

BORING BWB-8

DRILLING INFORMATION

HAMMER TYPE: Automatic | **CASING I.D./O.D.:** 4 inch/ 4.5 inch | **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA | **DRILL ROD O.D.:** 2.625 inch | **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): ⊻ 2.5 3/11/2020 7:45 am ▼ 5.5 3/11/2020 10:58 am ▼ 1.6 3/11/2020 11:08 am

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/10	5-6-7-8		TOPSOIL	S1: Moist, medium dense, black, FINE- COARSE SAND, some organic Silt, trace fine - coarse Gravel. Roots, wood chips and hay (Topsoil).
		S2	2 to 4	24/16	5-8-7-9		SAND	S2: Moist, medium dense, brown, FINE - COARSE SAND, trace inorganic Silt, trace fine - coarse Gravel.
	5	S3	4 to 6	24/18	8-9-6-5			S3: Wet, medium dense, brown, FINE - COARSE SAND, trace inorganic Silt, trace fine - medium Gravel.
		S4	6 to 8	24/21	2-1-4-5			S4: Similar to S3 but loose.
		S5	8 to 10	24/16	3-4-4-6			S5: Similar to S3.
	10	S6	10 to 12	24/14	3-3-4-5			S6: Similar to S4.
		S7	12 to 14	24/18	1-2-5-6			S7: Wet, loose, brown, FINE - COARSE SAND, trace inorganic Silt, trace fine - medium Gravel. Most of Sand is coarse.
	15	S8	14 to 16	24/6	2-2-5-7			S8: Wet, loose, brown, FINE - COARSE SAND, trace inorganic Silt.
		S9	16 to 18	24/20	5-5-7-7			S9: Similar to S3. Some sand is black.
		S10	18 to 20	24/6	2-3-6-7			S10: Wet, loose, brown, FINE - COARSE SAND, trace inorganic Silt, trace fine - medium Gravel.
	20	S11	20 to 22	24/18	1-3-7-7			S11: Wet, loose to medium dense, brown, FINE - COARSE SAND, some inorganic Silt, trace fine - medium Gravel.
						Sand started blowing in at the bottom of the hole at this depth. Switched to		

NOTES:
Stopped drilling for the day at ~ 31 ft (3/10/2020; 14:30). Resumed drilling (3/11/2020; 08:30).

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	25	S12	24 to 26	24/20	4-6-8-10	standard sampling and kept water head.	SAND	S12 (0"-12"): Similar to S11.
							SAND & SILT	S12 (12"-24"): Wet, medium dense, grayish brown, INORGANIC SILT, some fine Sand, trace Clay.
	30	S13	29 to 31	24/20	4-7-7-10			S13: Wet, medium dense, brownish gray, FINE SAND AND INORGANIC SILT, trace Clay.
	35	S14	34 to 36	24/16	6-6-7-8			S14: Wet, medium dense, brownish gray, FINE SAND AND INORGANIC SILT.
	40	S15	39 to 41	24/18	3-6-13-15			S15 (0"-12"): Similar to S14. S15 (12"-24"): Wet, medium dense, grayish brown, INORGANIC SILT, some fine Sand.
	45	S16	44 to 46	24/18	7-10-13-17			S16: Similar to S14 with trace fine Gravel.
	50	S17	49 to 51	24/18	3-6-7-7			S17 (0"-12"): Similar to S16. S17 (12"-24"): Wet, medium dense, brownish gray, INORGANIC SILT, trace to some fine Sand.
	55	S18	54 to 56	24/20	5-7-10-14			S18 (0"-12"): Wet, very stiff, gray, INORGANIC SILT, some Clay, some fine - medium Gravel. S18 (12"- 24"): Wet, medium dense, gray, INORGANIC SILT,

NOTES:
Stopped drilling for the day at ~ 31 ft (3/10/2020; 14:30). Resumed drilling (3/11/2020; 08:30).

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
								trace fine Sand.
	60							
	65	S19	64 to 66	24/20	9-11-15-19		SAND & SILT	S19: Wet, medioum dense, grayish brown, FINE - COARSE SAND, some inorganic Silt, some fine - medium Gravel, trace Clay.
	70							
	75	S20	74 to 76	24/22	9-11-15-21			S20: Wet, medium dense, gray and brown, INORGANIC SILT, some fine Sand, some fine - medium Gravel, trace Clay.
								Bottom of borehole at 76' Backfilled with soil cuttings.
	80							
	85							

NOTES:
Stopped drilling for the day at ~ 31 ft (3/10/2020; 14:30). Resumed drilling (3/11/2020; 08:30).

massDOT Moving Massachusetts Forward Highway	GEI Consultants, Inc. for BETA Group, Inc.	Probe Number P-1 Series

City/Town: Springfield	Bridge: Glen Road Bridge	Project File #: 1904391
Location: Route 67	Date & Time Started: 10/29/19 7:00 Date & Time Ended: 10/30/19 14:30	Total Hours:
Driller's Name: Zac Nader	Drilling Company: Northern Drill Service	Driller's Signature: N/A
Helper's Name: Justin	Inspector: P. Blessing	Inspector's Signature: N/A

INFORMATION LOG

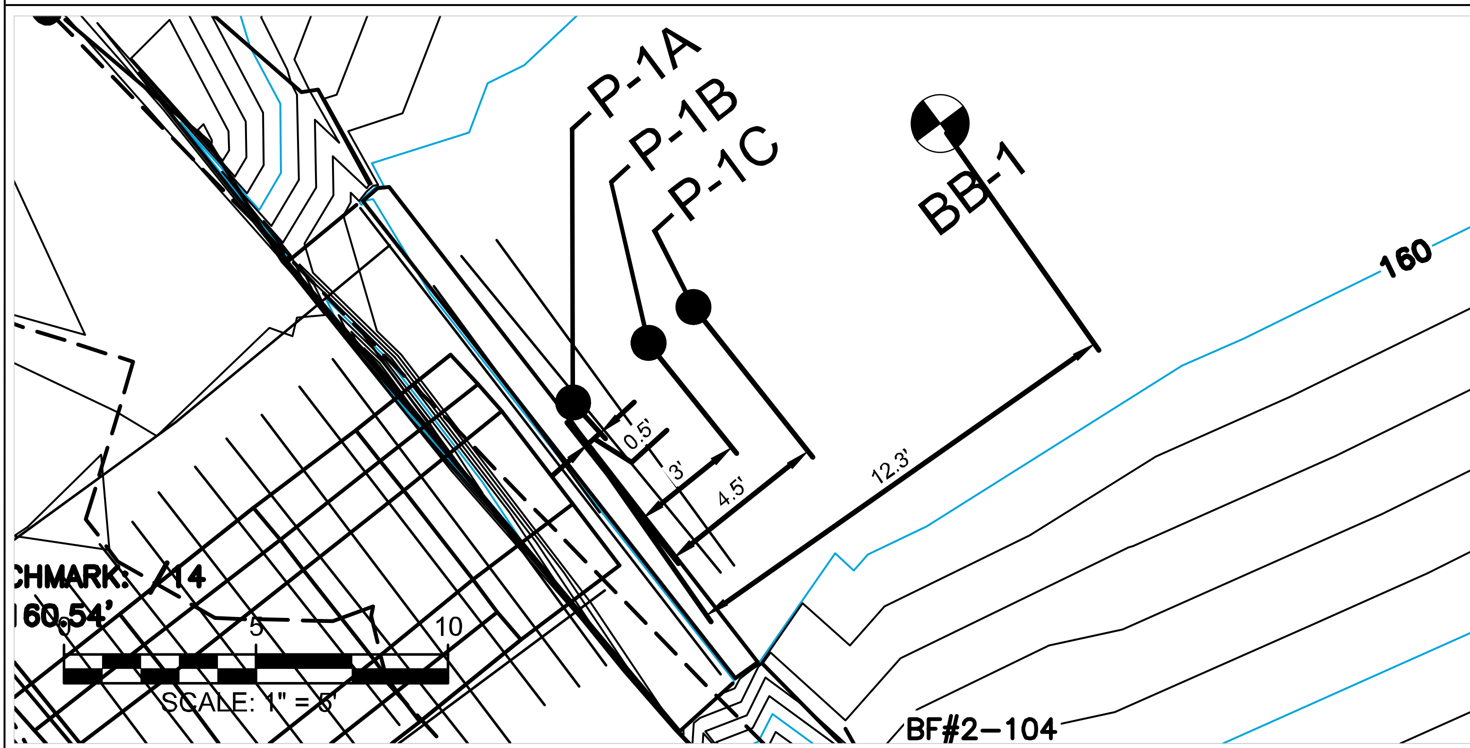
Number Probe	Northing	Easting	Depth	Distance	Ref or Req	Comments
P-1A	2869762	364133	8.5'	0.5'	Refusal	Refusal on abutment.
P-1B	2869764	364135	21.0'	3'	Required	Encountered BOA at 19'
P-1C	2869765	364136	21.0'	4.5'	Required	Reached required depth of 21'
BB-1	2869769	364143	76.0'	12.4'	Required	Reached required depth of 76'

BOA: Denotes bottom of abutment

Coordinates: Massachusetts State Plane, North American Datum of 1983 (NAD 83)

Remarks: Distance measured from the approximate location of the back face of the concrete cap on the east abutment

SKETCH (PLAN VIEW)



Remarks: Holes backfilled with cuttings and all-purpose gravel upon completion.

Drill Rig Used: Diedrich D-25	Drill Rods/Solid Augers: Drill Rods	Type: NW	Size: 2.625"	Hammer: Automatic

BORING INFORMATION

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~161.25
VERTICAL DATUM: NAVD 88
TOTAL DEPTH (ft): 8.5
LOGGED BY: Patrick Blessing
DATE START/END: 10/29/2019 - 10/29/2019
DRILLING COMPANY: Northern Drill Service, Inc.
DRILLER NAME: Zac Nader
RIG TYPE: Track Mounted Diedrich D-25

BORING P-1A

DRILLING INFORMATION

HAMMER TYPE: Automatic
AUGER I.D./O.D.: NA / NA
CASING I.D./O.D.: NA/ NA
DRILL ROD O.D.: 2.625 inch
CORE BARREL TYPE:
CORE BARREL I.D./O.D. NA / NA
DRILLING METHOD: Direct Push
WATER LEVEL DEPTHS (ft): Not Measured

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24	NR-NR-NR-NR			No samples collected.
		S2	2 to 4	24	NR-NR-NR-NR			
	5	S3	4 to 6	24/16	NR-NR-NR-NR		SAND & SILT	S3: Dry to Moist, brown to reddish brown, FINE - COARSE SAND AND SILT, trace to some fine - coarse gravel.
		S4	6 to 8	24/18	8-16-22-17		SAND & SILT	S4 (0"-12"): Dry to Moist, dense, brown, FINE - COARSE SAND AND SILT.
							GRAVEL	S4 (12"-24"): Dry to moist, dense, reddish brown, FINE - COARSE GRAVEL, some fine Sand, trace inorganic Fines. Gravel is fragmented cobbles.
		S5	8 to 8.5	6/3	75	Refusal on possible abutment foundation block.	GRAVEL	S5: Dry, very dense, FINE - COARSE GRAVEL, some fine - coarse Sand, trace inorganic Fines.
								Bottom of borehole at 8.5'
	10							
	15							
	20							

NOTES:

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~161.25 | **DATE START/END:** 10/29/2019 - 10/30/2019

VERTICAL DATUM: NAVD 88 | **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 21.0 | **DRILLER NAME:** Zac Nader

LOGGED BY: Patrick Blessing | **RIG TYPE:** Track Mounted Diedrich D-25

BORING P-1B

DRILLING INFORMATION

HAMMER TYPE: Automatic | **CASING I.D./O.D.:** NA/ NA | **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA | **DRILL ROD O.D.:** 2.625 inch | **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Direct Push

WATER LEVEL DEPTHS (ft): Not Measured

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation
= Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample Information: Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/20	NR-NR-NR-NR		TOPSOIL	S1 (0"-18"): Dry to Moist, black, FINE - COARSE GRAVEL, some fine - coarse Sand, trace to some Fines. Slag fragments and Organic roots present (Topsoil).
		S2	2 to 4	24/18	NR-NR-NR-NR		SAND	S1 (18"-24"): Dry, brown, FINE - COARSE SAND, tarce to some fine - coarse Gravel, trace inorganic Fines. S2: Dry, brown, FINE - COARSE SAND, trace to some fine - coarse Gravel, trace inorganic Fines.
	5	S3	4 to 6	24/20	9-10-9-10			S3: Dry to Moist, medium dense, brown, FINE - COARSE SAND, trace to some inorganic Fines.
		S4	6 to 8	24/24	4-8-9-9			S4: Moist to Wet, medium dense, brown to light brown, FINE - COARSE SAND, trace to some inorganic Fines. Fine sand from 7'-7.66'.
		S5	8 to 9.7	21/20	8-33-60	Possible refusal due to cobbles.		S5 (0"-15"): Wet, dense, brown, FINE - COARSE SAND, trace to some inorganic Fines.
	10						SAND & GRAVEL	S5 (15"-20"): Wet, dense, reddish brown, FINE - COARSE GRAVEL, some fine - coarse Sand, trace inorganic Silt. Gravel is fragmented cobbles.
	15	S6	13 to 15	24/21	8-25-29-80			S6 (0"-6"): Wet, very dense, brown, FINE - COARSE SAND, trace inorganic Fines. S6 (6"-24"): Wet, very dense, reddish brown, COARSE GRAVEL, some fine - coarse Sand. Gravel is possibly fragments of foundation block.
						Hard drilling and rig chatter. Possible foundation blocks.		Possible foundation blocks.
	20	S7	19 to 21	24/15	5-4-4-6	Bottom of possible foundation blocks.	SAND	S7: Wet, loose, gray, FINE - COARSE SAND, trace to some inorganic Fines, trace fine - medium coarse Gravel.
								Bottom of borehole at 21'

NOTES:

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

GEI WOBURN STD 1-LOCATION-LAYER NAME 1904391 - MCKNIGHT COMMUNITY TRAIL - GEI 2019 EXPLORATIONS.GPJ GEI DATA TEMPLATE 2011.GDT 4/22/20

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~161.25 **DATE START/END:** 10/29/2019 - 10/30/2019

VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 21.0 **DRILLER NAME:** Zac Nader

LOGGED BY: Patrick Blessing **RIG TYPE:** Track Mounted Diedrich D-25

BORING P-1C

DRILLING INFORMATION

HAMMER TYPE: Automatic **CASING I.D./O.D.:** NA/ NA **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA **DRILL ROD O.D.:** 2.625 inch **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Direct Push

WATER LEVEL DEPTHS (ft): Not Measured

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24	NR-NR-NR-NR			No samples collected.
		S2	2 to 4	24/24	NR-NR-NR-NR		SAND	S2: Dry, brown, FINE - COARSE SAND, trace to some fine - medium coarse Gravel, trace inorganic Fines.
	5	S3	4 to 6	24/21	9-11-10-12			S3: Dry, medium dense, brown, FINE - COARSE SAND, trace fine - medium coarse Gravel, trace inorganic Fines.
		S4	6 to 8	24/15	3-4-5-8			S4: Moist, loose, brown, FINE - COARSE SAND, trace inorganic Fines.
		S5	8 to 10	24/22	9-11-10-12			S5: Wet, medium dense, brown, FINE - COARSE SAND, trace to some inorganic Fines.
	10	S6	10 to 12	24/21	4-5-6-8			S6: Wet, medium dense, brown, FINE - COARSE SAND, trace fine - medium coarse Gravel, trace inorganic Fines.
	15							
	20	S7	19 to 21	24/15	3-2-3-2			S7: Wet, loose, grayish brown, FINE - COARSE SAND, trace to some inorganic Fines, trace fine - coarse Gravel. Wood timber fragments and organic peat present.
								Bottom of borehole at 21'

NOTES:

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

massDOT Highway	GEI Consultants, Inc. for BETA Group, Inc.	Probe Number P-2 Series Page 1 of 1

City/Town: Warren	Bridge: W-07-002 (1AA)	Project File #: 607673	
Location: Route 67	Date & Time Started: 3/4/20 09:30 Date & Time Ended: 3/6/20 12:00		Total Hours:
Driller's Name: Zac Nader	Drilling Company: Northern Drill Service	Driller's Signature: N/A	
Helper's Name: Justin	Inspector: H. Ghiye	Inspector's Signature: N/A	

INFORMATION LOG

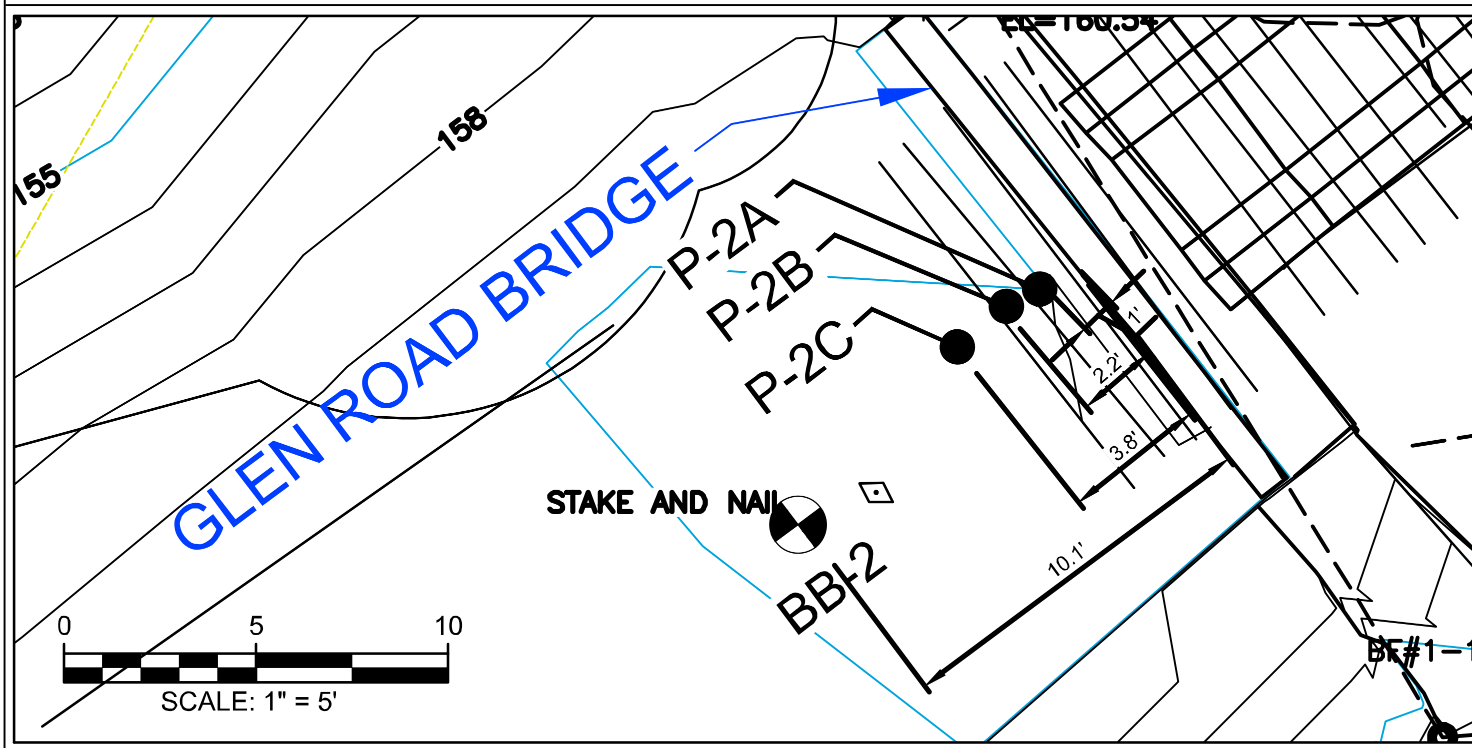
Number Probe	Northing	Easting	Depth	Distance	Ref or Req	Comments
P-2A	2869749	364118	20.0'	1.0'	Required	Cored 12' of abutment. BOA at 18'
P-2B	2869749	364117	25.0'	2.2'	Required	Encountered BOA at 17'
P-2C	2869748	364115	20.0'	3.8'	Required	Reached required depth of 20'
BB-2	2869743	364111	96.0'	10.1'	Required	Reached required depth of 96'

BOA: Denotes bottom of abutment

Coordinates: Massachusetts State Plane, North American Datum of 1983 (NAD 83)

Remarks: Distance measured from the approximate location of the back face of the concrete cap on the west abutment

SKETCH (PLAN VIEW)



Remarks: Holes backfilled with cuttings and all-purpose gravel upon completion.

Drill Rig Used: Diedrich D-25	Drill Rods/Solid Augers: Drill Rods	Type: NW	Size: 2.625"	Hammer: Automatic

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~161 | **DATE START/END:** 3/4/2020 - 3/4/2020

VERTICAL DATUM: NAVD 88 | **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 20.0 | **DRILLER NAME:** Zac Nader

LOGGED BY: H. Ghiye | **RIG TYPE:** Track Mounted Diedrich D-25

BORING P-2A

DRILLING INFORMATION

HAMMER TYPE: Automatic | **CASING I.D./O.D.:** 3 inch/ 3.5 inch | **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA | **DRILL ROD O.D.:** 2.625 inch | **CORE BARREL I.D./O.D.** NA / 2.96 inch

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): ⊻ 9.8 3/4/2020 11:35 am

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/16	4-5-1-1		TOPSOIL	S1: Moist, medium stiff, black, ORGANIC SILT AND PEAT, some fine - coarse Sand. Roots, glass, and wood chips present (Topsoil).
		S2	2 to 4	24/15	2-1-2-2		SAND	S2: Moist, very loose, light brown, FINE TO COARSE SAND, some inorganic Silt.
	5	S3	4 to 6	24/12	2-2-10-11	Switched to 3" O.D. split-spoon sampling to obtain better recovery.	SAND	S3 (0"- 12"): Moist, loose to medium dense, FINE - COARSE SAND, some inorganic Silt, trace fine - medium Gravel. S3 (12"- 24"): Moist, medium dense, reddish brown, FINE - COARSE SAND, some inorganic Silt, some fine - coarse Gravel. Gravel is red stone fragments (easily broken by hand).
		C1	6 to 11	60/50	63	Encountered possible granite block. Switched to NX coring.	RED STONE BLOCK	C1: Moist, soft, RED STONE.
	10	C2	11 to 16	60/44	27		RED STONE BLOCK	C2: Moist, soft, fractured, RED STONE.
	15	C3	16 to 18	24/24	21		RED STONE BLOCK	C3: Similar to C2.
		S4	18 to 20	24	1-1-2-3	Bottom of granite block. Switched to 2" O.D. split-spoon sampling in the bearing soil.	SAND	S4: Wet, very loose, grayish brown, FINE - COARSE SAND, trace fine Gravel, trace inorganic Silt.
	20							Bottom of borehole at 20' Backfilled with soil cuttings and all-purpose gravel (3/6/2020).

NOTES:
Left hole open after end of drilling (3/4/2020-3/5/2020). After drilling, water level probe could not be advanced deeper than 6.5 ft due to hole collapse with no GW level encountered at this depth (3/4/2020; 13:55 & 3/5/2020; 07:15).

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

BORING INFORMATION

LOCATION: Springfield, MA

GROUND SURFACE EL. (ft): ~161 | **DATE START/END:** 3/4/2020 - 3/6/2020

VERTICAL DATUM: NAVD 88 | **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 25.0 | **DRILLER NAME:** Zac Nader

LOGGED BY: H. Ghiye | **RIG TYPE:** Track Mounted Diedrich D-25

BORING P-2B

DRILLING INFORMATION

HAMMER TYPE: Automatic | **CASING I.D./O.D.:** 3 inch/ 3.5 inch | **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA | **DRILL ROD O.D.:** 2.625 inch | **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): ▽ 10.2 3/6/2020 9:40 am ▼ 9.7 3/4/2020 1:00 pm ▼ 9.7 3/6/2020 11:30 am After stopped drilling at ~ 12 ft.

