GEOLOGIC AND GEOTECHNICAL INVESTIGATION
SCENIC DRIVE LANDSLIDE

SAN MATEO COUNTY, CALIFORNIA

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SUBMITTED TO:

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1. EXECUTIVE SUMMARY

This report summarizes the results of Geo-Logic Associates' (GLA) evaluation of a landslide that occurred in January 2017 and damaged a portion of Scenic Drive in La Honda, California and forced its closure. The location of the landslide is shown in Figures 1 and 2. The landslide damaged an approximately 280-feet-long section of Scenic Drive and several private properties on both sides of the road that were subsequently red-tagged by the County. The evaluation was completed in general accordance with GLA's July 7, 2017 proposal to the San Mateo County Department of Public Works (County) that was prepared to address the County's objective of repairing and reopening Scenic Drive to traffic. Evaluation of the damaged residences was outside the scope of our investigation and is not addressed in this report.

1.1 Scope of Work

The scope of work performed to meet the County's objective to repair and reopen Scenic Drive included data review, preparation of a site-specific topographic map, site visits to observe and map surface geologic conditions, subsurface investigation, laboratory testing, geologic assessments, and engineering evaluations. The subsurface investigation included advancing three 30-inch diameter borings to allow downhole logging by GLA personnel and advancing three 6-inch diameter hollow stem auger borings that were completed as slope inclinometer monitoring points. Laboratory testing included moisture content and dry density, grain size distribution (including hydrometer to differentiate the silt and clay fractions of selected subsurface soils), Atterberg limits, unconfined compression, drained residual torsional shear, and drained fully softened peak torsional shear tests. Geologic and engineering analyses included review of stereo-paired aerial photographs, preparation of geologic cross sections, comparative slope stability calculations, and development of potentially feasible mitigation alternatives. Relevant data and evaluations are appended to this report.

1.2 Geologic Setting

The Scenic Drive landslide occurred in an area with a history of deep-seated landslides (Brabb and Pampeyan, 1972) that probably occurred thousands of years ago during wetter climatic conditions. Recent landsliding has also affected the site area; one recent slide occurred downslope of the current (2017) landslide between 1998 and 2005 and is identified as "The Scenic Drive Landslide" in some of the publications reviewed for this evaluation (Jayko et al. 1998; Wells et al. 2005; Wells, et al. 2006). The data reviewed and developed for this evaluation indicates the 2017 Scenic Drive landslide is spatially separated and not part of the 1998-2005 landslide.

1.3 Landslide Characterization

The results of the surface geologic mapping and subsurface borings indicate the landslide mass consists of a highly weathered and oxidized sandy clay matrix with siltstone fragments.

Geologic materials below the slide plane include relatively unweathered Purisima Formation sandy siltstone that is underlain by hard andesite tuff breccia. Observations in the large-diameter borings indicate the landslide occurred on a slip surface consisting of an approximately 0.5 inch to 3.5 inches thick layer of expansive clay that divides the highly weathered landslide debris and the relatively unweathered underlying Purisima Formation siltstone.

The landslide appears to be about 13 feet to 20 feet thick and likely moved as translational block sliding along the layer of expansive clay at a relatively shallow angle of 5 to 7 degrees. The toe of the landslide daylights close to the top of the scarp of the relatively larger pre-existing landslide that affected the lower portion of Scenic Drive between 1998 and 2005. Published information, geologic mapping, and subsurface investigation indicate the landslide reactivated existing landslide debris along a segment of a preexisting slip surface and it is likely that landslide debris extends north and northeast beyond the scarp of the current landslide.

Although standing groundwater was not encountered during the field investigation program, groundwater seeps were noted within the landslide debris during the work performed in October and November 2017 and saturated ground was observed along a portion of the landslide toe during geologic mapping performed in August and September 2017. Initial slope inclinometer readings between November 22, 2017 and April 11, 2018 indicate small movements of the slide mass are associated with rainfall and comparative slope stability calculations using laboratory test data show that increases in pore water pressure measurably decrease the safety factor of the slope. This information indicates high groundwater and/or transient pore water pressure in the slope contributed to the sliding.

1.4 Conceptual Mitigation Measures

The County requested that the evaluation of road repairs be limited to measures that could be completed within the Scenic Drive right-of-way. Therefore, repairs that would extend beyond these limits such as excavation of the slide mass, benching the subgrade, installing subdrains, and rebuilding the slope with engineered fill were not evaluated. Conceptual mitigation measures identified that could be performed within the right-of-way include:

- **Option 1 – Grading Repair**. This option consists of excavating a portion of the landslide mass to a depth below the slide plane from slightly east, or upslope, of Scenic Drive to slightly west, or downslope, of the roadway and replacing it with geogrid-reinforced, engineered soil fill. A subdrain should be incorporated into the design and installed before placing the engineered fill. The excavation would need to be performed in sequential sections to reduce the potential for sliding of the landslide debris mass above Scenic Drive into the excavation and would require equipment capable of reaching below the slide plan without personnel entering the excavations. Comparative stability analyses indicate this option will increase the safety factor of the existing slope from about 1.0 to 1.8 if effective drainage to remove water from engineered fill and the slide mass above the fill section is provided. Order-of-magnitude costs for Option 1 are estimated to be about $1.5 million.

- **Option 2 – Stitch Piers**. Stitch piers are drilled, cast-in-place, reinforced concrete piers spaced closely enough for soil arching to eliminate a need for lagging between the piers. For the purposes evaluating effectiveness and estimated costs, this option assumes a single row of stitch piers with a diameter of 2.5 feet, a center-to-center spacing of 5 feet, and a depth of at least 36 feet below the slide plane would be installed along the upslope side of Scenic Drive. Comparative stability analyses indicate stitch piers could increase the static safety factor of the slope from about 1.0 to 1.6 under drained conditions. However, stitch piers by themselves would only stabilize the slope above, or upslope of, the roadway and future movement of a repaired section of the road downslope of the piers is judged likely. The cost of the Option 2 stitch piers is estimated to be about $1.5 million.

- **Option 3 – Combined Grading Repair and Stitch Piers.** Although Options 1 and 2 each increases the safety factor of the slope to over 1.5, each has limitations if implemented by itself. For example, the Option 1 grading repair would require an excavation up to about 20 feet down to the slide plane, followed by backfilling of the excavation with a geogrid reinforced engineered fill column and a subsurface drainage system. The sides of the excavation will need to be sloped at a safe inclination or be shored during construction. If construction is only allowed within the Scenic Drive right-of-way, sloping would not be possible and shoring the upslope wall of the excavation would be required. If implemented in conjunction with the stitch piers, however, the piers would provide shoring for this portion of the excavation. A combined repair solution could increase the static safety factor of the slope from about 1.0 to 2.1 under drained conditions. As summarized above, stitch piers by themselves probably would not represent a long-term roadway mitigation measure unless the slide debris is removed and replaced to reduce the potential for future downslope movement of the roadway. The total estimated cost for Option 3 is estimated to be about $2.9 million.

The costs summarized above were generally based on the published 2016 Caltrans Contract Cost Data and are conceptual (or order of magnitude) Class 5 cost estimates as defined by the Association for the Advancement of Cost Engineering International (AACE) guidance (AACE Publication 56R-08). According to AACE, these estimates are suitable for budgetary or planning purposes and have an expected accuracy -20 to -30 percent to +30 to +50 percent.

2. INTRODUCTION

This report summarizes the results of Geo-Logic Associates' (GLA) evaluation of a landslide that occurred in January 2017 and damaged a portion of Scenic Drive in La Honda, California and forced its closure. The location of the landslide is shown in Figures 1 and 2. The evaluation was prepared in general accordance with GLA's July 7, 2017 proposal to the San Mateo County Department of Public Works (County). The objective of the scope of work described in the proposal was to characterize the landslide and develop preliminary mitigation options and associated order-of-magnitude cost estimates to repair and re-open the road.

2.1 Background

According to the County, evidence of damage to Scenic Drive was first observed on January 11, 2017. That damage included a water main break and pavement cracking within an approximately 280-feet-long segment of Scenic Drive. On January 12, 2017, the County performed temporary road repairs, but progressive landslide-related displacement occurred in the road and affected three adjacent properties at 331, 340, and 345 Scenic Drive over the following week. The locations of the residences and the damaged section of Scenic Driver are shown in Figure 2. The County judged that Scenic Drive could not be repaired and it was closed. The residences were subsequently red-tagged by the County due to damage.

A meeting was held at the site with the County on May 19, 2017 to perform a preliminary reconnaissance before developing a scope of work to evaluate the landslide. During this site visit, a landslide scarp was observed crossing Scenic Drive about 130 feet southwest of Fir View. The scarp traversed westward beneath the house at 345 Scenic Drive and continued northwestward onto property identified as APN 083133200 (no address), where it ended as distributed ground cracking. West of Scenic Drive, the scarp traversed the west-southwest corner of 350 Scenic Drive and continued behind (northeast of) the house at 340 Scenic Drive and downhill (west) from the house on 387 Woodland Vista before crossing Scenic Drive again north of the driveway at 316 Scenic Drive. Ground deformation was observed west and northwest of 331 Scenic Drive. The toe of the landslide was not clearly identified during the May 19 site visit due to brush and tree cover. Damage observed during the site visit included downed power poles and overhead utility lines, ground cracks and vertical offsets on Scenic Drive and private properties, broken buried utility lines, twisted houses and foundations, and lifted driveway slabs.

2.2 Purpose and Scope of Evaluation

As discussed during initial meetings with the County and noted in the GLA's July 7, 2017 proposal, the County's objective is to repair and reopen Scenic Drive to traffic. Our scope of work was designed to collect the data and information necessary to identify potential mitigation measures to meet this objective and included the following:

- Meetings with County representatives to discuss the County's initial observations and actions associated with the landslide;

- An initial site reconnaissance to observe conditions;

- Review of selected geologic maps, aerial photographs, and publications relevant to the landslide;

- Preparation of a project topographic map and digital terrain model (DTM) using drone-based aerial techniques and published Light Detection and Ranging (LiDAR) remote sensing information;

- Completion of geologic mapping and a subsurface investigation program that included soil borings, inclinometer installations, downhole logging, sample collection, and laboratory testing;

- Field monitoring of the inclinometers;

- Office geologic and engineering evaluations to characterize the landslide and develop recommendations and estimated costs for potential mitigation measures to stabilize and reopen the roadway; and

- Preparation of this report.

Evaluation of the damaged residences and an assessment of potential mitigation measures to address these structures were outside the scope of our investigation and were not performed.

3. EVALUATION METHODS

3.1 Data Review

The initial data reviewed for this evaluation was provided by the County and included: aerial images of the project area showing property boundaries, addresses, and APNs of the properties; a Google Map image showing location of the project area; and a vicinity map showing the Scenic Drive landslide and a photograph of the 345 Scenic Drive property. Background information regarding the landslide was also included in the County's May 2, 2017 Request for Proposal.

Other data and information reviewed for this evaluation included relevant published geologic reports, maps, and aerial photographs of the project area. Particularly relevant publications included three U.S. Geological Survey (USGS) publications describing landsliding that occurred between 1998 and 2005 downslope of the current (2017) landslide and that are collectively known as "The Scenic Drive Landslide" (USGS, 1998; 2005; 2006). A geotechnical engineering report prepared by C2Earth (2016) for the homeowner at 345 Scenic Drive was also reviewed.

3.2 Topographic Map Reparation

An aerial drone with a high-resolution camera was used on August 23, 2017 to obtain an aerial photograph of the site and to develop a digital elevation model (DEM) of the landslide and surrounding area. The DEM was used to prepare a topographic base map with 1-foot contour intervals. Figure 4 shows the topography and an aerial photograph of the site.

3.3 Geologic Mapping

The geologic mapping was performed on August 31 and September 1, 2017, using a tape measure, pocket-transit, clinometer, and rangefinder and by referencing existing site features such as telephone poles and storm drain inlets. Surface geologic conditions mapped at the site are shown in Figure 5. The topographic and geologic maps were then used to develop the six geologic cross sections shown in Figure 6.

3.4 Subsurface Exploration

The subsurface exploration program included three large-diameter borings (DH-1, DH-2, and DH-3) and three small-diameter borings (I-1, I-2, and I-3) at the approximate locations shown in Figure 5 (the locations were not surveyed). Tri-Valley Drilling Services, Inc. advanced the large-diameter borings between October 23 and 25, 2017 to depths between 39.5 and 49 feet below ground surface (bgs) using a 30-inch bucket auger drilling rig. A GLA certified engineering geologist (CEG) was lowered down each hole using an OSHA-approved wire-line winch system on the drill rig to allow direct observation of the geologic materials in the subsurface, including landslide debris, bedrock, geologic structure, and the landslide slip plane. Soil samples were collected from the landslide slip plane by hand and retrieved in baggies for use in laboratory testing. Upon completion, the large-diameter borings were backfilled with sand-slurry cement in accordance with San Mateo County Environmental Health Department (SMCEHD) regulations. Soil cuttings were left in piles adjacent to the borings for collection and disposal by the County.

The three small-diameter borings were drilled on November 13 and 14, 2017 using a track-mounted CME 55 drill rig with 8-inch diameter hollow stem augers to total depths that ranged between approximately 24.5 and 35 feet bgs. Soil samples were collected using a 2-inch outside diameter Standard Penetration Test (SPT) split-barrel sampler, a 2.5-inch outside diameter split barrel sampler, or a 3-inch outside diameter split barrel sampler. The samplers were driven by a 140-pound automatic trip hammer falling 30 inches. The number of blows required to drive the sampler was recorded for each 6-inch penetration interval. The number of blows required to drive the sampler the last 12 inches is recorded on the boring logs in Appendix A. Soil samples for laboratory testing were collected in sleeves inside the samplers.

