GEOSCIENCES TESTING AND RESEARCH INC

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GEOTECHNICAL ENGINEERING REPORT – REV 1
CHESTNUT STREET OVER IPSWICH RIVER
BRIDGE REPLACEMENT – BRIDGE NO. N-18-003
NORTH READING, MASSACHUSETTS

July 8, 2024
Project 22.259

Prepared by: Geosciences Testing and Research, Inc.
North Chelmsford, MA

Prepared for: Mr. Bob Niccoli, P.E.
The Engineering Corp, Inc.
282 Merrimack Street, 2nd Floor
Lawrence, MA 01843

July 8, 2024
GTR Project #22.259

Mr. Bob Niccoli, P.E.
The Engineering Corp, Inc.
282 Merrimack Street, 2nd Floor
Lawrence, MA 01843

Re: **Geotechnical Engineering Report – REV 1**
Bridge Replacement Bridge No. N-18-003: Chestnut Street Over Ipswich River
North Reading, Massachusetts

Dear Mr. Niccoli:

Geosciences Testing and Research, Inc. (GTR) is pleased to present this revised report summarizing the results of our geotechnical engineering study for the above-referenced project. This study was carried out in general accordance with our proposal dated July 25, 2022. This report is subject to the limitations presented in Appendix A.

We trust this satisfies your current requirements and have appreciated working with you on this project. Please contact the undersigned if you have any questions.

Sincerely,
Geosciences Testing and Research, Inc.

Anthony Jackson, EIT
Geotechnical Engineer

Curtis A. George, P.E. (NJ)
Principal

Attachments: Appendices A- D

TABLE OF CONTENTS

1. SUMMARY

This report summarizes Geosciences Testing and Research, Inc. (GTR's) geotechnical study to evaluate the subsurface conditions at the Chestnut Street Bridge Replacement Site (Site) and develop recommendations for the proposed replacement of bridge spanning the Ipswich River. GTR carried out this study in general accordance with our proposal dated July 25, 2022. Our design was performed based on AASHTO 2020 9^{th} Edition Specifications. This report is subject to the limitations in Appendix A.

2. INTRODUCTION

2.1 Scope of Study

This report provides recommendations for the design and construction of the new foundations for the proposed bridge replacement. The subsurface investigation and soil profiles are described herein. Based on the subsurface conditions, soil design parameters, seismic design parameters, foundation recommendations and construction recommendations are provided.

The scope of this study included the following tasks:

1. Perform a subsurface exploration program consisting of two borings with rock cores.
2. Evaluate the soil conditions, liquefaction potential, foundation capacity, settlement, and other soil properties under or in the vicinity of the proposed abutments.
3. Summarize the construction recommendations with regards to the chosen foundation system, including dewatering considerations and earthwork recommendations.

The information provided to us to prepare this report included the following and are attached in Appendix B:

1. A Site Survey Plan set entitled "Existing Conditions Plan in North Reading, MA" prepared by The Engineering Corp, Inc. (TEC) dated September 8, 2022.
2. A plan and profile view of the existing bridges culverts labeled "S-01030 Chestnut St Twin Culverts Ipswich River.pdf" received September 7, 2022.
3. A set of Bridge drawings entitled "Bridge Replacement North Reading Chestnut Street over Ipswich River" prepared by TEC and dated March 28, 2024.

Our scope of services did not include an environmental assessment to evaluate the subsurface conditions related to hazardous or toxic materials in the soil, bedrock, surface water, or groundwater around the site. Any statement in this report or on the boring logs regarding odors, suspicious items or conditions is strictly for the information of the client. We recommend engaging a qualified environmental professional, if necessary, to perform environmental services prior to/during construction.

2.2 Existing Conditions

The existing bridge is a portion of Chestnut Street in North Reading, MA, that crosses the Ipswich River (see Locus Plan in Figure 1). The bridge's construction is unknown at the time of writing this report, but from visual inspection and the references listed in Section 2.1, the bridge is most likely cast in place founded on shallow concrete footings. Twin asphalt covered corrugated metal arch pipe culverts allow flow of the Ipswich River below the bridge. The elevation of the roadway on the bridge is around +72 feet. The existing bridge clear span is around 39 feet. The current road width is approximately 30 feet from pavement edge to edge. The bottom of the riverbed elevation is around +60 feet (11-12 feet below road grade). The water in the canal at the crossing location is around elevation +63 feet at the time of drilling. See Appendix B for the existing bridge plans.

2.3 Proposed Construction

We understand that the proposed construction involves demolishing the existing bridge and replacing it with a new single span, pre-cast concrete bridge structure. The bridge will be supported by a shallow foundation system. From our initial discussions with TEC, GTR understands the proposed bridge will be one span with a width of approximately 40 feet. The elevation of the road way will remain the same. The bottom of the footings are anticipated to be at elevation +56.5 feet (approximately 15 to 16 feet below grade). The road will be closed during bridge construction and is anticipated to be completed in one phase.

3. SUBSURFACE INFORMATION

3.1 Subsurface Exploration Program

The subsurface exploration program consisted of two primary borings designated as GTR-1 and GTR-2. The subsurface investigation program was completed on August 25, 2022 by Carr-Dee Test Boring & Construction of Medford, MA. A truck mounted Deidrich D50 rotary drill rig with an automatic hammer was used to perform the borings and probes. Mud rotary drilling techniques were used to advance the borings in accordance with ASTM D5783-18. GTR-1 and GTR-2 were advanced to depths of 34.5 and 37.5 feet below ground surface (BGS), respectively. A 5-foot rock core was advanced in GTR-1, and a 10-foot rock core was advanced in GTR-2. Refer to Figure 2 for the approximate location of the borings with respect to the existing bridge features.

The drilling techniques and sampling methods are noted on the logs. Standard Penetration Test (SPT) soil sampling was performed from grade to practical refusal, with samples taken typically in five-foot intervals. The soil samples were collected using a 2-inch outside diameter, 24-inch long, split-spoon sampler in accordance with ASTM D1586 procedures. The sampler was inserted into the borehole and then advanced 24 inches into undisturbed materials using a 140-pound hammer and a 30-inch drop height. The total number of blows required to advance the sampler the second and third 6-inch intervals is referred to as the SPT N-value, which can be correlated to the shear strength and density of the soil. The rock cores were taken with an NX core barrel.

A GTR field representative was on-site during the boring program to observe the drilling activities and log the soil and rock samples. The soil samples were classified according to a modified Burmister soil classification system and subsequently collected in glass jars for further testing and/or identification. Appendix C contains copies of the boring logs prepared by GTR.

3.2 Subsurface Profile

The following subsections summarize the soils encountered during our subsurface investigation. GTR notes that these descriptions are a simplified representation of the site's geology, and that the typed soil boring logs, provided as Appendix C, should be reviewed for more detailed information.

3.2.1 Asphalt

Approximately six inches of asphalt was identified at grade in each boring location.

3.2.2 Granular Fill

The soil immediately beneath the asphalt is typical composed of brown, fine to coarse sand, some to little gravel, and trace silt. SPT N-Values were typically between 4 and 30 in this layer. The granular fill in the boring locations extended to approximately 8.5 feet BGS.

3.2.3 Sand

A loose sand layer was encountered from 8.5 to 18.5 feet BGS in GTR-1, and 8.5 to 13.5 feet BGS in GTR-2. SPT N-values were typically between 5 and 7 in this layer. The sand primarily consisted of fine sand with smaller amounts of silt and gravel

3.2.4 Sand and Gravel

Medium dense to dense sand and gravel was identified directly beneath the loose sand layer from 18.5 to 29 feet BGS in GTR-1, and 13.5 to 27.5 feet BGS in GTR-2. The soils were generally described as medium dense to dense, gray fine to coarse sand with 10% to 35% gravel, and trace silt. SPT N-Values were typically between 20 and 32 in this layer.

3.2.5 Bedrock

Competent bedrock was cored for 5 feet in boring GTR-1 at 29.5 feet below existing ground surface, and for 10 feet at 27.5 feet BGS in GTR-2. The cored bedrock consisted of gray, slightly weathered, moderately fractured, fine to coarse grained, very hard, Biotite Granite. The Rock Quality Designation (RQD) ranged from 37% to 58%.

3.2.6 Groundwater

Groundwater was measured in the borings between 8.5 and 9 feet below ground surface. The groundwater levels represent conditions during field activities at the time of drilling and, therefore, different levels due to storm events and/or seasonal fluctuations should be anticipated.

3.3 Soil Design Parameters

Due to the loose sands' potential for settlement when exposed to the loading of the proposed bridge replacement, GTR recommends over excavating soils below the footings and replacing with ¾-inch crushed stone fill per Section 5.2. Therefore, our design assumes that the loose sands will be removed and replaced. Table 1 lists the proposed soil parameters recommended for design based on our review of the boring logs and core results. Representative SPT N-values of the soil layers were used to estimate the shear strength.

Table 1. Recommended Soil Design Parameters

Soil Description	Unit Weight (lb/ft^3)	Friction Angle (º)	Active Earth Pressure, Ka	At Rest Earth Pressure, Ko	Passive Earth Pressure, Kp
Gravel Borrow/Stone	125	35	0.30	0.5	7
Sand	120	32	0.30	0.5	5.5
Granular Fill	125	32	0.25	0.5	5.5
Sand and Gravel	125	35	0.30	0.5	7

3.4 Seismic Design Parameters

The recommended 1,000 year seismic design return period parameters shown in Table 2 are based on the MassDOT LRFD Bridge Manual and AASHTO Guide Specifications for LRFD Bridge Seismic Design 2011 with 2015 Interim Revisions. The bridge is assumed to be non-critical non-essential. The site is not considered to be susceptible to liquefaction. Liquefaction is the sudden, temporary loss of soil shear strength due to earthquake motion for soils below the water table. The site is located in seismic design category (SDC) A based on the SD1 < 0.15. Table 3.5-1 - AASHTO Guide Specifications for LRFD Seismic Bridge Design, 2nd Edition.

