



College Street NE Extension Project Roadway Retaining Walls

Type, Size, & Location Study

November 2022 | Draft Report



Project No. 2613.01-3
November 1, 2022

City of Lacey Public Works
420 College Street SE
Lacey, Washington 98503

Attention: Mr. Martin Hoppe

Subject: DRAFT Type, Size, and Location Study
Roadway Retaining Walls
College Street NE Extension Project
Lacey, Washington

Mr. Hoppe:

In accordance with your request and written authorization, Zipper Geo Associates, LLC (ZGA) has completed a type, size, and location study related to roadway retaining walls that will be designed and constructed as part of the College Street NE Extension project. This report was completed in general accordance with our *Professional Services Agreement* (PW 2020-41) dated July 8, 2022. We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please don't hesitate to contact us.

Sincerely,
Zipper Geo Associates, LLC

Xx/xx/xx

Robert A. Ross, P.E..
Principal

Justin L. Brooks
Project Geologist

TABLE OF CONTENTS

1.	Introduction	1
2.	Project Understanding	1
3.	Existing Site Surface Conditions And Constraints	2
3.1	Sta. 32+00 to 34+36 (Walls 1 & 2).....	2
3.2	Sta. 34+36 to 38+00 (Walls 3 & 4).....	3
3.3	Sta. 38+00 to 42+60 (Walls 4 & 5).....	3
4.	Subsurface Soil & Groundwater Conditions And Constraints	4
4.1	General.....	4
4.2	Geologic Setting	5
4.3	Retaining Wall 1 – Soil and Groundwater Conditions.....	5
4.4	Retaining Wall 2 – Soil and Groundwater Conditions.....	5
4.5	Retaining Wall 3 – Soil and Groundwater Conditions.....	6
4.6	Retaining Walls 4 & 5 – Soil and Groundwater Conditions.....	7
4.7	Design Permanent Cut and Fill Slope Inclinations	7
5.	Traffic And Pedestrian Barrier Constraints	7
6.	Structural Geometric Requirements	8

List of Tables

Table 1: Proposed Retaining Walls.....	2
Table 2: Recommended Permanent Cut Slope Angles.....	7

List of Figures

Figure 1: Site and Exploration Plan

Figure 2: Schematic Wall Sections

List of Appendices

Appendix A: Subsurface Exploration Procedures and Logs

1. INTRODUCTION

On behalf of the City of Lacey Public Works Department (the City), ZGA has prepared this Type, Size, and Location (TS&L) study related to roadway retaining walls associated with the proposed College Street NE Extension project (the Project). The goal of this study was to identify controlling factors related to retaining walls that may impact overall geometric design and right-of-way acquisition decisions for the Project. In preparing this study, we evaluated the following factors related to retaining walls that could impact design decisions for the project:

- Subsurface soil and groundwater conditions
- Feasibility of preferred retaining wall system
- Existing utility conflicts
- Geometric factors including horizontal and vertical requirements, restrictions and clearances
- Maximum temporary and permanent cut/fill slope inclinations

The following documents, files, and information provide the basis for this TS&L report:

- Preliminary project autoCAD drawing files showing existing conditions, proposed roadway geometry, and cross-sections provide by the City on April 26, 2022

Section 2 of this report provides a description of the project and proposed retaining walls based on our current understanding and review of the documents referenced above. Subsequent sections of this report present our conclusions regarding how various factors may impact design decisions and typical roadway section width requirements as related to proposed retaining walls. Our conclusions are also represented graphically in the attached Figure 2, Schematic Wall Sections.

2. PROJECT UNDERSTANDING

The Project consists of widening existing portions of College Street NE between 6th Avenue NE and 8th Avenue NE, and new roadway extending College Street NE between 8th Avenue NE and 15th Avenue NE. The current right-of-way (ROW) width is inadequate to support proposed typical roadway sections. Proposed grade changes along ROW limits will be accommodated via cut/fill slopes and new retaining walls. Retaining walls may be utilized to limit new ROW acquisition requirements.

Based on preliminary design information provided by the City, we understand that five (5) new retaining walls are under consideration. However, if feasible, grade changes in the vicinity of the currently-proposed retaining walls may be accommodated by other means such as cut/fill slopes. We understand the retaining walls will be constructed with the RediRock retaining wall system. Basic information regarding the proposed retaining walls, as indicated in current design files provided by the City is provided below in Table 1. The maximum exposed heights of retaining walls in Table 1 are likely to change pending final design.

Table 1: Proposed Retaining Walls

Wall No.	Approximate Wall Limits¹	Wall Type (cut/fill)	Maximum Exposed Height² (ft)
1	Sta. 30+00 to 32+86, RT	Fill	4 ft
2	Sta. 32+00 to 34+18, LT	Cut	8 ft
3	Sta. 34+45 to 37+00, LT	Cut	5 ft
4	Sta. 36+50 to 42+60, RT	Fill	5 ft
5	Sta. 40+25 to 41+25, RT	Fill	3 ft

3. EXISTING SITE SURFACE CONDITIONS AND CONSTRAINTS

3.1 STA. 32+00 TO 34+36 (WALLS 1 & 2)

The proposed roadway alignment from the southern terminus of the project (approximately Sta. 32+00) extending north to the intersection of College St. NE with 8th Avenue NE (approximately Sta. 34+36) traverses along the existing College St. NE alignment and unimproved portions of the ROW west of the existing roadway. The existing ROW in this area is 64 feet wide and does not share a centerline with the existing roadway. Based on our conversations with the City, we understand the City has a slope easement east of the east ROW limits. However, the exact limits of this easement were unknown at the time this report was prepared.

This ROW along this segment is bordered to the east by developed residential properties. The closest existing single-family home is located about 20 feet east of the east ROW limits. There is an existing wood fence located along the east edge of the ROW which will likely be impacted during retaining wall construction.

The ROW along this segment is bordered to the west by a single developed residential property (705 College St. NE). The existing home on this property is located about 66 feet west of the ROW. North of the existing home, the ROW is bordered to the west by an existing property currently utilized as a house of worship. There are existing site features located on this property such as a parking lot and rockery that are located in close proximity to the ROW which may be impacted during retaining wall construction. Between the existing roadway's edge of pavement and west ROW limits, there are existing, relatively large-caliper conifer trees and other landscape features that will be impacted during retaining wall construction.

Within the existing roadway limits, the ground surface generally slopes gently downward towards the north. East of the existing roadway limits, the ground surface generally slopes steeply downwards to the level surfaces of existing residential properties. West of the existing roadway limits, the ground surface generally slopes gently upward to the west ROW limits.

Preliminary roadway sections indicating widening to the east of the existing roadway may be accomplished by placing fill on the existing slope. In order to maintain stability of fill placed on slopes,

¹ RT refers to the right (or west side of the ROW) and LT refers to the left (or east side of the ROW).

² Does not include embedment depth below finished grade at bottom of wall (typically 1 to 2 ft).

prior to placing the fill, existing slopes should be terraced. Each terrace should have a height ranging from a minimum of one (1) foot and a maximum of five (5) feet.

Based on information provided by the City, the following utilities are present near the proposed retaining wall alignments:

- Underground communication, cable TV, and power located between the east edge of the existing roadway and the ROW. These utilities may be impacted during construction of Retaining Wall 1.
- Underground gas located along and just outside of the east ROW limits. This utility may be impacted during construction of Retaining Wall 1.

3.2 STA. 34+36 TO 38+00 (WALLS 3 & 4)

From Sta. 34+36 to 38+00, the alignment generally traverses through an undeveloped portion of the College St. NE ROW. The existing ROW in this area is 64 feet wide.

This ROW along this segment is bordered to the east by developed residential properties. The closest existing single-family home (4600 8th Ave. NE) is located about 24 feet east of the ROW limits. However, there appears to be an existing structure located at about Sta. 37+31 located about 3.5 feet east of the ROW limits associated with the residential property located at 825 Westminster Ct NE. This structure may be impacted during retaining wall construction. Additionally, there is an existing fence located along the east ROW limits that may be impacted during Retaining Wall 4 construction.

The ROW along this segment is bordered to the west by an existing property currently utilized as a house of worship (875 College St. NE). At its closest point, the main structure associated with this property is located about 24 feet west of the ROW. However, there are other existing improvements including landscaping, trees, a rockery, a carport, curbs, a wood and brick sign, and fencing located in relatively close proximity to the west ROW that may be impacted during Retaining Wall 3 construction.

The ground surface within the current surveyed limits in this segment generally slopes gently downward from west to east.

Based on information provided by the City, the following utilities are present near the proposed retaining wall alignments:

- There appears to be several underground water service utilities located in close proximity to the Wall 3 alignment. These utilities may be impacted during Wall 3 construction.
- At about Sta. 35+86, there is an existing electrical transformer box surrounded by a retaining wall. This utility may be impacted during Wall 3 construction.
- Underground communications located in close proximity to the east ROW. This utility may impact Wall 4 construction.

3.3 STA. 38+00 TO 42+60 (WALLS 4 & 5)

From Sta. 38+00 to 42.60, the alignment generally traverses through a partially developed portion of the College St. NE ROW. The existing ROW in this area ranges from 74 to 82 feet wide.

Between Sta. 38+00 to 39+46, the ROW along this segment is bordered to the east by developed residential properties. The closest existing single-family home is located about 67 feet east of the ROW limits. However, there appears to be existing ancillary structures associated with these properties (829 & 833 Westminster Ct NE) located within about 3 to 5 feet east of the ROW limits. These structures may be impacted by Wall 4 construction.

Between Sta. 39+46 to 40+30, the ROW is bordered to the east by a City easement and an undeveloped parcel owned by the City beyond. There appears to be no existing structures in this area.

Between Sta. 40+30 to 42+60, the ROW is bordered to the east by a 20 foot wide City easement and a developed residential property beyond. There are two existing structures located on this parcel located at least 90 feet east of the easement line.

The ROW along this segment is bordered to the west by developed residential properties. The closest existing single-family home is located about 50 feet west of the ROW limits. However, there are existing improvements located in close proximity to Wall 5 that may be impacted during construction.

The ground surface within the current surveyed limits in this segment generally slopes gently downward in varied directions.

Based on information provided by the City, the following utilities are present near the proposed retaining wall alignments:

- Underground communications located in close proximity to the east ROW limits. This utility may impact Wall 4 construction.
- Utilities that serve the existing single-family homes located along the west side of the ROW may impact Wall 5 construction.

4. SUBSURFACE SOIL & GROUNDWATER CONDITIONS AND CONSTRAINTS

4.1 GENERAL

Subsurface soil and groundwater conditions along the proposed retaining wall alignments were evaluated through review of published geologic mapping and the completion of twelve (12) geotechnical test borings. The borings were completed to depths ranging from about 10 to 20 feet below the existing ground surface. Approximate locations of borings completed on the project site are presented on the attached Figure 1, Site and Exploration Plan.

Soils were visually described during recovery in general accordance with the Explanation of Exploration Logs provided in Appendix A. Detailed descriptive logs of the subsurface explorations and the procedures utilized in the subsurface exploration program are presented in Appendix A. Mapped surficial geology and generalized descriptions of subsurface soil conditions observed in specific areas of the site are presented below. Please refer to the exploration logs in Appendix A for a more detailed description of the conditions encountered at the exploration locations. Stratification boundaries on the boring logs represent the approximate depth of changes in soil types, although the transition between materials may have been gradual. If variations become apparent during construction, it may be necessary to reevaluate the recommendations of this report.

4.2 GEOLOGIC SETTING

Site geology was evaluated through review of geologic mapping available from the Washington State Department of Natural Resources' Washington Geologic Information Portal (geologyportal.dnr.wa.gov). Surficial geologic mapping from the Geologic Map of the Lacey 7.5-minute Quadrangle indicates the geologic sequence at the site consists of latest Vashon recessional outwash sand and minor silt (Q_{gos}) underlain by Vashon recessional outwash (Q_{go}). The mapping describes the Q_{gos} unit as:

“Moderately wellsorted, moderately to well-rounded, fine- to medium-grained sand with minor silt; noncohesive and highly permeable; thickness inferred from wells reaches up to 100 ft; deposited in and around the margins of glacial lakes; surrounds numerous steep-walled lakes and depressions (kettles), evidence that this unit was largely deposited during deglaciation when there was stagnant ice occupying much of the southern Puget Lowland.”

The mapping describes the Q_{go} unit as:

“Recessional and proglacial stratified, moderately to well-rounded, poorly to moderately sorted outwash sand and gravel of northern or mixed northern and Cascade source, locally containing silt and clay; also contains lacustrine deposits and ice-contact stratified drift. Some areas mapped as unit Q_{go} may instead be advance outwash (unit Q_{ga}), as it is difficult to tell the difference between the two without the presence of an intervening till.”

With the exception of minor areas of fill soils, soils encountered in our borings were generally consistent with the geologic mapping sequence.

4.3 RETAINING WALL 1 – SOIL AND GROUNDWATER CONDITIONS

Subsurface soil and groundwater conditions in the vicinity of Wall 1 were evaluated through the completion of borings B-1 through B-3. Soils encountered in these borings largely consisted of dense to very dense sandy gravel with cobbles and a variable silt content to the completion depths of about 21 to 21.5 feet below existing site grade. The upper 5 to 10 feet of material observed in these borings is interpreted to be fill associated with original construction of College St. NE. Below the fill, material observed in these borings is interpreted to be Vashon recessional outwash (Q_{go}). Groundwater was not observed in these borings at the time of drilling.

We identified the following constraints soil and groundwater conditions may have on ROW acquisition and temporary construction easement requirements for Wall 1.

- Temporary Cut Slope Angles: Temporary excavations for Wall 1 will likely not stand steeper than 1H:1V (horizontal:vertical).

4.4 RETAINING WALL 2 – SOIL AND GROUNDWATER CONDITIONS

Subsurface soil and groundwater conditions in the vicinity of Wall 2 were evaluated through the completion of borings B-4 and B-5. Soils encountered in these borings generally consisted of about 5 feet of very loose to medium dense mulch, topsoil, and sand and gravel with a variable silt content interpreted to be fill soils. Below the fill, soils generally consisted of very dense gravel and cobbles with a variable sand content largely interpreted to be Vashon recessional outwash (Q_{go}) to the completion depths of about 15 to 20.5 feet below the existing ground surface.

