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May 11, 2020
File: 175538106

Attention: Todd C. Gadbury, PE
Hamilton County Engineer's Office
223 West Galbraith Road
Cincinnati, Ohio 45215

Reference: Report of Geotechnical Exploration
Hillside Avenue Landslide
Delhi Township, Hamilton County, Ohio

Dear Mr. Gadbury,

Stantec Consulting Services Inc. has completed the geotechnical report for the landslide on Hillside Avenue in Hamilton County, Ohio. The enclosed report contains a brief description of the site, geologic conditions encountered, the scope of work performed, and geotechnical recommendations for remediation of the landslide.

Regards,

Stantec Consulting Services Inc.

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Attachment: Report of Landslide Exploration

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5-11-20
REGISTERED
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Hillside Avenue Landslide Report of Geotechnical Exploration

Delhi Township, Hamilton County, Ohio

May 11, 2020

Prepared for:

Hamilton County Engineer's Office

Prepared by:

Stantec Consulting Services Inc.
Cincinnati, Ohio

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Executive Summary

Slope instability is evident along sections of Hillside Avenue in Hamilton County, Ohio from about 1,000 feet west of Intersection Street to the intersection of Hillside Avenue and Anderson Ferry Road, over a total length of about 2,300 feet. The project site is located in Delhi Township of Hamilton County. The Hamilton County Engineer's Office is planning to repair and stabilize the roadway in areas where the slope instability has caused settlement, heaving, and tension cracks in the pavement of Hillside Avenue. Stantec Consulting Services Inc. (Stantec) was contracted by the Hamilton County Engineer's Office to perform the geotechnical exploration and develop preliminary design solutions for stabilization, most likely consisting of drilled shaft or pile-lagging walls.

Eight borings were advanced in four areas showing the greatest pavement distress to obtain subsurface data associated with the landslide. A slope inclinometer was installed in one of the borings near the middle of the affected alignment. The borings were advanced with a truck-mounted drill rig in accordance with the American Society for Testing and Materials (ASTM D 1586 and D 1587). The materials encountered were logged by an engineer, with attention given to soil type, consistency, and moisture content.

All borings were advanced through the existing roadway. Roadway materials typically consisted of 12 inches of asphalt pavement underlain by 6 to 12 inches of granular or concrete base material. The materials encountered during the exploration classified as lean clay and were described as stiff to very stiff (generally becoming stiffer with depth), brown to gray, and damp to moist. The lean clay samples contained various amounts of sand and gravel.

A layer of severely weathered light brown shale was typically observed below the soil at depths ranging from 6.0 to 11.3 feet. This severely weathered rock varied from 0.4 feet to 3.2 feet in thickness. This bedrock from the Kope formation is susceptible to landslides. This light brown shale decreased in weathering with depth and was described as moderately fractured, argillaceous, fissile, and friable. Gray shale was encountered below the light brown shale at depths ranging from 9.0 to 25.1 feet. The gray shale was typically described as moderately to highly weathered, slightly to moderately fractured, argillaceous, fissile, and sometimes interbedded with limestone or brown shale. Groundwater was observed at depths ranging from 1.0 to 8.0 feet in four of the borings. Groundwater was not encountered in the remaining four borings.

A drilled shaft wall is recommended along the south shoulder of Hillside Avenue at an offset of approximately 20 feet downhill of centerline in areas of pavement distress to repair and stabilize the roadway and shoulder. The recommended drilled shaft wall configuration includes three-foot diameter drilled shafts reinforced with W24x104 steel beams at five-foot center-to-center spacing. To protect against loss of material through the drilled shaft wall, unreinforced plug drilled shafts are recommended to be installed between the reinforced drilled shafts from the existing grade to the top of bedrock. Concrete lagging can be installed between the W-sections above grade to retain granular backfill, if necessary. The reinforced drilled shafts should be socketed at least 15 feet into bedrock. For budgetary planning purposes, an approximate cost of $2,000 per foot of wall length can be assumed for this wall. It is recommended that the drilled shaft wall on the downhill shoulder be applied to the following approximate sections along the Hillside Avenue, with the priority of these wall sections in terms of need shown parenthesis:

- From 600 to 800 feet west of Intersection Street (Priority 2)
- From 400 feet west of Intersection Street to Intersection Street (Priority 1)
- From 100 to 300 feet east of Intersection Street (Priority 2)
- From 500 to 600 feet west of Anderson Ferry Road (Priority 3).

Observations in the field revealed unstable slopes uphill from the roadway also. Constructing the drilled shaft wall described above along the downhill shoulder of Hillside Avenue in affected sections should protect the road from movement down the slope, however, analyses show that the roadway may still be impacted by movement occurring above the road that could cause material on the uphill side to move onto the road or cause heaving pavement within the road. Because of this potential, stability improvement measures consisting of a pile-lagging wall (W14x90 steel sections on 5-foot center-to-center spacing socketed 15 feet into bedrock) or launched soil nails are also recommended on the uphill (north) side of Hillside Avenue along the affected sections. For budgetary planning purposes, an approximate cost of $1,500 per foot of wall length can be assumed for this wall.

Additionally, observations of the section from 300 to 500 feet east of Intersection Street showed signs of uphill movement in the form of a very steep slope along the uphill shoulder. This gave the appearance that it had been necessary in the past for maintenance crews to remove material from the road that had slid from uphill. At this location, there were no signs of downhill movement like tension cracking or settlement. Only uphill stability improvement measures as described above are recommended along this section of Hillside Avenue from 300 to 500 feet east of Intersection Street

1.0 INTRODUCTION

Slope instability is evident along sections of Hillside Avenue in Hamilton County, Ohio from about 1,000 feet west of Intersection Street to the intersection of Hillside Avenue and Anderson Ferry Road, over a total length of about 2,300 feet. The project site is located in Delhi Township of Hamilton County. The Hamilton County Engineer's Office is planning to repair and stabilize the roadway in areas where the slope instability has caused settlement, heaving, and tension cracks in the pavement of Hillside Avenue. Stantec Consulting Services Inc. (Stantec) was contracted by the Hamilton County Engineer's Office to perform the geotechnical exploration and develop preliminary design solutions for stabilization, most likely consisting of drilled shaft or pile-lagging walls. Figure 1 shows the site vicinity.

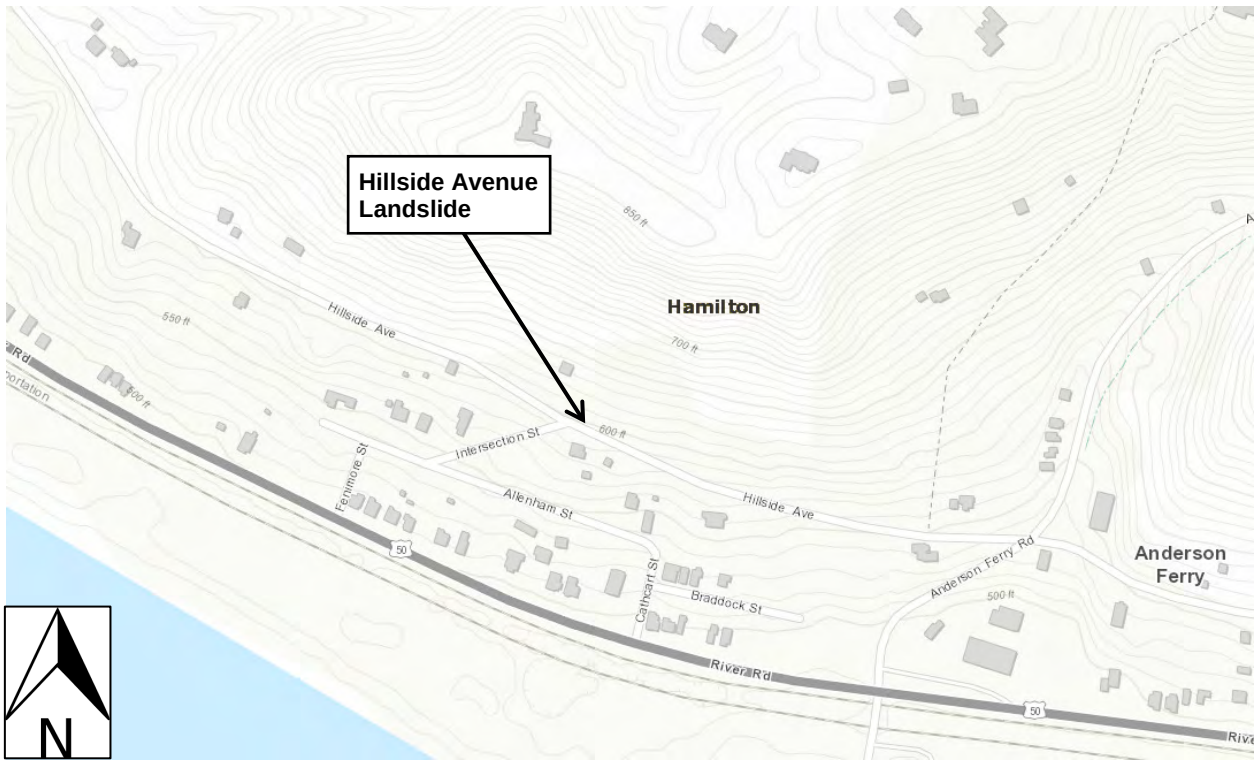


Figure 1. Site Vicinity (Ohio Department of Natural Resources Interactive Mapping)

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 GENERAL

The Physiographic Regions of Ohio Map (Ohio Department of Natural Resources (ODNR), 1998) indicates that the project is located in the Outer Bluegrass Region. The Outer Bluegrass Region is described as a dissected plateau of carbonate rocks. In the eastern portion of the region, caves and other karst features are relatively common. In the western portion, thin, early drift caps and narrow ridges can be found. The region has moderately high relief (generally 300 feet) with elevations of 455 to 1,120 feet.

2.2 SOIL GEOLOGY

According to the Quaternary Geology of Ohio map (ODNR, 1999), the project site is underlain by dissected ground moraine from the Pre-Illinoian Epoch. The ground moraine occurs on ridgetops and mixes with weathered bedrock as colluvium on slopes.

The soil survey (Web Soil Survey of Hamilton County, Ohio, United States Department of Agriculture [USDA], 2020) indicates that the project site is underlain by soils from the Urban land-Alfic Udarent-Pate complex. These soils typically consist of silty clay loam, silty clay, flaggy silty clay, weathered bedrock, and bedrock. These soils also possess a very low to moderately low capacity to transmit water and tend to be very well drained.

2.3 BEDROCK GEOLOGY

Bedrock mapping (Reconnaissance Bedrock Geology of the Burlington, KY-Ohio [ODNR, 1996]) and Descriptions of Geologic Map Units (ODNR, 2011) indicates that the overburden soils at the project site are underlain primarily by sedimentary bedrock from the Kope Formation. The Kope formation is comprised of shale and limestone. The bedrock is described as gray to bluish gray, weathers light gray to yellowish gray, planar, and thin to thick bedded. Bedrock ranges in thickness from 200 to 260 feet. Multiple geologic sources describe the colluvium that weathers from the Kope Formation to be prone to landslides and creeping slope movement.

According to the Ohio Mine Locator (ODNR, 2020), there are no mines in Ohio within five miles of the project footprint.

The Ohio Karst Areas map (ODNR, 2009) indicates there are no probable karst areas near the project site, but there are probable karst areas in Hamilton County due to interbedded Ordovician-age limestone and shale overlain by various amounts of glacial drift or alluvium.

2.4 SEISMIC

A review of the seismic data available in the project vicinity included the OhioSeis database developed by the ODNR, Division of Geological Survey. The review was performed using the internet mapping service (rev. 2012) at the following website: https://gis.ohiodnr.gov/website/dgs/earthquakes/.

Overall, Ohio has a relatively limited amount of seismic activity. Within a ten-mile radius of the project, there have been four earthquake epicenters in Ohio, with magnitudes ranging between 2.5 to 2.9. The available data reviewed included events that occurred from 1804 to present day.

2.5 SITE RECONNAISSANCE

Stantec and Hamilton County representatives visited the site on July 24, 2019. The alignment vicinity can be described as residential. The observed slope instability on Hillside Avenue affects both lanes of traffic. Signs of slope instability were observed along Hillside Avenue west of Anderson Ferry Road to about 1,000 feet west of Intersection Street. The signs of slope instability included damaged pavement caused by settlement and bulging, leaning trees and telephone poles, and scarps just outside the road surface. A drilled shaft repair project, described in Section 3.1, was performed to stabilize a landslide in 1973 that is within the project limits. The uphill ditch along Hillside Avenue is intermittent, having been filled in sections by material that had moved downward from up the uphill slope.

Review of the topographic contours along the alignment indicate the presence of several adjacent active landslides or remnant landslides not actively moving. Figure 2 presents the apparent active or historic currently inactive landslides along the alignment. The slope above Hillside Avenue extends for approximately 700 feet in plan and 250 feet in elevation. Hillside Avenue is approximately 1,000 feet in plan from the bank of the Ohio River and 130 feet higher in elevation than the normal pool of the river. It appears that approximately 15 acres of uphill land drains to this section of Hillside Avenue.

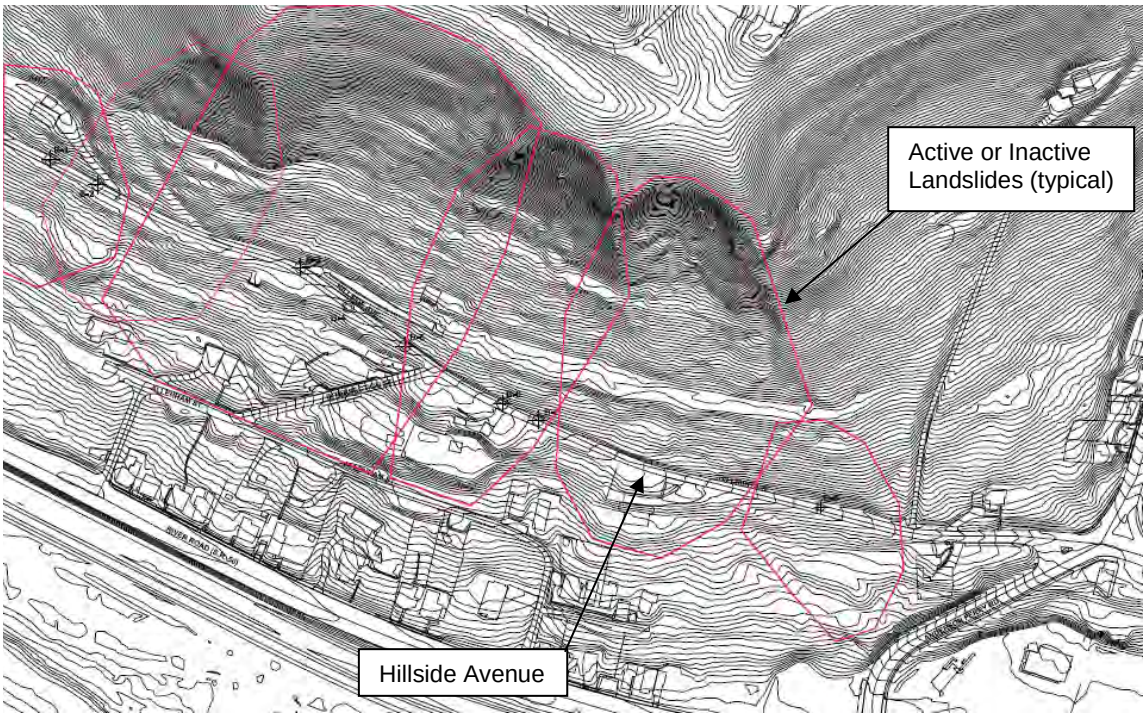


Figure 2. Topographic Contours in the Hillside Avenue Vicinity (CAGIS Online Interactive Mapping)

3.0 EXPLORATION

3.1 HISTORIC EXPLORATION PROGRAMS

The Ohio Department of Transportation (ODOT) Traffic Information Management System (TIMS) provides reports for one project performed along US 50, just south of the project site. Borings from 1952 were spaced 200 feet apart for approximately two miles for HAM-50-14.58 (PID 11993). No logs are available for review; however, soil profile sheets show various types of soil. The borings were shallow and do not provide top of bedrock information.

An existing drilled shaft wall is located just west of the project location. This wall was built in 1973 to address a previous slope instability issue. Soils encountered were typically brown and gray silty clay to 13 feet followed by brown and gray weathered shale to a depth between 16 and 18 feet. Gray shale was encountered below the weathered brown and gray shale and the drilled shafts extended to this gray shale. Drilled shafts with 18-inch diameters were placed on five-foot center-to-center spacing. Reinforcing steel for the shafts consisted of five No. 10 steel bars running vertically with No. 3 ties at 18-inch center-to-center spacing.

A search of the ODNR Oil & Gas Well Locator (2020) indicates no active wells within five miles of the project vicinity. A search of the ODNR Water Well Locator (2019) indicates one water well located 65 feet northeast of Hillside Avenue and 560 west of Intersection Street. The static water level of this well is 21 feet. The well log shows eight feet of topsoil followed by 10 feet of clay. Limestone was encountered at a depth of 18 feet and continued to the terminus of the well at 80 feet.

3.2 PROJECT EXPLORATION PROGRAM

Eight borings were advanced in four areas showing the greatest pavement distress to obtain subsurface data associated with the landslide. A slope inclinometer was installed in one of the borings near the middle of the affected alignment. A summary of these borings is shown in Table 1. Boring locations are shown on the site plan provided in Appendix A. The boring logs are also provided in Appendix A.

Table 1. Boring Summary

Boring No.	Ground Surface Elevation (feet)	Top of Bedrock Elevation (feet)	Bottom of Boring Elevation (feet)
B-1	612.0	606.0	588.3
B-2	613.4	603.6	588.6
B-3	611.5	604.0	587.6
B-4[1]	604.5	597.0	576.8
B-5	600.1	593.6	573.1
B-6	589.9	583.6	559.6
B-7	584.9	573.6	554.5
B-8	560.4	552.9	534.9

[1] Indicates boring with slope inclinometer

The borings were advanced in accordance with the American Society for Testing and Materials (ASTM D 1586 and D 1587). The borings were performed with a CME 45 truck-mounted drill rig using 3¼-inch inside diameter (ID) hollow stem augers to advance the borings through soil. Standard Penetration Test (SPT) sampling was performed at continuous intervals until bedrock was encountered. The energy ratio (ER) of the automatic hammer and drill rod system was measured to be 88.4 percent on April 24, 2018.

The SPT (ASTM D 1586) is performed by advancing a split-spoon sampler, 18 inches in length, with a 140-pound automatic hammer dropping 30 inches at select depth intervals in the boring. The number of hammer blows needed to advance the sampler each 6-inch increment is recorded. The blow count from the first 6-inch increment is discarded due to ground disturbance at the bottom of the boring. The sum of the blow counts from the last two 6-inch increments is called the field N-value (N_{field}). The field N-value is corrected to an equivalent rod energy ratio of 60 percent (N_{60}) according to the equation below.

$$N_{60} = N_{field}\left(\frac{ER}{60}\right)$$

The depths and elevations of the SPTs with the corresponding N_{60}-values are shown on the boring logs in Appendix A.

Upon encountering bedrock, rock coring was performed in each boring using NQ2-size equipment. Recovery, core loss, and rock quality designation (RQD) values were recorded as percentages for each coring run. The recovery is a measurement of the core sample obtained from a core run. The loss is the difference between the core run and the recovery. The RQD is measured by dividing the sum of all pieces of intact rock core longer than four inches in a run by the total length of the core run. These values are shown on the boring logs contained in Appendix A.

The materials encountered were logged by an engineer, with attention given to soil type, consistency, and moisture content. The borings were checked for the presence of groundwater during drilling and at its conclusion with the depth of water recorded. The borings were sealed and capped with asphalt cold patch. A slope inclinometer was installed in B-4.

The soil and rock samples obtained from the borings were returned to a geotechnical laboratory for visual classification and tested for water content. Engineering classification testing was performed on samples reflecting each of the main soil horizons. The engineering classification tests conducted on the samples were sieve and hydrometer analysis (ASTM D 422) and Atterberg limits (ASTM D 4318). The samples were classified according to the United Soil Classification System (USCS) method. Nine rock core samples were subjected to uniaxial compressive testing of rock (UCR, ASTM D 7021, Method C).

4.0 FINDINGS

All borings were advanced through the existing roadway. Roadway materials consisted of 12 inches of asphalt pavement underlain by 6 to 12 inches of granular or concrete base material.

The materials encountered during the exploration typically classified as lean clay and were described as stiff to very stiff (generally becoming stiffer with depth), brown to gray, and damp to moist. The lean clay samples contained various amounts of sand and gravel.

A layer of severely weathered light brown shale was typically seen below the soil at depths ranging from 6.0 feet in B-1 to 11.3 feet in B-7. This severely weathered rock varied from 0.4 feet to 3.2 feet in thickness. This light brown shale decreased in weathering with depth and was described as moderately fractured, argillaceous, fissile, and friable. UCR tests in the light brown shale resulted in compressive strengths ranging from 42 to 294 pounds per square inch (psi) with an average of 111 psi.

Gray shale was encountered below the light brown shale at depths ranging from 9.0 feet in B-1 to 25.1 feet in B-7. The gray shale was interbedded with limestone in B-1 and B-2 (20 to 40 percent of the unit) or with brown shale in B-3 and B-4 (about 40 percent of the unit). The gray shale was typically described as moderately to highly weathered, slightly to moderately fractured, argillaceous, and fissile. UCR tests in the gray shale resulted in compressive strengths ranging from 446 to 988 psi with an average of 792 psi. One UCR test in limestone resulted in a compressive strength of 23,880 psi.

Groundwater was observed in four of the borings at depths ranging from 1.0 foot in B-3 to 8.0 feet in B-2. Groundwater was not encountered in B-4, B-6, B-7, and B-8.

An initial reading of the slope inclinometer installed in B-4 was taken on February 20, 2020. One subsequent reading (March 13) indicated only negligible movement in the upper 4 feet. Because of the shallow depth of bedrock encountered in the borings and the suspected slow, creeping movement of the landslides, it was decided that additional inclinometer readings were unnecessary; and the assumption would be made that the failure surface is near the soil-bedrock interface. The slope inclinometer readings are presented in Appendix C.

5.0 ANALYSIS AND RECOMMENDATIONS

5.1 HILLSIDE AVENUE SLOPE INSTABILITY

As shown in Figure 2, the entire alignment of Hillside Avenue within the project limits is affected by either active or inactive remnant landslides. The landslides that are active appear to be moving at a slow, creeping, rate. It is likely that the slope movement along these sections of Hillside Avenue are caused by elevated pore pressure in the colluvial material immediately above the Kope Formation bedrock, and low shear strength along the soil/bedrock interface. Creeping slope movement is common in soil overburden formed from the Kope Formation in the Cincinnati area. The distress observed in the pavement, which was a combination of tension cracking, settlement, and heaving, was indicative of movement both uphill and downhill from Hillside Avenue.

5.2 STABILITY BACK ANALYSIS

To determine the approximate shear strength along the failure surface of the landslide, a back-analysis was performed using conventional, limit equilibrium methods as implemented in GeoStudio SLOPE/W 2018 software. The cross section at B-4 was selected as representative of the affected alignment. A simplified subsurface stratigraphy which included cohesive foundation soil and bedrock was modeled based on the soil and rock encountered in the borings. It was assumed that the failure surface travels along the top of the bedrock. Based on the weathered bedrock encountered in the borings, a layer of soft, highly weathered rock 3 feet thick was modeled at the soil/bedrock interface. The analysis cross section is shown in Appendix D.

The foundation soils and soft rock zone were initially given shear strength parameters based the results of the field and laboratory testing and experience with similar materials on other projects. These strength parameters were then adjusted to achieve a factor of safety of 1.0, simulating failure of the slope. A loss of cohesion was assumed along the failure surface. A unit weight of 110 pounds per cubic foot and an internal angle of friction of 22.5 degrees were determined for the overburden soil. A unit weight of 140 pounds per cubic foot and an internal friction angle of 15 degrees were determined for the highly weathered brown shale layer. A cross section showing the results of the slope stability back-analysis can be found in Appendix D.

5.3 DRILLED SHAFT WALL ANALYSIS

A potential remediation of constructing a drilled shaft wall on the south shoulder of Hillside Avenue was evaluated. The UA Slope Program, Version 2.3, was used to estimate the potential loading on the drilled shaft wall. The analysis cross section and failure surface developed in the slope stability back-analysis (Appendix D) in GeoStudio were modeled in the UA Slope Program. As described in ODOT GB 7, existing conditions without the drilled shafts were analyzed first and the foundation and bedrock materials were assigned the same values as in the back-analysis. A drained friction angle of 15 degrees, with a cohesion of 0 pounds per square foot, for the weathered rock was required to achieve a factor of safety of 1.00 in the UA Slope Program.

Using the same material parameters to achieve a factor of safety of 1.00 in the UA Slope Program, the proposed drilled shaft wall geometry was analyzed. An approximate offset of 20 feet right of centerline was chosen for the location of the new drilled shaft wall. The estimated depth to competent bedrock assumed in the model was

approximately 15 feet. In an iterative process, a drilled shaft wall consisting of three-foot diameter drilled shafts at five-foot center-to-center spacing was analyzed. It was assumed that the drilled shafts would take the full loading from uphill slices, because the system of unreinforced plug drilled shafts between the reinforced drilled shafts would act as a continuous retaining wall. The resulting loading was 60.6 kips per shaft. The results of the UA Slope analyses are presented in Appendix E.

The loading estimated above combined with a traffic surcharge live load of 250 pounds per square foot was modelled as a distributed load in a drilled shaft analysis using the computer software LPile v2019, supplied by Ensoft. The boring and laboratory testing results were used to estimate soil and bedrock parameters. The Weak Rock p-y curve was used for the soft rock zone of the bedrock socket. The unconfined compressive strength of the bedrock was modelled as 100 psi for the weathered brown shale and 750 psi for the gray shale. Stronger limestone layers were ignored in the model. The analysis was performed at both Service (I) and Strength (II) Limit States. Using this program, it was determined that three-foot diameter drilled shafts at five-foot center-to-center spacing socketed 15 feet into bedrock would be necessary to resist the anticipated loading. A W24x104 steel beam was modelled as reinforcement for the drilled shafts. The analysis resulted in a deflection of 0.86 inches at Service (I) Limit State, a maximum moment of 683 kip-feet at Strength (II) Limit State, and a maximum shear of 337 kips at Strength (II) Limit State. The results of the LPile analysis are provided in Appendix F.

5.4 REMEDIATION RECOMMENDATIONS

5.4.1 South Shoulder Drilled Shaft Wall

It is recommended that a drilled shaft wall be constructed along the south shoulder of Hillside Avenue in the affected areas at an approximate offset of 20 feet downhill of centerline. The recommended drilled shaft wall configuration includes three-foot diameter drilled shafts reinforced with W24x104 steel beams at five-foot center-to-center spacing. To protect against loss of material through the drilled shaft wall, unreinforced three-foot diameter plug drilled shafts are recommended to be installed between the reinforced drilled shafts from the existing grade to the top of bedrock. Concrete lagging could be installed between the W-sections above grade to retain granular backfill, if necessary. The reinforced drilled shafts should be socketed at least 15 feet into bedrock. With an estimated depth to competent bedrock of 15 feet and a rock socket of 15 feet, the reinforced shafts would be an estimated 30 feet long. The unreinforced plug shafts would extend down to the top of competent bedrock and not be socketed. Figure 3 shows the general layout of the recommended drilled shafts and reinforcing steel beams. For budgetary planning purposes, an approximate cost of $2,000 per foot of wall length can be assumed for this wall. This drilled shaft wall assumes that no additional uphill stabilization is performed as described in Section 5.4.2. If this uphill stabilization is performed, it is likely that this wall along the downhill shoulder could be redesigned using a smaller steel beam section.

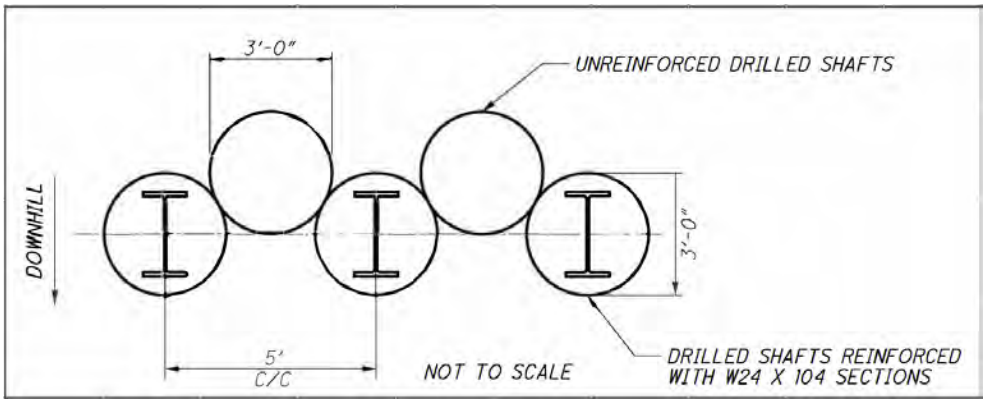


Figure 3. Recommended Drilled Shaft Wall Configuration

It is recommended that the drilled shaft wall be applied to the following approximate sections along the Hillside Avenue. The recommended priority for constructing the following walls is shown in parenthesis.

- From 600 to 800 feet west of Intersection Street (Priority 2)
- From 400 feet west of Intersection Street to Intersection Street (Priority 1)
- From 100 to 300 feet east of Intersection Street (Priority 2)
- From 500 to 600 feet west of Anderson Ferry Road (Priority 3).

Because surveying was not in the scope of work for this project, further observations and measurements should be performed along the alignment to provide more exact limits. Landslides along Hillside Avenue that are currently inactive could be triggered by even small changes in slope geometry, surface water drainage, or groundwater conditions. Future monitoring of the project alignment should be performed to detect areas of new active movement.

5.4.2 Addressing Uphill Slope Instability

The construction of a wall on the downhill side of the road will provide stability improvement to the roadway and provide some protection to underground utilities running beneath Hillside Avenue. However, there will be potential for continued instability up the slope with this wall configuration. A global stability analysis was performed with the wall described above in place. To perform this analysis, it was assumed that similar subsurface conditions as in the eight borings are present uphill from Hillside Avenue because no uphill borings were advanced. The resulting factor of safety for a failure uphill from the wall was 1.1. The analysis cross section is shown in Appendix D. Typically, a minimum factor of safety of 1.3 is suitable for roadway applications. Due to the uncertainty and inaccuracies of a slope model, continued creeping movement on a slope with a factor of safety of 1.1 is possible. Because of this, additional remediation measures are recommended along the uphill, or north, shoulder of the road.

Using the same wall design methodology as described in Section 5.3, it was determined that a pile-lagging wall constructed at an offset of 5 feet uphill from the edge of the pavement would consist of 2.5-foot diameter shafts at five-foot center-to-center spacing socketed 15 feet into bedrock. The shafts would be reinforced with W14x90 steel beam. Plug shafts would not be necessary for this wall. Concrete lagging could be installed between the flanges of the steel beams to retain free-draining gravel backfill that would support the slope above the wall. For budgetary

planning purposes, an approximate cost of $1,500 per foot of wall length can be assumed for this wall. The results of the UA Slope and LPILE analyses are presented in Appendices E and F, respectively.

Another option for improving the stability uphill from Hillside Avenue would be using launched soil nails. These have proven to be a cost-effective solution to address slope stability issues and have been installed in Hamilton County in the past. The design of the launched soil nails would be performed by the contractor retained for the installation.

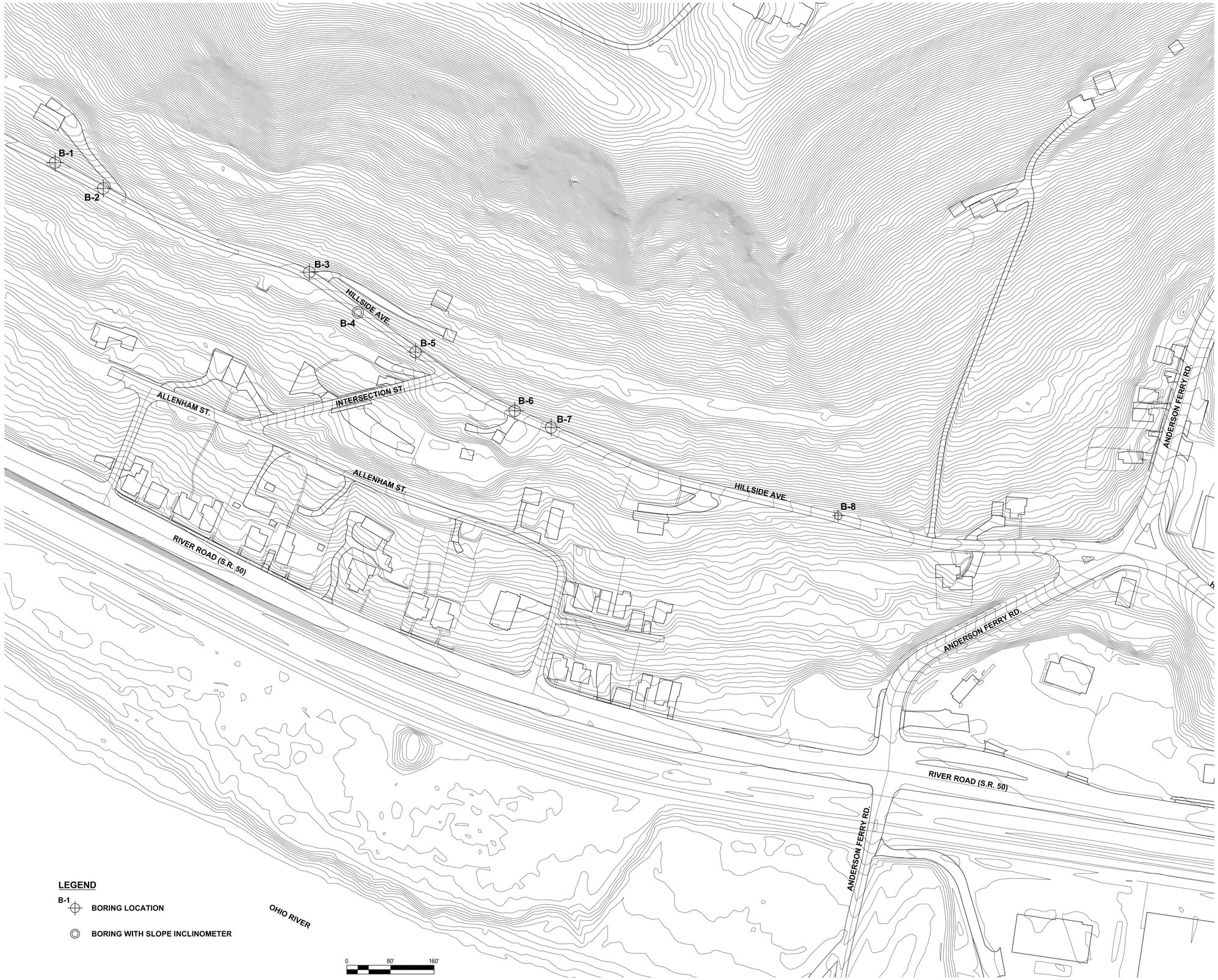
It is recommended that the uphill stability improvement measures be taken in the affected areas listed in Section 5.4.1. Additionally, observations of the section from 300 to 500 feet east of Intersection Street showed signs of uphill movement in the form of a very steep slope along the uphill shoulder that gave the appearance that it had been necessary in the past for maintenance crews to remove material from the road that had slid from uphill. At this location, there were no signs of downhill movement like tension cracking or settlement. Only uphill stability improvement measures are recommended along this section of Hillside Avenue from 300 to 500 feet east of Intersection Street.

5.5 CONCLUSION

The recommendations contained herein are based on the information discussed in this report and the interpretation of the subsurface conditions encountered at the site during our fieldwork. If future design changes are made, Stantec should be notified so that such changes can be reviewed, and the recommendations amended as necessary.

These conclusions and recommendations are based on data and subsurface conditions from the borings advanced during this exploration using the degree of care and skill ordinarily exercised under similar circumstances by competent members of the engineering profession. No warranties can be made regarding the continuity of conditions.

APPENDIX A
BORING LAYOUT AND BORING LOGS



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Consultant

Notes
Survey and topographic information was gathered from Cincinnati Area Geographic Information System (CAGIS). The data was downloaded from:
http://cagismaps.hamilton-co.org/cagisportal/mapdata/download

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Permit/Seal

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Client/Project Logo

Client/Project
Hamilton County Engineer's Office
HILLSIDE AVENUE LANDSLIDE
Cincinnati, Ohio

Title
BORING LOCATION PLAN

Project No. 175538106
Scale AS SHOWN
Revision
Sheet 1 of 1
Drawing No. 1

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SUBSURFACE LOG

Stantec Boring No. **B-1**

Client	Hamilton County Engineer's Office	Boring Location	400,550.8 N; 1,364,174.0 E
Project Number	175538106	Surface Elevation	612.0 ft — Elevation Datum: NAVD 88
Project Name	Hillside Avenue Landslide	Date Started	2/12/20 — Completed: 2/12/20
Project Location	Cincinnati, Hamilton County, Ohio	Depth to Water	7.5 ft — Date/Time: 2/12/20
Inspector	James Samples	Depth to Water	N/A — Date/Time: N/A
Driller	Tim Caudill	Drill Rig Type and ID	CME 45 Truck (811)

Overburden Drilling and Sampling Tools (Type and Size): 3.25 HSA, 2 Split Spoon w/o liners

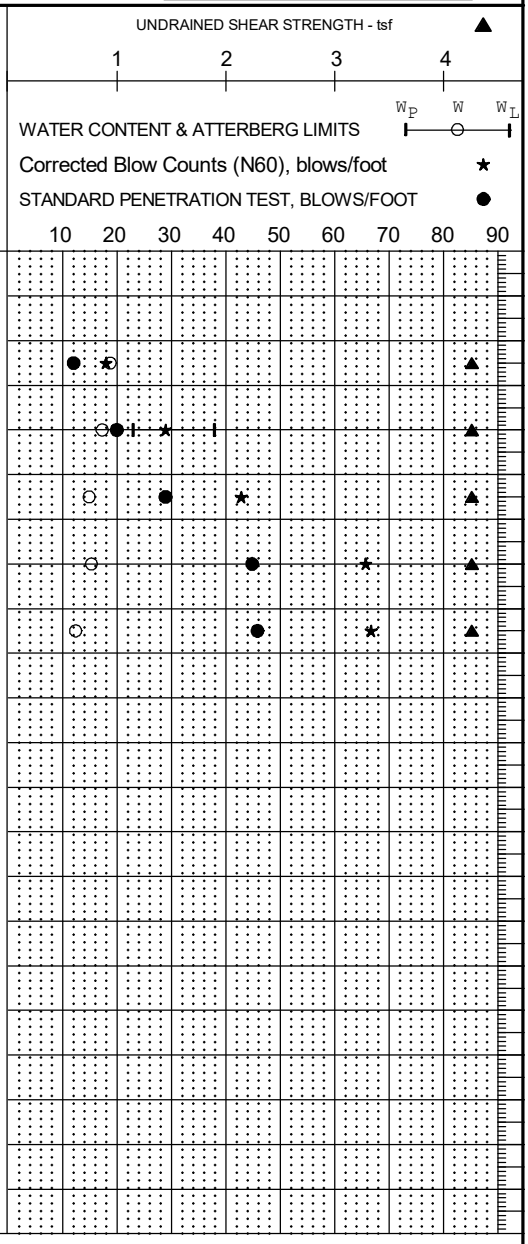
Rock Drilling and Sampling Tools (Type and Size): NQ2 Rock Core Bit

Sampler Hammer Type: Automatic — Weight: 140 lb — Drop: 30 in — Efficiency: 88 % (Avg.)