Table 2. Recommended Seismic Design Parameters

SEISMIC DESIGN CRITERIA	
Design Return Period Site Class	1,000 years
DESIGN SPECTRA	
As	0.131 g
SDs	0.264 g
SD1	0.096 g
Site Class	D
Seismic Design Category (SDC)	A

4. RECOMMENDED FOUNDATION SYSTEM

4.1 General

Based on the existing subsurface conditions, shallow foundations are recommended for the foundation. The bottoms of the footings are anticipated to be around 15 to 16 feet below existing ground. This potentially places the bottoms of the footings within loose sand layer in the abutments. We recommend over excavating the loose sand layer below the bottom of the footings if encountered and replaced with ¾-inch crushed stone. The ¾-inch crushed stone fill should be place wrapped in filter fabric and placed on the exposed subgrade. The footings should be designed to be at least 4 feet beneath the final mudline grade.

4.2 Shallow Foundation Bearing Capacity

For footings placed on the ¾-inch crushed stone overlying the natural sand and gravel subgrade at least 4 feet below proposed grade, the net factored bearing resistance is 7.38 ksf. An effective footing width of 3.85 feet (provided by BSC) was used in our analysis. A resistance factor of 0.45 was used to determine the above-recommended factored resistance. The resultant of the foundation pressures should fall within 1/3 of the center of the footing. If inclined loads or eccentricity are significant, we should review these recommended values.

4.3 Shallow Foundation Sliding Resistance

For resistance to sliding, a friction factor (i.e. coefficient of friction) of 0.58 is recommended for precast concrete on sand or stone fill. A resistance factor of 0.9 (precast concrete on sand) should be applied to the sliding resistance. The passive pressure in front of the proposed foundations below grade can only be used in the analysis of the sliding resistance if the embedment footing depth is considered permanent.

4.4 Shallow Foundation Earth Pressures

For the existing fill or any other compacted backfill acting on the foundation, an equivalent fluid unit weight of 65 lb/ft^3 (at-rest conditions) is recommended. For any wingwalls we recommend an equivalent fluid unit weight of 35 lb/ft^3 (active conditions). This assumes that the wing walls are allowed to rotate. If the walls are connected to the bridge or restrained from movement, the at-rest value recommended above should be used. These values assume that there is free drainage of water behind the walls. Hydrostatic pressure must be included below the water table.

Where the equivalent fluid pressure is less than 300 psf behind the walls, use a pressure of 300 psf to account for compaction induced stresses. Within 4 feet behind the walls, we recommend limiting compaction effort to hand-operated plate compactors. Additional surcharge loads from sloped backfill, vehicle traffic, etc. should also be applied when located within a line extending from the bottom heel of the footing at a slope of 1:1 and extending to the ground surface. To determine the lateral pressure associated with the vertical surcharge loads, multiply the vertical pressure by 0.5 for restrained walls or 0.3 for unrestrained walls allowed to rotate. In accordance with AASHTO and/or the MASS DOT Bridge Manual, the walls should be designed for earthquake loads.

4.5 Shallow Foundation Settlement

For the proposed construction the total settlement is estimated to be on the order of 1 inch (service state unfactored loading conditions). This settlement is expected to occur mostly during construction. An unfactored service load pressure 5.5 ksf (from initial conversations with TEC), an effective footing width of 3.85 feet, and a footing length of 32 feet was used in the analyses. If higher bearing resistance is needed then indicated or if loads or footing geometry are different than what we have assumed, we may need to verify and/or revise our analyses.

5. CONSTRUCTION CONSIDERATIONS

5.1 Excavations

Any excavations over 4 feet in depth should be performed in accordance with OSHA regulations by sloping or using temporary earth support. Excavations of up to 20 feet may be required for demolition/removal of the existing bridge footings, excavation and replacement of the loose sand and placing of new footings. All excavations should be performed in the dry as described in the dewatering section below. Excavations should be regularly evaluated for signs of movement or unsafe conditions by a competent person as defined by OSHA. The lateral limits of the excavation under each footing (the zone of influence) should be determined as follows:

(1) Offset a distance of one feet from the edge of the footing,
(2) Extend a line at an angle of 1H:1V from the offset until it intersects the subgrade.
(3) Repeat this for every edge of the footing.

Braced (due to the relatively shallow bedrock and deep cut) steel sheeting is a common system anticipated for this excavation support system. This will depend on the contractor's means and methods, water control/dewatering system, construction phasing and/or staging. The contractor should submit their chosen excavation procedure (support system, if required,) for review. The submittal should include the assumptions made regarding soil properties, geometry of excavation, lateral earth pressures and surcharge loads, staging and sequencing, and wall design calculations. The submittal should be prepared and stamped by a professional engineer licensed in the Commonwealth of Massachusetts and designed in accordance with Mass DOT and AASHTO requirements

5.2 Excavation Subgrade

GTR recommends excavating any loose fine sand layers/unsuitable soils encountered to the top of the natural sand and gravel layer or to a minimum one foot below the proposed bottom of footing depth. The soil should be replaced with ¾-inch crushed stone. The exposed sand subgrades should be excavated with a smooth, flat bucket. All footing and pavement subgrades should be protected from frost during construction. Surface water from rain events may cause the subgrade to become weak, disturbed and or unacceptable. These “wet” conditions are expected to be worse during the winter/spring periods and extra precautions should be made during these times. For the over-excavation of loose subgrade soils the following protection/remedial procedures can be performed.

1. Over excavate the footings by 12-inches using the above subgrade preparation procedure; place oversized non-woven filter fabric (Marafi 140N) on the exposed subgrade, backfill with ¾-inch crushed stone to the bottom of footing, wrap the additional non-woven filter fabric on top of the ¾-inch stone (this will prevent migration of fines).
2. Over excavate the footings by 4 to 6 inches, place a lean concrete mud mat (flowable fill) over the exposed subgrade.

5.3 Dewatering

All excavation and concrete placement activities should be performed in dry conditions. The contractor should control the flow of any perched groundwater, surface water or rain water into the excavations at all times in order to maintain stable sidewalls and bearing surfaces. Any bearing soils disturbed by water should be removed and replaced with compacted structural fill prior to structure placement. Pumping and sumps will be necessary to dewater the excavation. Steel sheeting and/or bulk sand bag cofferdam can be used to divert the river during construction based on the water levels and excavated heights depending on the contractor’s means and methods.

Any water removed from the excavations should be evaluated and, if necessary, disposed of in accordance with local and federal regulations. Consideration should be given to the lead-time necessary to test the water and obtain the EPA permit for discharging back into local storm drains or into the brook. The contractor should submit their water control plan for review. The water control plan should be submitted with the excavation procedure/earth support design. The water control plan should be prepared and stamped by a professional engineer licensed in the Commonwealth of Massachusetts.

5.4 Backfill

The foundation areas should be backfilled with material that satisfies MassDOT Gravel Borrow M1.03 Type A specifications. The Gravel Borrow should be placed in layers less than 12 inches in thickness and compacted to not less than 95% of its maximum dry density as determined by ASTM D1557, Method C. The Gravel Borrow should be free of organic material, trash, ice, frozen soil, and other deleterious material. Excavated on-site fill meeting the requirements of compacted Gravel Borrow as described above may be re-used, provided that it is not contaminated. Screening equipment may be necessary to allow the re-use of some of the excavated fill as acceptable backfill. The contractor will need to confirm this by performing selected grain size distribution analyses on the excavated and/or screened material. The results should be submitted to the engineer for review and assessment of suitability for on-site re-use. Any soil removed from the site should be evaluated, and if necessary, disposed of in accordance with local and federal regulations.

The culvert and possible wing wall areas should be backfilled with material that satisfies MassDOT Gravel Borrow M1.03 Type B specifications. The Gravel Borrow should be placed in layers less than 12 inches in thickness and compacted to not less than 95% of its maximum dry density as determined by ASTM D1557, Method B. The Gravel Borrow should be free of organic material, trash, ice, frozen soil, and other deleterious material. Excavated on-site fill meeting the requirements of compacted Gravel Borrow as described above may be re-used, provided that it is not contaminated. Screening equipment may be necessary to allow the re-use of some of the excavated fill as acceptable backfill. The contractor will need to confirm this by performing selected grain size distribution analyses on the excavated and/or screened material. The results should be submitted to the engineer for review and assessment of suitability for on-site re-use. Any soil removed from the site should be evaluated, and if necessary, disposed of in accordance with local and federal regulations.

