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Department of Civil and Environmental Engineering
Lafayette College
-
CE473 – Senior Capstone Design II
Spring 2015

Geotechnical Engineering Study and Design Report for "Elevating Easton" Project

Group: Geotechnical Team
Team Members: Travis Barr, Hailey Votta

Executive Summary:

Enclosed is a final geotechnical report for "Elevating Easton" project at Lafayette College. Based on our exploration and field work, the major subsurface condition affecting the project site is the presence of the Allentown Formation, a limestone and dolomite bedrock characterized by karst topography and sinkhole activity. Due to this geological condition as well as the potential of flooding, micropile foundations were designed for both the SPOT Landing structure and for the piers along the inclined elevator track. Spread footings as well as a cantilever retaining wall were designed for the proposed Marquis Landing structure.

Table of Contents:

1. Introduction

This report documents a geotechnical investigation as well as geotechnical design for the "Elevating Easton" project. The objectives of the investigation were to: (1) to establish geotechnical data that can be used for structural design; (2) assess rock/slope failure risk of any excavation on the escarpment, or at the base and top; (3) assess karst geology risk (i.e. sinkholes) in the project area; (4) assess stream embankment erosion along Bushkill Drive; (5) assess if there is any undermining from scour of any structures currently in the Bushkill Creek flow channel; and (6) create a graphical analysis of subsurface conditions to convey site characteristics to the other project teams. Using the information obtained through this investigation foundations were designed for the: (1) SPOT Landing Location, (2) span touchdown locations, and (3) Marquis Landing Location. Micropile foundations were determined to be the best suited for the SPOT Landing as well as the span touchdown locations due to the subsurface conditions as well as the possibility of uplift forces at the SPOT Landing. Spread footings were designed for the Marquis Landing Location.

2. Site Description

2.1 SPOT Landing/ Intermodal Transportation Center

The proposed project site of the SPOT Landing/ Intermodal Transportation Center is located west of The Spot located at the intersection of College Avenue, 3rd Street, and Bushkill Drive and to the south of Lafayette College campus on College Hill in the city of Easton, Pennsylvania. The current use of the site is that of the SPOT parking lot. As depicted in the site aerial photo map (Appendix A – Site Location), several buildings currently exist adjacent to the site: The Spot, a 3-story building used by Lafayette College, is closest in proximity directly east and a 1-story building owned by Lafayette

College known as the Mohican Building is located to the south of The Spot, with foundations located on both sides of Bushkill Creek.

It is important to note that the fill slope along the Bushkill Creek (south edge of the proposed site) on the site location has an approximate slope of 2.5H: 1V. The ground surface by this location is covered with concrete and evidence of erosion exists along Bushkill Creek at the base of the slope.

2.2 Elevator Span

The proposed location of the inclined elevator span begins west of The Spot. The proposed structure will begin in a new building attached to the west face of the SPOT and will terminate at a new landing facility at the top of the hill. The hill is at an approximate slope of 27°. The approximate horizontal length is 250 feet, with a vertical change of 150 feet. The span will consist of 11 touchdown locations along the slope and at landings.

2.2 Marquis Landing

The proposed project site of Marquis Landing is located at the top of the hill. It currently sits along a sidewalk connecting Ruef and Easton Halls. The current location is covered by grass and sloped towards the hill. Re-grading will need to occur to meet ADA requirements due to the topography.

3. Project Description

3.1 SPOT Landing/ Intermodal Transportation Center

The Intermodal Transportation Center will consist of a multi-story glass and masonry steel framed building. An attached glass atrium will house landing bays for the two inclined elevator tracks. Various entrances and exits both at and above grade will connect the various sides of the structure to the lower Arts Campus. The structure will have a raised platform between the existing SPOT and

Mohican buildings. The lower level of the structure will be flood resistant as it is located directly adjacent to Bushkill Creek.

3.2 Elevator Span

The inclined elevator span will consists of two tracks supported by central concrete columns. The ten concrete columns will be pre-cast post tensioned sections supporting a hammer beam upon which the supporting steel for the tracks will rest.

3.3 Marquis Landing

The Marquis Landing structure will consist of a raised platform above a machine room, housing all elevator mechanical equipment. The existing sidewalk will be redirected underneath the platform along a newly constructed retaining wall. Staircases to the platform will be supported in part by the retaining wall. A sidewalk leading directly to the platform will be placed on top of compacted fill.

4. Purpose and Scope

The purpose of this project was to investigate a means to sustainably connect Downtown Easton and the Lower Arts Campus to College Hill and the main campus. In order to facilitate this objective the geotechnical scope consisted of:

1. Foundation design for SPOT Landing, span pier locations, and Marquis Landing
2. Design of load bearing fills at Marquis Landing
3. Earth pressures for Marquis Landing retaining wall
4. Design of micropiles

5. Site Reconnaissance and Subsurface Conditions

5.1 Local Geology

The site is underlain by the Rickenbach and Allentown Formations as shown by the geological map of the region. As described by Drake (1967), the Rickenbach Formation is a carbonate rock comprised of medium to dark gray, finely to coarsely crystalline dolomite with chert lenses or beds and nodules. The Allentown Formation is another carbonate rock formation comprised of medium dark gray, thick bedded dolomite and impure limestone with chert stringers and nodules; weathered calcareous siltstone at the base. The borings conducted for the Lafayette College Film and Media Studies Center, which is located near our site location, found both dolomite and limestone rock at the base of the boreholes and rock core samples.

It is well known that the region was once subjected to prehistoric glacial activity. This site is located on the southern edge of the glacial advances in Pennsylvania. Deposits at this site contain primarily thin, clayey and silty soils.

Due to the pinnacled nature of carbonate rocks, the elevation of the bedrock is variable throughout the site area. The borings conducted for the Lafayette College Film and Media Studies Center encountered bedrock at depths of 25 to 30 feet below the ground surface for five of the six borings. This translates to an approximate elevation of bedrock of 158 to 153 feet.

Along the slope depth of bedrock was determined to be approximately 2 feet. At various points along the slope rock becomes visible. It is anticipated that sound sock will be found at a depth greater than 10 feet into the hill. This depth is highly variable depending on hill slope and vegetation.

Please refer to Drawing AE401 for boring locations and slope cross sections. Because available subsurface data indicates that bedrock is located at shallow depths, we do not anticipate high rock/slope failure risk.

Carbonate bedrock has a natural tendency to develop sinkholes. The DCNR Sinkhole Map available online to the public shows that there are four sinkholes documented within a 0.5 mile radius of the project site location. Please refer to Appendix B – DCNR Map for a DCNR Map image of the immediate area surrounding College Hill and marked sinkholes.

Our field exploration involved site observations and geotechnical report reviews to investigate the existing foundations and obtain subsurface information on the soils, rock, and groundwater.

5.2 Site Reconnaissance

Site reconnaissance was completed through the field exploration; please refer to Appendix C – Field Photographs for the field photographs of several field explorations and observations. Our team noticed a slope comprised of diverse fill materials under the N. 3rd Street Bridge, adjacent to The Spot. Large chunks of concrete, rocks and other debris jut out of the slope face (Figure B1). To the west of this slope and adjacent to a small dam, the south side wall of the Bushkill Creek exhibits many fractures and deterioration (Figures B5 and B6).

5.3 Hand Augers

On November 8th, the Geotechnical Team and Survey Team marked a traverse alignment on the project site. Please refer to Figures B16 to B20 for photographs of this field work. The Geotechnical Team performed field borings on November 18th and 19th at locations along the slope between Ruef Hall and The Spot. The boring logs are detailed in Appendix D – Boring Logs, and the subsurface information obtained through this work was used to develop the cross-section in Drawing AE401. The

locations of these borings are shown on the aerial map in Appendix E- Boring Location Map. Please see Figures B21 to B23 for photographic representation of this boring log field work.

5.4 Soil Borings

The Geotechnical Team reviewed the boring logs performed for the Lafayette College Film and Media Studies Center conducted by GeoStructures Inc. as well as Maser Consulting, the Proposed New Global Education Center conducted by Advantage Engineers, LLC, and the Sullivan Trail Residential Development conducted by Schnabel Engineering Associates, Inc. in order to understand the expected subsurface conditions on the project site. These sources suggest that there are layers of Fill, Glacial and Alluvial Deposits, and Residual Soil from weathered bedrock. Descriptions of these layers can be found in Tables 1 and 2.