Borehole Azimuth: N/A (Vertical) — Borehole Inclination (from Vertical): Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	TYPE	NUMBER	RECOVERY (ft)	BLOWS / PRESS.(psi) / RQD (%)
0	612.0	Hillside Ave Roadway				
1	611.0	Asphalt				
	610.5	Concrete base layer				
2–6		Light brown, stiff to very stiff lean clay with sand, trace gravel, damp	SPT	1	0.8	3-4-8
			SPT	2	1.3	5-8-12
			SPT	3	1.3	7-11-18
	606.0					
6–9		Light brown shale, severely weathered	SPT	4	1.5	4-20-25
			SPT	5	1.5	15-22-24
	603.0					
9–22		Gray shale (80%) with interbedded limestone (20%), moderately weathered, slightly to moderately fractured, argillaceous, fissle	RC	1	1.2	86
		UCR @ 13.2 ft. to 13.6 ft. = 954 PSI (Shale)	RC	2	4.9	60
		UCR @ 18.2 ft. to 18.6 ft. = 23,880 PSI (Limestone)	RC	3	4.5	91
						55

INSTRUMENTATION



SUBSURFACE LOG

Stantec Boring No. **B-1**

Client: Hamilton County Engineer's Office

Boring Location: 400,550.8 N; 1,364,174.0 E

Project Number: 175538106

Surface Elevation: 612.0 ft

Elevation Datum: NAVD 88

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (ft)	SAMPLES BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
22				RC	4	3.2		
23	588.3							
24		*Boring terminated and backfilled with bentonite chips, cuttings, and asphalt patch.*						

UNDRAINED SHEAR STRENGTH - tsf ▲ (1, 2, 3, 4)

WATER CONTENT & ATTERBERG LIMITS (W_P — W — W_L)

Corrected Blow Counts (N60), blows/foot ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●

10 20 30 40 50 60 70 80 90

SUBSURFACE LOG

Stantec Boring No. **B-2**

Client	Hamilton County Engineer's Office	Boring Location	400,503.4 N; 1,364,262.3 E
Project Number	175538106	Surface Elevation	613.4 ft — Elevation Datum: NAVD 88
Project Name	Hillside Avenue Landslide	Date Started	2/13/20 — Completed: 2/13/20
Project Location	Cincinnati, Hamilton County, Ohio	Depth to Water	8.0 ft — Date/Time: 2/13/20
Inspector	James Samples	Depth to Water	N/A — Date/Time: N/A
Driller	Tim Caudill	Drill Rig Type and ID	CME 45 Truck (811)

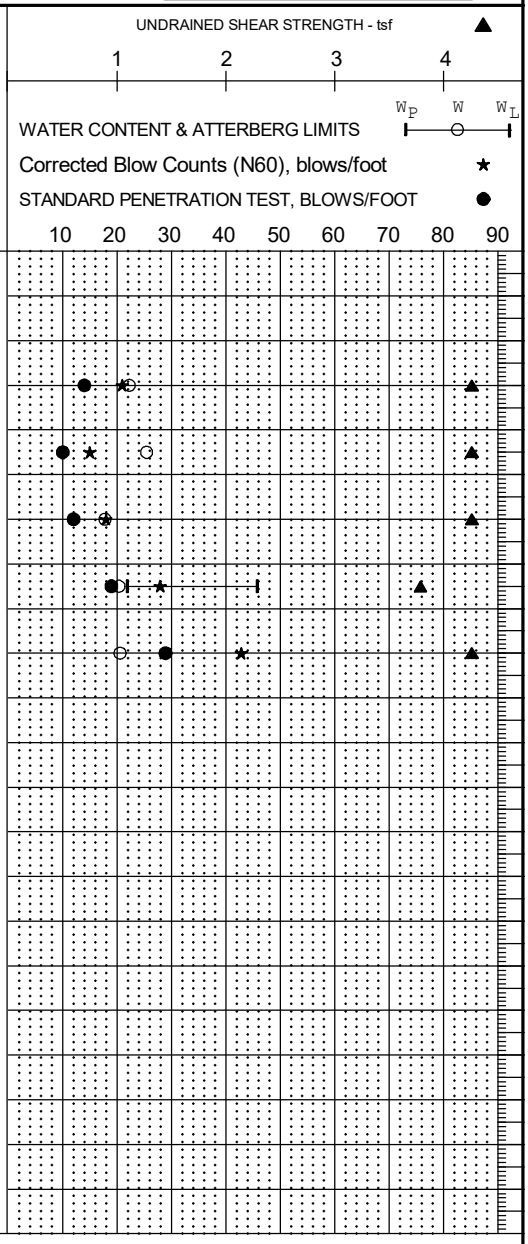
Overburden Drilling and Sampling Tools (Type and Size): 3.25 HSA, 2 Split Spoon w/o liners

Rock Drilling and Sampling Tools (Type and Size): NQ2 Rock Core Bit

Sampler Hammer Type: Automatic — Weight: 140 lb — Drop: 30 in — Efficiency: 88 % (Avg.)

Borehole Azimuth: N/A (Vertical) — Borehole Inclination (from Vertical): Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY	BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
	613.4	Hillside Ave Roadway				ft		
0	612.4	Asphalt						
1	611.4	Concrete base layer						
2–9	603.6	Light brown, stiff to very stiff lean clay, trace gravel, damp to moist		SPT	1	1.0	2-10-4	
				SPT	2	1.1	3-4-6	
				SPT	3	1.4	3-5-7	
				SPT	4	1.3	2-5-14	
				SPT	5	1.5	12-13-16	
10	603.4	Light brown shale, highly to severely weathered, highly fractured		RC	1	0.9	78	
11–22		Gray shale (80%) with interbedded limestone (20%), moderately weathered, slightly to moderately fractured, argillaceous UCR @ 11.1 ft. to 11.5 ft. = 780 PSI (Shale)		RC	2	4.7	60	
				RC	3	4.8	66	



SUBSURFACE LOG

Stantec Boring No. **B-2**

Client: Hamilton County Engineer's Office

Boring Location: 400,503.4 N; 1,364,262.3 E

Project Number: 175538106

Surface Elevation: 613.4 ft

Elevation Datum: NAVD 88

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (ft)	SAMPLES BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
22–24				RC	4	4.1	63	
25	588.6	*Boring terminated and backfilled with bentonite chips, cuttings, and asphalt patch.*						

UNDRAINED SHEAR STRENGTH - tsf ▲ (1, 2, 3, 4)

WATER CONTENT & ATTERBERG LIMITS (W_P — W — W_L)

Corrected Blow Counts (N60), blows/foot ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●

10 20 30 40 50 60 70 80 90

SUBSURFACE LOG

Stantec Boring No. **B-3**

Client	Hamilton County Engineer's Office	Boring Location	400,349.9 N; 1,364,639.5 E
Project Number	175538106	Surface Elevation	611.5 ft
		Elevation Datum	NAVD 88
Project Name	Hillside Avenue Landslide	Date Started	2/13/20
		Completed	2/13/20
Project Location	Cincinnati, Hamilton County, Ohio	Depth to Water	1.0 ft
		Date/Time	2/13/20
Inspector	James Samples	Depth to Water	N/A
		Date/Time	N/A
Driller	Tim Caudill	Drill Rig Type and ID	CME 45 Truck (811)

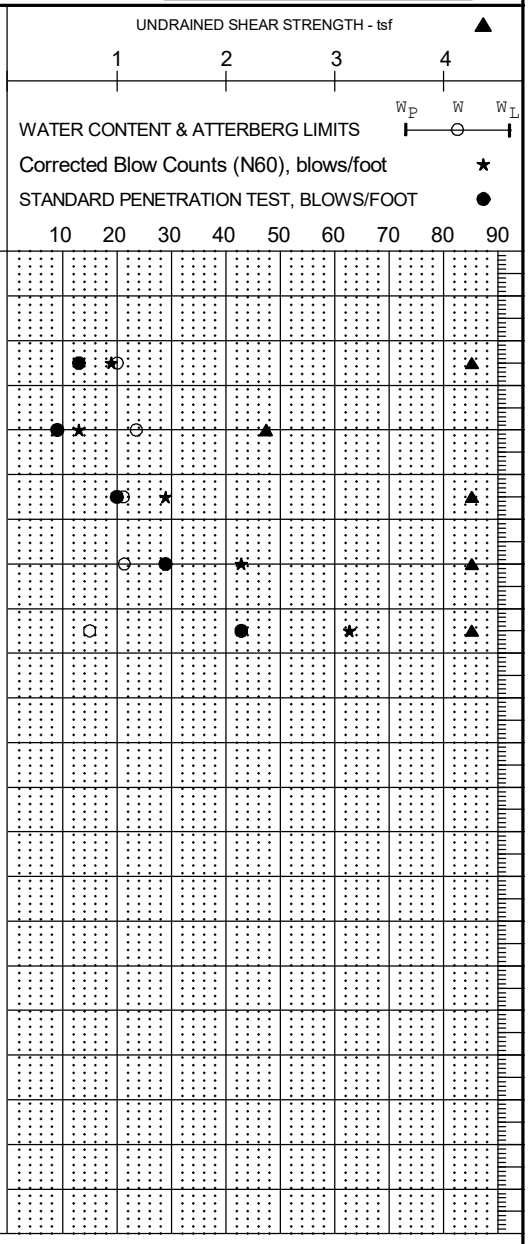
Overburden Drilling and Sampling Tools (Type and Size): 3.25 HSA, 2 Split Spoon w/o liners

Rock Drilling and Sampling Tools (Type and Size): NQ2 Rock Core Bit

Sampler Hammer Type: Automatic | Weight: 140 lb | Drop: 30 in | Efficiency: 88 % (Avg.)

Borehole Azimuth: N/A (Vertical) | Borehole Inclination (from Vertical): Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY (ft)	BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
	611.5	Hillside Ave Roadway						
0	610.5	Asphalt						
1	610.0	Gravel base layer						
2–7	604.0	Light brown, stiff to very stiff lean clay, trace gravel, damp to moist		SPT	1	1.0	1-4-9	
				SPT	2	0.6	2-5-4	
				SPT	3	1.1	3-6-14	
				SPT	4	1.2	5-11-18	
8–9	602.5	Light brown shale, severely weathered		SPT	5	1.5	9-17-26	
9–10	600.9	Light brown shale, highly weathered, slighlty fractured, argillaceous UCR @ 9.5 ft. to 9.9 ft. = 42 PSI		RC	1	1.5	73	
10–22		Gray shale (60%) interbedded with brown shale (40%), moderately weathered, slightly to moderately fractured, argillaceous, becomes more gray with depth UCR @ 14.1 ft. to 14.5 ft. = 55 PSI (Brown shale)		RC	2	4.4	66	
				RC	3	5.0	80	



SUBSURFACE LOG

Stantec Boring No. **B-3**

Client: Hamilton County Engineer's Office

Boring Location: 400,349.9 N; 1,364,639.5 E

Project Number: 175538106

Surface Elevation: 611.5 ft

Elevation Datum: NAVD 88

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (ft)	SAMPLES BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
22–23				RC	4	3.4	82	
24	587.6	*Boring terminated and backfilled with bentonite chips, cuttings, and asphalt patch.*						

UNDRAINED SHEAR STRENGTH - tsf ▲ (1, 2, 3, 4)

WATER CONTENT & ATTERBERG LIMITS (W_P — W — W_L)

Corrected Blow Counts (N60), blows/foot ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●

10 20 30 40 50 60 70 80 90

SUBSURFACE LOG

Stantec Boring No. **B-4**

Client	Hamilton County Engineer's Office	Boring Location	400,276.1 N; 1,364,728.5 E
Project Number	175538106	Surface Elevation	604.5 ft
		Elevation Datum	NAVD 88
Project Name	Hillside Avenue Landslide	Date Started	2/17/20
		Completed	2/17/20
Project Location	Cincinnati, Hamilton County, Ohio	Depth to Water	N/A
		Date/Time	N/A
Inspector	James Samples	Depth to Water	N/A
		Date/Time	N/A
Driller	Tim Caudill	Drill Rig Type and ID	CME 45 Truck (811)

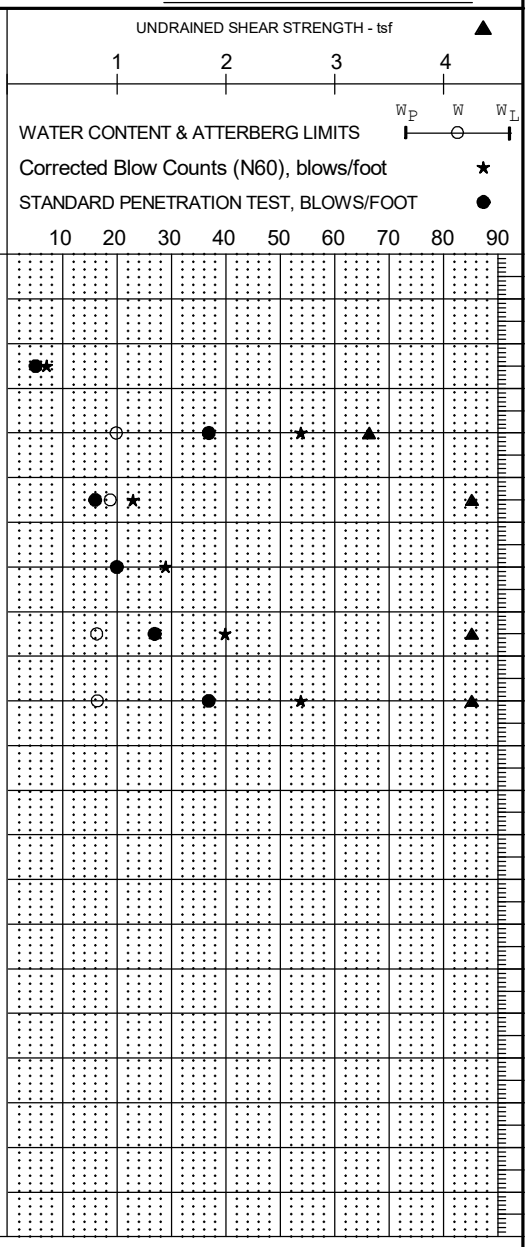
Overburden Drilling and Sampling Tools (Type and Size): 3.25 HSA, 2 Split Spoon w/o liners

Rock Drilling and Sampling Tools (Type and Size): NQ2 Rock Core Bit

Sampler Hammer Type: Automatic | Weight: 140 lb | Drop: 30 in | Efficiency: 88 % (Avg.)

Borehole Azimuth: N/A (Vertical) | Borehole Inclination (from Vertical): Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY (ft)	BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
	604.5	Hillside Ave Roadway						
0	603.5	Asphalt						
1	603.0	Gravel base layer						
2–7	597.0	Light brown, stiff to very stiff lean clay, trace to little gravel, damp		SPT	1	0.0	1-2-3	
				SPT	2	0.8	2-4-33	
				SPT	3	1.5	12-6-10	
				SPT	4	0.0	6-9-11	
8–10	594.0	Light brown shale, severely to highly weathered		SPT	5	1.3	7-10-17	
				SPT	6	1.5	6-14-23	
11–14	589.8	Light brown shale, moderately weathered, moderately fractured, argillaceous		RC	1	3.0	26	
15–22		Gray shale (60%) interbedded with brown shale (40%), moderately to highly weathered, moderately fractured, argillaceous, fissle, becoming more gray with depth		RC	2	5.0	56	



SUBSURFACE LOG

Stantec Boring No. **B-4**

Client: Hamilton County Engineer's Office

Boring Location: 400,276.1 N; 1,364,728.5 E

Project Number: 175538106

Surface Elevation: 604.5 ft

Elevation Datum: NAVD 88

UNDRAINED SHEAR STRENGTH - tsf ▲ (1, 2, 3, 4)

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

Corrected Blow Counts (N60), blows/foot ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●

(10, 20, 30, 40, 50, 60, 70, 80, 90)

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY (ft)	BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
22–27		Gray shale (60%) interbedded with brown shale (40%), moderately to highly weathered, moderately fractured, argillaceous, fissle, becoming more gray with depth - (Continued)		RC	3	3.5	30	
				RC	4	3.0	43	
	576.8							

Boring terminated and slope inclinometer casing installed.

SUBSURFACE LOG

Stantec Boring No. **B-5**

Client	Hamilton County Engineer's Office	Boring Location	400,203.7 N; 1,364,834.0 E
Project Number	175538106	Surface Elevation	600.1 ft — Elevation Datum: NAVD 88
Project Name	Hillside Avenue Landslide	Date Started	2/14/20 — Completed: 2/14/20
Project Location	Cincinnati, Hamilton County, Ohio	Depth to Water	1.0 ft — Date/Time: 2/14/20
Inspector	James Samples	Depth to Water	N/A — Date/Time: N/A
Driller	Tim Caudill	Drill Rig Type and ID	CME 45 Truck (811)

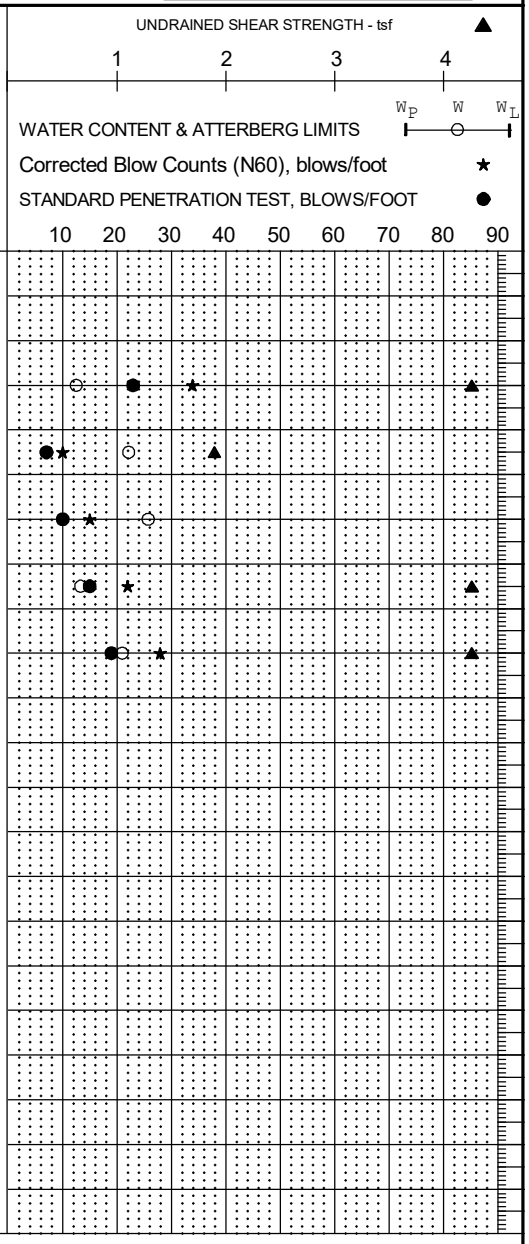
Overburden Drilling and Sampling Tools (Type and Size): 3.25 HSA, 2 Split Spoon w/o liners

Rock Drilling and Sampling Tools (Type and Size): NQ2 Rock Core Bit

Sampler Hammer Type: Automatic — Weight: 140 lb — Drop: 30 in — Efficiency: 88 % (Avg.)

Borehole Azimuth: N/A (Vertical) — Borehole Inclination (from Vertical): Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY (ft)	BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
	600.1	Hillside Ave Roadway						
0	599.1	Asphalt						
1	598.1	Gravel base layer						
2–6	593.6	Brown, stiff to very stiff lean clay, trace to little gravel, damp to moist		SPT	1	0.5	2-18-5	
				SPT	2	0.9	2-4-3	
				SPT	3	1.2	6-3-7	
7–9	590.4	Light brown shale, highly to severely weathered		SPT	4	1.5	42-5-10	
				SPT	5	1.2	6-7-12	
10–19	580.2	Light brown shale, moderately weathered, slighlty to moderately fractured, argillaceous, fissle		RC	1	5.0	60	
				RC	2	3.9	46	
20–22				RC	3	2.3	30	



SUBSURFACE LOG

Stantec Boring No. **B-5**

Client: Hamilton County Engineer's Office

Boring Location: 400,203.7 N; 1,364,834.0 E

Project Number: 175538106

Surface Elevation: 600.1 ft

Elevation Datum: NAVD 88

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (ft)	SAMPLES BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
22		Gray shale, moderately to highly weathered, slightly to moderately fractured, argillaceous, fissle - (Continued)						
23								
24								
25				RC	4	3.8	95	
26								
27	573.1							

UNDRAINED SHEAR STRENGTH - tsf ▲ (1, 2, 3, 4)

WATER CONTENT & ATTERBERG LIMITS (W_P — W — W_L)

Corrected Blow Counts (N60), blows/foot ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●

10 20 30 40 50 60 70 80 90

Boring terminated and backfilled with bentonite chips, cuttings, and asphalt patch.

28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

SUBSURFACE LOG

Stantec Boring No. **B-6**

Client	Hamilton County Engineer's Office	Boring Location	400,096.0 N; 1,365,015.0 E
Project Number	175538106	Surface Elevation	589.9 ft — Elevation Datum: NAVD 88
Project Name	Hillside Avenue Landslide	Date Started	2/11/20 — Completed: 2/11/20
Project Location	Cincinnati, Hamilton County, Ohio	Depth to Water	N/A — Date/Time: N/A
Inspector	James Samples	Depth to Water	N/A — Date/Time: N/A
Driller	Tim Caudill	Drill Rig Type and ID	CME 45 Truck (811)

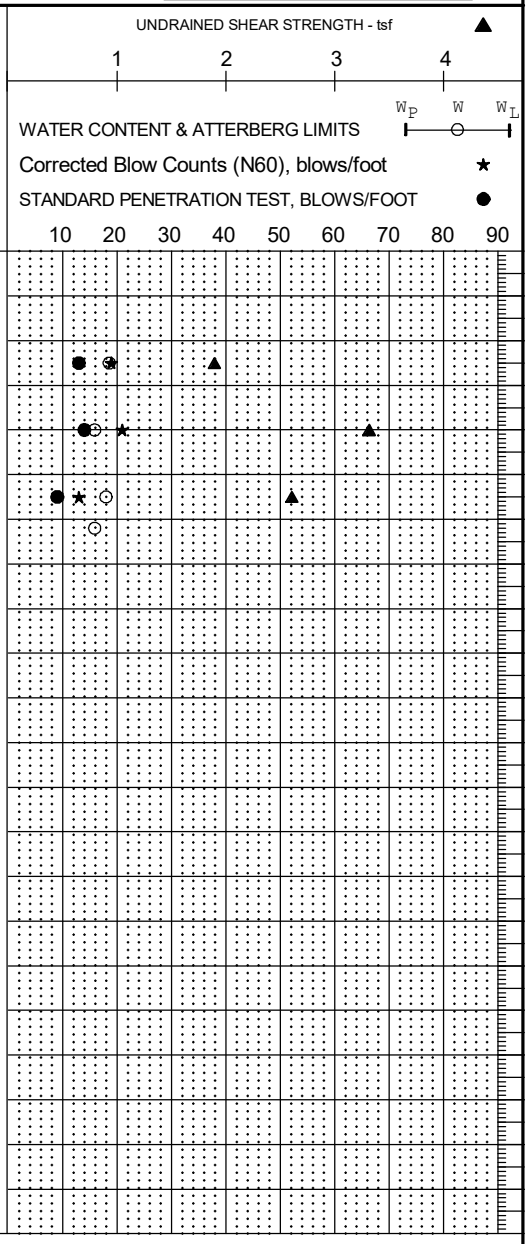
Overburden Drilling and Sampling Tools (Type and Size): 3.25 HSA, 2 Split Spoon w/o liners

Rock Drilling and Sampling Tools (Type and Size): NQ2 Rock Core Bit

Sampler Hammer Type: Automatic — Weight: 140 lb — Drop: 30 in — Efficiency: 88 % (Avg.)

Borehole Azimuth: N/A (Vertical) — Borehole Inclination (from Vertical): Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY	BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
	589.9	Hillside Ave Roadway				ft		
0	588.9	Asphalt						
1	588.4	Gravel base layer						
2	586.9	Dark gray, stiff lean clay with sand, some gravel, damp		SPT	1	1.0	4-6-7	
3–6	583.6	Light brown, stiff lean clay, trace gravel, damp		SPT	2	0.9	3-7-7	
				SPT	3	1.0	5-5-4	
				SPT	4	0.2	50/.3	
7–22	568.1	Light brown shale, moderately to highly weathered, moderately fractured, argillaceous		RC	1	1.0	15	
				RC	2	0.1	0	
				RC	3	1.8	32	
				RC	4	5.0	76	
		UCR @ 19.9 ft. to 20.2 ft. = 294 PSI						



SUBSURFACE LOG

Stantec Boring No. **B-6**

Client: Hamilton County Engineer's Office

Boring Location: 400,096.0 N; 1,365,015.0 E

Project Number: 175538106

Surface Elevation: 589.9 ft

Elevation Datum: NAVD 88

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (ft)	SAMPLES BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
22–30		Gray shale, moderately weathered, moderately fractured, argillaceous, fissle - (Continued)		RC	5	3.8	36	
				RC	6	5.0	62	
30	559.6							

UNDRAINED SHEAR STRENGTH - tsf ▲ (1, 2, 3, 4)

WATER CONTENT & ATTERBERG LIMITS (W_P — W — W_L)

Corrected Blow Counts (N60), blows/foot ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●

10 20 30 40 50 60 70 80 90

Boring terminated and backfilled with bentonite chips, cuttings, and asphalt patch.

SUBSURFACE LOG

Stantec Boring No. **B-7**

Client	Hamilton County Engineer's Office	Boring Location	400,066.1 N; 1,365,082.4 E
Project Number	175538106	Surface Elevation	584.9 ft — Elevation Datum: NAVD 88
Project Name	Hillside Avenue Landslide	Date Started	2/11/20 — Completed: 2/11/20
Project Location	Cincinnati, Hamilton County, Ohio	Depth to Water	N/A — Date/Time: N/A
Inspector	James Samples	Depth to Water	N/A — Date/Time: N/A
Driller	Tim Caudill	Drill Rig Type and ID	CME 45 Truck (811)

Overburden Drilling and Sampling Tools (Type and Size): 3.25 HSA, 2 Split Spoon w/o liners

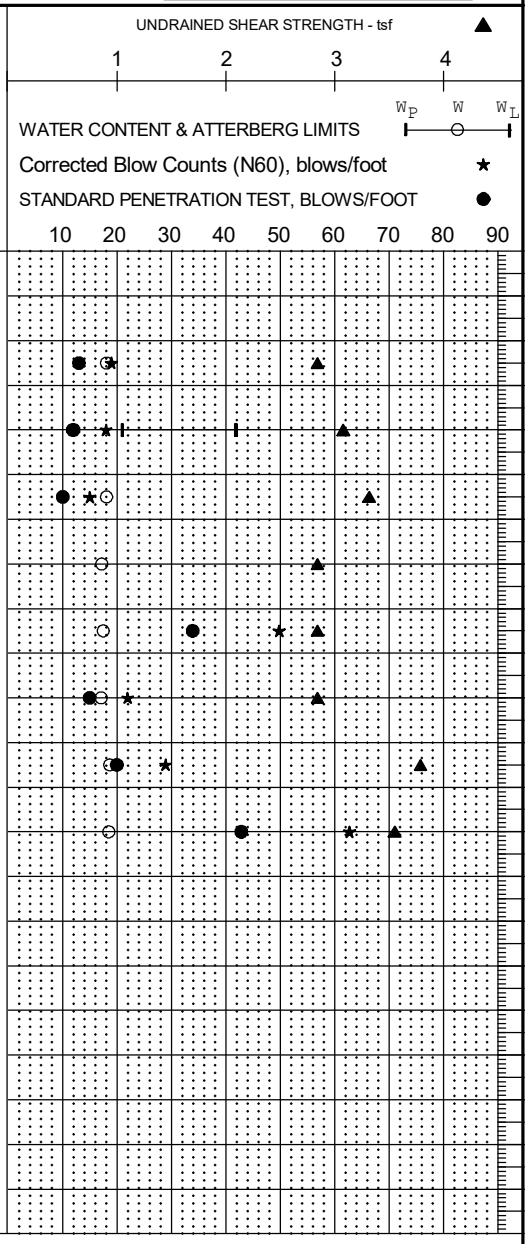
Rock Drilling and Sampling Tools (Type and Size): NQ2 Rock Core Bit

Sampler Hammer Type: Automatic — Weight: 140 lb — Drop: 30 in — Efficiency: 88 % (Avg.)

Borehole Azimuth: N/A (Vertical) — Borehole Inclination (from Vertical): Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	TYPE	NUMBER	RECOVERY (ft)	BLOWS / PRESS.(psi) / RQD (%)
0	584.9	Hillside Ave Roadway				
1	583.9	Asphalt				
	583.4	Gravel base layer				
2–7		Light brown with gray mottling, stiff lean clay with sand, trace gravel, damp	SPT	1	0.9	2-6-7
			SPT	2	1.1	3-7-5
			SPT	3	1.1	3-4-6
			SPT	4	0.5	2-50/.3
	577.4					
8–11		Dark brown, stiff to very stiff lean clay with sand, some gravel, damp	SPT	5	0.2	16-15-19
			SPT	6	1.0	15-6-9
			SPT	7	1.3	8-9-11
	573.6					
12–13		Light brown shale, highly to severely weathered	SPT	8	1.0	10-7-36
	571.4					
14–22		Light brown shale, moderately weathered, moderately to highly fractured, argillaceous UCR @ 14.5 ft. to 14.9 ft. = 54 PSI	RC	1	1.9	79
			RC	2	2.0	10

INSTRUMENTATION



SUBSURFACE LOG

Stantec Boring No. **B-7**

Client: Hamilton County Engineer's Office

Boring Location: 400,066.1 N; 1,365,082.4 E

Project Number: 175538106

Surface Elevation: 584.9 ft

Elevation Datum: NAVD 88

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY (ft)	BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
22–25	559.8	Light brown shale, moderately weathered, moderately to highly fractured, argillaceous - (Continued)		RC	3	4.5	46	
25–30	554.5	Gray shale, moderately to highly weathered, moderately fractured, argillaceous UCR @ 28.8 ft. to 29.2 ft. = 446 PSI		RC	4	5.0	44	

UNDRAINED SHEAR STRENGTH - tsf ▲ (1, 2, 3, 4)

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)

Corrected Blow Counts (N60), blows/foot ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●

10 20 30 40 50 60 70 80 90

Boring terminated and backfilled with bentonite chips, cuttings, and asphalt patch.

SUBSURFACE LOG

Stantec Boring No. **B-8**

Client	Hamilton County Engineer's Office	Boring Location	399,904.0 N; 1,365,607.9 E
Project Number	175538106	Surface Elevation	560.4 ft — Elevation Datum: NAVD 88
Project Name	Hillside Avenue Landslide	Date Started	2/10/20 — Completed: 2/10/20
Project Location	Cincinnati, Hamilton County, Ohio	Depth to Water	N/A — Date/Time: N/A
Inspector	James Samples	Depth to Water	N/A — Date/Time: N/A
Driller	Tim Caudill	Drill Rig Type and ID	CME 45 Truck (811)

Overburden Drilling and Sampling Tools (Type and Size): 3.25 HSA, 2 Split Spoon w/o liners

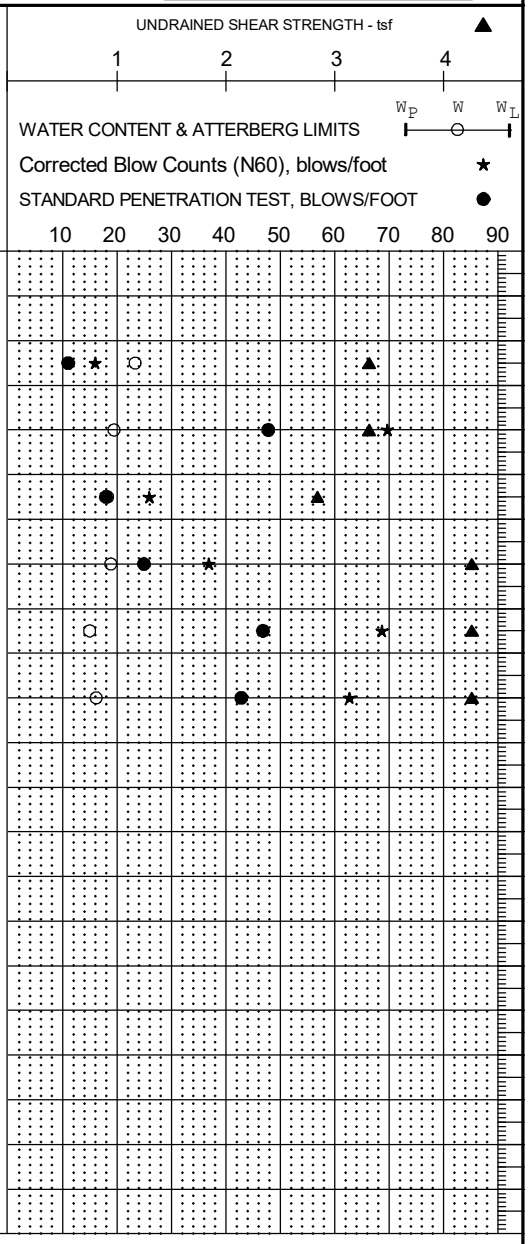
Rock Drilling and Sampling Tools (Type and Size): NQ2 Rock Core Bit

Sampler Hammer Type: Automatic — Weight: 140 lb — Drop: 30 in — Efficiency: 88 % (Avg.)

Borehole Azimuth: N/A (Vertical) — Borehole Inclination (from Vertical): Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	TYPE	NUMBER	RECOVERY (ft)	BLOWS / PRESS.(psi) / RQD (%)
0	560.4	Hillside Ave Roadway				
1	559.4	Asphalt				
	558.9	Concrete base layer				
2–7		Light brown, stiff to very stiff lean clay, trace to some gravel, limestone at 4.5 ft., damp to moist	SPT	1	0.8	3-4-7
			SPT	2	0.7	30-8-40
			SPT	3	0.6	38-7-11
			SPT	4	1.2	6-9-16
	552.9					
8–10		Light brown shale, highly to severely weathered	SPT	5	0.7	22-29-18
			SPT	6	1.3	8-17-26
	549.9					
11–13		Light brown shale, moderately to highly weathered, moderately fractured, argillaceous, fissle, friable	RC	1	3.5	46
	548.2					
14–22		Gray shale, moderately to highly weathered, moderately fractured, argillaceous UCR @ 18.5 ft. to 18.9 ft. = 988 PSI	RC	2	5.0	70

INSTRUMENTATION



SUBSURFACE LOG

Stantec Boring No. **B-8**

Client: Hamilton County Engineer's Office

Boring Location: 399,904.0 N; 1,365,607.9 E

Project Number: 175538106

Surface Elevation: 560.4 ft

Elevation Datum: NAVD 88

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (ft)	SAMPLES BLOWS / PRESS.(psi) / RQD (%)	INSTRUMENTATION
22–25	534.9	Gray shale, moderately to highly weathered, moderately fractured, argillaceous - (Continued)		RC	3	5.0	58	

Boring terminated and backfilled with bentonite chips, cuttings, and asphalt patch.

UNDRAINED SHEAR STRENGTH - tsf: 1 2 3 4

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

Corrected Blow Counts (N60), blows/foot ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●

10 20 30 40 50 60 70 80 90

APPENDIX B
LABORATORY TESTNG RESULTS

Stantec

Moisture Content of Soil

ASTM D 2216

Project Name Hillside Avenue

Project Number 175538106

Tested By

Test Method ASTM

Maximum Particle Size in Sample	No. 10	No. 4	3/8"	3/4"	1 1/2"	3"
Recommended Minimum Mass (g)	20	100	500	2,500	10,000	50,000

Material Type: Stratified, Laminated, Lensed, Homogeneous, Disturbed

Source	Lab ID	Date Tested	Material Type	Maximum Particle Size	Material Excluded Amount	Material Excluded Size	Pass Min. Mass? (Y/N)	Can Weight (g)	Wet Soil & Can Weight (g)	Dry Soil & CanWeight (g)	Moisture Content (%)
B-1, 1.5'-3.0'	1	3/2/20	Hom	No. 10			Yes	30.70	103.63	92.10	18.8
B-1, 3.0'-4.5'	2	3/2/20	Hom	No. 10			Yes	32.29	83.93	76.32	17.3
B-1, 4.5'-6.0'	3	3/2/20	Hom	No. 10			Yes	30.63	91.49	83.61	14.9
B-1, 6.0'-7.5'	4	3/2/20	Dist	No. 10			Yes	30.60	102.87	93.28	15.3
B-1, 7.5'-9.0'	5	3/2/20	Dist	No. 10			Yes	30.93	97.57	90.23	12.4
B-2, 2.0'-3.5'	6	3/2/20	Dist	No. 10			Yes	32.34	100.90	88.40	22.3
B-2, 3.5'-5.0'	7	3/2/20	Dist	No. 10			Yes	30.71	87.24	75.76	25.5
B-2, 5.0'-6.5'	8	3/2/20	Dist	No. 10			Yes	31.64	82.29	74.62	17.8
B-2, 6.5'-8.0'	9	3/2/20	Dist	No. 10			Yes	30.68	74.22	66.83	20.4
B-2, 8.0'-9.5'	10	3/2/20	Hom	No. 10			Yes	30.55	130.24	113.24	20.6
B-3, 1.5'-3.0'	11	3/2/20	Dist	No. 10			Yes	32.02	94.36	83.91	20.1
B-3, 3.0'-4.5'	12	3/2/20	Dist	No. 10			Yes	32.05	93.63	81.88	23.6
B-3, 4.5'-6.0'	13	3/2/20	Dist	No. 10			Yes	32.24	78.14	70.10	21.2
B-3, 6.0'-7.5'	14	3/2/20	Dist	No. 10			Yes	31.94	88.48	78.53	21.4
B-3, 7.5'-9.0'	15	3/2/20	Dist	No. 10			Yes	32.01	97.03	88.55	15.0
B-4, 3.0'-4.5'	16	3/2/20	Dist	No. 10			Yes	30.68	110.38	97.13	19.9
B-4, 4.5'-6.0'	17	3/2/20	Hom	No. 10			Yes	31.93	119.26	105.45	18.8
B-4, 7.5'-9.0'	18	3/2/20	Hom	No. 10			Yes	30.91	100.97	91.15	16.3
B-4, 9.0'-10.5'	19	3/2/20	Hom	No. 10			Yes	31.80	122.94	110.12	16.4
B-5, 2.0'-3.5'	20	3/2/20	Dist	No. 10			Yes	30.93	81.66	76.03	12.5
B-5, 3.5'-5.0'	21	3/2/20	Dist	No. 10			Yes	30.60	89.93	79.17	22.2
B-5, 5.0'-6.5'	22	3/2/20	Dist	No. 10			Yes	32.17	82.86	72.45	25.8
B-5, 6.5'-8.0'	23	3/2/20	Dist	No. 10			Yes	30.95	107.44	98.44	13.3
B-5, 8.0'-9.5'	24	3/2/20	Hom	No. 10			Yes	31.79	117.88	102.96	21.0
B-6, 1.5'-3.0'	25	3/2/20	Dist	3/8"			No	32.02	107.26	95.48	18.6
B-6, 3.0'-4.5'	26	3/2/20	Dist	No. 10			Yes	32.15	88.65	80.89	15.9
B-6, 4.5'-6.0'	27	3/2/20	Dist	No. 10			Yes	31.88	91.47	82.37	18.0
B-6, 6.0'-6.3'	28	3/2/20	Dist	No. 10			Yes	31.89	60.69	56.73	15.9

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Reviewed By REL

Stantec

Moisture Content of Soil

ASTM D 2216

Project Name Hillside Avenue

Project Number 175538106

Tested By

Test Method ASTM

Maximum Particle Size in Sample	No. 10	No. 4	3/8"	3/4"	1 1/2"	3"
Recommended Minimum Mass (g)	20	100	500	2,500	10,000	50,000

Material Type: Stratified, Laminated, Lensed, Homogeneous, Disturbed

Source	Lab ID	Date Tested	Material Type	Maximum Particle Size	Material Excluded Amount	Material Excluded Size	Pass Min. Mass? (Y/N)	Can Weight (g)	Wet Soil & Can Weight (g)	Dry Soil & CanWeight (g)	Moisture Content (%)
B-7, 1.5'-3.0'	29	3/2/20	Dist	No. 10			Yes	30.70	94.74	84.91	18.1
B-7, 3.0'-4.5'	30	3/2/20	Dist	No. 10			Yes	32.24	71.60	67.44	11.8
B-7, 4.5'-6.0'	31	3/2/20	Dist	No. 10			Yes	30.85	98.03	87.72	18.1
B-7, 6.0'-6.8'	32	3/2/20	Dist	No. 10			Yes	31.66	117.52	104.91	17.2
B-7, 7.5'-9.0'	33	3/2/20	Dist	No. 10			Yes	32.61	93.54	84.45	17.5
B-7, 9.0'-10.5'	34	3/2/20	Dist	No. 10			Yes	31.66	102.08	91.81	17.1
B-7, 10.5'-12.0'	35	3/2/20	Hom	No. 10			Yes	30.71	96.58	86.19	18.7
B-7, 12.0'-13.5'	36	3/2/20	Dist	No. 10			Yes	32.45	109.25	97.26	18.5
B-8, 1.5'-3.0'	37	3/2/20	Dist	No. 10			Yes	32.14	84.67	74.72	23.4
B-8, 3.0'-4.5'	38	3/2/20	Dist	No. 10			Yes	31.55	94.81	84.49	19.5
B-8, 4.5'-6.0'	39	3/2/20	Dist	No. 10			Yes	32.09	91.14	82.00	18.3
B-8, 6.0'-6.8'	40	3/2/20	Hom	No. 10			Yes	31.89	84.93	76.51	18.9
B-8, 7.5'-9.0'	41	3/2/20	Dist	No. 10			Yes	32.07	80.57	74.24	15.0
B-8, 9.0'-10.5'	42	3/2/20	Hom	No. 10			Yes	32.17	106.39	96.02	16.2

Stantec

Summary of Soil Tests

Project Name	Hillside Avenue	Project Number	175538106
Source	B-1, 3.0'-4.5'	Lab ID	2
Sample Type	SS	Date Received	3-2-20
		Date Reported	3-6-20

Test Results

Natural Moisture Content

Test Method: ASTM D 2216

Moisture Content (%): 17.3

Particle Size Analysis

Preparation Method: ASTM D 421

Gradation Method: ASTM D 422

Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
1 1/2"	37.5	100.0
3/4"	19	94.3
3/8"	9.5	94.3
No. 4	4.75	92.3
No. 10	2	88.4
No. 40	0.425	85.8
No. 200	0.075	83.3
	0.02	69.9
	0.005	40.4
	0.002	25.5
estimated	0.001	15.5