5.5 Construction Monitoring

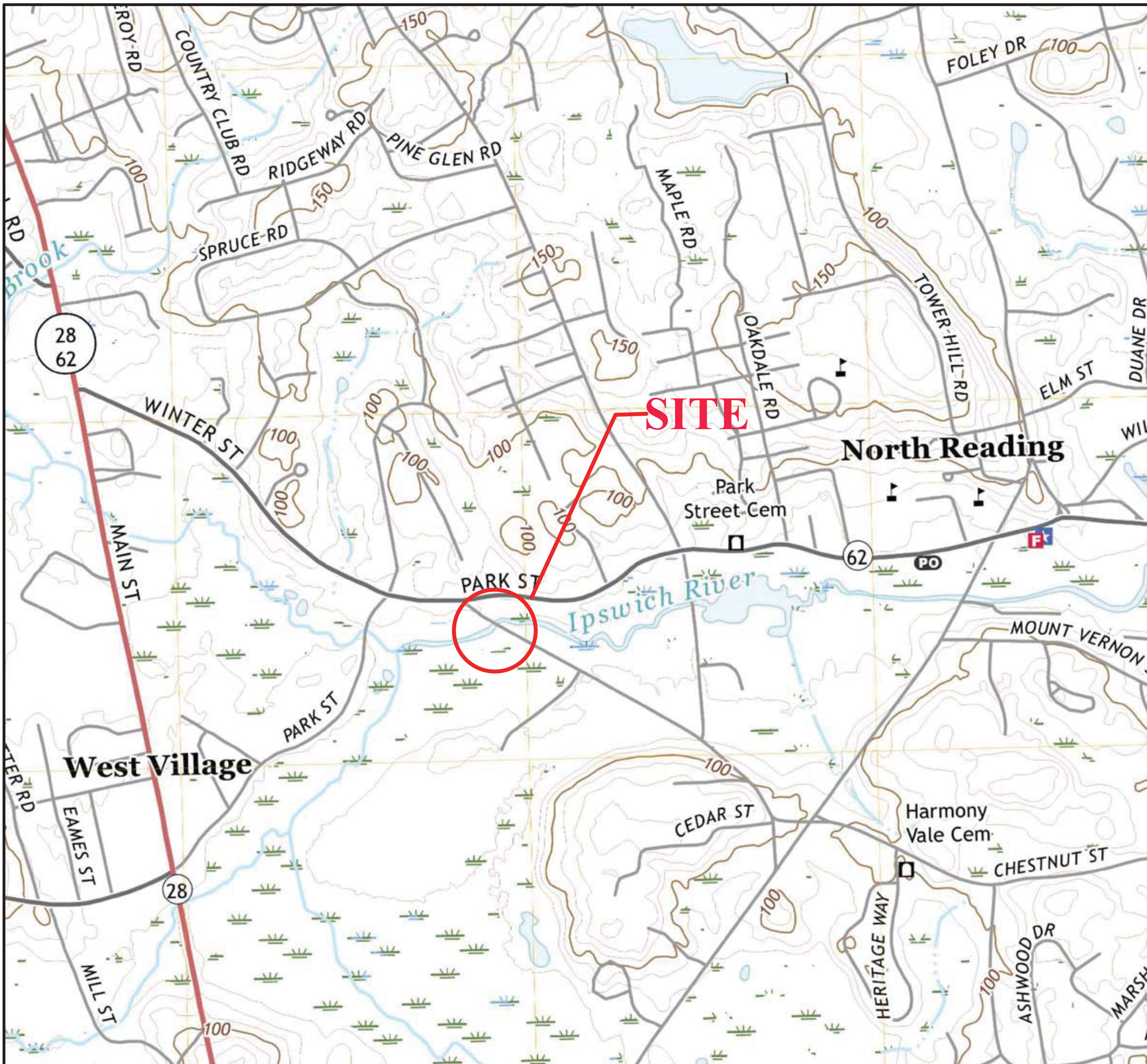
It is recommended that a geotechnical engineer or qualified geotechnical technician be present during construction to:

- Confirm the quality of the bearing material under footings, utilities or pavement,
- Observe and confirm that the soils used as fill and backfill and materials proposed for re-use are in accordance with the Mass DOT Standards and Contract Special Provisions,
- Observe and test the placement and compaction of stone fill and other compacted fills.

5.6 Final Design, Specifications, and Plan Review

GTR should be given the opportunity to review final plans and specifications for the foundations systems, earthwork, and other items related to our scope to confirm that the recommendations contained in our report are interpreted and implemented as intended.

FIGURES



PROJECT NORTH

CHESTNUT STREET BRIDGE REPLACEMENT
NORTH READING, MA

Locus Plan

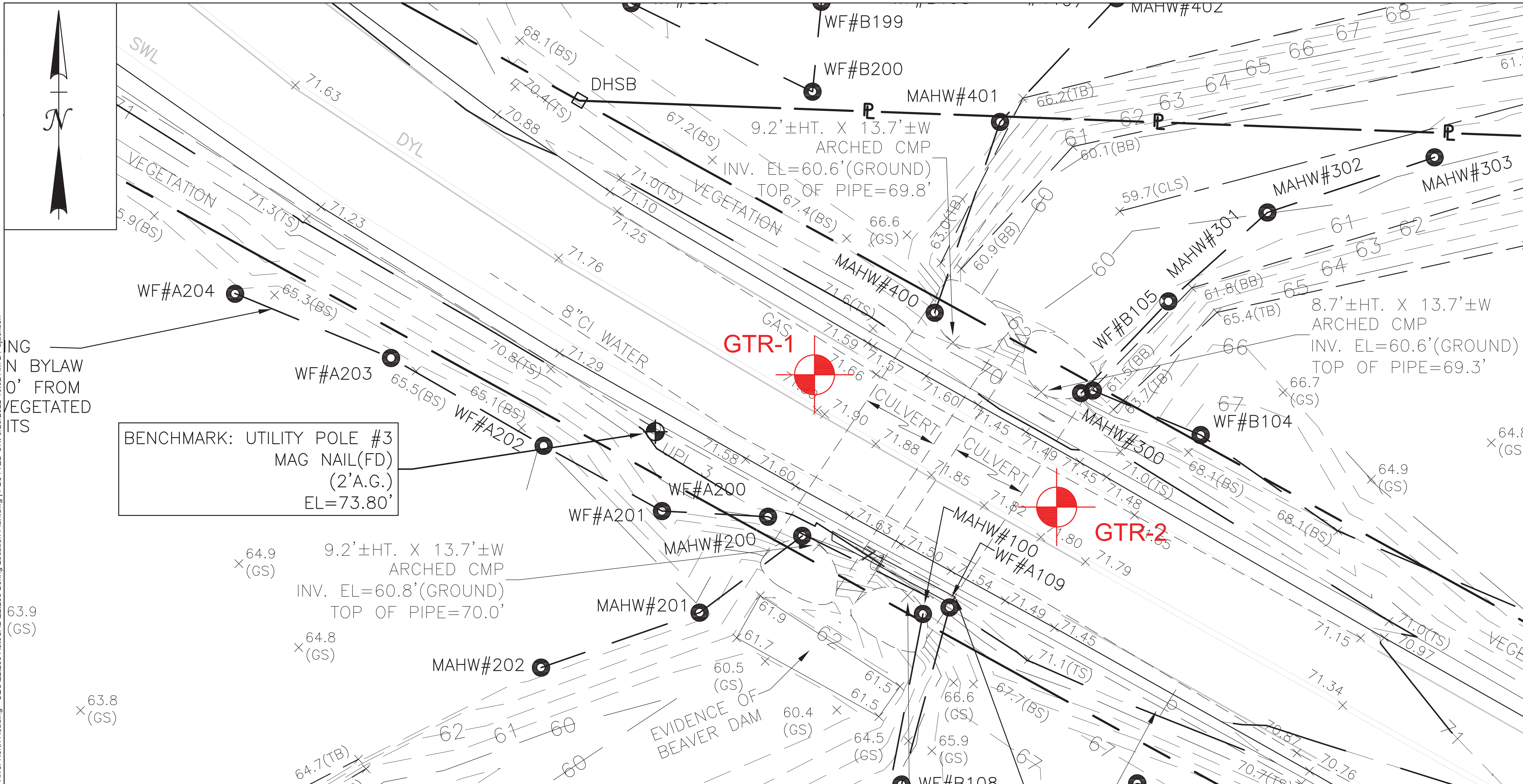
GEOSCIENCES TESTING AND RESEARCH, INC.

55 MIDDLESEX STREET, SUITE 225
NORTH CHELMSFORD, MA. 01863

(TEL) 978-251-9395
(FAX) 978-251-9396

GTR ENGINEERING SINCE 1995

DRAWN BY:	PDD	SCALE:	N/A	DESIGN BY:	
CHK BY:	CAG	PROJECT NO.:	22.259		
DATE:	9/1/2022	SHEET NO.:	FIGURE 1		



LEGEND:

Approximate location and designation of test borings.

NOTES:

1. Borings were performed by Car-Dee Test Boring & Construction and observed by GTR personnel on August 25, 2022.

GTR ENGINEERING SINCE 1995

GEOSCIENCES TESTING AND RESEARCH, INC.

55 MIDDLESEX STREET, SUITE 225
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(FAX) 978-251-9396

DESIGNED BY:	DRAWN BY:	APPROVED BY:
PDD	AMJ	CAG
DATE: 09/26/2022	DATE: 09/26/2022	DATE: 09/26/2022

CLIENT INFO:

SHEET NAME: BORING LOCATIONS

PROJECT NAME: CHESTNUT STREET BRIDGE REPLACEMENT OVER IPSWICH RIVER

PROJECT LOCATION: NORTH READING, MASSACHUSETTS

JOB NO:	SCALE:	SHEET NO:
22.259	N.T.S.	1 OF 1

APPENDIX A
GEOTECHNICAL LIMITATIONS

GEOTECHNICAL LIMITATIONS

1. The analyses and recommendations in this report are based in part upon the data obtained from the subsurface explorations. The nature and extent of variations between these explorations may not become evident until construction. If variations become evident, we will need to re-assess our recommendations provided in this report.
2. The simplified soil profile described in this report is intended to convey trends in subsurface conditions. Limited data was available. The boundaries between the strata are approximate and are idealized to convey trends in the subsurface information. The actual soil transitions are most likely more erratic than presented.
3. Water level readings from the borings are representative at the time of drilling. The data have been reviewed and interpretations have been made in the report. It must be noted, however, that fluctuations in the groundwater level does occur due to variations in rainfall, temperature, and other factors occurring since the measurements were made.
4. In the event that any changes in the nature, function, design, or location of the proposed construction are planned, then the conclusions of this report may become invalid. Geosciences Testing and Research, Inc. (GTR) personnel must review these changes so that they may be incorporated into our report. It is recommended that GTR be provided the opportunity for a general review of the final design and specifications so that our recommendations are properly interpreted and incorporated in the project documents.
5. It is recommended that GTR be retained to provide soil engineering services during the final design and/or construction phases of the project. This will enable compliance with our recommendations and to allow design changes as they become evident during construction as needed.
6. This report has been prepared for the exclusive use of client as related to this project. The report has been carried out in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made.
7. This geotechnical engineering report has been prepared for this project by GTR, is for design purposes only, and is not intended for bidding purposes. Contractors wishing a copy of this report may do so with the understanding that the scope is limited to design issues only.