GLA personnel visually classified the materials encountered and maintained a log of each boring. Visual classifications were made in general accordance with the Unified Soil Classification System (ASTM D2487 and D2488) and the results of the laboratory tests were used to verify or revise the field interpretations. Fine-grained soil classification, coarse-grained soil classification, and rock quality description information precedes the boring logs in Appendix A. On completion, the borings were backfilled with cement grout; soil cuttings were left in piles adjacent to the borings for collection and disposal by the County.

3.5 Laboratory Testing

Laboratory tests performed on samples recovered from the borings included moisture content and dry density, grain size distribution (including hydrometer to differentiate the silt and clay fractions of selected subsurface soils), Atterberg limits, unconfined compression, drained residual torsional shear, and drained fully softened peak torsional shear tests. The laboratory test results are included in Appendix B and Table B-1 in Appendix B summarizes the ASTM test methods and the test results. Most of the laboratory results are also shown on the boring logs in Appendix A.

3.6 Inclinometer Installation and Monitoring

Following completion of drilling, Borings I-1, I-2, and I-3 were converted to slope inclinometers by installing 2.75-inch outside diameter grooved casing manufactured by Durham Geo Slope Indicator, Inc. Following placement in the open boring, a tremie line was used to backfill the annulus between the casing and side walls of the boring with cement bentonite grout for inclinometer installation. A protective locking well box was installed at the ground surface at each inclinometer location.

On November 22, 2017, an initial baseline set of readings was collected in each inclinometer and subsequent monitoring was performed on December 12, 2017, and January 9, 18, 30, February 23, March 20, and April 11, 2018. The slope inclinometer readings are included in Appendix C and indicate relatively small maximum cumulate displacements of 0.13 inch in I-1, 0.03 inch in I-2, and 0.14 inch in I-3. The small displacements observed in the inclinometers generally followed heavy rainfall events. Monthly inclinometer monitoring will continue through September 2018.

4. GEOLOGIC SETTING

4.1 Regional Geologic Setting

The project is within the Santa Cruz Mountains of western California. The regional geologic setting is shown on a regional geologic map (Brabb and others, 1998) that was used to prepare the Geologic Index Map (Figure 1) and the Regional Geologic Map (Figure 2). As shown in these figures, bedrock underlying the Santa Cruz Mountains in the Scenic Road area consists mostly of Tertiary-age sedimentary formations, including the Tahana Member of the Purisima Formation (Tpt in Figure 2), the Lambert Shale (Tls), and Monterey Shale (Tm). Volcanic flows of basalt and diabase that are mapped collectively as the Mindego Basalt are interlayered with these formations (Brabb and others, 1998). These rocks were folded and deformed during uplift of the Santa Cruz Mountains and strike-slip faulting associated with the San Andreas fault system. The regional fabric of these bedrock formations trend northwest-southeast through the project area, although regional folding results in a wide variation of mapped stratigraphic orientations throughout the region (Brabb and others, 1998).

4.2 Local Geology

The greater La Honda area and the project site are underlain by the Tahana Member of the Purisima Formation, which consists of greenish-gray to white or buff, medium- to very fine-grained sandstone and siltstone, with some silty mudstone (Brabb and others, 1998). Volcanic rocks of the Mindego basalt are mapped to the north and east of La Honda and areas of Monterey Shale are mapped east of the site. Regional bedding orientation information is limited but the available data indicates beds generally dip between 4 and 17 degrees toward the southwest within the Purisima Formation near the project site (Brabb and others, 1998). None of the bedding attitudes mapped by Brabb and others (1998) are located within this landslide complex described below and identified as "Landslide A" in Figure 3.

4.3 Regional Landsliding[1]

The project area is in an area of known landsliding and published data for San Mateo County (ABAG, accessed online) shows that the La Honda area (including Scenic Drive), lies within areas classified as "mostly landslide." The CGS Seismic Hazard Zone map for the Mindego Hill 7.5-minute quadrangle located adjacent and east of La Honda (there is no CGS Seismic Hazard Zone map for the La Honda quadrangle) shows a relatively high density of large-scale landslides east of La Honda. Considering this information, Google Earth aerial imagery and stereo-paired aerial

[1] Evaluation of regional, large-scale, deep-seated landsliding was outside the scope of this report. The overview of regional geologic landsliding is provided for context to the Scenic Drive investigation. Data sources included Google Earth aerial imagery, stereo paired aerial photographs available at the USGS Menlo Park library, Association of Bay Area Governments (ABAG) maps, California Geological Survey (CGS) seismic hazard zone maps, and online USGS technical poster presentations that document large-scale landsliding that occurred downslope (southwest) of the project site between 1998 and 2005.

photographs taken between 1943 and 1973 were reviewed to assess the possible presence of regional scale deep-seated landsliding near the project.

Previous geologic mapping by Brabb and Pampeyan (1972) of the developed La Honda area east of the La Honda Creek drainage resulted in a conclusion that the area is underlain by a probable deep-seated landslide.

The results of this review indicate the project site and much of the rural residential development in the La Honda area lies on a west-facing plateau (or bench) adjacent to the La Honda Creek drainage to the west and in a low position relative to steep mountain slopes on the north, east, and south. The plateau is characterized by irregular, hummocky terrain and incised drainages and is judged to represent a large landslide based on topography and characteristic landslide geomorphology. This area is shown as Landslide A in Figure 3, and generally conforms to the probable deep-seated landslide mapped by Brabb and Pampeyan (1972). Both the surrounding mountain slopes and the inferred landslide mass are incised with swales and stream drainages, suggesting that the landslide is very old (probably thousands of years).

The aerial photographs indicate a slightly better defined topographic low surrounded by irregular concave slopes near the center of the Landslide A slide mass. This topographic low is interpreted to be a relatively younger, old landslide and is identified as "Landslide B" in Figure 3. The 1973 aerial photographs also indicate a subtle concave depression near the project location that suggests possible prior movement in this area (probably hundreds of years ago).

Three USGS Open File Reports (Jayko et al. 1998; Wells et al. 2005; Wells, et al. 2006) summarized the results of an investigation of a landslide complex that occurred downslope of the current Scenic Drive landslide within the area of Landslide B. Movement of this slide complex began in 1998, with recurrent movement during the winters of 2004-2005 and 2005-2006. This landslide complex cut the lower portion of Scenic Drive and is referred to by the USGS as "The Scenic Drive Landslide" and as the 1998-2006 Scenic Drive Landslide in this report. The USGS has characterized the landslide as a "complex rotational and translational earth and weak rock slump with localized slow earthflow behavior." The current (2017) landslide is located on the upper portion of Scenic Drive upslope of Landslide B in Figure 3 and is believed to be separate from the USGS 1998-2006 Scenic Drive Landslide. The upslope limits of the 1998-2006 Scenic Drive Landslide and the limits of the current (2017) landslide are shown in Figure 4.

5. SITE CONDITIONS

5.1 Geomorphology

As shown by the topographic contours on the Site Geologic Map (Figure 4), the current landslide is situated on a gently inclined bench above steep slopes separating upper and lower sections of Scenic Drive. The lower section of Scenic Drive shown on Figure 4 traverses a repaired section of the 1998-2006 Scenic Drive Landslide from northwest to southeast and the relatively steep slopes shown in Figure 4 form the scarp of the 1998-2006 landslide. The current landslide cuts Scenic Drive at two locations (north and south). On the north side of the landslide, the roadway is cut by paired scarps with a total relief of approximately 10 feet. A well-defined arcuate scarp is present along the east side of the landslide, where the maximum height of the scarp reaches approximately 18 feet. Vertical relief across the scarp decreases progressively to the southwest approaching the southern break in Scenic Drive. The scarp transitions to partitioned thrusts and translational faults where it cuts Scenic Drive at the southern limit of the landslide.

From the northern break in Scenic Drive, the scarp extends northwestward, stepping slightly to the southwest beneath the residence at 345 Scenic Drive. From there, the scarp continues to the northwest and culminates in a series of stepping, en-echelon tears approximately 360 feet northwest of the northern break in Scenic Drive. The linkage of these tears to the toe of the slide is not expressed at the ground surface in this area. Sizeable tension cracks that locally define uphill-facing internal scarps and grabens are present throughout the upper approximately one-quarter of the landslide mass. These scarps and grabens appear to reflect the down-drop of material into voids left behind by block movement away from the head scarp. The toe of the landslide extends northwestward along topographic contour for approximately 405 feet from about 15 feet west of the southern break in Scenic Drive. The toe of the landslide is expressed as an emergent thrust with associated ground cracking of the landslide mass. Back thrusts are locally present within the leading edge of the landslide mass above the toe.

5.2 Subsurface Conditions

Three large-diameter borings were advanced through the landslide mass to characterize the geologic structure of the landslide and underlying geologic materials. Two of the borings were drilled within the damaged section of Scenic Drive (DH-1 and DH-2), and a third boring (DH-3) was drilled through the driveway at 331 Scenic Drive. The borings were situated in a triangular array to allow geometric analysis of any persistent through-going structures encountered in the borings (such as the landslide plane). The three small-diameter borings (I-1, I-2, and I-3) were near large-diameter borings DH-1, DH-2, and DH-3, respectively. Geologic conditions encountered in each of the borings included:

- **Large Diameter Boring DH-1**. This boring was located within the damaged section of Scenic Drive approximately 65 feet south of the northern break in the roadway and in front of the residence at 340 Scenic Drive. Beneath an asphalt pavement section, a layer of colluvium consisting of dark grayish-brown clay was present to a depth of 9 feet below ground surface. Landslide debris consisting of light olive-brown highly sheared and oxidized claystone was present to a depth of 25.7 feet below ground surface. A landslide plane was observed at a depth of 25.7 feet below ground surface and consisted of an approximately 1/2-inch thick layer of medium to dark gray, highly plastic clay. A sample of slide plane material was collected for laboratory testing and the strike and dip of the plane was measured at N17°E/8°W. Relatively fresh, unoxidized, dark greenish gray claystone of the Purisima Formation was encountered directly beneath the landslide plane. The claystone was moderately hard, well-indurated, and thinly laminated. The claystone was underlain by very hard andesite tuff breccia (volcanic rock) of the Mindego Basalt. The contact between the two bedrock units was observed to be very distinct.

- **Small Diameter Boring I-1**. Boring I-1 was located approximately 15 feet south of DH 1. At the surface is a pavement section consisting of about 1 inch of asphalt concrete over about 3 inches of base rock. The pavement section was underlain by colluvium consisting of firm to very stiff fat clay of high plasticity to a depth of about 10 feet bgs. The fat clay was underlain by landslide debris consisting of claystone to a depth of about 20 feet where the landslide plane was encountered. Below the slide plane is Purisima Formation claystone bedrock to a depth of about 34 feet bgs and Mindego Basalt bedrock to the maximum explored depth of about 35 feet bgs where refusal to drilling was encountered.

- **Large Diameter Boring DH-2**. This boring was located within the damaged section of Scenic Drive, approximately 82 feet north of the southern break in Scenic Drive and in front of the driveway to 331 Scenic Drive. A thin layer of colluvium consisting of dark grayish-brown highly plastic clay about 1-foot-thick was present beneath the asphalt pavement section. Landslide debris consisting of gray to dark gray to light olive brown highly sheared and oxidized claystone was present below the colluvium to a depth of 18 feet below ground surface. Shearing within the laminated claystone landslide debris was chaotic and the landslide plane was observed at a depth of about 18.0 feet. The slip plane consisted of an approximately 0.2-foot thick layer of greenish gray, highly plastic, and sheared clay and had a strike and dip of N17°E/9°W. Relatively fresh, unoxidized, dark greenish gray claystone of the Purisima Formation was encountered directly beneath the landslide plane. The claystone was moderately hard, well-indurated, and thinly laminated. The claystone was underlain by very hard andesite tuff breccia of the Mindego Basalt and the contact between the two bedrock units was distinct.

- **Small Diameter Boring I-2**. Boring I-2 was located approximately 11 feet south-southeast of DH-2. At the surface is a pavement section consisting of about 1 inch of asphalt concrete over roughly 3 inches of base rock. The pavement section was underlain by landslide debris consisting of very stiff fat clay of high plasticity to a depth of about 5 feet and claystone to a depth of 16.5 feet bgs where the landslide plane was encountered. Below the slide plane is Purisima Formation claystone bedrock to a depth of about 27.5 feet bgs where the boring encountered refusal to drilling in the Mindego Basalt bedrock.

- **Large Diameter Boring DH-3**. This boring was in the driveway of 331 Scenic Drive. Materials below the concrete driveway of the residence consisted of dark brown highly plastic clay colluvium to a depth of 4 feet bgs. The colluvium was underlain by light olive brown, laminated, highly-sheared, and oxidized landslide debris to a depth of about 18 feet bgs. Shearing within the landslide debris was chaotic and randomly oriented. The landslide plane was observed at a depth of 13.6 feet bgs and consisted of a 3/4-inch thick layer of greenish gray, highly plastic, intensely sheared, and very soft clay gouge. The strike and dip of the landslide plane was measured at N18°E/7°NW and multiple shears were present between 13.6 and 13.9 feet bgs, with a variation in dip between 6 and 11 degrees. Relatively fresh to slightly weathered, unoxidized, dark greenish gray claystone of the Purisima Formation was encountered directly beneath the landslide plane. The claystone is moderately hard, well-indurated, and thinly laminated. The claystone was underlain by very hard andesite tuff breccia of the Mindego Basalt.

- **Small Diameter Boring I-3**. Boring I-3 was located approximately 20 feet south of DH 3. At the surface is an approximately 4-inch-thick section of concrete driveway. The concrete section is underlain by colluvium consisting of very stiff to hard high-plasticity fat clay to a depth of about 10 feet. The fat clay is underlain by landslide debris consisting of claystone to a depth of about 14.5 feet bgs where the landslide plane was encountered. Below the slide plane is Purisima Formation claystone bedrock to a depth of about 23 feet bgs and Mindego Basalt bedrock to the maximum explored depth of about 24.5 feet bgs where refusal to sampling was encountered.