Table 1: Strata Description for Sullivan Trail Residential Development

(Schnabel Engineering Associates, Inc)

Stratum	Depth	Description
Fill	Ground surface to depths of 1.7 to 6.9 ft.	Brown and black, sandy lean clay fill and sandy silt fill with trace gravel, rock, brick, and wood fragments (N=6 to 36). Brown, gray, and black clayey sand fill with trace gravel, rock, glass, and brick fragments (N=10 to 35).
Glacial Till	Ground surface and below the Fill to depths of 3 to 23.5 ft.	Brown and black sandy lean clay (CL) and sandy silt (ML) with trace gravel and rock fragments (N=5 to 37). Brown clayey sand (SC) and silty sand (SM) with trace gravel and rock fragments (N=6 to 49).
Residual	Below Glacial Till to depths of 6 to 30.5 ft.	Brown and gray sandy lean clay (CL) and sandy silt (ML) with rock fragments (N=3 to 43). Brown silty sand (SM) with rock fragments (N=18 to 27).
Allentown Formation	Below Glacial Till and Residual to maximum depth of exploration of 40.5 ft.	Fresh to highly weathered limestone. Hard to moderately hard. Slightly to moderately fractured. Contains calcite veins. (REC=28 to 100%; RQD=18 to 93%)

Table 2: Strata Description for Film and Media Studies Center (Maser Consulting P.A.)

Stratum	Thickness	Description
Fill 1	2.5 ft. to 20 ft.	Poorly compacted, loose to very loose, brown to gray, silty sand with gravel (SM). Local sub-layers of sandy silty clay (CLML) and silty sand with gravel (ML). Concentrations of cinders, bricks, and concrete with glass mortar, and coal exist.
Fill 2	2 ft. to 12 ft.	Well compacted, medium dense, brown, silty sand with gravel (SM). Cinders, bricks, and concrete fragments exist with large cobble-sized rock or concrete pieces.
Stratum 1: Glacial and Alluvial Deposits	4 ft. to 9 ft.	Lean clay with sand (CL), silt with sand (ML) and silty sand with gravel (ML).
Stratum 2: Glacial Sediment	17 ft. to 26 ft.	Medium to dense, brown, silty sand with gravel (SM).

Using the compiled data as well as the information gained through our site reconnaissance and hand augers, anticipated soil conditions were developed. The SPOT Landing is most likely underlain with silty sand fill comprised of pieces of concrete, rocks and other debris. Glacial and alluvial deposits may exist under the fill layer. On the slope a shallow layer of highly vegetated soil exists on top of extremely weathered rock. The Marquis Landing is being developed on top of poorly compacted and highly variable silty sand fill. Layers of glacial and alluvial deposits exist beneath this layer.

5.5 Rock Coring

Rock corings determined that the rock beneath the sites is fractured, voided, and weathered. The rock exhibited RR and RQD values less than 45 and 25 percent, respectively. Intact rock does not occur until approximately 10 feet beneath the beginning of the weathered zone.

5.6 Groundwater

The Film and Media Studies Center report remarks that a perched water aquifer was founded at a depth of 6 feet under the surface (although the B-4 boring report indicates that the perched aquifer resided 8-10 feet below surface). This corresponds to an elevation of 177 feet at the location of the SPOT Landing. Furthermore, this document reports another saturated layer at a depth of 21 feet below surface in B-7.

The site has a water table elevation of typically 163.5 feet above sea level. Similarly, Aerial LiDAR data utilized by the CE 473 Capstone Design II course at Lafayette College references a Bushkill Creek elevation of 164 feet above sea level. It is important to note that the elevation of the water table changes with time and space and is influenced by the time of the water year and precipitation.

5.7 Generalized Stratigraphy

5.7.1 SPOT Landing/ Intermodal Transportation Center

The proposed location of the Intermodal Transportation Center is in the parking behind The Spot. The parking lot is placed upon a layer of fill most likely composed of silty sand fill mixed with chunks of concrete, rocks and other debris. The depth of this layer is unknown though can be as deep as 20 feet as seen with the borings conducted at the FAMS site. Beneath the fill is most likely a layer of alluvial and glacial soils. Depth of bedrock can vary up to 25 to 30 feet below the ground surface.

5.7.2 Elevator Span

The Elevator Span located upon the slope is being founded on a shallow layer of organic soils reaching approximate depth of up to 2 feet according to the hand auger borings. Beneath this soil layer a highly weathered dolomite rock exists. A weathered zone of 10 feet is assumed.

5.7.3 Marquis Landing

The Marquis Landing site resides over a large quantity of highly variable fill material overlying the alluvial and glacial soils present in the area. Depth to rock is variable due to the karst topography and associated pinnacle structure. A weathered zone of 10 feet was also assumed at this site.

6. Conclusions and Recommendations

6.1 Scour and erosion potential

Minor scour of the Bushkill Creek riverbed was observed during site reconnaissance. Minor deterioration of the existing retaining wall was also observed. No remediation of these structures is recommended since there are no proposed slabs on grade for the SPOT Landing location and it is recommended that foundation support is provided by micropiles.

6.2 Micropile Foundations

The Film and Media Studies Center report recommends deep foundations, specifically micro-piles with grade beams spanning between pile caps to support walls. Our company recommends Type 1A micro-pile foundations at the SPOT Landing Location and span touchdown locations based on the varying depth to rock and well as the limited access along the slope face with traditional installation equipment. Micropiles are generally are less than 12 inches in diameter and no longer than 10 feet in bonded socket length. The spacing between micro-pile is typically three diameter lengths, center-to-center. Grout utilized in construction is often Portland cement based grout of Type I or Type III, with a water cement ratio of 0.45-0.50 by weight. This mixture has a compressive strength greater than 4,000 psi. Due to slenderness ratio of the micropiles, buckling is a concern in very soft ground conditions. Redundancy may need to be placed into design in order to combat potential sinkhole development.

With the recommendations of micro-pile foundations, our team does not expect any necessary rock excavation or shoring, except for that which is involved in the drilling of foundations. We also do not find great risk in erosion of our proposed structures by the stream. If proposed location moves closer to Bushkill Creek further analysis of scour needs to be conducted. As a note, because perched aquifers have been identified in the immediate area (as reported in the Film and Media Studies Center report), we anticipate minor water in excavations for pile caps. Finally, we do not believe temporary shoring will be necessary.

6.3 Spread Footings

Using subsurface investigation data, spread foundations were designed for the Marquis Landing Location. Spread footings are 5 feet wide along the perimeter of the landing structure. The spread footings support the machine room and associated equipment. It is recommended the foundations cast-in-place upon a layer of approved load-bearing fill for drainage and settlement considerations. Bearing capacity of soil much be greater than 100 psf in the vicinity of the spread footings. For the Marquis Landing foundation details please see Drawing AE402.

6.4 Load-Bearing Fill

In order for the inclined elevator to be properly designed and implemented, considerations need to be made regarding the loose fill located beneath the landing sites. All fill/backfill proposed to support building and site features that would be negatively impacted by settlement is considered load-bearing fill. The load-bearing fill for this project site should not contain organics, debris, or rock fragments larger than six inches and all soil materials should not exceed +/-2% of optimum moisture per the standard Proctor test (ASTM D698) when placed. The existing fill will most likely require processing and removal of unacceptable materials to be the above requirements. Moist wet fine-grained alluvial encountered at the site would not make acceptable fill due to the high moisture content. To conform

to the above requirement the fill would need to be dried or blended with drier material in order to be used. The course-grained alluvial at the site was determined by Maser to be an acceptable fill material. If additional materials are required it is recommended that imported fill be composed of silty sand with less than 30% passing through a #200 sieve. The plasticity index shall not exceed 10. Compaction of all fill materials should be achieved using a large vibratory compactor when practical.

7 Micropile Design

Using the above characteristics as well as subsurface investigation data, micropile foundations were designed for the SPOT Landing and Inclined Elevator piers and abutments. For this project, pile caps consisting of four different geometries have been designed. The selection of geometry was based upon loads provided by the Structural Design Team. SPOT Landing pile caps contain either two or three micropiles drilled vertically which will resist normal loading as well as potential flood uplift. All micropile lengths were determined to be 50 feet to ensure adequate depth into solid rock. Span touchdown locations have pile caps consisting of groups of either three or four micropiles. At least one of which is always battered at 30°. All micropiles are 7 inches in diameter with lengths varying to ensure a proper bonded length of 10 feet in solid rock. If 10 feet of bonded length is not achieved during installation of piles, lengths will need to be adjusted to ensure this dimension. Each micropile contains a No. 14 rebar core. For foundation details for each foundation location please see Drawing AE401.

8 Retaining Wall Design

A cantilever retaining wall was designed for the Marquis Landing location in order to provide the necessary grade to achieve ADA compliance. The retaining wall will be on the uphill side of the landing. Dimensions for the wall can be found in Drawing AE402. The wall will support two staircases

located on either side of the platform. The wall is embedded 4 feet below the final grade. The total length of the wall is 110 feet.