APPENDIX B
CONTRACT DOCUMENTS

NOTES:

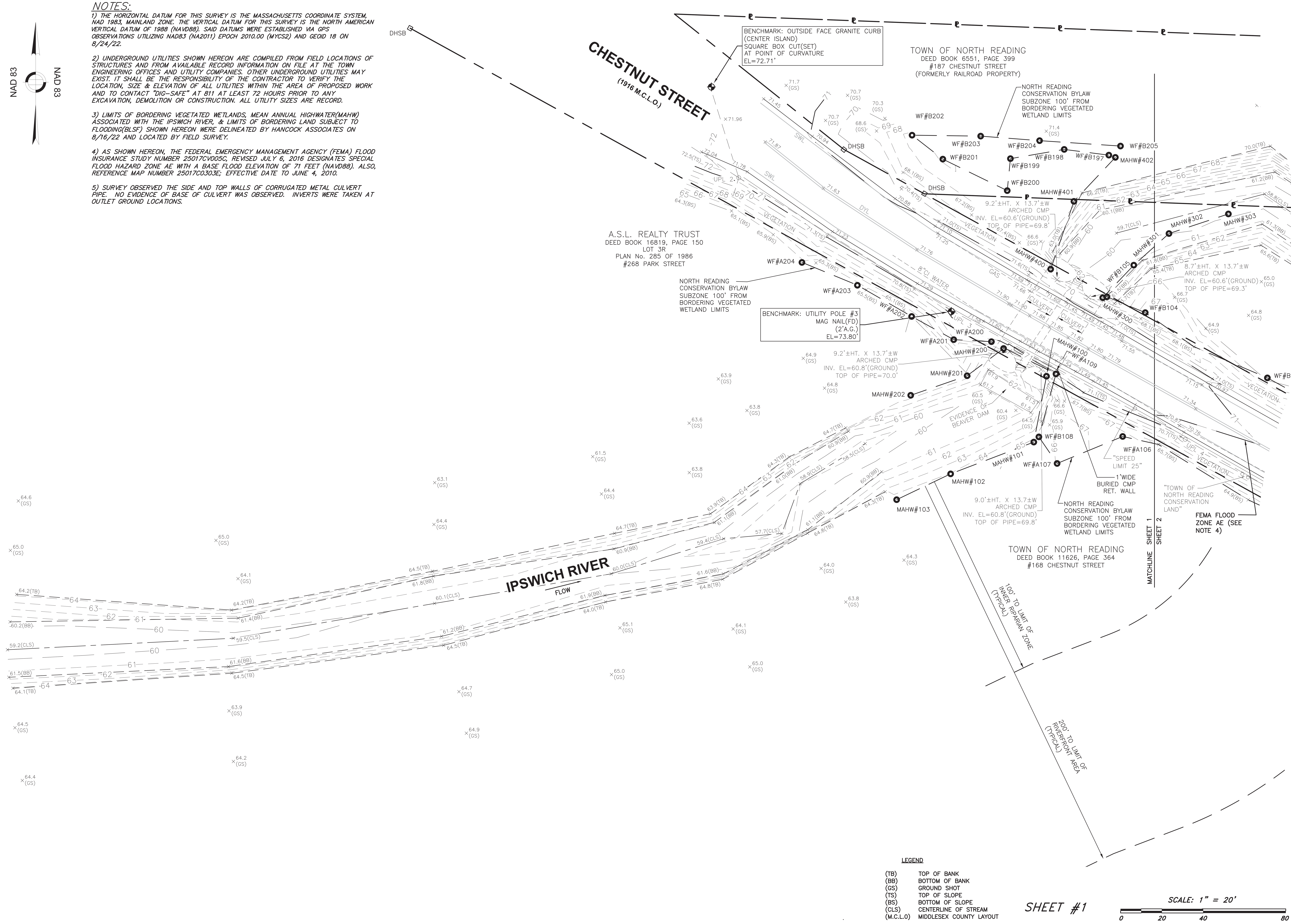
1) THE HORIZONTAL DATUM FOR THIS SURVEY IS THE MASSACHUSETTS COORDINATE SYSTEM, NAD 1983, MAINLAND ZONE. THE VERTICAL DATUM FOR THIS SURVEY IS THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88). SAID DATUMS WERE ESTABLISHED VIA GPS OBSERVATIONS UTILIZING NAD83 (NA2011) EPOCH 2010.00 (MYCS2) AND GEOID 18 ON 8/24/22.

2) UNDERGROUND UTILITIES SHOWN HEREON ARE COMPILED FROM FIELD LOCATIONS OF STRUCTURES AND FROM AVAILABLE RECORD INFORMATION ON FILE AT THE TOWN ENGINEERING OFFICES AND UTILITY COMPANIES. OTHER UNDERGROUND UTILITIES MAY EXIST. IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO VERIFY THE LOCATION, SIZE & ELEVATION OF ALL UTILITIES WITHIN THE AREA OF PROPOSED WORK AND TO CONTACT "DIG-SAFE" AT 811 AT LEAST 72 HOURS PRIOR TO ANY EXCAVATION, DEMOLITION OR CONSTRUCTION. ALL UTILITY SIZES ARE RECORD.

3) LIMITS OF BORDERING VEGETATED WETLANDS, MEAN ANNUAL HIGHWATER(MAHW) ASSOCIATED WITH THE IPSWICH RIVER, & LIMITS OF BORDERING LAND SUBJECT TO FLOODING(BLSF) SHOWN HEREON WERE DELINEATED BY HANCOCK ASSOCIATES ON 8/16/22 AND LOCATED BY FIELD SURVEY.

4) AS SHOWN HEREON, THE FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA) FLOOD INSURANCE STUDY NUMBER 25017CV005C, REVISED JULY 6, 2016 DESIGNATES SPECIAL FLOOD HAZARD ZONE AE WITH A BASE FLOOD ELEVATION OF 71 FEET (NAVD88). ALSO, REFERENCE MAP NUMBER 25017C0303E; EFFECTIVE DATE TO JUNE 4, 2010.

5) SURVEY OBSERVED THE SIDE AND TOP WALLS OF CORRUGATED METAL CULVERT PIPE. NO EVIDENCE OF BASE OF CULVERT WAS OBSERVED. INVERTS WERE TAKEN AT OUTLET GROUND LOCATIONS.



LEGEND

(TB)	TOP OF BANK
(BB)	BOTTOM OF BANK
(GS)	GROUND SHOT
(TS)	TOP OF SLOPE
(BS)	BOTTOM OF SLOPE
(CLS)	CENTERLINE OF STREAM
(M.C.L.O)	MIDDLESEX COUNTY LAYOUT

CHESTNUT STREET OVER IPSWICH RIVER BRIDGE REPLACEMENT

North Reading, Massachusetts 01864

PREPARED FOR:

TEC, INC.

282 Merrimack Street, 2nd floor
Lawrence, Massachusetts 01843

HANCOCK ASSOCIATES

Civil Engineers

Land Surveyors

Wetland Scientists

185 CENTRE STREET, DANVERS, MA 01923
VOICE (978) 777-3050, FAX (978) 774-7816
WWW.HANCOCKASSOCIATES.COM

NO.	BY	APP	DATE	ISSUE/REVISION DESCRIPTION

DATE:	9/8/22	DRAWN BY:	JAH
SCALE:	1"=20'	CHECK BY:	PLP

EXISTING CONDITIONS PLAN IN NORTH READING, MA

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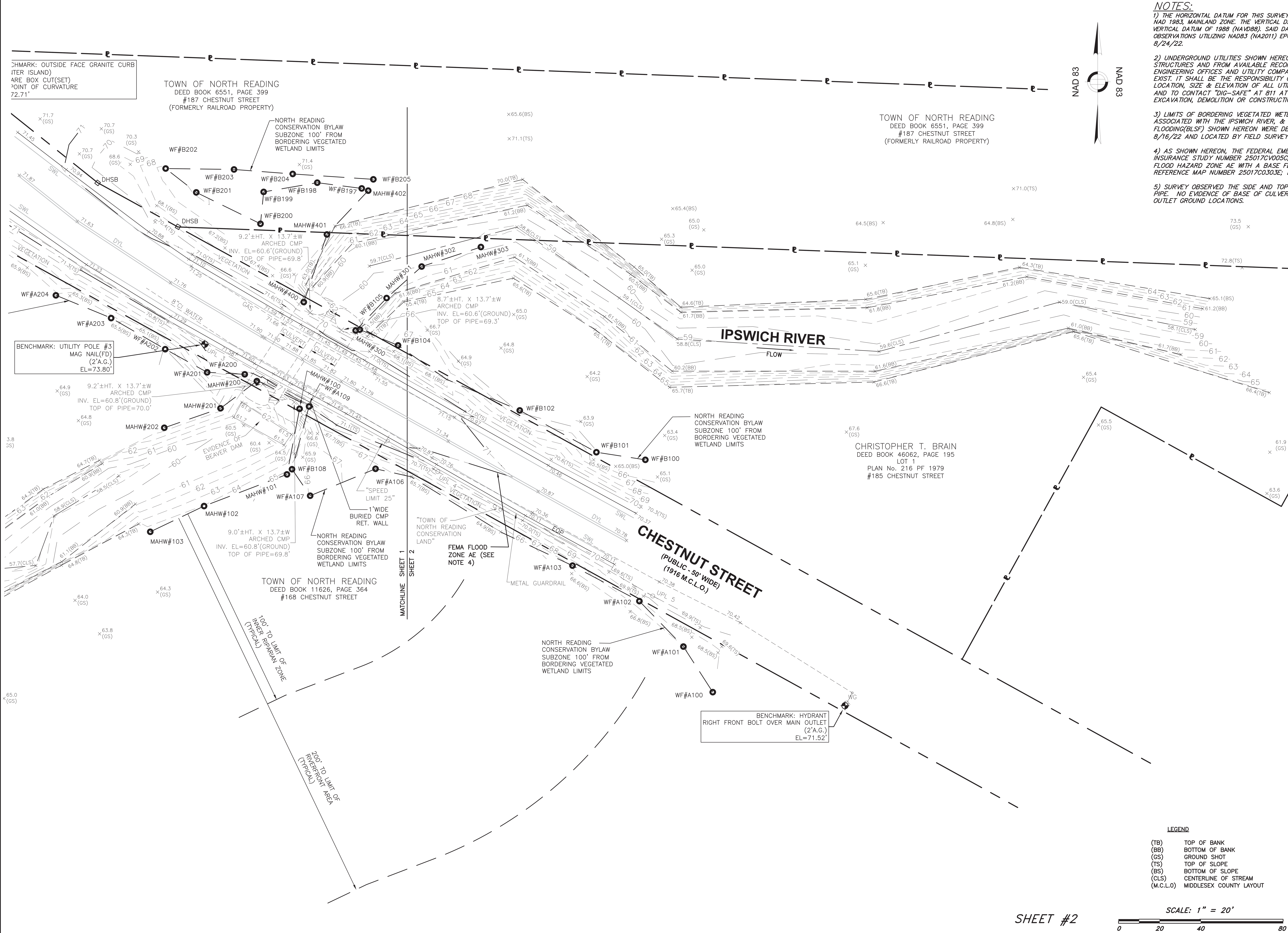
LAYOUT: SHEET