5.3 Engineering Geologic Model

Geologic cross sections through the mapped landslide at the locations in Figure 4 are shown in Figure 5 and were prepared using the topographic map, geologic mapping, and subsurface exploration results. Geologic mapping of the scarp and toe of the landslide combined with intercepts of the slide plane in the exploratory borings were used to constrain the geometry of the landslide. Based on this information, the landslide plane is sub-planar with a dip of approximately 5 to 7 degrees as measured on the cross sections. The landslide geometries shown in the cross sections are consistent with translational sliding (and inconsistent with rotational sliding) when combined with the distribution and magnitude of internal graben structures within the landslide mass. Except for DH-1 and I-1, the landslide planes shown in the cross sections are generally consistent with a geometric 3-point solution using the depths of sliding measured in the large and small diameter borings.[2]

[2] The landslide plane was encountered at approximately 25 feet below ground surface in DH-1 (queried on geologic cross section C-C'), and at approximately 20 feet below ground surface in I-1. Because this discrepancy could not be reconciled, two geometric 3-point solutions were calculated; the first using landslide plane intercepts in DH-1, DH-2, and DH-3, and the second substituting I-1 for DH-1. Using DH-1, the attitude of the slide plane was

As shown on the geologic cross sections, the landslide plane is generally sub-parallel to the bedrock contact between Purisima Formation claystone and the underlying Mindego Basalt. A 3-point geometric solution of the top of the Mindego Basalt indicates the strike and dip of this surface is about N02°W/5°W, which is similar to the strike and dip of the landslide plane. Based on these findings, it appears likely that the landslide plane is sub-parallel to stratigraphy and may be structurally-controlled by bedding. We also note that both the measured attitudes of the landslide plane and the top of the Mindego Basalt generally conform to the shallow (approximately 10 degrees) west-southwest dip direction of regional bedding mapped by Brabb and others (1998). Although the entirety of the landslide is likely underlain by a much larger, ancient deep-seated landslide, such deep-seated landslides can preserve regional structural geometry, especially if sliding occurs along bedding planes.

We also note that our geometric 3-point solutions differ from the strike of the landslide plane measured in-situ in our large-diameter borings, the latter of which consistently yielded a northeast strike (northwest dip direction). We have been unable to account for this discrepancy but have postulated that the magnetic field of the igneous Mindego Basalt may have affected the pocket transit (compass) used to record these measurements in the borings. We also note that measurement of very shallowly inclined surfaces with a hand-held pocket transit can be difficult and is prone to error. Nevertheless, a northwest dip direction of the landslide plane, and associated movement of the landslide in that direction, is inconsistent with the geometry of the landslide plane and the kinematic indicators that are clearly defined by our geologic mapping, subsurface exploration, and geologic cross sections.

The previous information indicates the 2017 landslide consists of re-activated ancient (Ols) landslide debris partially because the highly weathered and oxidized landslide debris contrasts sharply with the relatively intact, fresh to slightly weathered, un-oxidized claystone of the Purisima formation immediately below the landslide plane. In general, a contrast in geologic materials above and below a relatively thin, discrete, and well-developed clay gouge zone (the landslide plane) are associated with a well-developed landslide and are atypical of recent movement.

Highly weathered, oxidized, and crushed claystone in a sandy clay matrix was observed in the head scarp of the landslide. This material is very similar to the landslide debris observed in the borings and suggests that the landslide plane extends beyond the head scarp in the subsurface. Therefore, the geologic cross sections project the landslide plane back into the scarp as a queried contact beneath "older landslide deposits" (Ols in Figure 5). The lateral extent of the older landslide deposits beyond the scarp (to the north and west) could not be evaluated based on the aerial photographs reviewed for this study. However, based on the location of the

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calculated to be N06°W/4°W. Using I-1, the attitude of the landslide plane was calculated to be N14°W/7°W. The variation in strike and dip between the two solutions is small and is judged unlikely to affect the geologic model in a significant way. The variation in dip (between 4 and 7 degrees) generally conforms to the inclinations of the landslide planes measured directly on the cross sections (5 to 7 degrees). The latter solution (I-1/DH-2/DH-3) was incorporated into the cross sections because it resulted in a slightly steeper slide plane inclination of 7 degrees.

project area within a much larger old, deep-seated landslide (Landslide A, Figure 3), it is likely that the older landslide deposits are remnants of a pre-existing landslide and that the geomorphic features such as the scarp and toe have eroded.

5.4 Groundwater

Saturated ground was observed at the ground surface at the toe of the landslide between approximately 20 and 90 feet northwest of Scenic Drive when geologic mapping was performed on August 31 and September 1, 2017. During drilling for the large-diameter borings between October 23 and 25, 2017, abundant seepage was observed within the landslide debris and directly at the landslide plane in borings DH-1, DH-2, and DH-3 (no free-standing groundwater was encountered or observed in the large diameter borings). Free water was observed in samples collected near the landslide plane in small diameter borings I-1, I-2, and I-3 that were drilled on November 13-14, 2017. No free-standing ground water was encountered in the small diameter borings.[3]

5.5 Interpretation of Cause

The results of evaluation indicate the current landslide affecting Scenic Drive occurred within an old landslide deposit and that it moved on a pre-existing slide plane that consisted of weak, clayey soil. The results of laboratory testing and the comparative stability analyses described in Section 6 indicate rising groundwater levels and/or transient pore water pressures in response to precipitation or other factors such a pipe breaks or leaks could decrease stability sufficiently to trigger movement. This information suggests that high groundwater and/or pore water pressures were likely contributing factors to the landslide. Evidence of high groundwater and seepage at the site include:

- The landslide occurred between January 11 and 12, 2017 following heavy rains during an unusually wet winter. The USGS (1998, 2005, 2006) noted a correlation of ground movements with precipitation and that heavy rains during the winter of 1998 resulted in the “Scenic Drive Landslide” downslope of the current (2017) landslide;

- As part of this investigation, the May 2, 2017 County Task Order contained the following information from a C2Earth report and the Cuesta La Honda Guild letter provided by a property owner. In 2014 a leak occurred at a water meter at Fir View and Judson Drive about 100 feet upslope of the landslide. The Task Order states that the leak was not fixed for nearly 2 years and that over 1 million gallons of water may have been lost during that time. It is possible that water from this leak infiltrated the ground and

[3] It should be noted that groundwater levels are subject to seasonal fluctuations depending on rainfall, pumping, local irrigation, or other factors. The geologic mapping and subsurface exploration took place between late summer and late fall 2017 at the end of the dry season and before the onset of any significant rain during fall 2017. Some drainage of landslide mass probably occurred between the winter of 2017 and the late summer-early fall field investigation and the conditions observed in the field may not be representative of conditions at other times of the year.

affected the area of the landslide (the leak location is approximately along the projection of Geologic Section F-F’ through the central portion of the landslide parallel to the dip direction of the landslide plane and bedding);

- A November 11, 2016 geotechnical engineering report prepared by C2Earth for the homeowner at 345 Scenic Drive noted that the homeowner’s residence had “become increasingly distressed since the past winter” (the winter of 2015-2016) and that free-standing groundwater was encountered at a depth of approximately 17 feet below the ground surface in two exploratory pits excavated by C2Earth on July 27, 2016. The pits were left open over the summer and revisited on October 26, 2016, when groundwater levels were measured between 13.8 and 14.9 feet below ground surface in the pits. During exploratory drilling of two borings conducted by C2Earth on August 26, 2016, groundwater was measured at about 16 and 21 feet below ground surface;

- Seepage at the toe of the landslide was observed during geologic mapping in August and September 2017. Seepage was also observed in the large-diameter exploratory borings in October 2017, including: (i) saturated conditions in landslide debris at 17 feet below ground surface and abundant seepage approximately 20 feet below ground surface in DH-1; (ii) wet conditions and free water flowing along fracture surfaces in landslide debris and immediately below the slide plane in DH-2; and (iii) wet conditions and seepage from factures in DH-3. In addition, saturated conditions were observed in samples collected from two small diameter exploratory borings (I-1 and I-2) that were advanced in November 2017.

6. CONCEPTUAL REPAIR ALTERNATIVES

6.1 Identification of Potentially Feasible Repair Concepts

Potential mitigation measures for the roadway presented in this report are limited to repairs that can be achieved within the County's Scenic Drive right-of-way. Therefore, repairs that would extend beyond these limits such as excavation of the slide mass, benching the subgrade, installing subdrains, and rebuilding the slope with engineered fill were not evaluated. Based on these constraints, conceptual mitigation measures that could be performed within the right-of-way include:

- **Option 1 – Grading Repair**. This option consists of excavating a portion of the landslide mass to a depth below the slide plane from slightly east, or upslope, of Scenic Drive to slightly west, or downslope, of the roadway and replacing it with geogrid-reinforced, engineered soil fill. Drainage including subdrains should be incorporated into the design and installed before placing the engineered fill.

- **Option 2 – Stitch Piers**. Stitch piers are drilled, cast-in-place, reinforced concrete piers spaced closely enough for soil arching to eliminate a need for lagging between the piers. For the purposes of evaluating effectiveness and estimated costs, this option assumes a single row of stitch piers with a diameter of 2.5 feet, a center-to-center spacing of 5 feet, a total length of 36 feet, and 16 feet below the slide plane would be installed along the upslope side of Scenic Drive.

- **Option 3 – Combined Grading Repair and Stitch Piers.** Although Options 1 and 2 each increase the safety factor of the slope to over 1.5, each has limitations if implemented by itself.[4] Therefore, a combined option that includes excavation and replacement of a portion of the slide mass and stitch piers was also included for evaluation.

A conventional soldier pile and lagging wall on the downslope side of Scenic Drive was also considered but judged infeasible because of safety and constructability concerns with the excavation required to install the lagging.

It should be noted that these options are conceptual and intended to assess feasibility and planning level estimates of costs for repair of Scenic Drive only. We note that portions of the

[4] For example, the Option 1 grading repair would require an excavation up to about 20 feet down to the slide plane, followed by backfilling of the excavation with a geogrid reinforced engineered fill and a subsurface drainage system. The sides of the excavation will need to be sloped at a safe inclination or be shored during construction. If construction is only allowed within the Scenic Drive right-of-way, sloping would not be possible and shoring the upslope wall of the excavation would be required. If implemented in conjunction with the stitch piers, however, the piers would provide shoring for this portion of the excavation. Stitch piers by themselves probably would not represent a long-term roadway mitigation measure unless the slide debris is removed and replaced to reduce the potential for future downslope movement of the roadway.

landslide upslope and downslope of the Scenic Drive right-of-way will not be improved with any of these options. Design of the repairs was not included in the scope of this investigation.

6.2 Comparative Slope Stability Analyses

Comparative slope stability analyses were performed to identify a representative shear strength for use in the assessment of conceptual measures to repair Scenic Drive and to calculate the relative effectiveness of the repair concepts based on before-repair and after-repair safety factors. It is important to note that the stability analyses were performed for comparative purposes and do not provide an existing safety factor for the slope. The stability analyses were based on Cross Section F-F’ (Figure 5) because it crosses the landslide at a central location, the trend of the section is parallel to the dip direction of the landslide, and the section intercepts boring DH-3.

6.2.1 Method of Analysis

The computer program SLOPE/W, version 8.16.4 (GeoStudio, 2016) was used for the analyses. SLOPE/W is a two-dimensional slope stability analysis program based on limit equilibrium methods to evaluate the stability of circular or non-circular failure surfaces in soil or rock slopes. The safety factor calculations were performed for fully specified failure surfaces along the pre-defined failure plane in Section F-F’ using the Morgenstern-Price method of analysis. Search routines for critical circular failure surfaces were also assessed. Static analyses were performed; an assessment of seismic stability was outside the scope of this evaluation and was not performed.

Section F-F’ was first evaluated using the approximate pre-slide ground surface topography for a back-calculation of the mobilized shear strength of the slide plane material. Back-analysis of the landslide was performed based on the procedures described in Duncan Wright, and Brandon (2014) and Hussain et al. (2010). In the back-analysis, the earth material along the landslide plane was assumed to have zero cohesion and the friction angle of the landslide plane material was varied until a safety factor of about 1.0 was achieved. The shear strength developed by the back-analysis represents the approximate shear strength of the landslide plane material at the time of slide failure. Section F-F’ was then evaluated using the post-slide topography for comparative analyses to assess conceptual remediation alternatives discussed in Section 7 of this report.

6.2.2 Groundwater Conditions

Groundwater is frequently a contributing factor to landslide mobilization. For purposes of the back-analysis to calculate the slide plane mobilized shear strength, it is conservative to assume a lower phreatic surface (Hussain et al., 2010). Therefore, the back-analysis simulations were performed with an assumed groundwater surface beneath the slide plane. The comparative analyses performed to assess the conceptual remediation alternatives assumed three groundwater scenarios: (i) groundwater surface below the slide plane; (ii) a groundwater surface midway between the slide plane and the ground surface; and (iii) groundwater at the ground surface. These surfaces are shown in the slope stability analyses output in Appendix D.

6.2.3 Material Properties

The soil properties assumed for analysis are summarized in Table 6.2-1 and consisted of:

- Colluvium;
- Landslide debris;
- Landslide slip plane material;
- Claystone of the Purisima Formation;
- Mindego Basalt; and
- Engineered fill for re-construction of Scenic Drive.