Our team recommends using on-site unconsolidated material especially that of silty sand material to provide backfill for any necessary below grade walls. We make these recommendations with an assumption of a 95% standard Proctor density. Below are the characterizations for the recommended silty sand backfill according to GeoStructures (2012):

- Effective friction angle, 30°;
- Cohesion, 0 psf;
- Moist unit weight, 120 pcf;
- At-rest earth pressure coefficient, 0.5;
- At-rest equivalent unit weight, 60 pcf;
- Active earth pressure coefficient, 0.33;
- Active equivalent unit weight, 40 pcf;
- Passive earth pressure coefficient, 3.0;
- Passive equivalent unit weight, 360 pcf; and
- Base slide coefficient, 0.5.

9 Limitations

The included cross sections and geotechnical recommendations were based on field work, existing geotechnical reports, and engineering judgement. While the combination of these resources can provide a reasonable characteristic of the site, the given data will lead to imperfect results. All designs completed based upon these geotechnical recommendations should consider imperfect conditions and the potential costs associated with them. The Geotechnical Team does not assume any liability of unforeseen subsurface conditions determined during or after construction, as our recommendations are based upon the field work completed and the information provided from relevant geotechnical reports, which may not provide all the information necessary to fully understand the present subsurface conditions.

10 References

Drake, Avery Ala. *Geological Map of the Easton Quadrangle, New Jersey-Pennsylvania.* Department of the Interior United States Geologic Survey, 1967.

Geotechnical Engineering Report: Sullivan Trail Residential Development. Rep. West Chester, PA: Schnabel Engineering Associates, 2003. Print.

Kreischer, Darrick L., and Edward L. Balsavage. *Geotechnical Engineering Report: Proposed New Global Education Center*. Rep. Allentown, PA: Advantage Engineers, 2012. Print.

Maser Consulting P.A. *Geotechnical Study Lafayette College-FAMS.* Bethlehem, PA: Maser Consulting, 2014. Print.

Qubain, Bashar S., Eric J. Seksinsky, and Jianchao Li. *Geotechnical Investigation Report: Lafayette College Film and Media Studies Center*. Rep. King of Prussia, PA: GeoStructures, 2012. Print.

Sevon, W.D., Fleeger, G. M., and Shepps, V.C., 1999, Pennsylvania and the Ice Age (2nd ed.): Pennsylvania Geological Survey, 4th ser., Educational Series 6, 30 p.

Traylor, R. P., A. W. Cadden, and D. A. Bruce. *High Capacity Micropiles In Karst: Challenges and Opportunities*. Publication. N.p.: Deep Foundation, 2002. Print.

Appendix A – Site Location

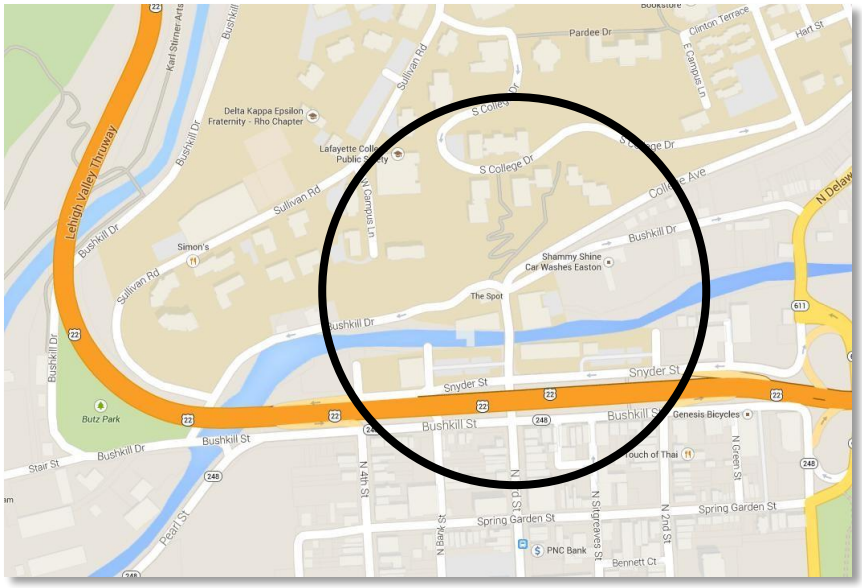

Figure A1. Google Maps image of project location in Easton, Pennsylvania.

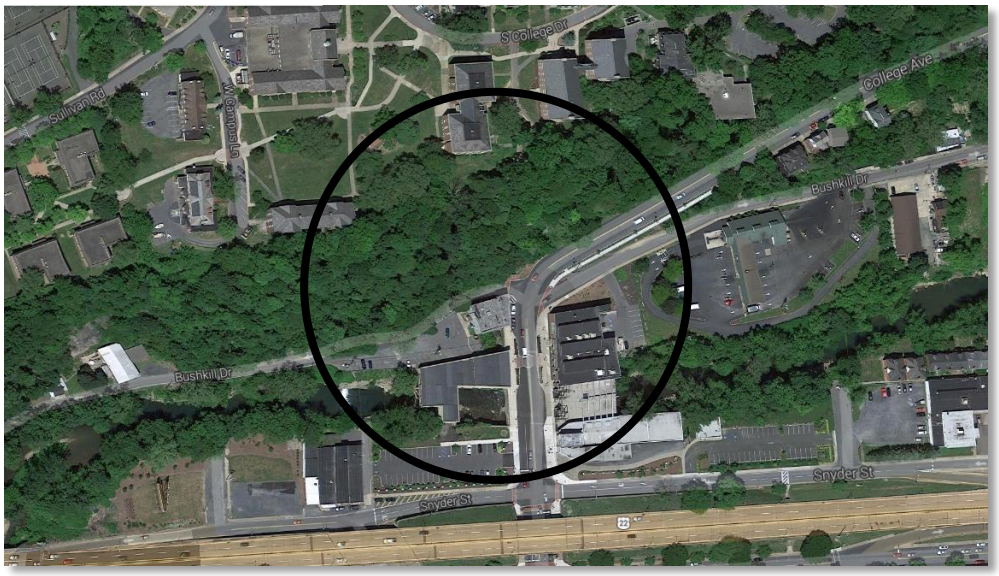

Figure A2. Google Maps aerial image of project location in Easton, Pennsylvania.

Appendix A- Site Location

Figure A3. Aerial photograph with LiDAR contour elevations. Contour information and photograph provided from CE 472

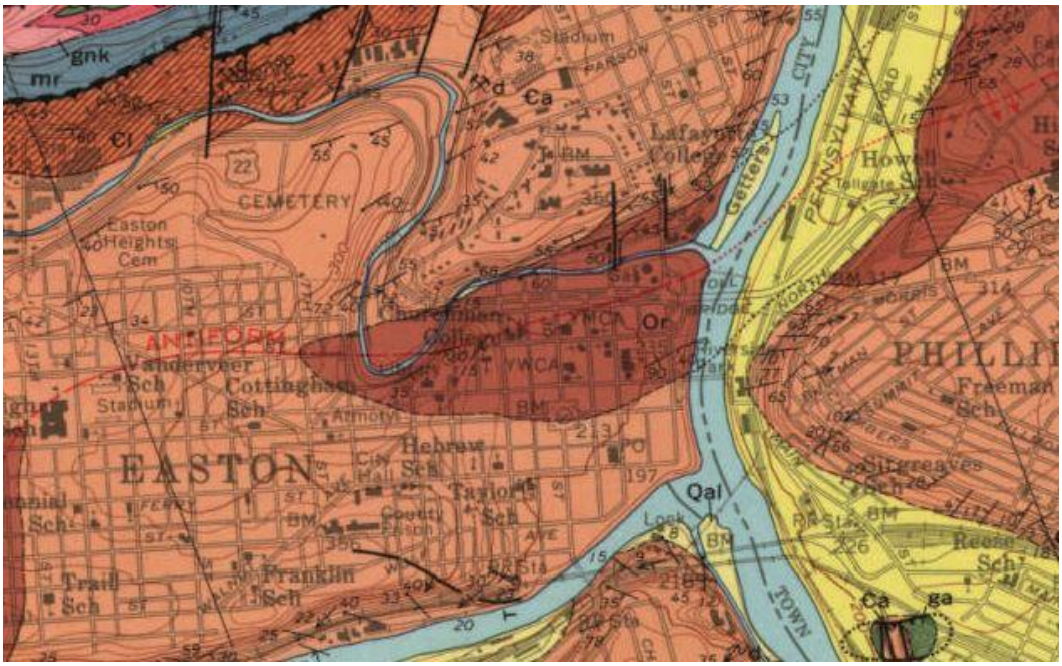

Figure A3. Geological Map of Lafayette College in Easton, PA (Drake)