We identified the following constraints soil and groundwater conditions may have on ROW acquisition and temporary construction easement requirements for Wall 2.

- Temporary Cut Slope Angles: Temporary excavations for Wall 2 will likely not stand steeper than 1H:1V.
- Bearing Soil Improvement: Very loose to medium dense fill soils, not suitable for retaining wall support may be encountered at foundation subgrade elevation for Wall 2. If encountered, the material will likely require improvement. We anticipate this improvement would consist of over-excavation and replacement of the fill soils to a maximum depth of about 2 feet below the bottom of wall. Such improvement will expand the limits of temporary excavations required to construct the wall.

4.5 RETAINING WALL 3 – SOIL AND GROUNDWATER CONDITIONS

Subsurface soil and groundwater conditions in the vicinity of Wall 3 were evaluated through the completion of borings B-6, B-7, and B-8. Soils encountered in these borings generally consisted of about 5 to 10 feet of loose silty sand and soft to medium stiff sandy silt interpreted to be latest Vashon recessional outwash (Q_{gos}) and/or fill soils. Boring B-6 encountered about 5 feet of the fill/ Q_{gos} soils, and borings B-7 and B-8 encountered about 10 feet. Below the fill/ Q_{gos} , these borings largely encountered medium dense grading to very dense, silt, sand, and gravel interpreted to be Vashon recessional outwash (Q_{go}) soils. These borings were completed in Q_{go} soils at depths ranging from 15.5 to 16 feet below existing site grade.

Groundwater was observed in borings B-6 and B-7 at about 10 to 7.5 feet below the existing ground surface, respectively. Groundwater encountered in these borings is interpreted to be a shallow aquifer within the Q_{go} unit bounded at some depth below the ground surface by glacial till. The saturated thickness of this aquifer is unknown, however could be upwards of 100 feet based on geologic mapping referenced above. The depth to groundwater is likely to be higher during winter and spring. A groundwater monitoring well was installed in boring B-7. Further implications of groundwater will be evaluated once additional groundwater monitoring data becomes available.

We identified the following constraints soil and groundwater conditions may have on ROW acquisition and temporary construction easement requirements for Wall 3.

- Temporary Cut Slope Angles: Based on the currently-planned maximum Wall 3 heights, we expect temporary excavations may be marginally stable at 1H:1V and may require a slightly flatter temporary cut slope angle. If groundwater is encountered in temporary excavations, they will likely not stand steeper than 1.5H:1V. We recommend the City consider implications of a 1.5H:1V cut slope angle for Wall 3.
- Bearing Soil Improvement: Loose/soft to medium stiff soils, not suitable for retaining wall support may be encountered at foundation subgrade elevation for Wall 3. If encountered, the material will likely require improvement. We anticipate this improvement would consist of over-excavation and replacement of the fill soils to a maximum depth of about 2 feet below the bottom of wall. Such improvement will expand the limits of temporary excavations required to construct the wall.

4.6 RETAINING WALLS 4 & 5 – SOIL AND GROUNDWATER CONDITIONS

Subsurface soil and groundwater conditions in the vicinity of Walls 4 and 5 were evaluated through the completion of borings B-9, B-10, B-11, and B-12. Soils encountered in borings B-9, B-11, and B-12 largely consisted of very loose grading to medium dense silty sands to sandy silts grading to sands with a minor silt fraction interpreted to be latest Vashon recessional outwash (Q_{gos}). Borings B-11 and B-12 were completed in Q_{gos} at about 11.5 feet below the existing ground surface. Boring B-9 encountered very dense gravel soils interpreted to be Vashon recessional outwash (Q_{go}) at about 10 feet, and was completed in this unit.

Boring B-10 was completed in close proximity to an underground communication utility and encountered about 5 feet of very loose to loose silty sand to sandy silt fill soils likely associated with construction of this utility. Below the very loose to loose fill, B-10 encountered medium dense silty sand to the completion depth of about 11.5 feet below existing site grade. Groundwater was not encountered in any of the borings completed near the proposed Wall 4 alignment.

We identified the following constraints soil and groundwater conditions may have on ROW acquisition and temporary construction easement requirements for Wall 4.

- **Bearing Soil Improvement:** Soils encountered at bearing subgrade elevation for Wall 4 are expected to consist of very loose to loose silty sands not suitable for foundation support. We anticipate improvement of foundation subgrade soils would consist of over-excavation and replacement of the fill soils to a maximum depth of about 2 feet below the bottom of wall. Such improvement will expand the limits of temporary excavations required to construct the wall.

4.7 DESIGN PERMANENT CUT AND FILL SLOPE INCLINATIONS

Soil and groundwater conditions will play a role in feasible permanent cut slope inclinations completed in native soils, and in turn, may have an impact on the need for cut retaining walls such as Walls 2 & 3 and the geometry of the walls and related ROW acquisition requirements. In a similar manner, feasible fill slope inclinations may impact decision making related to both cut and fill walls. For fill slopes constructed with properly placed and compacted structural fill, we recommend a maximum permanent fill slope angle of 2H:1V. The table below provides our recommendations for permanent cut slope angles completed in native soils for cut walls (Walls 2 and 3).

Table 2: Recommended Permanent Cut Slope Angles

Wall No.	Depth Below Existing Ground Surface (ft)	Recommended Permanent Cut Slope Angle Completed in Native Soils
2	0 – 5 ft	3H:1V
2	>5 ft	2H:1V
3	0 – 10 ft	3H:1V
3	>10 ft	2H:1V

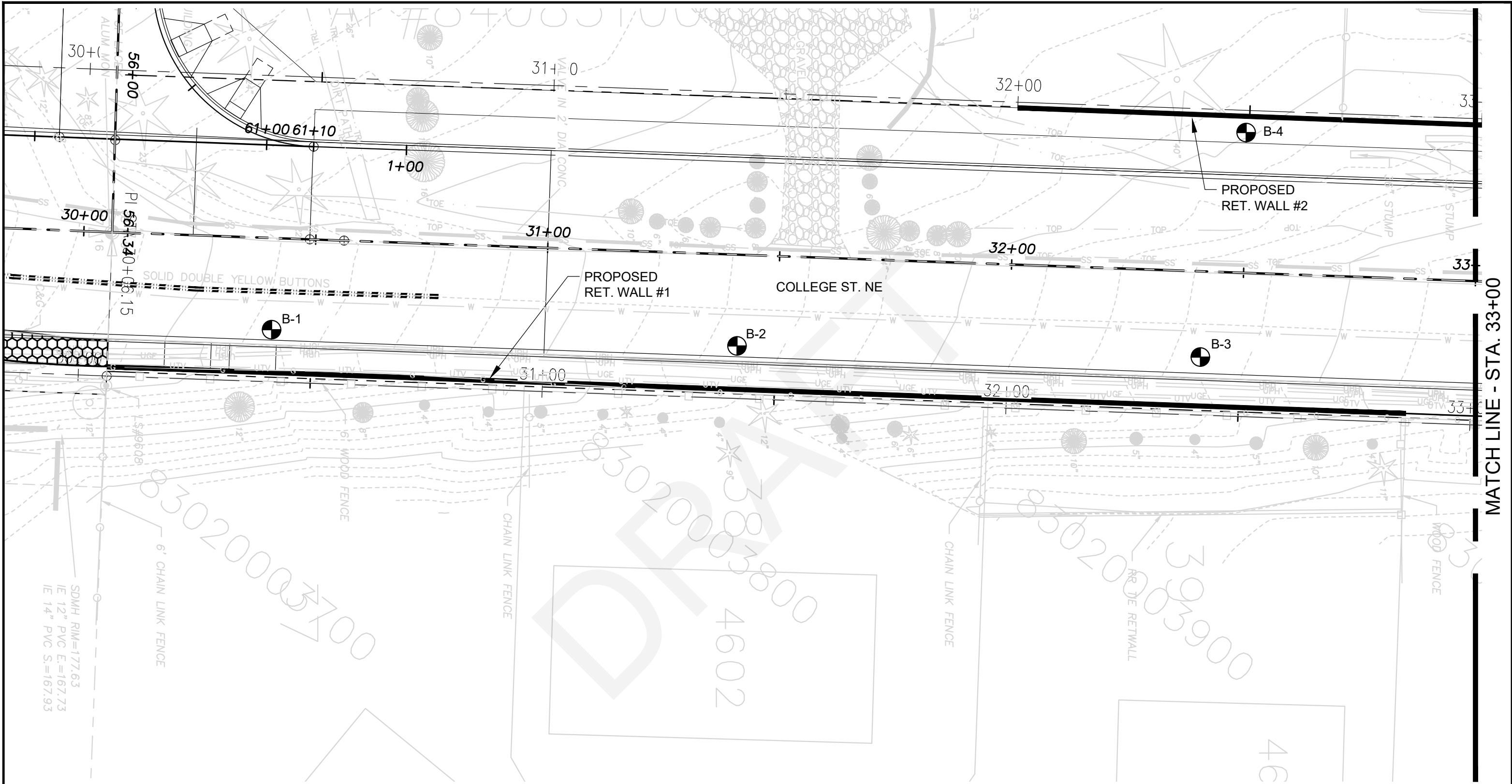
5. TRAFFIC AND PEDESTRIAN BARRIER CONSTRAINTS

Offset requirements for traffic barriers and pedestrian fences will increase the required width of typical roadway sections, and therefore may impact overall ROW width requirements. For the proposed

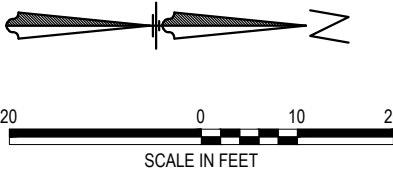
retaining wall system (RediRock), pedestrian fence posts can typically be directly mounted to the top of the wall using drilled epoxy anchors. However, guardrails require an offset. Placement of guardrails should be planned such that the back of the guardrail post is offset a minimum distance of 3 feet from the face of retaining walls.

6. STRUCTURAL GEOMETRIC REQUIREMENTS


The required width of retaining wall structures will vary as a function of the total retaining wall height (exposed height plus embedded height), backslope inclinations, and backfill strength characteristics. The proposed retaining walls will be designed as “gravity” type structures which rely on the overall mass of the structure to resist loads. As such, as loads increase, the maximum width, which occurs at the bottom of the structure, increases to provide the mass necessary to maintain stability. For a given wall height, the maximum width at the bottom of the structure increases with increasing backslope inclinations and decreasing backfill strength characteristics. For evaluating width requirements of individual walls, we have assumed that the City’s intent is to minimize required roadway section widths in an effort to minimize ROW acquisition requirements. Therefore, in developing structural width requirements for individual walls we assumed a maximum backslope angle of 2H:1V, and we assumed relatively high-strength backfill materials in an effort to minimize the required structural width of individual retaining walls. For wall backfill materials, we assumed material meeting the requirements of Gravel Backfill for Walls as specified in Section 9-03.12(2) of the WSDOT Standard Specifications. In addition, we assumed that retaining walls with a maximum total height of six (6) feet or less are not designed to accommodate seismic loading, which is typical design practice. Figure 2, Schematic Wall Sections provides graphical depictions showing anticipated wall geometries for various wall heights and backslope inclinations.



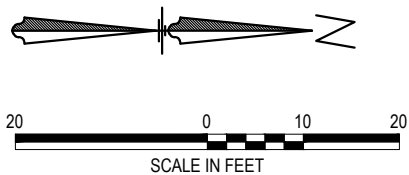
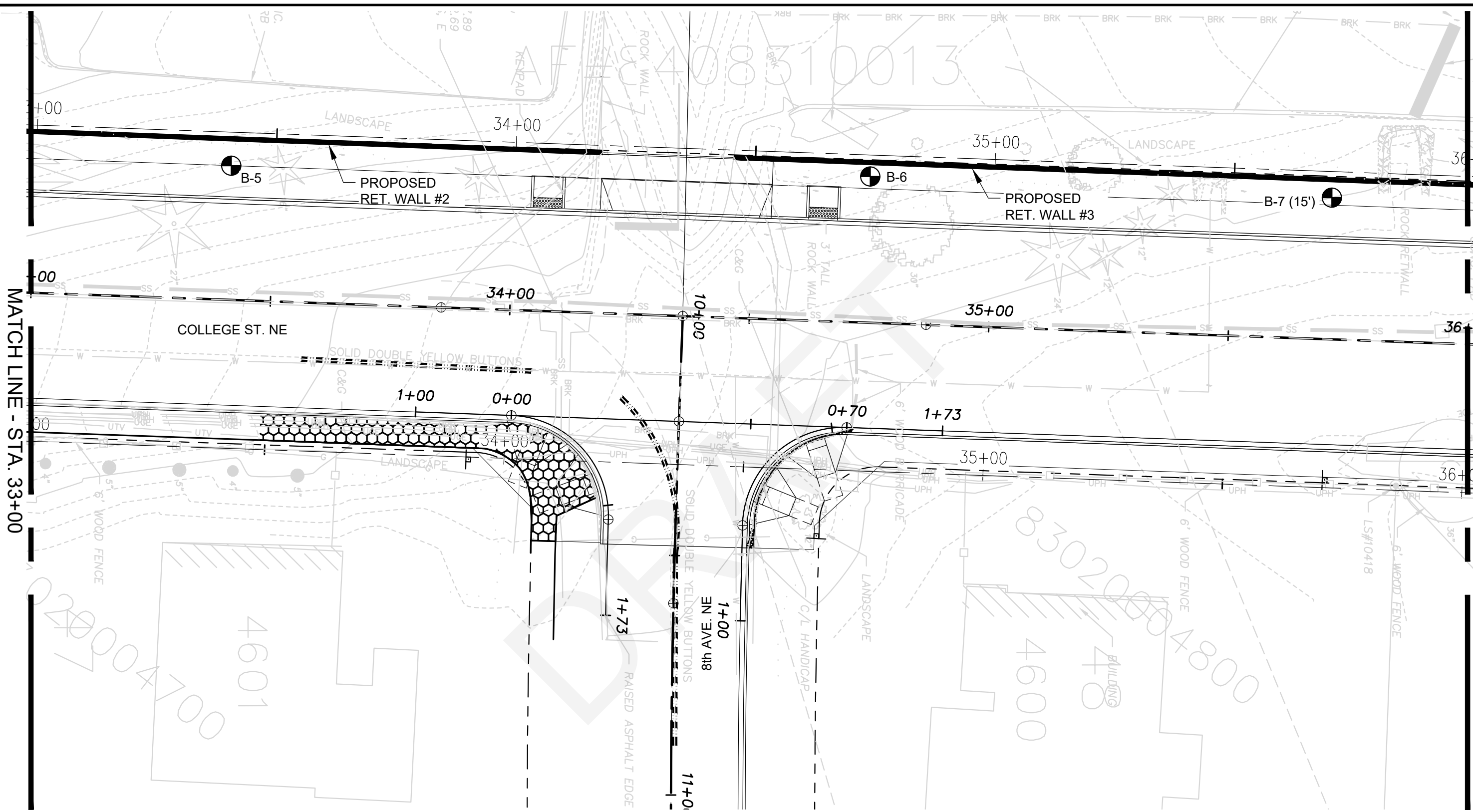
MATCH LINE - STA. 33+00