Unit weights were based on the laboratory testing and soil shear strengths were assumed based on soil stiffness encountered in the borings and engineering judgement. The shear strength of the slide plane material was based on a back-calculated friction angle of 10 degrees. This value compares well to empirical correlations (Stark and Hussain, 2012) that indicate a drained secant residual friction angle of about 11.5 degrees at low normal stress for the sample of slide plane soil from boring DH-1 that had a liquid limit of 84 percent and clay content of 60 percent. This value also correlates reasonably well with the torsional ring shear data provided in Appendix B. The torsional ring shear testing resulted in an average peak fully softened friction angle of 19.3 degrees and an average residual friction angle of 6.5 degrees.[5] Unit weight and shear strength of the engineered fill were based on typical properties of commonly available engineered fill material for reconstruction of Scenic Drive. All materials were modeled using drained shear strengths with zero cohesion.

Table 6.2-1 – Summary of Material Properties Assumed for Analysis

Material	Total Unit Weight (pcf)	Cohesion (psf)	Friction Angle (degs)
Colluvium	110	0	25
Landslide Debris	108	0	25
Claystone, Purisima (Tpt)	119	0	30
Slide Plane Material	100	0	10
Basalt (Tmb)	135	0	35
Engineered Fill	130	0	34

The geogrid reinforcement in the grading repair with geogrid-reinforced, engineered soil fill option was assumed to have a design tensile strength of 2,000 pounds, a vertical spacing of

[5] Ring shear results are inherently conservative as the material tested is remolded to a paste and is tested at the Liquid Limit. Also, if the ring shear residual strength was accurate, the existing slide mass would have failed well before the 2016/2017 rainy season. We believe using the back-calculated slide plane friction value of 10 degrees is sufficiently conservative for the purposes of our analysis.

2 feet, and horizontal installation. Pullout resistance was calculated internally by the model based on soil friction angle. Note that the material assumptions and spacing of the geogrid reinforcements are for conceptual analysis only. The type, vertical spacing, length, and minimum tensile strength of the geogrids should be determined in the final design phase.

The stitch piers were modelled with a force of 45,000 pounds acting on each stitch pier except for during construction when the factor of safet6y was lower than 1.0. A factor of safety of 1.0 was achieved when the force on each stitch pier was increased to 50,000 pounds. The stitch piers have a diameter of 2.5 feet and an in-plane center-to-center spacing of 5 feet. The actual force and required reinforcement in the stitch piers should be determined during the final design phase.

The weight of the house at 331 Scenic Drive was conservatively assumed to be zero. This assumption is conservative because the house resides near the toe of the slide mass and contributes to resisting forces to the slide mass.

6.2.4 Results of Analysis

The results of the stability analyses are summarized in Table 6.2-2 and the SLOPE/W outputs below are included in Appendix D. The results indicate the repair concepts should result in safety factors greater than 1.5 if full drainage provisions are incorporated into the design. The results also indicate excavation and replacement of the landslide debris below Scenic Drive should be performed in sections and that trench-shoring or other stabilization methods may be required during construction.

TABLE 6.2-2 SUMMARY OF SLOPE STABILITY ANALYSIS

Topography	Groundwater Condition	Calculated Factor of Safety				
		No Repair	Stitch Piers Only	RSE[1] Under Scenic Drive only	Stitch Piers with Construction Excavation	Stitch Piers and RSE with Slide Mass
Pre-slide (back-analysis)	Below slide plane	1.0	NA	NA	NA	NA
Post-slide	Below slide plane	1.36	1.63	1.81	1.0[3]	2.18
	Mid-way between Ground Surface & Slide Plane	1.0	1.20	1.62	NA	NA
	Ground Surface	0.56	0.67	1.45	NA	NA

Notes:
1. RSE denotes reinforced soil embankment consisting of engineered fill reinforced with geogrid to replace existing soil under the entire width of Scenic Drive.
2. All repairs will require a subsurface drainage system to achieve a drained soil condition. Design of the subsurface drainage system should be performed during the final engineering design phase.
3. Based on a force of 50,000 pounds acting on the stitch piers.

6.3 Conceptual Design of Alternatives

6.3.1 Option 1 – Grading Repair

Because the landslide under Scenic Drive is relatively thin (about 13 to 20 feet below the road surface), a grading repair involving removal of the landslide debris and backfilling the excavations with engineered fill and subsurface drains is a potential method to restore the road. With repair work limited to within the Scenic Drive right-of-way, the landslide mass upslope and downslope of the repaired road section would still remain. As discussed in Section 6.2, "Comparative Slope Stability Analyses," of this report, we back calculated the shear strength of the soil along the landslide plane at a factor of safety of 1.0. We then replaced the soil column under Scenic Drive with geogrid-reinforced, engineered soil fill having soil properties presented in Table 6.3-1 below. The results of our slope stability analysis suggest an increase in factor of safety from approximately 1.0 to 1.8 under a drained site condition, requiring a subsurface drain system to lower and maintain the groundwater level below the landslide plane.

The current County's repair plan does not include the private properties upslope and downslope of Scenic Drive. The repaired Scenic Drive would help "buttress" the existing landslide mass upslope of the repaired section. The landslide mass downslope of Scenic Drive would receive no "buttressing" effect from the repaired road section and is susceptible to future downslope movements. Therefore, geogrids should be incorporated within the engineered fill section for the grading repair of Scenic Drive. The objective of the geogrids is to create a reinforced soil embankment in the event that movement of the downslope landslide mass occurs. The type, length, and vertical spacing of the geogrid should be determined during the final engineering design of the grading repair scheme.

Stability of the landslide mass during construction was evaluated by modeling a row of stitch piers along the upslope side of Scenic Drive with an excavation immediately on the downslope side of the stitch piers. By applying a lateral force of 50,000 pounds on the stitch piers, a factor of safety of 1.0 was calculated. This safety factor is considered marginal and, in our opinion, the grading repair along Scenic Drive should be performed in relatively short sections to reduce the risk of the upslope landslide mass moving into the grading repair excavations which could affect the properties above the existing landslide scarp. The repair work should also be performed by equipment capable of reaching below the landslide plane without personnel entering the excavations.

The colluvium and landslide debris to be excavated from Scenic Drive consist of fat clay and claystone, both having high plasticity. These materials should not be re-used as engineered fill to backfill the road repair excavations. Material for backfilling the road repair excavations should have the following engineering properties.

Table 6.3-1 – Shear Strength of Road Repair Engineered Fill

Property	Value
Total density at 90% relative compaction	130 pcf
Soil friction angle, effective	34 degrees
Soil cohesion, effective	0 psf
Geosynthetic reinforcement tensile capacity	2,000 lbs
Geosynthetic reinforcement vertical spacing	2 ft

A subsurface drainage system should be installed to drain groundwater from the slide plane and overlying materials. The subsurface drainage system should be designed during the final engineering phase.

6.3.2 Option 2 – Stitch Piers

Stich piers are drilled, cast-in-place, reinforced concrete piers that are spaced closely enough for soil arching effects to provide a retaining function without relying on lagging. Typical center-to-center spacing of stitch piers is between 2 and 2½ times the pier diameter.

Our preliminary conceptual analysis indicates a single row of stitch piers with a diameter of 2.5 feet and a center-to-center spacing of 5 feet along the upslope side of Scenic Drive would increase the factor of safety of the landslide from 1.0 to approximately 1.6 under a drained site condition, requiring a subsurface drain system to lower and maintain the groundwater level below the landslide plane. Our preliminary analysis also indicates the length of the 2.5-foot diameter piers would be at least 36 feet below the road surface (at least 16 feet below the landslide plane). During the final design phase, the diameter, center-to-center spacing, and length of the stitch piers should be determined as well as their structural reinforcement.

The stitch piers option by itself does not address road surface repair or reconstruction to allow for traffic passage. Therefore, stitch piers should be considered in conjunction with the grading repair discussed above.

6.3.3 Option 3 – Combined Grading Repair and Stitch Piers

Although the grading repair only alternative (Option 1) or the stitch piers only alternative (Option 2) increases the factor of safety to over 1.5, these alternatives have some limitations if implemented alone. For Option 1 only, the grading repair would require an excavation up to about 20 feet deep or more to the slide plane, followed by a subsurface drainage system and backfilling of the excavation with a geogrid reinforced engineered fill. The sides of the excavation will need to be sloped at a safe inclination or be shored during construction. If construction is only allowed within the Scenic Drive right-of-way, sloping of the excavation walls would not be possible and the walls would have to be shored. The stitch piers would provide the shoring during construction of the engineered fill under Scenic Drive.

For Option 2 only, the stitch piers would retain the upslope landslide mass, essentially eliminating the driving force on Scenic Drive. However, the roadway needs to be repaired for traffic access, which may involve fill that would tend to destabilize the soils below the road. Unless the roadway repair extends below the slide plane, there is a potential for slide below Scenic Drive to remobilize, especially when the downslope slide mass moves in the future. Constructing a reinforced soil embankment along Scenic Drive with the stitch piers repair alternative would address these issues.

It is envisioned the repair would involve construction of the stitch piers along the upslope side of Scenic Drive, followed by excavation of Scenic Drive in sections, or slot cuts[6], and construction of the reinforced soil embankment to restore the roadway.

6.4 Preliminary Repair Cost Estimates

We have developed an opinion of probable construction costs for the implementation of the three repair alternatives using the 2016 Caltrans Contract Cost Data book. The estimates are considered as Class 5 cost estimates to provide very conceptual, or order of magnitude costs. The expected accuracy of these cost estimates would provide budgetary cost ranging from -20 to -30 percent to +30 to +50 percent. This information is based on the criteria set by the AACE (AACE Publication 56R-08).

Because design plans and specifications for the repair methods have not been prepared, our cost estimates are based on assumptions listed in Tables 6.4-1, 6.4-2, and 6.4-3 below. The cost estimates do not include costs for removal of trees, removal of overhead utilities, removal and reinstallation of underground utilities, traffic control during construction, and other factors not listed below. Actual costs should be solicited from contractors when the repair alternative is selected and the final design completed.

Table 6.4-1 – Cost Estimates for Grading Repair Alternative (Option 1)

Length of Scenic Drive to be repaired	350 feet
Additional length of repair beyond each end	25 feet
Average width of roadway to be repaired	16 feet
Average depth of repair	18 feet
Width of previous backfill	1 foot
New pavement section	4” AC/8” Cl 2 AB
Number of geogrid layers	9
Estimated Cost – grading repair only	$1.5M

[6] Slot cutting refers to a process of excavating a limited width of soil in an incremental manner to reduce the chances of back-cut instability. Adjacent slots are not excavated at the same time. An example is excavating a 100-foot wide section, leaving the next 100-foot wide section in place, then excavating the next 100-foot wide section, etc. The subsurface drainage and the geogrid-reinforced, engineered soil fill would be constructed in the excavated slots, then the adjacent slot would be excavated.

Table 6.4-2 – Cost Estimates for Stitch Piers Repair (Option 2)

Pier diameter	2.5 feet
Center to center pier spacing	5 feet
Average total pier depth	40 feet
Number of piers	81
Estimated Cost - stitch piers only	$1.5M

Table 6.4-3 – Combined Grading Repair and Stitch Pier (Option 3)

Estimated Cost – stitch piers with grading repair	$2.9M

7. LIMITATIONS

In preparing the findings and professional opinions presented in this report, we have endeavored to follow generally accepted principles and practices of the engineering geologic and geotechnical engineering professions in the area and at the time our services were performed. No warranty, express or implied, is provided.

The conclusions and recommendations contained in this report are based, in part, on information that has been provided to us. In the event that the provided information is modified or new information becomes available, our conclusions and recommendations shall not be considered valid unless we are retained to review the changes or new information and to make any necessary additions or changes to our recommendations. To remain as the project geotechnical engineer-of-record, GLA must be retained to provide geotechnical services as discussed under the Post-report Geotechnical Services section of this report.

Subsurface exploration is necessarily confined to selected locations and conditions may, and often do, vary between these locations. Should conditions different from those described in this report be encountered during project development, GLA should be consulted to review the conditions and determine whether our recommendations are still valid. Additional exploration, testing, and analysis may be required for such evaluation.

Should persons concerned with this project observe geotechnical features or conditions at the site or surrounding areas which are different from those described in this report, those observations should be reported immediately to GLA for evaluation.

It is important that the information in this report be made known to the design professionals involved with the project, that our recommendations be incorporated into project drawings and documents, and that the recommendations be carried out during construction by the contractor and subcontractors. It is not the responsibility of GLA to notify the design professionals and the project contractors and subcontractors.

The findings, conclusions and recommendations presented in this report are applicable only to the specific project development on this specific site. These data should not be used for other projects, sites, or purposes unless they are reviewed by GLA or a qualified geotechnical professional.

We appreciate the opportunity to be of service on this project.