SHEET: 1 OF 2

PROJECT NO.: 26397



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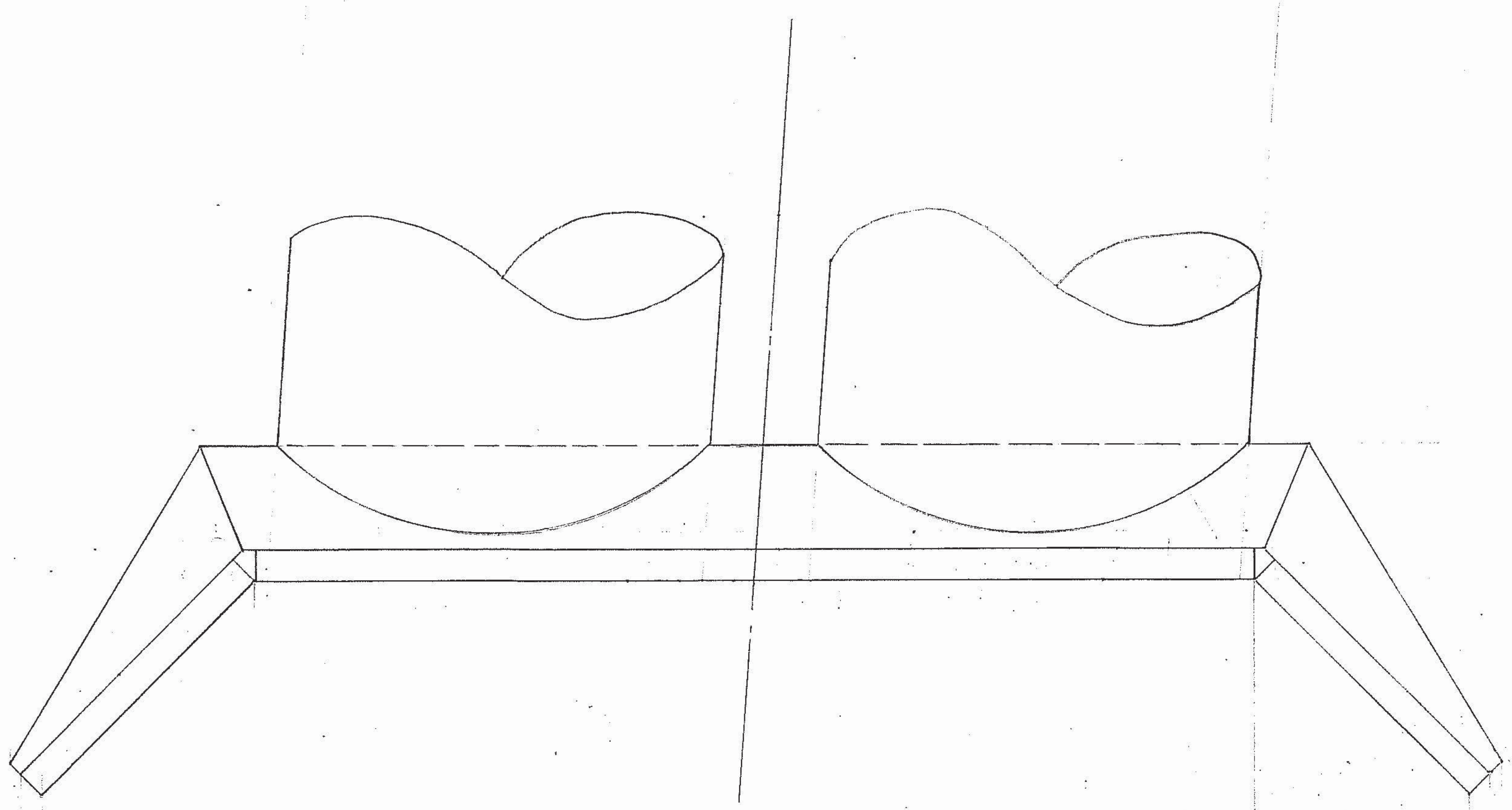
EXISTING CONDITIONS PLAN IN NORTH READING, MA

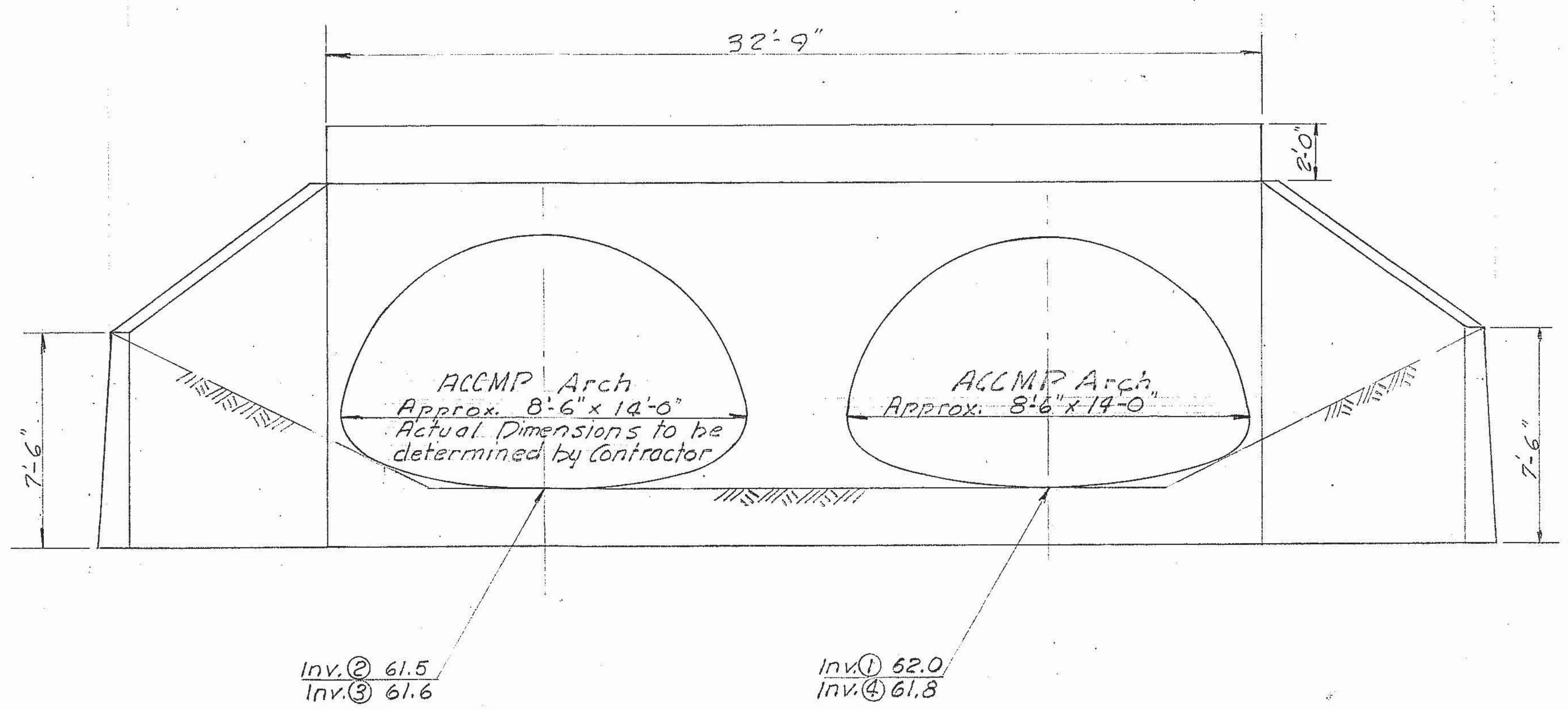
PATH: F:\Civil 3D Projects\26397 - TEC - Chestnut - North Reading