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	7.7	11.6
Coarse Sand	3.9	2.6
Medium Sand	2.6	---
Fine Sand	2.5	2.5
Silt	42.9	57.8
Clay	40.4	25.5

Atterberg Limits

Test Method: ASTM D 4318 Method A

Prepared: Dry

Liquid Limit:	38
Plastic Limit:	23
Plasticity Index:	15
Activity Index:	0.6

Moisture-Density Relationship

Test Not Performed

Maximum Dry Density (lb/ft^3):	N/A
Maximum Dry Density (kg/m^3):	N/A
Optimum Moisture Content (%):	N/A
Over Size Correction %:	N/A

California Bearing Ratio

Test Not Performed

Bearing Ratio (%):	N/A
Compacted Dry Density (lb/ft^3):	N/A
Compacted Moisture Content (%):	N/A

Specific Gravity

Estimated

Particle Size:	No. 10
Specific Gravity at 20° Celsius:	2.70

Classification

Unified Group Symbol:	CL
Group Name:	Lean clay with sand
AASHTO Classification:	A-6 (13)

Comments:

Reviewed By REL

Particle-Size Analysis of Soils
ASTM D 422

Project Name	Hillside Avenue	Project Number	175538106
Source	B-1, 3.0'-4.5'	Lab ID	2

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method	ASTM D 422
Prepared using	ASTM D 421
Particle Shape	Angular
Particle Hardness:	Hard and Durable
Tested By	JR
Test Date	03-03-2020
Date Received	03-02-2020

Maximum Particle size: 1 1/2" Sieve

Sieve Size	% Passing
1 1/2"	100.0
3/4"	94.3
3/8"	94.3
No. 4	92.3
No. 10	88.4

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

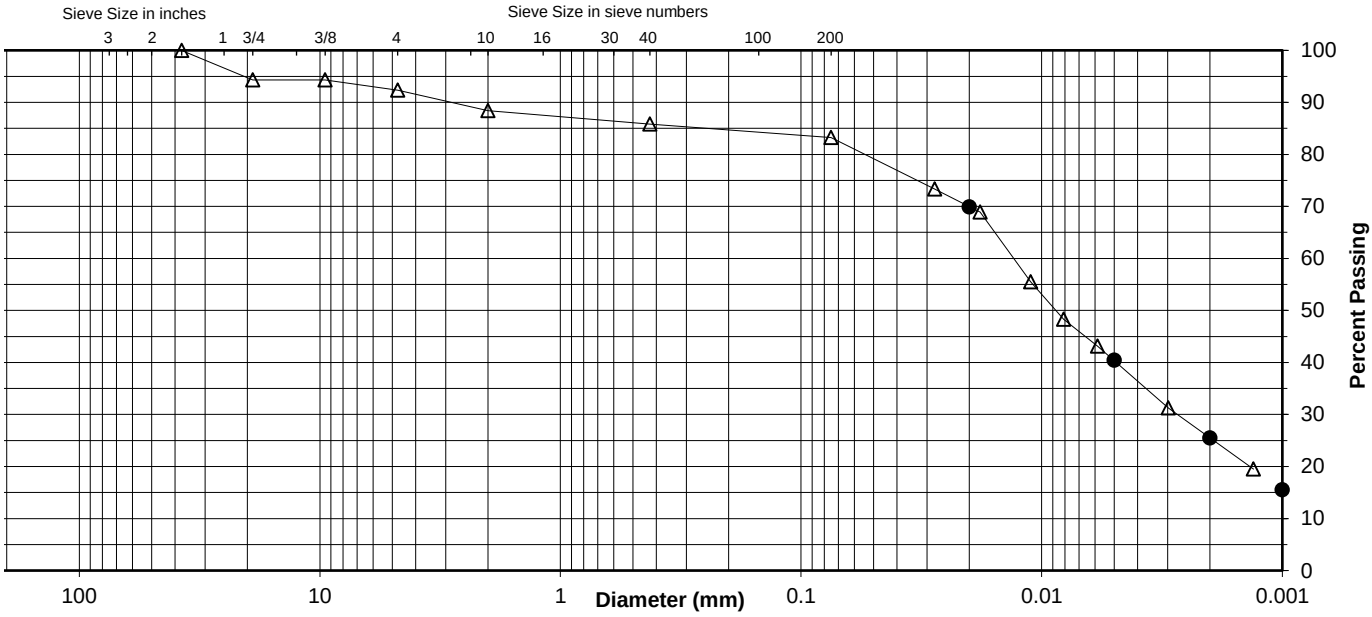
Specific Gravity 2.7

Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	85.8
No. 200	83.3
0.02 mm	69.9
0.005 mm	40.4
0.002 mm	25.5
0.001 mm	15.5

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	5.7	2.0	3.9	2.6	2.5	42.9	40.4
AASHTO	Gravel			Coarse Sand	Fine Sand	Silt	Clay
	11.6			2.6	2.5	57.8	25.5



Comments

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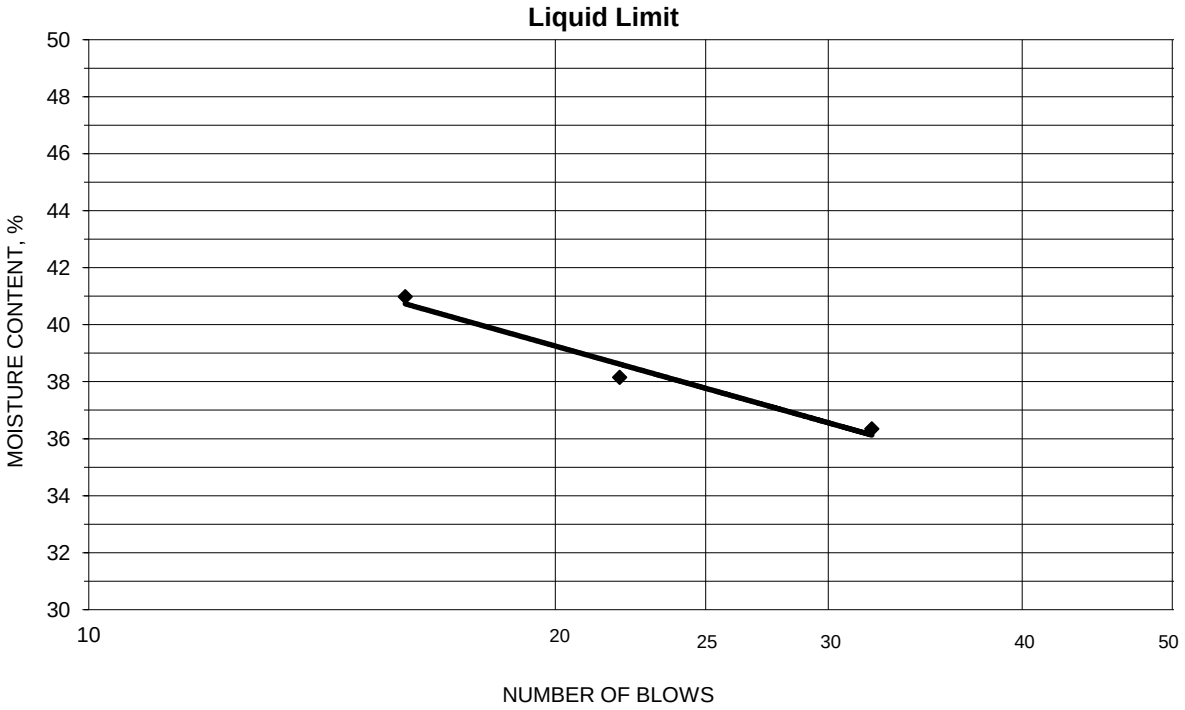
ATTERBERG LIMITS

Project	Hillside Avenue	Project No.	175538106
Source	B-1, 3.0'-4.5'	Lab ID	2
		% + No. 40	14
Tested By	MP	Test Method	ASTM D 4318 Method A
Date Received	03-02-2020		
Test Date	03-04-2020	Prepared	Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
22.14	19.16	10.96	32	36.3	
24.45	20.73	10.98	22	38.2	
24.27	20.43	11.06	16	41.0	38



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
26.37	23.50	11.05	23.1	23	15
26.50	23.65	11.03	22.6		

Remarks:

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Summary of Soil Tests

Project Name	Hillside Avenue	Project Number	175538106
Source	B-2, 6.5'-8.0'	Lab ID	9
Sample Type	SS	Date Received	3-2-20
		Date Reported	3-6-20

Test Results

Natural Moisture Content

Test Method: ASTM D 2216

Moisture Content (%): 20.4

Particle Size Analysis

Preparation Method: ASTM D 421

Gradation Method: ASTM D 422

Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
3/4"	19	100.0
3/8"	9.5	97.5
No. 4	4.75	95.6
No. 10	2	93.0
No. 40	0.425	90.2
No. 200	0.075	87.4
	0.02	81.3
	0.005	53.5
	0.002	36.8
estimated	0.001	26.3

Plus 3 in. material, not included: 0 (%)

Range	ASTM (%)	AASHTO (%)
Gravel	4.4	7.0
Coarse Sand	2.6	2.8
Medium Sand	2.8	---
Fine Sand	2.8	2.8
Silt	33.9	50.6
Clay	53.5	36.8

Atterberg Limits

Test Method: ASTM D 4318 Method A

Prepared: Dry

Liquid Limit:	46
Plastic Limit:	22
Plasticity Index:	24
Activity Index:	0.7

Moisture-Density Relationship

Test Not Performed

Maximum Dry Density (lb/ft^3):	N/A
Maximum Dry Density (kg/m^3):	N/A
Optimum Moisture Content (%):	N/A
Over Size Correction %:	N/A

California Bearing Ratio

Test Not Performed

Bearing Ratio (%):	N/A
Compacted Dry Density (lb/ft^3):	N/A
Compacted Moisture Content (%):	N/A

Specific Gravity

Estimated

Particle Size:	No. 10
Specific Gravity at 20° Celsius:	2.70

Classification

Unified Group Symbol:	CL
Group Name:	Lean clay
AASHTO Classification:	A-7-6 (22)

Comments:

Reviewed By REL

Particle-Size Analysis of Soils
ASTM D 422

Project Name	Hillside Avenue	Project Number	175538106
Source	B-2, 6.5'-8.0'	Lab ID	9

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method	ASTM D 422
Prepared using	ASTM D 421
Particle Shape	Angular
Particle Hardness:	Hard and Durable
Tested By	JR
Test Date	03-03-2020
Date Received	03-02-2020

Maximum Particle size: 3/4" Sieve

Sieve Size	% Passing
3/4"	100.0
3/8"	97.5
No. 4	95.6
No. 10	93.0

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

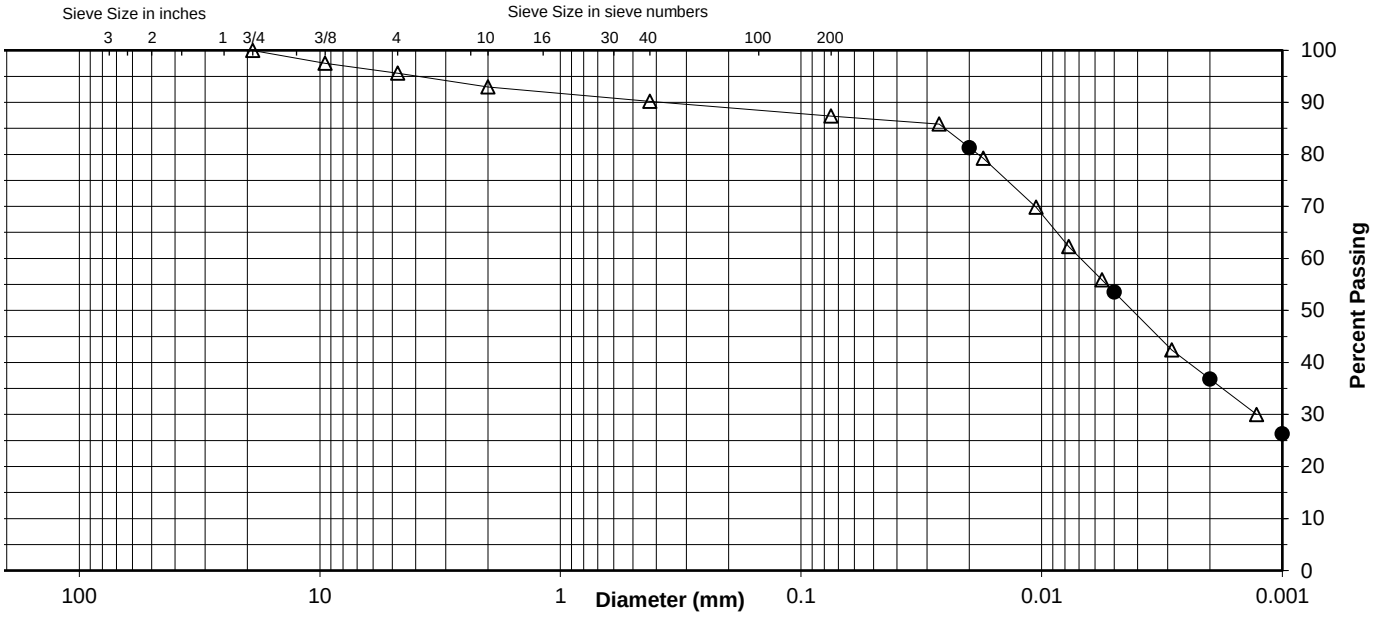
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	90.2
No. 200	87.4
0.02 mm	81.3
0.005 mm	53.5
0.002 mm	36.8
0.001 mm	26.3

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	4.4	2.6	2.8	2.8	33.9	53.5

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	7.0	2.8	2.8	50.6	36.8



Comments

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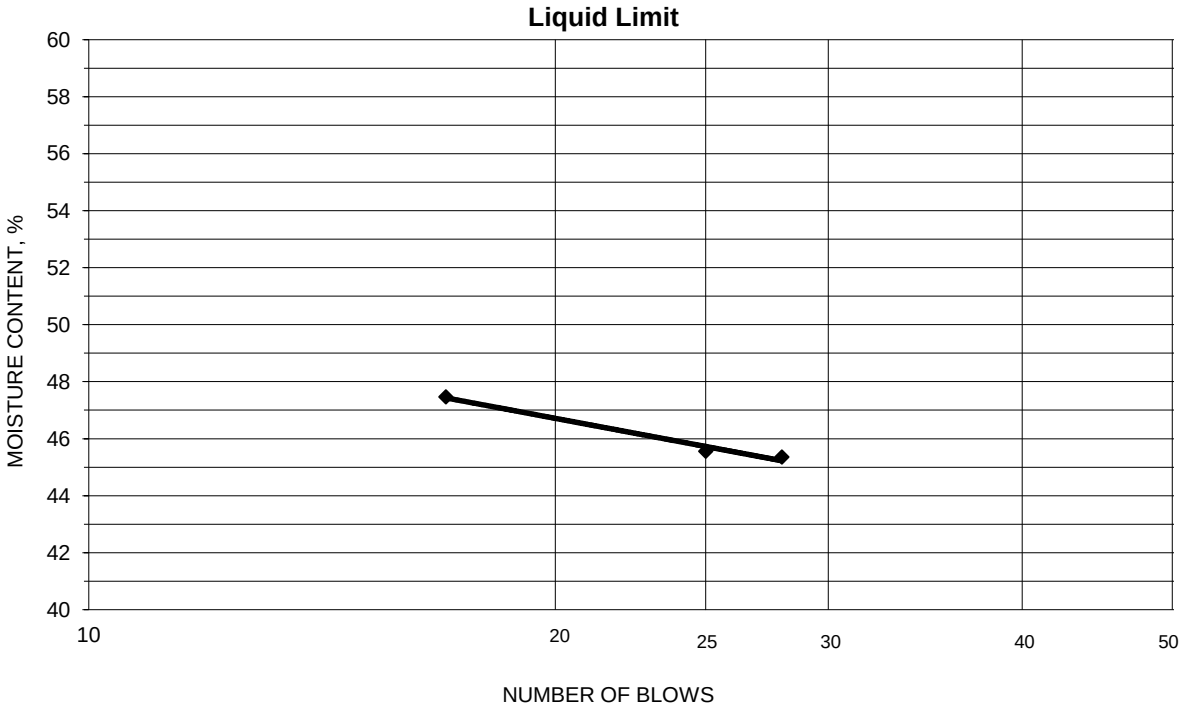
ATTERBERG LIMITS

Project	Hillside Avenue	Project No.	175538106
Source	B-2, 6.5'-8.0'	Lab ID	9
		% + No. 40	10
Tested By	JR	Test Method	ASTM D 4318 Method A
Date Received	03-02-2020		
Test Date	03-04-2020	Prepared	Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
19.99	17.06	10.60	28	45.4	
20.04	17.22	11.03	25	45.6	
19.49	16.77	11.04	17	47.5	46



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
16.75	15.72	11.00	21.8	22	24
16.60	15.57	11.00	22.5		

Remarks:

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Summary of Soil Tests

Project Name	Hillside Avenue	Project Number	175538106
Source	B-7, 3.0'-4.5'	Lab ID	30
Sample Type	SS	Date Received	3-2-20
		Date Reported	3-6-20

Test Results

Natural Moisture Content

Test Method: ASTM D 2216

Moisture Content (%): 11.8

Particle Size Analysis

Preparation Method: ASTM D 421

Gradation Method: ASTM D 422

Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
3/4"	19	100.0
3/8"	9.5	93.7
No. 4	4.75	90.4
No. 10	2	86.8
No. 40	0.425	82.7
No. 200	0.075	79.2
	0.02	70.2
	0.005	47.6
	0.002	34.9
estimated	0.001	27.2

Plus 3 in. material, not included: 0 (%)

Range	ASTM (%)	AASHTO (%)
Gravel	9.6	13.2
Coarse Sand	3.6	4.1
Medium Sand	4.1	---
Fine Sand	3.5	3.5
Silt	31.6	44.3
Clay	47.6	34.9

Atterberg Limits

Test Method: ASTM D 4318 Method A

Prepared: Dry

Liquid Limit:	42
Plastic Limit:	21
Plasticity Index:	21
Activity Index:	0.6

Moisture-Density Relationship

Test Not Performed

Maximum Dry Density (lb/ft^3):	N/A
Maximum Dry Density (kg/m^3):	N/A
Optimum Moisture Content (%):	N/A
Over Size Correction %:	N/A

California Bearing Ratio

Test Not Performed

Bearing Ratio (%):	N/A
Compacted Dry Density (lb/ft^3):	N/A
Compacted Moisture Content (%):	N/A

Specific Gravity

Estimated

Particle Size:	No. 10
Specific Gravity at 20° Celsius:	2.70

Classification

Unified Group Symbol:	CL
Group Name:	Lean clay with sand
AASHTO Classification:	A-7-6 (16)

Comments:

Reviewed By REL

Particle-Size Analysis of Soils
ASTM D 422

Project Name	Hillside Avenue	Project Number	175538106
Source	B-7, 3.0'-4.5'	Lab ID	30

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method	ASTM D 422
Prepared using	ASTM D 421
Particle Shape	Angular
Particle Hardness:	Hard and Durable
Tested By	JR
Test Date	03-03-2020
Date Received	03-02-2020

Maximum Particle size: 3/4" Sieve

Sieve Size	% Passing
3/4"	100.0
3/8"	93.7
No. 4	90.4
No. 10	86.8

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

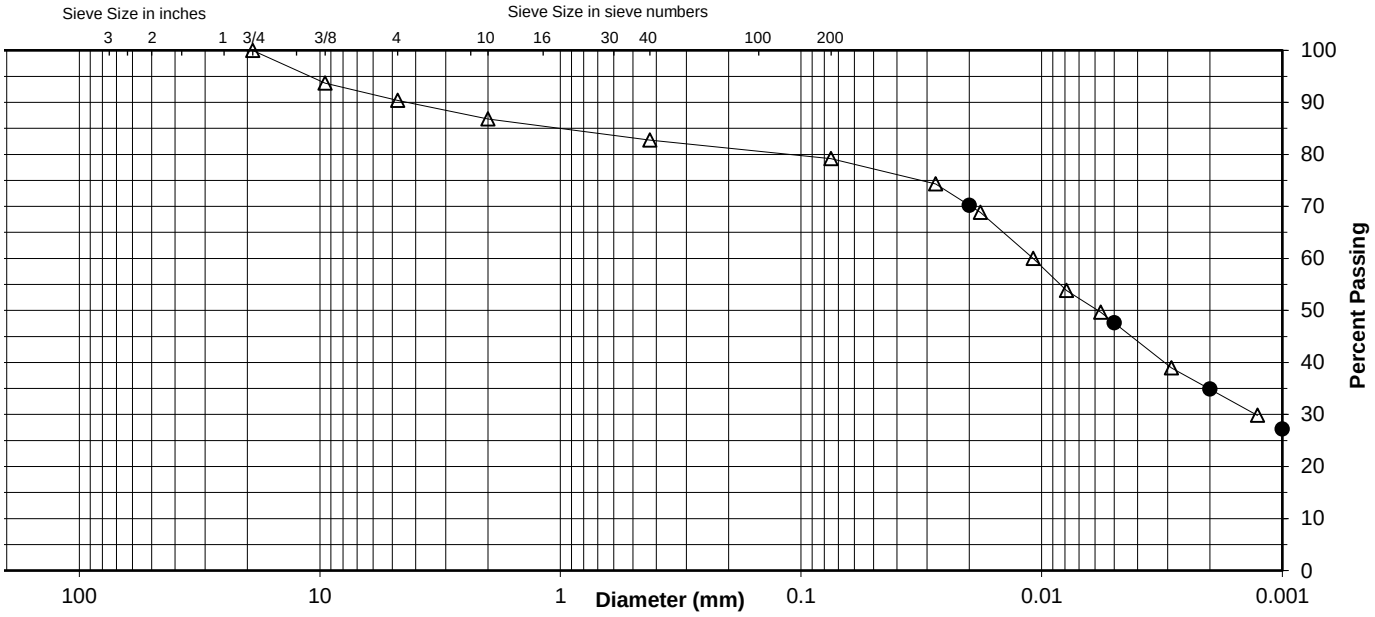
Specific Gravity 2.7

Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	82.7
No. 200	79.2
0.02 mm	70.2
0.005 mm	47.6
0.002 mm	34.9
0.001 mm	27.2

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	9.6	3.6	4.1	3.5	31.6	47.6
AASHTO	Gravel			Coarse Sand	Fine Sand	Silt	Clay
	13.2			4.1	3.5	44.3	34.9



Comments

Reviewed By REL

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Approved By: RJ

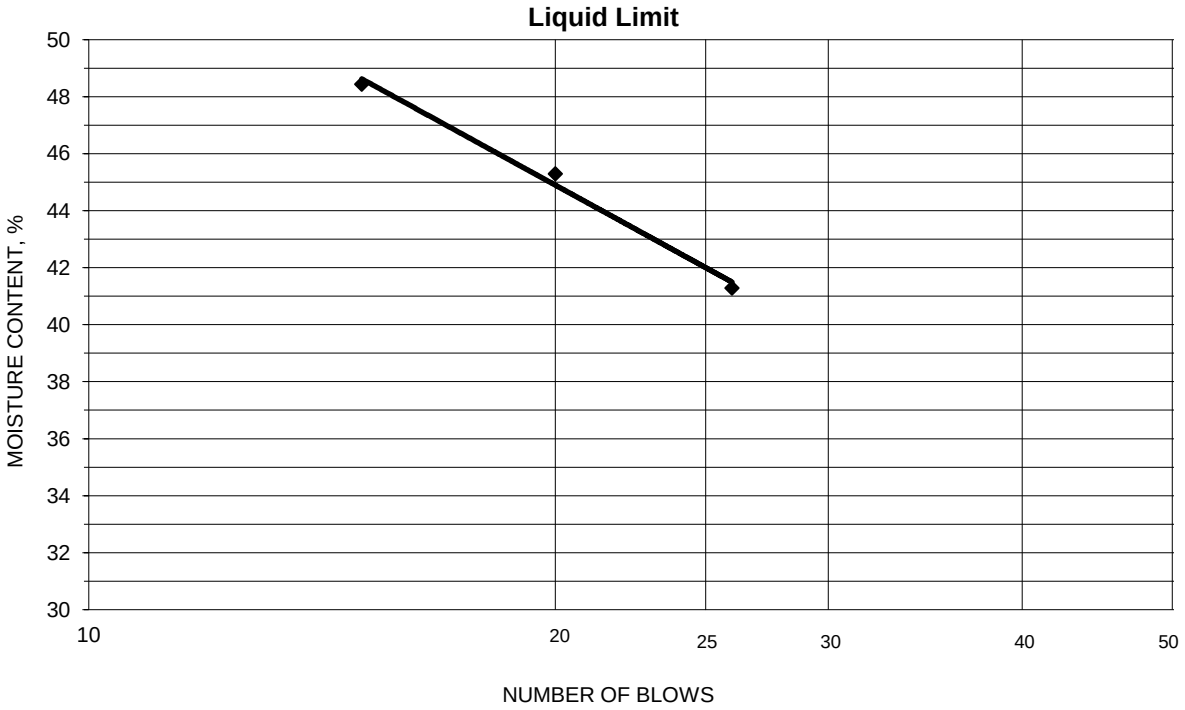
Stantec Consulting Services Inc.

Stantec

ATTERBERG LIMITS

Project	Hillside Avenue	Project No.	175538106
Source	B-7, 3.0'-4.5'	Lab ID	30
		% + No. 40	17
Tested By	JR	Test Method	ASTM D 4318 Method A
Date Received	03-02-2020		
Test Date	03-04-2020	Prepared	Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
20.50	17.61	10.61	26	41.3	
20.18	17.34	11.07	20	45.3	
21.02	17.77	11.06	15	48.4	42



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
16.30	15.38	11.02	21.1	21	21
16.56	15.59	11.00	21.1		

Remarks:

Reviewed By REL

Template: tmp_sum_input.xlsm
Version: 20170217
Approved By: RJ

Stantec

Uniaxial Compressive Strength of Intact Rock Core Specimens

ASTM D 7012, Method C

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-1
Hole Number	B-1	Depth (ft)	13.2'-13.6'
Date Received	02/26/2020		

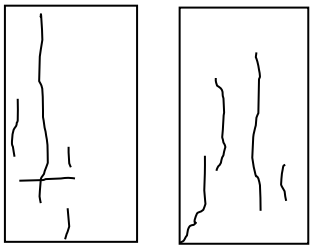
Temperature (^oC)	22	Moisture Condition	As Prepared, Moist	Date Tested	03/10/2020

Side Planeness	N/A	Height (in)	4.570	Wet Unit Weight (pcf)	156.2
Perpendicularity	N/A	Diameter (in)	1.956	Dry Unit Weight (pcf)	N/A
End Planeness	N/A	Area (in^2)	3.003	Moisture Content (%)	N/A
Parallelism	N/A				

Dimensions were not confirmed.

Loading Rate (lbf/sec)	14
Peak Load (lbf)	2866
Failure Type	Columnar
Compressive Strength (psi)	954
Compressive Strength (psf)	137376
Compressive Strength (tsf)	69

Failure Sketches



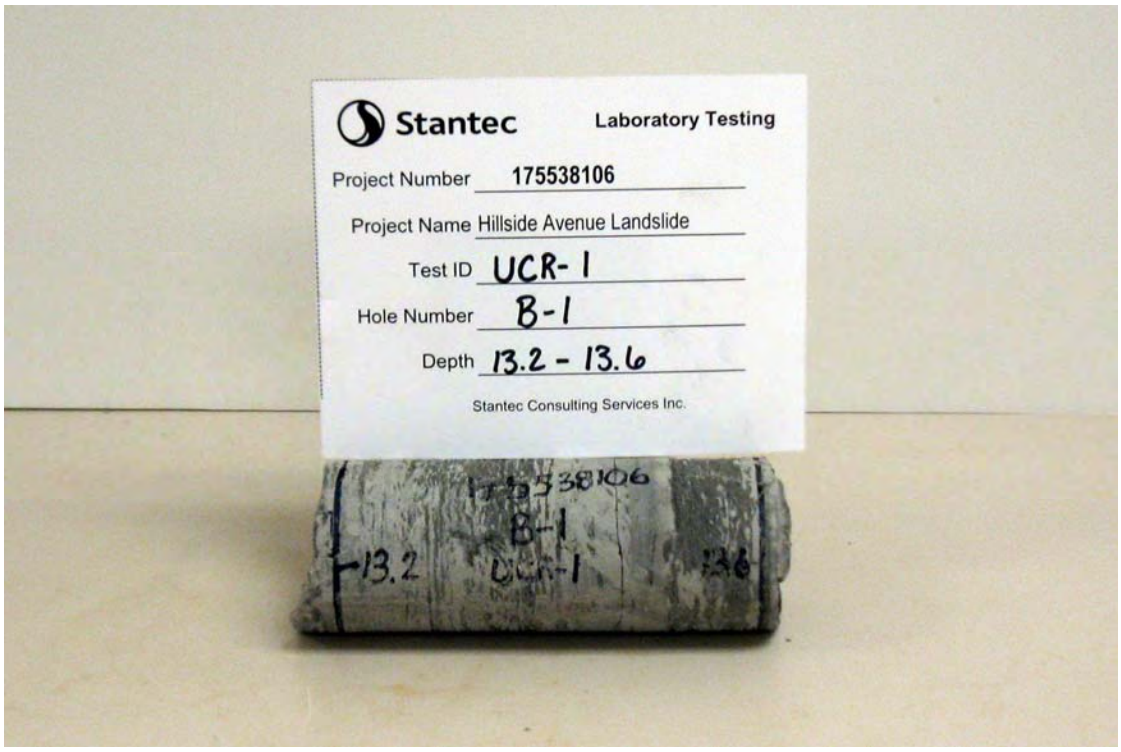
Comments Fragile nature of specimen inhibited preparation, required capping of ends with Hydro-Stone. Dimensional tolerances were not confirmed.

Reviewed By JW

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-1
Hole Number	B-1	Depth (ft)	13.2'-13.6'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

As Received



Core Preparation

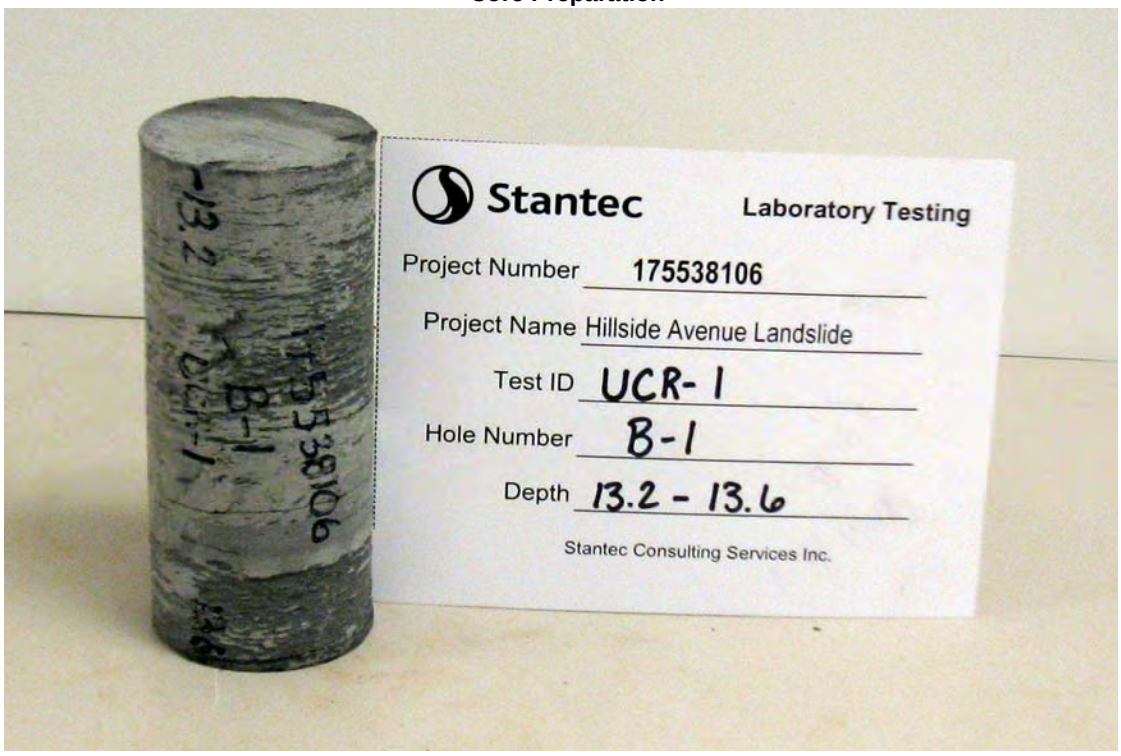
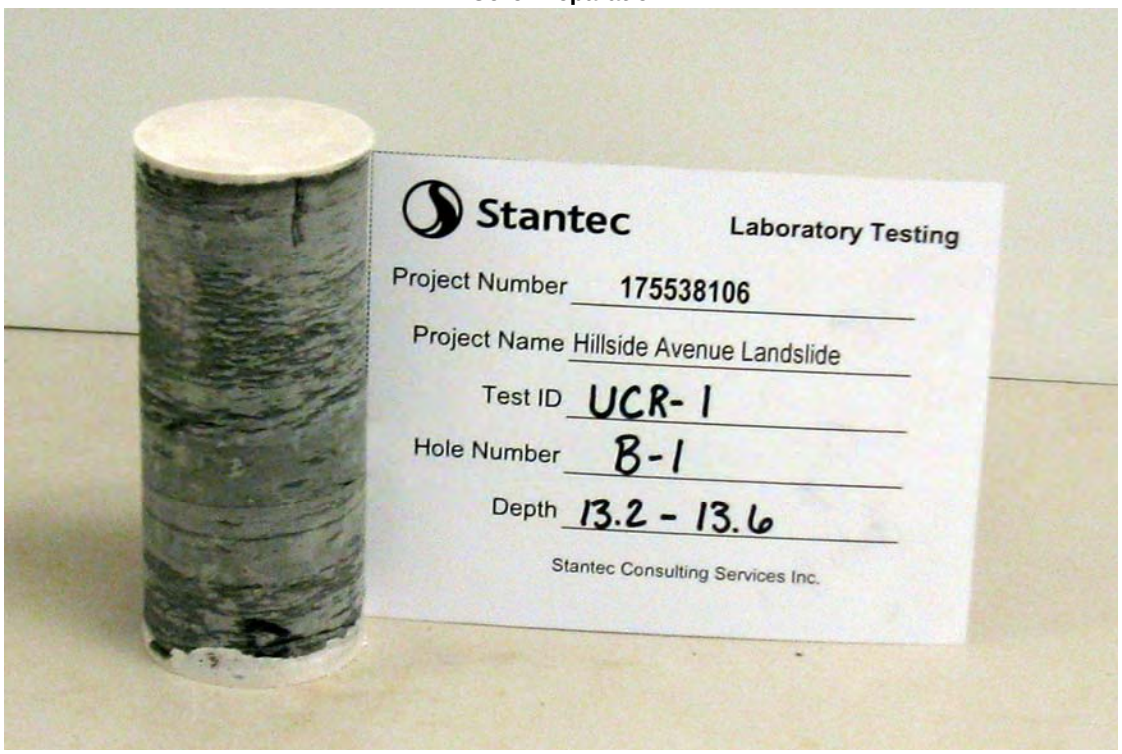


Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-1
Hole Number	B-1	Depth (ft)	13.2'-13.6'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Core Preparation



Post Test

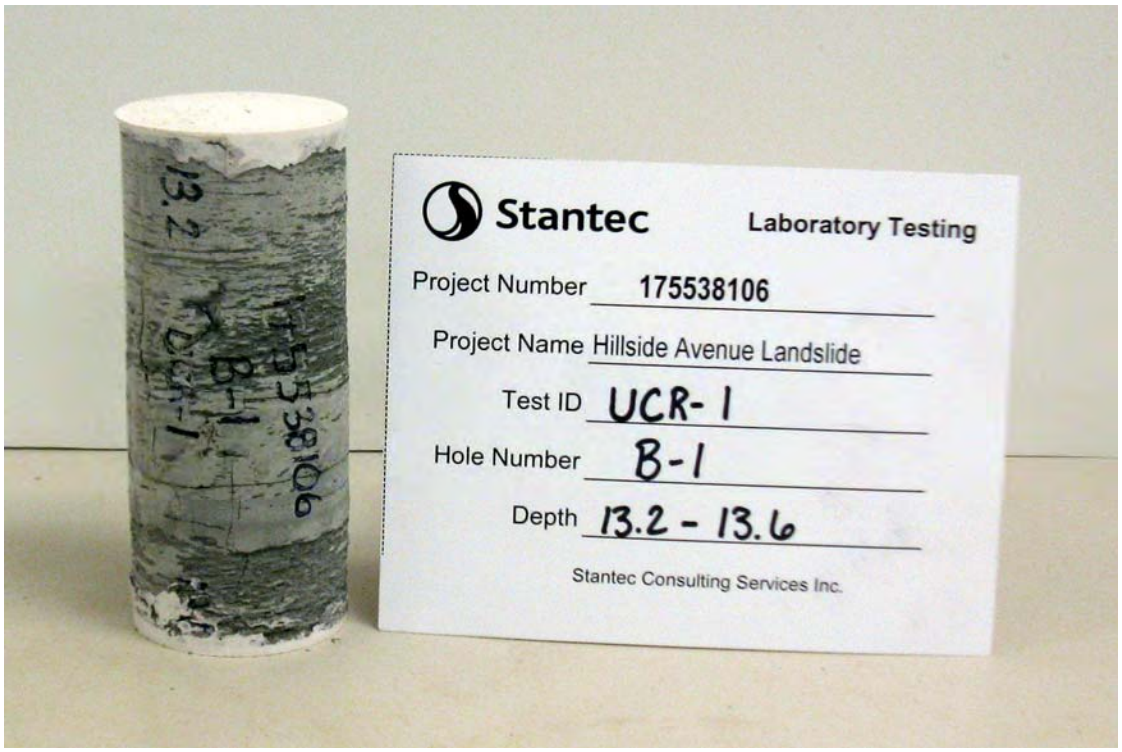


Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-1
Hole Number	B-1	Depth (ft)	13.2'-13.6'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Post Test

Stantec

Uniaxial Compressive Strength of Intact Rock Core Specimens

ASTM D 7012, Method C

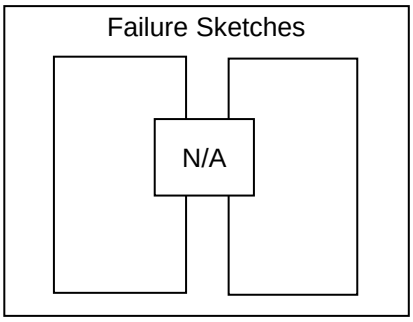
Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-2
Hole Number	B-1	Depth (ft)	18.2'-18.6'
Date Received	02/26/2020		

Temperature (^oC)	22	Moisture Condition	As Prepared, Moist	Date Tested	03/10/2020

Side Planeness	Pass	Height (in)	4.638	Wet Unit Weight (pcf)	169.6
Perpendicularity	Pass	Diameter (in)	1.983	Dry Unit Weight (pcf)	N/A
End Planeness	Pass	Area (in^2)	3.089	Moisture Content (%)	N/A
Parallelism	Pass				

Loading Rate (lbf/sec)	196
Peak Load (lbf)	73758
Failure Type	Undetermined
Compressive Strength (psi)	23880
Compressive Strength (psf)	3438720
Compressive Strength (tsf)	1719

Failure Sketches



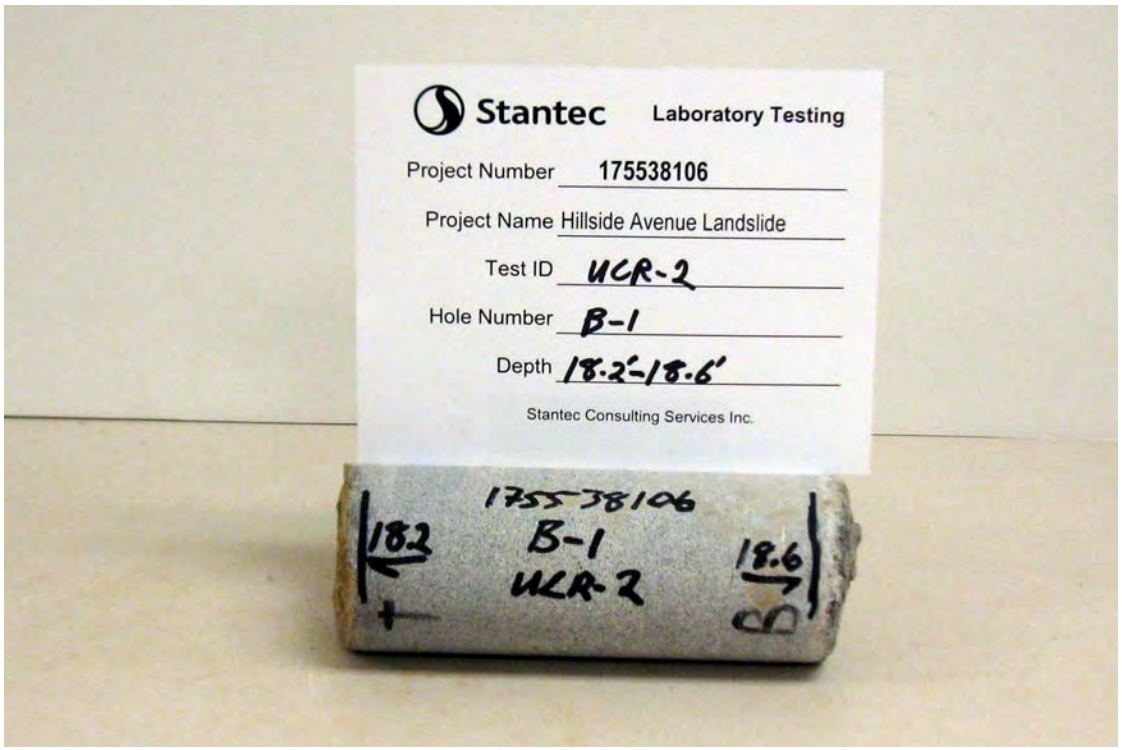
Comments Testing load indicated compressive failure of specimen, no external visual sign of failure was observed.