ABBREVIATIONS:

Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation
= Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample Information: Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/16	5-4-4-4		TOPSOIL	S1: Moist, medium stiff to stiff, black, ORGANIC SILT AND PEAT, some fine - coarse sand, trace fine - coarse Gravel. Roots present (Topsoil).
		S2	2 to 4	24/18	3-5-4-5		SAND	S2: Moist, loose, light brown, FINE - COARSE SAND, some inorganic Silt.
	5	S3	4 to 6	24/20	10-8-8-7		SAND	S3: Moist, medium dense, light brown, FINE - COARSE SAND, trace inorganic Silt, trace fine - medium Gravel.
		S4	6 to 8	24/16	4-3-4-5		SAND	S4: Similar to S2.
		S5	8 to 10	24/16	1-1-3-4		SAND / SILT	S5 (0"-12"): Similar to S2 and S4. S5 (12"-24"): Moist, soft to medium stiff, grayish brown to gray, INORGANIC SILT, some Clay, trace fine Sand.
	10	S6	10 to 12	24/12	3-3-3-4		SILT	S6: Wet, medium stiff, brown and gray, INORGANIC SILT, some Clay, fine Sand.
		S7	12 to 14	24/10	1-2-4-5	Stopped drilling at ~ 12 ft.	SILT	S7: Wet, loose, brownish gray, INORGANIC SILT, trace fine Sand.
	15	S8	14 to 15.8	21/10	WOH-5-98-100/3"		SILT	S8: Wet, loose to medium dense, brownish gray, INORGANIC SILT, trace fine Sand, trace fine to medium coarse Gravel. Red stone fragments present.
						Hard driving the split-spoon. Possibly top of red stone block. Drilled through and came out of the red stone block (core barrel was not available on this day with the driller to core the block). Overdrilled below bottom of block about 1 to 2 ft.		POSSIBLE RED STONE BLOCK
	20	S9	19 to 21	24/18	2-4-3-5		SAND & SILT	S9 (0"-18"): Wet, loose, blackish gray, FINE - COARSE SAND, some inorganic Silt, some fine - coarse Sand, some fine - coarse Gravel. Organic-like Odor. S9 (18"-24"): Wet, medium stiff, gray, INORGANIC SILT, some Clay.
		S10	21 to 23	24/16	1-1-1-2		SAND & SILT	S10 (0"-18"): Wet, very loose, gray, FINE - COARSE SAND, some inorganic Silt, some fine - medium Gravel. S10 (18"-24"): Wet, very soft to soft, gray, CLAY, some inorganic Silt.
		S11	23 to	24/20	2-3-2-1		SAND & SILT	S11 (0"-12"): Wet, loose, gray, FINE TO COARSE SAND, some inorganic Silt, some fine - medium Gravel.

NOTES:
Left hole open at ~ 12 ft (3/4/2020-3/5/2020). After stop of drilling at ~ 12 ft, water level probe could not be advanced deeper than 9.5 ft due to hole collapse with no GW encountered at this depth (3/4/2020; 13:55 & 3/5/2020; 07:10).

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

GEI Consultants

LOCATION: Springfield, MA
GROUND SURFACE EL. (ft): ~161 **DATE START/END:** 3/4/2020 - 3/6/2020
VERTICAL DATUM: NAVD 88 **DRILLING COMPANY:** Northern Drill Service, Inc.

BORING P-2B

Elev. (ft)	Depth (ft)	Sample Information: Sample No.	Sample Information: Depth (ft)	Sample Information: Pen./Rec. (in)	Sample Information: Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
			25					S11 (12"-24): Wet, loose to medium dense, INORGANIC SILT, trace fine Sand, trace Clay.
	25							Bottom of borehole at 25' Backfilled with soil cuttings and all-purpose gravel (3/6/2020).
	30							
	35							
	40							
	45							
	50							
	55							

NOTES:
Left hole open at ~ 12 ft (3/4/2020-3/5/2020). After stop of drilling at ~ 12 ft, water level probe could not be advanced deeper than 9.5 ft due to hole collapse with no GW encountered at this depth (3/4/2020; 13:55 & 3/5/2020; 07:10).

PROJECT NAME: McKnight Community Trail
CITY/STATE: Springfield, Massachusetts
GEI PROJECT NUMBER: 1904391

GEI Consultants

BORING INFORMATION		BORING
LOCATION: Springfield, MA		P-2C
GROUND SURFACE EL. (ft): ~161	DATE START/END: 3/6/2020 - 3/6/2020	PAGE 1 of 1
VERTICAL DATUM: NAVD 88	DRILLING COMPANY: Northern Drill Service, Inc.	
TOTAL DEPTH (ft): 20.0	DRILLER NAME: Zac Nader	
LOGGED BY: H. Ghiye	RIG TYPE: Track Mounted Diedrich D-25	

DRILLING INFORMATION

HAMMER TYPE: Automatic **CASING I.D./O.D.:** 4 inch/ 4.5 inch **CORE BARREL TYPE:**

AUGER I.D./O.D.: NA / NA **DRILL ROD O.D.:** 2.625 inch **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Driven casing and washed with rotary tooling.

WATER LEVEL DEPTHS (ft): ▼ 10.3 3/6/2020 11:15 am ▼ 9.8 3/6/2020 11:35 am

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S1	0 to 2	24/14	5-6-5-6		TOPSOIL	S1: Moist, medium dense, dark brown to black, FINE TO COARSE SAND, some fine to coarse gravel, some silt. Roots, glass and wood chips present (Topsoil).
	5	S2	4 to 6	24/10	5-7-4-4		SAND & SILT	S2: Moist, medium dense, light brown, FINE - COARSE SAND, some inorganic Silt, trace fine - coarse Gravel.
	10	S3	9 to 11	24/10	1-2-2-1			S3: Wet, loose, light brown, FINE - COARSE SAND AND INORGANIC SILT, some fine - medium Gravel.
	15	S4	14 to 16	24/18	2-4-3-3			S4 (0"-18"): Similar to S3. S4 (18"-24"): Wet, medium dense, gray, INORGANIC SILT.
		S5	16 to 18	24/18	3-3-3-3			S5 (0"-12"): Wet, loose, light brown, FINE - COARSE SAND, some fine - medium Gravel, trace inorganic Silt. S5 (12"-18"): Wet, medium dense, brownish gray, INORGANIC SILT, trace fine Sand. S5 (18"-24"): Wet, loose, dark brown to gray, FINE - COARSE SAND, some inorganic Silt, trace fine Gravel.
		S6	18 to 20	24/22	1-1-2-1			S6: Wet, very loose, blackish gray, INORGANIC SILT, trace fine - coarse Sand, trace fine - medium Gravel.
	20							Bottom of borehole at 20' Backfilled with soil cuttings and all-purpose gravel (3/6/2020).

GEI WOBURN STD 1-LOCATION-LAYER NAME 1904391 - MCKNIGHT COMMUNITY TRAIL - GEI 2020 EXPLORATIONS.GPJ GEI DATA TEMPLATE 2011.GDT 4/22/20

NOTES:

PROJECT NAME: McKnight Community Trail

CITY/STATE: Springfield, Massachusetts

GEI PROJECT NUMBER: 1904391

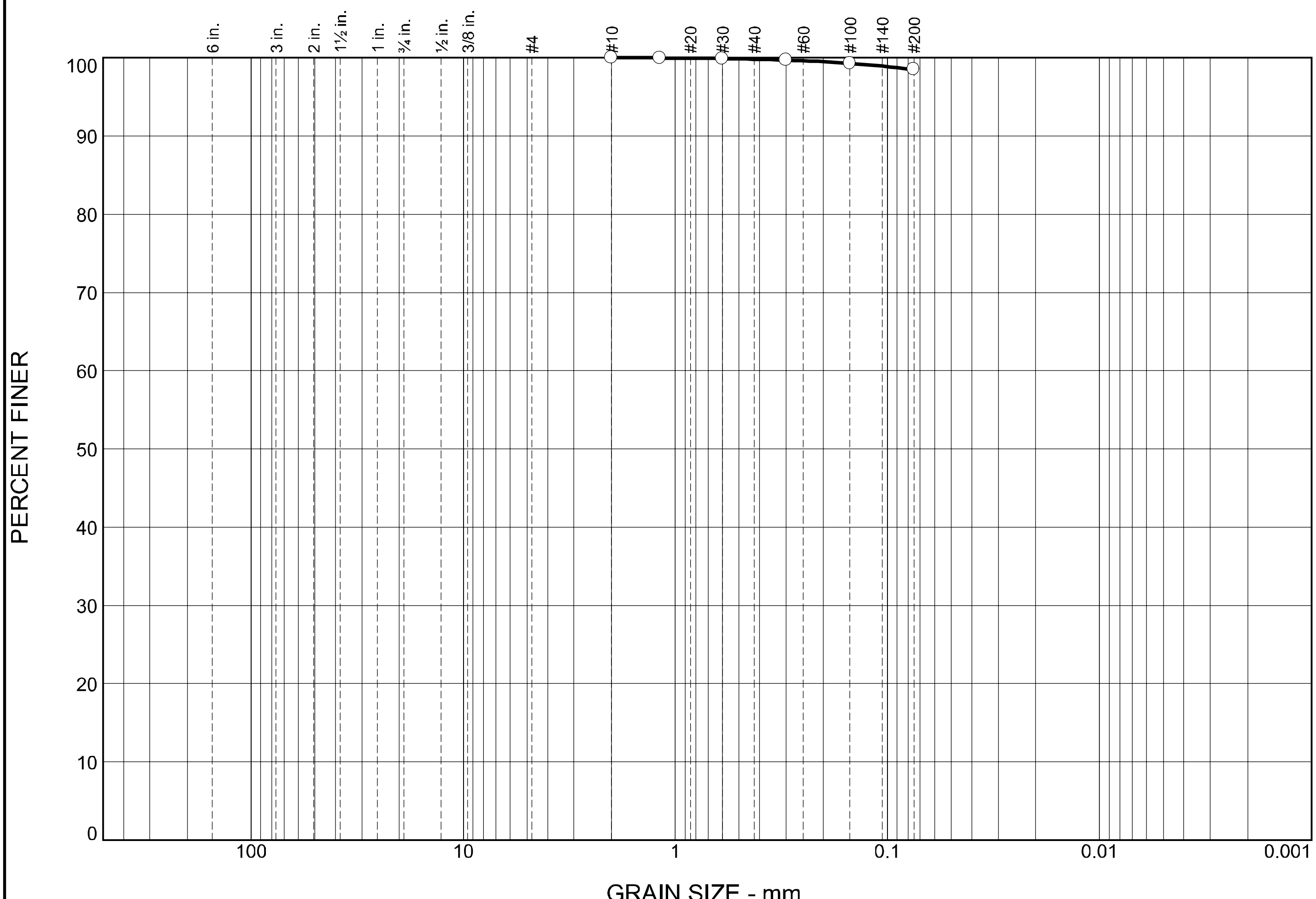
GEI Consultants

Appendix C

Laboratory Test Results

- Grain size test results – Exploration Samples
- Grain size test results – Sediment Samples
- Atterberg Limits test reports

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel Coarse	% Gravel Medium	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines
○	0.0	0.0	0.0	0.0	0.0	0.2	1.3	98.5

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○										

Material Description	USCS	AASHTO
○ Wet, soft to medium stiff, gray, INORGANIC CLAY, trace fine sand	CL	

Project No. 1904391 **Client:** BETA Group, Inc.

Project: McKnight Community Trail

○ **Source of Sample:** BWB-2 **Depth:** 24-26 ft **Sample Number:** S12

Remarks:

○As Received WC=42.7%

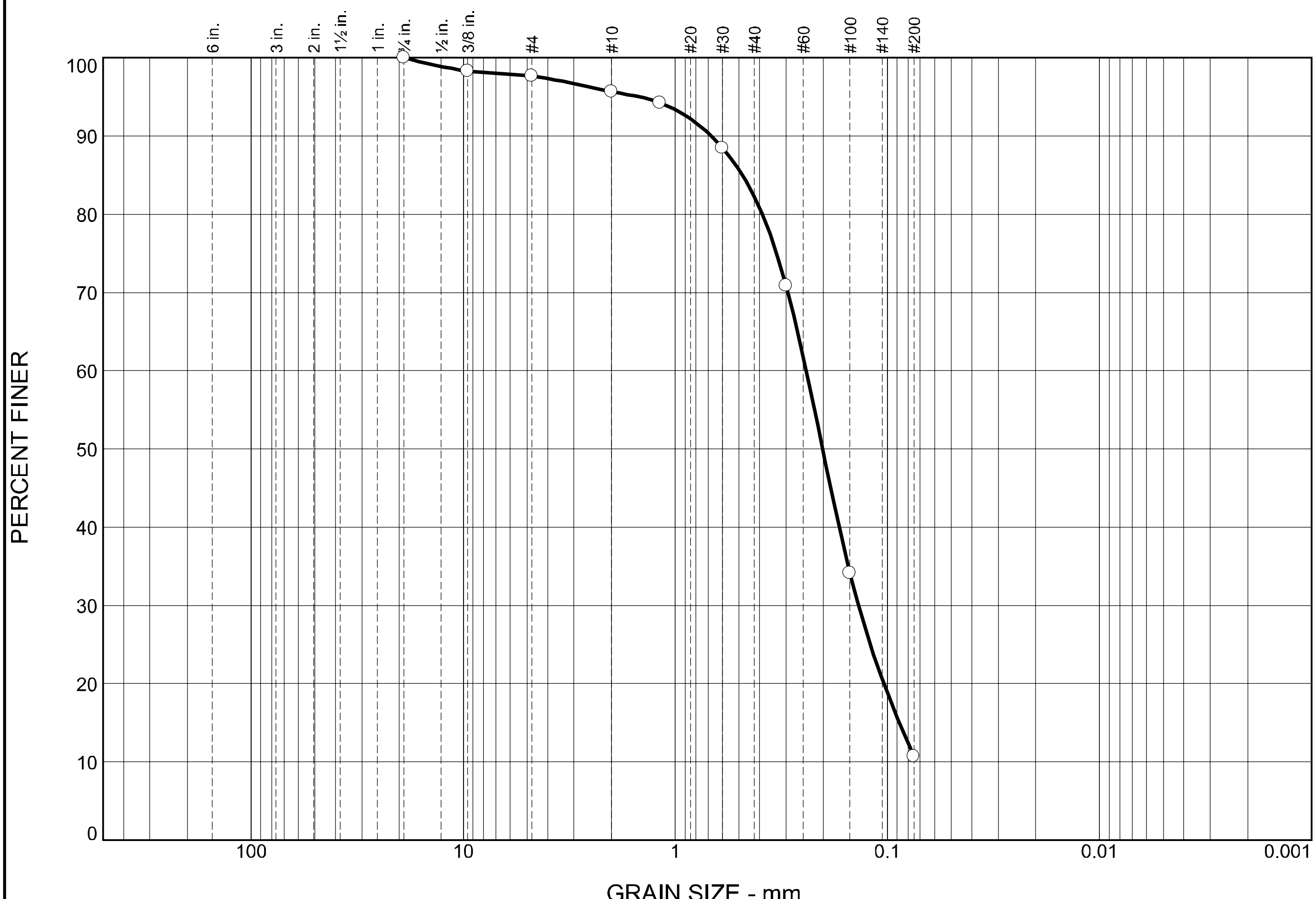
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel Coarse	% Gravel Medium	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines
○	0.0	0.0	0.0	1.7	2.6	13.4	71.6	10.7

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.4825	0.2412	0.2018	0.1368	0.0878			

Material Description	USCS	AASHTO
○ Wet, medium dense, brown, FINE TO COARSE SAND, some inorganic silt, trace fine to med gravel	SP-SM	-

Project No. 1904391 **Client:** BETA Group, Inc.

Project: McKnight Community Trail

○ **Source of Sample:** BWB-3 **Depth:** 4-6 ft **Sample Number:** S3 (0-12")

Remarks:

○As Received WC=22.1%

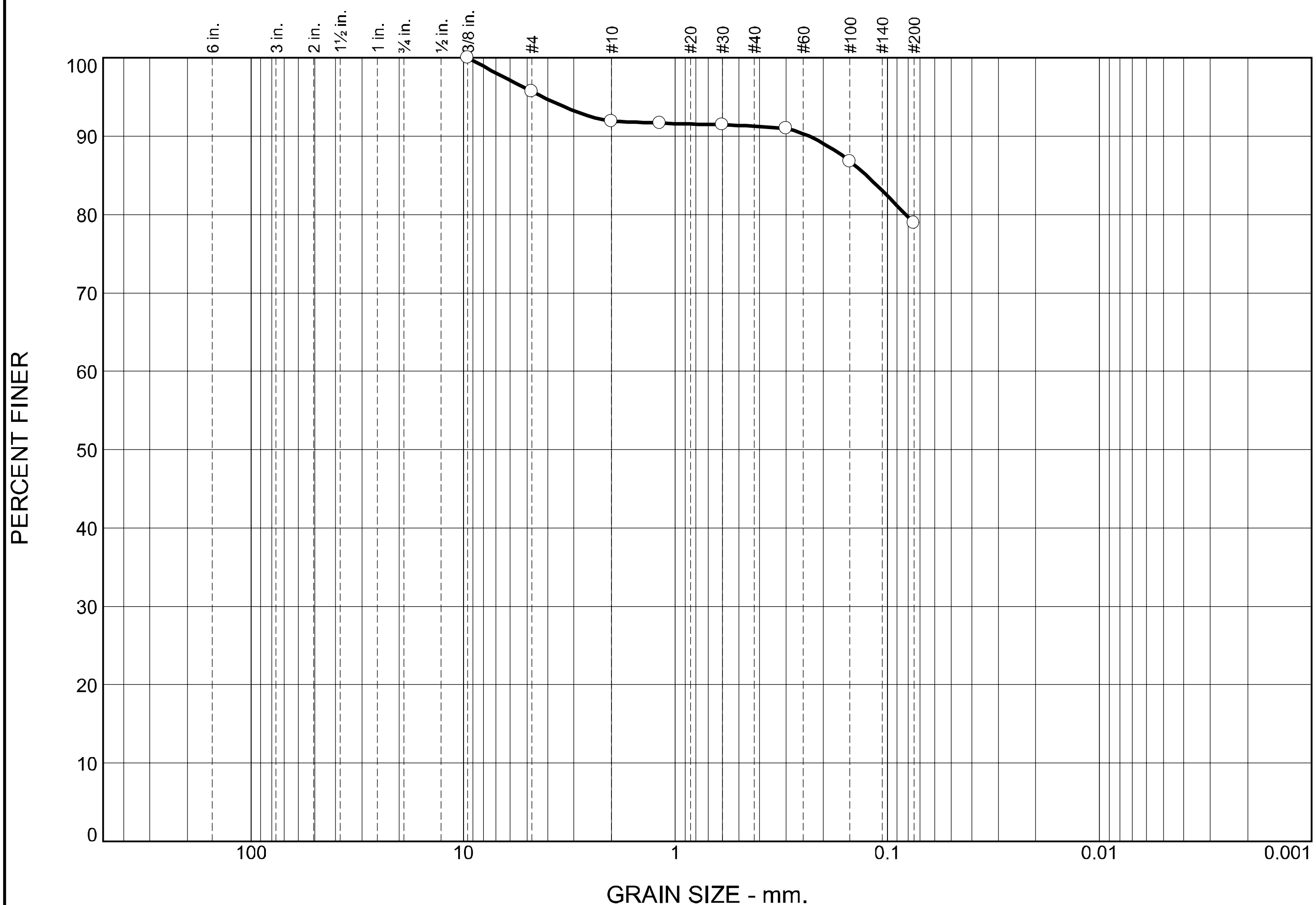
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel Coarse	% Gravel Medium	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines
○	0.0	0.0	0.0	0.0	8.1	0.7	12.3	78.9

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.1258							

Material Description	USCS	AASHTO
○ Wet, stiff, grayish brown, INORGANIC SILT, some fine sand, trace fine gravel	ML	-

Project No. 1904391 **Client:** BETA Group, Inc.

Project: McKnight Community Trail

○ **Source of Sample:** BWB-5 **Depth:** 10-12 ft **Sample Number:** S6

Remarks:

○As Received WC=30.3%

Fines classified visually

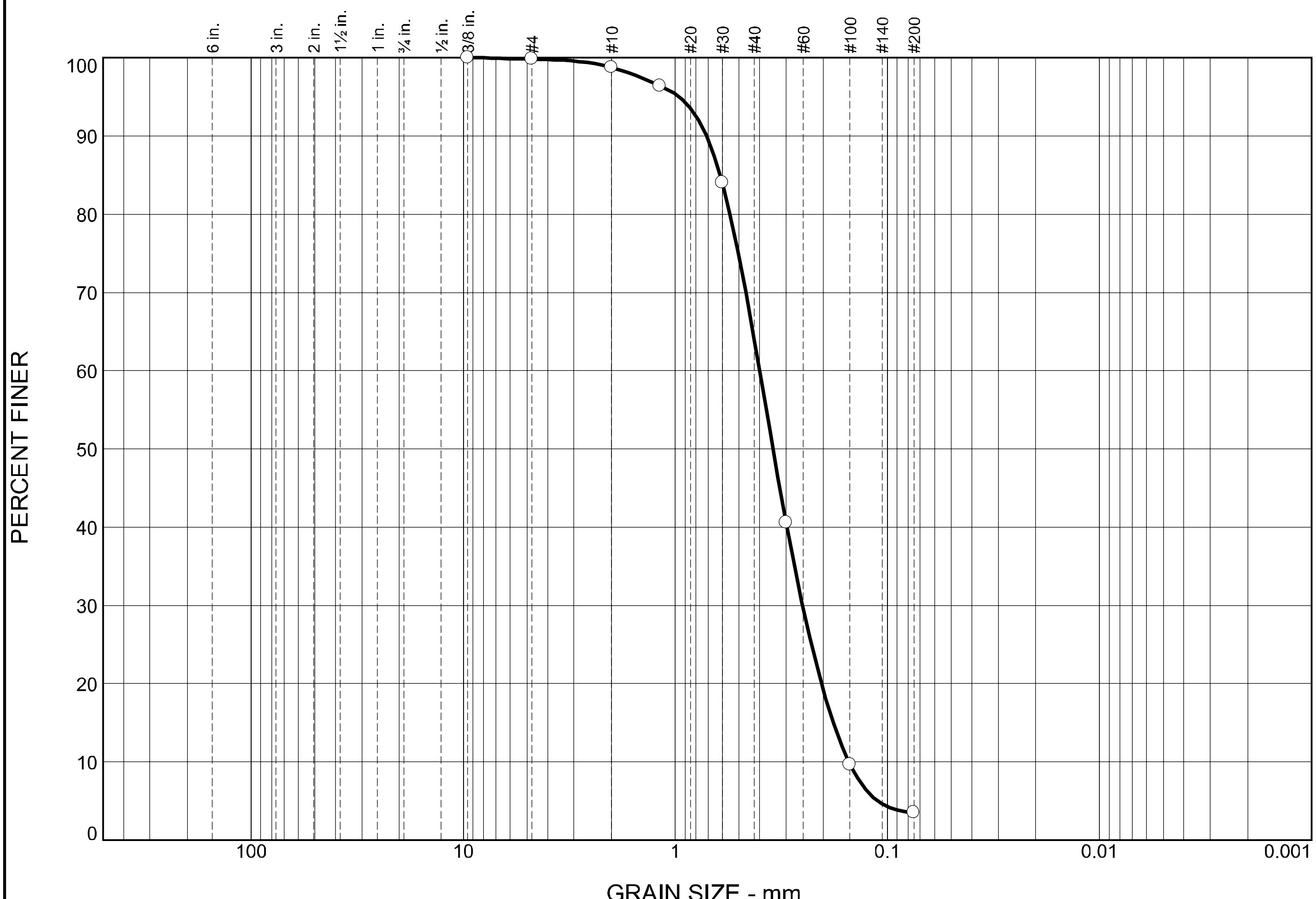
GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

GEI Consultants

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel Coarse	% Gravel Medium	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines
○	0.0	0.0	0.0	0.0	1.3	34.5	60.7	3.5

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.6140	0.3996	0.3457	0.2509	0.1797	0.1520	1.04	2.63

Material Description	USCS	AASHTO
○ Wet, medium dense, brown, FINE TO COARSE SAND, trace inorganic silt, trace fine gravel.	SP	

Project No. 1904391 **Client:** BETA Group, Inc.
Project: McKnight Community Trail

○ **Source of Sample:** BWB-7 **Depth:** 6-8 ft **Sample Number:** S4

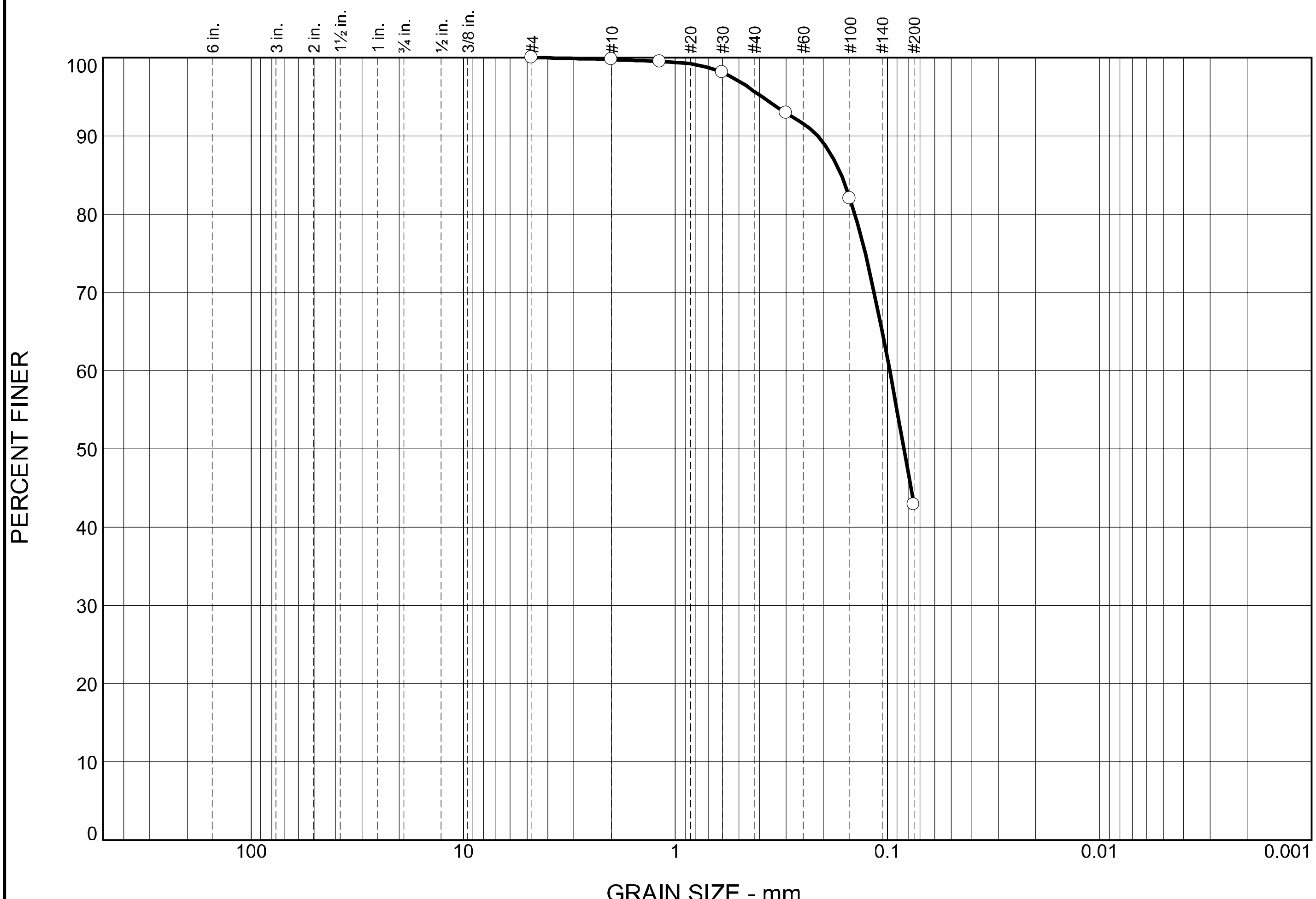
Remarks:
○As Received WC=25.1%
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel			% Sand		% Fines
			Coarse	Medium	Fine	Coarse	Fine	
○	0.0	0.0	0.0	0.0	0.2	4.1	52.8	42.9

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.1651	0.0975	0.0835					

Material Description	USCS	AASHTO
○ Wet, stiff, brownish gray, FINE SAND AND INORGANIC SILT.	SM	

Project No. 1904391 **Client:** BETA Group, Inc.