Appendix B- DCNR Map

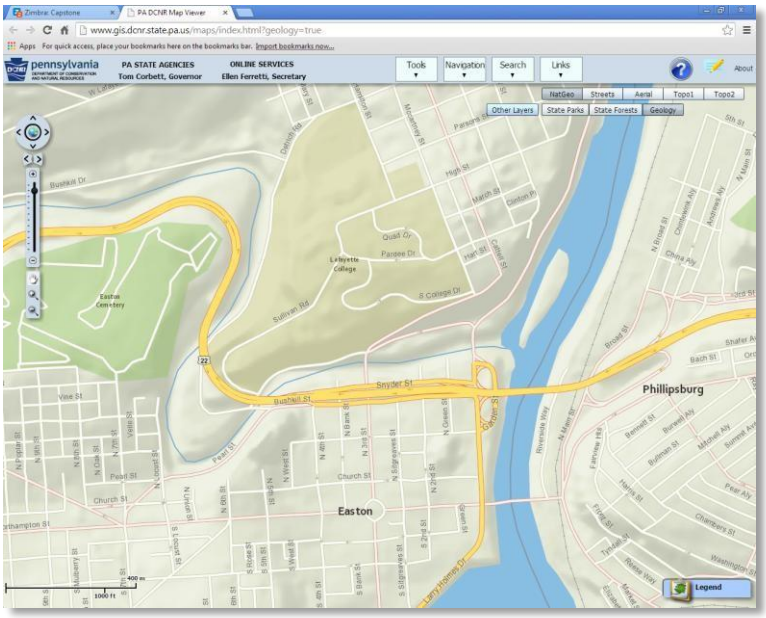

Figure B1. Image of site and surrounding areas. Recorded sinkholes marked by red dots.

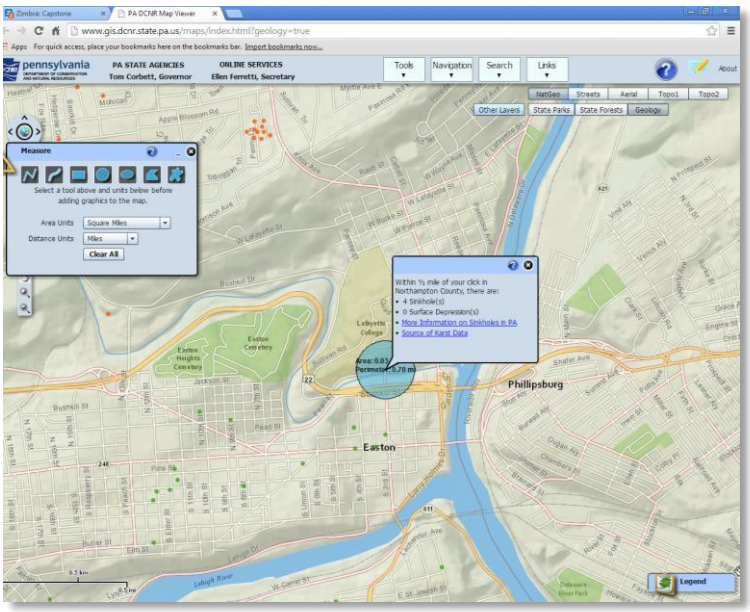

Figure B2. Image of site and surrounding areas. Resource displays four sinkholes within a 0.5 mile radius of site.

Appendix C- Field Photographs

Figure C1. Image of hillside slope between slope. College Hill and downtown Easton, PA.

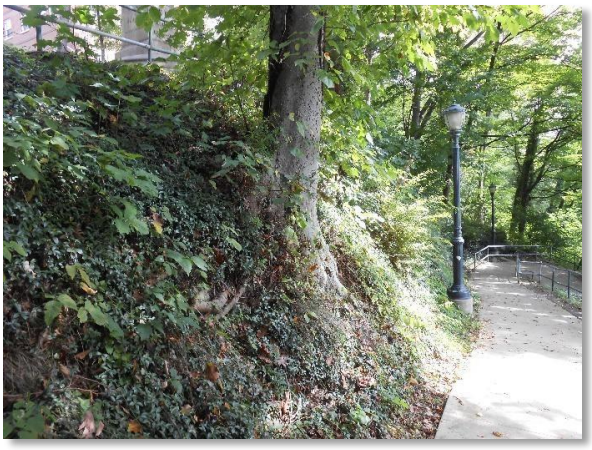

Figure C2. Another image of hillside Part of existing pathway visible.

Figure C3. Image of foundation under 3rd Street bridge, adjacent to The Spot.

Figure C4. Image of rocks forming the foundation of the retaining wall along College Avenue and Bushkill Drive.

Appendix C- Field Photographs

Figure C5. Image of Bushkill Creek walls, fractures visible.

Figure C6 Another image of Bushkill Creek walls, fractures visible. Parking area to the west of The Spot visible in the upper right.

Figure C7. Image rock outcrop to the west of site location, north of the Bushkill Creek.

Appendix C- Field Photographs

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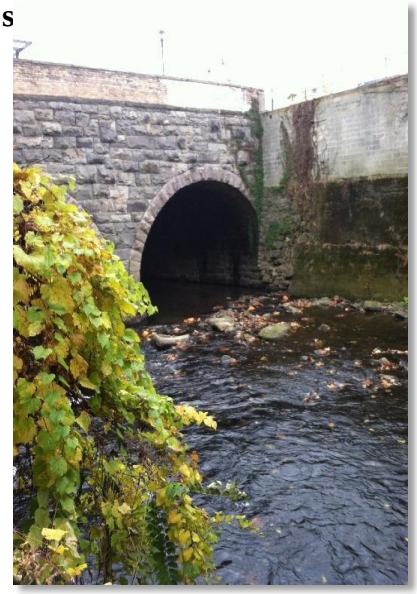


Figure C8. Walls under N. 3rd Street. Bridge and retaining wall visible. Photo taken November 7th, 2014.

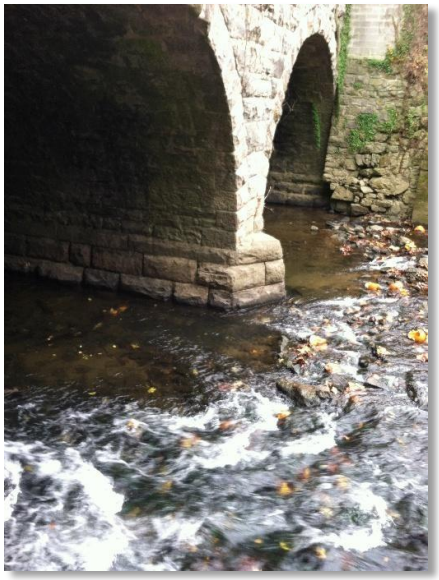


Figure C9. Scour formation under N. 3rd Street Bridge. Photo taken November 7th, 2014.

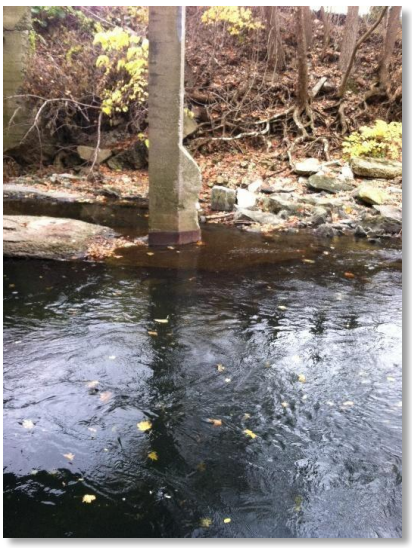


Figure C10. Scour formation under 3rd St. Photo taken November 7th.

Figure C11. Scour formation under Bushkill Creek retaining wall. Photo taken November 7th.

Appendix C- Field Photographs

Figure C12. Scour formation under Bushkill Creek's north retaining wall. Photo taken November 7th.

Figure C13. Potential scour formation under N. 3rd St. Bridge. Turbulent river flow hides view. Photo taken November 7th.