Reviewed By JW

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-2
Hole Number	B-1	Depth (ft)	18.2'-18.6'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

As Received



Core Preparation

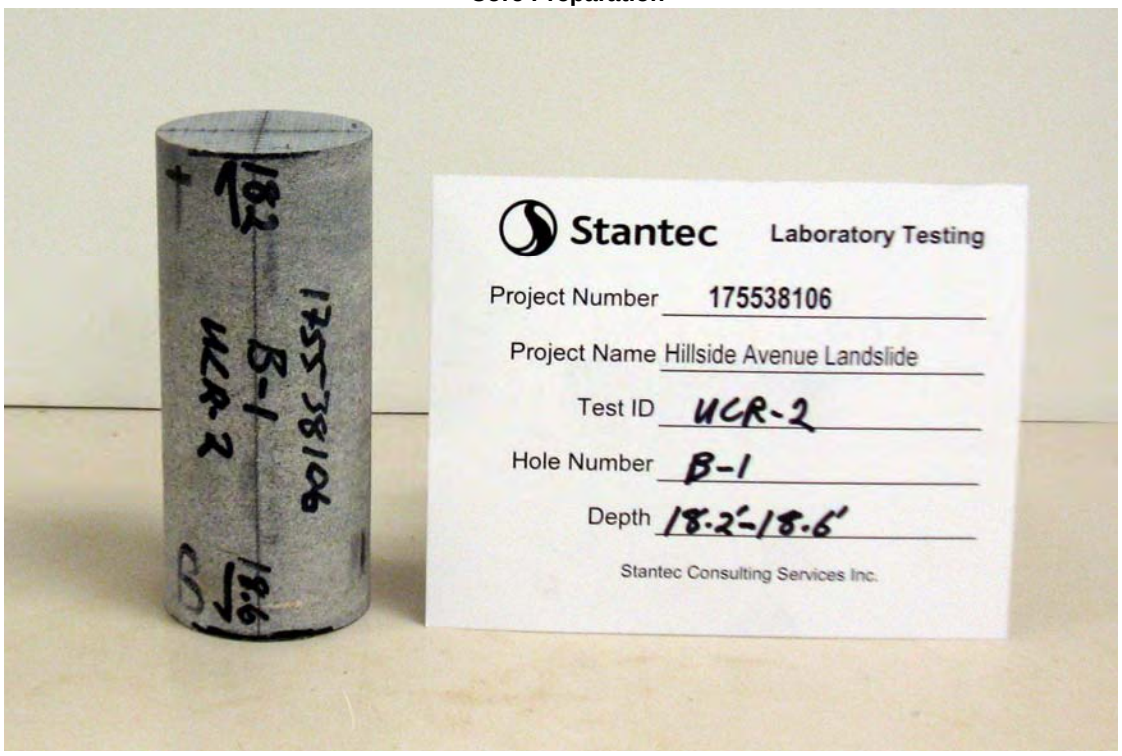


Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-2
Hole Number	B-1	Depth (ft)	18.2'-18.6'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Core Preparation

Post Test

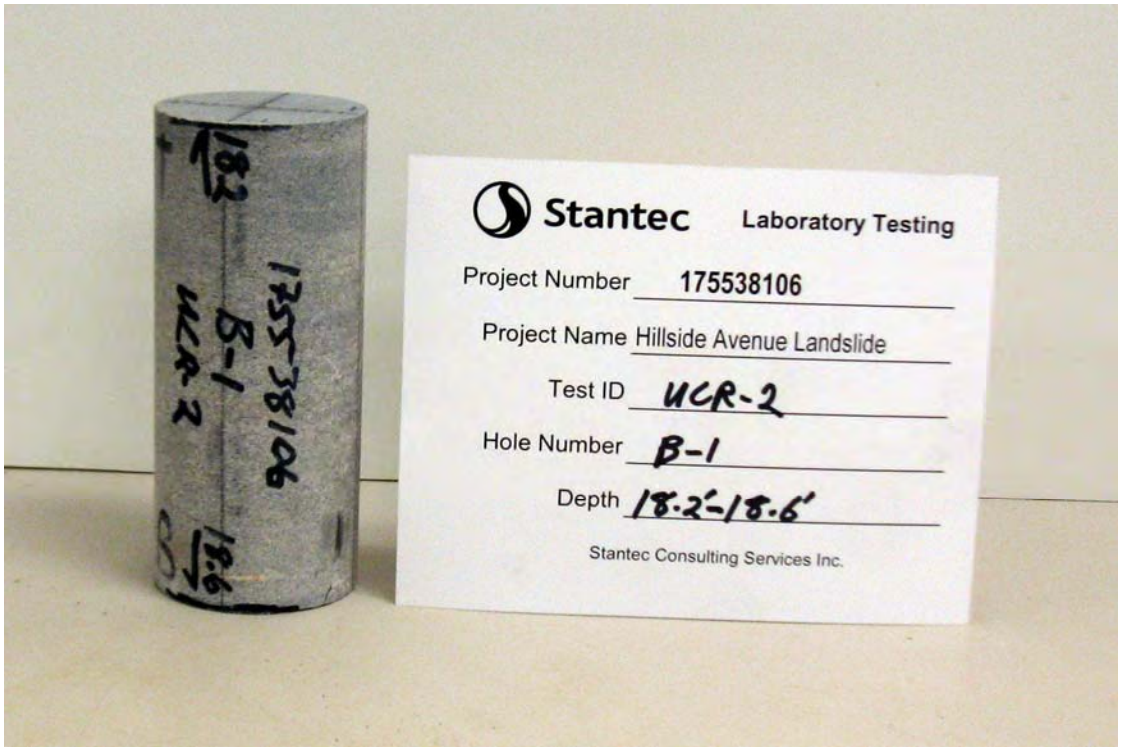


Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-2
Hole Number	B-1	Depth (ft)	18.2'-18.6'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Post Test

Stantec

Uniaxial Compressive Strength of Intact Rock Core Specimens

ASTM D 7012, Method C

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-3
Hole Number	B-2	Depth (ft)	11.1'-11.5'
Date Received	02/26/2020		

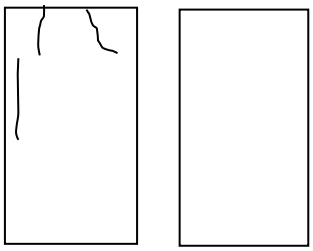
Temperature (^oC)	22	Moisture Condition	As Prepared, Moist	Date Tested	03/10/2020

Side Planeness	N/A	Height (in)	4.670	Wet Unit Weight (pcf)	155.7
Perpendicularity	N/A	Diameter (in)	1.963	Dry Unit Weight (pcf)	N/A
End Planeness	N/A	Area (in^2)	3.026	Moisture Content (%)	N/A
Parallelism	N/A				

Dimensions were not confirmed.

Loading Rate (lbf/sec)	12
Peak Load (lbf)	2361
Failure Type	Undetermined
Compressive Strength (psi)	780
Compressive Strength (psf)	112320
Compressive Strength (tsf)	56

Failure Sketches



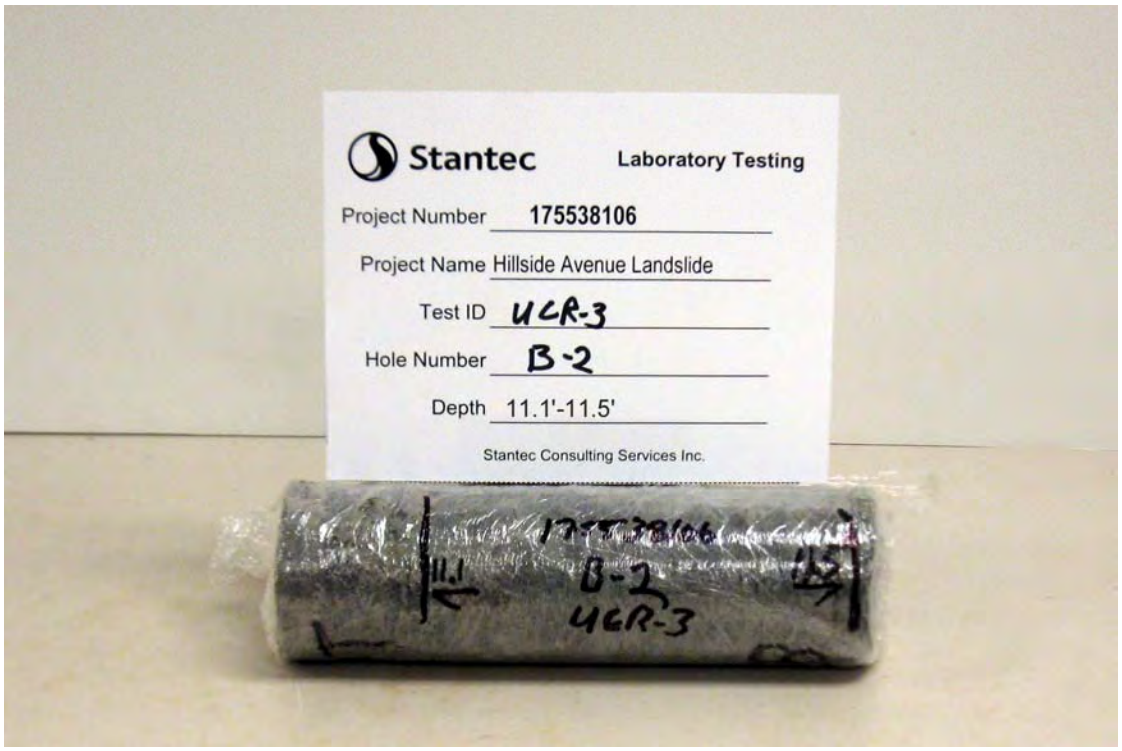
Comments Fragile nature of specimen inhibited preparation. Dimensional tolerances were not confirmed.

Reviewed By JW

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-3
Hole Number	B-2	Depth (ft)	11.1'-11.5'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

As Received



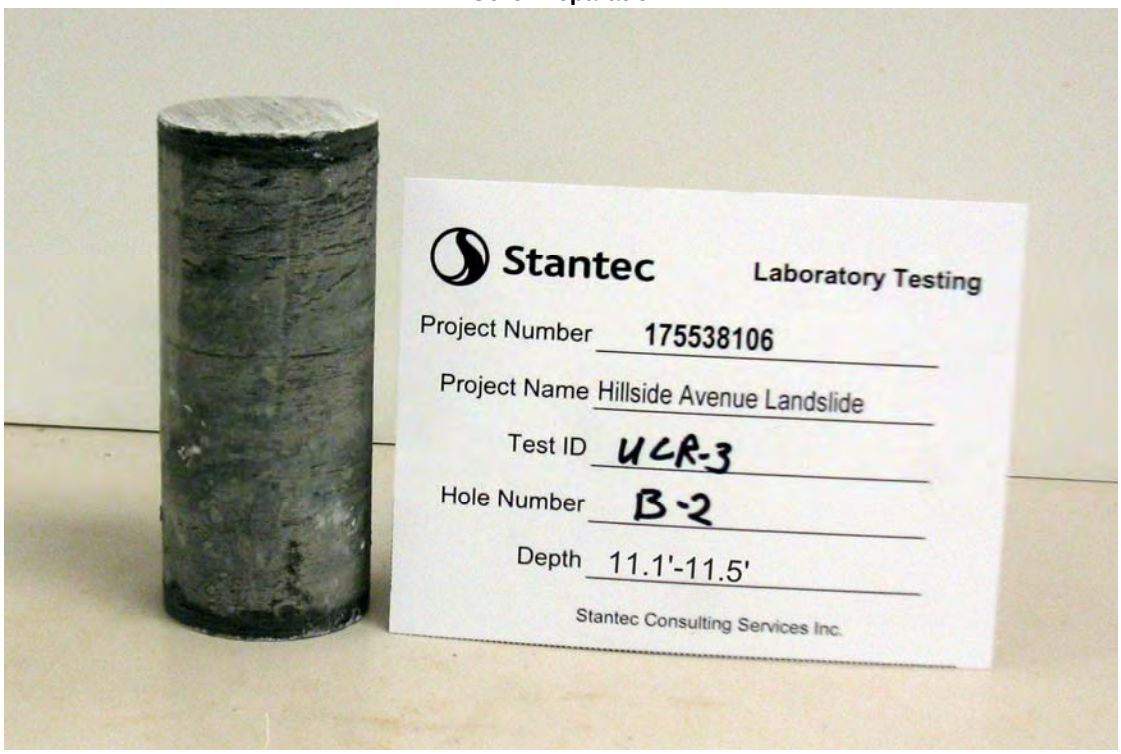
Core Preparation

Stantec

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-3
Hole Number	B-2	Depth (ft)	11.1'-11.5'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Core Preparation



Post Test

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-3
Hole Number	B-2	Depth (ft)	11.1'-11.5'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Post Test

Stantec

Uniaxial Compressive Strength of Intact Rock Core Specimens

ASTM D 7012, Method C

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, brownish gray, soft	Lab ID	UCR-4
Hole Number	B-3	Depth (ft)	9.5'-9.9'
Date Received	02/26/2020		

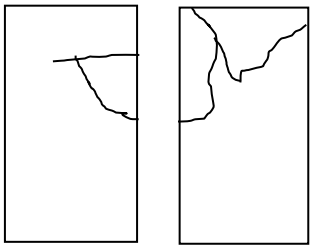
Temperature (^oC)	22	Moisture Condition	As Prepared, Moist	Date Tested	03/10/2020

Side Planeness	N/A	Height (in)	4.499	Wet Unit Weight (pcf)	142.2
Perpendicularity	N/A	Diameter (in)	1.988	Dry Unit Weight (pcf)	N/A
End Planeness	N/A	Area (in^2)	3.103	Moisture Content (%)	N/A
Parallelism	N/A				

Dimensions were not confirmed.

Loading Rate (lbf/sec)	0.7
Peak Load (lbf)	130
Failure Type	Undetermined
Compressive Strength (psi)	42
Compressive Strength (psf)	6048
Compressive Strength (tsf)	3

Failure Sketches



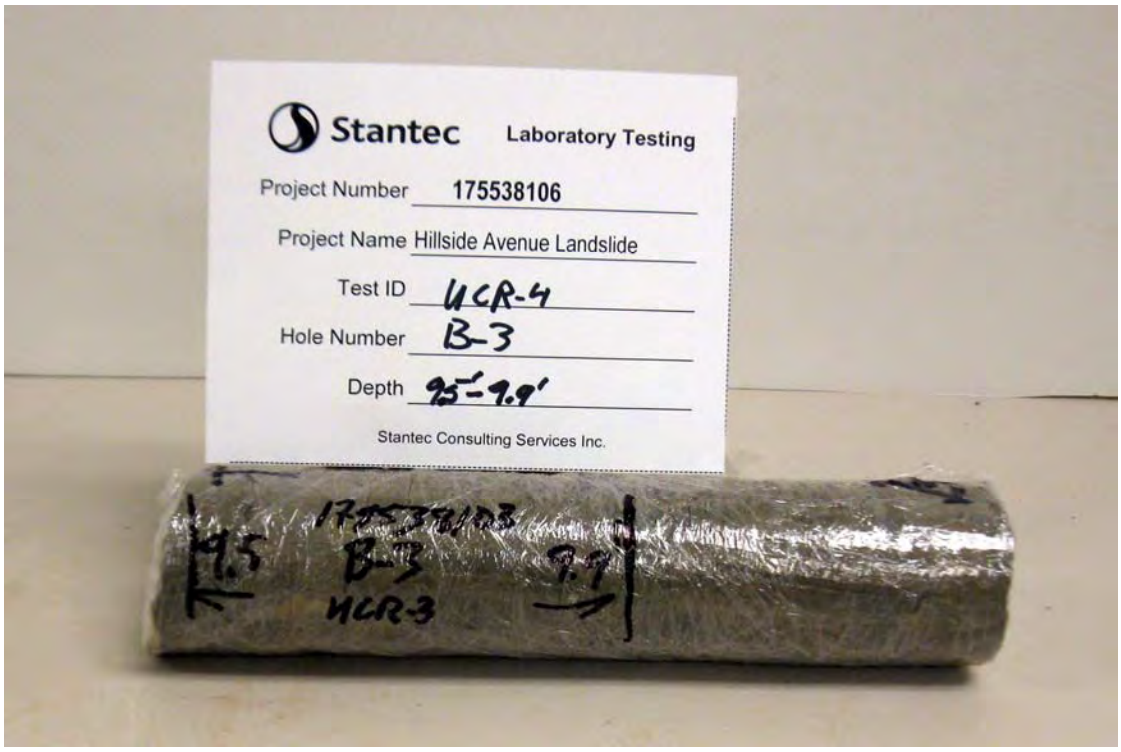
Comments Fragile nature of specimen inhibited preparation, required capping of ends with Hydro-Stone. Dimensional tolerances were not confirmed.

Reviewed By JW

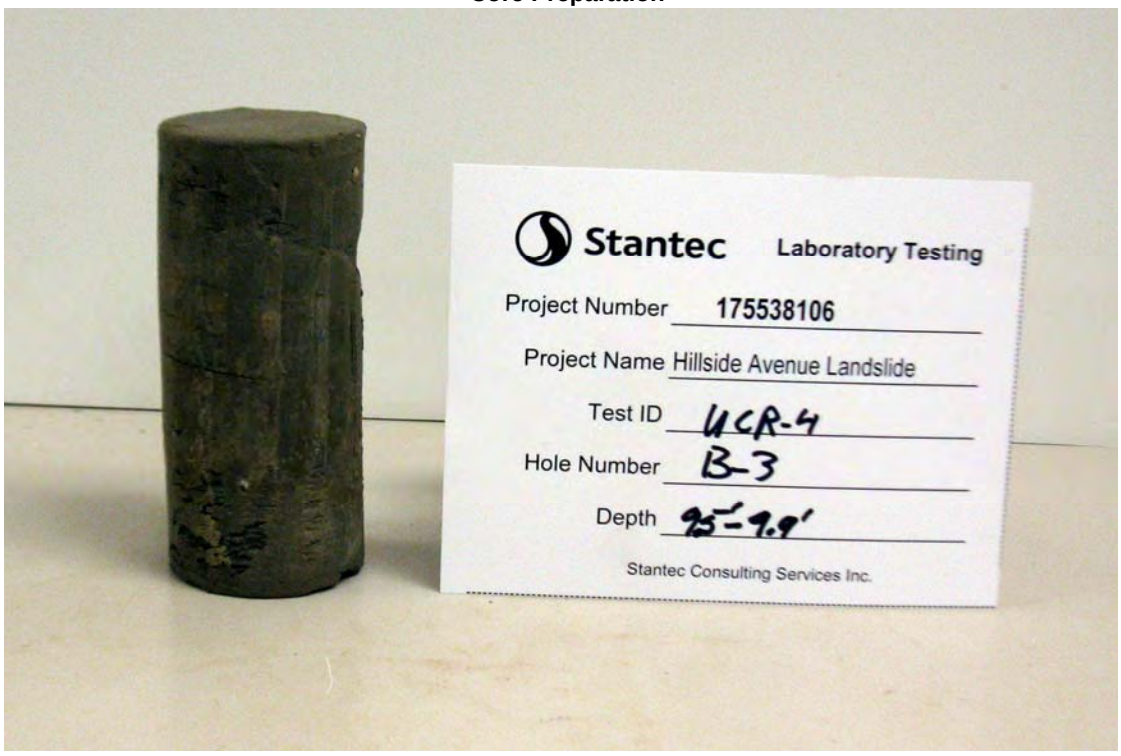
Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, brownish gray, soft	Lab ID	UCR-4
Hole Number	B-3	Depth (ft)	9.5'-9.9'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

As Received



Core Preparation



Stantec

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, brownish gray, soft	Lab ID	UCR-4
Hole Number	B-3	Depth (ft)	9.5'-9.9'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Core Preparation

Post Test

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, brownish gray, soft	Lab ID	UCR-4
Hole Number	B-3	Depth (ft)	9.5'-9.9'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Post Test

Stantec

Uniaxial Compressive Strength of Intact Rock Core Specimens

ASTM D 7012, Method C

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-5
Hole Number	B-5	Depth (ft)	14.1'-14.5'
Date Received	02/26/2020		

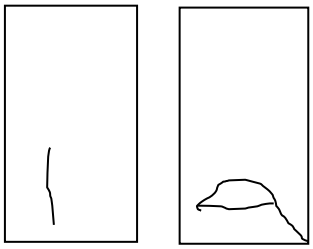
Temperature (^oC)	22	Moisture Condition	As Prepared, Moist	Date Tested	03/10/2020

Side Planeness	N/A	Height (in)	4.789	Wet Unit Weight (pcf)	140.2
Perpendicularity	N/A	Diameter (in)	2.011	Dry Unit Weight (pcf)	N/A
End Planeness	N/A	Area (in^2)	3.176	Moisture Content (%)	N/A
Parallelism	N/A				

Dimensions were not confirmed.

Loading Rate (lbf/sec)	1
Peak Load (lbf)	174
Failure Type	Undetermined
Compressive Strength (psi)	55
Compressive Strength (psf)	7920
Compressive Strength (tsf)	4

Failure Sketches



Comments Fragile nature of specimen inhibited preparation. Dimensional tolerances were not confirmed.

Reviewed By JW

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-5
Hole Number	B-5	Depth (ft)	14.1'-14.5'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

As Received

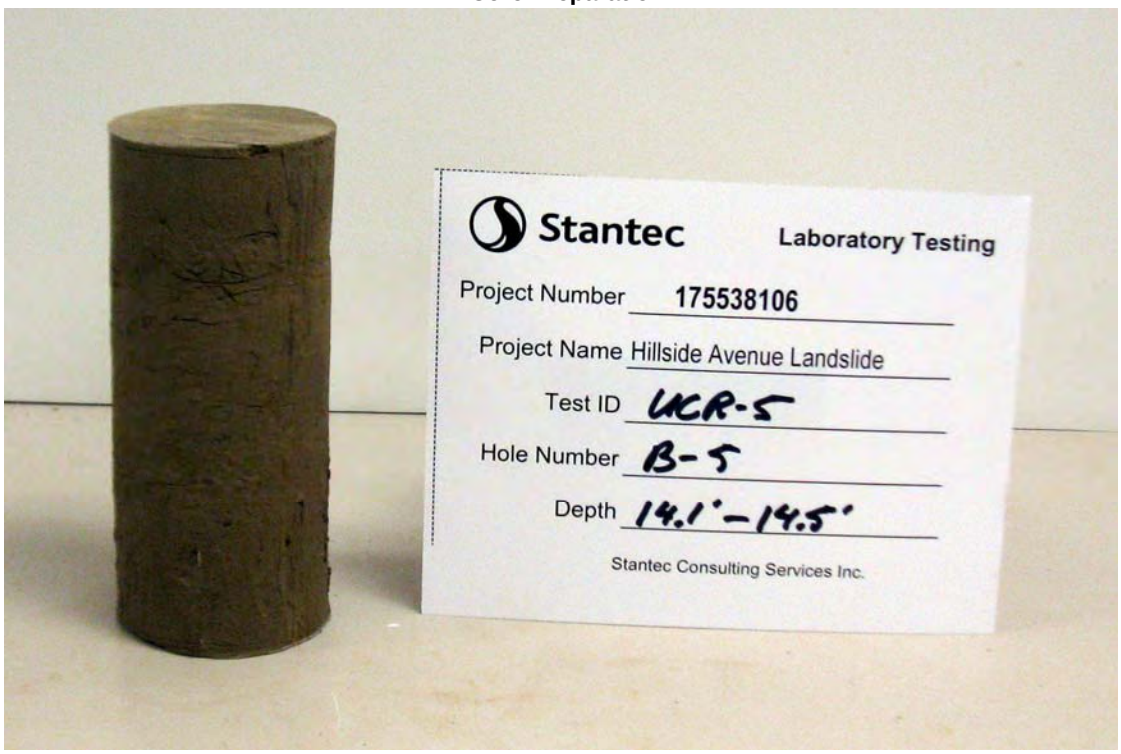
Core Preparation

Stantec

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-5
Hole Number	B-5	Depth (ft)	14.1'-14.5'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Core Preparation



Post Test

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-5
Hole Number	B-5	Depth (ft)	14.1'-14.5'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Post Test

Stantec

Uniaxial Compressive Strength of Intact Rock Core Specimens

ASTM D 7012, Method C

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-6
Hole Number	B-6	Depth (ft)	19.9'-20.2'
Date Received	02/26/2020		

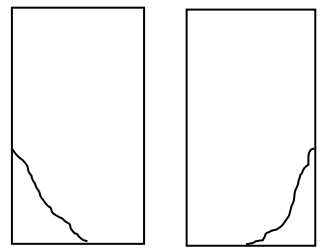
Temperature (^oC)	22	Moisture Condition	As Prepared, Moist	Date Tested	03/10/2020

Side Planeness	N/A	Height (in)	4.373	Wet Unit Weight (pcf)	145.6
Perpendicularity	N/A	Diameter (in)	1.945	Dry Unit Weight (pcf)	N/A
End Planeness	N/A	Area (in^2)	2.971	Moisture Content (%)	N/A
Parallelism	N/A				

Dimensions were not confirmed.

Loading Rate (lbf/sec)	8
Peak Load (lbf)	874
Failure Type	Shear
Compressive Strength (psi)	294
Compressive Strength (psf)	42336
Compressive Strength (tsf)	21

Failure Sketches



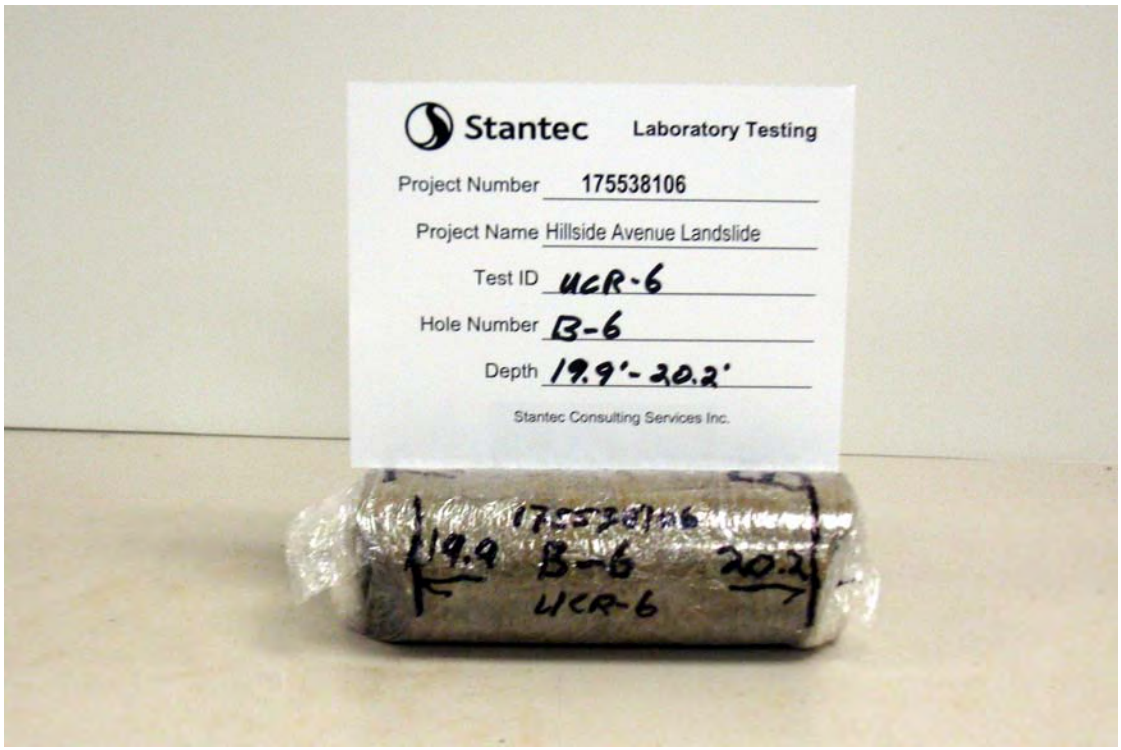
Comments Fragile nature of specimen inhibited preparation. Dimensional tolerances were not confirmed.

Reviewed By JW

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-6
Hole Number	B-6	Depth (ft)	19.9'-20.2'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

As Received

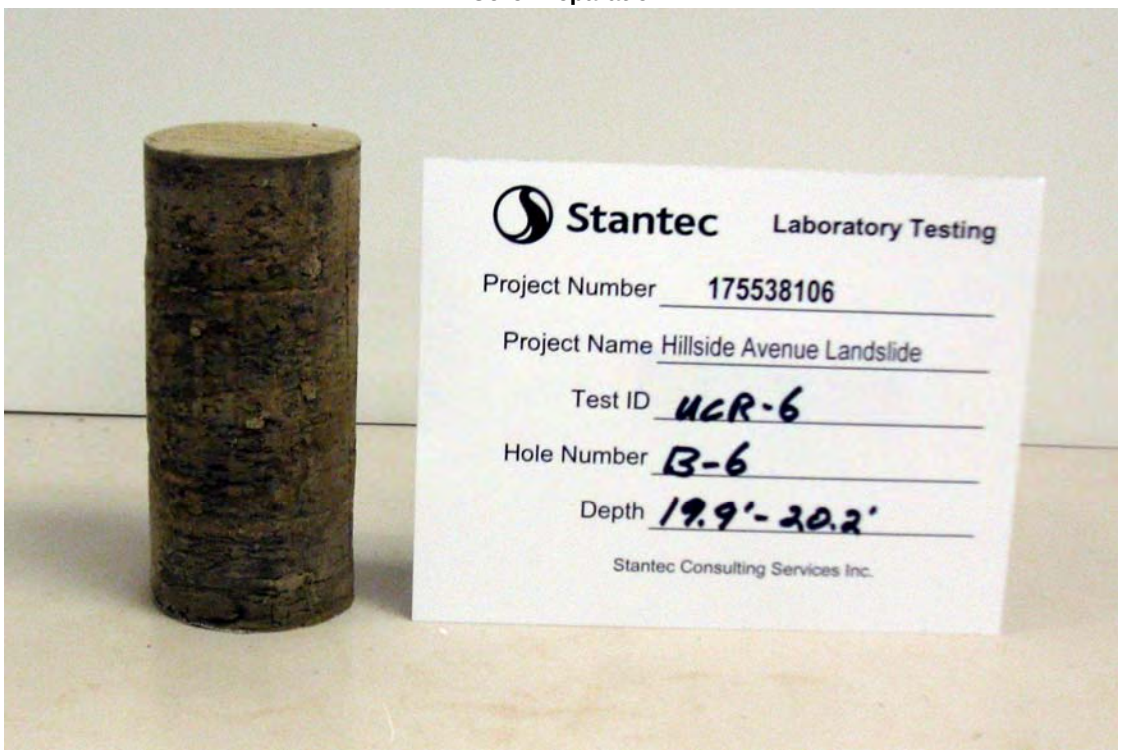


Core Preparation

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-6
Hole Number	B-6	Depth (ft)	19.9'-20.2'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Core Preparation



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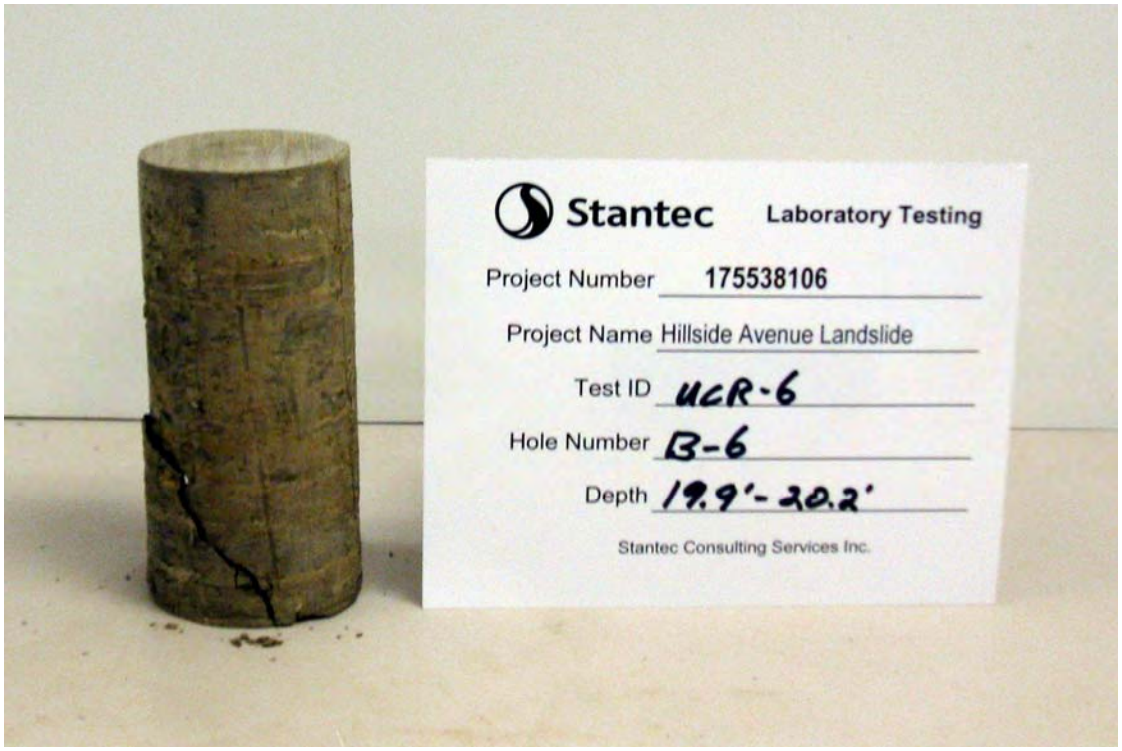


Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-6
Hole Number	B-6	Depth (ft)	19.9'-20.2'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Post Test

Stantec

Uniaxial Compressive Strength of Intact Rock Core Specimens

ASTM D 7012, Method C

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-7
Hole Number	B-7	Depth (ft)	14.5'-14.9'
Date Received	02/26/2020		

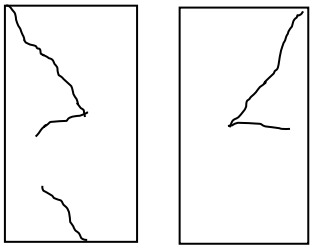
Temperature (^oC)	22	Moisture Condition	As Prepared, Moist	Date Tested	03/10/2020

Side Planeness	N/A	Height (in)	4.452	Wet Unit Weight (pcf)	141.4
Perpendicularity	N/A	Diameter (in)	1.979	Dry Unit Weight (pcf)	N/A
End Planeness	N/A	Area (in^2)	3.075	Moisture Content (%)	N/A
Parallelism	N/A				

Dimensions were not confirmed.

Loading Rate (lbf/sec)	2
Peak Load (lbf)	166
Failure Type	Shear
Compressive Strength (psi)	54
Compressive Strength (psf)	7776
Compressive Strength (tsf)	4

Failure Sketches



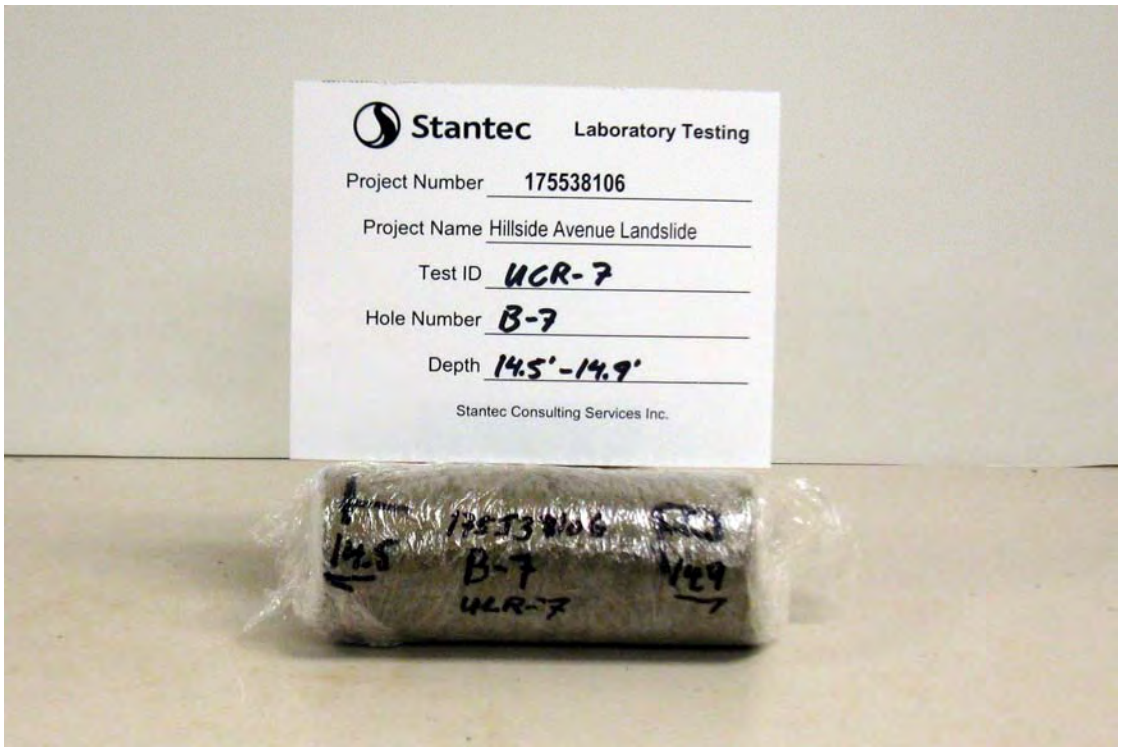
Comments Fragile nature of specimen inhibited preparation. Dimensional tolerances were not confirmed.

Reviewed By JW

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-7
Hole Number	B-7	Depth (ft)	14.5'-14.9'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

As Received



Core Preparation

Stantec

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-7
Hole Number	B-7	Depth (ft)	14.5'-14.9'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

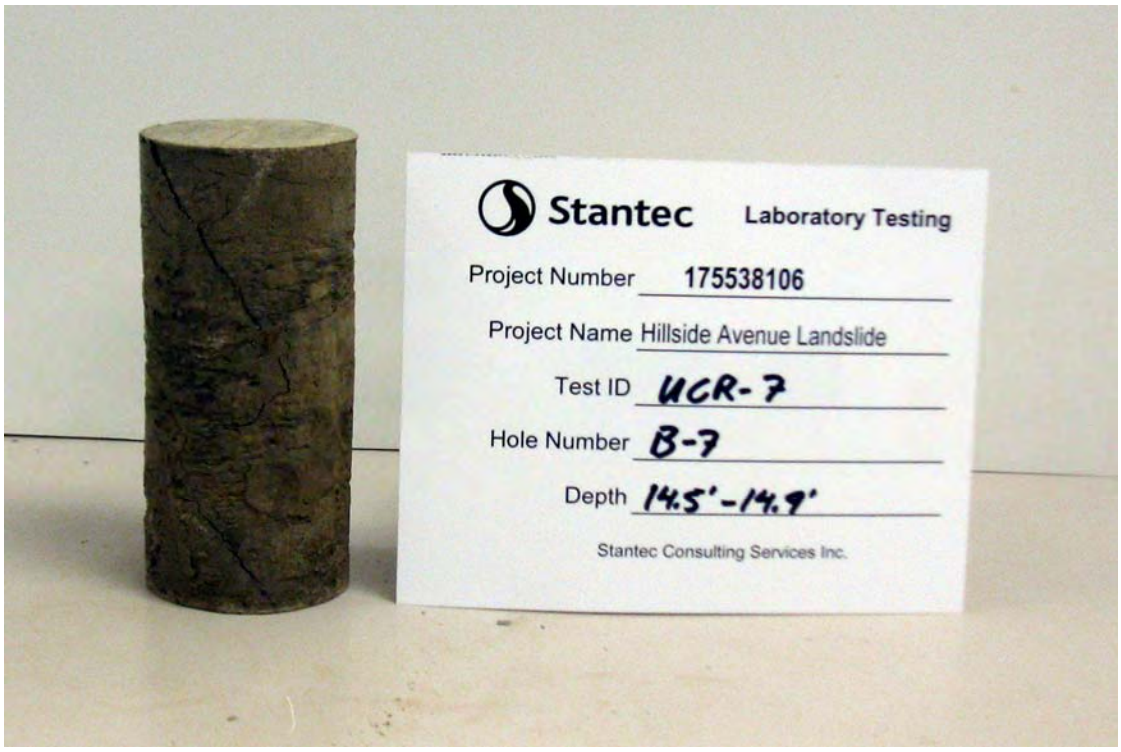
Core Preparation

Post Test

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Claystone, light brown, soft	Lab ID	UCR-7
Hole Number	B-7	Depth (ft)	14.5'-14.9'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Post Test



Stantec

Uniaxial Compressive Strength of Intact Rock Core Specimens

ASTM D 7012, Method C

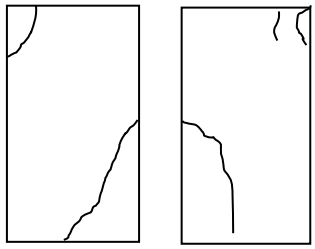
Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-8
Hole Number	B-7	Depth (ft)	28.8'-29.2'
Date Received	02/26/2020		
Temperature (^oC)	22	Moisture Condition	As Prepared, Moist
Date Tested	03/10/2020		

Side Planeness	N/A	Height (in)	4.639	Wet Unit Weight (pcf)	153.0
Perpendicularity	N/A	Diameter (in)	1.962	Dry Unit Weight (pcf)	N/A
End Planeness	N/A	Area (in^2)	3.022	Moisture Content (%)	N/A
Parallelism	N/A				

Dimensions were not confirmed.