Project: McKnight Community Trail

○ **Source of Sample:** BWB-8 **Depth:** 29-31 ft **Sample Number:** S13

Remarks:

○As Received WC=29.4%

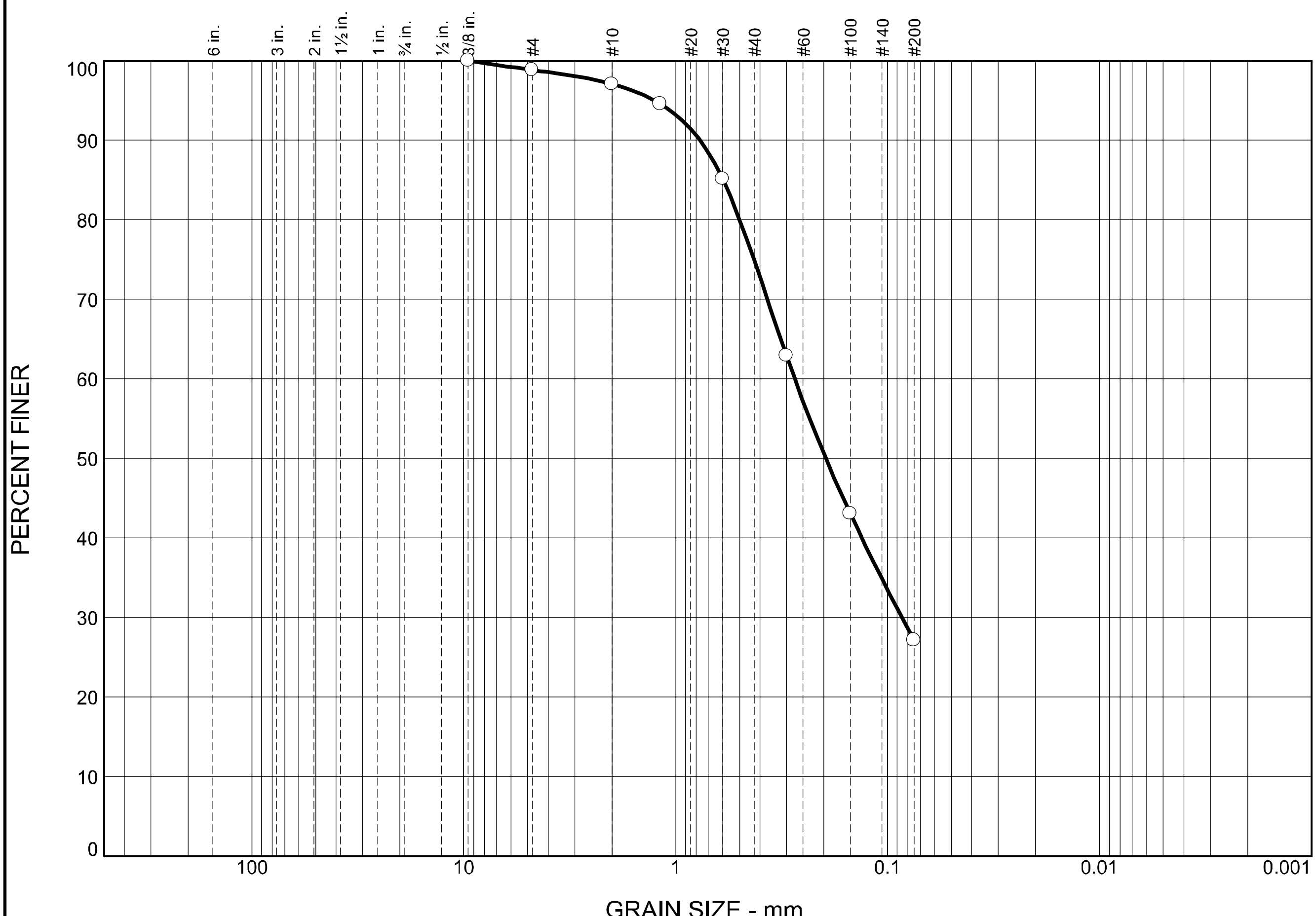
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel Coarse	% Gravel Medium	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines
○	0.0	0.0	0.0	0.0	2.9	22.2	47.8	27.1

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.5964	0.2742	0.1955	0.0855				

Material Description	USCS	AASHTO
○ Wet, dark-brown, FINE TO COARSE SAND, some organic silt, trace fine gravel	SM	-

Project No. 1904391 **Client:** BETA Group, Inc.

Project: McKnight Community Trail

○ **Source of Sample:** Scour **Sample Number:** SS-1

Remarks:

○As Received WC=69.7%

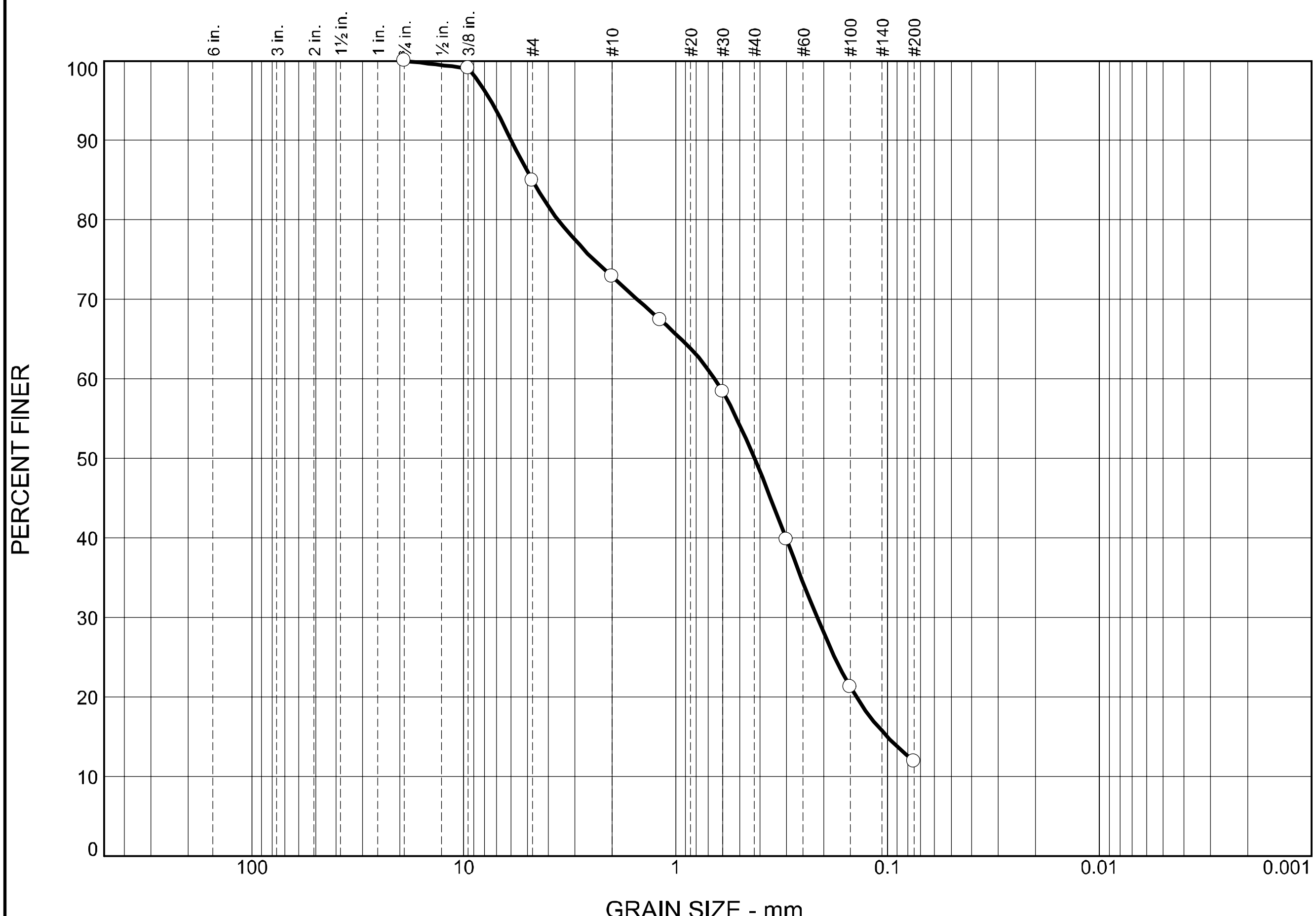
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel Coarse	% Gravel Medium	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines
○	0.0	0.0	0.0	0.9	26.2	22.9	38.1	11.9

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			4.7607	0.6543	0.4246	0.2148	0.1001			

Material Description	USCS	AASHTO
○ Wet, dark-brown, FINE TO COARSE SAND, some fine gravel, some organic silt	SP-SM	-

Project No. 1904391 **Client:** BETA Group, Inc.
Project: McKnight Community Trail

○ **Source of Sample:** Scour **Sample Number:** SS-2

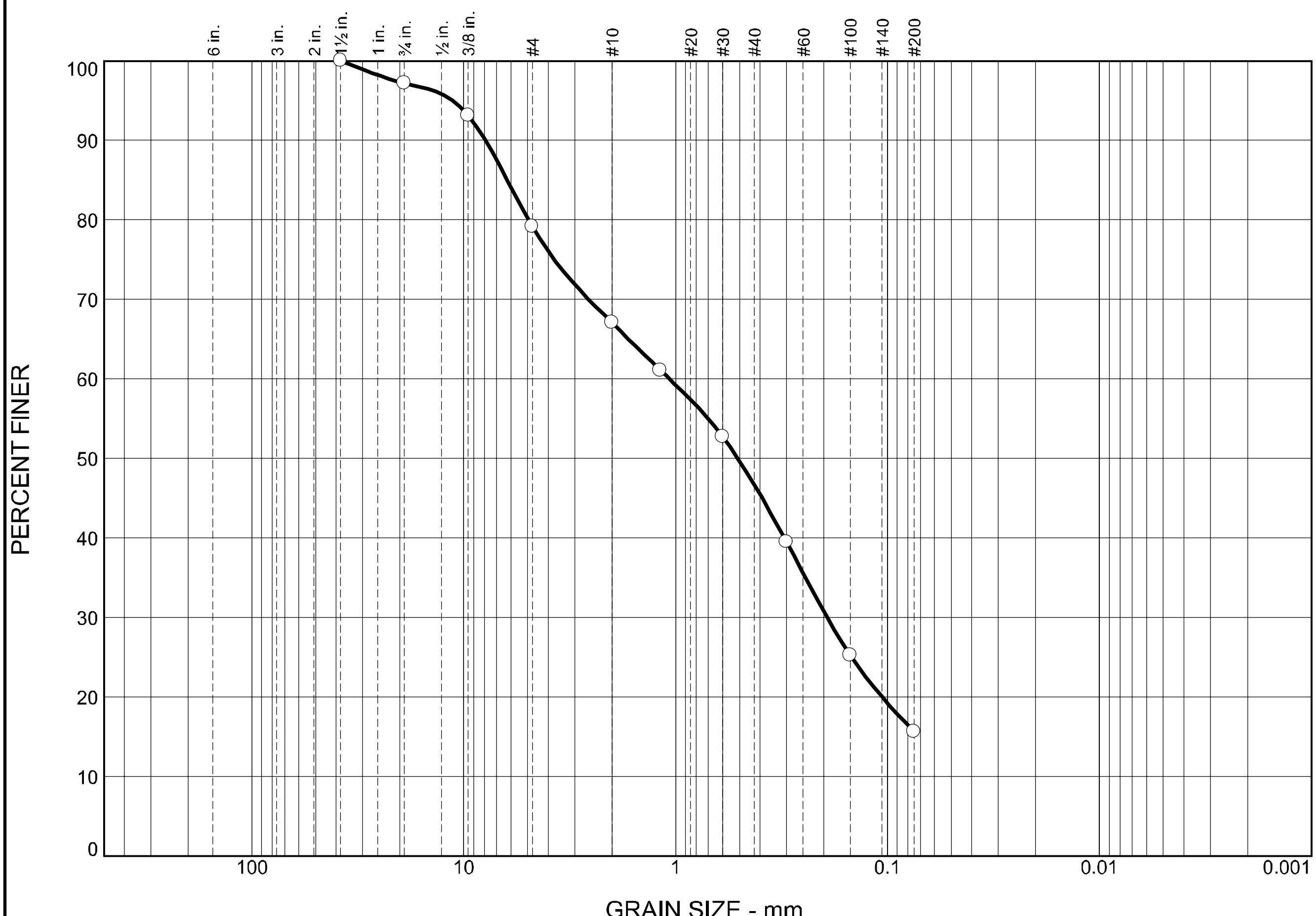
Remarks:
○As Received WC=33.6%
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel Coarse	% Gravel Medium	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines
○	0.0	0.0	1.8	5.1	26.0	20.4	31.1	15.6

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			6.2370	1.0710	0.5085	0.1926				

Material Description	USCS	AASHTO
○ Wet, dark-brown, FINE TO COARSE SAND, some fine to coarse gravel, some organic silt	SM	-

Project No. 1904391 **Client:** BETA Group, Inc.

Project: McKnight Community Trail

○ **Source of Sample:** Scour **Sample Number:** SS-3

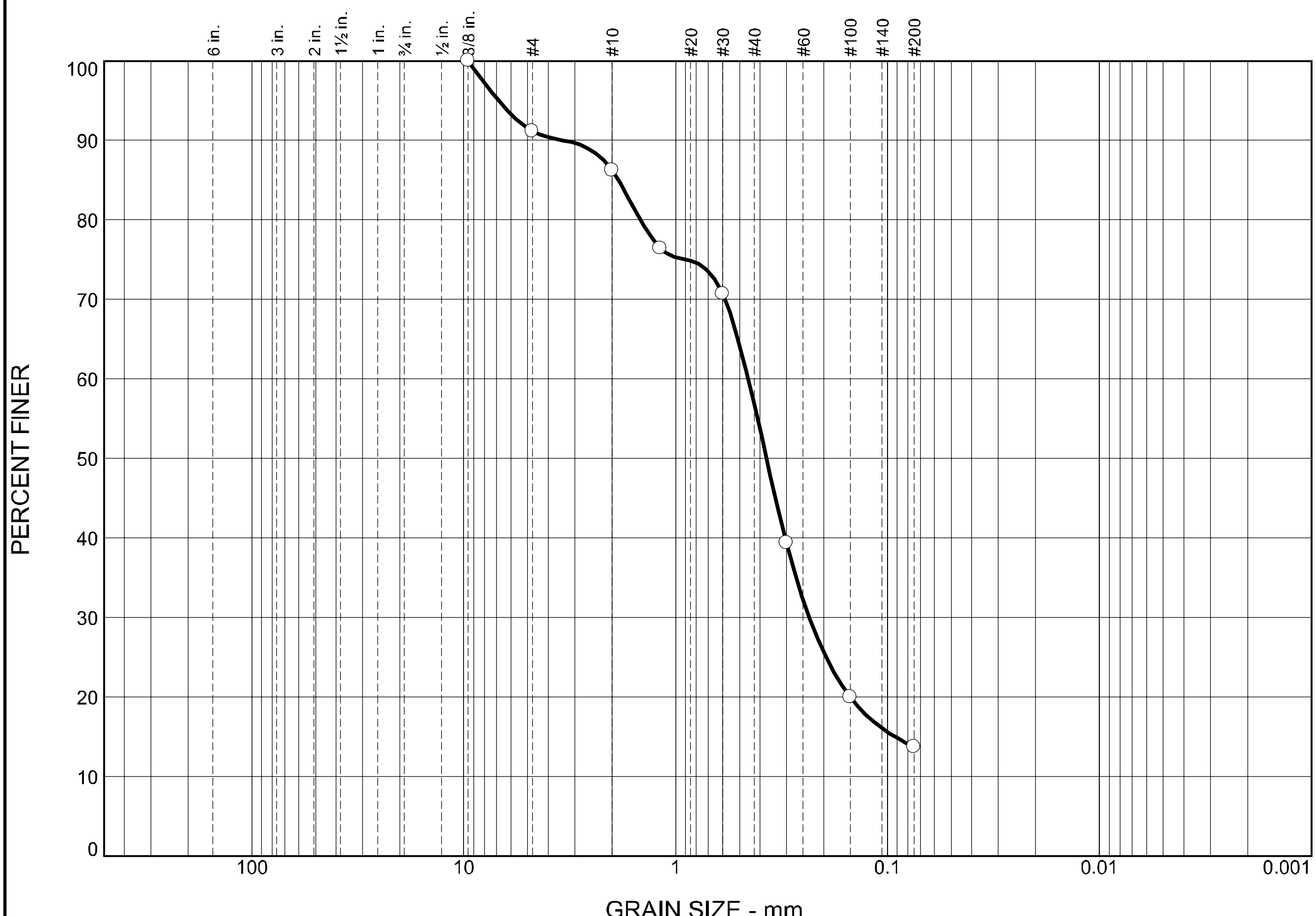
Remarks:
○As Received WC=31.2%
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel Coarse	% Gravel Medium	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines
○	0.0	0.0	0.0	0.0	13.8	29.5	43.0	13.7

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			1.8632	0.4543	0.3726	0.2340	0.0922			

Material Description	USCS	AASHTO
○ Wet, dark-brown, FINE TO COARSE SAND, some fine gravel, some organic silt	SM	-

Project No. 1904391 **Client:** BETA Group, Inc.

Project: McKnight Community Trail

○ **Source of Sample:** Scour **Sample Number:** SS-4

Remarks:

○As Received WC=31.5%

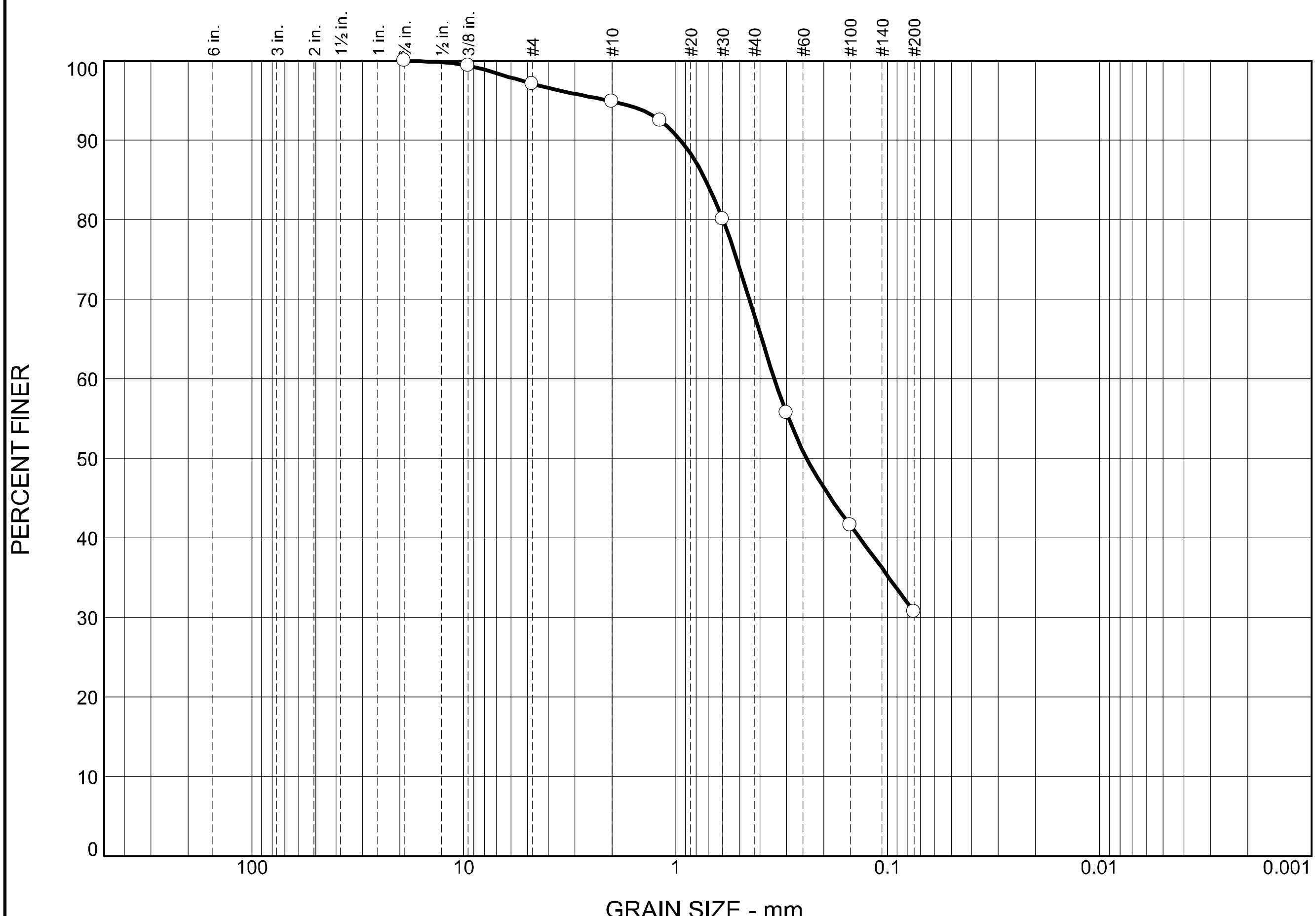
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel			% Sand		% Fines
			Coarse	Medium	Fine	Coarse	Fine	
○	0.0	0.0	0.0	0.6	4.5	26.9	37.3	30.7

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.7216	0.3418	0.2406					

Material Description	USCS	AASHTO
○ Wet, dark-brown, FINE TO COARSE SAND, some organic silt, trace fine gravel	SM	-

Project No. 1904391 **Client:** BETA Group, Inc.