DWG: 26397EC_DOT.dwg
LAYOUT: SHEET
SHEET: 2 OF 2
PROJECT NO.: 26397

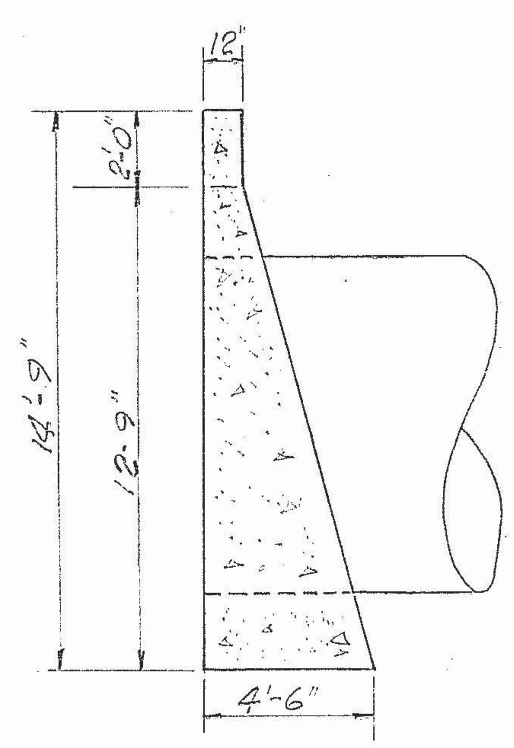
LEGEND

(TB)	TOP OF BANK
(BB)	BOTTOM OF BANK
(GS)	GROUND SHOT
(TS)	TOP OF SLOPE
(BS)	BOTTOM OF SLOPE
(CLS)	CENTERLINE OF STREAM
(M.C.L.O)	MIDDLESEX COUNTY LAYOUT

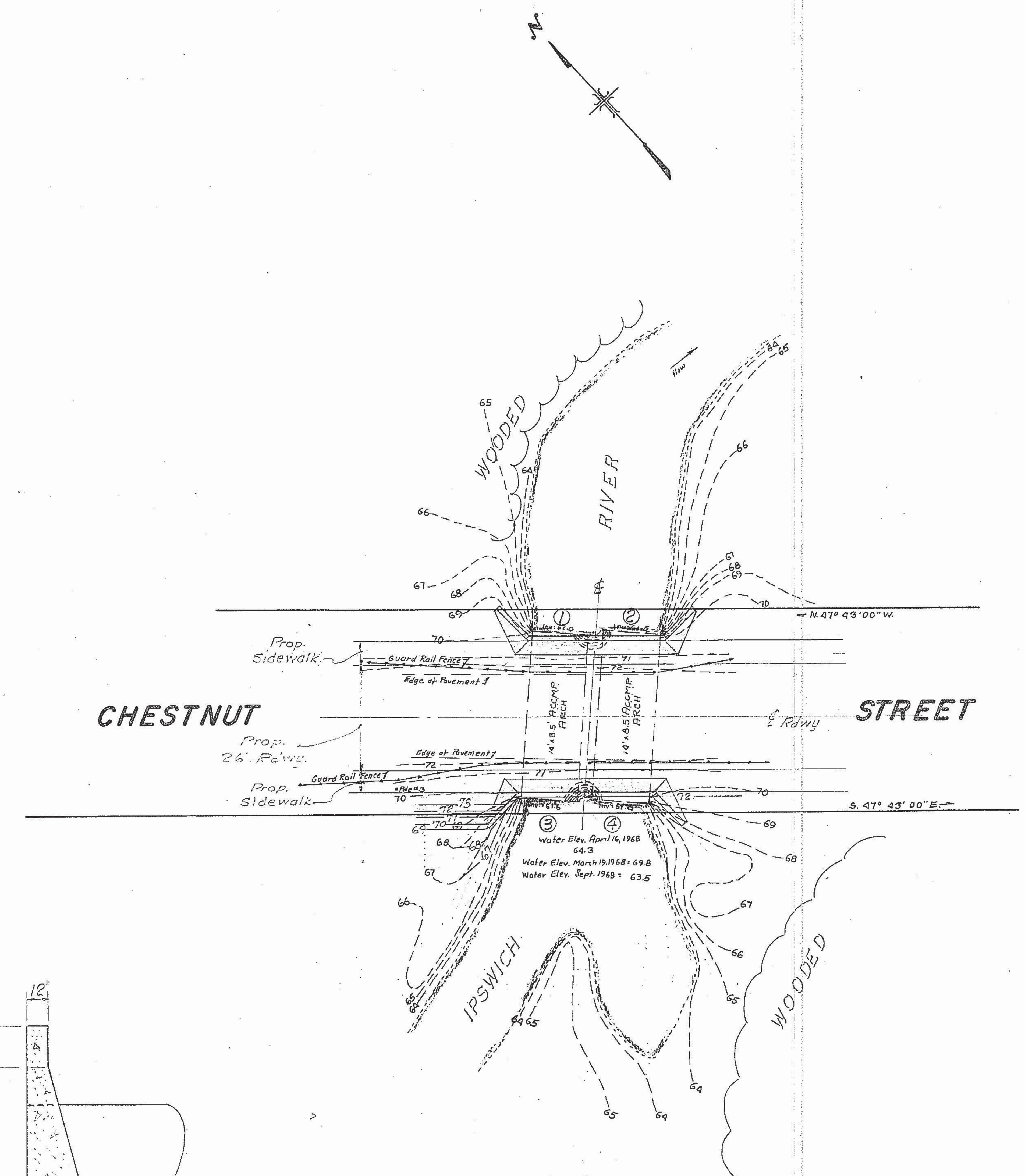




32'-9"
2'-0"
7'-6"
7'-6"
ACCMP Arch
Approx. 8'-6" x 14'-0"
Actual Dimensions to be determined by Contractor
ACCMP Arch
Approx. 8'-6" x 14'-0"
Inv.② 61.5
Inv.③ 61.6
Inv.① 62.0
Inv.④ 61.8



12"
2'-0"
14'-9"
12'-9"
4'-6"



N
WOODED
RIVER
Prop. Sidewalk
Guard Rail Fence
Edge of Pavement
CHESTNUT
STREET
Prop. 26' Rdwy.
Prop. Sidewalk
N.47° 43' 00" W.
S.47° 43' 00" E.
Water Elev. April 16, 1968 66.3
Water Elev. March 19, 1968 = 69.8
Water Elev. Sept. 1968 = 63.5
IPSWICH
WOODED

S-01030

APPENDIX C
TEST BORING LOGS

GEOSCIENCES TESTING AND RESEARCH, INC.

55 Middlesex Street, Suite 225, North Chelmsford, MA.
Phone: (978) 251-9395 www.gtrinc.net

Boring No.	GTR-1
Page:	1 of 2
GTR Job #:	22.259
GTR Rep:	P. Dion
Reviewer:	C. George

Project Name: Chestnut St
Location: Reading, MA

Drilling Co.	Carr - Dee Corp.		
Driller:	Steve DeSimone	Helper(s):	Elijah Muhammad
Start Date:	8/25/2022	End Date:	8/25/2022
Ground Surface Elev (ft):	~ +71.9 ft		
Boring Location:	42.57180, - 071.097050		
Note:			

Equipment	Casing	Sampler	Core
Type	HW	SS	NX
Size I.D.	4"	2	2.16"
Hammer Wt.	140	140	
Hammer Fall	30	30	

Groundwater		Depth (ft)		
Date	Time	Water	Casing	Hole
25-Aug	8:11	9'	35	35

Depth	Casing BPF	Sample Data: No.	Pen/ Recovery	Depth (ft.)	Blows per 6in	Field Test	Description and Classification	Stratum: Description	Additional Data	Notes
0							Top 6" Asphalt	ASPHALT		
		S-1	24/13	6"-2' 6"	9 - 15		S-1 : Medium dense, brown, fine to coarse	6"		
					14 - 12		SAND, little Gravel, trace Silt, dry			
5		S-2	24/16	5' - 7'	3 -2		S-2: Loose, brown, fine SAND, trace Silt, dry	GRANULAR FILL		
					2 - 4					
								8.5'		
10		S-3	24/18	10 ' - 12'	3 - 4		S-3: Loose, gray, fine SAND, trace Silt, wet			1
					3 - 2					
								SAND		
15		S-4	24/10	15' -17'	3 - 3		S-4: Loose, gray, fine SAND, trace Silt			
					4 - 7					
								18.5'		
20		S-5	24/1	20 - 22	14 - 12		S -5: Medium dense, gray, fine to coarse SAND,			2
					10 - 9		some Gravel, trace Silt			
		S-6	24/11	22 - 24	10 - 11		S-6: Medium dense, gray, fine to coarse SAND,			
					14 - 16		little Gravel, trace Silt	SAND AND		
								GRAVEL		
25		S-7	24/10	25 - 27	20 - 20		S-7: Dense, gray, fine to coarse SAND, little			
					12 - 14		Gravel, trace Silt			
										3
		S-8	0/0	29.5	50 < 1"		No Recovery			4
		RC-1	60/52	29.5 - 30.5	5:30			29.5'		

NOTES:
1. First three samples gathered via HAS, the rest were gathered via rotary wash
2. Little recovery, took second sample from 22 - 24 feet
3. Increased resistance of casing at approximately 27 feet
4. Split spoon refusal at 29.5 feet

Order of Sample Description (Modified Burmister)
1. Moisture Content: Dry, Moist, Wet
2. Soil Relative Density or Consistency
3. Color
4. Major Component: Should be capitalized
5. Minor Component: "and" - 35% to 50% minor grain size
"some" - 20% to 35% minor grain size
"little" - 10% to 20% minor grain size
"trace" - < 10% of minor grain size

PENETRATION RESISTANCE (N) GUIDE

Cohesionless Soils (Sands)	Cohesive Soils (Clays)
Relative Density / Blows per Foot	Consistency / Blows per Foot
Very Loose >> 0 - 4	Very Soft >> Below 2
Loose >> 4 - 10	Soft >> 2 - 4
Medium Dense >> 10 - 30	Medium Stiff >> 4 - 8
Dense >> 30 - 50	Stiff >> 8 - 15
Very Dense >> Over 50	Very Stiff >> 15 - 30
	Hard >> Over 30

GEOSCIENCES TESTING AND RESEARCH, INC.