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Aerial Photographs

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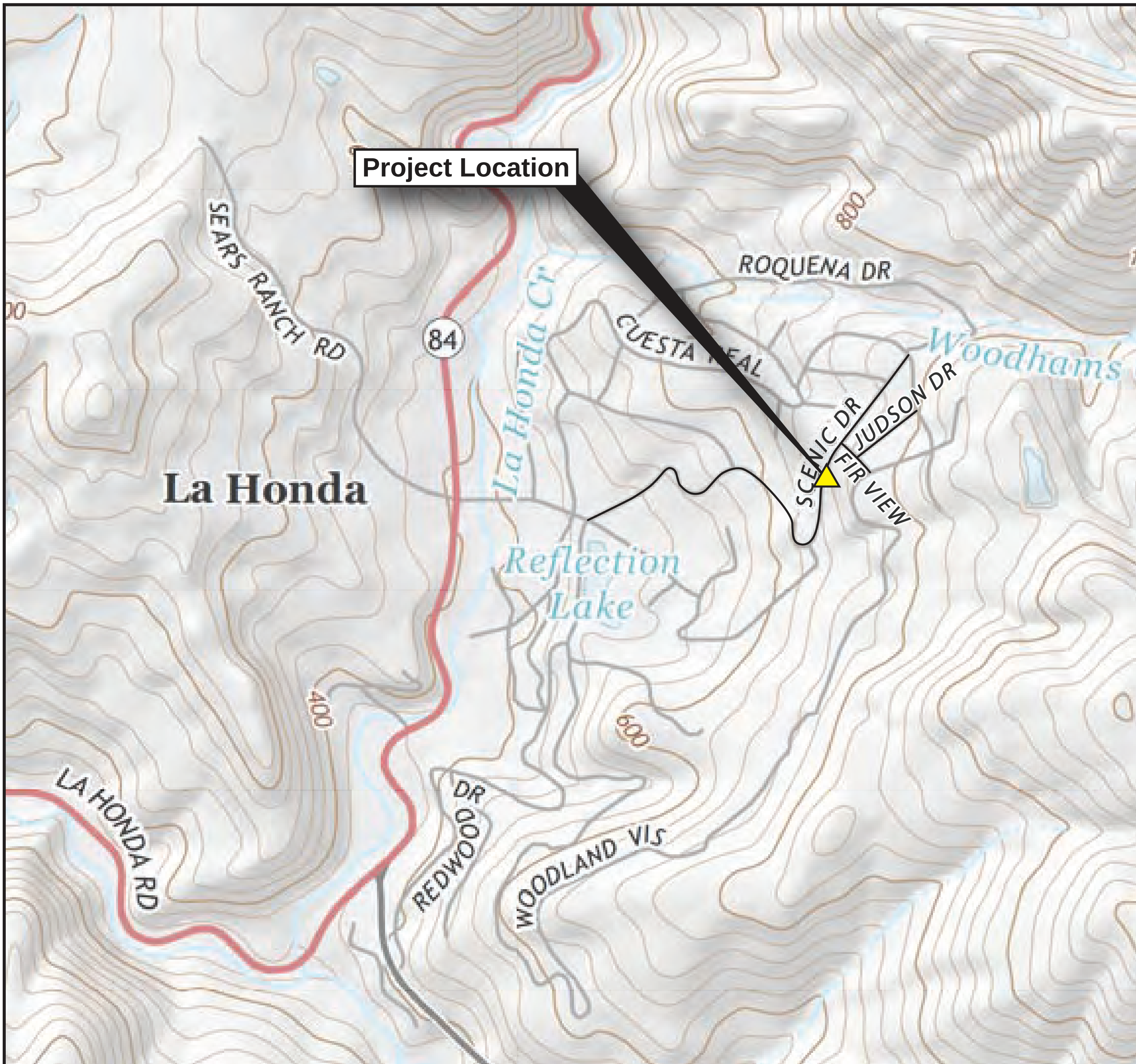
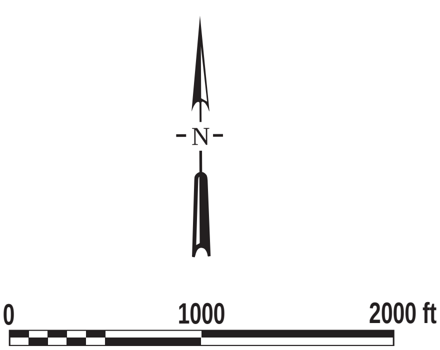
1960. Series GS-VACY-2, frames 168 & 169; black & white, taken 08/23/60; scale 1:30,000

1973. Series 3567-4, frames 098 & 099; black & white, taken 06/07/73; scale 1:12,000





Geo-Logic
ASSOCIATES

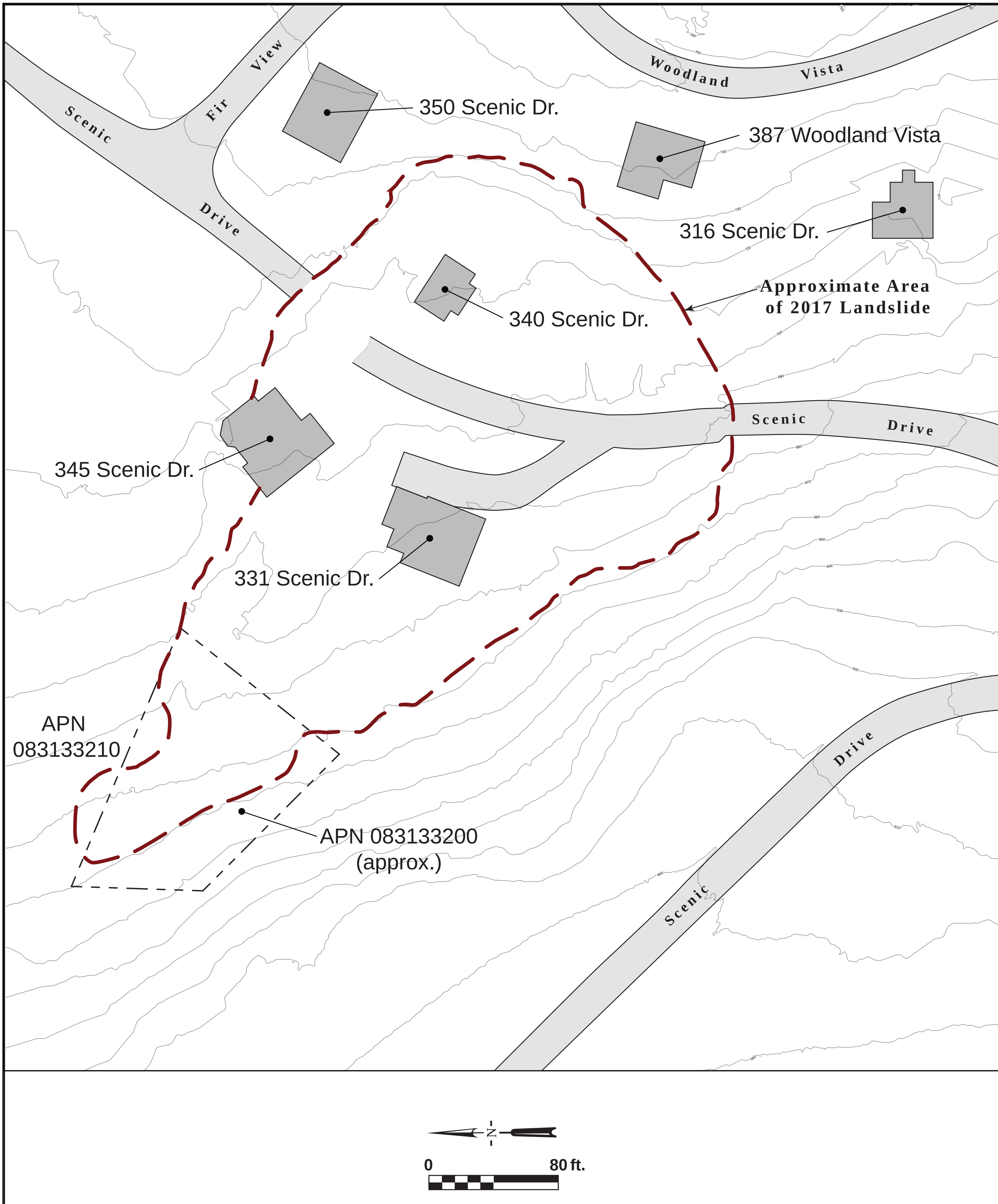
Drafted By:	GDG
Date:	May 2018
Checked By:	JF
Revision:	

VICINITY MAP

SCENIC DRIVE
SAN MATEO COUNTY, CALIFORNIA

FIGURE
1

PROJECT
PA17.1039.00



Geo-Logic ASSOCIATES	Drafted By: GDG	SITE PLAN	FIGURE 2
	Date: May 2018	SCENIC DRIVE SAN MATEO COUNTY, CALIFORNIA	PROJECT PA17.1039.00
	Checked By: JF		
	Revision:		

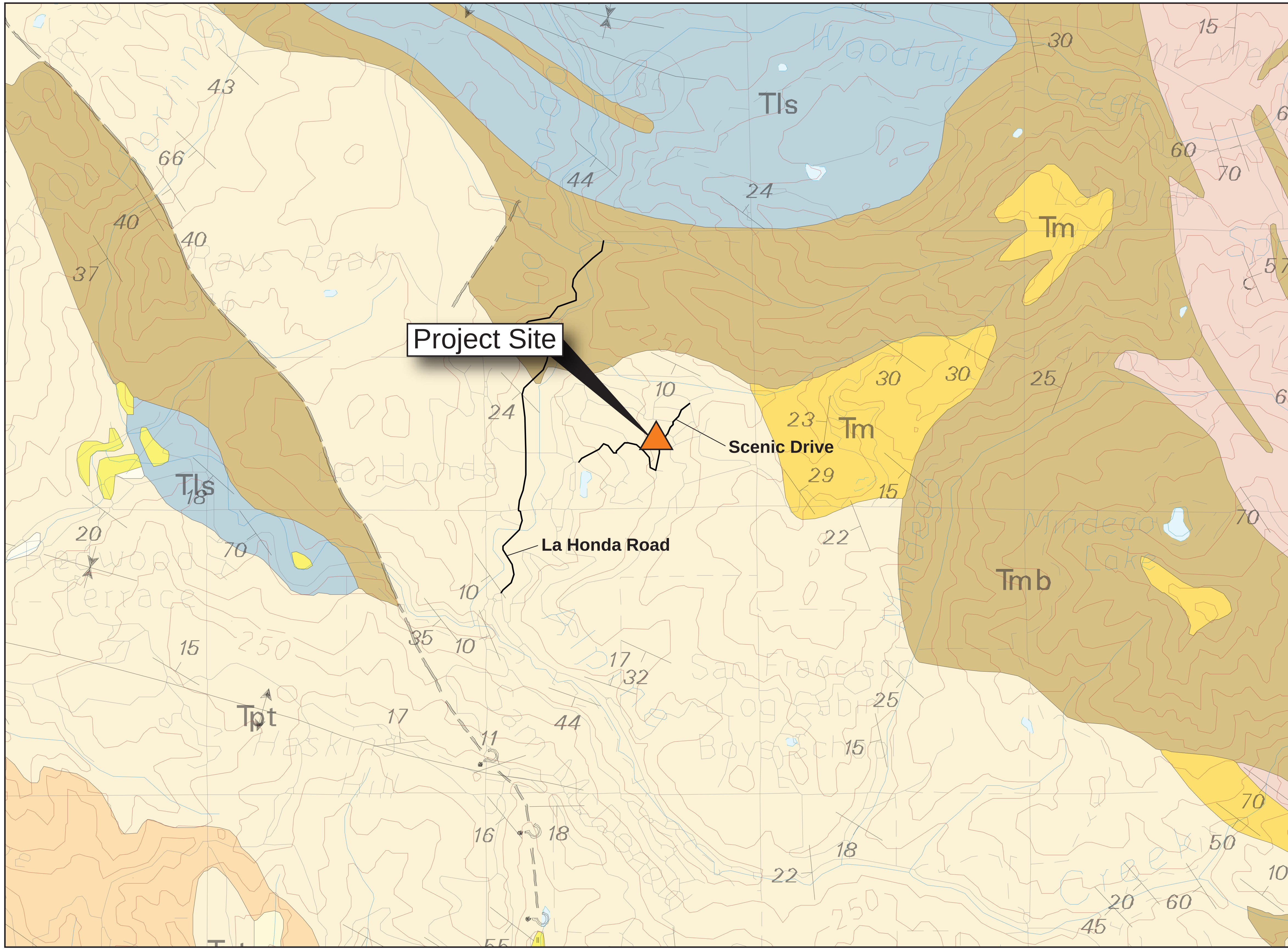
EXPLANATION

EARTH MATERIALS

Tpt	Purisima Formation, Tahana Member (Pliocene and upper Miocene)
Tm	Monterey Formation (middle Miocene)
Tls	Lambert Shale (lower Miocene)
Tmb	Mindego Basalt (Miocene and/or Oligocene)

SYMBOLS

- Contact - Depositional or intrusive contact, dashed where approximately located, dotted where concealed
- Fault - Dashed where approximately located, small dashes where inferred, dotted where concealed, queried where location is uncertain.
- Reverse or Thrust Fault - Dotted where concealed
- Anticline - Shows fold axis, dotted where concealed
- Syncline
- 35 Strike and dip of bedding
- Overturned bedding
- Flat bedding
- Vertical bedding
- 35 Strike and dip of foliation
- Vertical foliation
- 35 Strike and dip of joints in plutonic rocks
- Vertical joint