LEGEND:


B-1 GEOTECHNICAL BORING
 NUMBER & APPROX.
 LOCATION

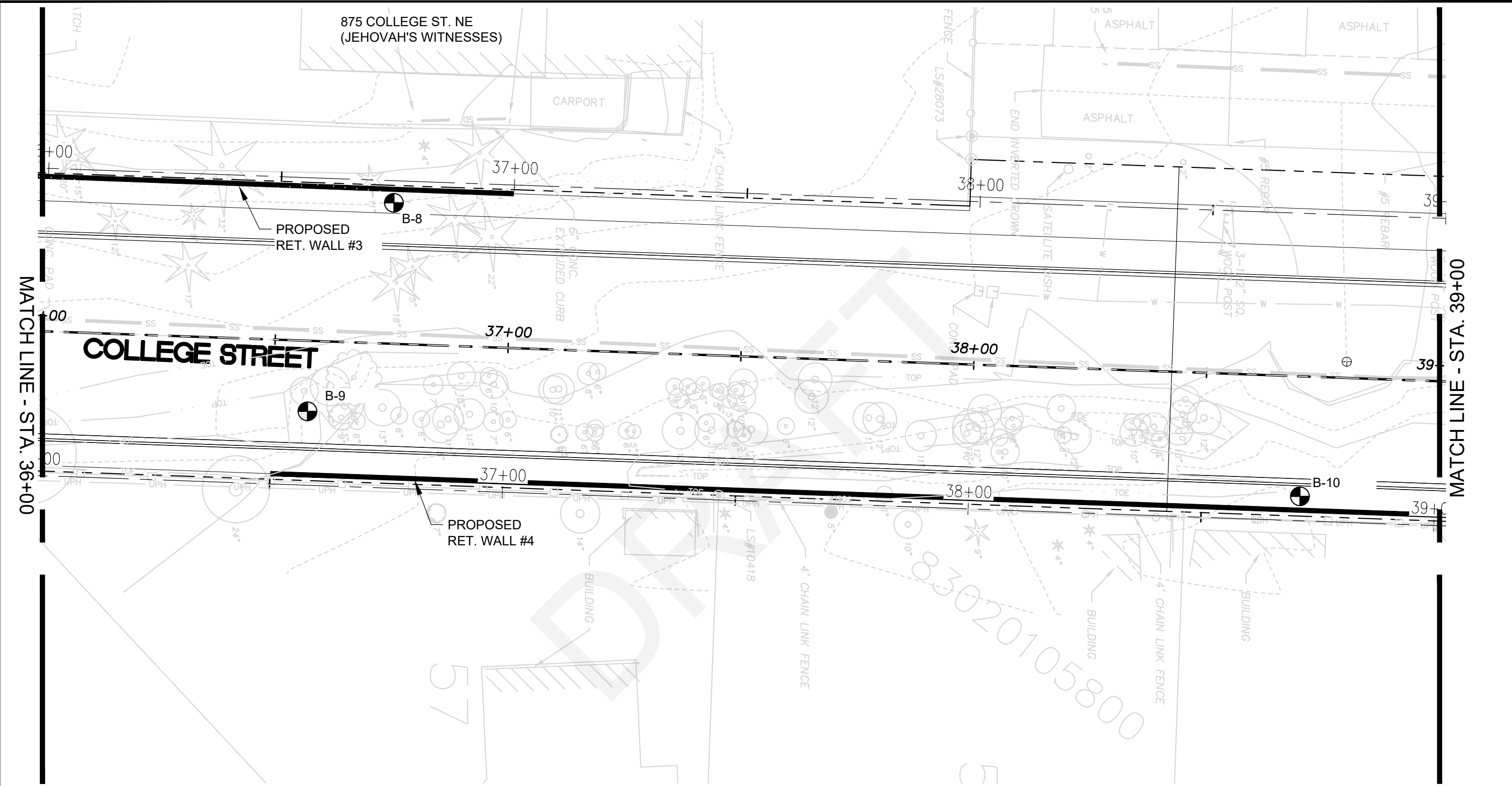
COLLEGE ST. NE EXTENSION LACEY, WA	
SITE AND EXPLORATION PLAN	
DATE: NOV. 2022	Job No. 2613.01
Zipper Geo Associates, LLC 19019 36th Ave. W., Suite E Lynnwood, WA	FIGURE 1 SHT. 1 of 4



LEGEND:

-  B-1 GEOTECHNICAL BORING NUMBER & APPROX. LOCATION

COLLEGE ST. NE EXTENSION LACEY, WA	
SITE AND EXPLORATION PLAN	
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MATCH LINE - STA. 36+00

MATCH LINE - STA. 39+00

COLLEGE STREET

875 COLLEGE ST. NE
(JEHOVAH'S WITNESSES)

CARPORT

PROPOSED
RET. WALL #3

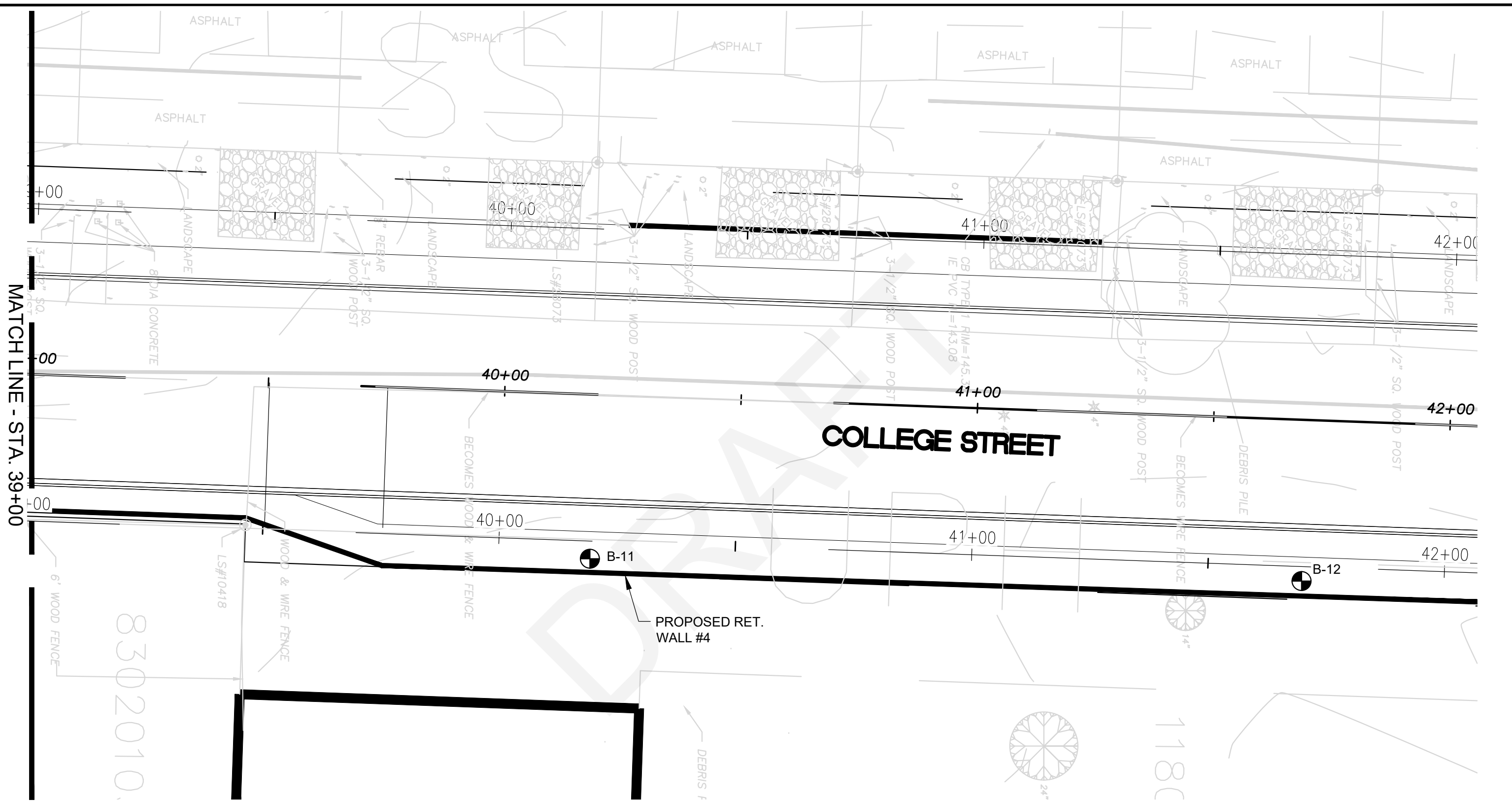
PROPOSED
RET. WALL #4

B-1 GEOTECHNICAL BORING
NUMBER & APPROX.
LOCATION

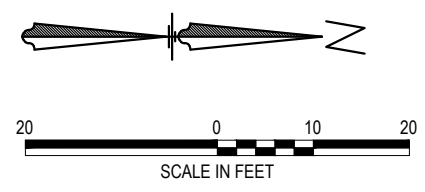


LEGEND:


COLLEGE ST. NE EXTENSION LACEY, WA	
SITE AND EXPLORATION PLAN	
DATE: NOV. 2022	Job No. 2613.01
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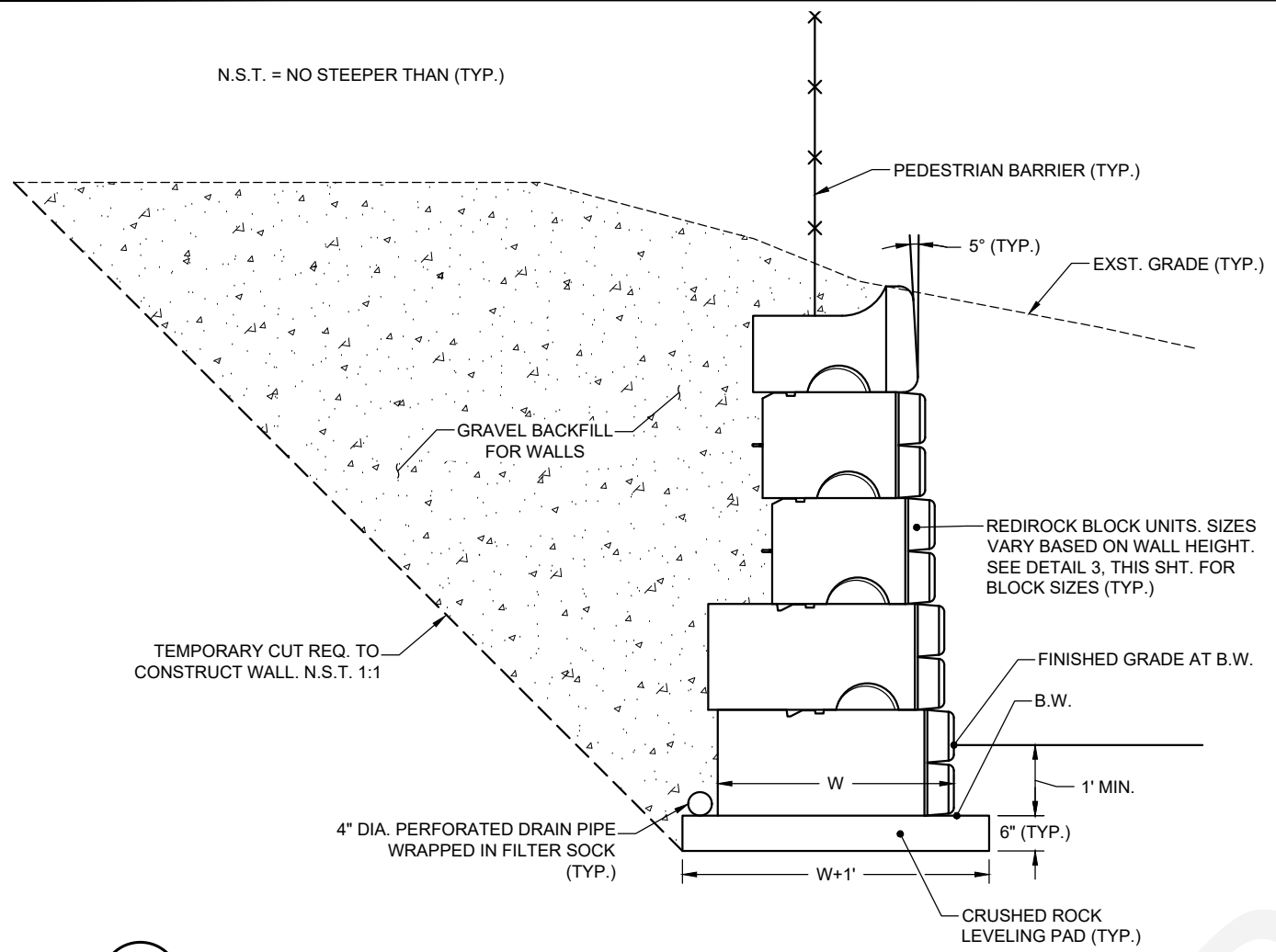
MATCHLINE - STA. 39+00