Loading Rate (lbf/sec)	10
Peak Load (lbf)	1348
Failure Type	Shear
Compressive Strength (psi)	446
Compressive Strength (psf)	64224
Compressive Strength (tsf)	32

Failure Sketches



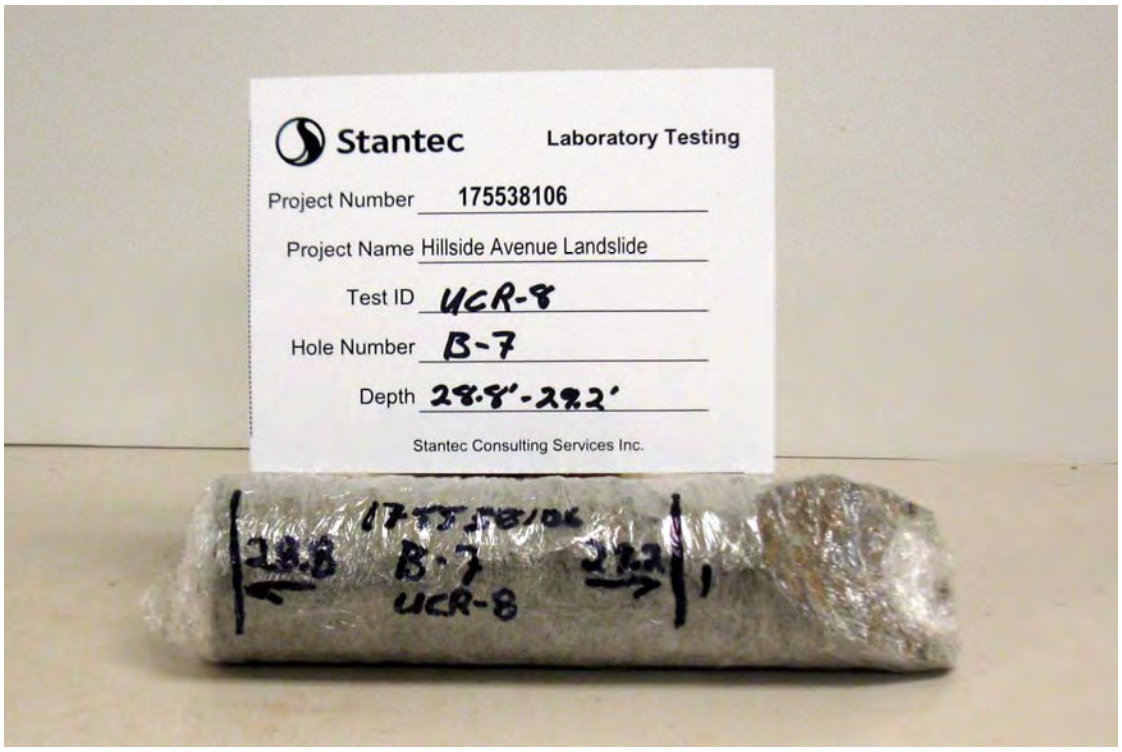
Comments Fragile nature of specimen inhibited preparation, required capping of ends with Hydro-Stone. Dimensional tolerances were not confirmed.

Reviewed By JW

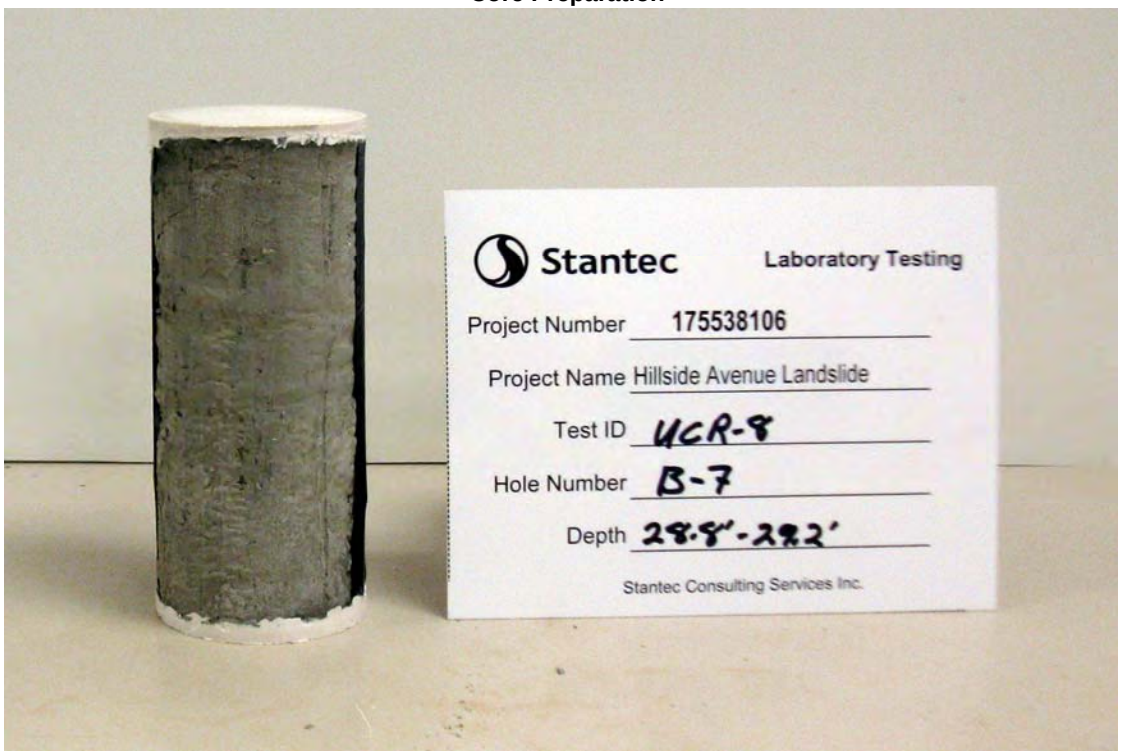
Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-8
Hole Number	B-7	Depth (ft)	28.8'-29.2'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

As Received



Core Preparation

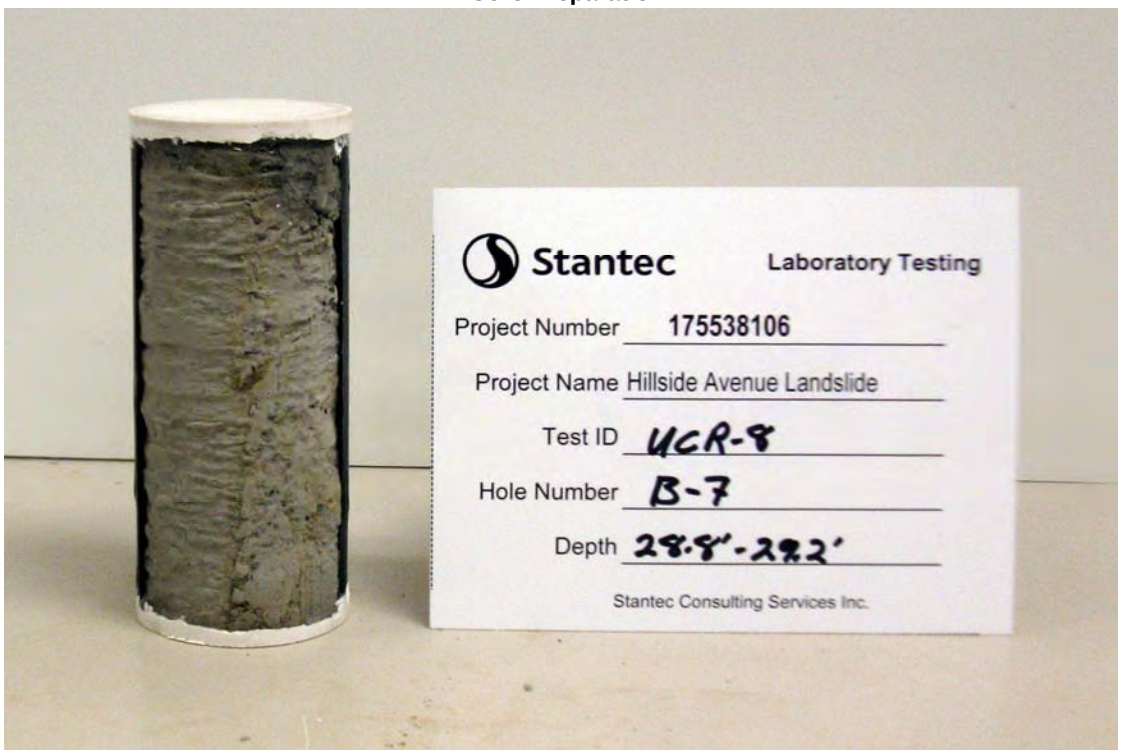


Stantec

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-8
Hole Number	B-7	Depth (ft)	28.8'-29.2'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Core Preparation



Post Test

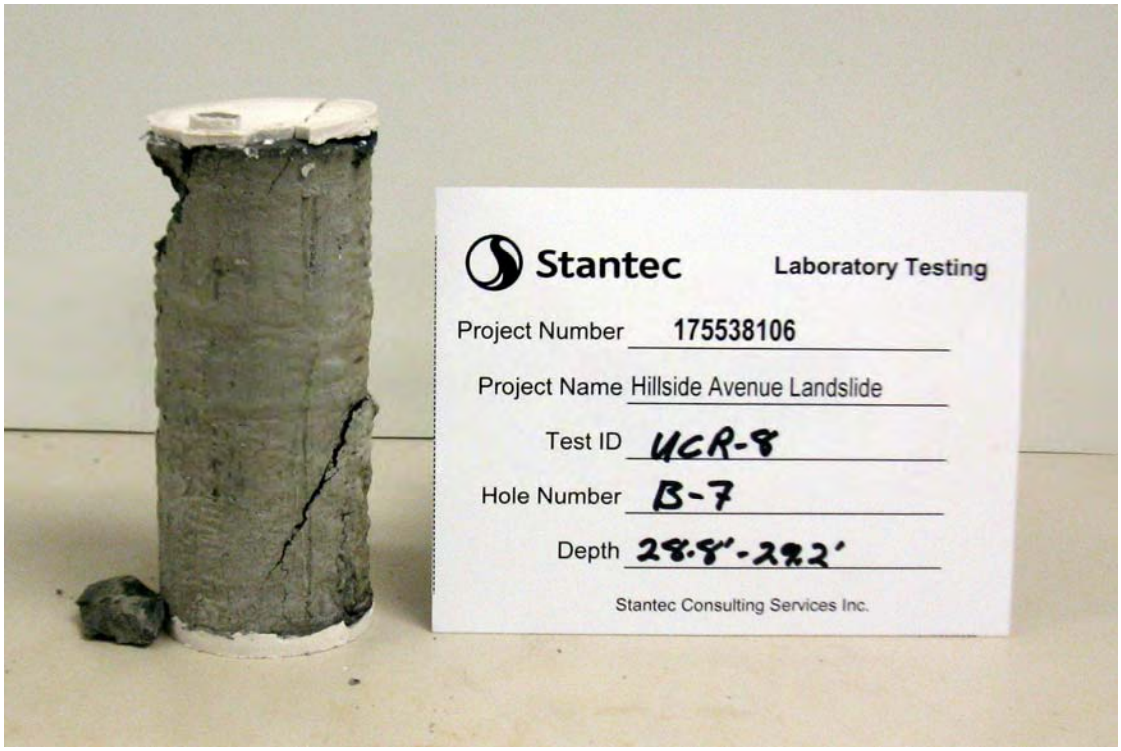
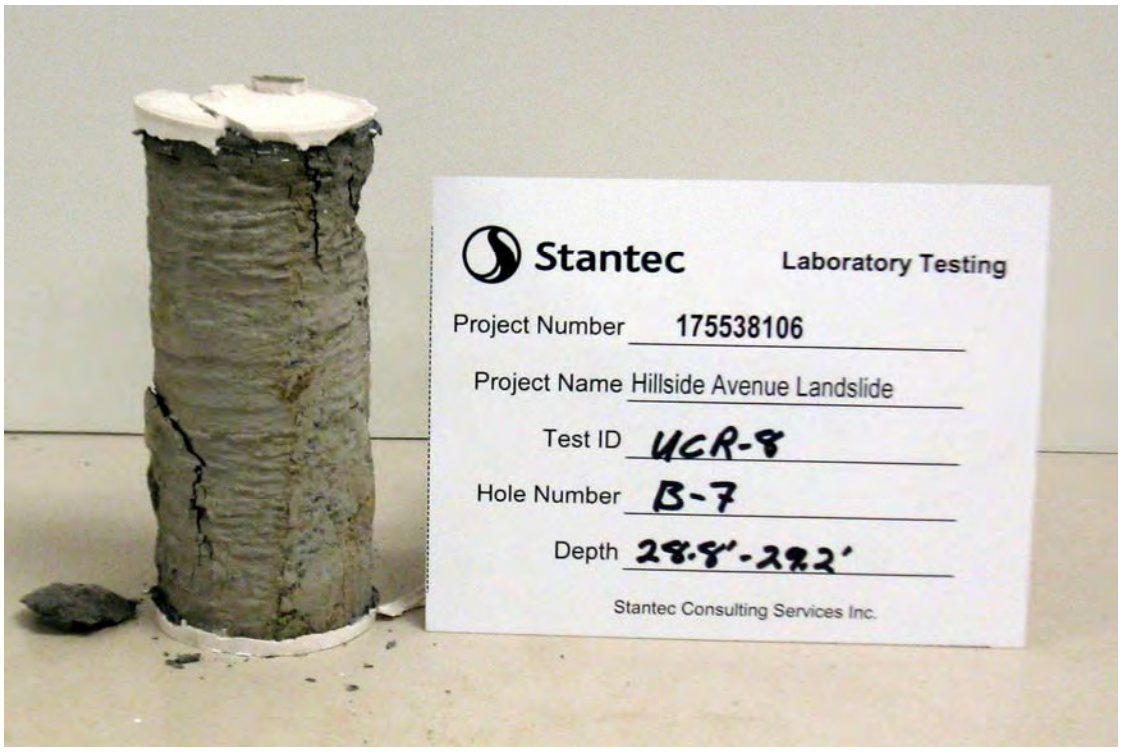


Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, soft	Lab ID	UCR-8
Hole Number	B-7	Depth (ft)	28.8'-29.2'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Post Test



Stantec

Uniaxial Compressive Strength of Intact Rock Core Specimens

ASTM D 7012, Method C

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, moderately hard	Lab ID	UCR-9
Hole Number	B-8	Depth (ft) 18.5'-18.9'	Date Received 02/26/2020

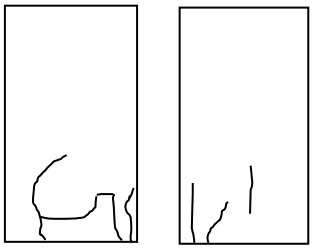
Temperature (^oC)	22	Moisture Condition	As Prepared, Moist	Date Tested	03/10/2020

Side Planeness	N/A	Height (in)	4.604	Wet Unit Weight (pcf)	155.3
Perpendicularity	N/A	Diameter (in)	1.928	Dry Unit Weight (pcf)	N/A
End Planeness	N/A	Area (in^2)	2.919	Moisture Content (%)	N/A
Parallelism	N/A				

Dimensions were not confirmed.

Loading Rate (lbf/sec)	13
Peak Load (lbf)	2883
Failure Type	Undetermined
Compressive Strength (psi)	988
Compressive Strength (psf)	142272
Compressive Strength (tsf)	71

Failure Sketches



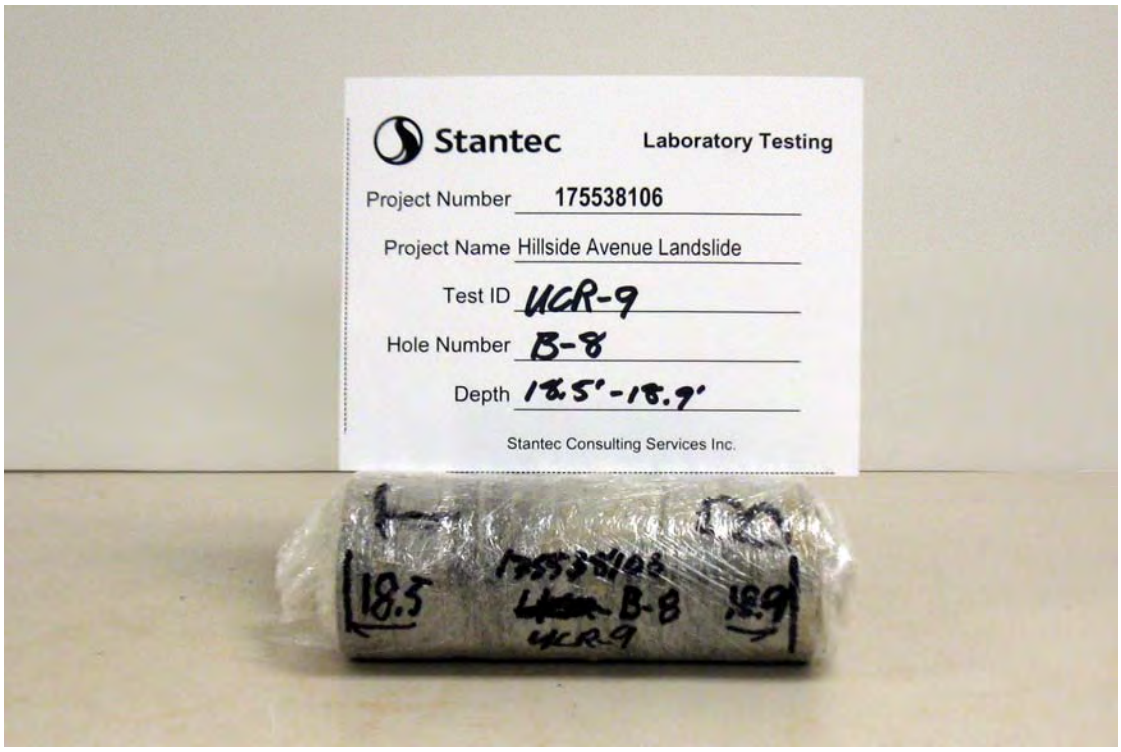
Comments Fragile nature of specimen inhibited preparation, required capping of ends with Hydro-Stone. Dimensional tolerances were not confirmed.

Reviewed By JW

Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, moderately hard	Lab ID	UCR-9
Hole Number	B-8	Depth (ft)	18.5'-18.9'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

As Received



Core Preparation

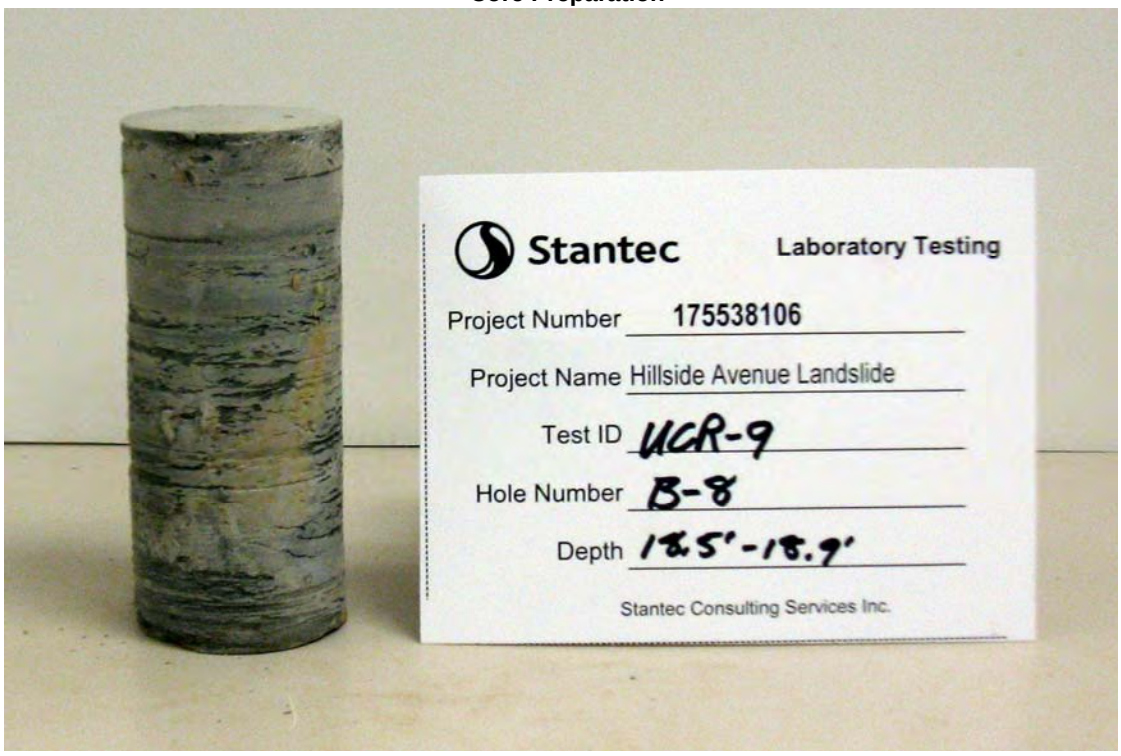
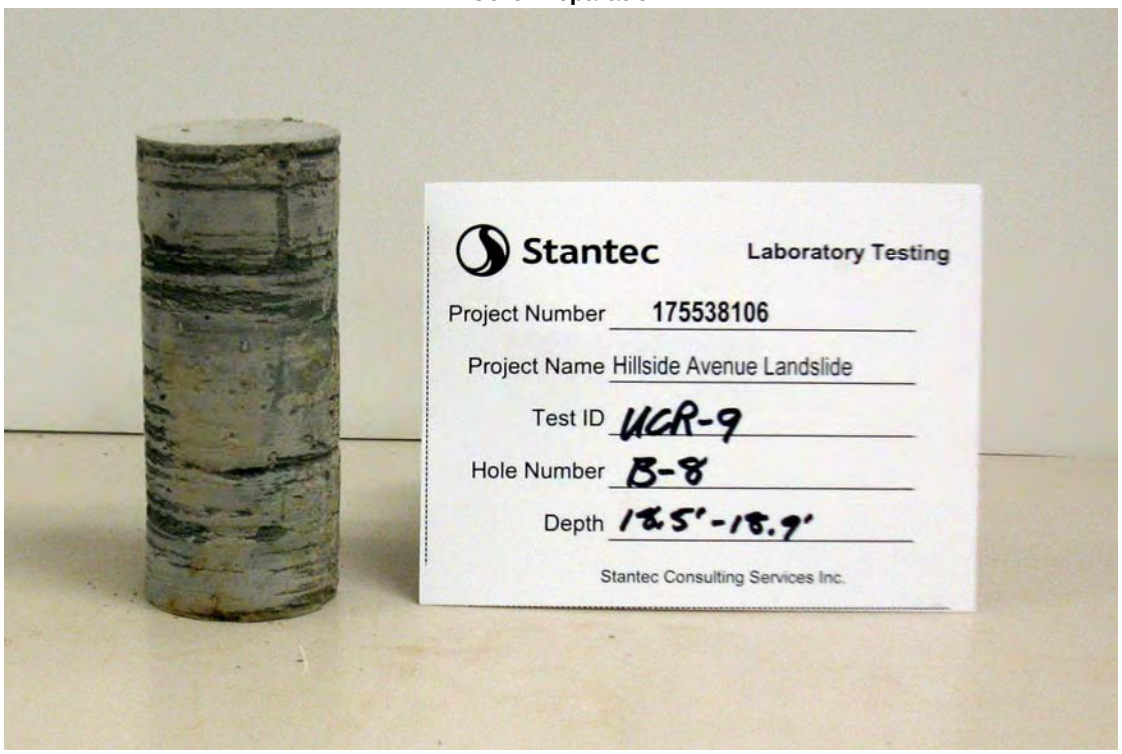


Photo Report

Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, moderately hard	Lab ID	UCR-9
Hole Number	B-8	Depth (ft)	18.5'-18.9'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Core Preparation

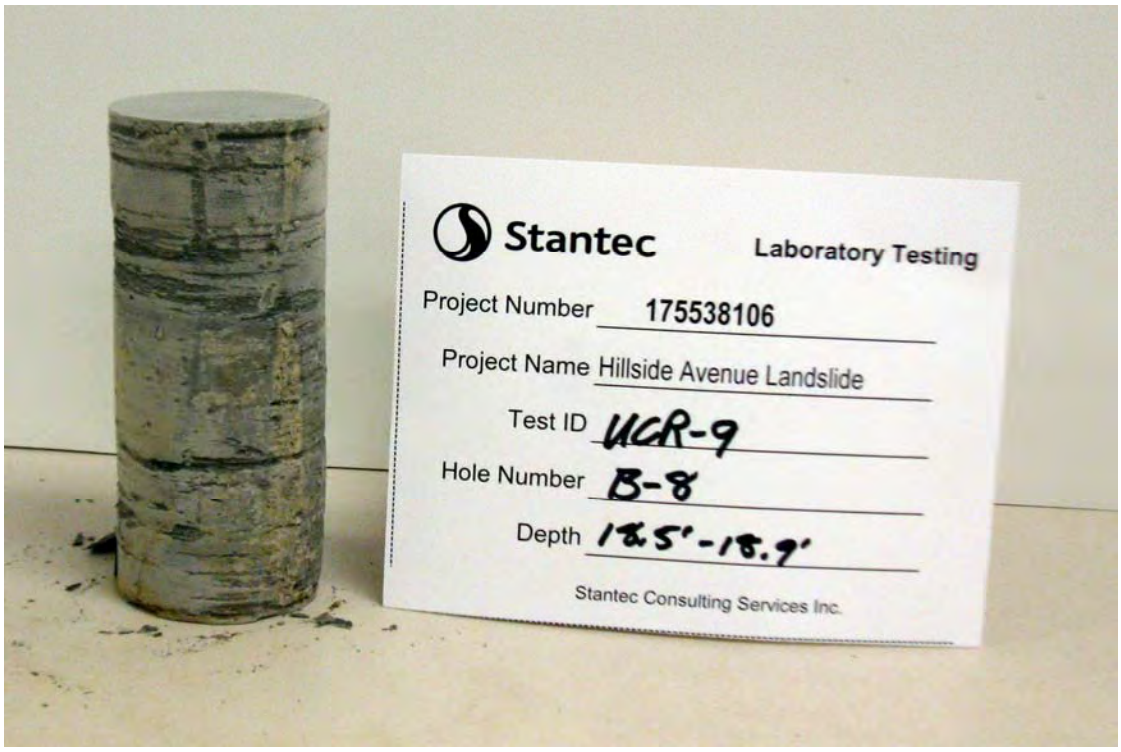


Post Test

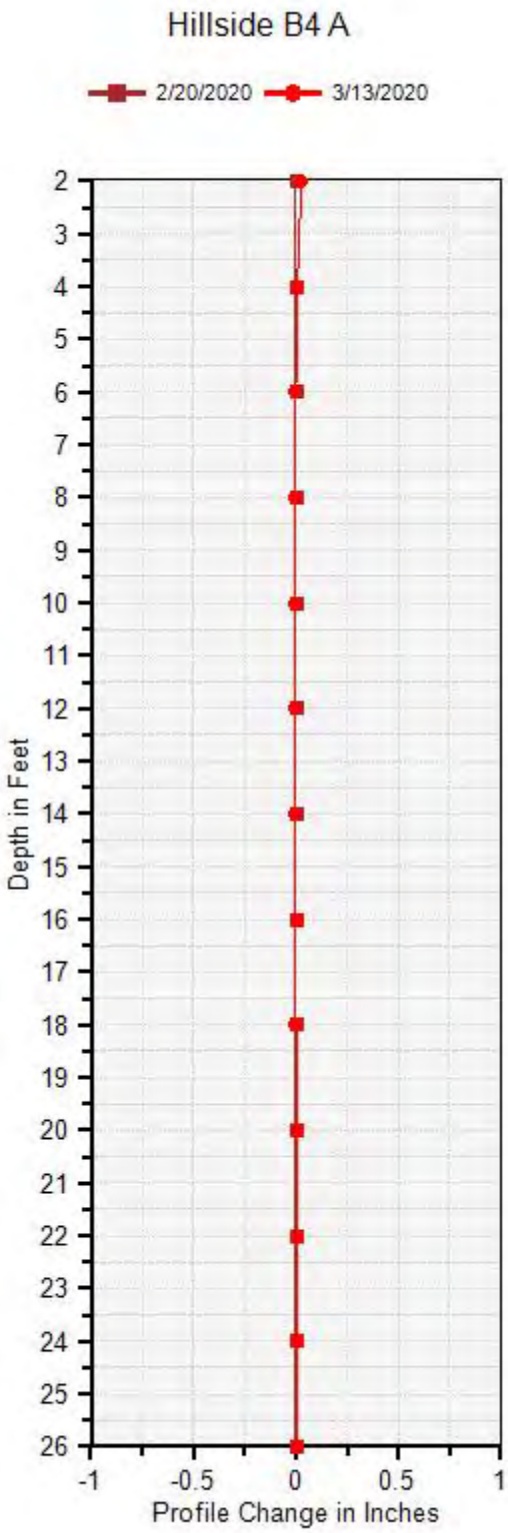
Photo Report

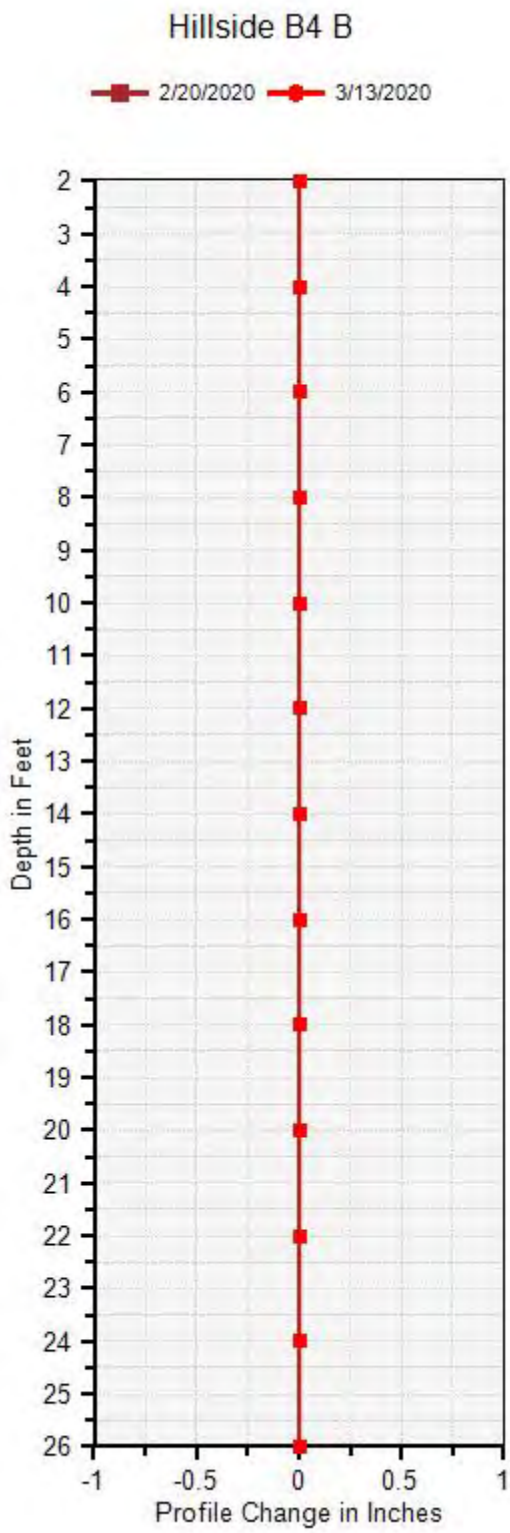
Project Name	Hillside Avenue Landslide	Project Number	175538106
Lithology	Shale, gray, moderately hard	Lab ID	UCR-9
Hole Number	B-8	Depth (ft)	18.5'-18.9'
Test Type	Uniaxial Compressive Strength of Intact Rock Core		

Post Test

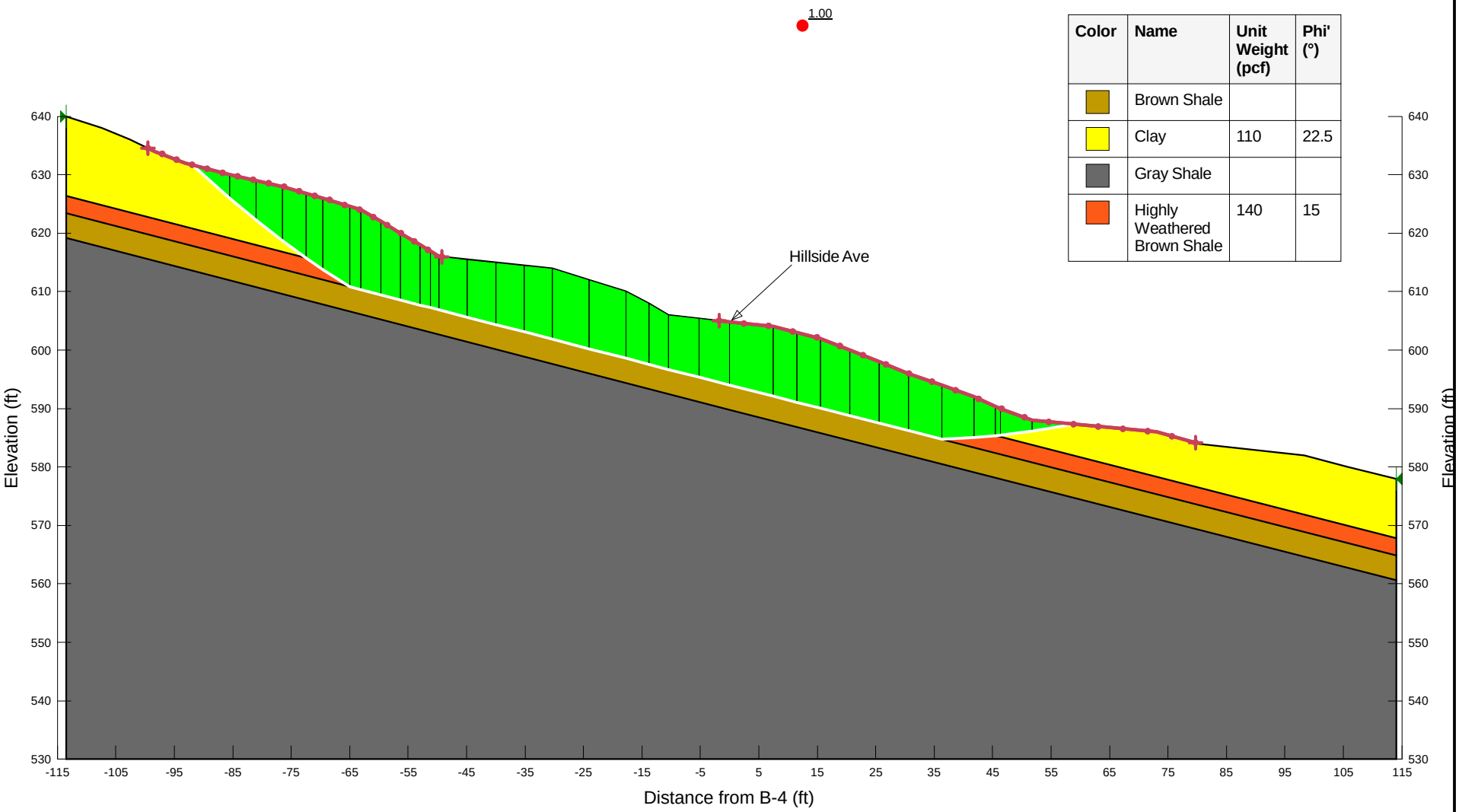


APPENDIX C
SLOPE INCLINOMETER READINGS


Hillside B4 A
2/20/2020
3/13/2020
Depth in Feet
Profile Change in Inches


Hillside B4 B
2/20/2020
3/13/2020
Depth in Feet
Profile Change in Inches

APPENDIX D
SLOPE STABILITY ANALYSES

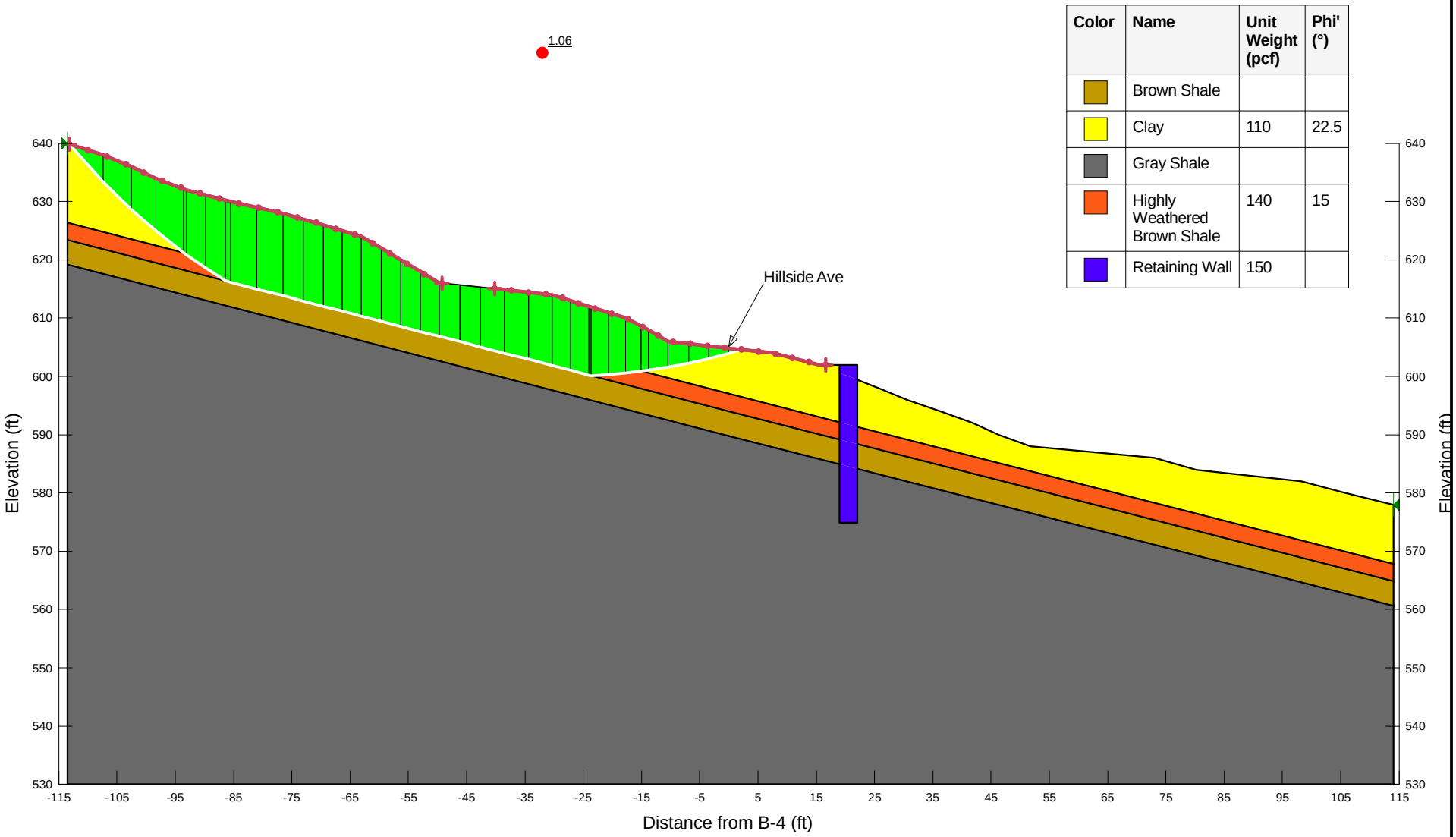


Color	Name	Unit Weight (pcf)	Phi' (°)
	Brown Shale		
	Clay	110	22.5
	Gray Shale		
	Highly Weathered Brown Shale	140	15

Back Analysis

Hillside Ave_back analysis.gsz

05/06/2020 1:300



Color	Name	Unit Weight (pcf)	Phi' (°)
	Brown Shale		
	Clay	110	22.5
	Gray Shale		
	Highly Weathered Brown Shale	140	15
	Retaining Wall	150	