Appendix C- Field Photographs

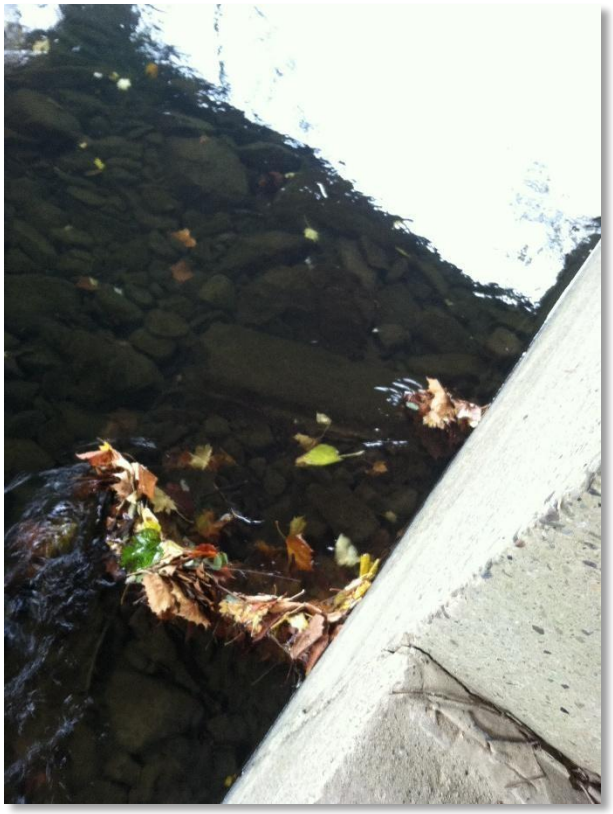


Figure C14. Potential scour formation undermining retention walls of Bushkill Creek. Photo taken November 7th, 2014.

Figure C15. Fractures underneath N. 3rd St. Bridge structure. Leaking water visible. Photo taken November 7th.

Appendix C- Field Photographs

Figure C16. Traverse alignment field work, at the north end of project site. Photo taken November 8th, 2014.

Figure C17. Traverse alignment field work, on "the hill." Photo taken November 8th, 2014.

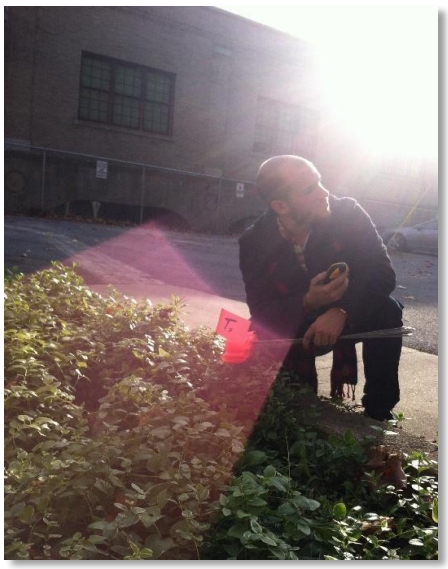


Figure C18. Traverse alignment field work, at the south end of project site, to the west of The Spot. Photo taken November 8th.

Figure C19. Traverse alignment field work, marking location T6 displayed by green circle. Photo taken November 8th.

Appendix C- Field Photographs

Figure C20. Traverse alignment field work, marking location T_6 displayed by green circle. Photo taken November 8th.

Figure C21. Boring log field work. Photo taken November 19th, 2014.

Figure C22. Boring log field work. Photo taken November 19th.

Figure C23. Boring log field work. Photo taken November 19th.

Appendix D- Boring Logs

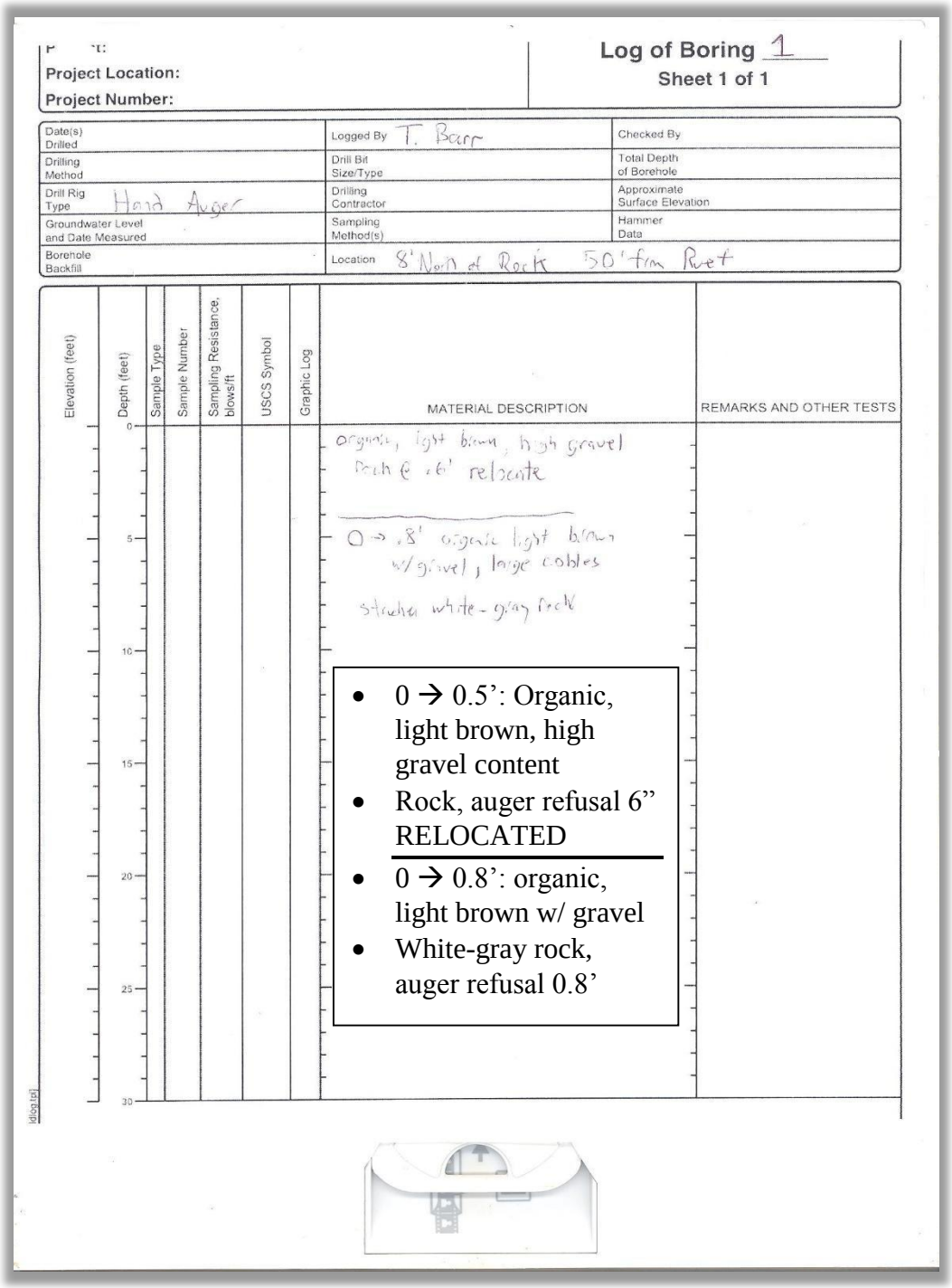


Figure D1. Detailed boring log for B-1.