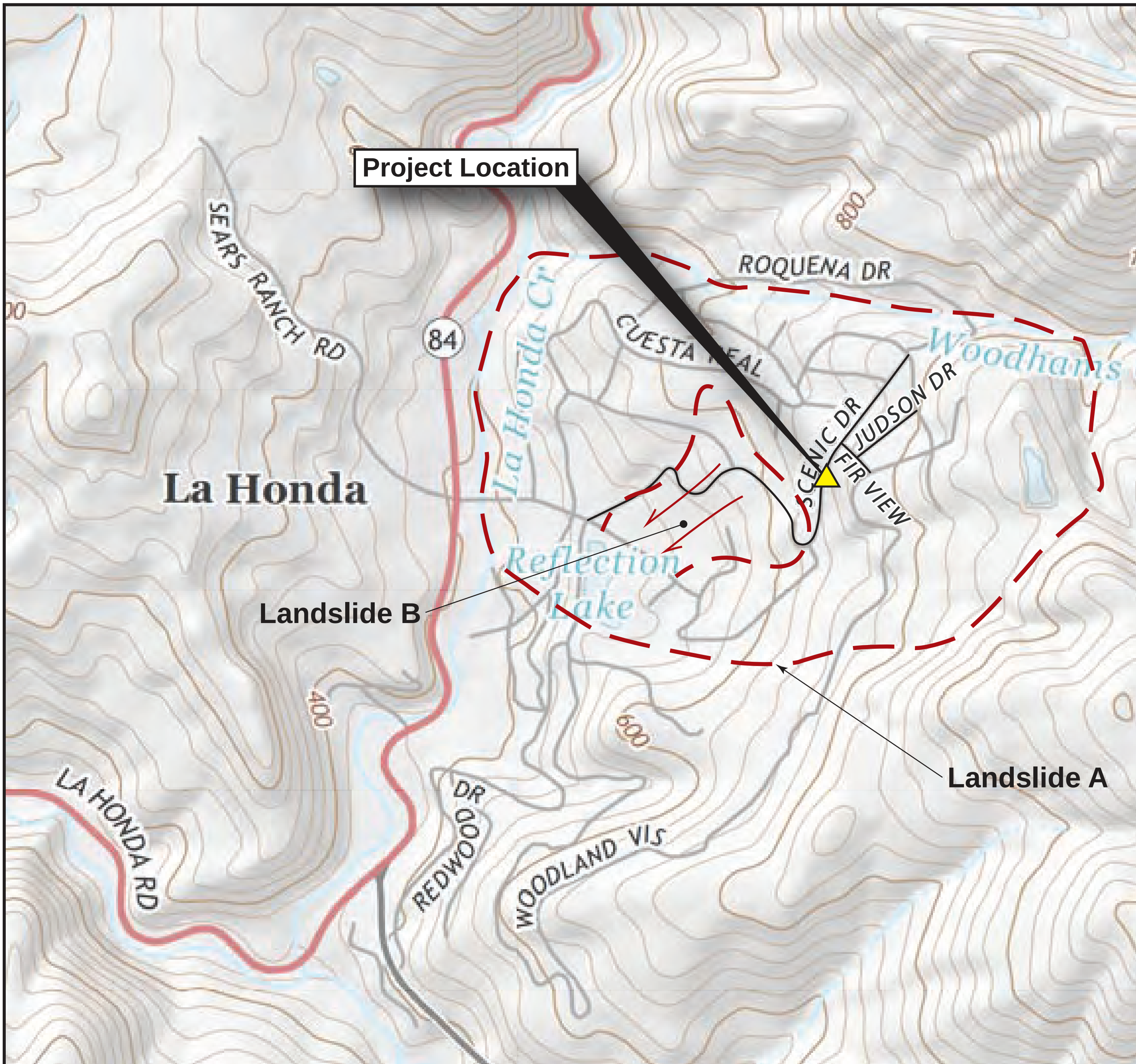
Base Map: Brabb, Graymer, and Jones, 1998

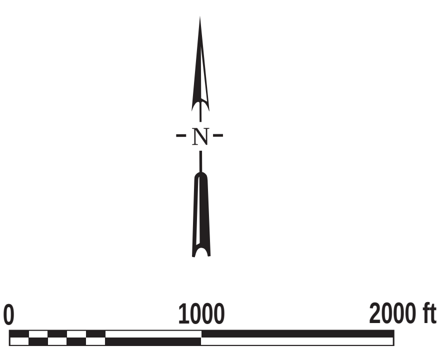
0 2,000 4,000
Scale in Feet

N

Geo-Logic ASSOCIATES

Drafted By: GDG	SCENIC DRIVE LANDSLIDE REGIONAL GEOLOGIC MAP	FIGURE 3	
Date: May 2018			
Checked By: JF	SAN MATEO COUNTY CALIFORNIA	PROJECT PA17.1039.00	
Revision:			





Probable landslide, arrows indicate approximate direction of movement.

Geo-Logic
ASSOCIATES

Drafted By:	GDG
Date:	May 2018
Checked By:	JF
Revision:	

LA HONDA AREA LANDSLIDE MAP

SCENIC DRIVE
SAN MATEO COUNTY, CALIFORNIA

FIGURE
4

PROJECT
PA17.1039.00

Geo-Logic ASSOCIATES

Drafted By: GDG	SITE GEOLOGIC MAP	FIGURE 5
Date: May 2018	SCENIC DRIVE	PROJECT
Checked By: JF	SAN MATEO COUNTY, CALIFORNIA	PA17.1039.00
Revision:		

Geo-Logic ASSOCIATES	Drafted By: GDG	GEOLOGIC CROSS SECTIONS	FIGURE 6
	Date: May 2018		
	Checked By: JF	SCENIC DRIVE SAN MATEO COUNTY, CALIFORNIA	PROJECT PA17.1039.00
	Revision:		

APPENDIX A

KEYS TO SOIL CLASSIFICATION, ROCK QUALITY DESCRIPTIONS,

AND

BORING LOGS

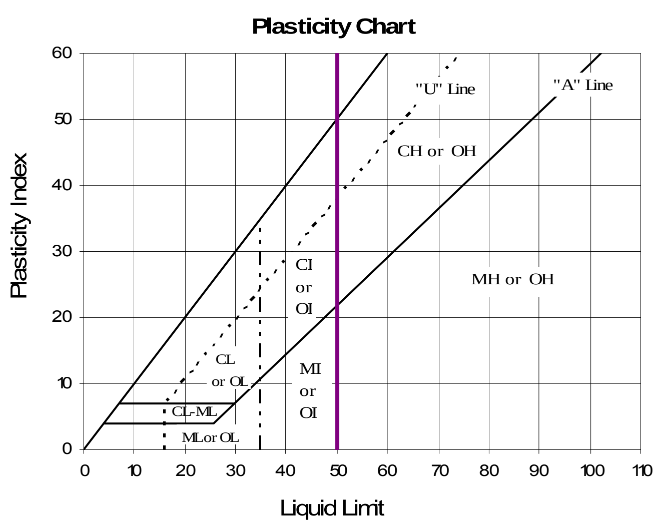
KEY TO SOIL CLASSIFICATION - FINE GRAINED SOILS
(50% OR MORE IS SMALLER THAN NO. 200 SIEVE SIZE)
(modified from ASTM D2487 to include fine grained soils with intermediate plasticity)

MAJOR DIVISIONS			GROUP SYMBOLS	GROUP NAMES
SILTS AND CLAYS (Liquid Limit less than 35) Low Plasticity	Inorganic	PI < 4 or plots below “A” line	ML	Silt, Silt with Sand or Gravel, Sandy or Gravelly Silt, Sandy or Gravelly Silt with Sand or Gravel
	Inorganic	PI > 7 or plots on or above “A” line	CL	Lean Clay, Lean Clay with Sand or Gravel, Sandy or Gravelly Lean Clay, Sandy or Gravelly Lean Clay with Sand or Gravel
	Inorganic	PI between 4 and 7	CL-ML	Silty Clay, Silty Clay with Sand or Gravel, Sandy or Gravelly Silty Clay, Sandy or Gravelly Silty Clay with Sand or Gravel
	Organic	See footnote 3	OL	Organic Silt (below “A” Line) or Organic Clay (on or above “A” Line) (1,2)
SILTS AND CLAYS (35 ≤ Liquid Limit < 50) Intermediate Plasticity	Inorganic	PI < 4 or plots below “A” line	MI	Silt, Silt with Sand or Gravel, Sandy or Gravelly Silt, Sandy or Gravelly Silt with Sand or Gravel
	Inorganic	PI > 7 or plots on or above “A” line	CI	Clay, Clay with Sand or Gravel, Sandy or Gravelly Clay, Sandy or Gravelly Clay with Sand or Gravel
	Organic	See footnote 3	OI	Organic Silt (below “A” Line) or Organic Clay (on or above “A” Line) (1,2)
SILTS AND CLAYS (Liquid Limit 50 or greater) High Plasticity	Inorganic	PI plots below “A” line	MH	Elastic Silt, Elastic Silt with Sand or Gravel, Sandy or Gravelly Elastic Silt, Sandy or Gravelly Elastic Silt with Sand or Gravel
	Inorganic	PI plots on or above “A” line	CH	Fat Clay, Fat Clay with Sand or Gravel, Sandy or Gravelly Fat Clay, Sandy or Gravelly Fat Clay with Sand or Gravel
	Organic	See note 3 below	OH	Organic Silt (below “A” Line) or Organic Clay (on or above “A” Line) (1,2)

1. If soil contains 15% to 29% plus No. 200 material, include “with sand” or “with gravel” to group name, whichever is predominant.
2. If soil contains ≥30% plus No. 200 material, include “sandy” or “gravelly” to group name, whichever is predominant. If soil contains ≥15% of sand or gravel sized material, add “with sand” or “with gravel” to group name.
3. Ratio of liquid limit of oven dried sample to liquid limit of not dried sample is less than 0.75.

CONSISTENCY	UNCONFINED SHEAR STRENGTH (KSF)	STANDARD PENETRATION (BLOWS/FOOT)
VERY SOFT	< 0.25	< 2
SOFT	0.25 – 0.5	2 – 4
FIRM	0.5 – 1.0	5 – 8
STIFF	1.0 – 2.0	9 – 15
VERY STIFF	2.0 – 4.0	16 – 30
HARD	> 4.0	> 30

MOISTURE	CRITERIA
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, but no visible water
Wet	Visible free water, usually soil is below the water table



GEO-LOGIC ASSOCIATES

KEY TO SOIL CLASSIFICATION – COARSE GRAINED SOILS

(MORE THAN 50% IS LARGER THAN NO. 200 SIEVE SIZE)

(modified from ASTM D2487 to include fines with intermediate plasticity)

MAJOR DIVISIONS			GROUP SYMBOLS	GROUP NAMES[1]
GRAVELS (more than 50% of coarse fraction is larger than No. 4 sieve size)	Gravels with less than 5% fines	$Cu \geq 4$ and $1 \leq Cc \leq 3$	GW	Well Graded Gravel, Well Graded Gravel with Sand
		$Cu < 4$ and/or $1 > Cc > 3$	GP	Poorly Graded Gravel, Poorly Graded Gravel with Sand
	Gravels with 5% to 12% fines	ML, MI or MH fines	GW-GM	Well Graded Gravel with Silt, Well Graded Gravel with Silt and Sand
			GP-GM	Poorly Graded Gravel with Silt, Poorly Graded Gravel with Silt and Sand
		CL, CI or CH fines	GW-GC	Well Graded Gravel with Clay, Well Graded Gravel with Clay and Sand
			GP-GC	Poorly Graded Gravel with Clay, Poorly Graded Gravel with Clay and Sand
	Gravels with more than 12% fines	ML, MI or MH fines	GM	Silty Gravel, Silty Gravel with Sand
		CL, CI or CH fines	GC	Clayey Gravel, Clayey Gravel with Sand
		CL-ML fines	GC-GM	Silty Clayey Gravel; Silty, Clayey Gravel with Sand
SANDS (50% or more of coarse fraction is smaller than No. 4 sieve size)	Sands with less than 5% fines	$Cu \geq 6$ and $1 \leq Cc \leq 3$	SW	Well Graded Sand, Well Graded Sand with Gravel
		$Cu < 6$ and/or $1 > Cc > 3$	SP	Poorly Graded Sand, Poorly Graded Sand with Gravel
	Sands with 5% to 12% fines	ML, MI or MH fines	SW-SM	Well Graded Sand with Silt, Well Graded Sand with Silt and Gravel
			SP-SM	Poorly Graded Sand with Silt, Poorly Graded Sand with Silt and Gravel
		CL, CI or CH fines	SW-SC	Well Graded Sand with Clay, Well Graded Sand with Clay and Gravel
			SP-SC	Poorly Graded Sand with Clay, Poorly Graded Sand with Clay and Gravel
	Sands with more than 12% fines	ML, MI or MH fines	SM	Silty Sand, Silty Sand with Gravel
		CL, CI or CH fines	SC	Clayey Sand, Clayey Sand with Gravel
		CL-ML fines	SC-SM	Silty, Clayey Sand; Silty, Clayey Sand with Gravel

US STANDARD SIEVES 3 Inch ¾ Inch No. 4 No. 10 No. 40 No. 200

	COARSE	FINE	COARSE	MEDIUM	FINE	
COBBLES & BOULDERS	GRAVELS		SANDS			SILTS AND CLAYS

RELATIVE DENSITY (SANDS AND GRAVELS)	STANDARD PENETRATION (BLOWS/FOOT)
Very Loose	0 - 4
Loose	5 – 10
Medium Dense	11 – 30
Dense	31 - 50
Very Dense	50+

1. Add “with sand” to group name if material contains 15% or greater of sand-sized particle. Add “with gravel” to group name if material contains 15% or greater of gravel-sized particle.

MOISTURE	CRITERIA
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, but no visible water
Wet	Visible free water, usually soi is below the water table

GEO-LOGIC ASSOCIATES

ROCK QUALITY DESCRIPTIONS

HARDNESS**

Very Hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of the geologist's pick
Hard	Can be scratched with knife or pick only with difficulty. Hard blow with hammer required to break sample.
Moderately Hard	Can be scratched with knife or pick. Gouges or grooves to ½ inch can be excavated by hard blow of point of a geologist's pick. Hand specimens broken with moderate blow.
Medium	Can be grooved or gouged 1/16 inch deep by firm pressure on knife or pick point. Can be excavated in small chips about 1 inch maximum in dimension by hard blows of the point of a geologist's pick.
Soft	Can be grooved or gouged readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small pieces can be broken by finger pressure,
Very Soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces one inch or more thickness can be broken with finger pressure. Can be scratched readily by finger nail.

FRACTURE DIMENSIONS*

Fracture	Block Size (or Spacing[1])
Crushed	~5 microns to 0.1 ft
Intensely	0.05 to 0.1 ft
Closely	0.1 to 0.5 ft
Moderately	0.5 to 1.0 ft
Slightly	1.0 to 3.0 ft
Massive	3.0 ft and larger

WEATHERING**

Fresh or Unweathered	Rock fresh, crystals bright, few joints and fractures may show slight staining. Rock rings under hammer if crystalline.
Very Slight	Rock generally fresh, fractures and joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock generally fresh, joints and fractures stained, and discoloration extends into rock up to 1 inch. Joints may contain clay. In granitic rock, some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitic rock, most feldspars are dull and discolored; some show clay. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately Severe	All rock except quartz discolored or stained. In granitic rock, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick. Rock goes "clunk" when struck.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitic rock, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very Severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil." Rock "fabric" not discernible or discernible only in small scattered locations. Quartz may be present as dikes or stringers.