Project: McKnight Community Trail

○ **Source of Sample:** Scour **Sample Number:** SS-5

Remarks:

○As Received WC=96.0%

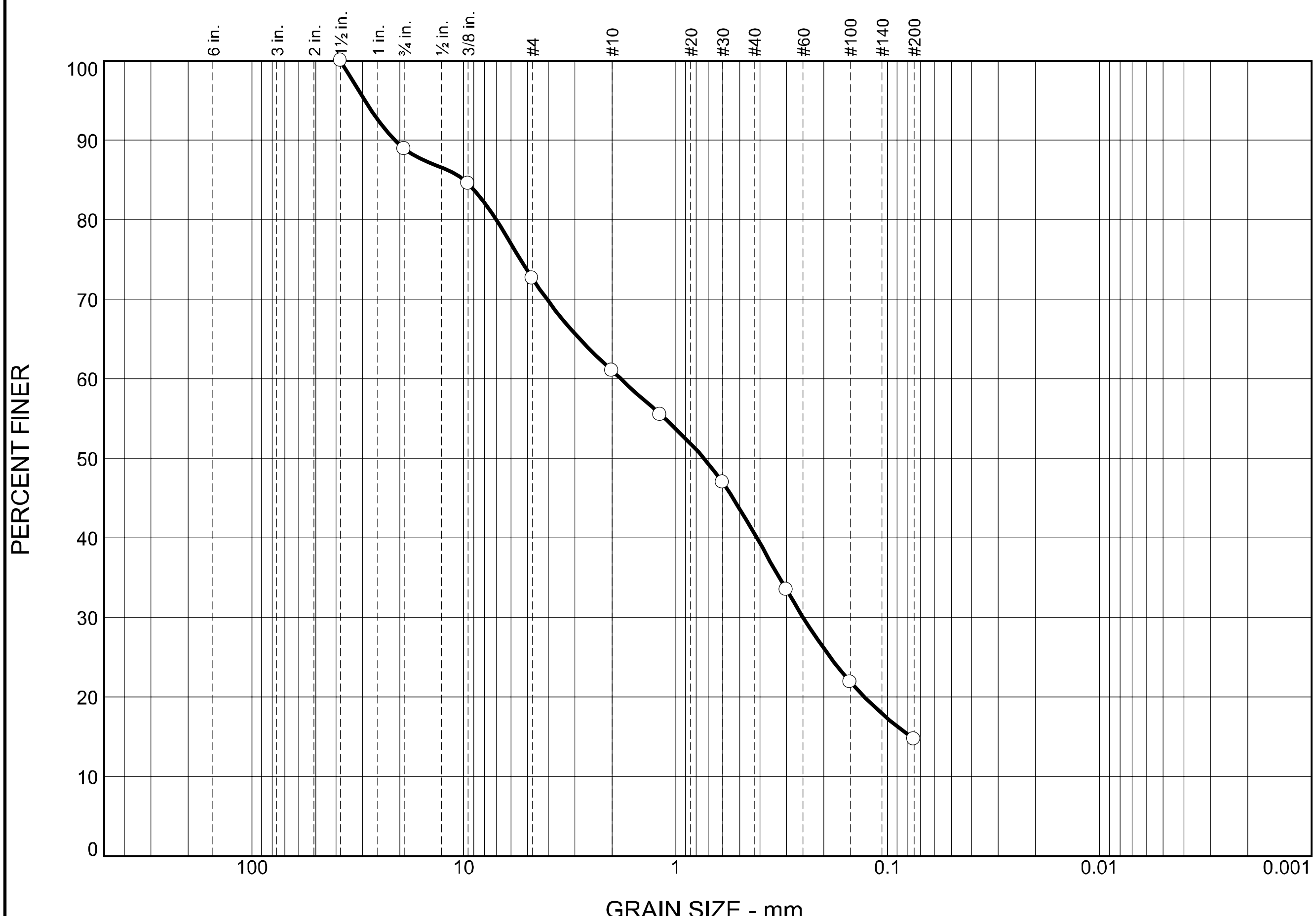
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

Particle Size Distribution Report



	% Boulders	% +3"	% Gravel Coarse	% Gravel Medium	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines
○	0.0	0.0	7.4	8.0	23.6	20.5	25.8	14.7

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			9.9563	1.8180	0.7355	0.2501	0.0778			

Material Description	USCS	AASHTO
○ Wet, dark-brown, FINE TO COARSE SAND, some fine to coarse gravel, some organic silt	SM	-

Project No. 1904391 **Client:** BETA Group, Inc.

Project: McKnight Community Trail

○ **Source of Sample:** Scour **Sample Number:** SS-6

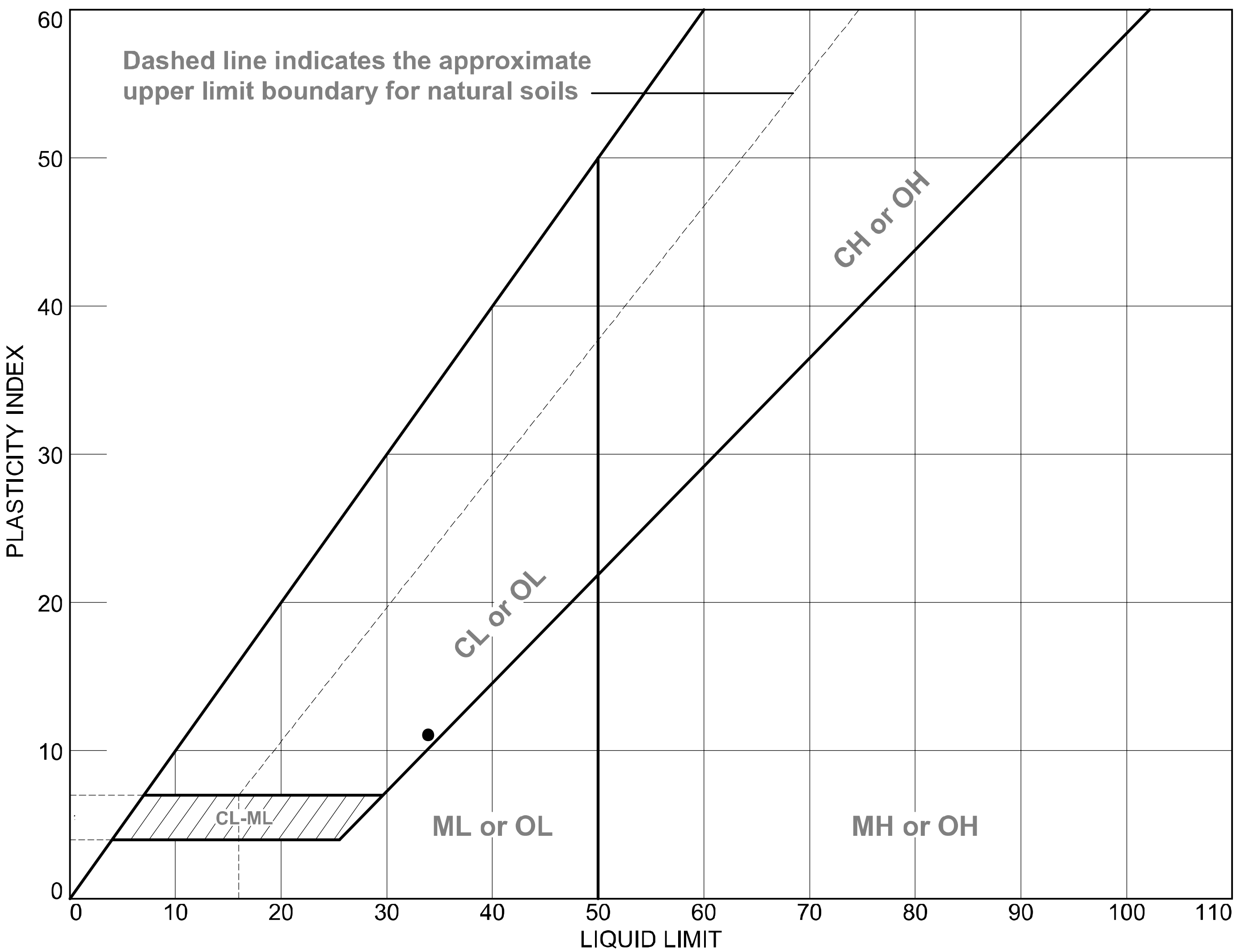
Remarks:
○As Received WC=41.9%
Fines classified visually

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: MA **Checked By:** EF

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

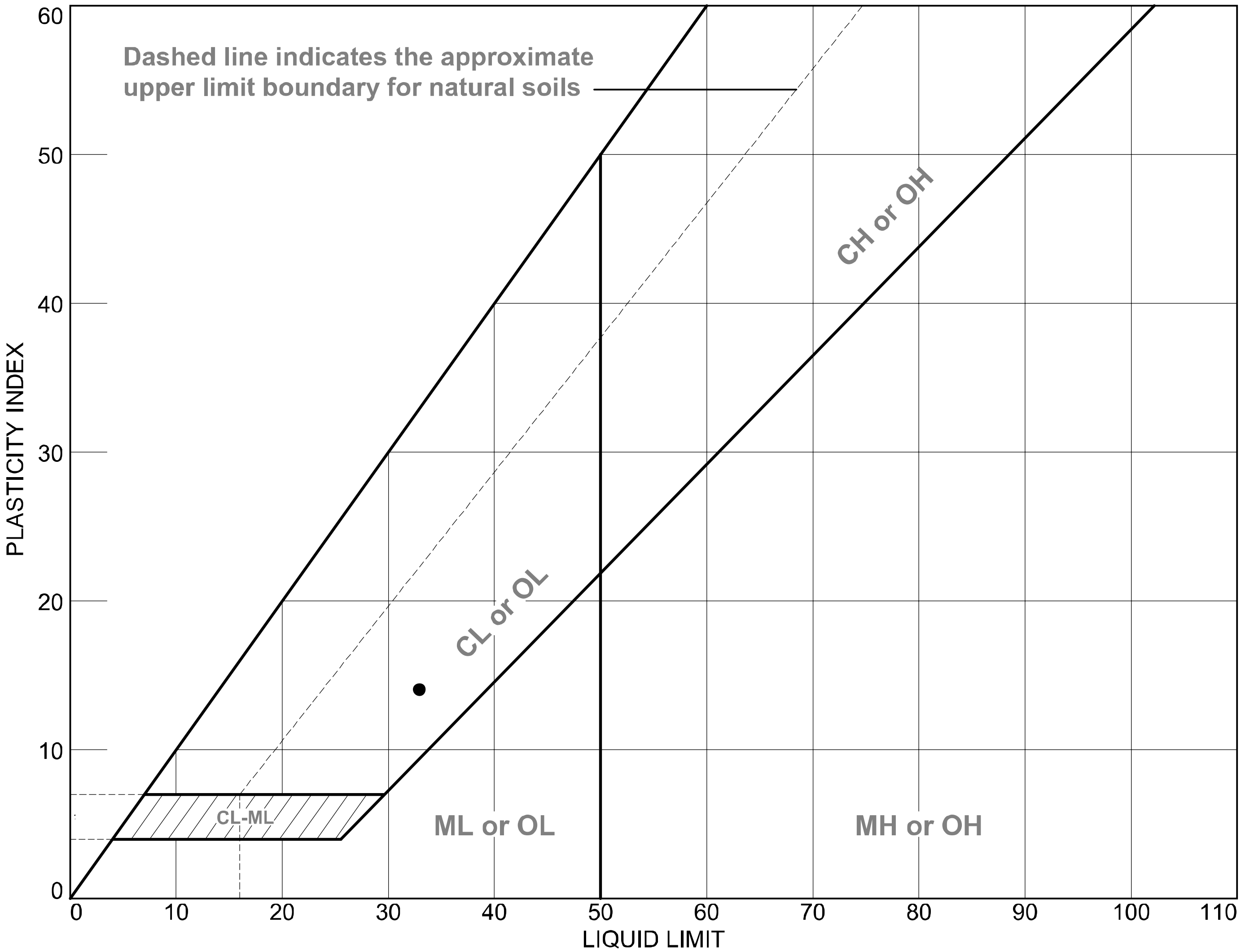
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	BB-2	S8	24-26 ft	40.1	23	34	11	CL

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Client: BETA Group, Inc.
Project: McKnight Community Trail
Project No.: 1904391 **Figure**

Tested By: MA **Checked By:** EF

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	BWB-3	S7	14-16 ft	33.9	19	33	14	CL

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Client: BETA Group, Inc.
Project: McKnight Community Trail

Project No.: 1904391 **Figure**

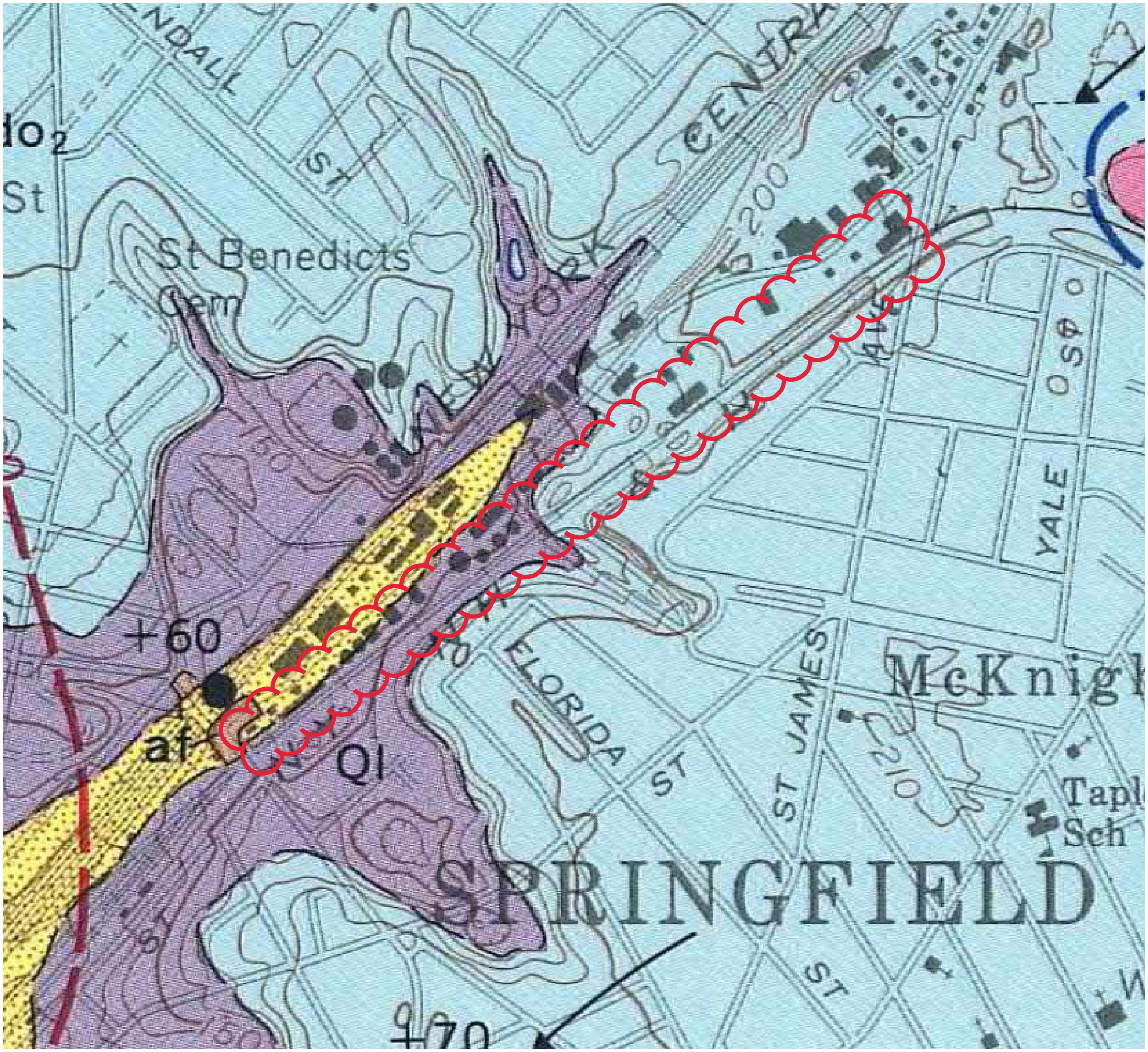
Tested By: MA **Checked By:** EF

Appendix D

Geotechnical Calculations

- Surficial Geology
- Blowcount Corrections
- Recommended Soil Properties
- Bearing Resistance on Soil – Existing Bridge Abutments
- Earth Pressure Coefficients
- Seismic Site Class Evaluation
- Helical Pile Check

SURFICIAL GEOLOGY



do2
St
St Benedicts
Cem
+60
af
Ql
FLORIDA
ST
ST JAMES
ST
YALE
210
200
McKnigh
Tapl
Sch
SPRINGFIELD
+70

Qst

Terrace deposits

Yellowish-brown, well-bedded sand, silt, and clay; locally pebbly. Highest terrace from 120 to 145 feet above Connecticut River; numerous non-paired terraces at lower levels on both sides of river. Highest terraces formed by deposition of post-lake sand and gravel on delta-outwash plain deposits (Qdo_2*) and lake deposits. Lower terraces are cut-and-fill deposits now trenched by modern streams adjusted to Connecticut River as base level. Some deposits are as much as 75 feet thick*

Qdo_2

Qdo_1

Delta-outwash plain deposits

Proglacial kettled to unkettled outwash grading downstream into topset and foreset beds of yellowish-brown to reddish-brown gravel, sand, silt, and clay deposited into glacial Lake Hitchcock. Qdo_1 *was deposited after* Qkd *while glacier front stood near line from Bass Pond to Turner Park; melt-water streams flowed southward.* Qdo_2 *deposited generally westward from Chicopee River (in Springfield North quadrangle) after glacier front had withdrawn to north*

Ql

Lake deposits

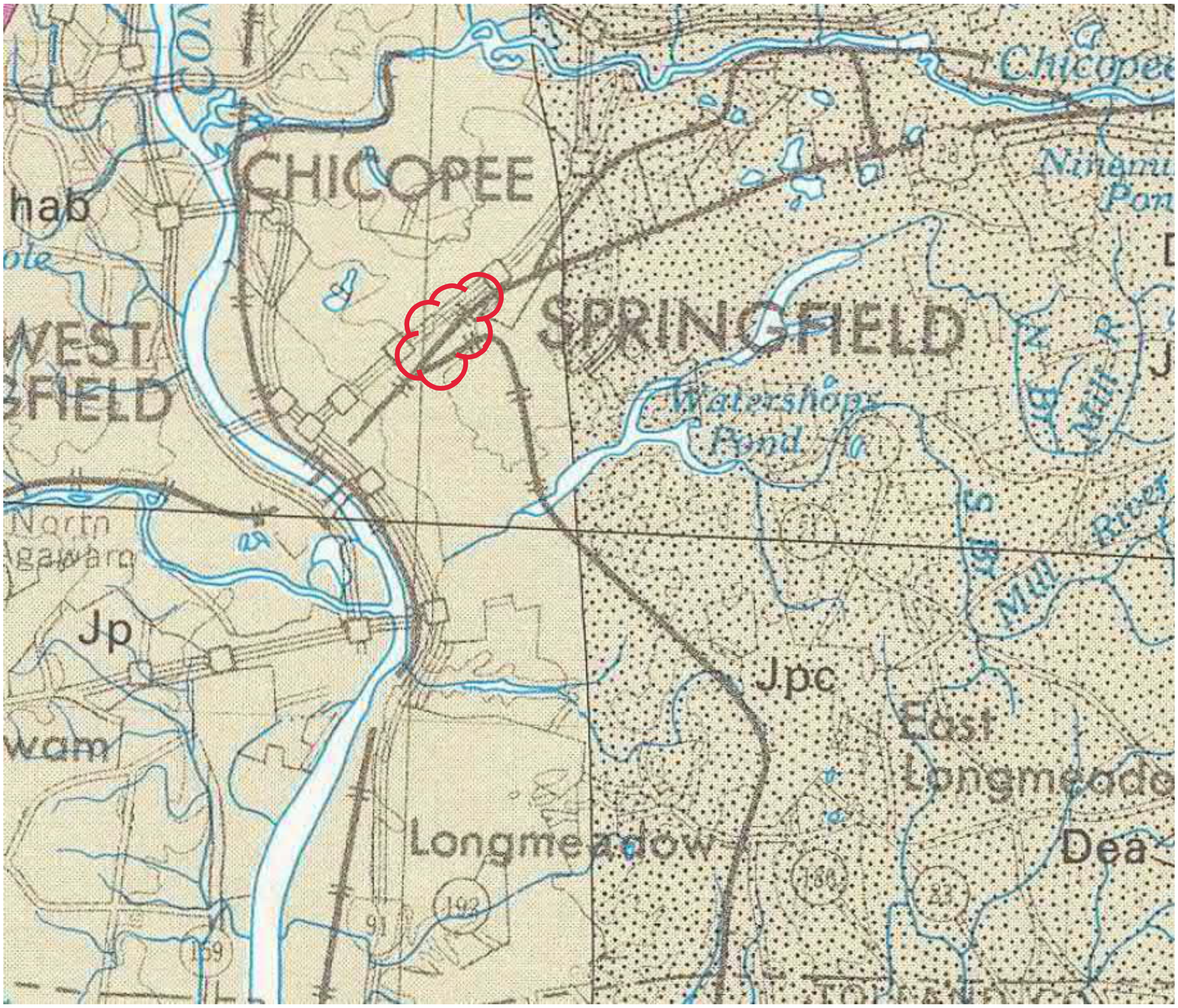
Laminated moderate yellowish-brown to gray clayey silt and sand overlying varved lake deposits of yellowish-gray, yellowish-brown, or reddish-brown silt and clay or very fine sand and clay, in alternating layers ½ inch to 2 inches thick. Formed in glacial Lake Hitchcock. May be as much as 230 feet thick. Lake deposits in sides of gullys are covered by colluvium

Note: Deposits from melt water graded directly to level of glacial Lake Hitchcock

GEOLOGIC QUADRANGLE MAP
SPRINGFIELD SOUTH QUADRANGLE, MASS.–CONN.
GQ-678

By
Joseph H. Hartshorn and Carl Koteff
1967

Ma



SEDIMENTARY AND VOLCANIC ROCKS OF HARTFORD BASIN

Portland Formation (Lower Jurassic)

Jp — Reddish-brown to pale red arkose and siltstone, and gray sandstone, gray siltstone, and black shale interpreted as lake beds

BEDROCK GEOLOGIC MAP OF MASSACHUSETTS

E-an Zen, Editor

Compiled By
Richard Goldsmith, Nicholas M. Ratcliffe,
Peter Robinson, and Rolfe S. Stanley

Assisted By
Norman L. Hatch, Jr., Andrew F. Shride,
Elaine G. A. Weed, and David R. Wones

BLOW COUNT CORRECTION

Client:	BETA Group, Inc.	Prepared By:	H. Ghiye
Project:	McKnight Community Trail	Date:	3/23/2020
Project No.:	1904391	Checked By:	A. Juliano
Subject:	Corrected Blow Counts	Date:	4/10/2020

Summary of Corrected Blow Counts by Layer

Upper Sand and Silt (Glenn Road Bridge)

Boring	No.	N_{60}			$N1_{60}$		
	Values	Avg.	Max.	Min.	Avg.	Max.	Min.
BB-2	6	9	16	4	12	25	4
P-2C	5	8	15	4	10	21	4
P-2B	11	9	21	3	11	30	3
P-2A	3	8	16	4	11	22	4
BB-1	8	7	11	3	10	17	4

Average N_{60}: 8 Average $N1_{60}$: 11

Upper Sand and Silt (Boardwalk)

Boring	No.	N_{60}			$N1_{60}$		
	Values	Avg.	Max.	Min.	Avg.	Max.	Min.
BWB-1	4	15	21	8	21	31	11
BWB-2	7	9	12	8	12	14	9
BWB-3	5	19	20	16	29	33	26
BWB-4	5	16	24	9	26	44	14
BWB-5	5	29	36	19	46	55	26
BWB-6	5	27	43	15	40	64	20
BWB-7	6	13	16	9	19	25	13
BWB-8	10	13	20	7	17	33	10