Appendix D – Boring Logs

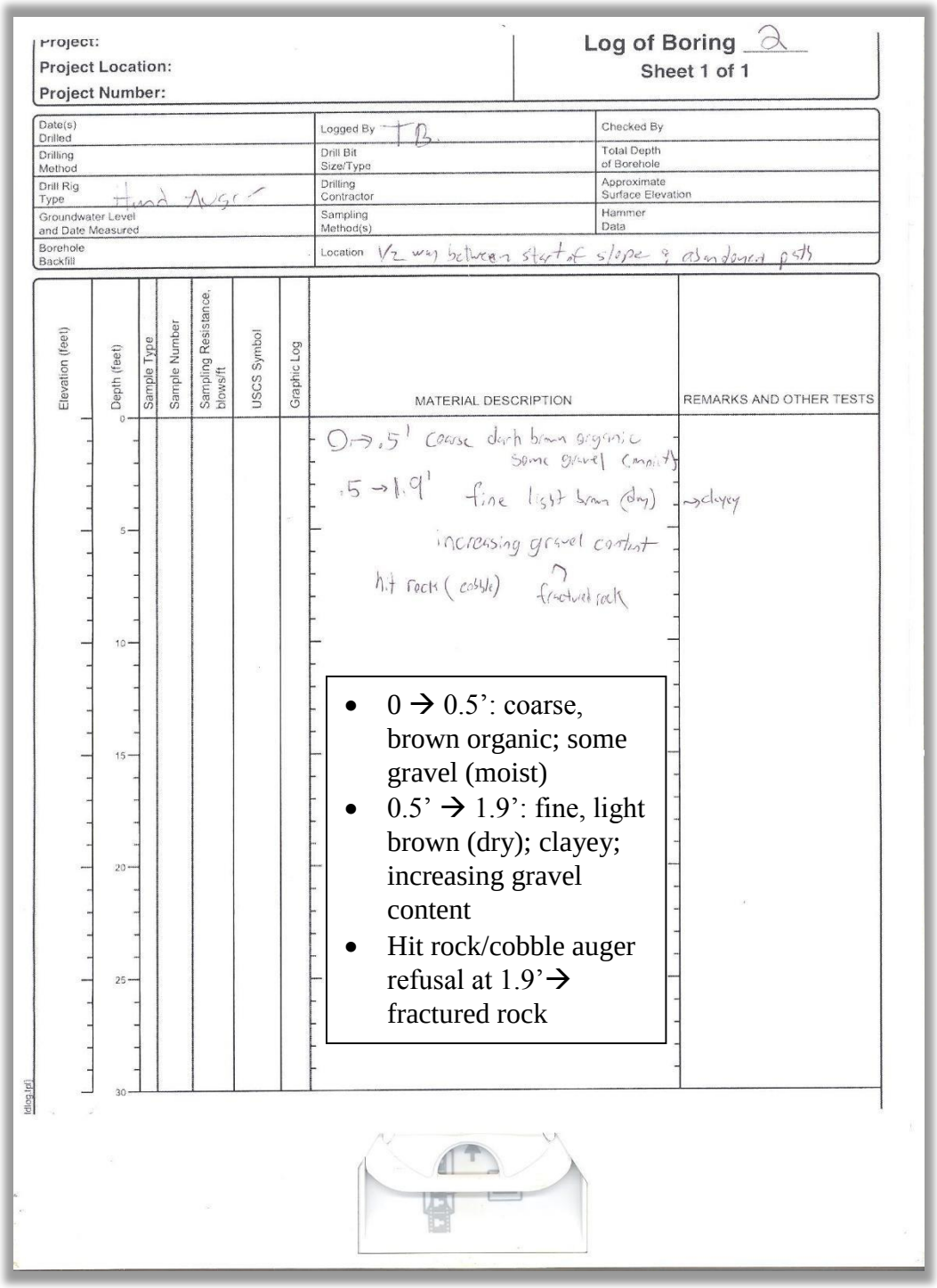


Figure D2. Detailed boring log for B-2.

Appendix D – Boring Logs

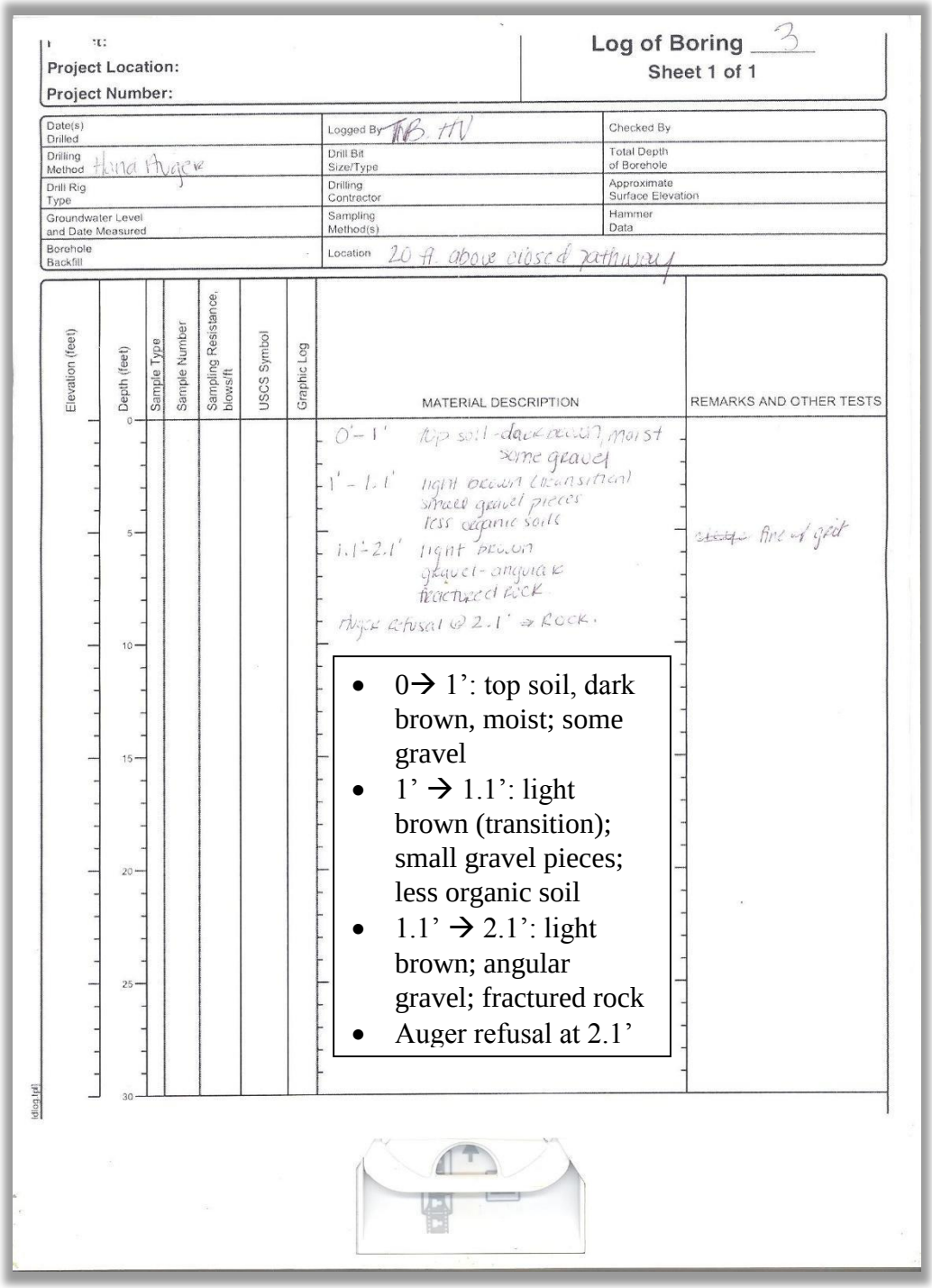


Figure D3. Detailed boring log for B-3.