1 Average distance between adjacent fractures

* Source of data unknown

** Source of data: "Subsurface Investigaiton for Design and Constructio of Foundation Buildings," (1976) American Society of Civil Engineers, Manuals and Reports on Engineering Practice – No. 5

GEO-LOGIC ASSOCIATES

DATE: 11/13/2017	LOG OF EXPLORATORY BORING	I-1

PROJECT NAME: Scenic Drive Landslide	**PROJECT NUMBER:** PA17.1039
DRILL RIG: CME 55, 140-pound automatic trip hammer	**LOGGED BY:** BT
HOLE DIAMETER: 6" hollow stem auger	**HOLE ELEVATION:** ±706.5
SAMPLER: D = 3" OD, 2½" ID Split-spoon X = 2½" OD, 2" ID Split-spoon I = Standard Penetrometer (2" OD SPT) S = Slough in sample	**GROUND WATER DEPTH:** Initial: --- Final: ---

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
PAVEMENT SECTION: 1" AC over 3" base rock	CH	1										
COLLUVIUM: **FAT CLAY:** Dark grayish brown (10YR 4/2) to very dark brown (10YR 2/2), moist, very stiff		2	S D D	8	3.75			34		77		
		3										
		4										
		5										
Very dark brown (10YR 2/2) to black (10YR 2/1), moist, firm		6	S D D	7	1.0		74	37	51	82	4	1785
		7										
		8										
		9										
		10										
LANDSLIDE DEBRIS: **CLAYSTONE:** Light olive brown (2.5Y 5/4), moist, soft rock, sheared, 1" fracture spacing, slightly weathered, iron oxide staining on fracture surfaces		11	S D D	21			68	35	41	82	2	7243
		12										
		13										
		14										
		15										
dark grayish brown (2.5Y 4/2), moist, soft rock, moderately weathered, sheared, minor sand and fine gravel, abundant iron oxide staining		16	S D D	20				32		89		
		17										
		18										
		19										
landslide plane at ±20 feet		20										

DATE: 11/13/2017	LOG OF EXPLORATORY BORING	I-1
PROJECT NAME: Scenic Drive Landslide		PROJECT NUMBER: PA17.1039
DRILL RIG: CME 55, 140-pound automatic trip hammer		LOGGED BY: BT
HOLE DIAMETER: 6" hollow stem auger		HOLE ELEVATION: ±706.5

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: --- Final: ---

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
BEDROCK: PURISIMA FORMATION: CLAYSTONE: Dark greenish gray (10Y 4/1), moist, soft rock, very slightly weathered, 1" fracture spacing, free water on fracture surfaces			S D									
		21	D S	24				34		86		
		22	I I	13								
		23										
		24										
		25	S									
		26	D D	40								
		27										
		28										
		29										
sandy		30	S									
		31	I I	75/ 10"								
		32										
MINDEGO BASALT: ANDESITE TUFF BRECCIA: Very hard drilling at 34 ft; refusal at 35 ft		33										
		34										
BOTTOM OF HOLE = 35 Feet No groundwater encountered. Note: installed 2.75-inch DGSI Slope Inclinometer Casing		35										
		36										
		37										
		38										
		39										
		40										

DATE: 11/13/2017	LOG OF EXPLORATORY BORING	I-2

PROJECT NAME: Scenic Drive Landslide	**PROJECT NUMBER:** PA17.1039
DRILL RIG: CME 55, 140-pound automatic trip hammer	**LOGGED BY:** BT
HOLE DIAMETER: 6" hollow stem auger	**HOLE ELEVATION:** ±696
SAMPLER: D = 3" OD, 2½" ID Split-spoon X = 2½" OD, 2" ID Split-spoon I = Standard Penetrometer (2" OD SPT) S = Slough in sample	**GROUND WATER DEPTH:** Initial: --- Final: ---

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
PAVEMENT SECTION: 1" AC over 3" base rock	CH											
LANDSLIDE DEBRIS: FAT CLAY: Light olive brown (2.5Y 5/4), moist, very stiff		1	S									
		2	D D	18	3.75			29		92		
		3										
		4										
CLAYSTONE: Light olive brown (2.5Y 5/4), moist, soft rock, sheared, slightly weathered, iron oxide staining on fracture surfaces		5	S									
		6	D D	13	3.5		56	32	36	86		
		7										
		8										
		9										
1 inch fracture spacing, moderately weathered,		10	S									
		11	D D	7				42		73		
		12										
		13										
		14										
		15	S									
as above, landslide plane at 16.5 ft, free water at base of landslide debris		16	D D	5								
BEDROCK: PURISIMA FORMATION: CLAYSTONE: Dark greenish gray (10Y 4/1), moist, soft rock, very slightly weathered, interbeds of fine to medium grained SANDSTONE		17	S X	11								
		18	X S									
		19	I I	35								
		20	S									

DATE: 11/13/2017	LOG OF EXPLORATORY BORING	I-2

PROJECT NAME: Scenic Drive Landslide **PROJECT NUMBER:** PA17.1039

DRILL RIG: CME 55, 140-pound automatic trip hammer **LOGGED BY:** BT

HOLE DIAMETER: 6" hollow stem auger **HOLE ELEVATION:** ±696

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: --- Final: ---

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
BEDROCK: PURISIMA FORMATION: CLAYSTONE: as above, sandy, thinly bedded			D	50/4"				21		102		
		21	S I I	47								
		22										
		23										
		24										
		25	S									
		26	I I	70/6"								
drilling refusal at 27.5 ft on **ANDESITE TUFF BRECCIA (Mindego Basalt)**		27										
BOTTOM OF HOLE = 27.6 Feet No groundwater encountered Note: installed 2.75-inch DGSI Slope Inclinometer Casing		28										
		29										
		30										
		31										
		32										
		33										
		34										
		35										
		36										
		37										
		38										
		39										
		40										

DATE: 11/14/2017	LOG OF EXPLORATORY BORING	I-3

PROJECT NAME: Scenic Drive Landslide **PROJECT NUMBER:** PA17.1039

DRILL RIG: CME 55, 140-pound automatic trip hammer **LOGGED BY:** BT

HOLE DIAMETER: 6" hollow stem auger **HOLE ELEVATION:** ±690.5

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: --- Final: ---

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
PAVEMENT SECTION: 4" concrete												
COLLUVIUM: FAT CLAY: Very dark brown (10YR 2/2), moist, hard, with rootlets	CH	1	S									
		2	D D	16	4.5+			21		96		
		3										
		4										
		5	S									
dark grayish brown (10YR 4/2), moist, very stiff		6	D D	15	3.5			31		87	4	3197
		7										
		8										
		9										
		10	S									
LANDSLIDE DEBRIS: CLAYSTONE: Light yellowish brown (2.5Y 6/4), moist, soft rock, sheared, severely weathered to FAT CLAY		11	D D	5			79	61	48	60		
		12	S X									
- iron oxide on fracture surfaces		13	X S	3								
- harder and less weathered, highly sheared fracture spacing is 0.5"		14	I I	5								
- landslide plane at 14.5' :FAT CLAY: light brownish gray (10YR 6/2) moist, very soft, intensely sheared; 0.75-1" thick		15	S	(drained torsion shear test @ 14.5 ft, see Figs. B-9 & B-10)								
		16	D D	80/ 11"				28		93		
BEDROCK: PURISIMA FORMATION: CLAYSTONE: Dark greenish gray (10Y 4/1), moist, soft rock, very slight weathering		17										
		18										
		19										
		20										

DATE: 11/14/2017	LOG OF EXPLORATORY BORING	I-3

PROJECT NAME: Scenic Drive Landslide **PROJECT NUMBER:** PA17.1039

DRILL RIG: CME 55, 140-pound automatic trip hammer **LOGGED BY:** BT

HOLE DIAMETER: 6" hollow stem auger **HOLE ELEVATION:** ±690.5

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: --- Final: ---

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
BEDROCK: PURISIMA FORMATION: CLAYSTONE: as above			D	50/5.5"								
		21										
		22										
		23										
MINDEGO BASALT: ANDESITE TUFF BRECCIA: Hard drilling at 23 ft, hard rock fargments recovered in sample		24	I	50/4.5"								
BOTTOM OF HOLE = 24.4 Feet No groundwater encountered		25										
Note: installed 2.75-inch DGSI Slope Inclinometer Casing		26										
		27										
		28										
		29										
		30										
		31										
		32										
		33										
		34										
		35										
		36										
		37										
		38										
		39										
		40										

DATE: 10/23/2017	LOG OF EXPLORATORY BORING	DH-1

PROJECT NAME: Scenic Drive Landslide **PROJECT NUMBER:** PA17.1039

DRILL RIG: Calweld 150H Bucket Auger Volvo 4x6 **LOGGED BY:** BT/JF/MV

HOLE DIAMETER: 30" **HOLE ELEVATION:**

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: 17' Final: NA

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
COLLUVIUM: **FAT CLAY:** Dark grayish brown (10YR 4/2), highly plastic with minor amounts of sand to pebble size, angular fragments of claystone, with abundant roots and carbonized plant fragments	CH	1										
		2										
(bottom of protective casing at 3 ft)		3										
		4										
		5										
		6										
		7										
		8										
LANDSLIDE DEBRIS: **CLAYSTONE:** Light olive brown (2.5Y 5/4), highly sheared, thinly laminated, shearing is randomly oriented and individual shears are cross cutting, only traceable over short distances		9										
		10										
		11										
		12										
		13										
		14										
15-16.5' abundant small scale shears filled with Fe-oxide, randomly oriented		15										
		16										
@ 17' saturated conditions		17										
		18										
@ 19-23' high angle shear (N42˚w/78˚N) @ 19.6' abundant seepage on north side of boring and minor seepage on east side of boring		19										
		20										

DATE: 10/23/2017	LOG OF EXPLORATORY BORING	DH-1

PROJECT NAME: Scenic Drive Landslide | **PROJECT NUMBER:** PA17.1039

DRILL RIG: Calweld 150H Bucket Auger Volvo 4x6 | **LOGGED BY:** BT/JF/MV

HOLE DIAMETER: 30" | **HOLE ELEVATION:** 0

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: 17' Final: NA

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
LANDSLIDE DEBRIS: (as above)		21										
		22										
Landslide plane at 25.7'; 1/2" thick medium to drak gray FAT CLAY, highly plastic; irregular and non-planer surface oriented N17˚/ 8˚W		23										
		24										
loose, crushed above landslide plane		25				97	84		52			
<u>BEDROCK</u>: **PURISIMA FORMATION: CLAYSTONE:** Dark greenish gray (10Y 4/1), wet, moderately hard, slightly weathered to fresh, thinly laminated @ 25.7' - 26.8'; high-angle shear oriented N28˚E/ 57˚W		26										
		27										
		28										
@28.9' bedding, N14˚E / 9˚W, sheared clay parallel to bedding		29										
		30										
@ 31.2' bedding contact very fine sandy siltstone		31										
		32										
		33										
MINDEGO BASALT: ANDESITE TUFF BRECCIA: olive gray (5YR 4/2) to yellowish brown (10YR 5/4); fine-grained phaneritic to aphanitic andesite clasts with minor to abundant sanidine(?), amphibole and pyroxene phenocrysts; hard rock , drilling refusal at 40 feet		34										
		35										
		36										
		37										
		38										
		39										
		40										
BOTTOM OF HOLE = 40 Feet												

DATE: 10/25/2017	LOG OF EXPLORATORY BORING	DH-2

PROJECT NAME: Scenic Drive Landslide **PROJECT NUMBER:** PA17.1039

DRILL RIG: Calweld 150H Bucket Auger Volvo 4x6 **LOGGED BY:** MV/BT

HOLE DIAMETER: 30" **HOLE ELEVATION:**

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: **Initial:** 4 - 6' **Final:** NA

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
COLLUVIUM: FAT CLAY: Dark grayish brown (10YR 4/2), with sand to gravel-size angular fragments of claystone	CH	1										
		2										
LANDSLIDE DEBRIS: CLAYSTONE: Gray (5Y 5/1) to dark gray (5Y 4/1) with light olive brown (2.5Y 5/4), highly sheared, thinly laminated; shearing is very chaotic		3										
		4										
@ 4' very wet		5										
@ 6' free water flowing along fracture surfaces		6										
		7										
@ 8.4' landslide debris changes to very fine clayey sand; matrix coarsens with depth, claystone fragments within		8										
		9										
		10										
		11										
		12										
- @15.6' to 18.15' abundant groundwater uncemented sandstone with rip-up clasts and fining upward graded sequence; bedding oriented N14°E / 9°W		13										
		14										
- Landslide Plane @ 17.95' to 18.15': CLAY greenish gray(5GY 5/1), highly plastic, sheared; approximately 0.2' thick; oriented N17°E/9°NW; strong iron-oxide staining at bottom of landslide plane		15										
		16										
		17										
		18										
BEDROCK: PURISIMA FORMATION: CLAYSTONE: Dark greenish gray (10Y 4/1), moderately hard, slightly weathered to fresh, thinly laminated		19										
		20										