Average N_{60}: 17 Average $N1_{60}$: 25

Lower Sand and Silt

Boring	No.	N_{60}			$N1_{60}$		
	Values	Avg.	Max.	Min.	Avg.	Max.	Min.
BB-2	4	30	79	8	20	50	6
BB-1	4	11	13	7	9	10	6
BWB-1	2	11	12	9	10	11	9
BWB-2	4	18	23	8	15	18	7
BWB-3	5	19	27	8	16	22	7
BWB-4	3	22	32	16	20	28	15
BWB-5	1	9	9	9	9	9	9
BWB-6	2	17	17	17	17	17	16
BWB-7	3	19	20	17	18	19	18
BWB-8	9	25	35	17	22	28	15

Average N_{60}: 20 Average $N1_{60}$: 17

Clay

Boring	No.	N_{60}			$N1_{60}$		
	Values	Avg.	Max.	Min.	Avg.	Max.	Min.
BB-2	6	9	12	4	8	11	4
BB-1	5	3	5	0	3	5	0
BWB-1	8	6	8	4	6	10	4
BWB-2	8	7	12	5	7	11	5
BWB-3	5	6	7	5	7	7	6
BWB-4	5	5	7	5	6	7	6
BWB-5	4	7	7	5	8	9	6
BWB-6	4	8	11	5	9	13	6
BWB-7	2	9	9	9	11	11	10

Average N_{60}: 6 Average $N1_{60}$: 7

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
			ER = hammer efficiency expressed as percent of theoretical free fall energy
			N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft)
			$C_N = 0.77 * \log_{10}(40/\sigma'_v)$ [$C_N < 2.0$]
			σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.:	161	ft
Depth to Groundwater:	9.3	ft
Average Total Unit Weight of Soil:	120	pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***BB-2***

Depth (ft)	El. (ft)	Layer Name	N	N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Type	ER (%)	C_E
				Corrected Blow Counts				Overburden Correction					Hammer Efficiency Correction		
0.75	160.3	Topsoil	--	--	--	--	--	90	0	90	0.090	2.00	Automatic	80	1.33
3	158.0	Sand	12	16	25	9	12	360	0	360	0.360	1.58	Automatic	80	1.33
5	156.0	Sand	8	11	15			600	0	600	0.600	1.40	Automatic	80	1.33
7	154.0	Sand	7	9	12			840	0	840	0.840	1.29	Automatic	80	1.33
9	152.0	Silt	4	5	6			1,080	0	1,080	1.080	1.21	Automatic	80	1.33
15	146.0	Silt	3	4	4			1,800	359	1,441	1.441	1.11	Automatic	80	1.33
19	142.0	Silt	5	7	7			2,280	608	1,672	1.672	1.06	Automatic	80	1.33
25	136.0	Clay	5	7	7	9	8	3,000	983	2,017	2.017	1.00	Automatic	80	1.33
30	131.0	Clay	3	4	4			3,600	1,295	2,305	2.305	0.95	Automatic	80	1.33
35	126.0	Clay	3	4	4			4,200	1,607	2,593	2.593	0.91	Automatic	80	1.33
40	121.0	Clay	9	12	11			4,800	1,919	2,881	2.881	0.88	Automatic	80	1.33
45	116.0	Clay	9	12	10			5,400	2,231	3,169	3.169	0.85	Automatic	80	1.33
50	111.0	Clay	9	12	10			6,000	2,543	3,457	3.457	0.82	Automatic	80	1.33
55	106.0	Silt	6	8	6	26	17	6,600	2,855	3,745	3.745	0.79	Automatic	80	1.33
65	96.0	Silt	7	9	7			7,800	3,479	4,321	4.321	0.74	Automatic	80	1.33
75	86.0	Clay	8	11	7			9,000	4,103	4,897	4.897	0.70	Automatic	80	1.33
85	76.0	Sand and Silt	17	23	15			10,200	4,727	5,473	5.473	0.67	Automatic	80	1.33
95	66.0	Sand	59	79	50			11,400	5,351	6,049	6.049	0.63	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants		
	Client: BETA Group, Inc.	**Prepared By:** H. Ghiye
	Project: McKnight Community Ttrail	**Date:** 3/23/2020
	Project No.: 1904391	**Checked By:** A. Juliano
	Subject: Corrected Blow Counts	**Date:** 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft) ER = hammer efficiency expressed as percent of theoretical free fall energy N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft) $C_N = 0.77 * \log_{10}(40/\sigma'_v)$ $[C_N < 2.0]$ σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.:	161	ft
Depth to Groundwater:	9.8	ft
Average Total Unit Weight of Soil:	120	pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: P-2C

Depth (ft)	El. (ft)	Layer Name	N	N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Type	ER (%)	C_E
				Corrected Blow Counts				Overburden Correction					Hammer Efficiency Correction		
1	160.0	Topsoil	11	--	--	--	--	120	0	120	0.120	1.94	Automatic	80	1.33
5	156.0	Sand	11	15	21	8	10	600	0	600	0.600	1.40	Automatic	80	1.33
10	151.0	Sand and Silt	4	5	6			1,200	12	1,188	1.188	1.18	Automatic	80	1.33
15	146.0	Sand and Silt	7	9	10			1,800	324	1,476	1.476	1.10	Automatic	80	1.33
17	144.0	Sand and Silt	6	8	9			2,040	449	1,591	1.591	1.08	Automatic	80	1.33
19	142.0	Silt	3	4	4			2,280	574	1,706	1.706	1.05	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
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References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

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10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft) $C_N = 0.77 * \log_{10}(40/\sigma'_v)$ [$C_N < 2.0$] σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.:	161	ft
Depth to Groundwater:	9.7	ft
Average Total Unit Weight of Soil:	120	pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***P-2B***

Depth (ft)	El. (ft)	Layer Name	N	N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Type	ER (%)	C_E
				Corrected Blow Counts				Overburden Correction					Hammer Efficiency Correction		
1	160.0	Topsoil	8	--	--	--	--	120	0	120	0.120	1.94	Automatic	80	1.33
3	158.0	Sand	9	12	19	9	11	360	0	360	0.360	1.58	Automatic	80	1.33
5	156.0	Sand	16	21	30			600	0	600	0.600	1.40	Automatic	80	1.33
7	154.0	Sand	7	9	12			840	0	840	0.840	1.29	Automatic	80	1.33
8	153.0	Sand	4	5	7			960	0	960	0.960	1.25	Automatic	80	1.33
10	151.0	Silt	4	5	6			1,200	19	1,181	1.181	1.18	Automatic	80	1.33
11	150.0	Silt	6	8	9			1,320	81	1,239	1.239	1.16	Automatic	80	1.33
13	148.0	Silt	6	8	9			1,560	206	1,354	1.354	1.13	Automatic	80	1.33
15	146.0	Silt	--	--	--			1,800	331	1,469	1.469	1.10	Automatic	80	1.33
20	141.0	Silt	7	9	10			2,400	643	1,757	1.757	1.05	Automatic	80	1.33
22	139.0	Sand and Clay	2	3	3			2,640	768	1,872	1.872	1.02	Automatic	80	1.33
24	137.0	Sand and Silt	5	7	7			2,880	892	1,988	1.988	1.00	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
			ER = hammer efficiency expressed as percent of theoretical free fall energy
			N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft)
			$C_N = 0.77 * \log_{10}(40/\sigma'_v)$ $[C_N < 2.0]$
			σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.: 161 ft
Depth to Groundwater: 9.8 ft
Average Total Unit Weight of Soil: 120 pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***P-2A***

				Corrected Blow Counts				Overburden Correction					Hammer Efficiency Correction		
Depth (ft)	El. (ft)	Layer Name	N	N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Type	ER (%)	C_E
1	160.0	Topsoil	6	--	--	--	--	120	0	120	0.120	1.94	Automatic	80	1.33
3	158.0	Sand	3	4	6	8	11	360	0	360	0.360	1.58	Automatic	80	1.33
5	156.0	Sand	12	16	22			600	0	600	0.600	1.40	Automatic	80	1.33
19	142.0	Sand	3	4	4			2,280	574	1,706	1.706	1.05	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft) ER = hammer efficiency expressed as percent of theoretical free fall energy N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft) $C_N = 0.77 * \log_{10}(40/\sigma'_v)$ [$C_N < 2.0$] σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.:	161.25	ft
Depth to Groundwater:	0.0	ft
Average Total Unit Weight of Soil:	120	pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***P-1B***

Depth (ft)	El. (ft)	Layer Name	N	Corrected Blow Counts: N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	Overburden Correction: σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Efficiency Correction: Hammer Type	ER (%)	C_E
1	160.3	Topsoil	--	--	--	--	--	120	62	58	0.058	2.00	Automatic	80	1.33
3	158.3	Sand	--	--	--	33	46	360	187	173	0.173	1.82	Automatic	80	1.33
5	156.3	Sand	19	25	42			600	312	288	0.288	1.65	Automatic	80	1.33
7	154.3	Sand	17	23	35			840	437	403	0.403	1.54	Automatic	80	1.33
9	152.3	Sand	--	--	--			1,080	562	518	0.518	1.45	Automatic	80	1.33
14	147.3	Sand and Gravel	54	72	94			1,680	874	806	0.806	1.31	Automatic	80	1.33
20	141.3	Sand	8	11	13			2,400	1,248	1,152	1.152	1.19	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants

Client: BETA Group, Inc.
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Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	N_{60} = (ER / 60%) * N	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft) ER = hammer efficiency expressed as percent of theoretical free fall energy N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft) $C_N = 0.77 * \log_{10}(40/\sigma'_v)$ [$C_N < 2.0$] σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.: 161.25 ft
Depth to Groundwater: 0.0 ft
Average Total Unit Weight of Soil: 120 pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***P-1C***

Depth (ft)	El. (ft)	Layer Name	N	N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Type	ER (%)	C_E
				Corrected Blow Counts				Overburden Correction					Hammer Efficiency Correction		
1	160.3		--	--	--	--	--	120	62	58	0.058	2.00	Automatic	80	1.33
3	158.3	Sand	--	--	--	18	27	360	187	173	0.173	1.82	Automatic	80	1.33
5	156.3	Sand	21	28	46			600	312	288	0.288	1.65	Automatic	80	1.33
7	154.3	Sand	9	12	18			840	437	403	0.403	1.54	Automatic	80	1.33
9	152.3	Sand	21	28	41			1,080	562	518	0.518	1.45	Automatic	80	1.33
11	150.3	Sand	11	15	20			1,320	686	634	0.634	1.39	Automatic	80	1.33
20	141.3	Sand	5	7	8			2,400	1,248	1,152	1.152	1.19	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
			ER = hammer efficiency expressed as percent of theoretical free fall energy
			N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft)
			$C_N = 0.77 * \log_{10}(40/\sigma'_v)$ $[C_N < 2.0]$
			σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.: 161.5 ft (Interpolated from Benchmarks)
Depth to Groundwater: 0.0 ft
Average Total Unit Weight of Soil: 120 pcf

Hammer Type	ER (%)	$C_E = ER / 60\%$
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: BB-1

Depth (ft)	El. (ft)	Layer Name	N	N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Type	ER (%)	C_E
				Corrected Blow Counts				Overburden Correction					Hammer Efficiency Correction		
1	160.5	Topsoil	--	--	--	--	--	120	62	58	0.058	2.00	Automatic	80	1.33
3	158.5	Sand	7	9	17			360	187	173	0.173	1.82	Automatic	80	1.33
5	156.5	Sand	7	9	15			600	312	288	0.288	1.65	Automatic	80	1.33
7	154.5	Sand	6	8	12			840	437	403	0.403	1.54	Automatic	80	1.33
9	152.5	Sand	3	4	6			1,080	562	518	0.518	1.45	Automatic	80	1.33
11	150.5	Sand	2	3	4	7	10	1,320	686	634	0.634	1.39	Automatic	80	1.33
15	146.5	Sand	3	4	5			1,800	936	864	0.864	1.28	Automatic	80	1.33
20	141.5	Sand and Silt	4	5	6			2,400	1,248	1,152	1.152	1.19	Automatic	80	1.33
25	136.5	Sand and Silt	8	11	12			3,000	1,560	1,440	1.440	1.11	Automatic	80	1.33
30	131.5	Clay	2	3	3			3,600	1,872	1,728	1.728	1.05	Automatic	80	1.33
35	126.5	Clay	4	5	5			4,200	2,184	2,016	2.016	1.00	Automatic	80	1.33
40	121.5	Clay	1	1	1	3	3	4,800	2,496	2,304	2.304	0.95	Automatic	80	1.33
45	116.5	Clay	0	0	0			5,400	2,808	2,592	2.592	0.92	Automatic	80	1.33
50	111.5	Clay	4	5	5			6,000	3,120	2,880	2.880	0.88	Automatic	80	1.33
55	106.5	Sand	5	7	6			6,600	3,432	3,168	3.168	0.85	Automatic	80	1.33
60	101.5	Sand	9	12	10	11	9	7,200	3,744	3,456	3.456	0.82	Automatic	80	1.33
65	96.5	Sand	9	12	10			7,800	4,056	3,744	3.744	0.79	Automatic	80	1.33
70	91.5	Sand	10	13	10			8,400	4,368	4,032	4.032	0.77	Automatic	80	1.33
75	86.5	Clay	8	11	8	11	8	9,000	4,680	4,320	4.320	0.74	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
			ER = hammer efficiency expressed as percent of theoretical free fall energy
			N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft)
			$C_N = 0.77 * \log_{10}(40/\sigma'_v)$ [$C_N < 2.0$]
			σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.:	162.5	ft	(Interpolated from Benchmarks)
Depth to Groundwater:	3.5	ft	
Average Total Unit Weight of Soil:	120	pcf	

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***BWB-1***

				Corrected Blow Counts				Overburden Correction					Hammer Efficiency Correction		
Depth (ft)	El. (ft)	Layer Name	N	N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Type	ER (%)	C_E
1	161.5	Topsoil	6	--	--	--	--	120	0	120	0.120	1.94	Automatic	80	1.33
3	159.5	Silt	10	13	21	15	21	360	0	360	0.360	1.58	Automatic	80	1.33
5	157.5	Silt	16	21	31			600	94	506	0.506	1.46	Automatic	80	1.33
7	155.5	Silt	12	16	22			840	218	622	0.622	1.39	Automatic	80	1.33
9	153.5	Silt	6	8	11			1,080	343	737	0.737	1.34	Automatic	80	1.33
11	151.5	Clay	5	7	9	6	6	1,320	468	852	0.852	1.29	Automatic	80	1.33
13	149.5	Clay	6	8	10			1,560	593	967	0.967	1.24	Automatic	80	1.33
15	147.5	Clay	4	5	6			1,800	718	1,082	1.082	1.21	Automatic	80	1.33
17	145.5	Clay	4	5	6			2,040	842	1,198	1.198	1.17	Automatic	80	1.33
20	142.5	Clay	3	4	5			2,400	1,030	1,370	1.370	1.13	Automatic	80	1.33
25	137.5	Clay	3	4	4			3,000	1,342	1,658	1.658	1.06	Automatic	80	1.33
30	132.5	Clay	4	5	5			3,600	1,654	1,946	1.946	1.01	Automatic	80	1.33
35	127.5	Clay	5	7	6			4,200	1,966	2,234	2.234	0.96	Automatic	80	1.33
40	122.5	Silt	7	9	9	11	10	4,800	2,278	2,522	2.522	0.92	Automatic	80	1.33
45	117.5	Silt	9	12	11			5,400	2,590	2,810	2.810	0.89	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
			ER = hammer efficiency expressed as percent of theoretical free fall energy
			N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft)
			$C_N = 0.77 * \log_{10}(40/\sigma'_v)$ $[C_N < 2.0]$
			σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.: 169.5 ft (Interpolated from Benchmarks)
Depth to Groundwater: 5.7 ft
Average Total Unit Weight of Soil: 120 pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***BWB-2***

Depth (ft)	El. (ft)	Layer Name	N	N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Type	ER (%)	C_E
				Corrected Blow Counts				Overburden Correction					Hammer Efficiency Correction		
0.5	169.0	Topsoil	–	--	--	--	--	60	0	60	0.060	2.00	Automatic	80	1.33
5	164.5	Sand and Silt	7	9	13			600	0	600	0.600	1.40	Automatic	80	1.33
7	162.5	Silt	8	11	14			840	81	759	0.759	1.33	Automatic	80	1.33
9	160.5	Silt	6	8	10			1,080	206	874	0.874	1.28	Automatic	80	1.33
11	158.5	Silt	6	8	10	9	12	1,320	331	989	0.989	1.24	Automatic	80	1.33
13	156.5	Silt	9	12	14			1,560	456	1,104	1.104	1.20	Automatic	80	1.33
15	154.5	Silt	6	8	9			1,800	580	1,220	1.220	1.17	Automatic	80	1.33
17	152.5	Silt	7	9	11			2,040	705	1,335	1.335	1.14	Automatic	80	1.33
19	150.5	Clay	5	7	7			2,280	830	1,450	1.450	1.11	Automatic	80	1.33
21	148.5	Clay	4	5	6			2,520	955	1,565	1.565	1.08	Automatic	80	1.33
23	146.5	Clay	5	7	7			2,760	1,080	1,680	1.680	1.06	Automatic	80	1.33
25	144.5	Clay	4	5	6			3,000	1,204	1,796	1.796	1.04	Automatic	80	1.33
27	142.5	Clay	6	8	8	7	7	3,240	1,329	1,911	1.911	1.02	Automatic	80	1.33
30	139.5	Clay	4	5	5			3,600	1,516	2,084	2.084	0.99	Automatic	80	1.33
35	134.5	Clay	4	5	5			4,200	1,828	2,372	2.372	0.94	Automatic	80	1.33
40	129.5	Clay	9	12	11			4,800	2,140	2,660	2.660	0.91	Automatic	80	1.33
45	124.5	Silt	15	20	17			5,400	2,452	2,948	2.948	0.87	Automatic	80	1.33
50	119.5	Sand and Silt	6	8	7	18	15	6,000	2,764	3,236	3.236	0.84	Automatic	80	1.33
55	114.5	Sand and Silt	15	20	16			6,600	3,076	3,524	3.524	0.81	Automatic	80	1.33
60	109.5	Sand	17	23	18			7,200	3,388	3,812	3.812	0.79	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "–."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
			ER = hammer efficiency expressed as percent of theoretical free fall energy
			N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft)
			$C_N = 0.77 * \log_{10}(40/\sigma'_v)$ $[C_N < 2.0]$
			σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.: 175.5 ft (Interpolated from Benchmarks)
Depth to Groundwater: 0.0 ft
Average Total Unit Weight of Soil: 120 pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***BWB-3***

Depth (ft)	El. (ft)	Layer Name	N	Corrected Blow Counts: N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	Overburden Correction: σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Efficiency Correction: Hammer Type	ER (%)	C_E
1	174.5	Topsoil	--	--	--	--	--	120	62	58	0.058	2.00	Automatic	80	1.33
3	172.5	Sand and Gravel	12	16	29			360	187	173	0.173	1.82	Automatic	80	1.33
5	170.5	Sand and Silt	15	20	33			600	312	288	0.288	1.65	Automatic	80	1.33
7	168.5	Sand and Silt	15	20	31	19	29	840	437	403	0.403	1.54	Automatic	80	1.33
9	166.5	Sand	14	19	27			1,080	562	518	0.518	1.45	Automatic	80	1.33
11	164.5	Sand and Silt	14	19	26			1,320	686	634	0.634	1.39	Automatic	80	1.33
15	160.5	Clay	4	5	7			1,800	936	864	0.864	1.28	Automatic	80	1.33
20	155.5	Clay	4	5	6			2,400	1,248	1,152	1.152	1.19	Automatic	80	1.33
25	150.5	Clay	5	7	7	6	7	3,000	1,560	1,440	1.440	1.11	Automatic	80	1.33
30	145.5	Clay	4	5	6			3,600	1,872	1,728	1.728	1.05	Automatic	80	1.33
35	140.5	Clay	5	7	7			4,200	2,184	2,016	2.016	1.00	Automatic	80	1.33
40	135.5	Silt	10	13	13			4,800	2,496	2,304	2.304	0.95	Automatic	80	1.33
45	130.5	Silt	6	8	7			5,400	2,808	2,592	2.592	0.92	Automatic	80	1.33
50	125.5	Sand	18	24	21	19	16	6,000	3,120	2,880	2.880	0.88	Automatic	80	1.33
60	115.5	Sand	20	27	22			7,200	3,744	3,456	3.456	0.82	Automatic	80	1.33
70	105.5	Sand	16	21	16			8,400	4,368	4,032	4.032	0.77	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/20/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
			ER = hammer efficiency expressed as percent of theoretical free fall energy
			N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft)
			$C_N = 0.77 * \log_{10}(40/\sigma'_v)$ $[C_N < 2.0]$
			σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.: 178 ft (Interpolated from Benchmarks)
Depth to Groundwater: 0.0 ft
Average Total Unit Weight of Soil: 120 pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring:	***BWB-4***			**Corrected Blow Counts**				**Overburden Correction**					**Hammer Efficiency Correction**		
Depth (ft)	**El. (ft)**	**Layer Name**	**N**	**N_{60}**	**$N1_{60}$**	**Avg. N_{60}**	**Avg. $N1_{60}$**	**σ_v (psf)**	**u (psf)**	**σ'_v (psf)**	**σ'_v (ksf)**	**C_N**	**Hammer Type**	**ER (%)**	**C_E**
1	177.0	Topsoil	--	--	--	--	--	120	62	58	0.058	2.00	Automatic	80	1.33
3	175.0	Sand	18	24	44			360	187	173	0.173	1.82	Automatic	80	1.33
5	173.0	Silt	11	15	24			600	312	288	0.288	1.65	Automatic	80	1.33
7	171.0	Silt	14	19	29	16	26	840	437	403	0.403	1.54	Automatic	80	1.33
9	169.0	Sand	7	9	14			1,080	562	518	0.518	1.45	Automatic	80	1.33
11	167.0	Sand and Silt	11	15	20			1,320	686	634	0.634	1.39	Automatic	80	1.33
15	163.0	Clay	4	5	7			1,800	936	864	0.864	1.28	Automatic	80	1.33
20	158.0	Clay	4	5	6			2,400	1,248	1,152	1.152	1.19	Automatic	80	1.33
25	153.0	Clay	4	5	6	5	6	3,000	1,560	1,440	1.440	1.11	Automatic	80	1.33
30	148.0	Clay	4	5	6			3,600	1,872	1,728	1.728	1.05	Automatic	80	1.33
35	143.0	Clay	5	7	7			4,200	2,184	2,016	2.016	1.00	Automatic	80	1.33
40	138.0	Silt	12	16	15			4,800	2,496	2,304	2.304	0.95	Automatic	80	1.33
45	133.0	Silt	13	17	16	22	20	5,400	2,808	2,592	2.592	0.92	Automatic	80	1.33
50	128.0	Sand	24	32	28			6,000	3,120	2,880	2.880	0.88	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/20/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
			ER = hammer efficiency expressed as percent of theoretical free fall energy
			N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft)
			$C_N = 0.77 * \log_{10}(40/\sigma'_v)$ $[C_N < 2.0]$
			σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.: 180.5 ft (Interpolated from Benchmarks)
Depth to Groundwater: 0.0 ft
Average Total Unit Weight of Soil: 120 pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***BWB-5***

Depth (ft)	El. (ft)	Layer Name	N	Corrected Blow Counts: N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	Overburden Correction: σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Efficiency Correction: Hammer Type	ER (%)	C_E
1.5	179.0	Topsoil	--	--	--	--	--	180	94	86	0.086	2.00	Automatic	80	1.33
3	177.5	Sand	22	29	53			360	187	173	0.173	1.82	Automatic	80	1.33
5	175.5	Sand	23	31	51			600	312	288	0.288	1.65	Automatic	80	1.33
7	173.5	Sand	27	36	55	29	46	840	437	403	0.403	1.54	Automatic	80	1.33
9	171.5	Sand and Silt	23	31	45			1,080	562	518	0.518	1.45	Automatic	80	1.33
11	169.5	Silt	14	19	26			1,320	686	634	0.634	1.39	Automatic	80	1.33
15	165.5	Clay	5	7	9			1,800	936	864	0.864	1.28	Automatic	80	1.33
20	160.5	Clay	5	7	8	7	8	2,400	1,248	1,152	1.152	1.19	Automatic	80	1.33
25	155.5	Clay	5	7	7			3,000	1,560	1,440	1.440	1.11	Automatic	80	1.33
30	150.5	Clay	4	5	6			3,600	1,872	1,728	1.728	1.05	Automatic	80	1.33
35	145.5	Sand, Silt and Gravel	7	9	9	9	9	4,200	2,184	2,016	2.016	1.00	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