Appendix D- Boring Logs

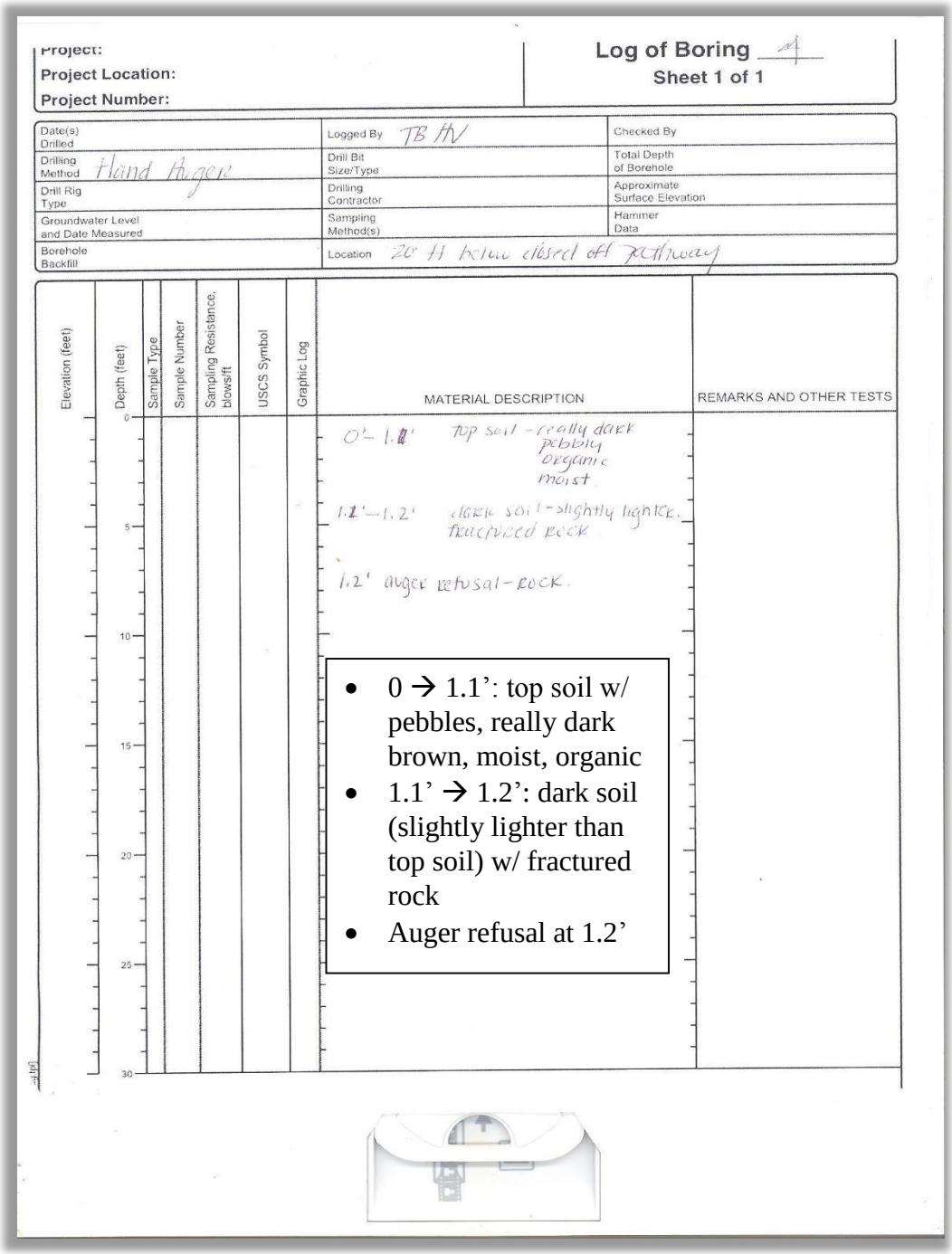


Figure D4. Detailed boring log for B-30.

Appendix D – Boring Logs

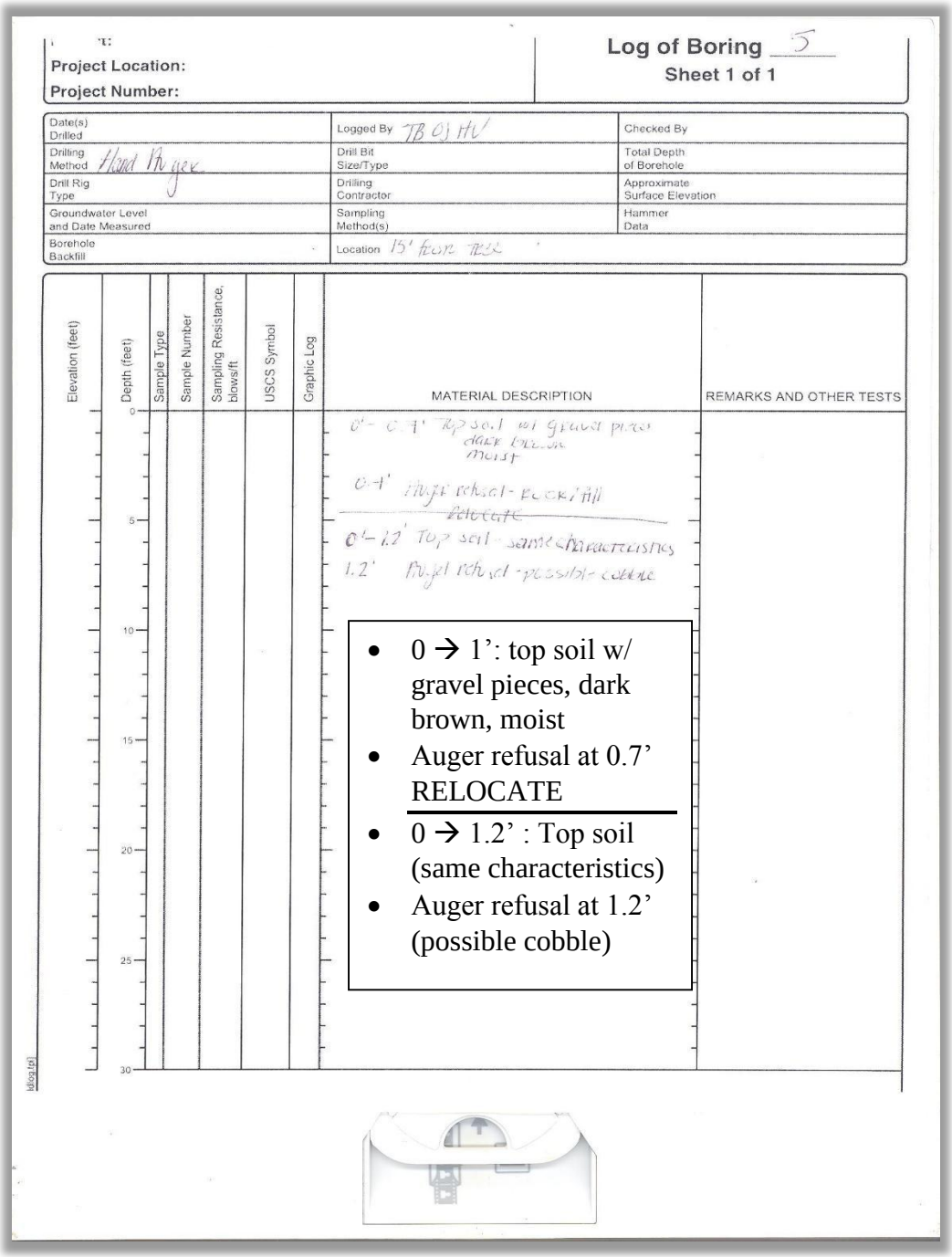


Figure D5. Detailed boring log for B-31.