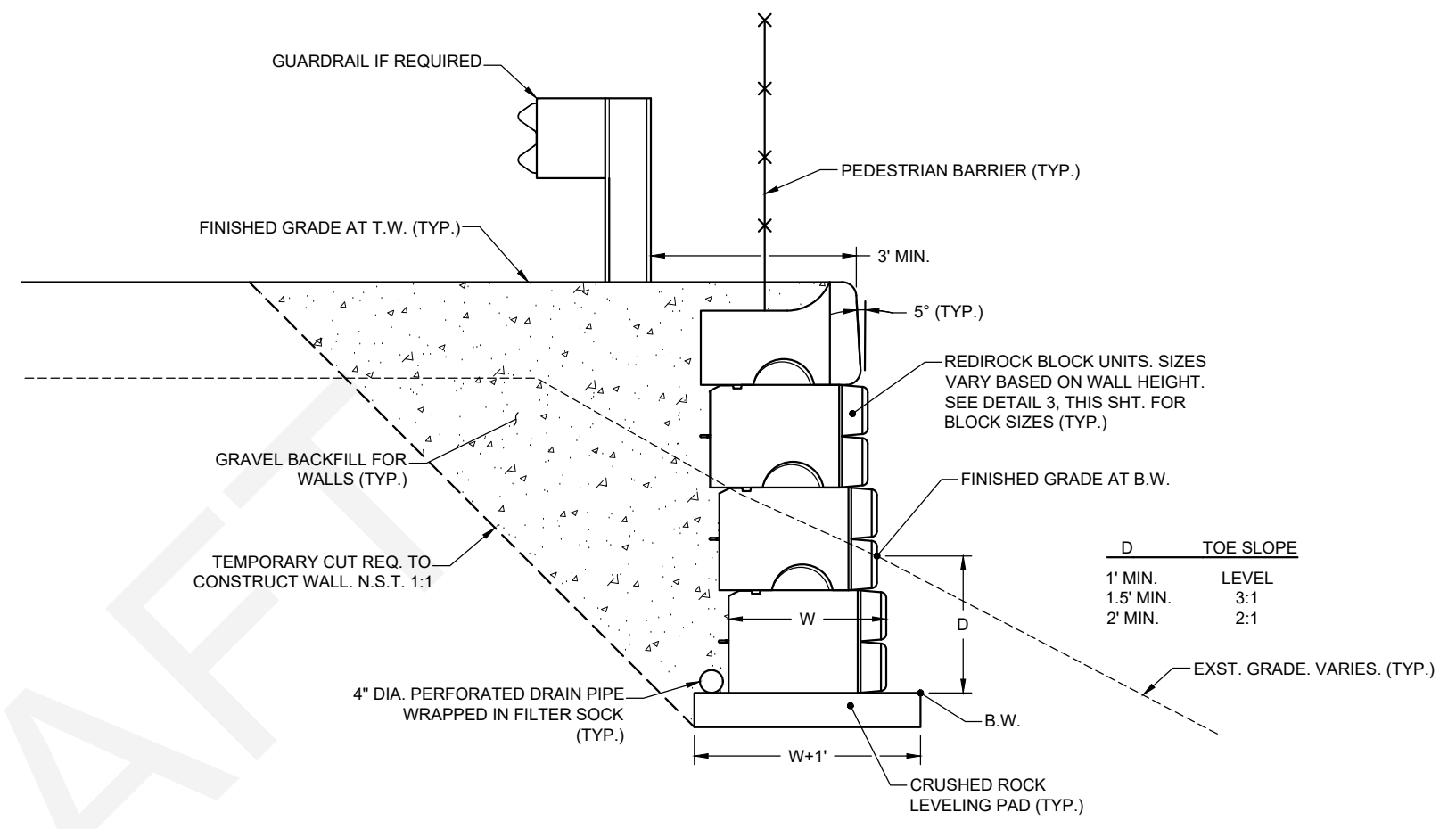
LEGEND:

 B-1 GEOTECHNICAL BORING NUMBER & APPROX. LOCATION

COLLEGE ST. NE EXTENSION LACEY, WA	
SITE AND EXPLORATION PLAN	
DATE: NOV. 2022	Job No. 2613.01
Zipper Geo Associates, LLC 19019 36th Ave. W., Suite E Lynnwood, WA	FIGURE 1 SHT. 4 OF 4

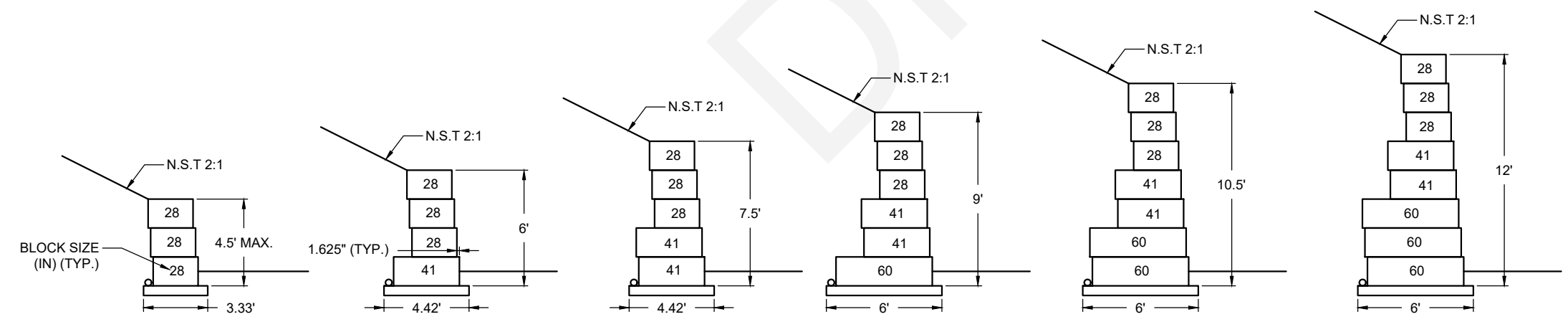


1 TYPICAL SECTION - CUT WALL
NOT TO SCALE



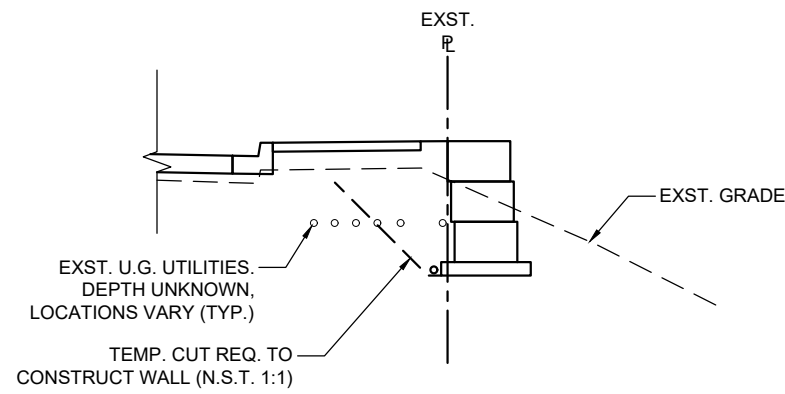
2 TYPICAL SECTION - FILL WALL
NOT TO SCALE

D	TOE SLOPE
1' MIN.	LEVEL
1.5' MIN.	3:1
2' MIN.	2:1

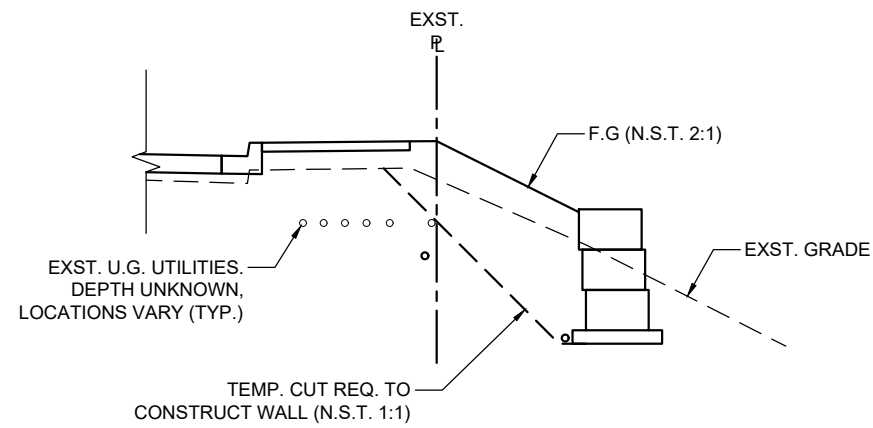


3 DESIGN SECTIONS
NOT TO SCALE

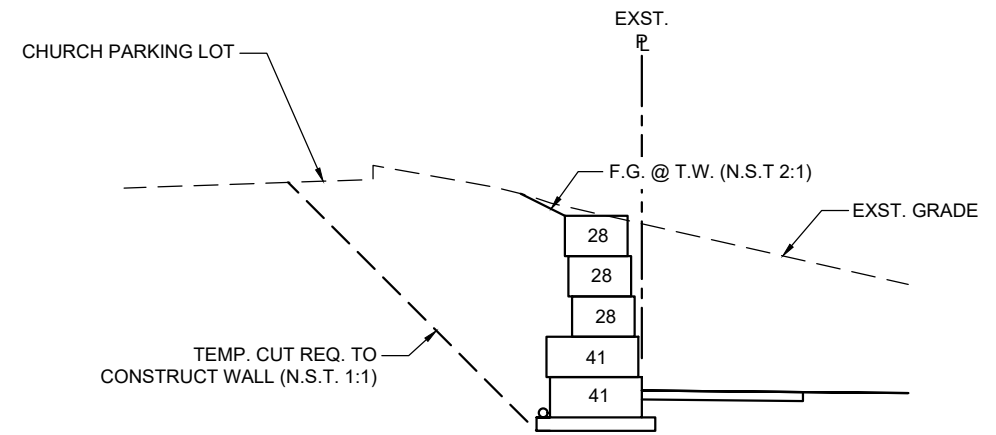
COLLEGE ST. NE EXTENSION LACEY, WA	
SCHEMATIC WALL SECTIONS	
DATE: NOV. 2022	Job No. 2613.01
Zipper Geo Associates, LLC 19019 36th Ave. W., Suite E Lynnwood, WA	FIGURE SHT. 1 of 2



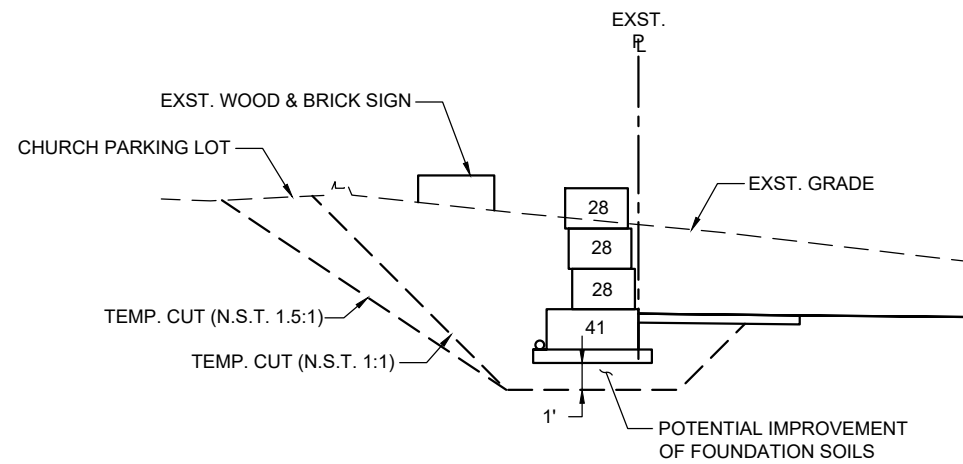
1 SECTION - WALL 1
(STA. 30+75 RT)



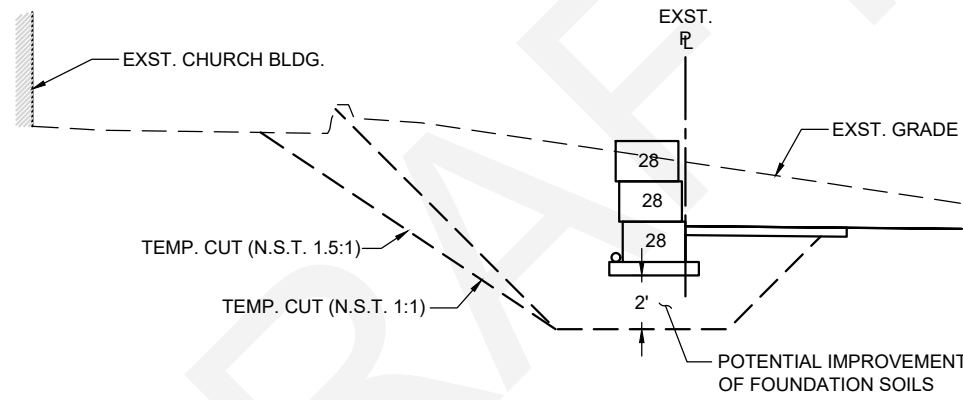
2 SECTION - WALL 1 ALT.
(STA. 30+75 RT)



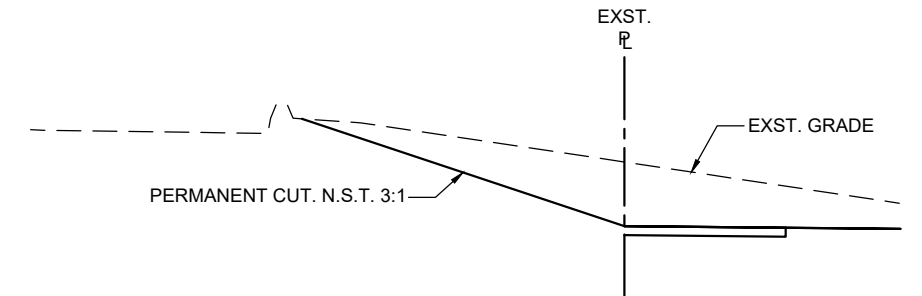
3 SECTION - WALL 2
(STA. 34+00 LT)