Client: BETA Group, Inc.	**Prepared By:** H. Ghiye
Project: McKnight Community Ttrail	**Date:** 3/23/2020
Project No.: 1904391	**Checked By:** A. Juliano
Subject: Corrected Blow Counts	**Date:** 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
			ER = hammer efficiency expressed as percent of theoretical free fall energy
			N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft)
			$C_N = 0.77 * \log_{10}(40/\sigma'_v)$ $[C_N < 2.0]$
			σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.:	184	ft	(Interpolated from Benchmarks)
Depth to Groundwater:	0.6	ft	
Average Total Unit Weight of Soil:	120	pcf	

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***BWB-6***

Depth (ft)	El. (ft)	Layer Name	N	N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Type	ER (%)	C_E
				Corrected Blow Counts				**Overburden Correction**					**Hammer Efficiency Correction**		
1	183.0	Topsoil	--	--	--	--	--	120	25	95	0.095	2.00	Automatic	80	1.33
3	181.0	Sand	19	25	44	27	40	360	150	210	0.210	1.76	Automatic	80	1.33
5	179.0	Sand	17	23	36			600	275	325	0.325	1.61	Automatic	80	1.33
7	177.0	Sand and Silt	32	43	64			840	399	441	0.441	1.51	Automatic	80	1.33
9	175.0	Silt	20	27	38			1,080	524	556	0.556	1.43	Automatic	80	1.33
11	173.0	Silt	11	15	20			1,320	649	671	0.671	1.37	Automatic	80	1.33
15	169.0	Clay	5	7	8	8	9	1,800	899	901	0.901	1.27	Automatic	80	1.33
20	164.0	Clay	8	11	13			2,400	1,211	1,189	1.189	1.18	Automatic	80	1.33
25	159.0	Clay	5	7	7			3,000	1,523	1,477	1.477	1.10	Automatic	80	1.33
30	154.0	Clay	4	5	6			3,600	1,835	1,765	1.765	1.04	Automatic	80	1.33
34.5	149.5	Clay	--	--	--			4,140	2,115	2,025	2.025	1.00	Automatic	80	1.33
35.5	148.5	Sand and Silt	13	17	17	17	17	4,260	2,178	2,082	2.082	0.99	Automatic	80	1.33
40	144.0	Sand and Silt	13	17	16			4,800	2,459	2,341	2.341	0.95	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants	**Client:** BETA Group, Inc. **Project:** McKnight Community Ttrail **Project No.:** 1904391 **Subject:** Corrected Blow Counts	**Prepared By:** H. Ghiye **Date:** 3/23/2020 **Checked By:** A. Juliano **Date:** 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	N_{60} = (ER / 60%) * N	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft) ER = hammer efficiency expressed as percent of theoretical free fall energy N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft) $C_N = 0.77 * \log_{10}(40/\sigma'_v)$ $[C_N < 2.0]$ σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.: 187.5 ft (Interpolated from Benchmarks)
Depth to Groundwater: 0.8 ft
Average Total Unit Weight of Soil: 120 pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***BWB-7***

Depth (ft)	El. (ft)	Layer Name	N	Corrected Blow Counts: N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	Overburden Correction: σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Efficiency Correction: Hammer Type	ER (%)	C_E
1	186.5	Topsoil	--	--	--	--	--	120	12	108	0.108	1.98	Automatic	80	1.33
3	184.5	Sand	11	15	25	13	19	360	137	223	0.223	1.74	Automatic	80	1.33
5	182.5	Sand	10	13	21			600	262	338	0.338	1.60	Automatic	80	1.33
7	180.5	Sand	10	13	20			840	387	453	0.453	1.50	Automatic	80	1.33
9	178.5	Sand	7	9	13			1,080	512	568	0.568	1.42	Automatic	80	1.33
11	176.5	Sand	9	12	16			1,320	636	684	0.684	1.36	Automatic	80	1.33
15	172.5	Silt	12	16	20			1,800	886	914	0.914	1.26	Automatic	80	1.33
20	167.5	Clay	7	9	11	9	11	2,400	1,198	1,202	1.202	1.17	Automatic	80	1.33
25	162.5	Clay	7	9	10			3,000	1,510	1,490	1.490	1.10	Automatic	80	1.33
30	157.5	Sand	13	17	18	19	18	3,600	1,822	1,778	1.778	1.04	Automatic	80	1.33
35	152.5	Sand and Silt	14	19	18			4,200	2,134	2,066	2.066	0.99	Automatic	80	1.33
40	147.5	Sand and Silt	15	20	19			4,800	2,446	2,354	2.354	0.95	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "--."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

GEI Consultants

Client: BETA Group, Inc.
Project: McKnight Community Ttrail
Project No.: 1904391
Subject: Corrected Blow Counts

Prepared By: H. Ghiye
Date: 3/23/2020
Checked By: A. Juliano
Date: 4/10/2020

References: 1) American Association of State Highway and Transportation Officials (AASHTO) "AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations:

Ref. 1 Eqn. No.	Equation		
10.4.6.2.4-2	$N_{60} = (ER / 60\%) * N$	where:	N_{60} = SPT blow count corrected for hammer efficiency (blows/ft) ER = hammer efficiency expressed as percent of theoretical free fall energy N = Uncorrected SPT blow count (blows/ft)
10.4.6.2.4-3	$N1_{60} = C_N * N_{60}$	where:	$N1_{60}$ = SPT blow count corrected for overburden and hammer efficiency (blows/ft) $C_N = 0.77 * \log_{10}(40/\sigma'_v)$ [$C_N < 2.0$] σ'_v = vertical effective stress (ksf)

Assumptions:

Ground Surface El.: 191 ft (Interpolated from Benchmarks)
Depth to Groundwater: 1.6 ft
Average Total Unit Weight of Soil: 120 pcf

Hammer Type	ER (%)	C_E = ER / 60%
Donut	45	0.75
Safety	60	1.00
Automatic	80	1.33

Boring: ***BWB-8***

Depth (ft)	El. (ft)	Layer Name	N	Corrected Blow Counts: N_{60}	$N1_{60}$	Avg. N_{60}	Avg. $N1_{60}$	Overburden Correction: σ_v (psf)	u (psf)	σ'_v (psf)	σ'_v (ksf)	C_N	Hammer Efficiency Correction: Hammer Type	ER (%)	C_E
1	190.0	Topsoil	–	--	--	--	--	120	0	120	0.120	1.94	Automatic	80	1.33
3	188.0	Sand	15	20	33	13	17	360	87	273	0.273	1.67	Automatic	80	1.33
5	186.0	Sand	15	20	31			600	212	388	0.388	1.55	Automatic	80	1.33
7	184.0	Sand	5	7	10			840	337	503	0.503	1.46	Automatic	80	1.33
9	182.0	Sand	8	11	15			1,080	462	618	0.618	1.39	Automatic	80	1.33
11	180.0	Sand	7	9	12			1,320	587	733	0.733	1.34	Automatic	80	1.33
13	178.0	Sand	7	9	12			1,560	711	849	0.849	1.29	Automatic	80	1.33
15	176.0	Sand	7	9	12			1,800	836	964	0.964	1.25	Automatic	80	1.33
17	174.0	Sand	12	16	19			2,040	961	1,079	1.079	1.21	Automatic	80	1.33
19	172.0	Sand	9	12	14			2,280	1,086	1,194	1.194	1.17	Automatic	80	1.33
21	170.0	Sand	10	13	15			2,520	1,211	1,309	1.309	1.14	Automatic	80	1.33
25	166.0	Sand and Silt	14	19	20	25	22	3,000	1,460	1,540	1.540	1.09	Automatic	80	1.33
30	161.0	Sand and Silt	14	19	19			3,600	1,772	1,828	1.828	1.03	Automatic	80	1.33
35	156.0	Sand and Silt	13	17	17			4,200	2,084	2,116	2.116	0.98	Automatic	80	1.33
40	151.0	Sand and Silt	19	25	24			4,800	2,396	2,404	2.404	0.94	Automatic	80	1.33
45	146.0	Sand and Silt	23	31	28			5,400	2,708	2,692	2.692	0.90	Automatic	80	1.33
50	141.0	Sand and Silt	13	17	15			6,000	3,020	2,980	2.980	0.87	Automatic	80	1.33
55	136.0	Silt	17	23	19			6,600	3,332	3,268	3.268	0.84	Automatic	80	1.33
65	126.0	Sand	26	35	27			7,800	3,956	3,844	3.844	0.78	Automatic	80	1.33
75	116.0	Silt	26	35	26			9,000	4,580	4,420	4.420	0.74	Automatic	80	1.33

Notes:
1. MassDOT considers an uncorrected SPT blow count (N) of 120 blows/ft "practical refusal." Therefore, if N was greater than 120 blows/ft, we input the value as 120 blows/ft.
2. N-Values from SPT's that encountered refusal prior to full penetration were not included in the averages and are noted as "–."
3. Groundwater not encountered in the borehole upon completion of drilling. Depth to groundwater assumed 0.0.

RECOMMENDED SOIL PROPERTIES

Recommended Soil Properties

Purpose:
The purpose of this calculation is to select representative soil properties for the McKnight Community Trail project. The soil properties will be used in our engineering analyses.

Approach:
We selected values for unit weight, angle of internal friction, and undrained shear strength of the soils. Values were selected for the general soil layers observed in the borings and for proposed fills to be used during construction.

Unit Weight
We selected a saturated (total) unit weight in pounds per cubic foot (pcf). The buoyant unit weight can then be determined by subtracting the unit weight of water (62.4 pcf).

Angle of Internal Friction
We selected an angle of internal friction (ϕ) in degrees for granular soils. We used Mohr-Coulomb drained properties for each soil.

Undrained Shear Strength
We selected an undrained shear strength (S_u or c) for clayey soils based on in-situ and laboratory testing.

Proposed Fills
We selected properties for gravel borrow and gravel borrow for bridge foundations based on the required material gradations and compaction requirements per MassDOT.

Subsurface Investigation and SPT Correlations for Observed Soil Layers:
We reviewed Standard Penetration Test (SPT) N-Values collected from boring BB-1, previously performed in October 2019, at about 12 feet east of the northeast abutment of Glenn Road Bridge. We also reviewed SPT N-Values from recently performed boring BB-2 and geoprobes P-2A through P-2C to the west of the southwest abutment of Glenn Road Bridge, and from borings BWB-1 through BWB-8 at locations of the proposed Boardwalks. BB-2, P-2A through P-2C, and BWB-1 through BWB-8 were completed from March 4 through March 16, 2020.

We estimated angles of internal friction for the granular soils above based on N-Values corrected for overburden and hammer efficiency ($N1_{60}$). SPTs from all borings and geoprobes were performed with an automatic hammer. We assumed an efficiency of 80 percent for the automatic hammer based on published data.

A summary of corrected N-Values based on general soil type is shown below. Our N-Value correction calculations are attached. We did not include refusals due to cobbles or boulders, and we limited the uncorrected (field) N-value to a maximum of 100 blows per foot, less than the N-value of 120 blows per foot which MassDOT considers "practical refusal."

Soil Layer	Average N_{60}	Average $N1_{60}$
Upper Sand and Silt (Glen Road Bridge)	8	11
Upper Sand and Silt (Boardwalks)	17	25
Clay	6	7
Lower Sand and Silt	20	17

Results:
We selected the following soil properties for each layer/soil type based on the reference provided in the following pages, our engineering judgment and laboratory testing:

A. Granular Soils

Layer/Soil Type	Total Unit Weight, γ (pcf)	Friction Angle, ϕ (deg)
Upper Sand and Silt (Glen Road Bridge)	120	30
Upper Sand and Silt (Boardwalks)	125	34
Lower Sand and Silt	120	32
Gravel Borrow	130	35
Gravel Borrow for Bridge Foundations	135	37
New Retained Backfill (Ordinary Borrow)	120	32

B. Clayey Soils

Layer/Soil Type	Total Unit Weight, γ (pcf)	Undrained Shear Strength, c or S_u (ksf)	Liquid Limit, LL (%)	Plasticity Index, PI (%)
Clay	115	0.70	34	14

Notes:

1. Undrained shear strength is based on "Table 33. Conventional methods of interpretation for S_u from in-situ tests" of FHWA-IF-02-034 from SPT testing using the following equation:

$$S_{u(N60)} = f_1 \times N_{60} \times p_a / 100$$

where,
f_1 = 5.5 for PI = 15; and
p_a = 14.7 psi = 2.12 ksf

2. Liquid Limit, LL (%) and Plasticity Index, PI (%) are based on laboratory testing.

References:

AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014.

Terzaghi, K., Peck, R.B., 1968. Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley & Sons, New York.

Caltrans Geotechnical Manual, March 2014.

NAVFAC Design Manual 7.01 Soil Mechanics, Naval Facilities Engineering Command, September 1986.

Peck, Hanson, and Thornburn, 1974, tables 1.5 and 5.3.

US Federal Highway Administration (FHWA-IF-02-034). Geotechnical Engineering Circular No.5 – Evaluation of Soil and Rock Properties

AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014

Table 10.4.6.2.4-1 recommends using the following correlation to select friction angles of granular soils:

Table 10.4.6.2.4-1—Correlation of *SPT* $N1_{60}$ Values to Drained Friction Angle of Granular Soils (modified after Bowles, 1977)

$N1_{60}$	ϕ_f
<4	25–30
4	27–32
10	30–35
30	35–40
50	38–43

Soil Mechanics in Engineering Practice

Karl Terzaghi and Ralph Peck compiled various parameters of soils into the tables below:

Table 6.3
Porosity, Void Ratio, and Unit Weight of Typical Soils in Natural State

Description	Porosity, n (%)	Void ratio, e	Water content, w (%)	Unit weight grams/cm³ γ_d	grams/cm³ γ	lb/ft³ γ_d	lb/ft³ γ
1. Uniform sand, loose	46	0.85	32	1.43	1.89	90	118
2. Uniform sand, dense	34	0.51	19	1.75	2.09	109	130
3. Mixed-grained sand, loose	40	0.67	25	1.59	1.99	99	124
4. Mixed-grained sand, dense	30	0.43	16	1.86	2.16	116	135
5. Glacial till, very mixed-grained	20	0.25	9	2.12	2.32	132	145
6. Soft glacial clay	55	1.2	45	–	1.77	–	110
7. Stiff glacial clay	37	0.6	22	–	2.07	–	129
8. Soft slightly organic clay	66	1.9	70	–	1.58	–	98
9. Soft very organic clay	75	3.0	110	–	1.43	–	89
10. Soft bentonite	84	5.2	194	–	1.27	–	80

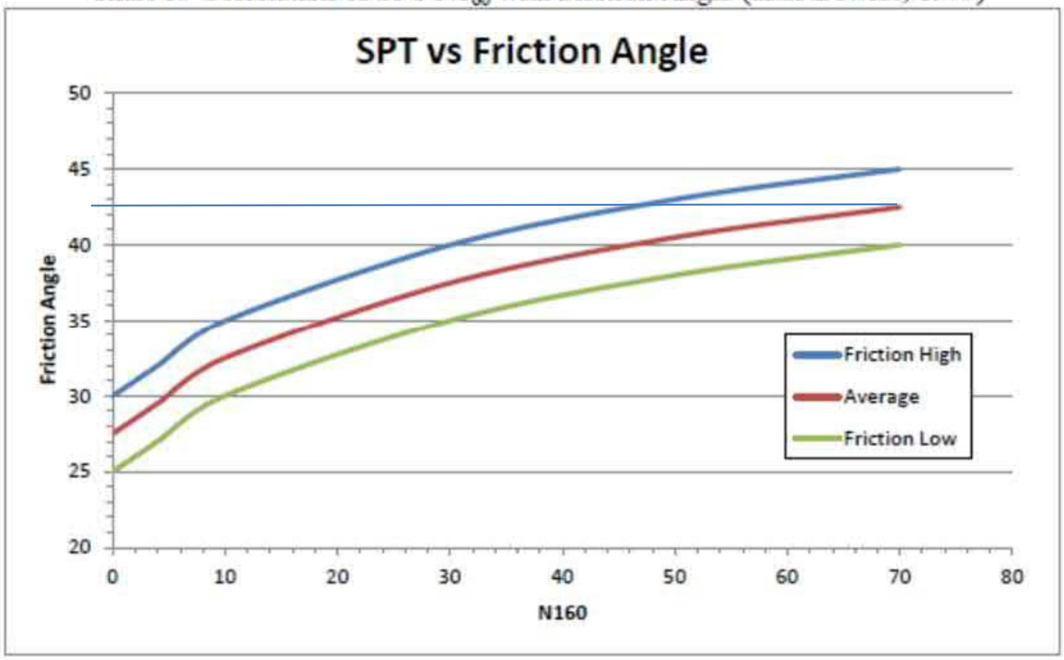
w = water content when saturated, in per cent of dry weight.
γ^d = unit weight in dry state.
γ = unit weight in saturated state.

Table 17.1
Representative Values of ϕ for Sands and Silts

Material	Degrees Loose	Degrees Dense
Sand, round grains, uniform	27.5	34
Sand, angular grains, well graded	33	45
Sandy gravels	35	50
Silty sand	27–33	30–34
Inorganic silt	27–30	30–35

Caltrans Geotechnical Manual (March 2014)

Chart 1: Correlation of SPT $N1_{60}$ with Friction Angle (after Bowles, 1977)



Choose the friction angle (expressed to the nearest degree) based upon the soil type, particle size(s), and rounding or angularity. Experience should be used to select specific values within the ranges. In general, finer materials or materials with significant (about 30+ %) silt-sized material will fall in the lower portion of the range. Coarser materials with less than 5% fines will fall in the upper portion of the range. The extreme range of phi angles for any $N1_{60}$ is five degrees, so the adjustment factors for particle size and roundness should be only a degree or two. The following bullets provide help in determining which value to select for a given $N1_{60}$ and soil type:

- Use the maximum value for GW
- Use the average for GM and SP
- Use the minimum for SC
- Use the minimum + 0.5 for ML
- Use the average +1 for SW
- Use the average -1 for GC
- Use the Maximum -1 for GP

Values may also be increased with increasing grain size and/or particle angularity, and decreased with decreasing grain size and/or increasing roundness. For example, an SP with $N1_{60}$ = 30 could be assigned phi angles of 37, 38 or 39 degrees for fine, medium and coarse grain sizes respectively.

NAVFAC Design Manual 7.01 Soil Mechanics

TABLE 6
Typical Values of Soil Index Properties

	Particle Size and Gradation				Voids[1]					Unit Weight[2] (lb./cu.ft.)						
	Approximate Size Range (mm)		Approx. D_{10} (mm)	Approx. Range Uniform Coefficient C_u	Void Ratio			Porosity (%)		Dry Weight			Wet Weight		Submerged Weight	
	D_{max}	D_{min}			e_{max} loose	e_{cr}	e_{min} dense	n_{max} loose	n_{min} dense	Min loose	100% Mod. AASHO	Max dense	Min loose	Max dense	Min loose	Max dense
GRANULAR MATERIALS																
Uniform Materials																
a. Equal spheres (theoretical values)	-	-	-	1.0	0.92	-	0.35	47.6	26	-	-	-	-	-	-	-
b. Standard Ottawa SAND	0.84	0.59	0.67	1.1	0.80	0.75	0.50	44	33	92	-	110	93	131	57	69
c. Clean, uniform SAND (fine or medium)	-	-	-	1.2 to 2.0	1.0	0.80	0.40	50	29	83	115	118	84	136	52	73
d. Uniform, inorganic SILT	0.05	0.005	0.012	1.2 to 2.0	1.1	-	0.40	52	29	80	-	118	81	136	51	73
Well-graded Materials																
a. Silty SAND	2.0	0.005	0.02	5 to 10	0.90	-	0.30	47	23	87	122	127	88	142	54	79
b. Clean, fine to coarse SAND	2.0	0.05	0.09	4 to 6	0.95	0.70	0.20	49	17	85	132	138	86	148	53	86
c. Micaceous SAND	-	-	-	-	1.2	-	0.40	55	29	76	-	120	77	138	48	76
d. Silty SAND & GRAVEL	100	0.005	0.02	15 to 300	0.85	-	0.14	46	12	89	-	146[3]	90	155[3]	56	92
MIXED SOILS																
Sandy or Silty CLAY	2.0	0.001	0.003	10 to 30	1.8	-	0.25	64	20	60	130	135	100	147	38	85
Skip-graded Silty CLAY with stones or rk fgmts	250	0.001	-	-	1.0	-	0.20	50	17	84	-	140	115	151	53	89
Well-graded GRAVEL, SAND, SILT & CLAY mixture	250	0.001	0.002	25 to 1000	0.70	-	0.13	41	11	100	140	148[4]	125	156[4]	62	94
CLAY SOILS																
CLAY (30%-50% clay sizes)	0.05	0.5μ	0.001	-	2.4	-	0.50	71	33	50	105	112	94	133	31	71
Colloidal CLAY (-0.002 mm: 50%)	0.01	10Å	-	-	12	-	0.60	92	37	13	90	106	71	128	8	65
ORGANIC SOILS																
Organic SILT	-	-	-	-	3.0	-	0.55	75	35	40	-	110	87	131	25	69
Organic CLAY (30% - 50% clay sizes)					4.4	-	0.70	81	41	30		100	81	125	18	62

Representative Range of Dry Unit Weights (after FHWA-HI-97-021)	
Rock Type	**Unit Weight Range (kcf)**
Shale	0.140 – 0.159
Sandstone	0.108 – 0.172
Limestone	0.121 – 0.178
Schist	0.159 – 0.185
Gneiss	0.159 – 0.185
Granite	0.153 – 0.185
Basalt	0.127 – 0.191

1. Dry unit weights are for moderately weathered to unweathered rock.
2. Wide range in unit weights for shale, sandstone, and limestone represents effect of variations in porosity, cementation, grain size, etc.
3. Specimens with unit weights falling outside these ranges may be encountered.

Peck, Hanson, and Thornburn, 1974

Approximate Consistency of Clays (Use only as a rough estimate)
(Peck, Hanson, and Thornburn, 1974, tables 1.5 and 5.3)

Consistency	Typical N-value Blows/ft	Field Identification	Unconfined Compressive Strength, q_u (ksf)	Undrained Strength, c or S_u (ksf)
Very Soft	Below 2	Easily penetrated several inches by fist	Less than 0.5	Less than 0.25
Soft	2-4	Easily penetrated several inches by thumb	0.5 – 1.0	0.25 – 0.5
Medium	4-8	Can be penetrated several inches by thumb with moderate effort	1.0 – 2.0	0.5 – 1.0
Stiff	8-15	Readily indented by thumb but penetrated only with great effort	2.0 – 4.0	1.0 – 2.0
Very Stiff	15-30	Readily indented by thumbnail	4.0 – 8.0	2.0 – 4.0
Hard	Over 30	Indented with difficulty by thumbnail	Over 8.0	Over 4.0

Correlations not reliable for highly sensitive clays, meaning clays for which the remolded strength is less than one tenth of the peak strength.

FHWA-IF-02-034 - Geotechnical Engineering Circular No.5 - Evaluation of Soil and Rock Properties

Table 33. Conventional methods of interpretation for s_u from in-situ tests.

IN-SITU TEST	COMMENTS	REFERENCES
VST: $s_{uv} = 6T/(7\pi D^3)$ for H/D = 2	Static equilibrium analysis Empirical: $\mu \approx 2.5(PI)^{-0.3} \leq 1.1$	Chandler (1988, ASTM 1014)
PMT: $s_{upmt} = dp/d(\ln \varepsilon_v)$ $s_{upmt} = (p_L\text{-}p_o)/N_c$	Cavity expansion theory Empirical bearing factor $N_c = 5.5$	Windle & Wroth (1977, ICSMFE). Baguelin et al. (1972, JSFMD).
SPT: $s_{u(N60)} = f_1 N_{60} p_a/100$	Empirical: $f_1 = 4.5$ for PI = 50 Empirical: $f_1 = 5.5$ for PI = 15	Stroud (1974, ESOPT-1) Stroud (1989, PTUK)
CPT: $s_{ucpt} = (q_c\text{-}\sigma_{vo})/N_c$ $s_{ucpt} = (q_t\text{-}\sigma_{vo})/N_{kt}$	Limit plasticity theory Cavity expansion theory Corrected cone tip resistance, q_t N_{kT} = 10 (TC) = 15 (DSS) = 20 (TE)	Meyerhof (1951, Geotechnique) Vesic (1977, NCHRP) Aas, et al. (1986, ASCE GSP 6)
$CPTu_2$: $s_{ucptu2} = \Delta u/N_u$	$N_{u2} = 7.9$ (uncorrected vane) Charts: $N_u = f(I_r, A_f, u_1 \text{ or } u_2)$ Cavity expansion + critical state	Tavenas, et al. (1982, ESOPT). Robertson and Campanella (1983) Mayne & Bachus (1989, ISOPT)
DMT: $s_{uDMT} = 0.22\, \sigma_{vo}'(\tfrac{1}{2}K_D)^{1.25}$ $s_{uDMT} = (p_o\text{-}u_o)/10$ $s_{uDMT} = d_s\sigma_{vo}'\,(0.5K_D)^{1.25}$	Based on mix of UU, UC, VST Cavity expansion theory Empirical and test-dependent: TC: $d_s = 0.20$ VST: $d_s = 0.19$ DSS: $d_s = 0.14$	Marchetti (1980, JGE). Schmertmann (1991) Lacasse & Lunne (1988, ISOPT)
PLT: $s_{uplt} = q_{ult}/6.18$	Limit plasticity theory	Meyerhof (1951, Geotechnique)

BEARING RESISTANCE
GLEN ROAD BRIDGE ABUTMENT

FACTORED BEARING RESISTANCE FOR ABUTMENT FOUNDATIONS ON SAND AND SILT

The following package provides bearing resistance calculations for the foundations of the Glenn Road bridge

References utilized for these calculations (including those pertaining to resistance factors) are provided at the back of this calculation. Cross sections are attached for reference.