GTR ENGINEERING SINCE 1995

55 Middlesex Street, Suite 225, North Chelmsford, MA.
Phone: (978) 251-9395 www.gtrinc.net

Boring No.	GTR-1
Page:	2 of 2
GTR Job #:	22.259
GTR Rep:	P. Dion
Reviewer:	C. George

Project Name: Chestnut St
Location: Reading, MA

Drilling Co. Carr - Dee Corp.
Driller: Steve DeSimone Helper(s): Elijah Muhammad
Start Date: 8/25/2022 End Date: 8/25/2022
Ground Surface Elev (ft): ~ +71.9 ft
Boring Location: 42.57180, - 071.097050
Note:

Equipment	Casing	Sampler	Core
Type	HW	SS	NX
Size I.D.	4"	2	2.16"
Hammer Wt.	140	140	
Hammer Fall	30	30	

Groundwater Date	Time	Depth (ft) Water	Casing	Hole
25-Aug	8:11	9'	35	35

Depth	Casing BPF	Sample Data No.	Pen/ Recovery	Depth (ft.)	Blows per 6in	Field Test	Description and Classification	Stratum Description	Additional Data	Notes
30		RC-1	60/51	30.5 - 31.5	5:00	RQD =	C-1: Gray, fine to coarse grained, slightly weathered, slightly to moderately fractured, very hard, BIOTITE GRANITE	BIOTITE GRANITE		5
				31.5 - 32.5	5:30	58%				
				32.5 - 33.5	6:15					
				33.5 - 34.5	6:00					
35							End of boring at 34.5 feet below ground surface with 5 ft rock core.	34.5'		
40										
45										
50										
55										

NOTES:
5. Values in "Blows per 6in" Column have units of minutes/foot

Order of Sample Description (Modified Burmister)
1. Moisture Content: Dry, Moist, Wet
2. Soil Relative Density or Consistency
3. Color
4. Major Component: Should be capitalized
5. Minor Component: "and" - 35% to 50% minor grain size
   "some" - 20% to 35% minor grain size
   "little" - 10% to 20% minor grain size
   "trace" - < 10% of minor grain size

PENETRATION RESISTANCE (N) GUIDE

Cohesionless Soils (Sands)	Cohesive Soils (Clays)
Relative Density / Blows per Foot	Consistency / Blows per Foot
Very Loose >> 0 - 4	Very Soft >> Below 2
Loose >> 4 - 10	Soft >> 2 - 4
Medium Dense >> 10 - 30	Medium Stiff >> 4 - 8
Dense >> 30 - 50	Stiff >> 8 - 15
Very Dense >> Over 50	Very Stiff >> 15 - 30
	Hard >> Over 30

GEOSCIENCES TESTING AND RESEARCH, INC.

55 Middlesex Street, Suite 225, North Chelmsford, MA.
Phone: (978) 251-9395 www.gtrinc.net

Boring No.	GTR -2
Page:	1 of 2
GTR Job #:	22.259
GTR Rep:	P. Dion
Reviewer:	C. George

Project Name: Chestnut St
Location: Reading, MA

Drilling Co.	Carr - Dee Corp.		
Driller:	Steve DeSimone	Helper(s):	Elijah Muhammad
Start Date:	8/26/2022	End Date:	8/26/2022
Ground Surface Elev (ft):	~ +71.8 ft		
Boring Location:	42.571795, -071.096870		
Note:			

Equipment	Casing	Sampler	Core
Type	HW	SS	NX
Size I.D.	4"	2	2.16"
Hammer Wt.	140	140	
Hammer Fall	30	30	

Groundwater		Depth (ft)		
Date	Time	Water	Casing	Hole
26-Aug	8:30	8.5'	37.5	37.5

Depth	Casing BPF	Sample Data: No.	Pen/ Recovery	Depth (ft.)	Blows per 6in	Field Test	Description and Classification	Stratum: Description	Additional Data	Notes
0							Top 6" Asphalt	ASPHALT		
		S-1	24/15	0.5 - 2.5	20 -18		S-1: Dense, brown, fine to coarse SAND, some	6"		
					21 -23		Gravel, trace Silt, dry			
5		S-2	24/7	5 - 7	5 -4		S-2: Loose, brown, fine to coarse SAND and	GRANULAR FILL		
					5 - 9		Gravel, trace Silt, dry			
								8.5'		
10		S-3	24/11	10 - 12	WR - 2		S-3: Loose, gray, fine to medium SAND, little			1
					3 - 2		Gravel, wet	SAND		
								13.5'		
15		S-4	24/11	15 -17	7 - 13		S-4: Medium dense, gray, fine to coarse SAND			
					17 -15		and Gravel, trace Silt			
		S-5	24/17	17 - 19	16 - 12		S-5: Medium dense, gray, fine to coarse SAND,			
					8 -10		little Gravel, trace Silt			
								SAND AND		
20		S-6	24/11	20 -22	16 - 12		S-6: Dense, gray, fine to Coarse SAND, some	GRAVEL		
					19 -21		Gravel, trace Silt			
										2
25		S-7	24/8	25 - 27	11 -10		S-7: Medium dense, gray, fine to coarse SAND,			
					12 - 16		some Gravel, trace Silt			3
		RC-1	40/60	27.5 - 28.5	7:00	RQD =	C-1: Black,fine grained, slightly weathered,	27.5'		
				28.5 - 29.5	8:00	37%	moderately fractured, very hard, BIOTITE	BIOTITE		4
				29.5 - 30.5	5:30		GRANITE	GRANITE		
				30.5 - 31.5	7:15					

NOTES:
1. First three sample gathered via HSA, last four samples gathered via rotary wash
2. Increased resitance to casing hammer at approximately 23 feet
3. Casing hammer refusal: over 50 blows for 0 inches
4. Values in "Blows per 6in" Column have units of minutes/foot

Order of Sample Description (Modified Burmister)
1. Moisture Content: Dry, Moist, Wet
2. Soil Relative Density or Consistency
3. Color
4. Major Component: Should be capitalized
5. Minor Component: "and" - 35% to 50% minor grain size
   "some" - 20% to 35% minor grain size
   "little" - 10% to 20% minor grain size
   "trace" - < 10% of minor grain size

PENETRATION RESISTANCE (N) GUIDE

Cohesionless Soils (Sands)	Cohesive Soils (Clays)
Relative Density / Blows per Foot	Consistency / Blows per Foot
Very Loose >> 0 - 4	Very Soft >> Below 2
Loose >> 4 - 10	Soft >> 2 - 4
Medium Dense >> 10 - 30	Medium Stiff >> 4 - 8
Dense >> 30 - 50	Stiff >> 8 - 15
Very Dense >> Over 50	Very Stiff >> 15 - 30
	Hard >> Over 30

GEOSCIENCES TESTING AND RESEARCH, INC.

55 Middlesex Street, Suite 225, North Chelmsford, MA.
Phone: (978) 251-9395 www.gtrinc.net

Boring No.	GTR-2
Page:	2 of 2
GTR Job #:	22.259
GTR Rep:	P. Dion
Reviewer:	C. George

Project Name: Chestnut St
Location: Reading, MA

Drilling Co. Carr - Dee Corp.
Driller: Steve DeSimone Helper(s): Elijah Muhammad
Start Date: 8/26/2022 End Date: 8/26/2022
Ground Surface Elev (ft): ~ +71.8 ft
Boring Location: 42.571795, -071.096870
Note:

Equipment	Casing	Sampler	Core
Type	HW	SS	NX
Size I.D.	4"	2	2.16"
Hammer Wt.	140	140	
Hammer Fall	30	30	

Groundwater Date	Time	Depth (ft) Water	Casing	Hole
26-Aug	8:30	8.5'	37.5	37.5

Depth	Casing BPF	No.	Pen/ Recovery	Depth (ft.)	Blows per 6in	Field Test	Description and Classification	Stratum Description	Additional Data	Notes
30				31.5 - 32.5	4:30					5
		RC-2	51/60	32.5 - 33.5	6:45	RQD =	C-2: Gray, fine to medium grained, slightly weathered, moderately to highly fractured, very hard, BIOTITE GRANITE	BIOTITE GRANITE		
				33.5 - 34.5	7:15	40%				
				34.5 - 35.5	7:45					
35				35.5 - 36.5	6:15					
				36.5 - 37.5	12:15					
							End of boring at 37.5 feet below ground surface with 10 ft rock core.	37.5'		
40										
45										
50										
55										

NOTES:
5. Driller increased drilling pressure.

Order of Sample Description (Modified Burmister)
1. Moisture Content: Dry, Moist, Wet
2. Soil Relative Density or Consistency
3. Color
4. Major Component: Should be capitalized
5. Minor Component: "and" - 35% to 50% minor grain size
   "some" - 20% to 35% minor grain size
   "little" - 10% to 20% minor grain size
   "trace" - < 10% of minor grain size

PENETRATION RESISTANCE (N) GUIDE

Cohesionless Soils (Sands)	Cohesive Soils (Clays)
Relative Density / Blows per Foot	Consistency / Blows per Foot
Very Loose >> 0 - 4	Very Soft >> Below 2
Loose >> 4 - 10	Soft >> 2 - 4
Medium Dense >> 10 - 30	Medium Stiff >> 4 - 8
Dense >> 30 - 50	Stiff >> 8 - 15
Very Dense >> Over 50	Very Stiff >> 15 - 30
	Hard >> Over 30

GEOSCIENCES TESTING AND RESEARCH, INC.