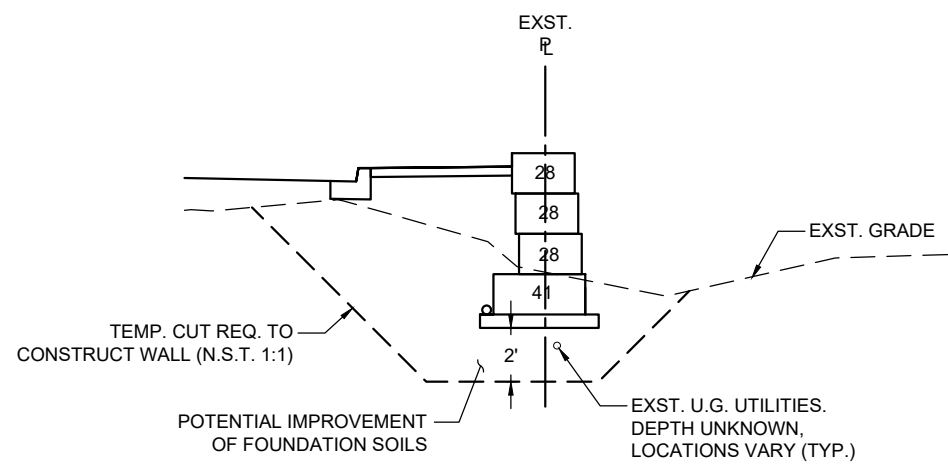
4 SECTION - WALL 3
(STA. 34+75 LT)



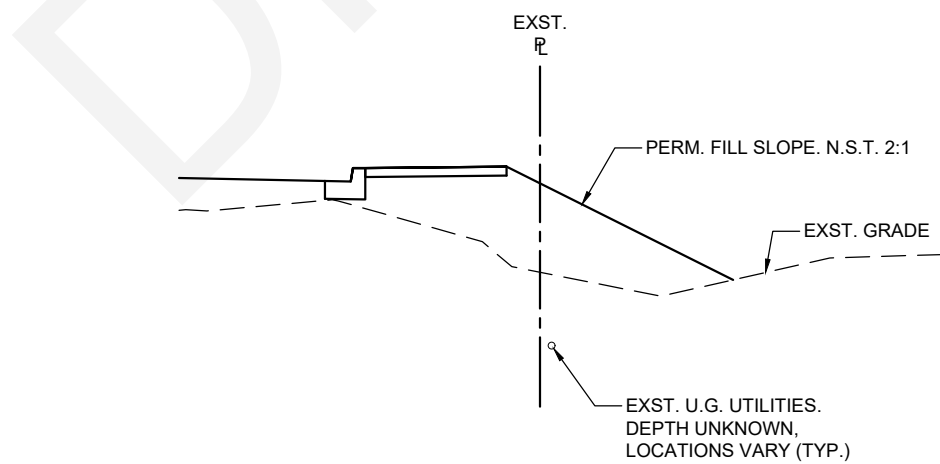
5 SECTION - WALL 3
(STA. 36+75 LT)



6 SECTION - WALL 3 ALT.
(STA. 36+75 LT)



7 SECTION - WALL 4
(STA. 38+00 RT)



8 SECTION - WALL 4 ALT.
(STA. 38+00 RT)

COLLEGE ST. NE EXTENSION LACEY, WA	
SCHEMATIC WALL SECTIONS	
DATE: NOV. 2022	Job No. 2613.01
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APPENDIX A

SUBSURFACE EXPLORATION PROCEDURES AND LOGS

DRAFT

Our field exploration for this study included 12 borings advanced in August and September of 2022. Approximate exploration locations are shown on the Site and Exploration Plan, Figure 1. Exploration locations were determined by measuring distances from existing site features with a fiberglass tape relative to a topographic map of the site provided by the City of Lacey. As such, the exploration locations should be considered accurate to the degree implied by the measurement method. The approximate ground surface elevation at each exploration location was determined by interpolating the information provided on the topographic plan. The following sections describe our procedures associated with the exploration. Descriptive logs of the explorations are enclosed in this appendix.

Soil Boring Procedures

Our exploratory borings were advanced with a hollow stem auger, using a track-mounted drill rig operated by an independent drilling firm working under subcontract to our firm. An engineering geologist from our firm continuously observed the borings, logged the subsurface conditions encountered, and obtained representative soil samples. All samples were stored in moisture-tight containers and transported to our laboratory for further visual classification and testing.

Throughout the drilling operation, soil samples were obtained at 2.5- to 5-foot depth intervals by means of the Standard Penetration Test (ASTM: D-1586). This testing and sampling procedure consists of driving a standard 2-inch outside diameter steel split spoon sampler 18 inches into the soil with a 140-pound hammer free falling 30 inches. The number of blows required to drive the sampler through each 6-inch interval is recorded, and the total number of blows struck during the final 12 inches is recorded as the Standard Penetration Resistance, or “blow count” (N value). If a total of 50 blows is struck within any 6-inch interval, the driving is stopped and the blow count is recorded as 50 blows for the actual penetration distance. The resulting Standard Penetration Resistance values indicate the relative density of granular soils and the relative consistency of cohesive soils.

The enclosed boring logs describe the vertical sequence of soils and materials encountered in each boring, based primarily upon our field classifications and supported by our subsequent laboratory examination and testing. Where a soil contact was observed to be gradational, our logs indicate the average contact depth. Where a soil type changed between sample intervals, we inferred the contact depth. Our logs also graphically indicate the blow count, sample type, sample number, and approximate depth of each soil sample obtained from the boring, as well as any laboratory tests performed on these soil samples. If any groundwater was encountered in a borehole, the approximate groundwater depth, and date of observation, is depicted on the log. Groundwater depth estimates are typically based on the moisture content of soil samples, the wetted portion of the drilling rods, the water level measured in the borehole after the auger has been extracted, or through the use of an observation well.

A groundwater observation well was installed at one of the boring locations (B-7). The well consisted of a length of slotted 1-inch PVC pipe placed in the bottom of the borehole. A blank PVC riser extended from the lower slotted section to the ground surface. Washed silica sand was utilized to backfill the annular space between the slotted interval and the borehole to allow entry of water into the well, while a mixture of bentonite clay and soil cuttings was used to backfill around the blank riser. A concrete surface seal and locking metal monument cover were placed at the surface. The groundwater level measured within each observation well subsequent to completion of drilling and the well installation is indicated by a triangular symbol on the logs, along with the date of measurement. This information is also discussed in the text.

EXPLANATION OF EXPLORATION LOGS

SOIL DESCRIPTION: Soil descriptions presented on the borings logs are based on visual observations. Soil descriptions include density (coarse-grained soils) or consistency (fine-grained soils), moisture, color, major soil type, and grain size modifiers and should not be interpreted to suggest laboratory or field testing unless indicated on the logs. Soil descriptions include the following: Density/consistency, moisture, color, grain size modifier (adjective implying 31-49 percent), major soil type (CAPITALIZED implying 50+ percent), minor grain size modifier (some implying 6-12 percent, with implying 13-30 percent, and trace implying 0-5 percent), descriptive modifiers (i.e. roots, fill debris, cemented, etc.), and interpreted general geologic description. Descriptions may also include comments describing geologic properties such as dilatancy, toughness, structure, plasticity, and angularity of coarse-grained particles. Additional information regarding geologic properties is presented in the report text as applicable.

DENSITY/CONSISTENCY: Soil density/consistency in borings is related to the blow count number in blows per foot using the sampling method indicated on the logs. Soil density/consistency in test pits is related to a "Field Test" as described below. Soil consistency in test pits or borings may be augmented by field Torvane or Pocket Penetrometer testing.

Coarse-Grained Soils

Density Descriptor	SPT (# blows/ft)	Field Test
Very Loose	0 – 4	Easily penetrated with ½ -inch steel rod pushed by hand.
Loose	5 – 10	Difficult to penetrate with ½ -inch steel rod pushed by hand.
Medium Dense	11 – 30	Easily penetrated a foot with ½-inch steel rod driven with 5-lb hammer.
Dense	31 – 50	Difficult to penetrate a foot with ½-inch steel rod driven with 5-lb hammer.
Very Dense	>50	Penetrated only a few inches with ½-inch steel rod driven with 5-lb hammer.

Fine-Grained Soils

Consistency Descriptor	SPT (# blows/ft)	Torvane	Pocket Penetrometer	Field Test
		Undrained shear strength (tsf)	Unconfined Compressive Strength (tsf)	
Very Soft	0 – 2	<0.125	<0.25	Easily penetrates several inches by thumb.
Soft	3 – 4	0.125 – 0.25	0.25 – 0.5	Easily penetrates one inch by thumb.
Medium Stiff	5 – 8	0.25 – 0.5	0.5 – 1.0	Penetrated over ½ inch by thumb with moderate effort.
Stiff	9 – 15	0.5 – 1.0	1.0 – 2.0	Indented by thumb but penetrated only with great effort.
Very Stiff	16 – 30	1.0 – 2.0	2.0 – 4.0	Readily indented by thumbnail.
Hard	>30	>2.0	>4.0	Indented by thumbnail with difficult effort.

MOISTURE

Descriptor	Field Test
Dry	Absence of moisture, dusty, dry to the touch.
Damp	Too low to achieve compaction
Moist	Appears near optimum moisture content for compaction
Wet	Too wet to achieve compaction
Saturated	Below the groundwater table, visible free moisture.

MAJOR SOIL TYPE: Coarse-grained soils with over 50% of the material retained on the U.S. No. 200 sieve. Coarse-grained soils include boulders, cobbles, gravels and sands. Fine-grained soils with over 50% of the material passing the U.S. No. 200 sieve. Fine-grained soils include silts and clays.

GRAIN SIZE

Descriptor	Sieve Size	Grain Size
Boulder	>12"	>12"
Cobble	3 – 12"	3 – 12"
Gravel	3" – #4	3" – 0.19"
Sand	>#4 – #200	<0.19" – >0.0029"
Silt/Clay	Passing #200	<0.0029"

GRAIN SIZE MODIFIERS

Descriptor	Approximate Percentage
Trace	0 – 5
Some	6 – 12
With	13 – 30
Adjective (silty, clayey, sandy, gravelly)	31 – 50

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling **Bore Hole Dia.:** 6 inch
Top Elevation: 179 ft **Drilling Method:** CFA **Hammer Type:** Auto
Date Drilled: 9/13/2022 **Drill Rig:** Diedrich D70 **Logged by:** JLB

B-1

Depth (ft)	SOIL DESCRIPTION	Sample Number SAMPLES Recovery	Ground Water	PENETRATION RESISTANCE (blows/foot)		Blow Counts	Testing
				▲ Standard Penetration Test	△ Hammer Weight and Drop:		
0	Six (6) inches of asphalt						
0 - 4.5	Dense, wet, brown, sandy GRAVEL, trace organics/roots, trace charcoal. (FILL)	S-1 18				37	
4.5 - 7.5	Very dense, wet, brown, sandy SILT some gravel, with organics. (FILL)	S-2 8				52	
7.5 - 9.5	Very dense, moist, grey brown, silty SAND with gravel, trace organics. (FILL)	S-3 9				71/12	
9.5 - 15	No recovery. Subrounded GRAVEL and sand in cuttings. (Qgo)	S-4 0				50/6	
15 - 20	No recovery. Very dense, brown, moist GRAVEL. (Qgo)	S-5 0				50/6	
20 - 21	Very dense, moist, brown, sandy GRAVEL with silt, with cobbles, some FE mottling. (Qgo)	S-6 1				78/12	
21 - 25	B-1 completed at approximately 21 feet. No groundwater observed at time of drilling.						

SAMPLE LEGEND

- 2-inch O.D. split spoon sample
- 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing
- Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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Lacey, Washington 98513

Date: 9/31/2022

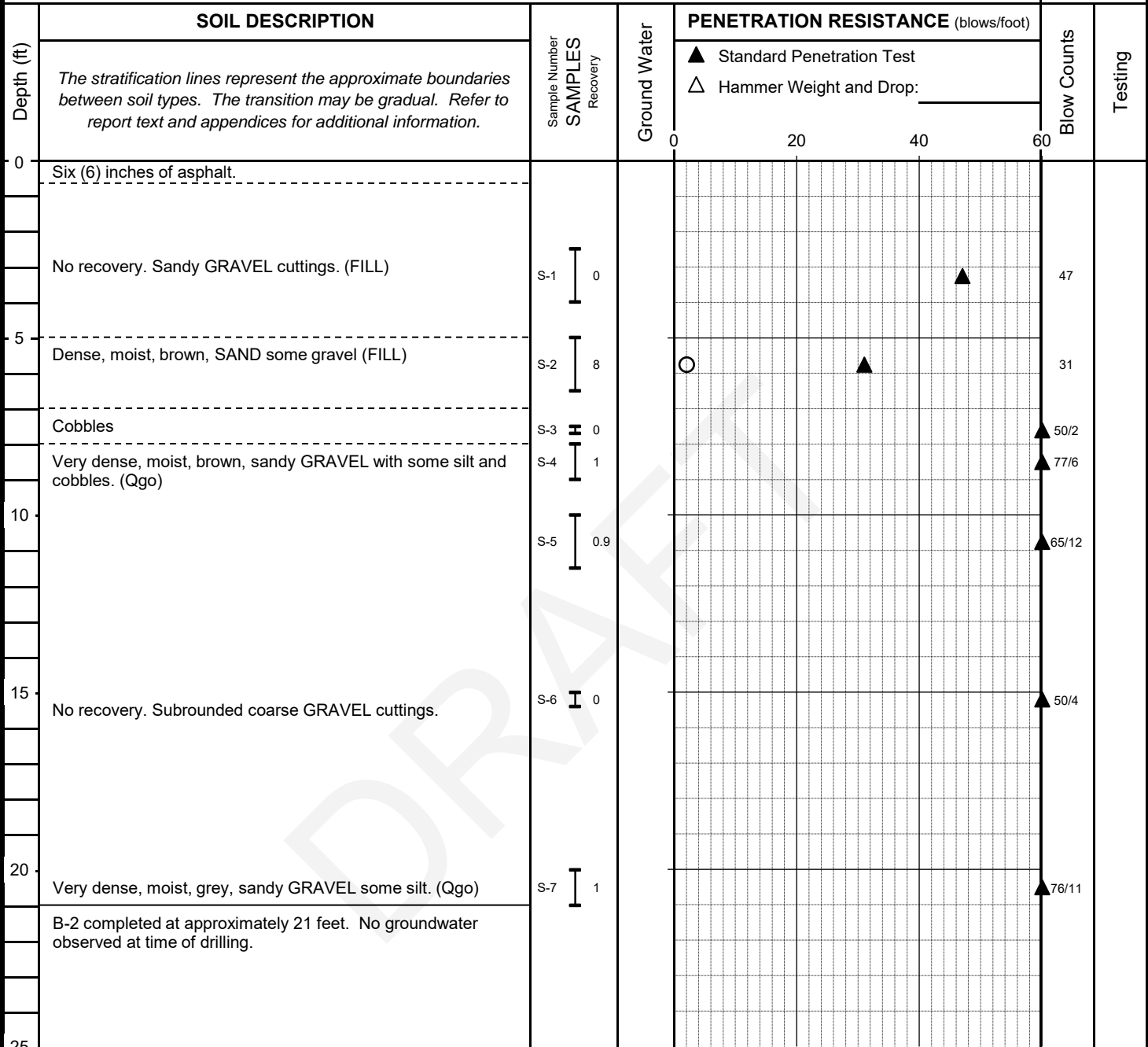
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BORING LOG: B-1