Bearing resistances were calculated with the following formula:

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5\gamma \ B N_{\gamma m} C_{w\gamma} \quad (10.6.3.1.2a\text{-}1)$$

in which:

$$N_{cm} = N_c s_c i_c \quad (10.6.3.1.2a\text{-}2)$$

$$N_{qm} = N_q s_q d_q i_q \quad (10.6.3.1.2a\text{-}3)$$

$$N_\gamma m = N_\gamma s_\gamma i_\gamma \quad (10.6.3.1.2a\text{-}4)$$

where:

c = cohesion, taken as undrained shear strength (ksf)

N_c = cohesion term (undrained loading) bearing capacity factor as specified in Table 10.6.3.1.2a-1 (dim)

N_q = surcharge (embedment) term (drained or undrained loading) bearing capacity factor as specified in Table 10.6.3.1.2a-1 (dim)

N_γ = unit weight (footing width) term (drained loading) bearing capacity factor as specified in Table 10.6.3.1.2a-1 (dim)

γ = total (moist) unit weight of soil above or below the bearing depth of the footing (kcf)

D_f = footing embedment depth (ft)

B = footing width (ft)

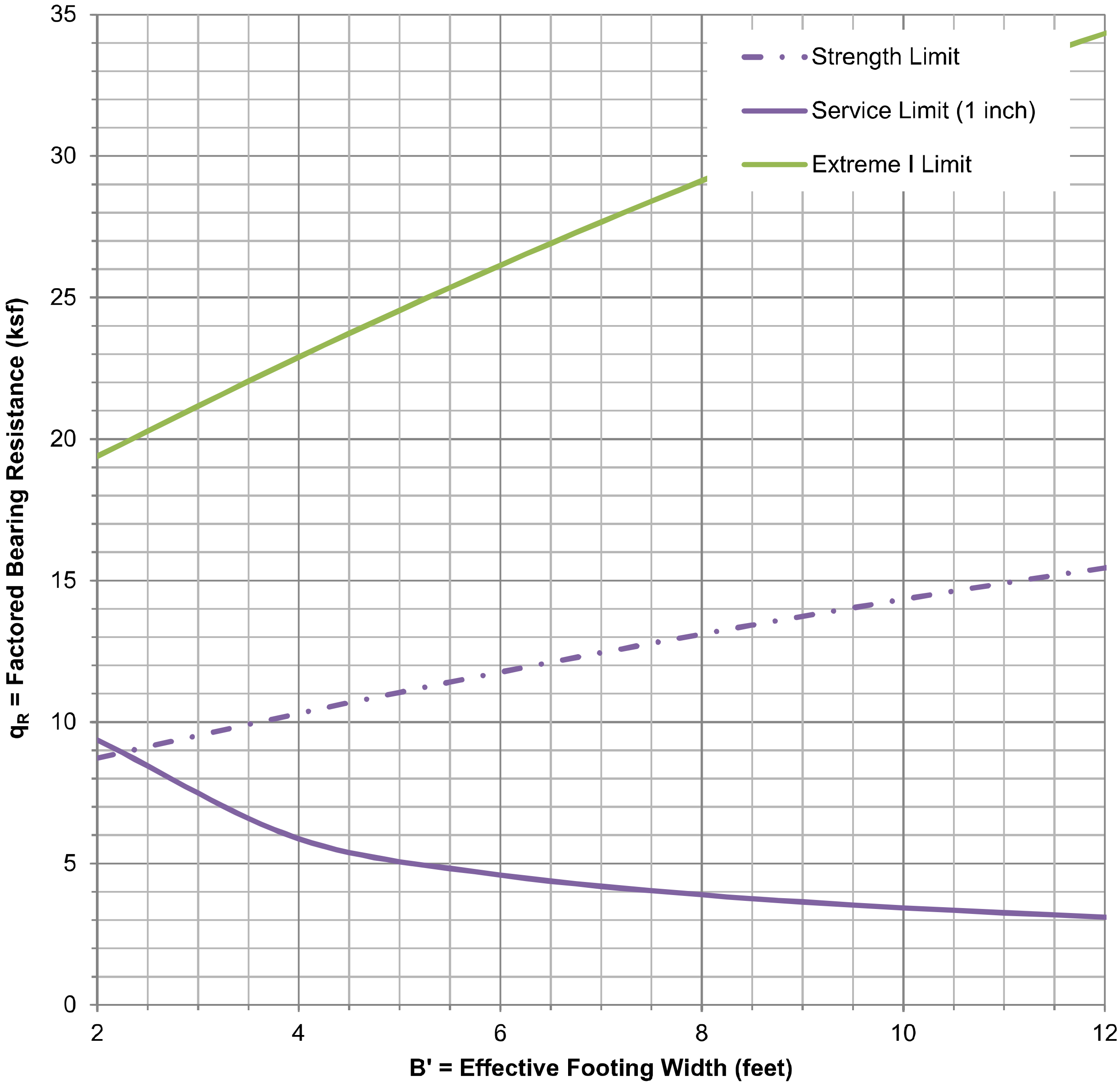
$C_{wq}, C_{w\gamma}$ = correction factors to account for the location of the groundwater table as specified in Table 10.6.3.1.2a-2 (dim)

s_c, s_γ, s_q = footing shape correction factors as specified in Table 10.6.3.1.2a-3 (dim)

d_q = correction factor to account for the shearing resistance along the failure surface passing through cohesionless material above the bearing elevation as specified in Table 10.6.3.1.2a-4 (dim)

i_c, i_γ, i_q = load inclination factors determined from Eqs. 10.6.3.1.2a-5 or 10.6.3.1.2a-6, and 10.6.3.1.2a-7 and 10.6.3.1.2a-8 (dim)

Additional formulas for correction factors are provided at the back of this calculation packet.
We assumed all load inclination factors to be 1.0.



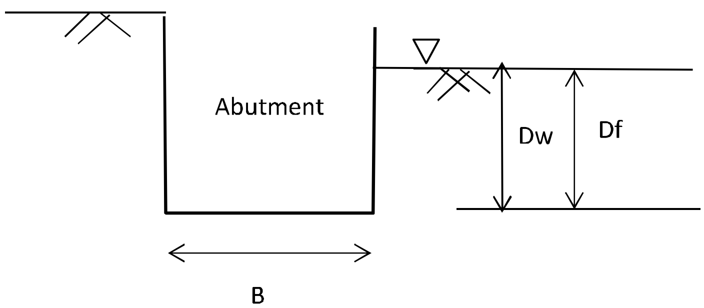
Notes:

1. B' represents the smallest dimension (i.e. effective footing width).
2. Groundwater was conservatively measured to be 9.3 ft (~El. 151.7).
3. The strength limit values are based on a resistance factor of 0.45 for the abutment footing, and the extreme limit values are based on a resistance factor of 1.0.
4. Based on results of the probes, an embedment depth of 8.5 ft (bottom of footing at El. +142.5) was assumed.
5. Level ground in front and behind the abutment was assumed (i.e., no sloping ground).

McKnight Community Trail Springfield, Massachusetts	GEI Consultants	FACTORED BEARING RESISTANCE VERSUS EFFECTIVE FOOTING WIDTH - GLEN ROAD BRIDGE
BETA Group, Inc. Norwood, Massachusetts	Project 1904391	April 2020 Fig. 6

FACTORED BEARING RESISTANCE CALCULATIONS - GLENN ROAD BRIDGE

Note: All references are to AASHTO LRFD Bridge Design Specifications, unless otherwise noted. See attached sheets with applicable table and equation references.



RESISTANCE FACTORS

Strength Limit	0.45
Extreme I Limit	1.0
Service Limit	1.0

BEARING SOIL PROPERTIES/SUBSURFACE INFORMATION

Bearing Soil Type		Upper Sand and Silt
Unit Weight of Bearing Soil (γ)	pcf	125
Cohesion of Bearing Soil (c)	psf	0
Friction Angle of bearing Soil (ϕ')	°	34
Es, Modulus of Elasticity	ksi	3
ν, Poisson's ratio		0.3
Depth to Groundwater, Dw	ft	9.3
Bearing Capacity Factor (N_c)		42.2
Bearing Capacity Factor (N_q)		29.4
Bearing Capacity Factor (N_γ)		41.1

FOOTING GEOMETRY

Bottom of Footing Elevation (NAVD 88)	ft	142.5
Minimum Footing Depth (D_f)	ft	8.5
Footing Length (L)	ft	16.0

Effective Width, B' (B' = B - 2e)	ft	2.0	4.0	6.0	8.0	10.0	12.0	14.0
Effective Length, L' =L	ft	16.0	16.0	16.0	16.0	16.0	16.0	16.0
L'/B'		8.0	4.0	2.7	2.0	1.6	1.3	1.1
Df/B'		4.3	2.1	1.4	1.1	0.9	0.7	0.6
A'	sf	32.0	64.0	96.0	128.0	160.0	192.0	224.0
βz		1.34	1.19	1.14	1.11	1.10	1.09	1.08

BEARING RESISTANCE EQUATION FACTORS/COEFFICIENTS

Effective Width, B' (B' = B - 2e)	ft	2.0	4.0	6.0	8.0	10.0	12.0	14.0
N_{cm}		45.8	49.5	53.2	56.9	60.6	64.2	67.9
Shape Correction Factor (s_c)		1.09	1.17	1.26	1.35	1.44	1.52	1.61
Load Inclination Factor (i_c)		1.0	1.0	1.0	1.0	1.0	1.0	1.0
N_{qm}		31.9	34.4	36.9	39.4	41.9	44.3	46.8
Shape Correction Factor (s_q)		1.08	1.17	1.25	1.34	1.42	1.51	1.59
Load Inclination Factor (i_q)		1.0	1.0	1.0	1.0	1.0	1.0	1.0
Depth Correction Factor (d_q)		1.0	1.0	1.0	1.0	1.0	1.0	1.0
$N_{\gamma m}$		39.0	37.0	34.9	32.9	30.8	28.7	26.7
Shape Correction Factor (s_γ)		0.95	0.90	0.85	0.80	0.75	0.70	0.65
Load Inclination Factor (i_γ)		1.0	1.0	1.0	1.0	1.0	1.0	1.0
Groundwater Coefficient, C_{wq}		0.5	0.5	0.5	0.5	0.5	0.5	0.5
Groundwater Coefficient, $C_{w\gamma}$		0.5	0.5	0.5	0.5	0.5	0.5	0.5

CALCULATED BEARING RESISTANCES

Nominal Bearing Resistance (q_n, ksf)	19.4	22.9	26.1	29.1	31.9	34.3	36.5
Strength Limit Factored Bearing Resistance (CIP): q_R (ksf)	**8.7**	**10.3**	**11.8**	**13.1**	**14.3**	**15.4**	**16.4**
Extreme I Limit Factored Bearing Resistance (CIP): q_R (ksf)	**19.4**	**22.9**	**26.1**	**29.1**	**31.9**	**34.3**	**36.5**
Service Limit Bearing, qo, for 1 inch (Factored) (ksf)	**9.4**	**5.9**	**4.6**	**3.9**	**3.4**	**3.1**	**2.9**

Table 10.4.6.2.4-1—Correlation of *SPT* $N1_{60}$ Values to Drained Friction Angle of Granular Soils (modified after Bowles, 1977)

$N1_{60}$	ϕ_f
<4	25–30
4	27–32
10	30–35
30	35–40
50	38–43

Table 10.6.3.1.2a-1—Bearing Capacity Factors N_c (Prandtl, 1921), N_q (Reissner, 1924), and N_γ (Vesic, 1975)

ϕ_f	N_c	N_q	N_γ	ϕ_f	N_c	N_q	N_γ
0	5.14	1.0	0.0	23	18.1	8.7	8.2
1	5.4	1.1	0.1	24	19.3	9.6	9.4
2	5.6	1.2	0.2	25	20.7	10.7	10.9
3	5.9	1.3	0.2	26	22.3	11.9	12.5
4	6.2	1.4	0.3	27	23.9	13.2	14.5
5	6.5	1.6	0.5	28	25.8	14.7	16.7
6	6.8	1.7	0.6	29	27.9	16.4	19.3
7	7.2	1.9	0.7	30	30.1	18.4	22.4
8	7.5	2.1	0.9	31	32.7	20.6	26.0
9	7.9	2.3	1.0	32	35.5	23.2	30.2
10	8.4	2.5	1.2	33	38.6	26.1	35.2
11	8.8	2.7	1.4	34	42.2	29.4	41.1
12	9.3	3.0	1.7	35	46.1	33.3	48.0
13	9.8	3.3	2.0	36	50.6	37.8	56.3
14	10.4	3.6	2.3	37	55.6	42.9	66.2
15	11.0	3.9	2.7	38	61.4	48.9	78.0
16	11.6	4.3	3.1	39	67.9	56.0	92.3
17	12.3	4.8	3.5	40	75.3	64.2	109.4
18	13.1	5.3	4.1	41	83.9	73.9	130.2
19	13.9	5.8	4.7	42	93.7	85.4	155.6
20	14.8	6.4	5.4	43	105.1	99.0	186.5
21	15.8	7.1	6.2	44	118.4	115.3	224.6
22	16.9	7.8	7.1	45	133.9	134.9	271.8

Table C10.4.6.3-1—Elastic Constants of Various Soils (modified after U.S. Department of the Navy, 1982; Bowles, 1988)

Soil Type	Typical Range of Young's Modulus Values, E_s (ksi)	Poisson's Ratio, ν (dim)
Clay:		
Soft sensitive	0.347–2.08	0.4–0.5 (undrained)
Medium stiff to stiff	2.08–6.94	
Very stiff	6.94–13.89	
Loess	2.08–8.33	0.1–0.3
Silt	0.278–2.78	0.3–0.35
Fine Sand:		
Loose	1.11–1.67	0.25
Medium dense	1.67–2.78	
Dense	2.78–4.17	
Sand:		
Loose	1.39–4.17	0.20–0.36
Medium dense	4.17–6.94	
Dense	6.94–11.11	0.30–0.40
Gravel:		
Loose	4.17–11.11	0.20–0.35
Medium dense	11.11–13.89	
Dense	13.89–27.78	0.30–0.40

Estimating E_s from *SPT N* Value	
Soil Type	E_s (ksi)
Silts, sandy silts, slightly cohesive mixtures	$0.056\ N1_{60}$
Clean fine to medium sands and slightly silty sands	$0.097\ N1_{60}$
Coarse sands and sands with little gravel	$0.139\ N1_{60}$
Sandy gravel and gravels	$0.167\ N1_{60}$
Estimating E_s from q_c (static cone resistance)	
Sandy soils	$0.028q_c$

Table 10.6.3.1.2a-2—Coefficients C_{wq} and $C_{w\gamma}$ for Various Groundwater Depths

D_w	C_{wq}	$C_{w\gamma}$
0.0	0.5	0.5
D_f	1.0	0.5
$>1.5B + D_f$	1.0	1.0

Where the position of groundwater is at a depth less than 1.5 times the footing width below the footing base, the bearing resistance is affected. The highest anticipated groundwater level should be used in design.

Table 10.6.3.1.2a-3—Shape Correction Factors s_c, s_γ, s_q

Factor	Friction Angle	Cohesion Term (s_c)	Unit Weight Term (s_γ)	Surcharge Term (s_q)
Shape Factors s_c, s_γ, s_q	$\phi_f = 0$	$1+\left(\frac{B}{5L}\right)$	1.0	1.0
	$\phi_f > 0$	$1+\left(\frac{B}{L}\right)\left(\frac{N_q}{N_c}\right)$	$1-0.4\left(\frac{B}{L}\right)$	$1+\left(\frac{B}{L}\tan\phi_f\right)$

Table 10.6.3.1.2a-4—Depth Correction Factor d_q

Friction Angle, ϕ_f (degrees)	D_f/B	d_q
32	1	1.20
	2	1.30
	4	1.35
	8	1.40
37	1	1.20
	2	1.25
	4	1.30
	8	1.35
42	1	1.15
	2	1.20
	4	1.25
	8	1.30

The parent information from which Table 10.6.3.1.2a-4 was developed covered the indicated range of friction angle, ϕ_f. Information beyond the range indicated is not available at this time.

$$S_e = \frac{\left[q_o\left(1-\nu^2\right)\sqrt{A'}\right]}{144\ E_s\beta_z} \tag{10.6.2.4.2-1}$$

where:

q_o = applied vertical stress (ksf)

A' = effective area of footing (ft²)

E_s = Young's modulus of soil taken as specified in Article 10.4.6.3 if direct measurements of E_s are not available from the results of in situ or laboratory tests (ksi)

Table 10.6.2.4.2-1—Elastic Shape and Rigidity Factors, EPRI (1983)

L/B	Flexible, β_z (average)	β_z Rigid
Circular	1.04	1.13
1	1.06	1.08
2	1.09	1.10
3	1.13	1.15
5	1.22	1.24
10	1.41	1.41

Table 10.5.5.2.2-1—Resistance Factors for Geotechnical Resistance of Shallow Foundations at the Strength Limit State

Method/Soil/Condition			Resistance Factor
Bearing Resistance	φ_b	Theoretical method (Munfakh et al., 2001), in clay	0.50
		Theoretical method (Munfakh et al., 2001), in sand, using *CPT*	0.50
		Theoretical method (Munfakh et al., 2001), in sand, using *SPT*	0.45
		Semi-empirical methods (Meyerhof, 1957), all soils	0.45
		Footings on rock	0.45
		Plate Load Test	0.55
Sliding	φ_τ	Precast concrete placed on sand	0.90
		Cast-in-Place Concrete on sand	0.80
		Cast-in-Place or precast Concrete on Clay	0.85
		Soil on soil	0.90
	φ_{ep}	Passive earth pressure component of sliding resistance	0.50

10.5.5—Resistance Factors

10.5.5.1—Service Limit States

Resistance factors for the service limit states shall be taken as 1.0, except as provided for overall stability in Article 11.6.2.3.

A resistance factor of 1.0 shall be used to assess the ability of the foundation to meet the specified deflection criteria after scour due to the design flood.

10.5.5.3—Extreme Limit States

10.5.5.3.1—General

Design of foundations at extreme limit states shall be consistent with the expectation that structure collapse is prevented and that life safety is protected.

10.5.5.3.2—Scour

The provisions of Articles 2.6.4.4.2 and 3.7.5 shall apply to the changed foundation conditions resulting from scour. Resistance factors at the strength limit state shall be taken as specified herein. Resistance factors at the extreme event shall be taken as 1.0 except that for uplift resistance of piles and shafts, the resistance factor shall be taken as 0.80 or less.

The foundation shall resist not only the loads applied from the structure but also any debris loads occurring during the flood event.

C10.5.5.3.2

The specified resistance factors should be used provided that the method used to compute the nominal resistance does not exhibit bias that is unconservative. See Paikowsky et al. (2004) regarding bias values for pile resistance prediction methods.

Design for scour is discussed in Hannigan et al. (2005).

10.5.5.3.3—Other Extreme Limit States

Resistance factors for extreme limit state, including the design of foundations to resist earthquake, ice, vehicle or vessel impact loads, shall be taken as 1.0. For uplift resistance of piles and shafts, the resistance factor shall be taken as 0.80 or less.

C10.5.5.3.3

The difference between compression skin friction and tension skin friction should be taken into account through the resistance factor, to be consistent with how this is done for the strength limit state (see Article 10.5.5.2.3).

Table 11.5.6-1—Resistance Factors for Permanent Retaining Walls

Wall-Type and Condition		Resistance Factor
Nongravity Cantilevered and Anchored Walls		
Axial compressive resistance of vertical elements		Article 10.5 applies
Passive resistance of vertical elements		0.75
Pullout resistance of anchors (1)	• Cohesionless (granular) soils • Cohesive soils • Rock	0.65 (1) 0.70 (1) 0.50 (1)
Pullout resistance of anchors (2)	• Where proof tests are conducted	1.0 (2)
Tensile resistance of anchor tendon	• Mild steel (e.g., ASTM A615 bars) • High strength steel (e.g., ASTM A722 bars)	0.90 (3) 0.80 (3)
Flexural capacity of vertical elements		0.90
Mechanically Stabilized Earth Walls, Gravity Walls, and Semi-Gravity Walls		
Bearing resistance	• Gravity and semi-gravity walls • MSE walls	0.55 0.65
Sliding		1.0
Tensile resistance of metallic reinforcement and connectors	Strip reinforcements (4) • Static loading • Combined static/earthquake loading Grid reinforcements (4) (5) • Static loading • Combined static/earthquake loading	 0.75 1.00 0.65 0.85
Tensile resistance of geosynthetic reinforcement and connectors	• Static loading • Combined static/earthquake loading	0.90 1.20
Pullout resistance of tensile reinforcement	• Static loading • Combined static/earthquake loading	0.90 1.20
Prefabricated Modular Walls		
Bearing		Article 10.5 applies
Sliding		Article 10.5 applies
Passive resistance		Article 10.5 applies

11.5.7—Resistance Factors—Service and Strength

Resistance factors for the service limit states shall be taken as 1.0, except as provided for overall stability in Article 11.6.2.3.

For the strength limit state, the resistance factors provided in Table 11.5.7-1 shall be used for wall design, unless region specific values or substantial successful experience is available to justify higher values.

11.5.8—Resistance Factors—Extreme Event Limit State

Unless otherwise specified, all resistance factors shall be taken as 1.0 when investigating the extreme event limit state.

For overall stability of the retaining wall when earthquake loading is included, a resistance factor, ϕ, of 0.9 shall be used. For bearing resistance, a resistance factor of 0.8 shall be used for gravity and semigravity walls and 0.9 for MSE walls.

For tensile resistance of metallic reinforcement and connectors, when earthquake loading is included, the following resistance factors shall be used:

- Strip reinforcements, $\phi = 1.0$
- Grid reinforcement, $\phi = 0.85$

Table 11.5.7-1 Notes 4 and 5 also apply to these resistance factors for metallic reinforcements.

For tensile resistance of geosynthetic reinforcement and connectors, a resistance factor, ϕ, of 1.20 shall be used.

For pullout resistance of metallic and geosynthetic reinforcement, a resistance factor, ϕ, of 1.20 shall be used.