Appendix D – Boring Logs

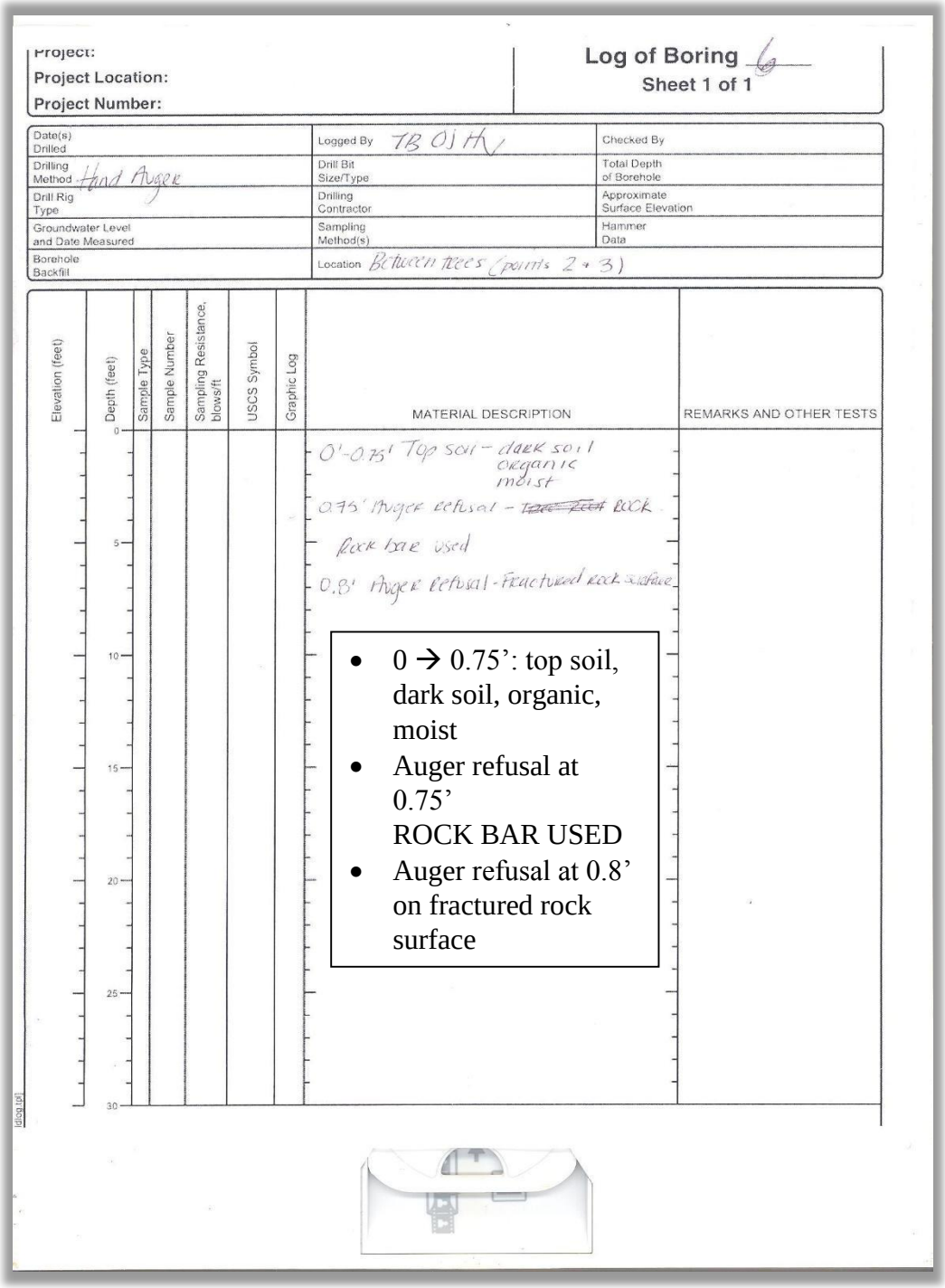
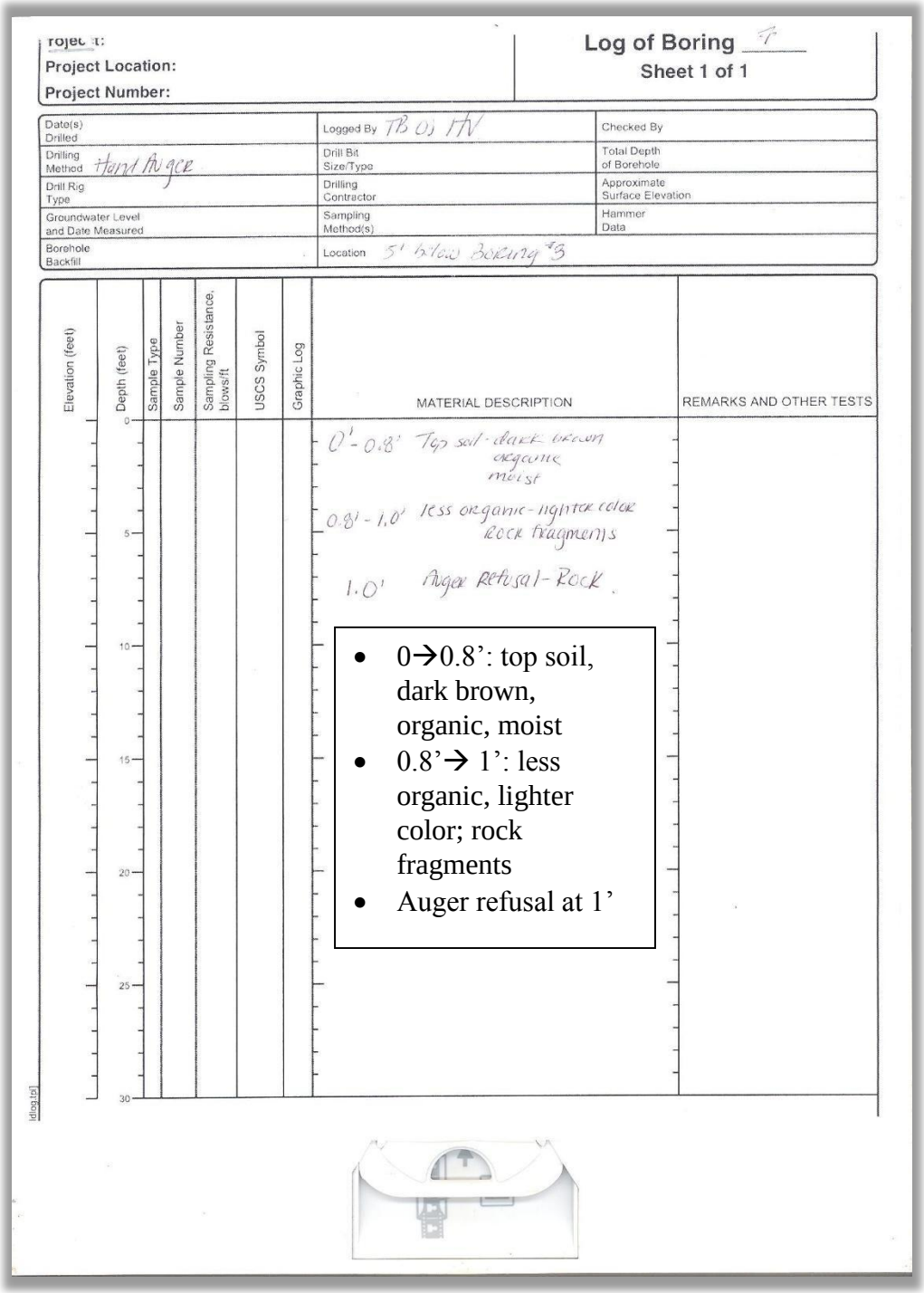


Figure D6. Detailed boring log for B-6.

Appendix D – Boring Logs



- 0→0.8': top soil, dark brown, organic, moist
- 0.8'→ 1': less organic, lighter color; rock fragments
- Auger refusal at 1'

Figure D7. Detailed boring log for B-7.

Appendix D – Boring Logs

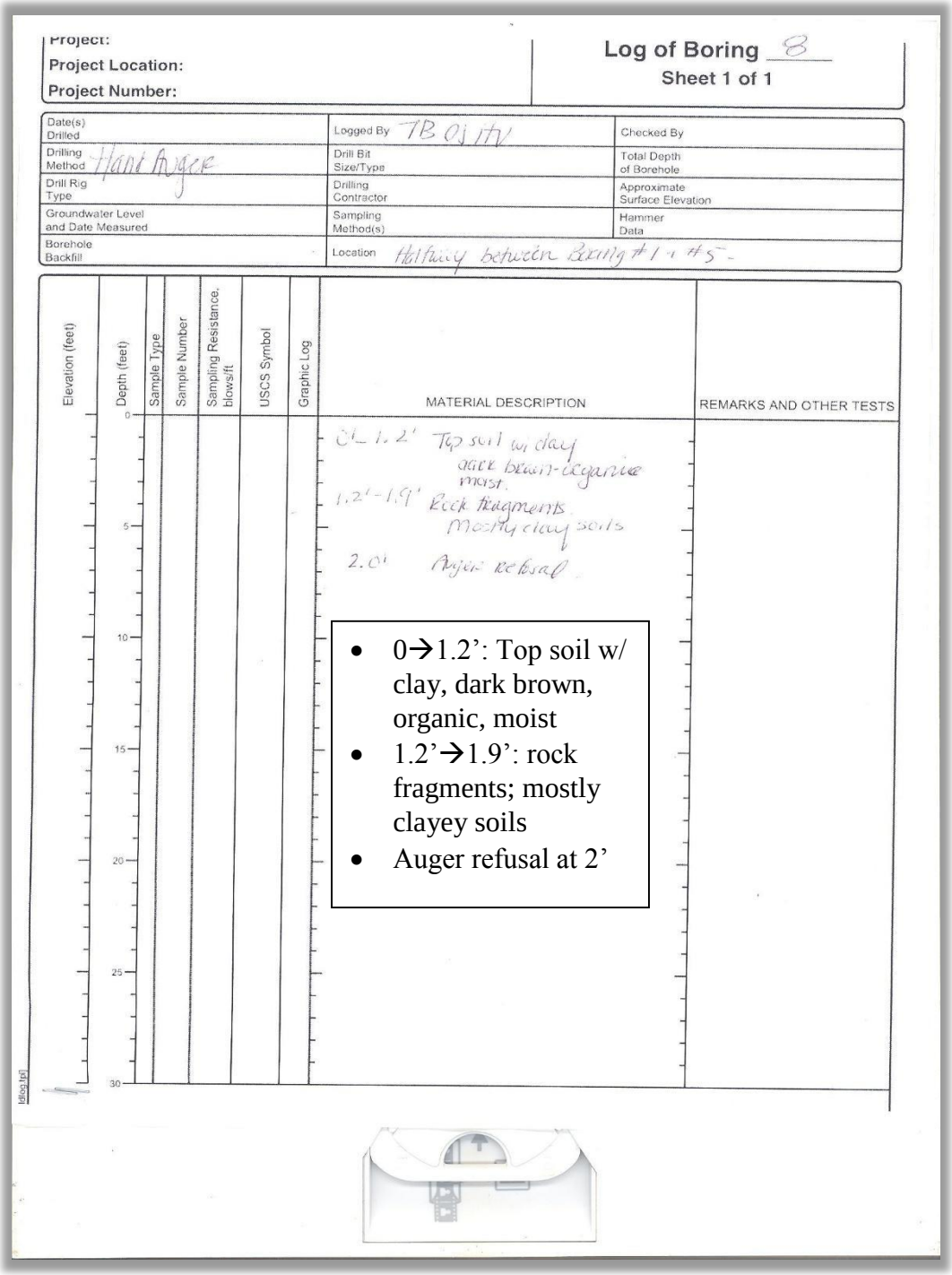


Figure D8. Detailed boring log for B-8.

Appendix E- Boring Location Map

Figure E1. Boring Location Map. Pink circles indicate hand auger boring locations on the slope.