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling **Bore Hole Dia.:** 6
Top Elevation: 172.5 ft **Drilling Method:** CFA **Hammer Type:** Auto
Date Drilled: 9/13/2022 **Drill Rig:** Diedrich D70 **Logged by:** JLB

B-2



SAMPLE LEGEND

- 2-inch O.D. split spoon sample
- 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing
- Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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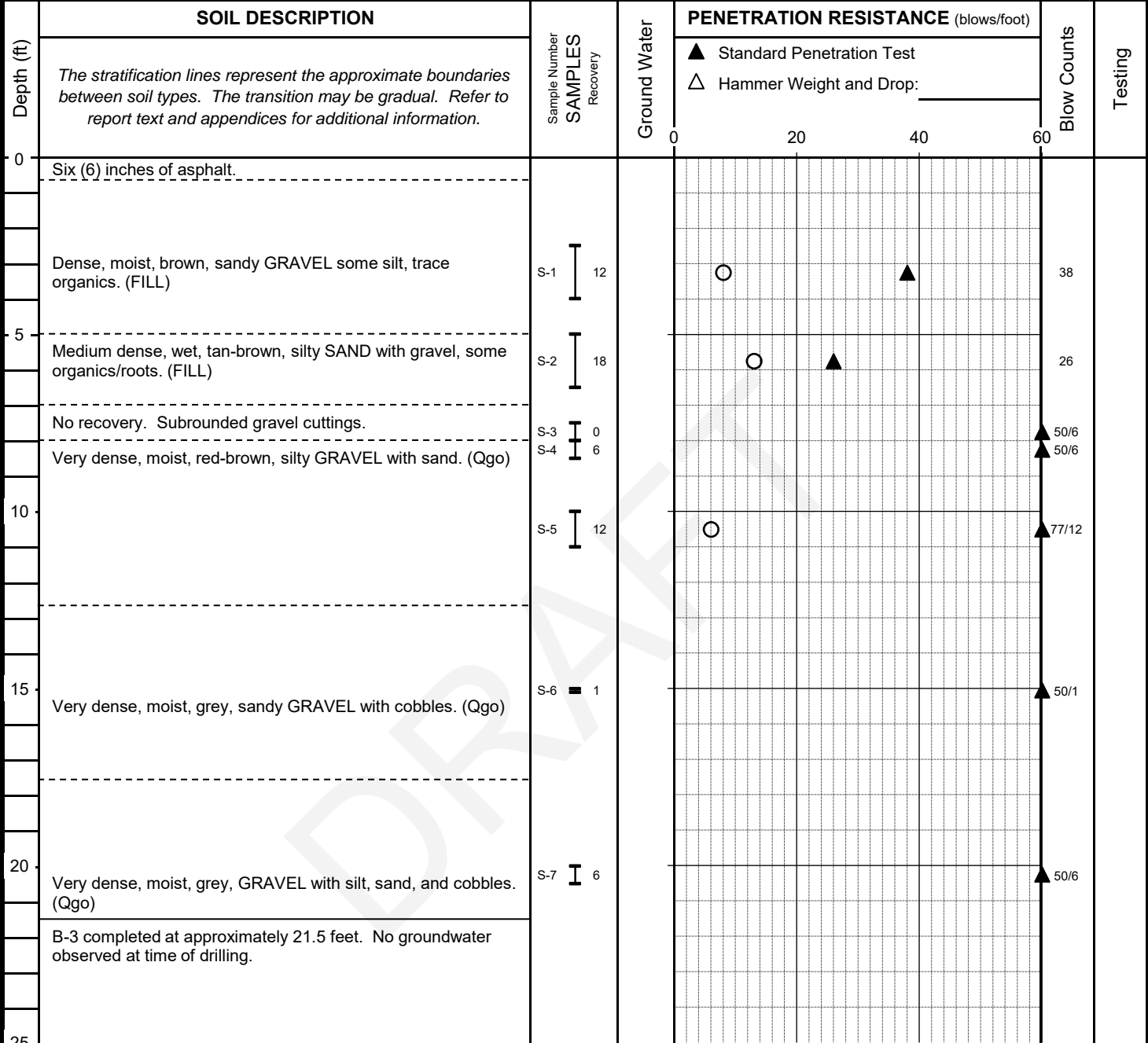
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BORING LOG: B-2

Page 1 of 1

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling **Bore Hole Dia.:** 6
Top Elevation: 166.5 ft **Drilling Method:** CFA **Hammer Type:** Auto
Date Drilled: 9/13/2022 **Drill Rig:** Diedrich D70 **Logged by:** JLB

B-3



SAMPLE LEGEND

- 2-inch O.D. split spoon sample
- 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing
- Groundwater level at time of drilling (ATD) or on date of measurement.

% Fines (<0.075 mm)

% Water (Moisture) Content

Plastic Limit Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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BORING LOG: B-3

Page 1 of 1

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling **Bore Hole Dia.:** 6 inch
Top Elevation: 170 ft **Drilling Method:** Track HSA **Hammer Type:** auto
Date Drilled: 9/2/2022 **Drill Rig:** CME 75 **Logged by:** EKC

B-4

Depth (ft)	SOIL DESCRIPTION	Sample Number SAMPLES Recovery	PENETRATION RESISTANCE (blows/foot)				Blow Counts	Testing
			Ground Water					
0	<i>The stratification lines represent the approximate boundaries between soil types. The transition may be gradual. Refer to report text and appendices for additional information.</i>		▲ Standard Penetration Test △ Hammer Weight and Drop:					
0	about 5 inches topsoil. Mulch. Very loose, dark brown silty SAND with mulch. (FILL/TOPSOIL)	S-1 3"					0	
	Medium dense, moist, dark brown to brown silty SAND with gravel; geotextile pieces. (FILL)	S-2 3"		○	▲		15	
5	Very dense, moist, light brown sandy SILT with gravel; very fine to fine sand. (FILL)	S-3 10"		○			62/10	
	No recovery. Gravel and cobbles inferred by drilling action.	S-4 H 0"					50/3	
10	Rough drilling; moved over about 2ft. Rock fragment in spoon.	S-5 3"					50/3	
	Rough drilling.							
15	No recovery. Gravel and cobbles inferred by drilling action. Boring terminated at about 15 feet. No groundwater ATD.	S-6 I 0"					50/5	
20								
25								

SAMPLE LEGEND

- ┆ 2-inch O.D. split spoon sample
- ┆ 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- ▨ Clean Sand
- ▨ Bentonite
- Grout/Concrete
- ▨ Screened Casing
- Blank Casing
- ▼ Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit —○— Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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Date: 9/30/2022

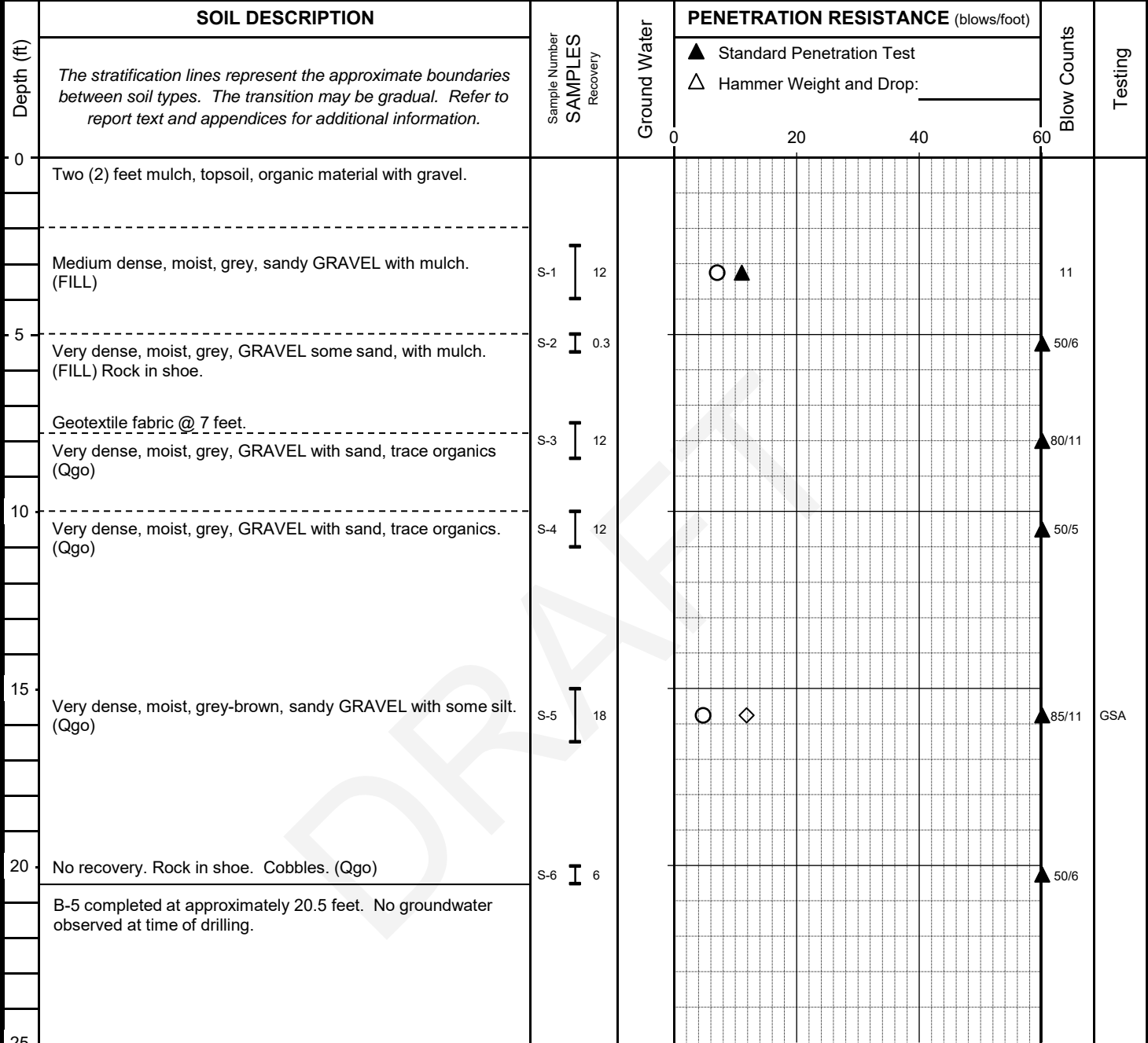
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BORING LOG: B-4

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling **Bore Hole Dia.:** 6
Top Elevation: 166 ft **Drilling Method:** CFA **Hammer Type:** Auto
Date Drilled: 9/13/2022 **Drill Rig:** Diedrich D70 **Logged by:** JLB

B-5



SAMPLE LEGEND

- ┆ 2-inch O.D. split spoon sample
- ┆ 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- ▨ Clean Sand
- ▨ Bentonite
- Grout/Concrete
- ▨ Screened Casing
- Blank Casing
- ▼ Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit ———— ○ ———— Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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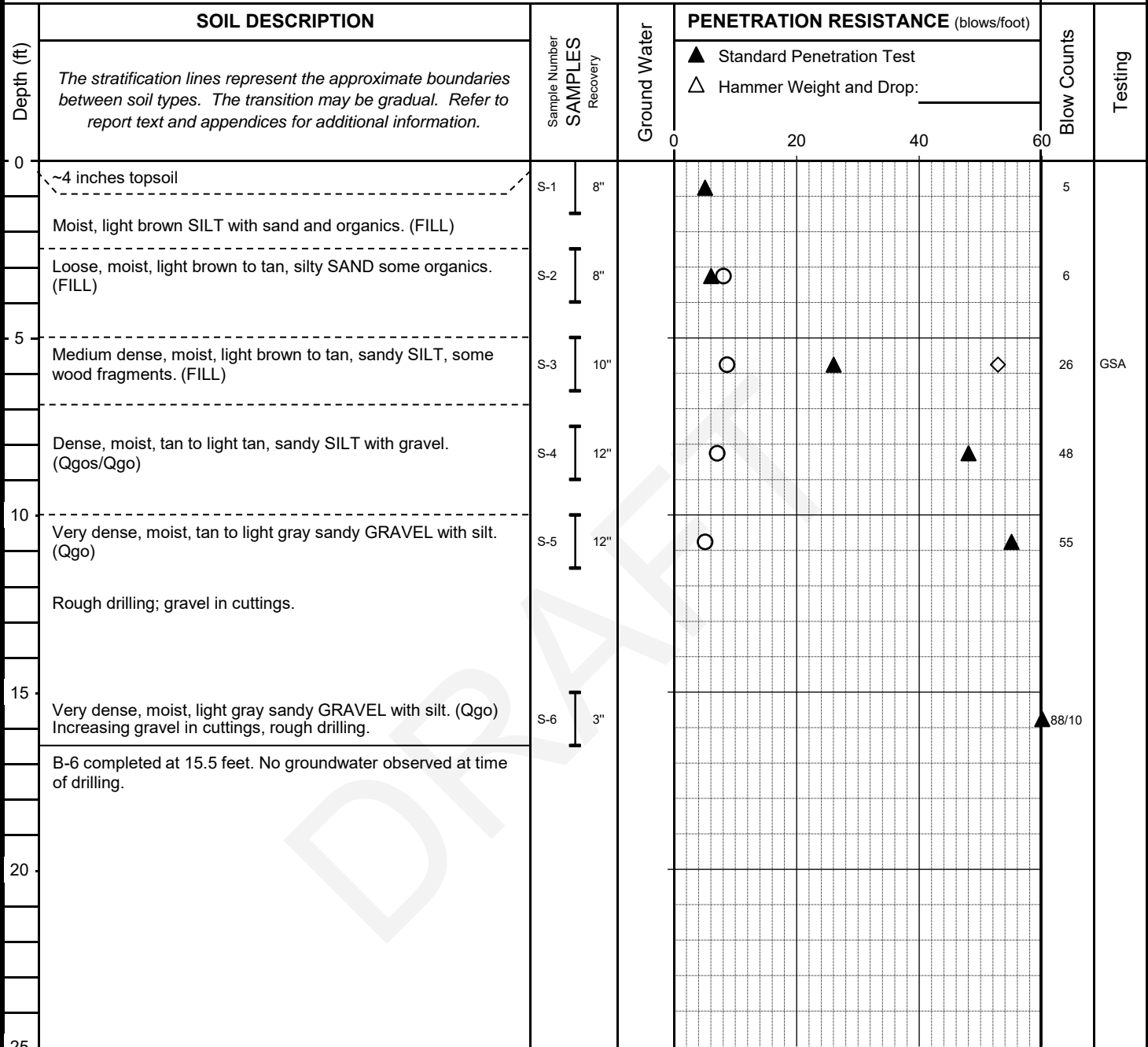
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BORING LOG: B-5