EARTH PRESSURES

Purpose: Calculate lateral earth pressure coefficients

Reference: American Association of State Highway and Transportation Officials (AASHTO)
"AASHTO LRFD Bridge Design Specifications, 8th Edition, 2017"

Equations: See attached

Calculations:

	Upper Sand and Silt (Glen Road Bridge)	**Upper Sand and Silt (Boardwalks)**	**Lower Sand and Silt**	**Gravel Borrow**	**Gravel Borrow for Bridge Foundations**	**New Retained Backfill (Ordinary Borrow)**
Effective Friction Angle of Soil, ϕ'_f (deg)	30	34	32	35	37	32
Friction Angle Between Fill and Wall, δ (deg)	15.0	17.0	16.0	17.5	18.5	16.0
Angle of Fill to the Horizontal, β (deg)	0	0	0	0	0	0
Angle of Back Face of Wall to the Horizontal, θ (deg)	90	90	90	90	90	90
At-Rest Lateral Earth Pressure Coefficient, k_o (Eq. 3.11.5.2-1)	**0.50**	**0.44**	**0.47**	**0.43**	**0.40**	**0.47**
Γ (Eq. 3.11.5.3-2)	2.58	2.80	2.69	2.86	2.97	2.69
Active Lateral Earth Pressure Coefficient, k_a (Eq. 3.11.5.3-1)	**0.30**	**0.26**	**0.28**	**0.25**	**0.23**	**0.28**
$-\delta/\phi_f$	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
β/ϕ_f	0.0	0.0	0.0	0.0	0.0	0.0
Coefficient of Passive Pressure for β/ϕ_f = 0 and -$\delta/\phi f$ = -1, k_p (Figure 3.11.5.4-1)	6.5	9.5	7.7	10.5	12.9	7.7
Reduction Factor of k_p, R (Figure 3.11.5.4-1)	0.746	0.688	0.717	0.674	0.641	0.717
Coefficient of Passive Pressure, k_p	**4.85**	**6.54**	**5.52**	**7.08**	**8.27**	**5.52**

Notes:

Reference: American Association of State Highway and Transportation Officials (AASHTO)
"AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014"

Equations: **At-Rest Lateral Earth Pressure Coefficient, k_o**

3.11.5.2—At-Rest Lateral Earth Pressure Coefficient, k_o

For normally consolidated soils, vertical wall, and level ground, the coefficient of at-rest lateral earth pressure may be taken as:

$$k_o = 1 - \sin\phi'_f \qquad (3.11.5.2\text{-}1)$$

where:

ϕ'_f = effective friction angle of soil
k_o = coefficient of at-rest lateral earth pressure

Active Lateral Earth Pressure Coefficient, k_a

3.11.5.3—Active Lateral Earth Pressure Coefficient, k_a

Values for the coefficient of active lateral earth pressure may be taken as:

$$k_a = \frac{\sin^2(\theta + \phi'_f)}{\Gamma\,[\sin^2\theta\,\sin(\theta - \delta)]} \qquad (3.11.5.3\text{-}1)$$

in which:

$$\Gamma = \left[1 + \sqrt{\frac{\sin(\phi'_f + \delta)\sin(\phi'_f - \beta)}{\sin(\theta - \delta)\sin(\theta + \beta)}}\right]^2 \qquad (3.11.5.3\text{-}2)$$

where:

δ = friction angle between fill and wall taken as specified in Table 3.11.5.3-1 (degrees)
β = angle of fill to the horizontal as shown in Figure 3.11.5.3-1 (degrees)
θ = angle of back face of wall to the horizontal as shown in Figure 3.11.5.3-1 (degrees)
ϕ'_f = effective angle of internal friction (degrees)

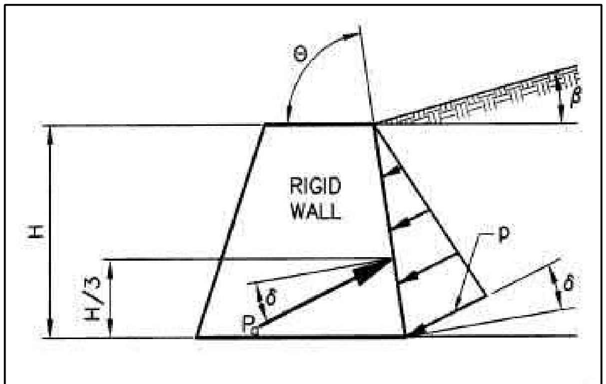


Figure 3.11.5.3-1—Notation for Coulomb Active Earth Pressure

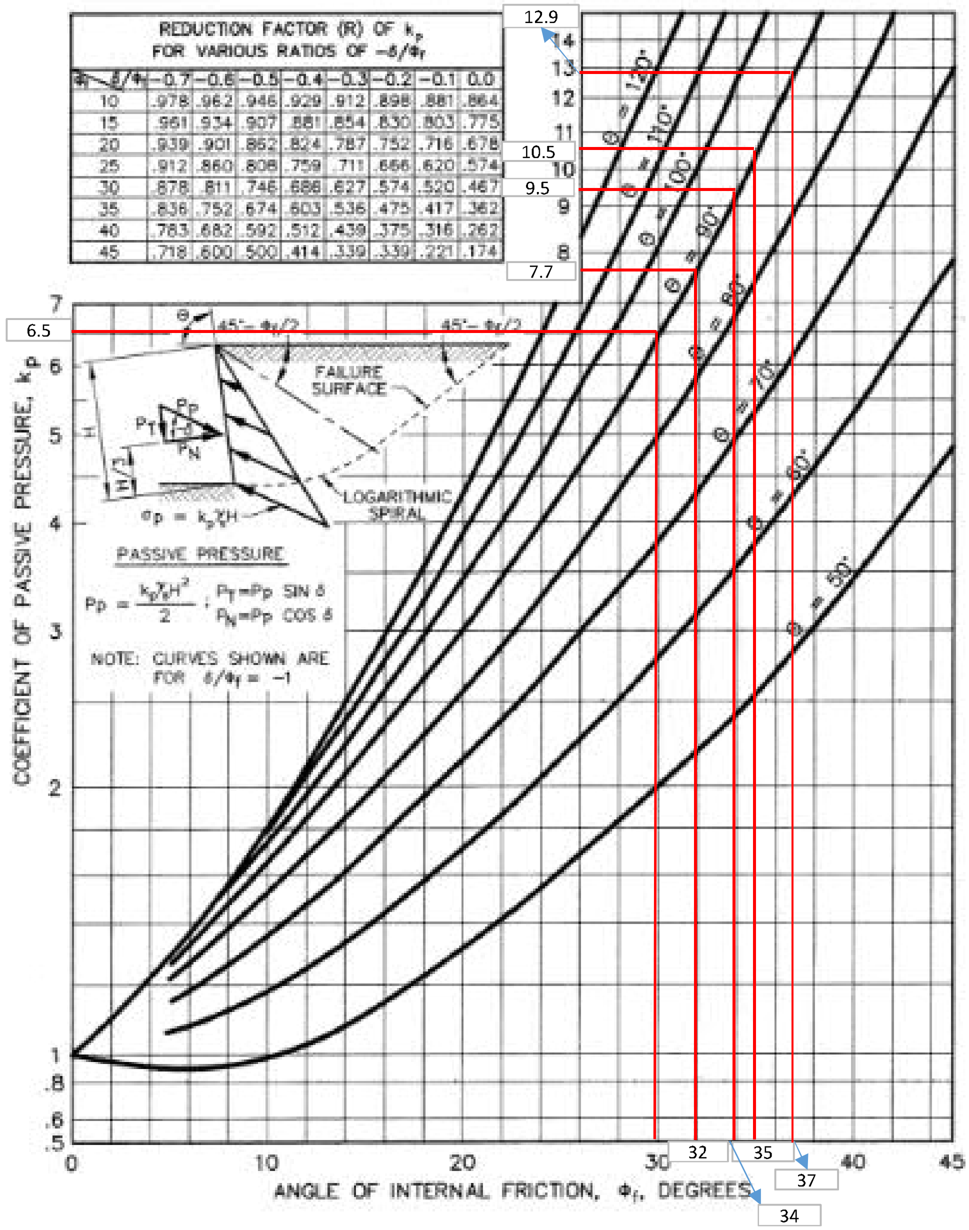
Table 3.11.5.3-1—Friction Angle for Dissimilar Materials (U.S. Department of the Navy, 1982a)

Interface Materials	Friction Angle, δ (degrees)	Coefficient of Friction, tan δ (dim.)
Mass concrete on the following foundation materials:		
• Clean sound rock	35	0.70
• Clean gravel, gravel-sand mixtures, coarse sand	29 to 31	0.55 to 0.60
• Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel	24 to 29	0.45 to 0.55
• Clean fine sand, silty or clayey fine to medium sand	19 to 24	0.34 to 0.45
• Fine sandy silt, nonplastic silt	17 to 19	0.31 to 0.34
• Very stiff and hard residual or preconsolidated clay	22 to 26	0.40 to 0.49
• Medium stiff and stiff clay and silty clay	17 to 19	0.31 to 0.34
Masonry on foundation materials has same friction factors.		
Steel sheet piles against the following soils:		
• Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls	22	0.40
• Clean sand, silty sand-gravel mixture, single-size hard rock fill	17	0.31
• Silty sand, gravel or sand mixed with silt or clay	14	0.25
• Fine sandy silt, nonplastic silt	11	0.19
Formed or precast concrete or concrete sheet piling against the following soils:		
• Clean gravel, gravel-sand mixture, well-graded rock fill with spalls	22 to 26	0.40 to 0.49
• Clean sand, silty sand-gravel mixture, single-size hard rock fill	17 to 22	0.31 to 0.40
• Silty sand, gravel or sand mixed with silt or clay	17	0.31
• Fine sandy silt, nonplastic silt	14	0.25
Various structural materials:		
• Masonry on masonry, igneous and metamorphic rocks:		
○ dressed soft rock on dressed soft rock	35	0.70
○ dressed hard rock on dressed soft rock	33	0.65
○ dressed hard rock on dressed hard rock	29	0.55
• Masonry on wood in direction of cross grain	26	0.49
• Steel on steel at sheet pile interlocks	17	0.31

Passive Lateral Earth Pressure Coefficient, k_p

3.11.5.4—Passive Lateral Earth Pressure Coefficient, k_p

For noncohesive soils, values of the coefficient of passive lateral earth pressure may be taken from Figure 3.11.5.4-1 for the case of a sloping or vertical wall with a horizontal backfill or from Figure 3.11.5.4-2 for the case of a vertical wall and sloping backfill. For conditions that deviate from those described in Figures 3.11.5.4-1 and 3.11.5.4-2 the passive pressure may be calculated by using a trial procedure based on wedge theory, e.g., see Terzaghi et al. (1996). When wedge theory is used, the limiting value of the wall friction angle should not be taken larger than one-half the angle of internal friction, ϕ_f.



REDUCTION FACTOR (R) OF k_p FOR VARIOUS RATIOS OF $-\delta/\phi_f$

ϕ_f \ δ/ϕ_f	−0.7	−0.6	−0.5	−0.4	−0.3	−0.2	−0.1	0.0
10	.978	.962	.946	.929	.912	.898	.881	.864
15	.961	.934	.907	.881	.854	.830	.803	.775
20	.939	.901	.862	.824	.787	.752	.716	.678
25	.912	.860	.808	.759	.711	.666	.620	.574
30	.878	.811	.746	.686	.627	.574	.520	.467
35	.836	.752	.674	.603	.536	.475	.417	.362
40	.783	.682	.592	.512	.439	.375	.316	.262
45	.718	.600	.500	.414	.339	.339	.221	.174

Figure 3.11.5.4-1—Computational Procedures for Passive Earth Pressures for Vertical and Sloping Walls with Horizontal Backfill (U.S. Department of the Navy, 1982a)

SEISMIC SITE CLASSIFICATION

Seismic Site Class Evaluation - Glenn Road Bridge, Springfield, Massachusetts

Purpose: Evaluate seismic design criteria in accordance with 2011 AASHTO Guide Specifications for LRFD Seismic Bridge Design with 2012 through 2015 Interim Revisions. Evaluate borings BB-1 and BB-2 based on N60 values (Assuming CE=1.33 for automatic hammer.)

Method B: $\bar{N}$ **method**

Layer	BB-1		
	N_i	Layer (D_i)	D_i/N_i
1	5	26.00	4.98
2	2	28.00	12.73
3	8	20.00	2.42
4	8	26.00	3.25
	Σ =	100.00	23.38
		$\bar{N}$	**4.3**

Layer	BB-2		
	N_i	Layer (D_i)	D_i/N_i
1	7	24.00	3.65
2	6	30.00	4.74
3	19	46.00	2.37
	Σ =	100.00	10.76
		$\bar{N}$	**9.3**

$$\bar{N} = \frac{\sum d_i}{\sum {d_i}/{N_i}}$$

From AASHTO Eq. 3.4.2.2-2

Method C: $\bar{S}_u$ **method**

Layer (cohensionless)	BB-1		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	5	26.00	4.98
2	8	20.00	2.42
	Σ =	46.00	7.40
		$\bar{N}_{ch}$	**6.2**

Layer (cohensionless)	BB-2		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	7	24.00	3.65
2	19	46.00	2.37
	Σ =	70.00	6.02
		$\bar{N}_{ch}$	**11.6**

Layer (cohension)	BB-1		
	S_{ui}	Layer (D_i)	D_i/S_{ui}
1	0.70	28.00	40.00
2	0.70	26.00	37.14
	Σ =	54.00	77.14
		$\bar{S}_u$	**0.7**

Layer (cohension)	BB-2		
	S_{ui}	Layer (D_i)	D_i/S_{ui}
1	0.70	30.00	42.86
	Σ =	30.00	42.86
		$\bar{S}_u$	**0.7**

$$\bar{N}_{ch} = \frac{d_s}{\sum_{i=1}^{m} \frac{d_i}{N_{chi}}}$$

From AASHTO Eq. 3.4.2.2-3

$$\bar{S}_u = \frac{d_c}{\sum_{i=1}^{k} \frac{d_i}{S_{ui}}}$$

From AASHTO Eq. 3.4.2.2-4

From AASHTO Table 3.4.2.1-1
Site Class E

Site Seismic Coefficients

Horizontal Peak Ground Acceleration,	PGA =	*0.075*	MassDOT App A
Horizontal Response Spectral Acceleration (0.2 sec),	S_s =	*0.130*	MassDOT App A
Horizontal Response Spectral Acceleration (1 sec),	S_1 =	*0.055*	MassDOT App A
	F_{PGA} =	*2.5*	AASHTO Table 3.4.2.3-1
	F_A =	*2.5*	AASHTO Table 3.4.2.3-1
	F_V =	*3.5*	AASHTO Table 3.4.2.3-2

Design Response Spectra

Acceleration Coefficient,	$A_s = PGA \times F_{PGA}$	A_S =	0.188	AASHTO Eq. 3.4.1-1
Design Spectral Acceleration (0.2 sec),	$S_{DS} = S_S \times F_A$	S_{DS} =	0.325	AASHTO Eq. 3.4.1-2
Design Spectral Acceleration (1 sec),	$S_{D1} = S_1 \times F_V$	S_{D1} =	0.193	AASHTO Eq. 3.4.1-3

From AASHTO Table 3.5-1
SDC B

Seismic Site Class Evaluation - Glenn Road Bridge - St. James Avenue, Springfield, Massachusetts

Purpose: Evaluate seismic design criteria in accordance with 2011 AASHTO Guide Specifications for LRFD Seismic Bridge Design with 2012 through 2015 Interim Revisions. Evaluate boring B2-1 based on N60 values (Assuming CE=1.33 for automatic hammer.)

Method B: $\bar{N}$ **method**

Layer	BWB-1		
	N_i	Layer (D_i)	D_i/N_i
1	11	10.00	0.91
2	4	29.00	7.25
3	8	61.00	7.39
	Σ =	100.00	15.55
		$\bar{N}$	**6.4**

Layer	BWB-2		
	N_i	Layer (D_i)	D_i/N_i
1	7	18.00	2.74
2	5	26.00	5.20
3	13	56.00	4.31
	Σ =	100.00	12.25
		$\bar{N}$	**8.2**

Layer	BWB-3		
	N_i	Layer (D_i)	D_i/N_i
1	14	14.00	1.00
2	5	25.00	5.56
3	14	61.00	4.36
	Σ =	100.00	10.91
		$\bar{N}$	**9.2**

Layer	BWB-4		
	N_i	Layer (D_i)	D_i/N_i
1	12	14.00	1.17
2	4	25.00	6.25
3	16	61.00	3.81
	Σ =	100.00	11.23
		$\bar{N}$	**8.9**

Layer	BWB-5		
	N_i	Layer (D_i)	D_i/N_i
1	22	14.00	0.64
2	5	20.00	4.00
3	7	66.00	9.43
	Σ =	100.00	14.06
		$\bar{N}$	**7.1**

Layer	BWB-6		
	N_i	Layer (D_i)	D_i/N_i
1	20	14.00	0.70
2	6	20.50	3.73
3	13	65.50	5.04
	Σ =	100.00	9.47
		$\bar{N}$	**10.6**

Layer	BWB-7		
	N_i	Layer (D_i)	D_i/N_i
1	10	19.00	1.90
2	7	10.00	1.43
3	14	71.00	5.07
	Σ =	100.00	8.40
		$\bar{N}$	**11.9**

Layer	BWB-8		
	N_i	Layer (D_i)	D_i/N_i
1	10	22.00	2.32
2	18	78.00	4.33
	Σ =	100.00	6.65
		$\bar{N}$	**15.0**

$$\bar{N} = \frac{\sum d_i}{\sum {d_i}/{N_i}}$$

From AASHTO Eq. 3.4.2.2-2

Method C: $\overline{S}_u$ **method**

Layer (cohensionless)	BWB-1		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	11	10.00	0.91
2	8	61.00	7.39
	Σ =	71.00	8.30
		$\overline{N}_{ch}$	**8.6**

Layer (cohensionless)	BWB-1		
	S_{ui}	(D_i)	D_i/S_{ui}
1	0.70	29.00	41.43
	Σ =	29.00	41.43
		$\overline{S}_u$	**0.7**

Layer (cohensionless)	BWB-2		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	7	18.00	2.74
2	13	56.00	4.31
	Σ =	74.00	7.05
		$\overline{N}_{ch}$	**10.5**

Layer (cohensionless)	BWB-2		
	S_{ui}	(D_i)	D_i/S_{ui}
1	0.70	26.00	37.14
	Σ =	26.00	37.14
		$\overline{S}_u$	**0.7**

Layer (cohensionless)	BWB-3		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	14	14.00	1.00
2	14	61.00	4.36
	Σ =	75.00	5.36
		$\overline{N}_{ch}$	**14.0**

Layer (cohensionless)	BWB-3		
	S_{ui}	(D_i)	D_i/S_{ui}
1	0.70	25.00	35.71
	Σ =	25.00	35.71
		$\overline{S}_u$	**0.7**

Layer (cohensionless)	BWB-4		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	12	14.00	1.17
2	16	61.00	3.81
	Σ =	75.00	4.98
		$\overline{N}_{ch}$	**15.1**

Layer (cohensionless)	BWB-4		
	S_{ui}	(D_i)	D_i/S_{ui}
1	0.70	25.00	35.71
	Σ =	25.00	35.71
		$\overline{S}_u$	**0.7**

Layer (cohensionless)	BWB-5		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	22	14.00	0.64
2	7	66.00	9.43
	Σ =	80.00	10.06
		$\overline{N}_{ch}$	**7.9**

Layer (cohensionless)	BWB-5		
	S_{ui}	(D_i)	D_i/S_{ui}
1	0.70	20.00	28.57
	Σ =	20.00	28.57
		$\overline{S}_u$	**0.7**

Layer (cohensionless)	BWB-6		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	20	14.00	0.70
2	13	65.50	5.04
	Σ =	79.50	5.74
		$\overline{N}_{ch}$	**13.9**

Layer (cohensionless)	BWB-6		
	S_{ui}	(D_i)	D_i/S_{ui}
1	0.70	20.50	29.29
	Σ =	20.50	29.29
		$\overline{S}_u$	**0.7**

Layer (cohensionless)	BWB-7		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	10	19.00	1.90
2	14	71.00	5.07
	Σ =	90.00	6.97
		$\bar{N}_{ch}$	**12.9**

Layer (cohensionless)	BWB-7		
	S_{ui}	(D_i)	D_i/S_{ui}
1	0.70	10.00	14.29
	Σ =	10.00	14.29
		$\bar{S}_u$	**0.7**

Layer (cohensionless)	BWB-8		
	N_{chi}	Layer (D_i)	D_i/N_{chi}
1	10	22.00	2.32
2	18	78.00	4.33
	Σ =	100.00	6.65
		$\bar{N}_{ch}$	**15.0**

Layer (cohensionless)	BWB-8		
	S_{ui}	(D_i)	D_i/S_{ui}
	Σ =	0.00	0.00
		$\bar{S}_u$	

$$\bar{N}_{ch} = \frac{d_s}{\sum_{i=1}^{m} \frac{d_i}{N_{chi}}}$$

From AASHTO Eq. 3.4.2.2-3

From AASHTO Eq. 3.4.2.2-4

$$\bar{S}_u = \frac{d_c}{\sum_{i=1}^{k} \frac{d_i}{s_{ui}}}$$

From AASHTO Table 3.4.2.1-1
Site Class E

Site Seismic Coefficients

Horizontal Peak Ground Acceleration,	PGA =	*0.075*	MassDOT App A
Horizontal Response Spectral Acceleration (0.2 sec),	S_s =	*0.130*	MassDOT App A
Horizontal Response Spectral Acceleration (1 sec),	S_1 =	*0.055*	MassDOT App A

F_{PGA} =	*2.5*	AASHTO Table 3.4.2.3-1
F_A =	*2.5*	AASHTO Table 3.4.2.3-1
F_V =	*3.5*	AASHTO Table 3.4.2.3-2

Design Response Spectra

Acceleration Coefficient,	$A_s = PGA \times F_{PGA}$	A_S =	0.188	AASHTO Eq. 3.4.1-1
Design Spectral Acceleration (0.2 sec),	$S_{DS} = S_S \times F_A$	S_{DS} =	0.325	AASHTO Eq. 3.4.1-2
Design Spectral Acceleration (1 sec),	$S_{D1} = S_1 \times F_V$	S_{D1} =	0.193	AASHTO Eq. 3.4.1-3

From AASHTO Table 3.5-1
SDC B

HELICAL PILE CHECK

	Client	Beta Group, Inc.			Page	1 of 1
GEI Consultants	Project	McKnight Community Trail			Pg. Rev.	
	By	H. Ghiye	Chk.	A. Juliano	App.	
	Date	4/13/2020	Date	4/13/2020	Date	

Project No.	1904391	Document No.	N/A
Subject	Helical Pile Embedment Depth Check		

Highest axial load applied on the pile is 17 kips.

Use individual bearing method with Perko's N-value correlations (attached). See boring logs in Appendix B.

SPTs from all borings were performed with an automatic hammer. We assumed an efficiency of 80 percent for the automatic hammer based on published data.

For Upper Sand and Silt:

$$N_{70} = {}^{80}/_{70}\,(12) = 13.7 \approx 14\; blows$$

$$q_{ult} = 12(0.065)(14) = 10.9\; tsf$$

- Try 3x12-inch helices spaced at $2.5\left({}^{12"}/_{12"/1ft}\right) = 2.5\; ft$

Net bearing area with 4.5-inch diameter shaft:

$$A_{net} = \pi\frac{(12")^2}{4} - \pi\frac{(4.5")^2}{4} = 97\; in^2 = 0.67\; ft^2$$

Ultimate capacity:

$$3(0.67\; ft^2)(10.9\; tsf) = 21.9\; tons$$

Assume a safety factor of 3.0, allowable capacity:

$$\frac{21.9\; tons}{3} = 7.3\; tons = 14.6\; kips \approx 15\; kips$$ ➔ No Good

- Try 4x12-inch helices spaced at $2.5\left({}^{12"}/_{12"/1ft}\right) = 2.5\; ft$

Net bearing area with 4.5-inch diameter shaft:

$$A_{net} = \pi\frac{(12")^2}{4} - \pi\frac{(4.5")^2}{4} = 97\; in^2 = 0.67\; ft^2$$

Ultimate capacity:

$$4(0.67\; ft^2)(10.9\; tsf) = 29.3\; tons$$

Assume a safety factor of 3.0, allowable capacity:

$$\frac{29.3\; tons}{3} = 9.75\; tons = 19.5\; kips > 17\; kips$$ ➔ Okay

- Try 3x14-inch helices spaced at $2.5\left({}^{14"}/_{12"/1ft}\right) = 2.92\; ft \approx 3\; ft$

Net bearing area with 4.5-inch diameter shaft:

	Client	Beta Group, Inc.			Page	1 of 1
GEI Consultants	Project	McKnight Community Trail			Pg. Rev.	
	By	H. Ghiye	Chk.	A. Juliano	App.	
	Date	4/13/2020	Date	4/13/2020	Date	

Project No.	1904391	Document No.	N/A
Subject	Helical Pile Embedment Depth Check		

$$A_{net} = \pi\frac{(14")^2}{4} - \pi\frac{(4.5")^2}{4} = 138\ in^2 = 0.96\ ft^2$$

Ultimate capacity:

$$3(0.96\ ft^2)(10.9\ tsf) = 31.3\ tons$$

Assume a safety factor of 3.0, allowable capacity:

$$\frac{31.3\ tons}{3} = 10.45\ tons = 20.9\ kips > 17\ kips \Rightarrow \text{Okay}$$

Total Weight of Steel:

$$A_{total\_steel}\ of\ 3 \times 14"\ helices = 3 \times 0.96\ ft^2 = 2.88\ ft^2$$

$$A_{total_{steel}}\ of\ 4 \times 12"\ helices = 4 \times 0.67\ ft^2 = 2.68\ ft^2$$

Therefore, use 4x12-inch diameter helices spaced at 2.5 ft since if the most economical option.