55 Middlesex Street, Suite 225, North Chelmsford, MA.
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GTR ENGINEERING SINCE 1995

ROCK CORE PHOTO LOG

GTR-1 | RC-1 dry
GTR-2 | RC-1, RC-2 dry

GTR-1 | RC-1 wet
GTR-2 | RC-1, RC-2 wet

Project:	Chestnut Street over the Ipswich River Bridge Replacement
Project Number:	22.259
Drawn By:	P. Dion
Date:	09/06/2022

APPENDIX D
CALCULATIONS

22.259 CHESTNUT STREET OVER IPSWICH RIVER
NORTH READING, MASSACHUSETTS
AASHTO LRFD (9th Ed.)
CORRECTED SPT N VALUES

Boring GTR-1 N value Correction

Layer	DEPTH	FIELD N VALUE	Unit Weight (pcf)	Effective Unit Weight	Effective Stress (ksf)	C_N	N_{60}	$N1_{60}$
GRAN. FILL	2	29	125	125	0.25	1.70	39	66
	6	4	125	62.6	0.50	1.47	5	8
SAND	11	7	125	62.6	0.81	1.30	9	12
	16	7	125	62.6	1.13	1.19	9	11
SAND AND GRAVEL	21	22	125	62.6	1.44	1.11	29	33
	23	25	125	62.6	1.56	1.08	33	36
	26	31	125	62.6	1.75	1.05	41	43

Boring GTR-2 N value Correction

Layer	DEPTH	FIELD N VALUE	Unit Weight (pcf)	Effective Unit Weight	Effective Stress (ksf)	C_N	N_{60}	$N1_{60}$
GRAN. FILL	2	39	125	125	0.25	1.70	52	88
	6	9	125	62.6	0.50	1.47	12	18
SAND	11	5	125	62.6	0.81	1.30	7	9
SAND AND GRAVEL	16	30	125	62.6	1.13	1.19	40	48
	21	20	125	62.6	1.44	1.11	27	30
	23	31	125	62.6	1.56	1.08	41	45
	26	22	125	62.6	1.75	1.05	29	31

ER (hammer efficiency) = 0.8 for automatic trip hammer

Where:

$$N1 = C_N N \qquad (10.4.6.2.4\text{-}1)$$

$$C_N = [0.77 \log_{10}(40/\sigma'_v)], \text{ and } C_N < 2.0$$

$$N_{60} = (ER / 60\%)N \qquad (10.4.6.2.4\text{-}2)$$

Approximate ranges for $N1_{60}$ values :

Layer	$N1_{60}$	$N1_{60\,Avg}$	Recomm. Φf values
G. FILL	8-88	45	32
SAND	9-12	11	32
SAND & GRAVEL	30-48	38	35

N160	Φf	
<4	25-30	
4	27-32	
10	30-35	← Sand
30	35-40	← Gran. Fill/Sand and Gravel

22.259 CHESTNUT STREET OVER IPSWICH RIVER
NORTH READING, MASSACHUSETTS
AASHTO LRFD (9th Ed.)
RECOMMENDED SOIL DESIGN PARAMETERS

Material	Angle of Internal Friction, Φf (degrees)	Wall Friction Angle, δ (degrees)*
Gravel Borrow	35	17
Sand	32	17
Granular Fill	32	17
Sand and Gravel	35	17

*Table C3.11.5.3.1 Friction Angle for dissimilar Materials

Interpolated Active and Passive Coefficients with Wall Friction				
Material	*K_p	Interpolated Reduction Factor	Actual K_p	└K_a
Gravel Borrow	10.5	0.664	7.0	0.25
Sand	6.75	0.789	5.3	0.28
Granular Fill	7.5	0.739	5.5	0.28
Sand and Gravel	10.5	0.664	7.0	0.25

* Values where obtained from Figure 3.11.5.4.1
└Assumes walls will be vertical (θ = 90°) and fill will be flush with top of wall (β=0) (Eq. 3.11.5.3-1 AASHTO)

Ko at Rest Pressure

Material	Ko
Gravel Borrow	0.426
Sand	0.470
Granular Fill	0.470
Sand and Gravel	0.426

Where Ko=1-Sin(φ) Eq. 3.11.5.2-1 AASHTO

Recommended Values			
Material	K_p	K_a	K_o
Gravel Borrow	7	0.30	0.5
Sand	5.5	0.30	0.5
Granular Fill	5.5	0.25	0.5
Sand and Gravel	7	0.30	0.5

Determine Coefficient of Friction

Resistance Factor = 0.9 from Table 10.5.5.2.2-1 Precast concrete on sand

0.8tanø' for Precast concrete footing from 10.6.3.4-2
ø' = 36 degrees for crushed stone, 0.8*tan(36) = 0.58

22.259 CHESTNUT STREET OVER IPSWICH RIVER
NORTH READING, MASSACHUSETTS
AASHTO LRFD (9th Ed.)
SEISMIC SITE CLASS CALCULATIONS

Peck et al.
AASHTO C3.10.3.1-1: Method B

Granular Fill		Sand		Sand and Gravel		Bedrock	
Boring Number	Blow[1] Count	Boring Number	Blow Count	Boring Number	Blow Count	Boring Number	Blow Count
GTR-1	29	GTR-1	7	GTR-1	22	GTR-1	100
	4		7		25	GTR-2	100
GTR-2	39	GTR-2	5		32		
	9			GTR-2	40		
					30		
					22		
Avg N_1	20	Avg N_2	6	Avg N_3	29	Avg N_4	100
d_1	10	d_2	7	d_3	15	d_4	68
d/N	0.49	d/N	1.11	d/N	0.53	d/N	0.68

AASHTO C3.10.3.1-1: Method B

$$\bar{N} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{N_i}}$$

$\bar{N}$	36

Seimic Site Class D: Stiff Soil with 15 < $\bar{N}$ < 50 blows per foot

22.259 CHESTNUT STREET OVER IPSWICH RIVER
NORTH READING, MASSACHUSETTS
AASHTO LRFD (9th Ed.)
RECOMMENDED SEISMIC DESIGN PARAMETERS

Mass DOT LRFD Bridge Manual and AASHTO Bridge Specifications for LRFD Seismic Bridge Design

Parameter	Value
Site Class	D
Peak seismic ground acceleration (PGA) coefficient on rock for site class B	0.082 g
Horiz rock response spectral acceleration coefficient at .2 sec period (Ss) for site class B	0.165 g
Horiz rock response spectral acceleration coefficient at 1 sec period (S_1) for site class B	0.040 g
Site factor for converting PGA from site class B to site class D	1.6
Site factor for converting Ss from site class B to site class D	1.6
Site factor for converting S1 from site class B to site class D	2.4
Peak seismic ground acceleration (PGA) coefficient on rock for site class D	0.13
Horiz rock response spectral acceleration coefficient at .2 sec period (Ss) for site class D	0.264
Horiz rock response spectral acceleration coefficient at 1 sec period (S1) for site class D	0.096 g

Table 3.5-1—Partitions for Seismic Design Categories A, B, C, and D

Value of $S_{D1} = F_v S_1$	SDC
$S_{D1} < 0.15$	A
$0.15 \leq S_{D1} < 0.30$	B
$0.30 \leq S_{D1} < 0.50$	C
$0.50 \leq S_{D1}$	D

22.259 CHESTNUT STREET OVER IPSWICH RIVER
NORTH READING, MASSACHUSETTS
AASHTO LRFD (9th Ed.)
BEARING CAPACITY FOR STONE FILL OR SAND AND GRAVEL

$q_n = cN_cs_ci_c + \gamma D_fN_qs_qd_qi_qC_{wq} + 0.5\gamma BN_gs_gi_gC_{wg}$ AASHTO 10.6.3.1.2a

$q_R = q_n{*}f_b$

q_n = nominal bearing resistance - psf

q_R = factored bearing resistance - psf

f_b = resistance factor = 0.45 - dimensionless

c = cohesion of soil - psf

γ = total unit weight of soil - pcf

D_f = Depth to bottom of footing - ft

B' = effective footing width - ft

L = footing width - ft

ϕ= soil friction angle - degrees

N_c, N_q, N_γ = bearing capacity factors - non dimensional

s_c,s_q,s_g = shape factors - non-dimensional

d_q = depth shearing resistance factor - non dimensional

i_c,i_q,i_g = inclination factors - typically = 1 as horizontal loads are usually unknown - non dimensional

C_{wq}, C_{wg} = groundwater location factors - non dimensional

c = 0	ϕ = 35	s_c = 1.09	i_c = 1.00
γ = 125	N_c = 46.1	s_q = 1.09	i_q = 1.00
D_f = 4	N_q = 33.3	s_γ = 0.95	i_g = 1.00
B' = 3.85	N_γ = 48	d_q = 1.2	
L = 30	C_{wq} = 0.5	C_{wg} = 0.5	

Notes:
1. Over Excavate any loose Sand to the m. dense/dense Sand and Gravel Layer.
2. No abutment scour from Hydraulics

q_n =	0	psf	(cohesion term)
q_n =	10932	psf	(embedment term)
q_n =	5479	psf	(footing width term)
q_n =	16410	psf	(total nominal resistance)

q_R = 7385 psf = 7.38 ksf (factored bearing resistance)

$q=q_R$ = 7.38 ksf = 3.69 tsf

22.259 CHESTNUT STREET OVER IPSWICH RIVER
NORTH READING, MASSACHUSETTS
AASHTO LRFD (9th Ed.)
ELASTIC SETTLEMENT, HOUGH METHOD (GTR-1)

Se = ΣΔHi — AASHTO 10.6.2.4.2B

ΔHi = Hc*(1/C')*log(σo'+Δσv/σo') — 10.6.2.4.2b-2

n = number of soil layers within zone of stress influence

ΔHi = elastic settlement of layer (ft)

Hc = initial height of layer (ft)

C' = bearing capacity index — Figure 10.6.2.4.2b-1

σo' = initial vertical effective stress at the midpoint of the layer (ksf)

Δσv = increase in vertical stress at the midpoint of the layer (ksf)

Check Settlement at Center Footing

$q_o = q_R$=	5.5	ksf	water depth =	9	
footing size =	3.85	ft	footing depth =	17	

Depth Below Grade (ft)	Depth Below Footing (ft)	Depth Below Footing to midpoint (B)	Layer Width H_c (feet)	$N1_{60}$	C'	$\Delta\sigma v$ (ksf)	γ (kcf)	σ_o' (ksf)	S_e (in)
17	0			-			0.063	1.031	-
31	14	7.00	14	36	100	1.93	0.063	1.470	0.61
						Total Settlement =			0.61