Global Stabilty

Hillside Ave_global stability.gsz

05/06/2020 1:300

APPENDIX E
UA SLOPE ANALYSES

UA Slope Program Version 2.3 - C:\Users\jsamples\Desktop\Hillside Ave\02_UA Slope\Hillside Ave_no wall.ua3

File Run Options Help

Calculated Results

Factor of Safety: 1.00

Force per Shaft: 0.000 lb

Acting Point X: 0.000 ft Y: 0.000 ft

Analysis Unit System

(●) English ( ) Metric

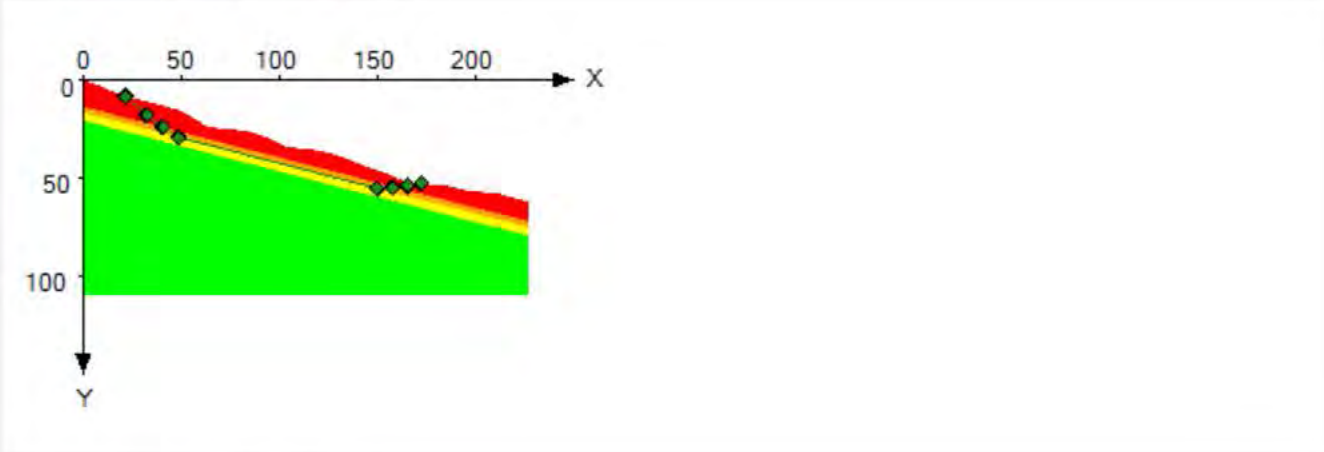
Number of Vertical Sections and Soil Layers

Vertical Section Num: 21 Soil Layer Num: 4

Analysis Method

( ) Total Stress (●) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	0.0	22.5	110.0

Slope Profile Vertical Sections

	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Sectio
X (ft)	27.88	36.94	50.35	63.71	83.18	95.73	103.04	113.47	120.92

Drilled Shaft Information

(●) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

( ) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (●) Off 0.000 (n)

Xmin 0.00 Diameter: 0.30 ft

Xmax 0.00 CTC Spacing: 0.00 ft

XDelta 0.00 X Coordinate: 0.00 ft

[ ] Auto Save Data

Run

Performed by: James Samples 4/6/2020
Checked by: Eric Kistner 4/7/2020

Pore Water Pressure

Pore Pressure Options: (●) No Pore ( ) Constant Ratio 0.00 ( ) Specified phreatic

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8
X (ft)	21.47	32.41	40.44	48.47	149.75	157.47	165.20	172.31
Y (ft)	8.30	17.79	23.80	29.16	55.28	54.76	53.84	52.67

UA Slope Program Version 2.3 - C:\Users\jsamples\Desktop\Hillside Ave\02_UA Slope\Hillside Ave_wall.ua3

File Run Options Help

Calculated Results

Factor of Safety: 1.37

Force per Shaft: 60626.228 lb

Acting Point X: 132.450 ft Y: 45.928 ft

Analysis Unit System

(●) English ( ) Metric

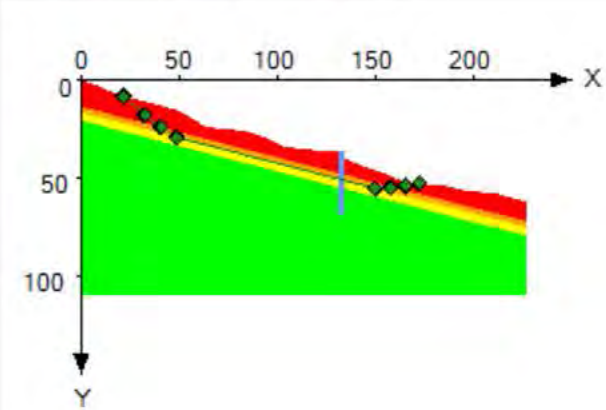
Number of Vertical Sections and Soil Layers

Vertical Section Num: 21 Soil Layer Num: 4

Analysis Method

( ) Total Stress (●) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	0.0	22.5	110.0

Slope Profile Vertical Sections

	7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14	Section 15
X (ft)		83.18	95.73	103.04	113.47	120.92	132.45	132.46	144.03

Drilled Shaft Information

( ) Calculate without Drilled Shaft

(●) Automatic Load Transfer Factor

( ) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (●) Off 0.160 (n)

Xmin 0.00 Diameter: 3.00 ft

Xmax 0.00 CTC Spacing: 5.00 ft

XDelta 0.00 X Coordinate: 132.45 ft

[ ] Auto Save Data

Run

Performed by: James Samples 4/6/2020
Checked by: Eric Kistner 4/7/2020

Pore Water Pressure

Pore Pressure Options: (●) No Pore ( ) Constant Ratio 0.00 ( ) Specified phreatic

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8
X (ft)	21.47	32.41	40.44	48.47	149.75	157.47	165.20	172.31
Y (ft)	8.30	17.79	23.80	29.16	55.28	54.76	53.84	52.67

UA Slope Program Version 2.3 - C:\Users\jsamples\Desktop\Hillside Ave\02_UA Slope\Secondary Wall\Hillside Ave_secondary_no wall.ua3*

File Run Options Help

Calculated Results

Factor of Safety: 1.06

Force per Shaft: 0.000 lb

Acting Point X: 97.970 ft Y: 0.000 ft

Analysis Unit System

(●) English ( ) Metric

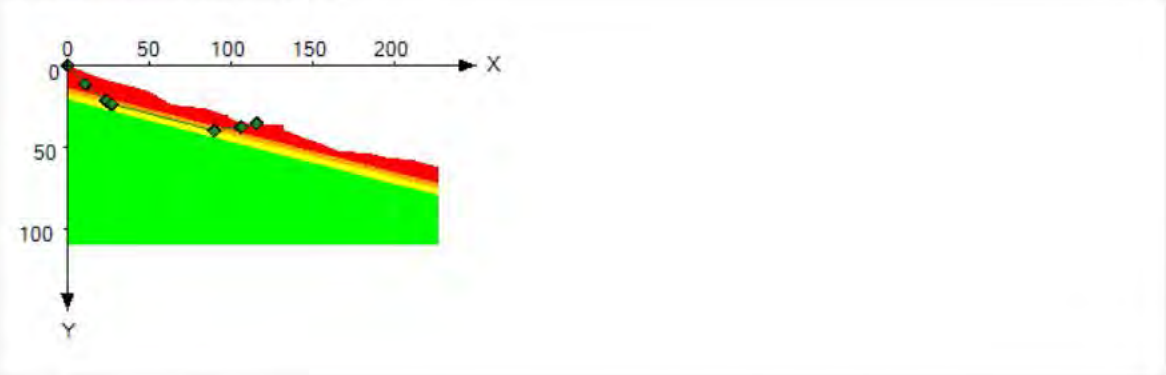
Number of Vertical Sections and Soil Layers

Vertical Section Num: 23 Soil Layer Num: 4

Analysis Method

( ) Total Stress (●) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	0.0	22.5	110.0
Layer2	0.0	15.0	140.0
Layer3	2000.0	40.0	140.0
Layer4	2000.0	40.0	150.0

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Se
X (ft)	0.00	6.03	15.13	27.88	36.94	50.35	63.71	83.18	95.73	97.9
Y1 (ft)	0.00	2.00	6.00	10.00	12.00	16.00	24.00	26.00	30.00	30.0
Y2 (ft)	13.60	15.16	17.52	20.82	23.17	26.64	30.11	35.15	38.40	38.9
Y3 (ft)	16.60	18.16	20.52	23.82	26.17	29.64	33.11	38.15	41.40	41.9
Y4 (ft)	20.80	22.36	24.72	28.02	30.37	33.84	37.31	42.35	45.60	46.

Coordinates of Crest X: 0.28 ft Y: 0.09 ft Coordinates of Toe X: 115.66 ft Y: 35.41 ft

Drilled Shaft Information

(●) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

( ) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (●) Off 0.262 (n)

Xmin 0.00 Diameter: 2.50 ft

Xmax 0.00 CTC Spacing: 5.00 ft

XDelta 0.00 X Coordinate: 97.97 ft

[ ] Auto Save Data

Run

Performed by: James Samples 4/23/2020
Checked by: Eric Kistner 4/27/2020

Pore Water Pressure

Pore Pressure Options: (●) No Pore Pressure ( ) Constant Ratio 0.00 ( ) Specified phreatic

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
X (ft)	0.28	10.89	23.66	26.99	89.81	106.52	115.66
Y (ft)	0.09	11.34	21.43	23.59	39.87	37.73	35.41

UA Slope Program Version 2.3 - C:\Users\jsamples\Desktop\Hillside Ave\02_UA Slope\Secondary Wall\Hillside Ave_secondary_no wall.ua3*

File Run Options Help

Calculated Results

Factor of Safety: 1.37

Force per Shaft: 33352.979 lb

Acting Point X: 97.970 ft Y: 35.913 ft

Analysis Unit System

(●) English ( ) Metric

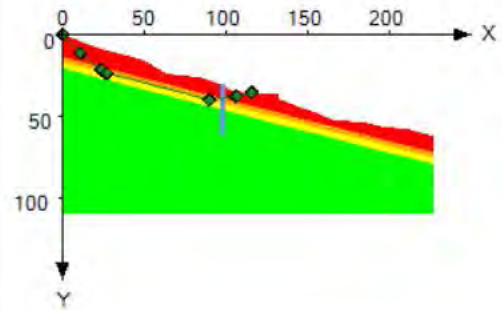
Number of Vertical Sections and Soil Layers

Vertical Section Num: 23 Soil Layer Num: 4

Analysis Method

( ) Total Stress (●) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	0.0	22.5	110.0
Layer2	0.0	15.0	140.0
Layer3	2000.0	40.0	140.0
Layer4	2000.0	40.0	150.0

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Se
X (ft)	0.00	6.03	15.13	27.88	36.94	50.35	63.71	83.18	95.73	97.9
Y1 (ft)	0.00	2.00	6.00	10.00	12.00	16.00	24.00	26.00	30.00	30.0
Y2 (ft)	13.60	15.16	17.52	20.82	23.17	26.64	30.11	35.15	38.40	38.9
Y3 (ft)	16.60	18.16	20.52	23.82	26.17	29.64	33.11	38.15	41.40	41.9
Y4 (ft)	20.80	22.36	24.72	28.02	30.37	33.84	37.31	42.35	45.60	46

Coordinates of Crest X: 0.28 ft Y: 0.09 ft Coordinates of Toe X: 115.66 ft Y: 35.41 ft

Drilled Shaft Information

( ) Calculate without Drilled Shaft

(●) Automatic Load Transfer Factor

( ) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (●) Off 0.262 (n)

Xmin 0.00 Diameter: 2.50 ft

Xmax 0.00 CTC Spacing: 5.00 ft

XDelta 0.00 X Coordinate: 97.97 ft

[ ] Auto Save Data

Run

Performed by: James Samples 4/23/2020
Checked by: Eric Kistner 4/27/2020

Pore Water Pressure

Pore Pressure Options: (●) No Pore Pressure ( ) Constant Ratio 0.00 ( ) Specified phreatic

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
X (ft)	0.28	10.89	23.66	26.99	89.81	106.52	115.66
Y (ft)	0.09	11.34	21.43	23.59	39.87	37.73	35.41

APPENDIX F
LPILE ANALYSES

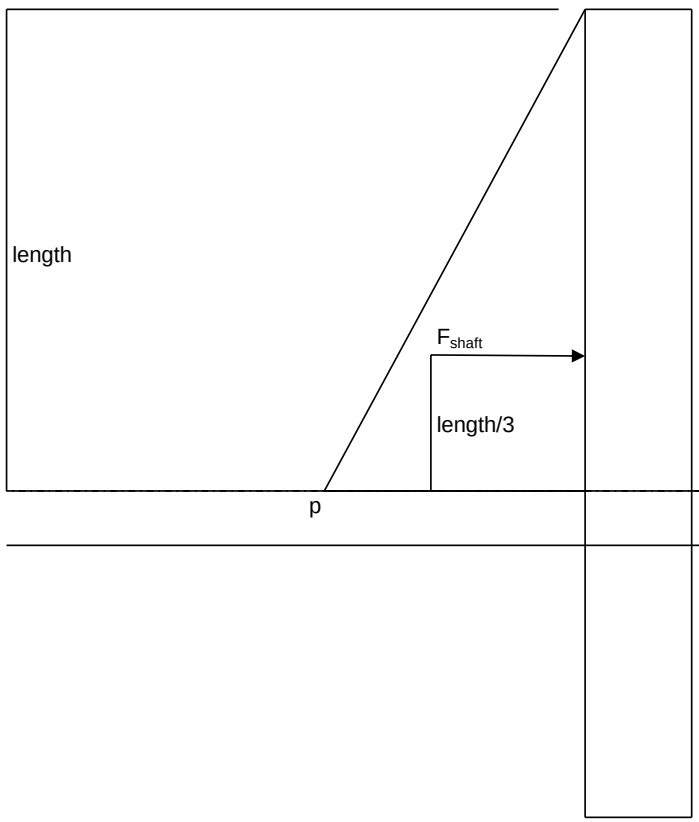
Performed by: J. Samples 4/13/2020
Checked by: E.Kistner 4/14/2020

SUMMARY OF DRILLED SHAFT CALCULATIONS

LOADING CONDITIONS

Loading conditions were evaluated using shaft loads determined from the UA SLOPE (Version 2.3) computer program. This shaft load, combined with an assumed traffic surcharge live load, was applied to the drilled shaft above the assumed failure surface. The drilled shaft was evaluated using LPILEv2019 which is a program for the analysis of piles and drilled shafts under lateral loads. Unfactored loads (Service I Limit State) were utilized to estimate shaft head deflection and factored loads (Strength I Limit State) were used to evaluate geotechnical resistance.

Analysis Cross Section:	B-4	
Shaft Location from Centerline	20	feet



Projected Ground line Depth = 0.00

Note:
x_2 represents the maximum value of the triangular distributed load that will be used in LPILE determined from F_{shaft} from the University of Akron program.

Assumed Failure Surface Depth = 14.85

Top of Rock Depth = 14.85

Bottom of Drilled Shaft Depth = 29.05

Performed by: J. Samples 4/13/2020
Checked by: E.Kistner 4/14/2020

Estimated Depth to Bedrock =	14.85	feet	UA Slope Input
Estimated Depth to Failure Surface=	14.85	feet	UA Slope Input
Shaft Size =	3	feet	UA Slope Input
Center to Center Spacing =	5.00	feet	UA Slope Input
F_{shaft} =	60,626	pounds	UA Slope Output
Factor of Safety =	1.37		UA Slope Output
p = (2*Fshaft)/H * (1 ft/12 in)	680	pounds per inch	

DISTRIBUTED LOAD FOR LPILE INPUT

F_{live} = assumed traffic surcharge load =	250	psf	
Phi =	22.5	degrees	based blow counts (conservative)
K_a =	0.446		
x1 = F_{live} * s * Ka * (1 ft/12 in)	47	pounds per inch	
x2 = [2*Fshaft/(Depth to Failure Surface)] + x1			

Service (I) Limit State:

x1 =	47	pounds per inch
x2 =	727	pounds per inch
Total Load =	68914	pounds

Strength (I) Limit State:

x1 =	81	pounds per inch (Load Factor = 1.75)
x2 =	1102	pounds per inch (Load Factor = 1.5)
Total Load =	112694	pounds

CHOOSE MATERIAL p-y CURVES for LPILE Program

Material Type	***Value***	***Units***	
Soft Clay			
γ=	110	pcf	based on ODOT recommendations
c=	1,000	psf	based on ODOT recommendations
Bedrock - Brown Shale (Weak Rock)			
γ=	140	pcf	based on average UCR results
E=	9,000	psi	=90 x qu
qu=	100	psi	based on UCR results
RQD=	26	%	based on average RQD from B-4
Km=	0.00005		conservative for weak rock
Bedrock - Gray Shale (Weak Rock)			
γ=	150	pcf	based on average UCR results
E=	67,500	psi	=90 x qu
qu=	750	psi	based on UCR results
RQD=	43	%	based on average RQD from B-4
Km=	0.00005		conservative for weak rock
p-y Modification Factor			
p = 0.64 (Spacing/Diameter)$^{0.34}$	0.76		

SHAFT CONCRETE AND STEEL MATERIAL PROPERTIES FOR LPILE

Parameter	***Value***		***Note***
f'_c =	4,000	psi	(ODOT Class S Concrete)
E_c =	3,604,997	psi	E_c = 57,000 * SQRT(f'c)
$f_{y\ steel}$=	50,000	psi	
E_{steel}=	2.9E+07	psi	

Performed by: J. Samples 4/13/2020
Checked by: E.Kistner 4/14/2020

LPILE VERSION 2019 RUNS

SERVICE (I) AND STRENGTH (I) LIMIT STATES

Purpose: Achieve a shaft head deflection of less than 2.0 inches for Service (I) Limit State. Recommend a rock socket length by observation of the shear and moment curves. Provide shear and moment design parameters for the selection of steel beam reinforcement.

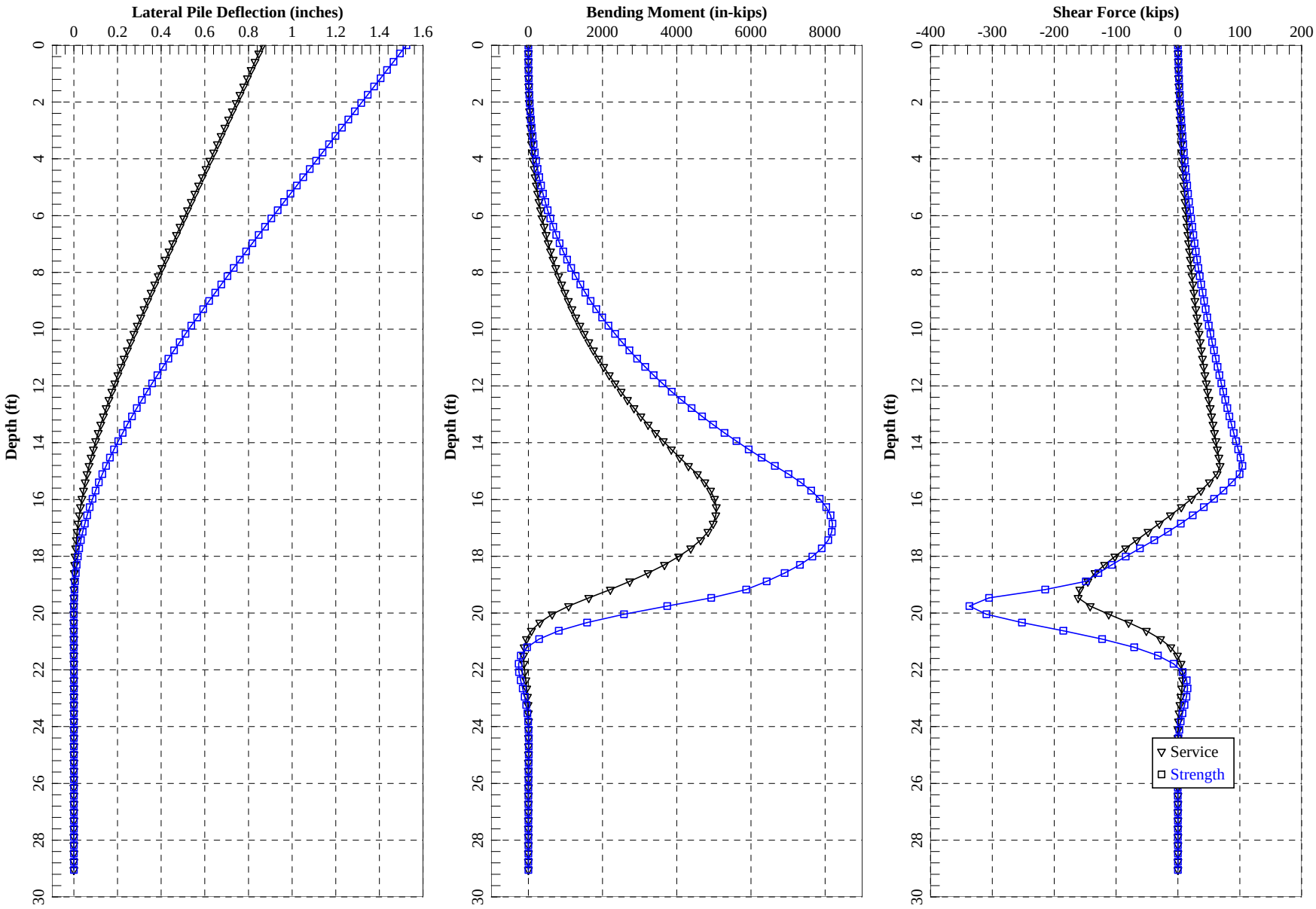
Run ID	Filename	Reinforcement Description	Deflection at Pile Head (in)	Maximum Moment (in-lbs)	Maximum Shear (lbs)
1	W24x104_3dia_5ctc	W24x104	0.86	N/A	N/A
2	W24x104_3dia_5ctc	W24x104	N/A	8,196,006	337,032

Based on the calculations and assumptions presented above, it appears a 36-inch diameter drilled shaft with a center-to-center spacing of 60 inches can provide tolerable deflections when placed approximately 20 feet right of centerline. A minimum 15-foot rock socket is recommended.

PROPERTIES OF SELECTED SECTIONS

Run ID	Source	Reinforcement Description	Area of Steel (in^2)	Moment of Inertia (in^4)	Section Modulus (in^3)
1 & 2	AISC Manual of Steel Construction	W24x104	30.7	3,100	258

Hillside Ave W24x104 Graphs



Performed by: James Samples 4/13/2020
Checked by: Eric Kistner 4/14/2020

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LPile for Windows, Version 2019-11.001

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
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Files Used for Analysis

Path to file locations:
\Users\jsamples\Desktop\Hillside Ave\03_Lpile\

Name of input data file:
W24x104_3dia_5ctc.lp11

Name of output report file:
W24x104_3dia_5ctc.lp11

Name of plot output file:
W24x104_3dia_5ctc.lp11

Performed by: James Samples 4/13/2020
Checked by: Eric Kistner 4/14/2020

Name of runtime message file:
W24x104_3dia_5ctc.lp11

Date and Time of Analysis

Date: April 13, 2020 Time: 12:56:19

Problem Title

Project Name: Hillside Ave Landslide

Job Number: 175538106

Client: Hamilton County Engineer's Office

Engineer: James Samples

Description: Wall Design with 20 ft Offset

Program Options and Settings

```
Computational Options:
 - Use unfactored loads in computations (conventional analysis)
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed                =          500
 - Deflection tolerance for convergence                =   1.0000E-05 in
 - Maximum allowable deflection                        =     100.0000 in
 - Number of pile increments                           =          100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Analysis uses p-y modification factors for p-y curves
 - Analysis uses layering correction (Method of Georgiadis)
 - Analysis includes loading by multiple distributed lateral loads acting on pile
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats



--------------------------------------------------------------------------------
                     Pile Structural Properties and Geometry
--------------------------------------------------------------------------------

Number of pile sections defined                        =            2
```


Performed by: James Samples 4/13/2020
Checked by: Eric Kistner 4/14/2020

```
Total length of pile                                  =       29.050 ft
Depth of ground surface below top of pile             =      14.8500 ft

Pile diameters used for p-y curve computations are defined using 4 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.

            Depth Below          Pile
Point        Pile Head         Diameter
 No.            feet            inches
-----      -------------     -------------
  1             0.000          12.8000
  2             3.380          12.8000
  3             3.380          36.0000
  4            29.050          36.0000


Input Structural Properties for Pile Sections:
----------------------------------------------

Pile Section No. 1:

   Section 1 is a AISC strong axis steel pile
   Length of section                                  =     3.380000 ft
   AISC Section Type                                  = W


   AISC Section Name                                  = W24X104


   Pile width                                         =    12.800000 in
   Shear capacity of section                          =       0.0000 lbs

Pile Section No. 2:

   Section 2 is an elastic pile
   Cross-sectional Shape                              =   Circular Pile
   Length of section                                  =    25.670000 ft
   Width of top of section                            =    36.000000 in
```

```
   Width of bottom of section                        =    36.000000 in
   Top Area                                          =    30.700000 sq. in
   Bottom Area                                       =    30.700000 sq. in
   Moment of Inertia at Top                          =        3100. in^4
   Moment of Inertia at Bottom                       =        3100. in^4
   Elastic Modulus                                   =    29000000. psi
```

Ground Slope and Pile Batter Angles

```
Ground Slope Angle                                   =        0.000 degrees
                                                     =        0.000 radians

Pile Batter Angle                                    =        0.000 degrees
                                                     =        0.000 radians
```

Soil and Rock Layering Information

The soil profile is modelled using 2 layers

Layer 1 is weak rock, p-y criteria by Reese, 1997

```
   Distance from top of pile to top of layer         =    14.850000 ft
   Distance from top of pile to bottom of layer      =    19.050000 ft
   Effective unit weight at top of layer             =   140.000000 pcf
   Effective unit weight at bottom of layer          =   140.000000 pcf
   Uniaxial compressive strength at top of layer     =   100.000000 psi
   Uniaxial compressive strength at bottom of layer  =   100.000000 psi
   Initial modulus of rock at top of layer           =        9000. psi
   Initial modulus of rock at bottom of layer        =        9000. psi
   RQD of rock at top of layer                       =    26.000000 %
   RQD of rock at bottom of layer                    =    26.000000 %
   k rm of rock at top of layer                      =    0.0000500
```


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Checked by: Eric Kistner 4/14/2020

```
   k rm of rock at bottom of layer                    =    0.0000500


Layer 2 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer          =    19.050000 ft
   Distance from top of pile to bottom of layer       =    40.000000 ft
   Effective unit weight at top of layer              =   150.000000 pcf
   Effective unit weight at bottom of layer           =   150.000000 pcf
   Uniaxial compressive strength at top of layer      =   750.000000 psi
   Uniaxial compressive strength at bottom of layer   =   750.000000 psi
   Initial modulus of rock at top of layer            =       67500. psi
   Initial modulus of rock at bottom of layer         =       67500. psi
   RQD of rock at top of layer                        =    43.000000 %
   RQD of rock at bottom of layer                     =    43.000000 %
   k rm of rock at top of layer                       =    0.0000500
   k rm of rock at bottom of layer                    =    0.0000500


 (Depth of the lowest soil layer extends 10.950 ft below the pile tip)


**** Warning - Possible Input Data Error ****

Values entered for effective unit weight of rock were outside the limits of
50 pcf to 150 pcf.

The maximum input value, in layer   0, for effective unit weight = 150.00 pcf

This data may be erroneous. Please check your data.



--------------------------------------------------------------------------------
                        Summary of Input Soil Properties
--------------------------------------------------------------------------------

Layer         Soil Type          Layer      Effective    Uniaxial                    E50       Rock Mass
Layer           Name             Depth       Unit Wt.       qu          RQD %         or         Modulus
 Num.     (p-y Curve Type)        ft           pcf          psi                       krm          psi
```


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1	Weak	14.8500	140.0000	100.0000	26.0000	5.00E-05	9000.
	Rock	19.0500	140.0000	100.0000	26.0000	5.00E-05	9000.
2	Weak	19.0500	150.0000	750.0000	43.0000	5.00E-05	67500.
	Rock	40.0000	150.0000	750.0000	43.0000	5.00E-05	67500.

p-y Modification Factors for Group Action

Distribution of p-y modifiers with depth defined using 2 points

Point No.	Depth X ft	p-mult	y-mult
1	14.850	1.0000	1.0000
2	40.000	1.0000	1.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading for Individual Load Cases

Distributed lateral load intensity for Load Case 1 defined using 2 points

Distributed lateral load intensity for Load Case 2 defined using 2 points

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Checked by: Eric Kistner 4/14/2020

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	No
2	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	No

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 2

Pile Section No. 1:

Dimensions and Properties of Steel AISC Strong Axis:

Length of Section = 3.380000 ft
Flange Width = 12.800000 in

```
Section Depth                                       =    24.100000 in
Flange Thickness                                    =     0.750000 in
Web Thickness                                       =     0.500000 in
Yield Stress of Pipe                                =    50.000000 ksi
Elastic Modulus                                     =       29000. ksi
Cross-sectional Area                                =    30.700000 sq. in.
Moment of Inertia                                   =        3100. in^4
Elastic Bending Stiffness                           =    89900000. kip-in^2
Plastic Modulus, Z                                  =   289.000000in^3
Plastic Moment Capacity = Fy Z                      =       14450.in-kip

Axial Structural Capacities:
----------------------------

Nom. Axial Structural Capacity = Fy As              =     1535.000 kips
Nominal Axial Tensile Capacity                      =    -1535.000 kips



Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

   Number     Axial Thrust Force
                   kips
   ------     ------------------
      1               0.000

Definition of Run Messages:

   Y = part of pipe section has yielded.


Axial Thrust Force =      0.000 kips

    Bending       Bending       Bending      Depth to      Max Total  Run
   Curvature      Moment       Stiffness      N Axis        Stress    Msg
    rad/in.       in-kip        kip-in2         in            ksi
------------- ------------- ------------- ------------- ------------- ---
   0.00000572   514.1817237     89818473.    12.0500000     1.9804834
   0.00001145         1028.     89818473.    12.0500000     3.9609668
```


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0.00001717	1543.	89818473.	12.0500000	5.9414502	
0.00002290	2057.	89818473.	12.0500000	7.9219337	
0.00002862	2571.	89818473.	12.0500000	9.9024171	
0.00003435	3085.	89818473.	12.0500000	11.8829005	
0.00004007	3599.	89818473.	12.0500000	13.8633839	
0.00004580	4113.	89818473.	12.0500000	15.8438673	
0.00005152	4628.	89818473.	12.0500000	17.8243507	
0.00005725	5142.	89818473.	12.0500000	19.8048342	
0.00006297	5656.	89818473.	12.0500000	21.7853176	
0.00006870	6170.	89818473.	12.0500000	23.7658010	
0.00007442	6684.	89818473.	12.0500000	25.7462844	
0.00008015	7199.	89818473.	12.0500000	27.7267678	
0.00008587	7713.	89818473.	12.0500000	29.7072512	
0.00009159	8227.	89818473.	12.0500000	31.6877346	
0.00009732	8741.	89818473.	12.0500000	33.6682181	
0.0001030	9255.	89818473.	12.0500000	35.6487015	
0.0001088	9769.	89818473.	12.0500000	37.6291849	
0.0001145	10284.	89818473.	12.0500000	39.6096683	
0.0001202	10798.	89818473.	12.0500000	41.5901517	
0.0001259	11312.	89818473.	12.0500000	43.5706351	
0.0001317	11826.	89818473.	12.0500000	45.5511185	
0.0001374	12340.	89818473.	12.0500000	47.5316020	
0.0001431	12855.	89818473.	12.0500000	49.5120854	
0.0001488	13226.	88861272.	12.0500000	50.0000000	Y
0.0001546	13360.	86433359.	12.0500000	50.0000000	Y
0.0001603	13432.	83800739.	12.0500000	50.0000000	Y
0.0001660	13498.	81303575.	12.0500000	50.0000000	Y
0.0001717	13557.	78937457.	12.0500000	50.0000000	Y
0.0001775	13610.	76691343.	12.0500000	50.0000000	Y
0.0001832	13658.	74558147.	12.0500000	50.0000000	Y
0.0001889	13702.	72532141.	12.0500000	50.0000000	Y
0.0001946	13743.	70605849.	12.0500000	50.0000000	Y
0.0002004	13780.	68772556.	12.0500000	50.0000000	Y
0.0002061	13813.	67026205.	12.0500000	50.0000000	Y
0.0002118	13844.	65361302.	12.0500000	50.0000000	Y
0.0002175	13873.	63772850.	12.0500000	50.0000000	Y
0.0002233	13899.	62256280.	12.0500000	50.0000000	Y
0.0002347	13947.	59422338.	12.0500000	50.0000000	Y
0.0002462	13988.	56823148.	12.0500000	50.0000000	Y
0.0002576	14023.	54435866.	12.0500000	50.0000000	Y

0.0002691	14055.	52235636.	12.0500000	50.0000000	Y
0.0002805	14082.	50201523.	12.0500000	50.0000000	Y
0.0002920	14106.	48315753.	12.0500000	50.0000000	Y
0.0003034	14128.	46563108.	12.0500000	50.0000000	Y
0.0003149	14147.	44930469.	12.0500000	50.0000000	Y
0.0003263	14164.	43406443.	12.0500000	50.0000000	Y
0.0003378	14179.	41981071.	12.0500000	50.0000000	Y
0.0003492	14194.	40645595.	12.0500000	50.0000000	Y
0.0003607	14206.	39389601.	12.0500000	50.0000000	Y
0.0003721	14218.	38208731.	12.0500000	50.0000000	Y
0.0003836	14228.	37095857.	12.0500000	50.0000000	Y
0.0003950	14238.	36044580.	12.0500000	50.0000000	Y
0.0004065	14247.	35051451.	12.0500000	50.0000000	Y
0.0004179	14255.	34110035.	12.0500000	50.0000000	Y
0.0004294	14262.	33218146.	12.0500000	50.0000000	Y
0.0004408	14269.	32370779.	12.0500000	50.0000000	Y
0.0004522	14275.	31565283.	12.0500000	50.0000000	Y
0.0004637	14282.	30799114.	12.0500000	50.0000000	Y
0.0004751	14287.	30067958.	12.0500000	50.0000000	Y
0.0004866	14292.	29371210.	12.0500000	50.0000000	Y
0.0004980	14297.	28705698.	12.0500000	50.0000000	Y
0.0005095	14301.	28068959.	12.0500000	50.0000000	Y
0.0005209	14305.	27460208.	12.0500000	50.0000000	Y
0.0005324	14309.	26877299.	12.0500000	50.0000000	Y
0.0005438	14313.	26317710.	12.0500000	50.0000000	Y
0.0005553	14316.	25781197.	12.0500000	50.0000000	Y
0.0005667	14320.	25266362.	12.0500000	50.0000000	Y
0.0005782	14323.	24771272.	12.0500000	50.0000000	Y
0.0005896	14325.	24294809.	12.0500000	50.0000000	Y
0.0006011	14328.	23836496.	12.0500000	50.0000000	Y
0.0006125	14331.	23395317.	12.0500000	50.0000000	Y
0.0006240	14333.	22970165.	12.0500000	50.0000000	Y
0.0006354	14335.	22559527.	12.0500000	50.0000000	Y
0.0006469	14337.	22163424.	12.0500000	50.0000000	Y
0.0006583	14339.	21781099.	12.0500000	50.0000000	Y
0.0006698	14341.	21411844.	12.0500000	50.0000000	Y
0.0006812	14343.	21055002.	12.0500000	50.0000000	Y
0.0007270	14350.	19737211.	12.0500000	50.0000000	Y

Performed by: James Samples 4/13/2020
Checked by: Eric Kistner 4/14/2020

Summary of Results for Nominal (Unfactored) Moment Capacity for Section 1

Load No.	Axial Thrust kips	Nominal Moment Capacity in-kips
1	0.00000000	14350.