Page 1 of 1

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling **Bore Hole Dia.:** 6 inches
Top Elevation: 159 ft **Drilling Method:** Track CFA **Hammer Type:** auto
Date Drilled: 9/2/2022 **Drill Rig:** CME 75 **Logged by:** EKC

B-6



SAMPLE LEGEND

- ┃ 2-inch O.D. split spoon sample
- ┃┃ 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- ▨ Clean Sand
- ▩ Bentonite
- Grout/Concrete
- ▨ Screened Casing
- Blank Casing
- ▼ Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit ———○——— Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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Date: 9/30/2022 Project No.: 2613.01

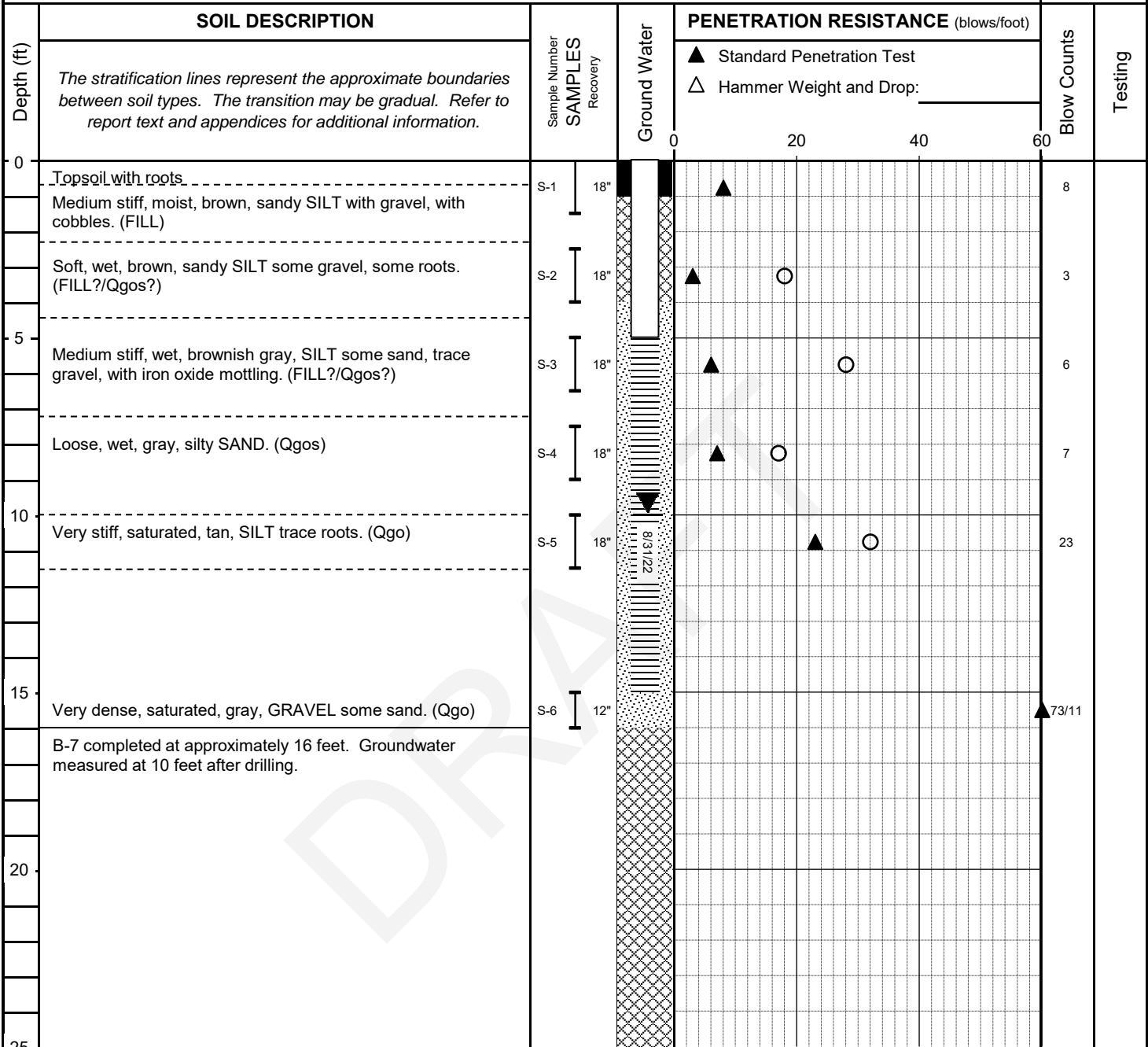
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BORING LOG: B-6

Page 1 of 1

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling **Bore Hole Dia.:** 6 inches
Top Elevation: 155 ft **Drilling Method:** Track CFA **Hammer Type:** auto
Date Drilled: 8/31/2022 **Drill Rig:** CME 75 **Logged by:** JLB

B-7



SAMPLE LEGEND

- ┆ 2-inch O.D. split spoon sample
- ┆ 3-inch I.D. Shelby tube sample

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

GROUNDWATER LEGEND

- ▨ Clean Sand
- ▨ Bentonite
- Grout/Concrete
- ▨ Screened Casing
- Blank Casing
- ▼ Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit —○— Liquid Limit

Natural Water Content

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Date: 9/30/2022

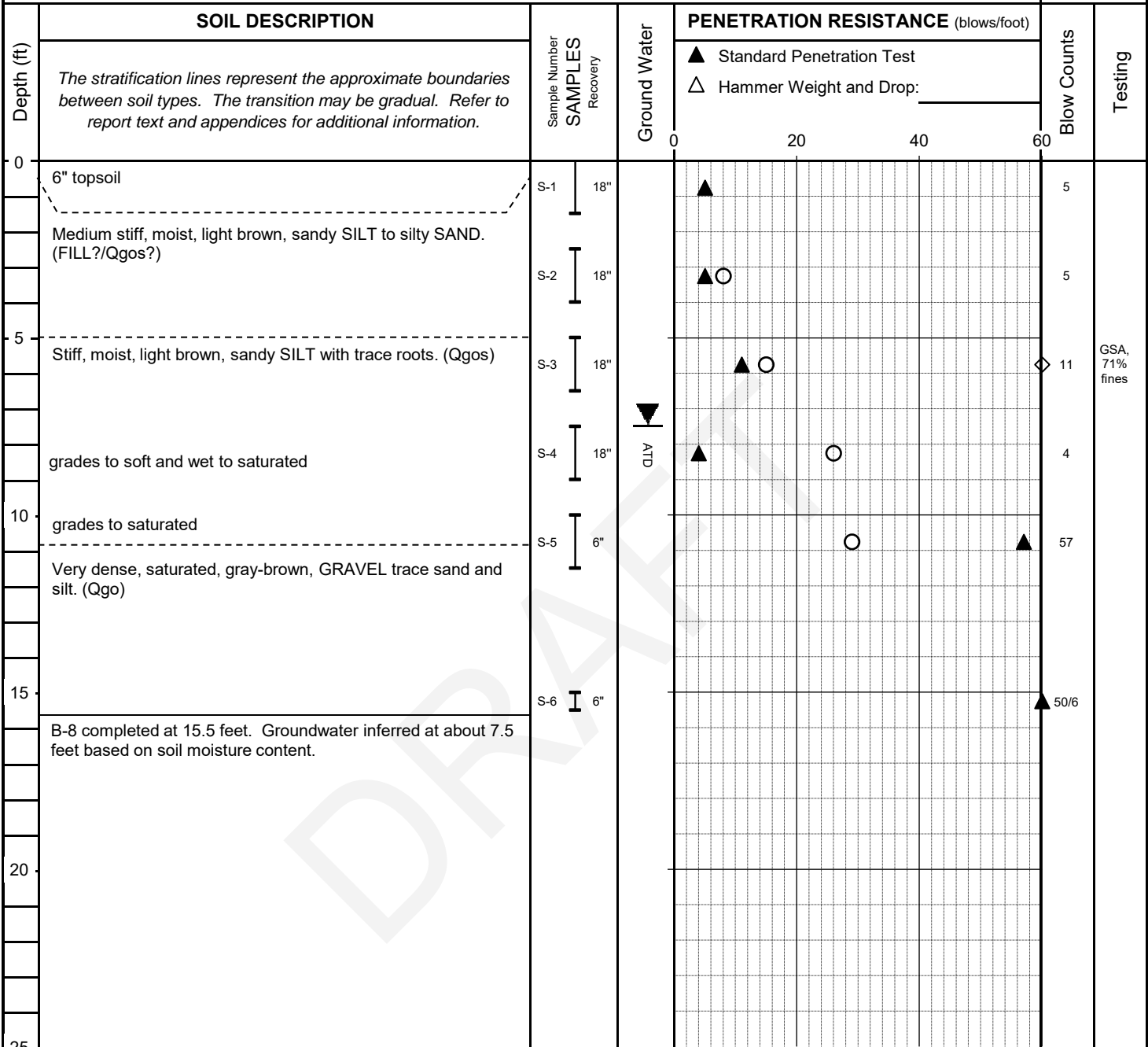
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BORING LOG: B-7

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling **Bore Hole Dia.:** 6 inch
Top Elevation: 154 ft **Drilling Method:** Track CFA **Hammer Type:** auto
Date Drilled: 8/31/2022 **Drill Rig:** CME 75 **Logged by:** JLB

B-8



SAMPLE LEGEND

- 2-inch O.D. split spoon sample
- 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing
- Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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Date: 9/30/2022 Project No.: 2613.01

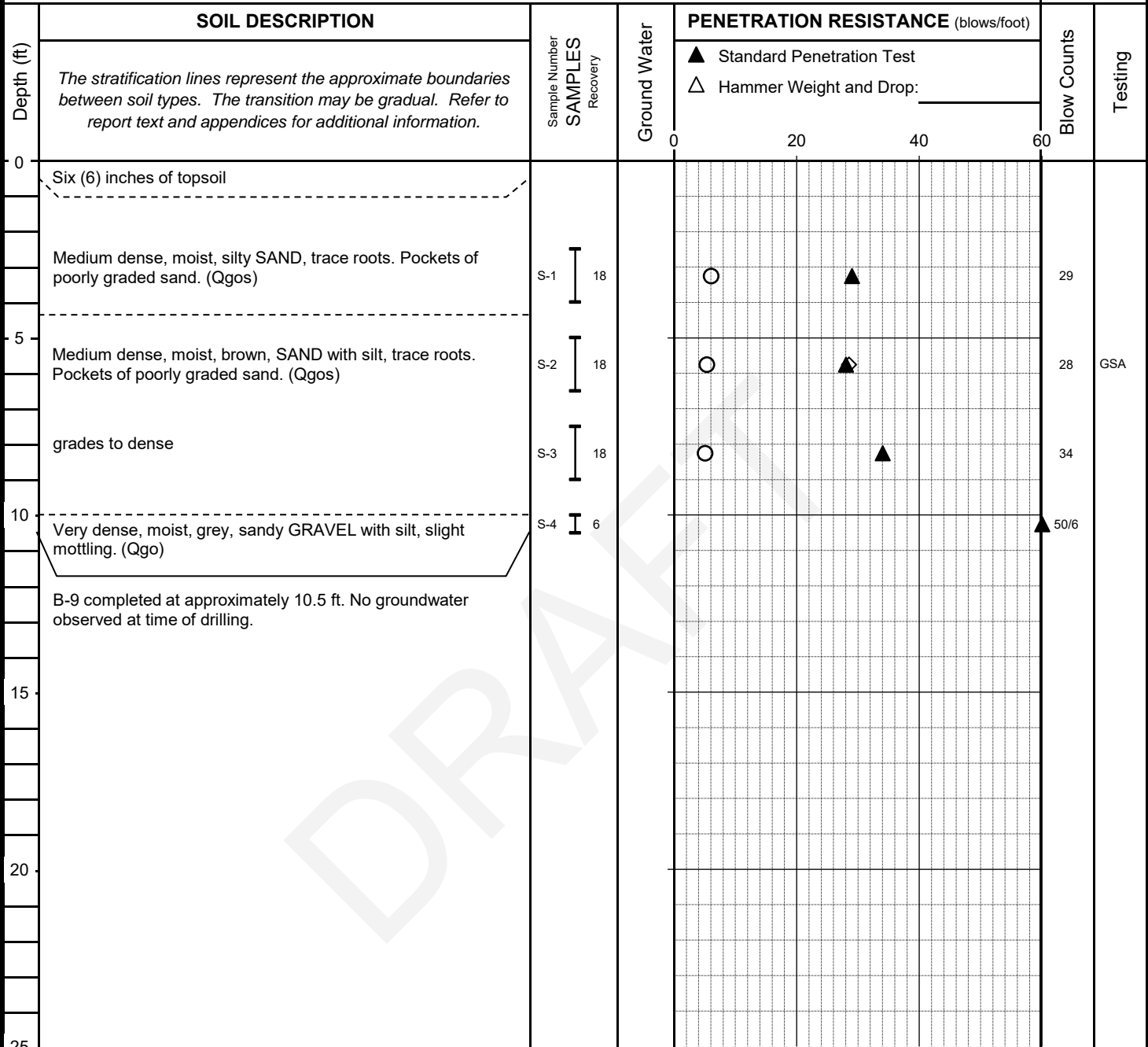
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BORING LOG: B-8