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

Pile Section No. 2:

Moment-curvature properties were derived from elastic section properties

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs

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Checked by: Eric Kistner 4/14/2020

1	14.8500	0.00	N.A.	Yes	N.A.	N.A.
2	19.0500	4.2000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.8644	-3.28E-05	-1.18E-07	-0.00495	6.78E-08	8.98E+10	0.00	0.00	50.3256
0.2905	0.8472	305.7832	192.8245	-0.00495	0.6313	8.98E+10	0.00	0.00	60.3024
0.5810	0.8299	1344.	426.2245	-0.00495	2.7755	8.98E+10	0.00	0.00	73.6047
0.8715	0.8127	3277.	705.9966	-0.00495	6.7663	8.98E+10	0.00	0.00	86.9071
1.1620	0.7954	6267.	1032.	-0.00495	12.9375	8.98E+10	0.00	0.00	100.2094
1.4525	0.7782	10474.	1405.	-0.00495	21.6227	8.98E+10	0.00	0.00	113.5118
1.7430	0.7609	16060.	1824.	-0.00495	33.1558	8.98E+10	0.00	0.00	126.8141
2.0335	0.7437	23187.	2289.	-0.00494	47.8705	8.98E+10	0.00	0.00	140.1165
2.3240	0.7265	32017.	2800.	-0.00494	66.1004	8.98E+10	0.00	0.00	153.4189
2.6145	0.7092	42712.	3358.	-0.00494	88.1794	8.98E+10	0.00	0.00	166.7212
2.9050	0.6920	55432.	3963.	-0.00494	114.4412	8.98E+10	0.00	0.00	180.0236
3.1955	0.6748	70341.	4614.	-0.00494	145.2194	8.98E+10	0.00	0.00	193.3259
3.4860	0.6576	87598.	5311.	-0.00493	508.6349	8.99E+10	0.00	0.00	206.6283

3.7765	0.6404	107367.	6054.	-0.00493	623.4199	8.99E+10	0.00	0.00	219.9306
4.0670	0.6232	129808.	6844.	-0.00493	753.7236	8.99E+10	0.00	0.00	233.2330
4.3575	0.6060	155083.	7680.	-0.00492	900.4844	8.99E+10	0.00	0.00	246.5354
4.6480	0.5889	183355.	8563.	-0.00491	1065.	8.99E+10	0.00	0.00	259.8377
4.9385	0.5718	214784.	9492.	-0.00491	1247.	8.99E+10	0.00	0.00	273.1401
5.2290	0.5547	249532.	10467.	-0.00490	1449.	8.99E+10	0.00	0.00	286.4424
5.5195	0.5376	287761.	11489.	-0.00489	1671.	8.99E+10	0.00	0.00	299.7448
5.8100	0.5206	329633.	12557.	-0.00488	1914.	8.99E+10	0.00	0.00	313.0471
6.1005	0.5037	375309.	13672.	-0.00486	2179.	8.99E+10	0.00	0.00	326.3495
6.3910	0.4867	424951.	14832.	-0.00485	2467.	8.99E+10	0.00	0.00	339.6519
6.6815	0.4699	478720.	16040.	-0.00483	2780.	8.99E+10	0.00	0.00	352.9542
6.9720	0.4531	536779.	17293.	-0.00481	3117.	8.99E+10	0.00	0.00	366.2566
7.2625	0.4363	599288.	18593.	-0.00479	3480.	8.99E+10	0.00	0.00	379.5589
7.5530	0.4197	666410.	19939.	-0.00476	3869.	8.99E+10	0.00	0.00	392.8613
7.8435	0.4031	738306.	21332.	-0.00473	4287.	8.99E+10	0.00	0.00	406.1636
8.1340	0.3867	815137.	22771.	-0.00470	4733.	8.99E+10	0.00	0.00	419.4660
8.4245	0.3703	897066.	24257.	-0.00467	5209.	8.99E+10	0.00	0.00	432.7684
8.7150	0.3541	984255.	25788.	-0.00464	5715.	8.99E+10	0.00	0.00	446.0707
9.0055	0.3380	1076864.	27367.	-0.00460	6253.	8.99E+10	0.00	0.00	459.3731
9.2960	0.3221	1175055.	28991.	-0.00455	6823.	8.99E+10	0.00	0.00	472.6754
9.5865	0.3063	1278990.	30662.	-0.00450	7426.	8.99E+10	0.00	0.00	485.9778
9.8770	0.2907	1388831.	32379.	-0.00445	8064.	8.99E+10	0.00	0.00	499.2801
10.1675	0.2752	1504740.	34143.	-0.00440	8737.	8.99E+10	0.00	0.00	512.5825
10.4580	0.2600	1626877.	35953.	-0.00434	9446.	8.99E+10	0.00	0.00	525.8848
10.7485	0.2450	1755405.	37810.	-0.00427	10193.	8.99E+10	0.00	0.00	539.1872
11.0390	0.2303	1890486.	39712.	-0.00420	10977.	8.99E+10	0.00	0.00	552.4896
11.3295	0.2157	2032280.	41662.	-0.00412	11800.	8.99E+10	0.00	0.00	565.7919
11.6200	0.2015	2180950.	43657.	-0.00404	12664.	8.99E+10	0.00	0.00	579.0943
11.9105	0.1876	2336657.	45699.	-0.00395	13568.	8.99E+10	0.00	0.00	592.3966
12.2010	0.1739	2499564.	47787.	-0.00386	14514.	8.99E+10	0.00	0.00	605.6990
12.4915	0.1607	2669830.	49922.	-0.00376	15502.	8.99E+10	0.00	0.00	619.0013
12.7820	0.1477	2847619.	52103.	-0.00365	16535.	8.99E+10	0.00	0.00	632.3037
13.0725	0.1352	3033092.	54330.	-0.00354	17612.	8.99E+10	0.00	0.00	645.6061
13.3630	0.1231	3226411.	56604.	-0.00342	18734.	8.99E+10	0.00	0.00	658.9084
13.6535	0.1114	3427736.	58924.	-0.00329	19903.	8.99E+10	0.00	0.00	672.2108
13.9440	0.1001	3637230.	61291.	-0.00315	21119.	8.99E+10	0.00	0.00	685.5131
14.2345	0.08939	3855055.	63704.	-0.00301	22384.	8.99E+10	0.00	0.00	698.8155
14.5250	0.07917	4081372.	66163.	-0.00285	23698.	8.99E+10	0.00	0.00	712.1178
14.8155	0.06950	4316343.	68184.	-0.00269	25063.	8.99E+10	0.00	0.00	447.2926
15.1060	0.06042	4556750.	63156.	-0.00252	26459.	8.99E+10	-3332.	192229.	0.00

15.3965	0.05195	4756669.	50839.	-0.00234	27619.	8.99E+10	-3735.	250636.	0.00
15.6870	0.04413	4911199.	37115.	-0.00215	28517.	8.99E+10	-4139.	326958.	0.00
15.9775	0.03696	5015436.	21985.	-0.00196	29122.	8.99E+10	-4542.	428351.	0.00
16.2680	0.03048	5064477.	5448.	-0.00176	29407.	8.99E+10	-4946.	565603.	0.00
16.5585	0.02468	5053420.	-12143.	-0.00157	29342.	8.99E+10	-5147.	726871.	0.00
16.8490	0.01957	4979819.	-30216.	-0.00137	28915.	8.99E+10	-5223.	930440.	0.00
17.1395	0.01512	4842754.	-48453.	-0.00118	28119.	8.99E+10	-5240.	1207836.	0.00
17.4300	0.01134	4642005.	-66643.	-9.97E-04	26954.	8.99E+10	-5196.	1597613.	0.00
17.7205	0.00818	4378118.	-84558.	-8.22E-04	25421.	8.99E+10	-5083.	2166877.	0.00
18.0110	0.00561	4052465.	-101947.	-6.58E-04	23530.	8.99E+10	-4894.	3041647.	0.00
18.3015	0.00359	3667345.	-118522.	-5.09E-04	21294.	8.99E+10	-4616.	4485181.	0.00
18.5920	0.00206	3226129.	-133938.	-3.75E-04	18732.	8.99E+10	-4229.	7145460.	0.00
18.8825	9.74E-04	2733526.	-145576.	-2.59E-04	15872.	8.99E+10	-2448.	8760318.	0.00
19.1730	2.55E-04	2211173.	-158604.	-1.63E-04	12839.	8.99E+10	-5026.	6.87E+07	0.00
19.4635	-1.65E-04	1627739.	-161426.	-8.90E-05	9451.	8.99E+10	3407.	7.18E+07	0.00
19.7540	-3.66E-04	1085710.	-141802.	-3.64E-05	6304.	8.99E+10	7851.	7.48E+07	0.00
20.0445	-4.19E-04	639093.	-111791.	-2.98E-06	3711.	8.99E+10	9367.	7.79E+07	0.00
20.3350	-3.87E-04	306304.	-79827.	1.53E-05	1779.	8.99E+10	8971.	8.09E+07	0.00
20.6255	-3.12E-04	82538.	-51080.	2.29E-05	479.2502	8.99E+10	7522.	8.39E+07	0.00
20.9160	-2.27E-04	-49824.	-28097.	2.35E-05	289.3033	8.99E+10	5664.	8.70E+07	0.00
21.2065	-1.48E-04	-113353.	-11544.	2.04E-05	658.1763	8.99E+10	3832.	9.00E+07	0.00
21.4970	-8.51E-05	-130313.	-905.5659	1.56E-05	756.6543	8.99E+10	2272.	9.30E+07	0.00
21.7875	-3.94E-05	-119666.	4948.	1.08E-05	694.8359	8.99E+10	1087.	9.61E+07	0.00
22.0780	-9.91E-06	-95815.	7333.	6.61E-06	556.3470	8.99E+10	281.7323	9.91E+07	0.00
22.3685	6.65E-06	-68541.	7484.	3.42E-06	397.9788	8.99E+10	-195.0021	1.02E+08	0.00
22.6590	1.40E-05	-43636.	6410.	1.25E-06	253.3702	8.99E+10	-421.0156	1.05E+08	0.00
22.9495	1.54E-05	-23847.	4846.	-6.11E-08	138.4689	8.99E+10	-476.6098	1.08E+08	0.00
23.2400	1.35E-05	-9851.	3263.	-7.14E-07	57.1977	8.99E+10	-431.7461	1.11E+08	0.00
23.5305	1.04E-05	-1101.	1917.	-9.27E-07	6.3910	8.99E+10	-340.0381	1.14E+08	0.00
23.8210	7.06E-06	3517.	910.1580	-8.80E-07	20.4222	8.99E+10	-237.8204	1.17E+08	0.00
24.1115	4.24E-06	5245.	246.4957	-7.10E-07	30.4545	8.99E+10	-142.9383	1.18E+08	0.00
24.4020	2.11E-06	5236.	-127.0435	-5.07E-07	30.4010	8.99E+10	-71.3699	1.18E+08	0.00
24.6925	7.02E-07	4359.	-292.7286	-3.21E-07	25.3115	8.99E+10	-23.6875	1.18E+08	0.00
24.9830	-1.22E-07	3195.	-326.8566	-1.74E-07	18.5506	8.99E+10	4.1075	1.18E+08	0.00
25.2735	-5.13E-07	2080.	-289.4958	-7.20E-08	12.0795	8.99E+10	17.3273	1.18E+08	0.00
25.5640	-6.24E-07	1176.	-222.5935	-8.88E-09	6.8310	8.99E+10	21.0561	1.18E+08	0.00
25.8545	-5.75E-07	528.4365	-152.0473	2.42E-08	3.0683	8.99E+10	19.4179	1.18E+08	0.00
26.1450	-4.55E-07	116.3843	-91.4142	3.67E-08	0.6758	8.99E+10	15.3688	1.18E+08	0.00
26.4355	-3.20E-07	-108.9034	-45.8217	3.68E-08	0.6323	8.99E+10	10.7887	1.18E+08	0.00
26.7260	-1.99E-07	-203.0843	-15.3292	3.08E-08	1.1792	8.99E+10	6.7055	1.18E+08	0.00

Performed by: James Samples 4/13/2020
Checked by: Eric Kistner 4/14/2020

27.0165	-1.05E-07	-215.7783	2.5441	2.26E-08	1.2529	8.99E+10	3.5488	1.18E+08	0.00
27.3070	-4.08E-08	-185.3466	11.1289	1.49E-08	1.0762	8.99E+10	1.3765	1.18E+08	0.00
27.5975	-1.47E-09	-138.1873	13.6150	8.60E-09	0.8024	8.99E+10	0.04978	1.18E+08	0.00
27.8880	1.92E-08	-90.4231	12.5748	4.17E-09	0.5250	8.99E+10	-0.6465	1.18E+08	0.00
28.1785	2.76E-08	-50.5156	9.8265	1.43E-09	0.2933	8.99E+10	-0.9303	1.18E+08	0.00
28.4690	2.91E-08	-21.9131	6.4905	2.83E-11	0.1272	8.99E+10	-0.9836	1.18E+08	0.00
28.7595	2.78E-08	-5.2636	3.1430	-4.99E-10	0.03056	8.99E+10	-0.9369	1.18E+08	0.00
29.0500	2.57E-08	0.00	0.00	-6.01E-10	0.00	8.99E+10	-0.8663	5.88E+07	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.86440254 inches
Computed slope at pile head      =    -0.00494653 radians
Maximum bending moment           =       5064477. inch-lbs
Maximum shear force              =       -161426. lbs
Depth of maximum bending moment  =    16.26800000 feet below pile head
Depth of maximum shear force     =    19.46350000 feet below pile head
Number of iterations             =             19
Number of zero deflection points =              4
```

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 2

Pile-head conditions are Shear and Moment (Loading Type 1)

```
Shear force at pile head                              =          0.0 lbs
Applied moment at pile head                           =          0.0 in-lbs
Axial thrust load on pile head                        =          0.0 lbs
```


Performed by: James Samples 4/13/2020
Checked by: Eric Kistner 4/14/2020

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	1.5237	2.79E-05	2.35E-07	-0.00848	5.76E-08	8.98E+10	0.00	0.00	85.9933
0.2905	1.4941	522.5036	325.8824	-0.00848	1.0787	8.98E+10	0.00	0.00	100.9731
0.5810	1.4645	2272.	712.6877	-0.00848	4.6907	8.98E+10	0.00	0.00	120.9462
0.8715	1.4350	5491.	1169.	-0.00848	11.3370	8.98E+10	0.00	0.00	140.9193
1.1620	1.4054	10423.	1695.	-0.00848	21.5188	8.98E+10	0.00	0.00	160.8924
1.4525	1.3758	17310.	2291.	-0.00848	35.7371	8.98E+10	0.00	0.00	180.8655
1.7430	1.3463	26395.	2956.	-0.00848	54.4930	8.98E+10	0.00	0.00	200.8386
2.0335	1.3167	37921.	3691.	-0.00848	78.2876	8.98E+10	0.00	0.00	220.8117
2.3240	1.2871	52129.	4496.	-0.00848	107.6221	8.98E+10	0.00	0.00	240.7848
2.6145	1.2576	69264.	5370.	-0.00848	142.9974	8.98E+10	0.00	0.00	260.7579
2.9050	1.2281	89568.	6314.	-0.00847	184.9148	8.98E+10	0.00	0.00	280.7310
3.1955	1.1985	113283.	7327.	-0.00847	233.8752	8.98E+10	0.00	0.00	300.7041
3.4860	1.1690	140653.	8410.	-0.00846	816.6934	8.99E+10	0.00	0.00	320.6772
3.7765	1.1395	171919.	9563.	-0.00846	998.2400	8.99E+10	0.00	0.00	340.6503
4.0670	1.1100	207325.	10785.	-0.00845	1204.	8.99E+10	0.00	0.00	360.6234
4.3575	1.0806	247113.	12077.	-0.00844	1435.	8.99E+10	0.00	0.00	380.5965
4.6480	1.0512	291527.	13439.	-0.00843	1693.	8.99E+10	0.00	0.00	400.5696
4.9385	1.0218	340808.	14870.	-0.00842	1979.	8.99E+10	0.00	0.00	420.5427
5.2290	0.9925	395200.	16371.	-0.00840	2295.	8.99E+10	0.00	0.00	440.5158
5.5195	0.9632	454945.	17941.	-0.00839	2642.	8.99E+10	0.00	0.00	460.4889
5.8100	0.9340	520286.	19581.	-0.00837	3021.	8.99E+10	0.00	0.00	480.4620
6.1005	0.9049	591466.	21291.	-0.00835	3434.	8.99E+10	0.00	0.00	500.4351
6.3910	0.8758	668727.	23070.	-0.00832	3883.	8.99E+10	0.00	0.00	520.4081
6.6815	0.8468	752312.	24919.	-0.00830	4368.	8.99E+10	0.00	0.00	540.3812
6.9720	0.8180	842464.	26838.	-0.00826	4892.	8.99E+10	0.00	0.00	560.3543
7.2625	0.7892	939425.	28826.	-0.00823	5455.	8.99E+10	0.00	0.00	580.3274
7.5530	0.7606	1043439.	30884.	-0.00819	6059.	8.99E+10	0.00	0.00	600.3005
7.8435	0.7321	1154748.	33011.	-0.00815	6705.	8.99E+10	0.00	0.00	620.2736
8.1340	0.7038	1273594.	35208.	-0.00810	7395.	8.99E+10	0.00	0.00	640.2467
8.4245	0.6756	1400221.	37475.	-0.00805	8130.	8.99E+10	0.00	0.00	660.2198
8.7150	0.6477	1534871.	39811.	-0.00799	8912.	8.99E+10	0.00	0.00	680.1929
9.0055	0.6199	1677786.	42217.	-0.00793	9742.	8.99E+10	0.00	0.00	700.1660
9.2960	0.5924	1829211.	44693.	-0.00786	10621.	8.99E+10	0.00	0.00	720.1391
9.5865	0.5651	1989386.	47238.	-0.00779	11551.	8.99E+10	0.00	0.00	740.1122
9.8770	0.5381	2158556.	49853.	-0.00771	12534.	8.99E+10	0.00	0.00	760.0853

Performed by: James Samples 4/13/2020
Checked by: Eric Kistner 4/14/2020

10.1675	0.5113	2336962.	52538.	-0.00762	13569.	8.99E+10	0.00	0.00	780.0584
10.4580	0.4849	2524848.	55292.	-0.00753	14660.	8.99E+10	0.00	0.00	800.0315
10.7485	0.4589	2722456.	58115.	-0.00743	15808.	8.99E+10	0.00	0.00	820.0046
11.0390	0.4332	2930028.	61009.	-0.00732	17013.	8.99E+10	0.00	0.00	839.9777
11.3295	0.4079	3147809.	63972.	-0.00720	18278.	8.99E+10	0.00	0.00	859.9508
11.6200	0.3830	3376039.	67004.	-0.00707	19603.	8.99E+10	0.00	0.00	879.9239
11.9105	0.3586	3614963.	70107.	-0.00694	20990.	8.99E+10	0.00	0.00	899.8970
12.2010	0.3346	3864822.	73278.	-0.00679	22441.	8.99E+10	0.00	0.00	919.8701
12.4915	0.3112	4125860.	76520.	-0.00664	23957.	8.99E+10	0.00	0.00	939.8432
12.7820	0.2884	4398319.	79831.	-0.00647	25539.	8.99E+10	0.00	0.00	959.8163
13.0725	0.2661	4682441.	83212.	-0.00629	27188.	8.99E+10	0.00	0.00	979.7894
13.3630	0.2445	4978471.	86662.	-0.00611	28907.	8.99E+10	0.00	0.00	999.7625
13.6535	0.2235	5286649.	90182.	-0.00591	30697.	8.99E+10	0.00	0.00	1020.
13.9440	0.2033	5607220.	93772.	-0.00570	32558.	8.99E+10	0.00	0.00	1040.
14.2345	0.1838	5940425.	97431.	-0.00547	34493.	8.99E+10	0.00	0.00	1060.
14.5250	0.1651	6286508.	101160.	-0.00524	36502.	8.99E+10	0.00	0.00	1080.
14.8155	0.1473	6645711.	104223.	-0.00499	38588.	8.99E+10	0.00	0.00	678.0509
15.1060	0.1304	7013154.	99598.	-0.00472	40722.	8.99E+10	-3332.	89082.	0.00
15.3965	0.1144	7340111.	87281.	-0.00444	42620.	8.99E+10	-3735.	113822.	0.00
15.6870	0.09940	7621679.	73558.	-0.00415	44255.	8.99E+10	-4138.	145134.	0.00
15.9775	0.08544	7852956.	58428.	-0.00385	45598.	8.99E+10	-4542.	185304.	0.00
16.2680	0.07255	8029038.	41891.	-0.00354	46620.	8.99E+10	-4945.	237633.	0.00
16.5585	0.06074	8145022.	23948.	-0.00323	47294.	8.99E+10	-5349.	307006.	0.00
16.8490	0.05002	8196006.	4599.	-0.00291	47590.	8.99E+10	-5752.	400855.	0.00
17.1395	0.04042	8177087.	-16157.	-0.00260	47480.	8.99E+10	-6156.	530883.	0.00
17.4300	0.03192	8083361.	-38319.	-0.00228	46936.	8.99E+10	-6559.	716255.	0.00
17.7205	0.02452	7909926.	-61409.	-0.00197	45929.	8.99E+10	-6688.	950894.	0.00
18.0110	0.01818	7655216.	-84511.	-0.00167	44450.	8.99E+10	-6566.	1258843.	0.00
18.3015	0.01288	7320714.	-107031.	-0.00138	42507.	8.99E+10	-6354.	1719466.	0.00
18.5920	0.00857	6908996.	-128628.	-0.00110	40117.	8.99E+10	-6037.	2455344.	0.00
18.8825	0.00519	6423920.	-148891.	-8.44E-04	37300.	8.99E+10	-5589.	3751742.	0.00
19.1730	0.00268	5870928.	-214601.	-6.06E-04	34089.	8.99E+10	-32111.	4.17E+07	0.00
19.4635	9.68E-04	4927721.	-305320.	-3.97E-04	28613.	8.99E+10	-19937.	7.18E+07	0.00
19.7540	-8.12E-05	3742238.	-337032.	-2.28E-04	21729.	8.99E+10	1743.	7.48E+07	0.00
20.0445	-6.25E-04	2577936.	-309671.	-1.06E-04	14969.	8.99E+10	13954.	7.79E+07	0.00
20.3350	-8.20E-04	1583210.	-252184.	-2.53E-05	9193.	8.99E+10	19027.	8.09E+07	0.00
20.6255	-8.01E-04	819706.	-185403.	2.13E-05	4760.	8.99E+10	19287.	8.39E+07	0.00
20.9160	-6.71E-04	290583.	-122589.	4.28E-05	1687.	8.99E+10	16750.	8.70E+07	0.00
21.2065	-5.02E-04	-34987.	-70782.	4.78E-05	203.1509	8.99E+10	12973.	9.00E+07	0.00
21.4970	-3.38E-04	-202907.	-32435.	4.32E-05	1178.	8.99E+10	9027.	9.30E+07	0.00

21.7875	-2.01E-04	-261123.	-7023.	3.42E-05	1516.	8.99E+10	5552.	9.61E+07	0.00
22.0780	-9.99E-05	-251874.	7605.	2.42E-05	1462.	8.99E+10	2841.	9.91E+07	0.00
22.3685	-3.25E-05	-208098.	14216.	1.53E-05	1208.	8.99E+10	951.4550	1.02E+08	0.00
22.6590	6.86E-06	-152760.	15514.	8.32E-06	886.9911	8.99E+10	-206.9687	1.05E+08	0.00
22.9495	2.55E-05	-99936.	13771.	3.42E-06	580.2762	8.99E+10	-792.8092	1.08E+08	0.00
23.2400	3.07E-05	-56748.	10681.	3.82E-07	329.5029	8.99E+10	-979.9989	1.11E+08	0.00
23.5305	2.82E-05	-25468.	7361.	-1.21E-06	147.8793	8.99E+10	-924.6563	1.14E+08	0.00
23.8210	2.23E-05	-5425.	4444.	-1.81E-06	31.5006	8.99E+10	-749.0602	1.17E+08	0.00
24.1115	1.56E-05	5515.	2222.	-1.81E-06	32.0236	8.99E+10	-525.5580	1.18E+08	0.00
24.4020	9.64E-06	10069.	739.2873	-1.51E-06	58.4638	8.99E+10	-325.2809	1.18E+08	0.00
24.6925	5.06E-06	10669.	-125.6241	-1.10E-06	61.9519	8.99E+10	-170.9390	1.18E+08	0.00
24.9830	1.93E-06	9193.	-537.3414	-7.20E-07	53.3782	8.99E+10	-65.2729	1.18E+08	0.00
25.2735	4.58E-08	6923.	-653.8068	-4.07E-07	40.1989	8.99E+10	-1.5461	1.18E+08	0.00
25.5640	-9.07E-07	4635.	-603.1723	-1.83E-07	26.9105	8.99E+10	30.5963	1.18E+08	0.00
25.8545	-1.23E-06	2718.	-477.3427	-4.08E-08	15.7809	8.99E+10	41.5951	1.18E+08	0.00
26.1450	-1.19E-06	1307.	-334.7831	3.72E-08	7.5864	8.99E+10	40.1947	1.18E+08	0.00
26.4355	-9.73E-07	383.7194	-207.4944	7.00E-08	2.2280	8.99E+10	32.8338	1.18E+08	0.00
26.7260	-7.03E-07	-140.1049	-108.9173	7.47E-08	0.8135	8.99E+10	23.7222	1.18E+08	0.00
27.0165	-4.52E-07	-375.6523	-40.9891	6.47E-08	2.1812	8.99E+10	15.2498	1.18E+08	0.00
27.3070	-2.52E-07	-425.8810	0.3915	4.92E-08	2.4729	8.99E+10	8.4912	1.18E+08	0.00
27.5975	-1.09E-07	-372.9230	21.5981	3.37E-08	2.1654	8.99E+10	3.6755	1.18E+08	0.00
27.8880	-1.66E-08	-275.2992	28.9826	2.11E-08	1.5985	8.99E+10	0.5612	1.18E+08	0.00
28.1785	3.84E-08	-170.8560	27.6997	1.25E-08	0.9921	8.99E+10	-1.2972	1.18E+08	0.00
28.4690	7.04E-08	-82.1768	21.2970	7.58E-09	0.4772	8.99E+10	-2.3761	1.18E+08	0.00
28.7595	9.13E-08	-22.3730	11.7867	5.55E-09	0.1299	8.99E+10	-3.0802	1.18E+08	0.00
29.0500	1.09E-07	0.00	0.00	5.12E-09	0.00	8.99E+10	-3.6821	5.88E+07	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 2:

```
Pile-head deflection             =     1.52367704 inches
Computed slope at pile head      =    -0.00848273 radians
Maximum bending moment           =       8196006. inch-lbs
```

```
Maximum shear force              =       -337032. lbs
Depth of maximum bending moment  =    16.84900000 feet below pile head
Depth of maximum shear force     =    19.75400000 feet below pile head
Number of iterations             =             20
Number of zero deflection points =              4
```

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	0.8644	-0.00495	-161426.	5064477.
2	V, lb	0.00	M, in-lb	0.00	0.00	1.5237	-0.00848	-337032.	8196006.

Maximum pile-head deflection = 1.5236770442 inches
Maximum pile-head rotation = -0.0084827320 radians = -0.486025 deg.

Summary of Warning Messages

The following warning was reported 700 times

**** Warning ****

```
An unreasonable input value for unconfined compressive strength has been
specified for a soil defined using the weak rock criteria. The input value
is greater than 500 psi. Please check your input data for correctness.


The analysis ended normally.
```

CHECK FOR BEAM CLEARANCE

- Chosen beam size: W24x104
- d = 24.1 in
- b_f = 12.8 in
- $\sqrt{24.1^2+12.8^2}$ = 27.3 in
- 3-inch clearance for a drilled shaft size of 36 inches = 36 in - 2 (3 in) = 30 in
- 27.3 in < 30 in → **ACCEPTABLE**

CHECK FOR DEFLECTION

- Allowable Deflection – 1% or less of the drilled shaft length above bedrock (1% of 14.85 feet = 1.78 inches) or 2 inches (if the shaft is within 10 feet of the edge of roadway); whichever is less (Page 31 of GB-7)
- Use 1.78 inches
- W24x104 deflection from LPILE is 0.86 inches
- 0.86 in < 1.78 in → **ACCEPTABLE**

CHECK FOR SHEAR CAPACITY OF BEAM

- Section 6 of 8th edition of LRFD Bridge Design Manual
- Chosen beam size: W24x104
    - Maximum Shear from LPILE – 384.8 kips
- $V_n = C\ V_p$

$$V_p = 0.58 F_{yw} D t_w \qquad (6.10.9.3.2\text{-}3)$$

where:

d_o = transverse stiffener spacing (in.)
V_n = nominal shear resistance of the web panel (kip)
V_p = plastic shear force (kip)
C = ratio of the shear-buckling resistance to the shear yield strength

- $V_n = 1.0\ (0.58\ F_{yw}\ D\ t_w)$
- V_n = 1.0 (0.58) (50 ksi) (24.1 in) (0.5 in)
- V_n = 349.5 kips > 337.0 kips → **ACCEPTABLE**

CHECK FOR BUCKLING OF BEAM

- Chosen beam size: W24x104

- If $\frac{D}{t_w} \leq 1.12\sqrt{\frac{Ek}{F_{yw}}}$, then:

$$C = 1.0 \qquad (6.10.9.3.2\text{-}4)$$

in which:

k = shear-buckling coefficient

$$= 5 + \frac{5}{\left(\frac{d_o}{D}\right)^2} \qquad (6.10.9.3.2\text{-}7)$$

- $k = 5 + \frac{5}{\left(\frac{60\text{ in}}{24.1\text{ in}}\right)^2} = 5.807$

- $1.12\sqrt{\frac{(29{,}000\text{ ksi})\ (5.807)}{50\text{ ksi}}} = 65.0$

- $\frac{D}{t_w} = \frac{24.1}{0.5} = 48.2 < 65.0 \rightarrow$ **ACCEPTABLE**

CHECK MOMENT CAPACITY

- Chosen beam size: W24x104
  - Beam stickup is approximately 3.38 feet for moment calculation (conservative)
  - Maximum moment from LPILE – 683 ft-kips
  - From "Steel Construction Manual", AISC 14th Edition – an unbraced length of 3.38 feet for a W24x104 beam can support a moment capacity of approximately 1,084 ft-kips; which is greater than 683 ft-kips → **ACCEPTABLE**

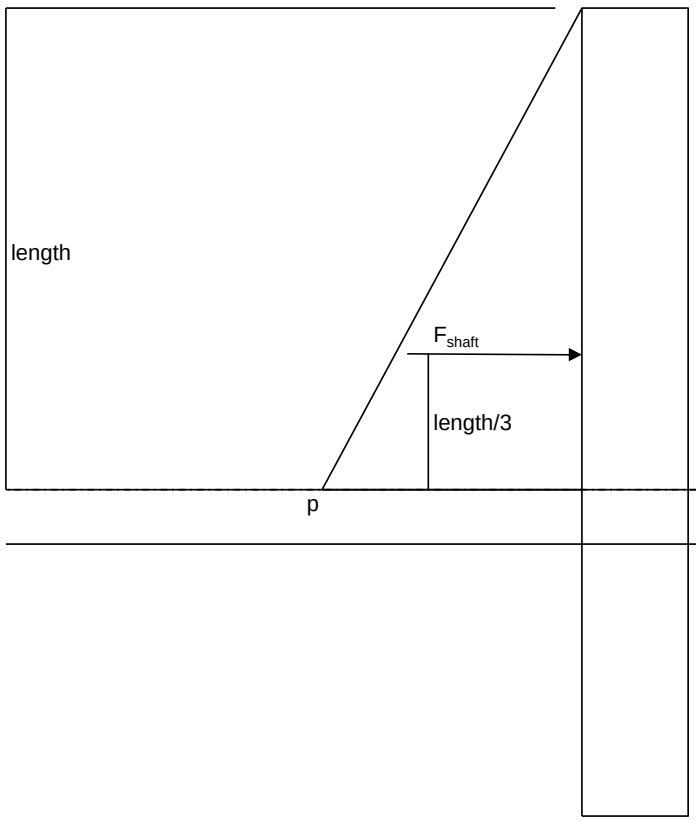
Performed by: J. Samples 4/23/2020
Checked by: E.Kistner 4/27/2020

SUMMARY OF DRILLED SHAFT CALCULATIONS

LOADING CONDITIONS

Loading conditions were evaluated using shaft loads determined from the UA SLOPE (Version 2.3) computer program. This shaft load, combined with an assumed traffic surcharge live load, was applied to the drilled shaft above the assumed failure surface. The drilled shaft was evaluated using LPILEv2019 which is a program for the analysis of piles and drilled shafts under lateral loads. Unfactored loads (Service I Limit State) were utilized to estimate shaft head deflection and factored loads (Strength I Limit State) were used to evaluate geotechnical resistance.

Analysis Cross Section:	B-4
Shaft Location from Centerline	15.5 feet



Projected Ground line Depth = 0.00

Note:
x_2 represents the maximum value of the triangular distributed load that will be used in LPILE determined from F_{shaft} from the University of Akron program.

Assumed Failure Surface Depth = 8.83

Top of Rock Depth = 11.98

Bottom of Drilled Shaft Depth = 26.18

Performed by: J. Samples 4/23/2020
Checked by: E.Kistner 4/27/2020

Estimated Depth to Bedrock =	11.98	feet	UA Slope Input
Estimated Depth to Failure Surface=	8.83	feet	UA Slope Input
Shaft Size =	2.5	feet	UA Slope Input
Center to Center Spacing =	5.00	feet	UA Slope Input
F_{shaft} =	33,353	pounds	UA Slope Output
Factor of Safety =	1.37		UA Slope Output
p = (2*Fshaft)/H * (1 ft/12 in)	630	pounds per inch	

DISTRIBUTED LOAD FOR LPILE INPUT

F_{live} = assumed traffic surcharge load =	0	psf	
Phi =	22.5	degrees	based blow counts (conservative)
K_a =	0.446		
x1 = F_{live} * s * Ka * (1 ft/12 in)	0	pounds per inch	
x2 = [2*Fshaft/(Depth to Failure Surface)] + x1			

Service (I) Limit State:

x1 =	0	pounds per inch
x2 =	630	pounds per inch
Total Load =	33353	pounds

Strength (I) Limit State:

x1 =	0	pounds per inch (Load Factor = 1.75)
x2 =	944	pounds per inch (Load Factor = 1.5)
Total Load =	50029	pounds

CHOOSE MATERIAL p-y CURVES for LPILE Program

Material Type	*Value*	*Units*	
Soft Clay			
γ=	110	pcf	based on ODOT recommendations
c=	1,000	psf	based on ODOT recommendations
Bedrock - Brown Shale (Weak Rock)			
γ=	140	pcf	based on average UCR results
E=	9,000	psi	=90 x qu
qu=	100	psi	based on UCR results
RQD=	26	%	based on average RQD from B-4
Km=	0.00005		conservative for weak rock
Bedrock - Gray Shale (Weak Rock)			
γ=	150	pcf	based on average UCR results
E=	67,500	psi	=90 x qu
qu=	750	psi	based on UCR results
RQD=	43	%	based on average RQD from B-4
Km=	0.00005		conservative for weak rock
p-y Modification Factor			
p = 0.64 (Spacing/Diameter)$^{0.34}$	0.81		

SHAFT CONCRETE AND STEEL MATERIAL PROPERTIES FOR LPILE

Parameter	*Value*		*Note*
f'_c =	4,000	psi	(ODOT Class S Concrete)
E_c =	3,604,997	psi	E_c = 57,000 * SQRT(f'c)
$f_{y\ steel}$=	50,000	psi	
E_{steel}=	2.9E+07	psi	

Performed by: J. Samples 4/23/2020
Checked by: E.Kistner 4/27/2020

LPILE VERSION 2019 RUNS

SERVICE (I) AND STRENGTH (I) LIMIT STATES

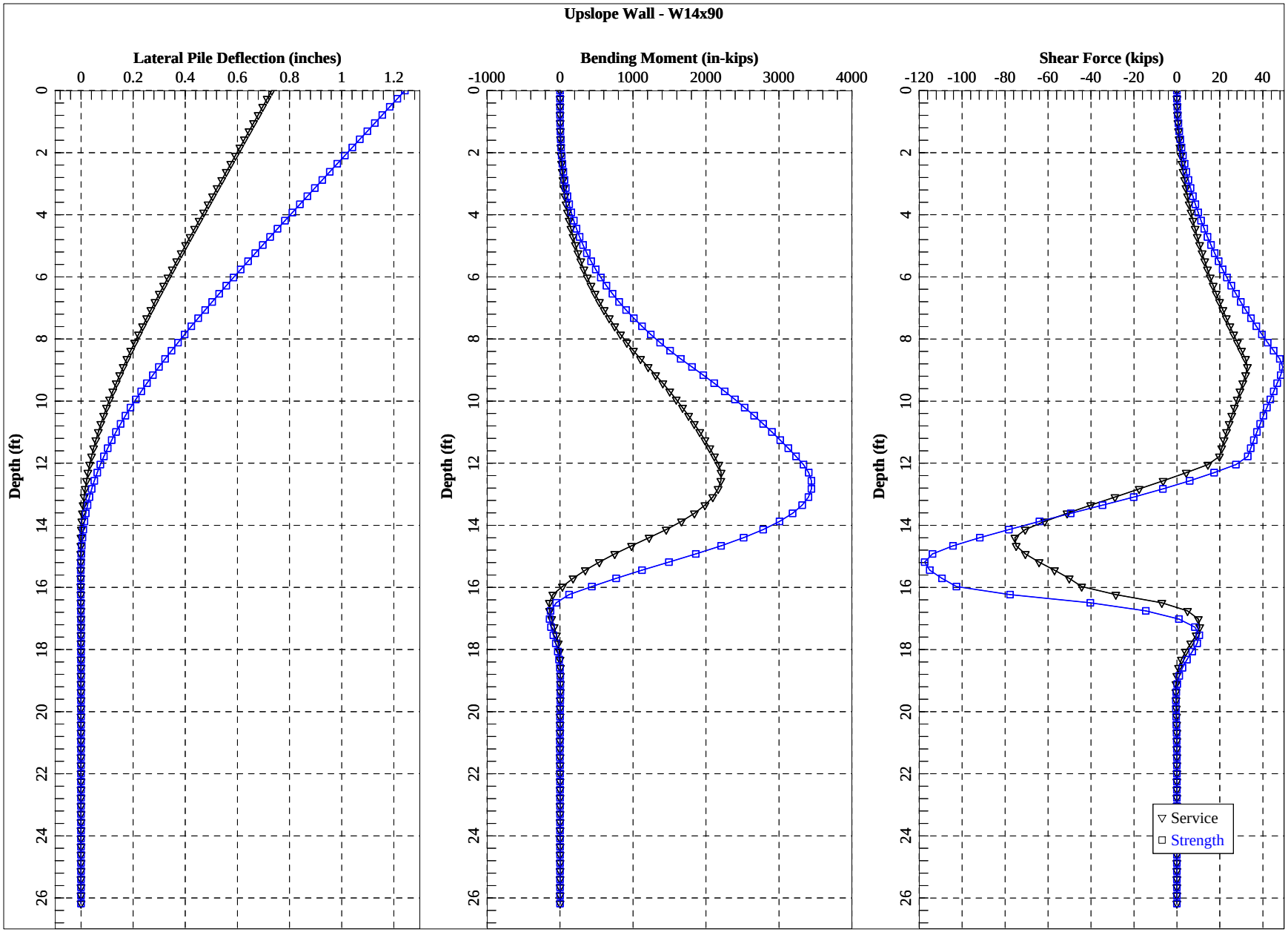
Purpose: Achieve a shaft head deflection of less than 2.0 inches for Service (I) Limit State. Recommend a rock socket length by observation of the shear and moment curves. Provide shear and moment design parameters for the selection of steel beam reinforcement.

Run ID	Filename	Reinforcement Description	Deflection at Pile Head (in)	Maximum Moment (in-lbs)	Maximum Shear (lbs)
1	W14x90_2.5dia_5ctc	W14x90	0.73	N/A	N/A
2	W14x90_2.5dia_5ctc	W14x90	N/A	3,443,978	117,381

Based on the calculations and assumptions presented above, it appears a 30-inch diameter drilled shaft with a center-to center spacing of 60 inches can provide tolerable deflections when placed approximately 15.5 feet left of centerline. A minimum 15-foot rock socket is recommended.

PROPERTIES OF SELECTED SECTIONS

Run ID	Source	Reinforcement Description	Area of Steel (in^2)	Moment of Inertia (in^4)	Section Modulus (in^3)
1 & 2	AISC Manual of Steel Construction	W14x90	26.5	999	143



Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

```
================================================================================

                     LPile for Windows, Version 2019-11.001

                 Analysis of Individual Piles and Drilled Shafts
                Subjected to Lateral Loading Using the p-y Method
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================================================================================

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--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\Users\jsamples\Desktop\Hillside Ave\03_Lpile\Secondary Wall\

Name of input data file:
W14x90_2.5dia_5ctc_secondary.lp11

Name of output report file:
W14x90_2.5dia_5ctc_secondary.lp11

Name of plot output file:
W14x90_2.5dia_5ctc_secondary.lp11
```


Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

Name of runtime message file:
W14x90_2.5dia_5ctc_secondary.lp11

Date and Time of Analysis

Date: May 6, 2020 Time: 10:29:57

Problem Title

Project Name: Hillside Ave Landslide

Job Number: 175538106

Client: Hamilton County Engineer's Office

Engineer: James Samples

Description: Wall Design with 20 ft Offset

Program Options and Settings

```
Computational Options:
 - Use unfactored loads in computations (conventional analysis)
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed                =          500
 - Deflection tolerance for convergence                =   1.0000E-05 in
 - Maximum allowable deflection                        =     100.0000 in
 - Number of pile increments                           =          100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Analysis uses p-y modification factors for p-y curves
 - Analysis uses layering correction (Method of Georgiadis)
 - Analysis includes loading by multiple distributed lateral loads acting on pile
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats



--------------------------------------------------------------------------------
                     Pile Structural Properties and Geometry
--------------------------------------------------------------------------------

Number of pile sections defined                        =            2
```


Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

```
Total length of pile                                  =       26.180 ft
Depth of ground surface below top of pile             =       8.8300 ft

Pile diameters used for p-y curve computations are defined using 4 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.
```

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	14.5000
2	1.220	14.5000
3	1.220	36.0000
4	26.180	36.0000

```
Input Structural Properties for Pile Sections:
----------------------------------------------

Pile Section No. 1:

   Section 1 is a AISC strong axis steel pile
   Length of section                                  =     1.220000 ft
   AISC Section Type                                  = W


   AISC Section Name                                  = W14X90


   Pile width                                         =    14.500000 in
   Shear capacity of section                          =       0.0000 lbs

Pile Section No. 2:

   Section 2 is an elastic pile
   Cross-sectional Shape                              =   Circular Pile
   Length of section                                  =    24.960000 ft
   Width of top of section                            =    36.000000 in
```

```
   Width of bottom of section                          =    36.000000 in
   Top Area                                            =    26.500000 sq. in
   Bottom Area                                         =    26.500000 sq. in
   Moment of Inertia at Top                            =   999.000000 in^4
   Moment of Inertia at Bottom                         =   999.000000 in^4
   Elastic Modulus                                     =    29000000. psi
```

```
--------------------------------------------------------------------------------
                       Ground Slope and Pile Batter Angles
--------------------------------------------------------------------------------

Ground Slope Angle                                     =        0.000 degrees
                                                       =        0.000 radians

Pile Batter Angle                                      =        0.000 degrees
                                                       =        0.000 radians


--------------------------------------------------------------------------------
                       Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 4 layers

Layer 1 is soft clay, p-y criteria by Matlock, 1970

   Distance from top of pile to top of layer           =     8.830000 ft
   Distance from top of pile to bottom of layer        =     8.980000 ft
   Effective unit weight at top of layer               =   110.000000 pcf
   Effective unit weight at bottom of layer            =   110.000000 pcf
   Undrained cohesion at top of layer                  =  1000.000000 psf
   Undrained cohesion at bottom of layer               =  1000.000000 psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000

   NOTE: Default values for Epsilon-50 will be computed for this layer.
```


Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

Layer 2 is soft clay, p-y criteria by Matlock, 1970

```
   Distance from top of pile to top of layer          =     8.980000 ft
   Distance from top of pile to bottom of layer       =    11.980000 ft
   Effective unit weight at top of layer              =   140.000000 pcf
   Effective unit weight at bottom of layer           =   140.000000 pcf
   Undrained cohesion at top of layer                 =        2000. psf
   Undrained cohesion at bottom of layer              =        2000. psf
   Epsilon-50 at top of layer                         =       0.0000
   Epsilon-50 at bottom of layer                      =       0.0000

   NOTE: Default values for Epsilon-50 will be computed for this layer.
```

Layer 3 is weak rock, p-y criteria by Reese, 1997

```
   Distance from top of pile to top of layer          =    11.980000 ft
   Distance from top of pile to bottom of layer       =    16.180000 ft
   Effective unit weight at top of layer              =   140.000000 pcf
   Effective unit weight at bottom of layer           =   140.000000 pcf
   Uniaxial compressive strength at top of layer      =   100.000000 psi
   Uniaxial compressive strength at bottom of layer   =   100.000000 psi
   Initial modulus of rock at top of layer            =        9000. psi
   Initial modulus of rock at bottom of layer         =        9000. psi
   RQD of rock at top of layer                        =    26.000000 %
   RQD of rock at bottom of layer                     =    26.000000 %
   k rm of rock at top of layer                       =    0.0000500
   k rm of rock at bottom of layer                    =    0.0000500
```

Layer 4 is weak rock, p-y criteria by Reese, 1997

```
   Distance from top of pile to top of layer          =    16.180000 ft
   Distance from top of pile to bottom of layer       =    40.000000 ft
   Effective unit weight at top of layer              =   150.000000 pcf
   Effective unit weight at bottom of layer           =   150.000000 pcf
   Uniaxial compressive strength at top of layer      =   750.000000 psi
   Uniaxial compressive strength at bottom of layer   =   750.000000 psi
   Initial modulus of rock at top of layer            =       67500. psi
```

```
   Initial modulus of rock at bottom of layer          =       67500. psi
   RQD of rock at top of layer                         =    43.000000 %
   RQD of rock at bottom of layer                      =    43.000000 %
   k rm of rock at top of layer                        =    0.0000500
   k rm of rock at bottom of layer                     =    0.0000500


 (Depth of the lowest soil layer extends 13.820 ft below the pile tip)


**** Warning - Possible Input Data Error ****

Values entered for effective unit weight of rock were outside the limits of
50 pcf to 150 pcf.

The maximum input value, in layer   1, for effective unit weight = 150.00 pcf

This data may be erroneous. Please check your data.
```

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	Rock Mass Modulus psi
1	Soft	8.8300	110.0000	1000.0000	--	--	default	--
	Clay	8.9800	110.0000	1000.0000	--	--	default	--
2	Soft	8.9800	140.0000	2000.	--	--	default	--
	Clay	11.9800	140.0000	2000.	--	--	default	--

Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

3	Weak	11.9800	140.0000	--	100.0000	26.0000	5.00E-05	9000.
	Rock	16.1800	140.0000	--	100.0000	26.0000	5.00E-05	9000.
4	Weak	16.1800	150.0000	--	750.0000	43.0000	5.00E-05	67500.
	Rock	40.0000	150.0000	--	750.0000	43.0000	5.00E-05	67500.

---

p-y Modification Factors for Group Action

Distribution of p-y modifiers with depth defined using 4 points

Point No.	Depth X ft	p-mult	y-mult
1	8.830	0.8100	1.0000
2	11.980	0.8100	1.0000
3	11.980	1.0000	1.0000
4	40.000	1.0000	1.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading for Individual Load Cases

Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

Distributed lateral load intensity for Load Case 1 defined using 2 points

Distributed lateral load intensity for Load Case 2 defined using 2 points

---

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	No
2	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	No

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 2

Pile Section No. 1:

```
Dimensions and Properties of Steel AISC Strong Axis:
---------------------------------------------

Length of Section                                    =     1.220000 ft
Flange Width                                         =    14.500000 in
Section Depth                                        =    14.000000 in
Flange Thickness                                     =     0.710000 in
Web Thickness                                        =     0.440000 in
Yield Stress of Pipe                                 =    50.000000 ksi
Elastic Modulus                                      =       29000. ksi
Cross-sectional Area                                 =    26.500000 sq. in.
Moment of Inertia                                    =   999.000000 in^4
Elastic Bending Stiffness                            =    28971000. kip-in^2
Plastic Modulus, Z                                   =   157.000000in^3
Plastic Moment Capacity = Fy Z                       =        7850.in-kip

Axial Structural Capacities:
----------------------------

Nom. Axial Structural Capacity = Fy As               =     1325.000 kips
Nominal Axial Tensile Capacity                       =    -1325.000 kips




Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

   Number     Axial Thrust Force
                   kips
   ------     ------------------
      1                0.000

Definition of Run Messages:

   Y = part of pipe section has yielded.


Axial Thrust Force =      0.000 kips
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Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in2	Depth to N Axis in	Max Total Stress ksi	Run Msg
0.00000505	144.0258703	28500178.	7.0000000	1.0156035	
0.00001011	288.0517407	28500178.	7.0000000	2.0312069	
0.00001516	432.0776110	28500178.	7.0000000	3.0468104	
0.00002021	576.1034813	28500178.	7.0000000	4.0624139	
0.00002527	720.1293517	28500178.	7.0000000	5.0780173	
0.00003032	864.1552220	28500178.	7.0000000	6.0936208	
0.00003537	1008.	28500178.	7.0000000	7.1092242	
0.00004043	1152.	28500178.	7.0000000	8.1248277	
0.00004548	1296.	28500178.	7.0000000	9.1404312	
0.00005054	1440.	28500178.	7.0000000	10.1560346	
0.00005559	1584.	28500178.	7.0000000	11.1716381	
0.00006064	1728.	28500178.	7.0000000	12.1872416	
0.00006570	1872.	28500178.	7.0000000	13.2028450	
0.00007075	2016.	28500178.	7.0000000	14.2184485	
0.00007580	2160.	28500178.	7.0000000	15.2340519	
0.00008086	2304.	28500178.	7.0000000	16.2496554	
0.00008591	2448.	28500178.	7.0000000	17.2652589	
0.00009096	2592.	28500178.	7.0000000	18.2808623	
0.00009602	2736.	28500178.	7.0000000	19.2964658	
0.0001011	2881.	28500178.	7.0000000	20.3120693	
0.0001061	3025.	28500178.	7.0000000	21.3276727	
0.0001112	3169.	28500178.	7.0000000	22.3432762	
0.0001162	3313.	28500178.	7.0000000	23.3588796	
0.0001213	3457.	28500178.	7.0000000	24.3744831	
0.0001263	3601.	28500178.	7.0000000	25.3900866	
0.0001314	3745.	28500178.	7.0000000	26.4056900	
0.0001364	3889.	28500178.	7.0000000	27.4212935	
0.0001415	4033.	28500178.	7.0000000	28.4368970	
0.0001466	4177.	28500178.	7.0000000	29.4525004	
0.0001516	4321.	28500178.	7.0000000	30.4681039	
0.0001567	4465.	28500178.	7.0000000	31.4837074	
0.0001617	4609.	28500178.	7.0000000	32.4993108	
0.0001668	4753.	28500178.	7.0000000	33.5149143	
0.0001718	4897.	28500178.	7.0000000	34.5305177	
0.0001769	5041.	28500178.	7.0000000	35.5461212	
0.0001819	5185.	28500178.	7.0000000	36.5617247	

Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

0.0001870	5329.	28500178.	7.0000000	37.5773281	
0.0001920	5473.	28500178.	7.0000000	38.5929316	
0.0001971	5617.	28500178.	7.0000000	39.6085351	
0.0002072	5905.	28500178.	7.0000000	41.6397420	
0.0002173	6193.	28500178.	7.0000000	43.6709489	
0.0002274	6481.	28500178.	7.0000000	45.7021558	
0.0002375	6769.	28500178.	7.0000000	47.7333628	
0.0002476	7057.	28500178.	7.0000000	49.7645697	
0.0002577	7274.	28223979.	7.0000000	50.0000000	Y
0.0002678	7391.	27593911.	7.0000000	50.0000000	Y
0.0002779	7428.	26726020.	7.0000000	50.0000000	Y
0.0002880	7448.	25855751.	7.0000000	50.0000000	Y
0.0002982	7465.	25038062.	7.0000000	50.0000000	Y
0.0003083	7481.	24268323.	7.0000000	50.0000000	Y
0.0003184	7495.	23543056.	7.0000000	50.0000000	Y
0.0003285	7509.	22858512.	7.0000000	50.0000000	Y
0.0003386	7520.	22211131.	7.0000000	50.0000000	Y
0.0003487	7531.	21598440.	7.0000000	50.0000000	Y
0.0003588	7541.	21017793.	7.0000000	50.0000000	Y
0.0003689	7550.	20466819.	7.0000000	50.0000000	Y
0.0003790	7559.	19943385.	7.0000000	50.0000000	Y
0.0003891	7567.	19445237.	7.0000000	50.0000000	Y
0.0003992	7574.	18970874.	7.0000000	50.0000000	Y
0.0004093	7580.	18518739.	7.0000000	50.0000000	Y
0.0004194	7587.	18087399.	7.0000000	50.0000000	Y
0.0004295	7592.	17675205.	7.0000000	50.0000000	Y
0.0004397	7598.	17280986.	7.0000000	50.0000000	Y
0.0004498	7603.	16903933.	7.0000000	50.0000000	Y
0.0004599	7607.	16542512.	7.0000000	50.0000000	Y
0.0004700	7612.	16196087.	7.0000000	50.0000000	Y
0.0004801	7616.	15863751.	7.0000000	50.0000000	Y
0.0004902	7620.	15544446.	7.0000000	50.0000000	Y
0.0005003	7623.	15237782.	7.0000000	50.0000000	Y
0.0005104	7627.	14942626.	7.0000000	50.0000000	Y
0.0005205	7630.	14658741.	7.0000000	50.0000000	Y
0.0005306	7633.	14385192.	7.0000000	50.0000000	Y
0.0005407	7636.	14121616.	7.0000000	50.0000000	Y
0.0005508	7639.	13867488.	7.0000000	50.0000000	Y
0.0005609	7641.	13622100.	7.0000000	50.0000000	Y
0.0005710	7644.	13385397.	7.0000000	50.0000000	Y

0.0005812	7646.	13156463.	7.0000000	50.0000000	Y
0.0005913	7648.	12935259.	7.0000000	50.0000000	Y
0.0006014	7650.	12721461.	7.0000000	50.0000000	Y
0.0006418	7658.	11931440.	7.0000000	50.0000000	Y
0.0006822	7664.	11233292.	7.0000000	50.0000000	Y
0.0007227	7669.	10611904.	7.0000000	50.0000000	Y
0.0007631	7673.	10055337.	7.0000000	50.0000000	Y
0.0008035	7677.	9554026.	7.0000000	50.0000000	Y
0.0008439	7680.	9100118.	7.0000000	50.0000000	Y
0.0008844	7683.	8687127.	7.0000000	50.0000000	Y
0.0009248	7685.	8309985.	7.0000000	50.0000000	Y
0.0009652	7687.	7964068.	7.0000000	50.0000000	Y
0.0010056	7689.	7645740.	7.0000000	50.0000000	Y
0.0010461	7691.	7351809.	7.0000000	50.0000000	Y
0.0010865	7692.	7079619.	7.0000000	50.0000000	Y
0.0011269	7693.	6826753.	7.0000000	50.0000000	Y
0.0011674	7695.	6591403.	7.0000000	50.0000000	Y
0.0012078	7696.	6371585.	7.0000000	50.0000000	Y
0.0012482	7696.	6165972.	7.0000000	50.0000000	Y

Summary of Results for Nominal (Unfactored) Moment Capacity for Section 1

Load No.	Axial Thrust kips	Nominal Moment Capacity in-kips
1	0.00000000	7696.

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural

Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

design standard being followed.

Pile Section No. 2:

Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	8.8300	0.00	N.A.	No	0.00	1362.
2	8.9800	0.07543	Yes	No	1362.	61387.
3	11.9800	3.1500	No	Yes	N.A.	N.A.
4	16.1800	7.3500	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.7318	8.34E-06	5.10E-08	-0.00556	6.05E-08	2.85E+10	0.00	0.00	4.6697
0.2618	0.7143	23.0442	36.6759	-0.00556	0.1672	2.85E+10	0.00	0.00	18.6788
0.5236	0.6968	230.4418	124.6979	-0.00556	1.6724	2.85E+10	0.00	0.00	37.3576
0.7854	0.6794	806.5463	271.4014	-0.00556	5.8533	2.85E+10	0.00	0.00	56.0365
1.0472	0.6619	1936.	476.7863	-0.00556	14.0480	2.85E+10	0.00	0.00	74.7153
1.3090	0.6445	3802.	740.8525	-0.00556	68.5097	2.90E+10	0.00	0.00	93.3941
1.5708	0.6270	6591.	1064.	-0.00556	118.7502	2.90E+10	0.00	0.00	112.0729
1.8326	0.6096	10485.	1445.	-0.00555	188.9208	2.90E+10	0.00	0.00	130.7518
2.0944	0.5921	15670.	1885.	-0.00555	282.3431	2.90E+10	0.00	0.00	149.4306
2.3562	0.5747	22330.	2384.	-0.00555	402.3389	2.90E+10	0.00	0.00	168.1094
2.6180	0.5573	30649.	2941.	-0.00555	552.2299	2.90E+10	0.00	0.00	186.7882
2.8798	0.5398	40811.	3558.	-0.00554	735.3377	2.90E+10	0.00	0.00	205.4670
3.1416	0.5224	53002.	4232.	-0.00554	954.9841	2.90E+10	0.00	0.00	224.1459
3.4034	0.5050	67404.	4966.	-0.00553	1214.	2.90E+10	0.00	0.00	242.8247
3.6652	0.4877	84203.	5758.	-0.00552	1517.	2.90E+10	0.00	0.00	261.5035
3.9270	0.4703	103584.	6609.	-0.00551	1866.	2.90E+10	0.00	0.00	280.1823
4.1888	0.4530	125729.	7519.	-0.00550	2265.	2.90E+10	0.00	0.00	298.8612
4.4506	0.4358	150824.	8487.	-0.00549	2718.	2.90E+10	0.00	0.00	317.5400
4.7124	0.4185	179053.	9514.	-0.00547	3226.	2.90E+10	0.00	0.00	336.2188
4.9742	0.4014	210601.	10599.	-0.00545	3795.	2.90E+10	0.00	0.00	354.8976
5.2360	0.3843	245651.	11744.	-0.00542	4426.	2.90E+10	0.00	0.00	373.5764
5.4978	0.3673	284388.	12947.	-0.00539	5124.	2.90E+10	0.00	0.00	392.2553
5.7596	0.3504	326997.	14208.	-0.00536	5892.	2.90E+10	0.00	0.00	410.9341
6.0214	0.3336	373661.	15529.	-0.00532	6733.	2.90E+10	0.00	0.00	429.6129
6.2832	0.3170	424566.	16908.	-0.00528	7650.	2.90E+10	0.00	0.00	448.2917
6.5450	0.3005	479895.	18345.	-0.00523	8647.	2.90E+10	0.00	0.00	466.9706
6.8068	0.2841	539833.	19842.	-0.00518	9727.	2.90E+10	0.00	0.00	485.6494
7.0686	0.2679	604564.	21397.	-0.00511	10893.	2.90E+10	0.00	0.00	504.3282
7.3304	0.2520	674273.	23010.	-0.00504	12149.	2.90E+10	0.00	0.00	523.0070
7.5922	0.2363	749143.	24683.	-0.00497	13498.	2.90E+10	0.00	0.00	541.6858

7.8540	0.2208	829360.	26414.	-0.00488	14943.	2.90E+10	0.00	0.00	560.3647
8.1158	0.2056	915107.	28204.	-0.00479	16488.	2.90E+10	0.00	0.00	579.0435
8.3776	0.1907	1006570.	30052.	-0.00468	18136.	2.90E+10	0.00	0.00	597.7223
8.6394	0.1762	1103931.	31959.	-0.00457	19891.	2.90E+10	0.00	0.00	616.4011
8.9012	0.1620	1207377.	32811.	-0.00444	21755.	2.90E+10	-217.5028	4218.	143.1774
9.1630	0.1482	1310089.	32022.	-0.00431	23605.	2.90E+10	-427.8865	9068.	0.00
9.4248	0.1349	1408577.	30685.	-0.00416	25380.	2.90E+10	-423.0510	9849.	0.00
9.6866	0.1221	1502891.	29365.	-0.00400	27079.	2.90E+10	-417.3124	10736.	0.00
9.9484	0.1098	1593085.	28065.	-0.00383	28704.	2.90E+10	-410.6219	11748.	0.00
10.2102	0.09804	1679227.	26787.	-0.00366	30256.	2.90E+10	-402.9387	12912.	0.00
10.4720	0.08684	1761392.	25535.	-0.00347	31737.	2.90E+10	-394.2208	14262.	0.00
10.7338	0.07624	1839666.	24312.	-0.00327	33147.	2.90E+10	-384.4238	15841.	0.00
10.9956	0.06627	1914146.	23121.	-0.00307	34489.	2.90E+10	-373.4999	17707.	0.00
11.2574	0.05695	1984940.	21967.	-0.00286	35765.	2.90E+10	-361.3984	19937.	0.00
11.5192	0.04830	2052167.	20852.	-0.00264	36976.	2.90E+10	-348.0659	22637.	0.00
11.7810	0.04036	2115959.	19782.	-0.00241	38125.	2.90E+10	-333.4483	25955.	0.00
12.0428	0.03314	2176459.	14446.	-0.00218	39215.	2.90E+10	-3063.	290423.	0.00
12.3046	0.02666	2206726.	4354.	-0.00194	39761.	2.90E+10	-3361.	396158.	0.00
12.5664	0.02093	2203817.	-6423.	-0.00170	39708.	2.90E+10	-3500.	525410.	0.00
12.8282	0.01595	2166369.	-17549.	-0.00147	39034.	2.90E+10	-3583.	705981.	0.00
13.0900	0.01171	2093554.	-28844.	-0.00124	37722.	2.90E+10	-3607.	968166.	0.00
13.3518	0.00818	1985136.	-40108.	-0.00102	35768.	2.90E+10	-3563.	1368996.	0.00
13.6136	0.00533	1841550.	-51108.	-8.08E-04	33181.	2.90E+10	-3440.	2029052.	0.00
13.8754	0.00310	1664016.	-61558.	-6.18E-04	29982.	2.90E+10	-3213.	3254911.	0.00
14.1372	0.00144	1454771.	-70602.	-4.49E-04	26212.	2.90E+10	-2545.	5538264.	0.00
14.3990	2.82E-04	1220407.	-75428.	-3.04E-04	21989.	2.90E+10	-526.5645	5867252.	0.00
14.6608	-4.64E-04	980845.	-74817.	-1.84E-04	17673.	2.90E+10	915.3629	6196241.	0.00
14.9226	-8.76E-04	750318.	-70521.	-9.04E-05	13519.	2.90E+10	1820.	6525229.	0.00
15.1844	-0.00103	537748.	-64125.	-2.06E-05	9689.	2.90E+10	2252.	6854217.	0.00
15.4462	-0.00101	347407.	-56976.	2.74E-05	6260.	2.90E+10	2299.	7183206.	0.00
15.7080	-8.60E-04	179755.	-50135.	5.60E-05	3239.	2.90E+10	2057.	7512194.	0.00
15.9698	-6.54E-04	32402.	-44341.	6.75E-05	583.8164	2.90E+10	1631.	7841182.	0.00
16.2316	-4.36E-04	-98849.	-28417.	6.39E-05	1781.	2.90E+10	8506.	6.13E+07	0.00
16.4934	-2.52E-04	-146148.	-7016.	5.06E-05	2633.	2.90E+10	5118.	6.37E+07	0.00
16.7552	-1.18E-04	-142932.	4936.	3.49E-05	2575.	2.90E+10	2491.	6.62E+07	0.00
17.0170	-3.28E-05	-115134.	9975.	2.09E-05	2074.	2.90E+10	717.0411	6.87E+07	0.00
17.2788	1.34E-05	-80260.	10626.	1.03E-05	1446.	2.90E+10	-302.4142	7.11E+07	0.00
17.5406	3.22E-05	-48370.	8967.	3.37E-06	871.5263	2.90E+10	-753.6878	7.36E+07	0.00
17.8024	3.45E-05	-23918.	6471.	-5.54E-07	430.9625	2.90E+10	-835.4527	7.61E+07	0.00
18.0642	2.87E-05	-7713.	4032.	-2.27E-06	138.9685	2.90E+10	-717.1521	7.85E+07	0.00

18.3260	2.02E-05	1415.	2086.	-2.61E-06	25.4932	2.90E+10	-521.9582	8.10E+07	0.00
18.5878	1.23E-05	5391.	753.0533	-2.24E-06	97.1343	2.90E+10	-326.3111	8.35E+07	0.00
18.8496	6.16E-06	6146.	-24.0469	-1.62E-06	110.7470	2.90E+10	-168.4051	8.60E+07	0.00
19.1114	2.13E-06	5240.	-382.5295	-9.99E-07	94.4119	2.90E+10	-59.8114	8.84E+07	0.00
19.3732	-1.20E-07	3743.	-471.0286	-5.12E-07	67.4405	2.90E+10	3.4713	9.09E+07	0.00
19.6350	-1.09E-06	2280.	-414.6970	-1.85E-07	41.0864	2.90E+10	32.3904	9.34E+07	0.00
19.8968	-1.28E-06	1137.	-302.3377	1.65E-10	20.4923	2.90E+10	39.1395	9.58E+07	0.00
20.1586	-1.09E-06	380.6466	-187.3398	8.25E-08	6.8585	2.90E+10	34.0702	9.83E+07	0.00
20.4204	-7.65E-07	-39.7694	-95.2796	1.01E-07	0.7166	2.90E+10	24.5370	1.01E+08	0.00
20.6822	-4.55E-07	-218.0142	-33.2692	8.70E-08	3.9282	2.90E+10	14.9400	1.03E+08	0.00
20.9440	-2.19E-07	-248.8063	1.7505	6.17E-08	4.4830	2.90E+10	7.3542	1.06E+08	0.00
21.2058	-6.73E-08	-207.0153	16.8682	3.69E-08	3.7300	2.90E+10	2.2700	1.06E+08	0.00
21.4676	1.36E-08	-142.8199	19.7153	1.80E-08	2.5733	2.90E+10	-0.4575	1.06E+08	0.00
21.7294	4.57E-08	-83.1400	16.5730	5.73E-09	1.4980	2.90E+10	-1.5430	1.06E+08	0.00
21.9912	4.96E-08	-38.6886	11.5222	-8.76E-10	0.6971	2.90E+10	-1.6725	1.06E+08	0.00
22.2530	4.02E-08	-10.7439	6.7632	-3.56E-09	0.1936	2.90E+10	-1.3572	1.06E+08	0.00
22.5148	2.72E-08	3.8061	3.1889	-3.93E-09	0.06858	2.90E+10	-0.9183	1.06E+08	0.00
22.7766	1.55E-08	9.2926	0.9245	-3.22E-09	0.1674	2.90E+10	-0.5232	1.06E+08	0.00
23.0384	6.96E-09	9.6150	-0.2666	-2.20E-09	0.1732	2.90E+10	-0.2350	1.06E+08	0.00
23.3002	1.70E-09	7.6178	-0.7257	-1.26E-09	0.1373	2.90E+10	-0.05732	1.06E+08	0.00
23.5620	-9.71E-10	5.0550	-0.7643	-5.76E-10	0.09108	2.90E+10	0.03278	1.06E+08	0.00
23.8238	-1.92E-09	2.8157	-0.6111	-1.49E-10	0.05073	2.90E+10	0.06475	1.06E+08	0.00
24.0856	-1.91E-09	1.2155	-0.4083	6.96E-11	0.02190	2.90E+10	0.06436	1.06E+08	0.00
24.3474	-1.48E-09	0.2504	-0.2287	1.49E-10	0.00451	2.90E+10	0.04999	1.06E+08	0.00
24.6092	-9.70E-10	-0.2213	-0.09873	1.51E-10	0.00399	2.90E+10	0.03273	1.06E+08	0.00
24.8710	-5.34E-10	-0.3699	-0.01899	1.19E-10	0.00666	2.90E+10	0.01803	1.06E+08	0.00
25.1328	-2.24E-10	-0.3406	0.02122	8.01E-11	0.00614	2.90E+10	0.00757	1.06E+08	0.00
25.3946	-3.07E-11	-0.2366	0.03474	4.88E-11	0.00426	2.90E+10	0.00104	1.06E+08	0.00
25.6564	8.25E-11	-0.1223	0.03200	2.94E-11	0.00220	2.90E+10	-0.00278	1.06E+08	0.00
25.9182	1.54E-10	-0.03552	0.01947	2.08E-11	6.40E-04	2.90E+10	-0.00519	1.06E+08	0.00
26.1800	2.13E-10	0.00	0.00	1.89E-11	0.00	2.90E+10	-0.00720	5.30E+07	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.73175527 inches
Computed slope at pile head      =    -0.00555622 radians
Maximum bending moment           =       2206726. inch-lbs
Maximum shear force              =        -75428. lbs
Depth of maximum bending moment  =    12.30460000 feet below pile head
Depth of maximum shear force     =    14.39900000 feet below pile head
Number of iterations             =             18
Number of zero deflection points =              6
```

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 2

Pile-head conditions are Shear and Moment (Loading Type 1)

```
Shear force at pile head                              =          0.0 lbs
Applied moment at pile head                           =          0.0 in-lbs
Axial thrust load on pile head                        =          0.0 lbs
```

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	1.2423	3.21E-06	-2.04E-07	-0.00917	2.33E-08	2.85E+10	0.00	0.00	6.9971
0.2618	1.2135	34.5297	54.9556	-0.00917	0.2506	2.85E+10	0.00	0.00	27.9886
0.5236	1.1847	345.2969	186.8490	-0.00917	2.5059	2.85E+10	0.00	0.00	55.9772
0.7854	1.1559	1209.	406.6713	-0.00917	8.7707	2.85E+10	0.00	0.00	83.9658
1.0472	1.1271	2900.	714.4226	-0.00917	21.0496	2.85E+10	0.00	0.00	111.9543
1.3090	1.0983	5697.	1110.	-0.00916	102.6558	2.90E+10	0.00	0.00	139.9429
1.5708	1.0695	9875.	1594.	-0.00916	177.9368	2.90E+10	0.00	0.00	167.9315
1.8326	1.0407	15711.	2165.	-0.00916	283.0813	2.90E+10	0.00	0.00	195.9201
2.0944	1.0120	23480.	2825.	-0.00916	423.0665	2.90E+10	0.00	0.00	223.9087
2.3562	0.9832	33459.	3572.	-0.00916	602.8698	2.90E+10	0.00	0.00	251.8973
2.6180	0.9544	45924.	4407.	-0.00915	827.4683	2.90E+10	0.00	0.00	279.8858
2.8798	0.9257	61152.	5331.	-0.00915	1102.	2.90E+10	0.00	0.00	307.8744

Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

3.1416	0.8969	79418.	6342.	-0.00914	1431.	2.90E+10	0.00	0.00	335.8630
3.4034	0.8682	100999.	7441.	-0.00913	1820.	2.90E+10	0.00	0.00	363.8516
3.6652	0.8396	126171.	8628.	-0.00912	2273.	2.90E+10	0.00	0.00	391.8402
3.9270	0.8110	155211.	9903.	-0.00910	2797.	2.90E+10	0.00	0.00	419.8288
4.1888	0.7824	188394.	11266.	-0.00908	3394.	2.90E+10	0.00	0.00	447.8173
4.4506	0.7539	225997.	12717.	-0.00906	4072.	2.90E+10	0.00	0.00	475.8059
4.7124	0.7255	268296.	14255.	-0.00903	4834.	2.90E+10	0.00	0.00	503.7945
4.9742	0.6971	315567.	15882.	-0.00900	5686.	2.90E+10	0.00	0.00	531.7831
5.2360	0.6689	368087.	17597.	-0.00897	6632.	2.90E+10	0.00	0.00	559.7717
5.4978	0.6408	426131.	19399.	-0.00892	7678.	2.90E+10	0.00	0.00	587.7603
5.7596	0.6128	489976.	21290.	-0.00887	8828.	2.90E+10	0.00	0.00	615.7489
6.0214	0.5850	559899.	23268.	-0.00882	10088.	2.90E+10	0.00	0.00	643.7374
6.2832	0.5574	636175.	25335.	-0.00875	11463.	2.90E+10	0.00	0.00	671.7260
6.5450	0.5301	719081.	27489.	-0.00868	12956.	2.90E+10	0.00	0.00	699.7146
6.8068	0.5029	808893.	29731.	-0.00859	14575.	2.90E+10	0.00	0.00	727.7032
7.0686	0.4761	905887.	32061.	-0.00850	16322.	2.90E+10	0.00	0.00	755.6918
7.3304	0.4495	1010339.	34479.	-0.00840	18204.	2.90E+10	0.00	0.00	783.6804
7.5922	0.4233	1122526.	36985.	-0.00828	20226.	2.90E+10	0.00	0.00	811.6689
7.8540	0.3975	1242724.	39579.	-0.00815	22391.	2.90E+10	0.00	0.00	839.6575
8.1158	0.3721	1371209.	42261.	-0.00801	24706.	2.90E+10	0.00	0.00	867.6461
8.3776	0.3471	1508257.	45031.	-0.00786	27176.	2.90E+10	0.00	0.00	895.6347
8.6394	0.3227	1654145.	47888.	-0.00768	29804.	2.90E+10	0.00	0.00	923.6233
8.9012	0.2988	1809149.	49257.	-0.00750	32597.	2.90E+10	-266.7489	2804.	214.5389
9.1630	0.2756	1963637.	48349.	-0.00729	35381.	2.90E+10	-526.1210	5997.	0.00
9.4248	0.2530	2112933.	46703.	-0.00707	38071.	2.90E+10	-521.6634	6477.	0.00
9.6866	0.2312	2257080.	45072.	-0.00683	40668.	2.90E+10	-516.2239	7016.	0.00
9.9484	0.2101	2396133.	43461.	-0.00658	43174.	2.90E+10	-509.7512	7623.	0.00
10.2102	0.1898	2530154.	41871.	-0.00631	45588.	2.90E+10	-502.2045	8312.	0.00
10.4720	0.1704	2659218.	40307.	-0.00603	47914.	2.90E+10	-493.5436	9099.	0.00
10.7338	0.1519	2783412.	38772.	-0.00574	50152.	2.90E+10	-483.7268	10004.	0.00
10.9956	0.1343	2902831.	37270.	-0.00543	52303.	2.90E+10	-472.7105	11054.	0.00
11.2574	0.1178	3017585.	35804.	-0.00511	54371.	2.90E+10	-460.4493	12282.	0.00
11.5192	0.1022	3127795.	34379.	-0.00478	56357.	2.90E+10	-446.8972	13731.	0.00
11.7810	0.08777	3233593.	32998.	-0.00443	58263.	2.90E+10	-432.0086	15462.	0.00
12.0428	0.07440	3335128.	27508.	-0.00407	60092.	2.90E+10	-3063.	129341.	0.00
12.3046	0.06217	3406429.	17313.	-0.00371	61377.	2.90E+10	-3427.	173164.	0.00
12.5664	0.05110	3443909.	5976.	-0.00334	62052.	2.90E+10	-3790.	233042.	0.00
12.8282	0.04120	3443978.	-6503.	-0.00296	62054.	2.90E+10	-4154.	316766.	0.00
13.0900	0.03247	3403047.	-20125.	-0.00259	61316.	2.90E+10	-4518.	437067.	0.00
13.3518	0.02491	3317529.	-34615.	-0.00223	59775.	2.90E+10	-4707.	593759.	0.00

13.6136	0.01847	3185553.	-49382.	-0.00188	57397.	2.90E+10	-4694.	798374.	0.00
13.8754	0.01312	3007253.	-63992.	-0.00154	54185.	2.90E+10	-4607.	1103477.	0.00
14.1372	0.00879	2783479.	-78202.	-0.00123	50153.	2.90E+10	-4439.	1586455.	0.00
14.3990	0.00541	2515894.	-91727.	-9.39E-04	45331.	2.90E+10	-4171.	2421659.	0.00
14.6608	0.00289	2207138.	-104203.	-6.83E-04	39768.	2.90E+10	-3771.	4099126.	0.00
14.9226	0.00112	1861168.	-113780.	-4.62E-04	33535.	2.90E+10	-2326.	6525229.	0.00
15.1844	-1.57E-05	1492236.	-117381.	-2.81E-04	26887.	2.90E+10	34.1769	6854217.	0.00
15.4462	-6.43E-04	1123642.	-115017.	-1.39E-04	20246.	2.90E+10	1470.	7183206.	0.00
15.7080	-8.88E-04	769558.	-109374.	-3.61E-05	13866.	2.90E+10	2122.	7512194.	0.00
15.9698	-8.70E-04	436423.	-102629.	2.93E-05	7863.	2.90E+10	2172.	7841182.	0.00
16.2316	-7.04E-04	124720.	-77656.	5.97E-05	2247.	2.90E+10	13727.	6.13E+07	0.00
16.4934	-4.95E-04	-51505.	-40318.	6.37E-05	928.0263	2.90E+10	10044.	6.37E+07	0.00
16.7552	-3.04E-04	-128603.	-14484.	5.39E-05	2317.	2.90E+10	6403.	6.62E+07	0.00
17.0170	-1.56E-04	-142510.	943.8073	3.92E-05	2568.	2.90E+10	3419.	6.87E+07	0.00
17.2788	-5.75E-05	-122673.	8361.	2.48E-05	2210.	2.90E+10	1303.	7.11E+07	0.00
17.5406	-4.87E-07	-89975.	10426.	1.33E-05	1621.	2.90E+10	11.4148	7.36E+07	0.00
17.8024	2.59E-05	-57163.	9458.	5.31E-06	1030.	2.90E+10	-627.6660	7.61E+07	0.00
18.0642	3.28E-05	-30547.	7182.	5.50E-07	550.3926	2.90E+10	-821.3232	7.85E+07	0.00
18.3260	2.94E-05	-12036.	4702.	-1.76E-06	216.8730	2.90E+10	-757.5059	8.10E+07	0.00
18.5878	2.18E-05	-1002.	2602.	-2.47E-06	18.0618	2.90E+10	-579.2657	8.35E+07	0.00
18.8496	1.39E-05	4314.	1096.	-2.29E-06	77.7376	2.90E+10	-379.7825	8.60E+07	0.00
19.1114	7.43E-06	5883.	170.6252	-1.73E-06	105.9998	2.90E+10	-209.2298	8.84E+07	0.00
19.3732	2.99E-06	5387.	-293.9538	-1.12E-06	97.0542	2.90E+10	-86.5297	9.09E+07	0.00
19.6350	3.83E-07	4036.	-447.7479	-6.11E-07	72.7210	2.90E+10	-11.3785	9.34E+07	0.00
19.8968	-8.50E-07	2573.	-424.8863	-2.53E-07	46.3643	2.90E+10	25.9326	9.58E+07	0.00
20.1586	-1.21E-06	1366.	-324.8462	-3.94E-08	24.6193	2.90E+10	37.7547	9.83E+07	0.00
20.4204	-1.10E-06	532.1476	-210.2360	6.35E-08	9.5882	2.90E+10	35.2082	1.01E+08	0.00
20.6822	-8.08E-07	45.4163	-113.2515	9.48E-08	0.8183	2.90E+10	26.5340	1.03E+08	0.00
20.9440	-5.02E-07	-179.4340	-45.0516	8.76E-08	3.2330	2.90E+10	16.8833	1.06E+08	0.00
21.2058	-2.57E-07	-237.6519	-4.8926	6.50E-08	4.2820	2.90E+10	8.6827	1.06E+08	0.00
21.4676	-9.36E-08	-210.1750	13.7103	4.07E-08	3.7869	2.90E+10	3.1603	1.06E+08	0.00
21.7294	-1.61E-09	-151.5073	18.7599	2.11E-08	2.7299	2.90E+10	0.05441	1.06E+08	0.00
21.9912	3.88E-08	-92.3026	16.7885	7.86E-09	1.6631	2.90E+10	-1.3095	1.06E+08	0.00
22.2530	4.78E-08	-46.0218	12.1994	3.59E-10	0.8292	2.90E+10	-1.6121	1.06E+08	0.00
22.5148	4.11E-08	-15.6513	7.4908	-2.99E-09	0.2820	2.90E+10	-1.3855	1.06E+08	0.00
22.7766	2.90E-08	1.0447	3.7767	-3.78E-09	0.01882	2.90E+10	-0.9790	1.06E+08	0.00
23.0384	1.73E-08	8.0783	1.3207	-3.28E-09	0.1456	2.90E+10	-0.5845	1.06E+08	0.00
23.3002	8.38E-09	9.3431	-0.04181	-2.34E-09	0.1683	2.90E+10	-0.2829	1.06E+08	0.00
23.5620	2.63E-09	7.8156	-0.6255	-1.41E-09	0.1408	2.90E+10	-0.08872	1.06E+08	0.00
23.8238	-4.62E-10	5.4126	-0.7404	-6.90E-10	0.09752	2.90E+10	0.01561	1.06E+08	0.00

24.0856	-1.71E-09	3.1636	-0.6252	-2.25E-10	0.05700	2.90E+10	0.05770	1.06E+08	0.00
24.3474	-1.88E-09	1.4841	-0.4350	2.66E-11	0.02674	2.90E+10	0.06341	1.06E+08	0.00
24.6092	-1.54E-09	0.4303	-0.2536	1.30E-10	0.00775	2.90E+10	0.05206	1.06E+08	0.00
24.8710	-1.06E-09	-0.1095	-0.1157	1.48E-10	0.00197	2.90E+10	0.03577	1.06E+08	0.00
25.1328	-6.14E-10	-0.2964	-0.02693	1.26E-10	0.00534	2.90E+10	0.02073	1.06E+08	0.00
25.3946	-2.70E-10	-0.2788	0.01992	9.46E-11	0.00502	2.90E+10	0.00910	1.06E+08	0.00
25.6564	-2.00E-11	-0.1713	0.03528	7.02E-11	0.00309	2.90E+10	6.76E-04	1.06E+08	0.00
25.9182	1.71E-10	-0.05712	0.02726	5.78E-11	0.00103	2.90E+10	-0.00578	1.06E+08	0.00
26.1800	3.43E-10	0.00	0.00	5.47E-11	0.00	2.90E+10	-0.01158	5.30E+07	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 2:

```
Pile-head deflection             =     1.24228245 inches
Computed slope at pile head      =    -0.00916542 radians
Maximum bending moment           =       3443978. inch-lbs
Maximum shear force              =       -117381. lbs
Depth of maximum bending moment  =    12.82820000 feet below pile head
Depth of maximum shear force     =    15.18440000 feet below pile head
Number of iterations             =             24
Number of zero deflection points =              6
```

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs

Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	0.7318	-0.00556	-75428.	2206726.
2	V, lb	0.00	M, in-lb	0.00	0.00	1.2423	-0.00917	-117381.	3443978.

Maximum pile-head deflection = 1.2422824536 inches
Maximum pile-head rotation = -0.0091654206 radians = -0.525140 deg.

Summary of Warning Messages

The following warning was reported 264 times

**** Warning ****

An unreasonable input value for shear strength has been specified for a soil defined using the soft clay criteria. The input value is greater than 1250 psf. Please check your input data for correctness.

The following warning was reported 936 times

**** Warning ****

An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.

Performed by: James Samples 5/6/2020
Checked by: Eric Kistner 5/7/2020

CHECK FOR BEAM CLEARANCE

- Chosen beam size: W14x90
- d = 14 in
- b_f = 14.5 in
- $\sqrt{14^2+14.5^2}$ = 20.2 in
- 3-inch clearance for a drilled shaft size of 30 inches = 36 in - 2 (3 in) = 24 in
- 20.2 in < 24 in → **ACCEPTABLE**

CHECK FOR DEFLECTION

- Allowable Deflection – 1% or less of the drilled shaft length above bedrock (1% of 11.98 feet = 1.44 inches) or 2 inches (if the shaft is within 10 feet of the edge of roadway); whichever is less (Page 31 of GB-7)
- Use 1.44 inches
- W14x90 deflection from LPILE is 0.73 inches
- 0.73 in < 1.44 in → **ACCEPTABLE**

CHECK FOR SHEAR CAPACITY OF BEAM

- Section 6 of 8th edition of LRFD Bridge Design Manual
- Chosen beam size: W14x90
    - Maximum Shear from LPILE – 117.8 kips
- $V_n = C\ V_p$

$$V_p = 0.58 F_{yw} D t_w \qquad (6.10.9.3.2\text{-}3)$$

where:

d_o = transverse stiffener spacing (in.)
V_n = nominal shear resistance of the web panel (kip)
V_p = plastic shear force (kip)
C = ratio of the shear-buckling resistance to the shear yield strength

- $V_n = 1.0\ (0.58\ F_{yw}\ D\ t_w)$
- V_n = 1.0 (0.58) (50 ksi) (14 in) (0.44 in)
- V_n = 178.6 kips > 117.8 kips → **ACCEPTABLE**

CHECK FOR BUCKLING OF BEAM

- Chosen beam size: W14x90

- If $\frac{D}{t_w} \leq 1.12\sqrt{\frac{Ek}{F_{yw}}}$, then:

$$C = 1.0 \qquad (6.10.9.3.2\text{-}4)$$

in which:

k = shear-buckling coefficient

$$= 5 + \frac{5}{\left(\frac{d_o}{D}\right)^2} \qquad (6.10.9.3.2\text{-}7)$$

- $k = 5 + \frac{5}{\left(\frac{60\text{ in}}{14\text{ in}}\right)^2} = 5.272$

- $1.12\sqrt{\frac{(29{,}000\text{ ksi})\ (5.272)}{50\text{ ksi}}} = 61.9$

- $\frac{D}{t_w} = \frac{14}{0.44} = 31.8 < 61.9 \rightarrow$ **ACCEPTABLE**

CHECK MOMENT CAPACITY

- Chosen beam size: W14x90
  - Beam stickup is approximately 1.22 feet for moment calculation (conservative)
  - Maximum moment from LPILE – 287 ft-kips
  - From "Steel Construction Manual", AISC 14th Edition – an unbraced length of 1.22 feet for a W14x90 beam can support a moment capacity of approximately 574 ft-kips; which is greater than 287 ft-kips → **ACCEPTABLE**

APPENDIX G
PHOTOGRAPHS OF ROCK CORE

Stantec

Hillside Avenue Landslide - Rock Core Photos

Rock core from B-1, 9.0 to 23.7 ft.

Rock core from boring B-2, 9.8 to 25.8 ft.

Stantec

Hillside Avenue Landslide - Rock Core Photos

Rock core from boring B-3, 9.0 to 23.9 ft.

Rock core from boring B-4, 10.5 to 27.7 ft.

Stantec

Hillside Avenue Landslide - Rock Core Photos

Rock core from boring B-5, 9.7 to 23.2 ft.

Rock core from boring B-5, 23.2 to 27.0 ft.

Hillside Avenue Landslide - Rock Core Photos

Rock core from boring B-6, 6.3 to 25.3 ft.

Rock core from boring B-6, 25.3 to 30.3 ft.

Stantec

Hillside Avenue Landslide - Rock Core Photos

Rock core from boring B-7, 13.5 to 30.4 ft.

Rock core from boring B-8, 10.5 to 25.5 ft.