Page 1 of 1

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling **Bore Hole Dia.:** 6 inch
Top Elevation: 151 ft **Drilling Method:** CFA **Hammer Type:** Auto
Date Drilled: 9/13/2022 **Drill Rig:** Diedrich D70 **Logged by:** JLB

B-9



SAMPLE LEGEND

- 2-inch O.D. split spoon sample
- 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing
- Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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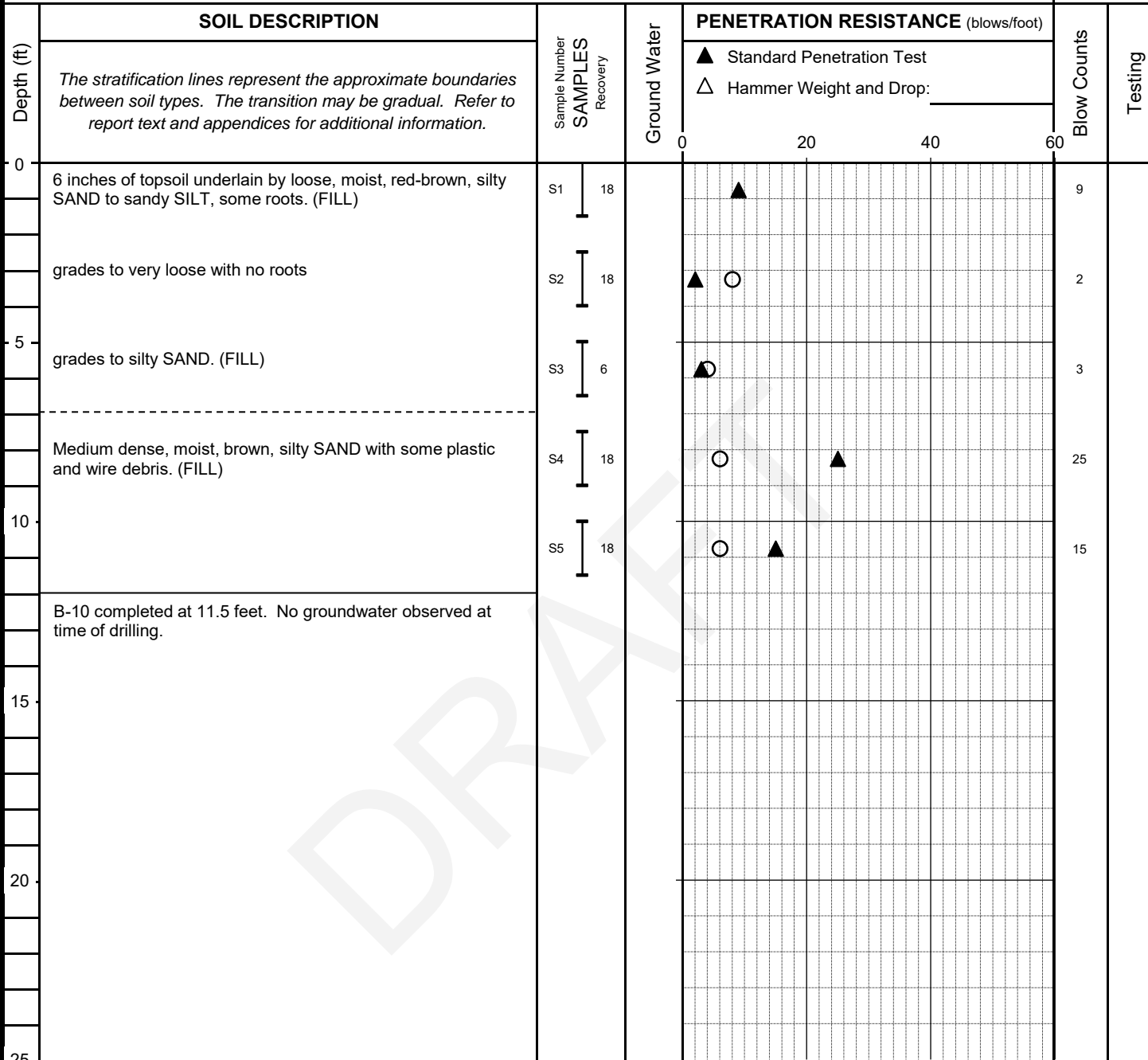
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BORING LOG: B-9
 Page 1 of 1

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling, **Bore Hole Dia.:** 6 inch
Top Elevation: 147 ft **Drilling Method:** Track CFA **Hammer Type:** auto
Date Drilled: 8/31/2022 **Drill Rig:** CME 75 **Logged by:** JLB

B-10



SAMPLE LEGEND

- 2-inch O.D. split spoon sample
- 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing
- Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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Date: 9/15/2022

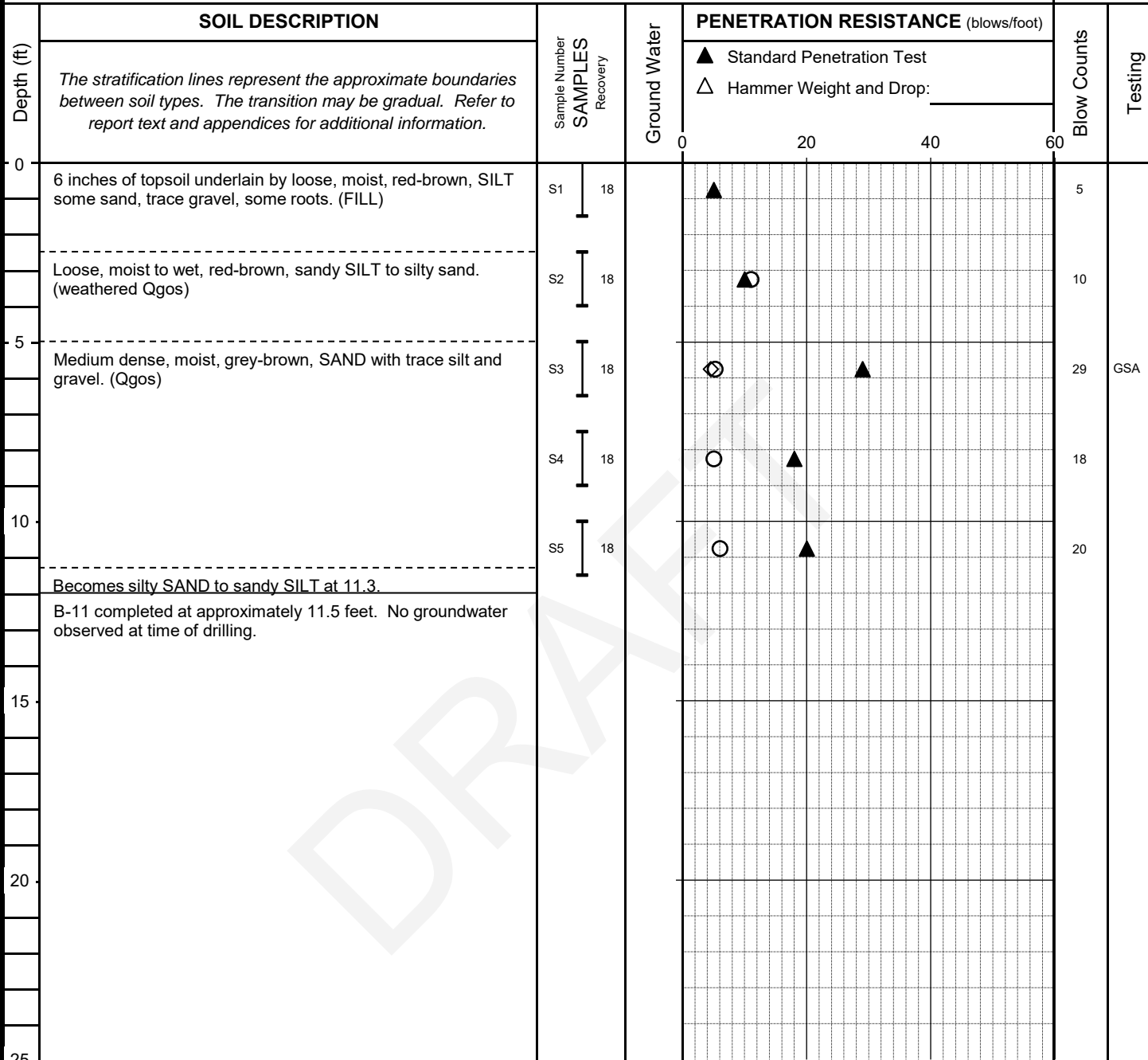
Project No.: 2613.01

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BORING LOG: B-10

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling, **Bore Hole Dia.:** 6 inch
Top Elevation: 147 ft **Drilling Method:** Track CFA **Hammer Type:** auto
Date Drilled: 8/31/2022 **Drill Rig:** CME 75 **Logged by:** JLB

B-11



SAMPLE LEGEND

- 2-inch O.D. split spoon sample
- 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing
- Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit ———— ○ ———— Liquid Limit

Natural Water Content

TESTING KEY

- GSA = Grain Size Analysis
- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
- Att. = Atterberg Limits

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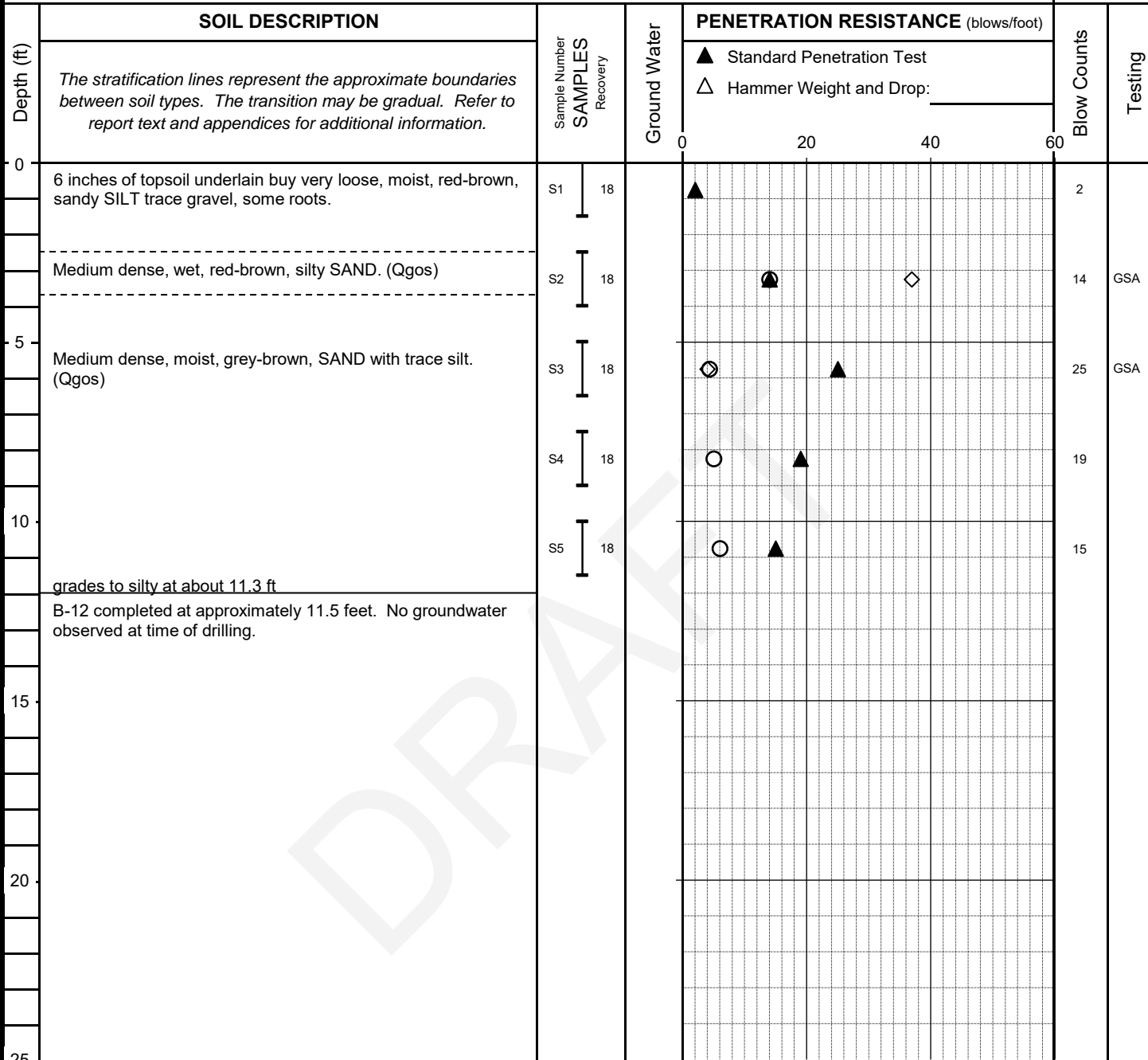
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BORING LOG: B-11

Boring Location: See Figure 1, Site and Exploration Plan **Drilling Company:** Holocene Drilling, **Bore Hole Dia.:** 6 inch
Top Elevation: 145.5 ft **Drilling Method:** Track CFA **Hammer Type:** auto
Date Drilled: 8/31/2022 **Drill Rig:** CME 75 **Logged by:** JLB

B-12



SAMPLE LEGEND

- ┆ 2-inch O.D. split spoon sample
- ┆ 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- ▨ Clean Sand
- ▨ Bentonite
- Grout/Concrete
- ▨ Screened Casing
- Blank Casing
- ▼ Groundwater level at time of drilling (ATD) or on date of measurement.

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit ———○——— Liquid Limit

Natural Water Content

TESTING KEY

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- 200W = 200 Wash Analysis
- Consol. = Consolidation Test
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BORING LOG: B-12