DATE: 10/25/2017	LOG OF EXPLORATORY BORING	DH-2

PROJECT NAME: Scenic Drive Landslide   PROJECT NUMBER: PA17.1039

DRILL RIG: Calweld 150H Bucket Auger Volvo 4x6   LOGGED BY: MV/BT

HOLE DIAMETER: 30"   HOLE ELEVATION: 0

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: 4 - 6' Final: NA

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
BEDROCK: PURISIMA FORMATION: CLAYSTONE: as above - High-angle shear truncated by landslide plane @ 18-20': oriented N58˚W/83˚S; N48˚W/66˚N; N19˚W/ 61˚E @ 24.6' shear oriented N28˚W/54˚E		21 22 23 24 25 26										
MINDEGO BASALT: ANDESITE TUFF BRECCIA: Fine-grained phaneritic to aphanitic andesite clasts with minor to abundant plagioclase, amphibole and pyroxene phenocrysts; ranges in color from light yellowish brown (10YR 6/4) to olive (5Y 5/3) and olive gray (5Y 4/2) depending on degree of oxidation; upper contact is marked by 1/16" thick clay layer likely resulting from flexural slip; ~ abundant chaotic healed fractures with calcium carbonate in filing at 29' very hard below 33 ft		27 28 29 30 31 32 33 34 35 36 37 38 39										
BOTTOM OF HOLE = 39.5 Feet		40										

GEO-LOGIC ASSOCIATES   PAGE: 2 of 2

DATE: 10/23/2017	LOG OF EXPLORATORY BORING	DH-3

PROJECT NAME: Scenic Drive Landslide **PROJECT NUMBER:** PA17.1039

DRILL RIG: Calweld 150H Bucket Auger on 1998 Volvo 4x6 **LOGGED BY:** MY/BT

HOLE DIAMETER: 30" **HOLE ELEVATION:** ±690.5

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: 7' Final: NA

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
COLLUVIUM: FAT CLAY: Dark brown (10YR 4/2), moderately sorted, with few to little amount of sand and pebble size clasts of angular siltstone	CH	1										
		2										
		3										
LANDSLIDE DEBRIS: CLAYSTONE: Light yellowish brown (2.5Y 6/4), angular fragments, thinly laminated; chaotically oriented in a plastic clay matrix		4										
		5										
		6										
@7' wet		7										
		8										
LANDSLIDE DEBRIS: CLAYSTONE: Light Olive brown (2.5Y 4/5), highly sheared, thinly laminated, shearing is chaotic and randomly oriented		9										
		10										
		11										
Dark gray (5Y 4/1), moderately to highly sheared , thinly laminated with abundant strong brown (7.5YR 5/6) oxidized fractures producing abundant seepage		12										
		13										
		14										
LANDSLIDE PLANE (13.6' to 13.9'): Greenish gray (5GY 5/1), highly plastic, intensely sheared, very soft clay gouge approximately 3/4" thick with multiple shears below oriented N18˚E / 7˚NW; dip varies from 6˚ - 11˚ between uppermost and lowermost shears		15										
		16										
		17										
		18										
BEDROCK: PURISIMA FORMATION: (see next page)		19										
		20										

DATE: 10/23/2017	LOG OF EXPLORATORY BORING	DH-3

PROJECT NAME: Scenic Drive Landslide — **PROJECT NUMBER:** PA17.1039

DRILL RIG: Calweld 150H Bucket Auger on 1998 Volvo 4x6 — **LOGGED BY:** MY/BT

HOLE DIAMETER: 30" — **HOLE ELEVATION:** ±690.5

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: 7' Final: NA

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
BEDROCK: PURISIMA FORMATION: CLAYSTONE: Dark greenish gray (10Y 4/1), well indurated, moderately hard, slightly weathered to fresh, thinly laminated		21										
		22										
MINDEGO BASALT: ANDESITE TUFF BRECCIA: Olive gray (5Y 4/2) to pale brown (10YR 6/3) and yellowish brown (10YR 5/16), fine-grained phaneritic to aphanitic and site clasts with minor to abundant sanidine(?) phenocrysts, with minor fragments of thinly banded welded tuff		23										
		24										
		25										
		26										
		27										
		28										
@26 - 30'; oxidized fracture producing groundwater seepage		29										
@27 - 30'; calcite-healed fractures 1/32" - 1/4" think, oriented approx N73˚W/57˚SW		30										
		31										
		32										
		33										
		34										
		35										
		36										
@37.3 - 39' subparallel shears healed with calcium carbonate oriented N87˚E/28˚SE		37										
		38										
		39										
		40										

DATE: 10/23/2017	LOG OF EXPLORATORY BORING	DH-3

PROJECT NAME: Scenic Drive Landslide **PROJECT NUMBER:** PA17.1039

DRILL RIG: Calweld 150H Bucket Auger on 1998 Volvo 4x6 **LOGGED BY:** MY/BT

HOLE DIAMETER: 30" **HOLE ELEVATION:** ±690.5

SAMPLER:
D = 3" OD, 2½" ID Split-spoon
X = 2½" OD, 2" ID Split-spoon
I = Standard Penetrometer (2" OD SPT)
S = Slough in sample

GROUND WATER DEPTH: Initial: 7' Final: NA

DESCRIPTION OF EARTH MATERIALS	SOIL TYPE	DEPTH (ft)	SAMPLE	BLOWS PER FOOT	POCKET PEN (tsf)	% PASSING #200 SIEVE	LIQUID LIMIT	WATER CONTENT	PLASTICITY INDEX	DRY DENSITY (pcf)	FAILURE STRAIN (%)	UNCONFINED COMPRESSIVE STRENGTH (psf)
MINDEGO BASALT: ANDESITE TUFF BRECCIA: (as above)												
		41										
		42										
		43										
		44										
		45										
		46										
		47										
		48										
		49										
BOTTOM OF HOLE = 49 Feet												
		50										
		51										
		52										
		53										
		54										
		55										
		56										
		57										
		58										
		59										
		60										

APPENDIX B

LABORATORY TEST RESULTS

ATTERBERG LIMITS

Summary Report

ASTM D-4318

Geo-Logic ASSOCIATES

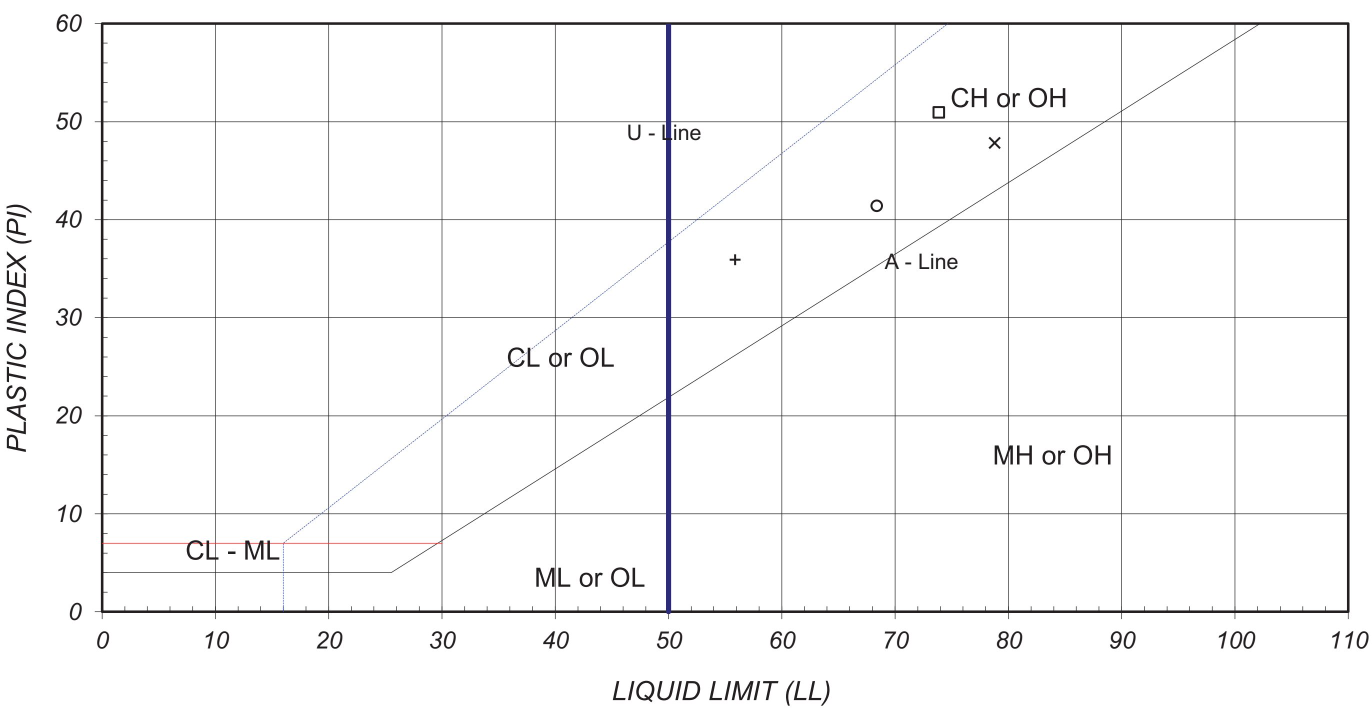
Client:	Project No:	Lab Log No.:
Pacific Geotechnical Engineering	PA17.1039.00	4324

Project Name:	Report Date:
San Mateo Scenic Drive Landslide	January 17, 2018

LSN	SYMBOL	SAMPLE IDENTIFICATION	SAMPLE DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	PLASTIC INDEX
4324B	□	I-1 @ 6'	dark gray brown fat clay	74	23	51
4324C	○	I-1 @ 11'	gray brown fat clay w/ sand	68	27	41
4324G	+	I-2 @ 6'	gray brown fat clay w/ sand	56	20	36
4324L	x	I-3 @ 11'	brown fat clay w/ sand	79	31	48

* Visual Classification based on ASTM D-2488

PLASTICITY CHART



This testing is based upon accepted industry practice as well as the test method listed. These results apply only to the samples supplied and tested for the above referenced job.

L : Labexcel \ Projects \ Client \ Pacific Geotech \ PA17.1039.00 \ 4324

Print Date:	Entered By:	Reviewed By:	LLN:
01/17/18	PP	JL	4324

DCN: PI-rp (rev. 9/18/12)

Figure B-1

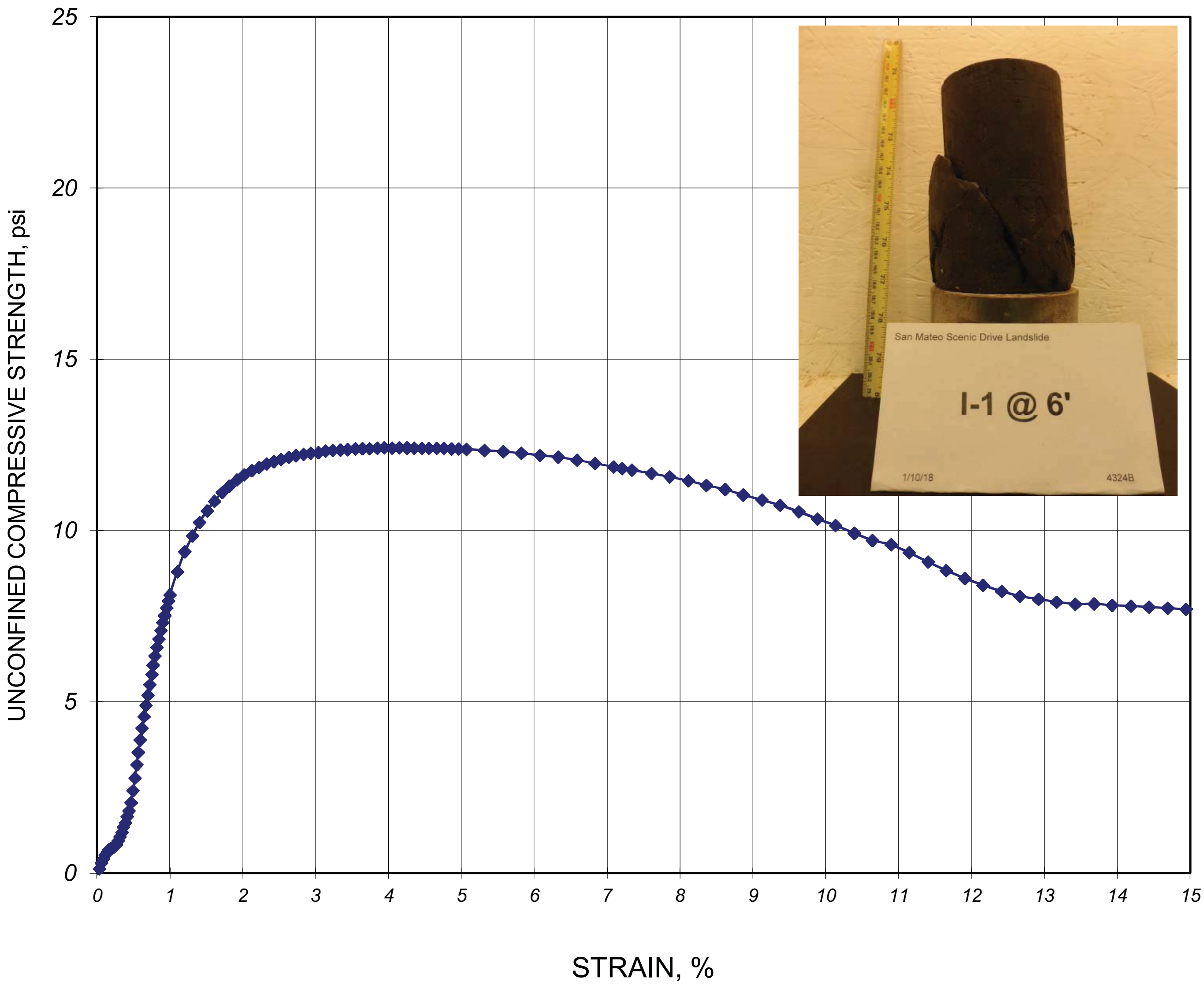
UNCONFINED COMPRESSIVE STRENGTH

Geo-Logic ASSOCIATES

ASTM D-2166

Client / Project Name:	Project No:	Lab Log:
Pacific Geotechnical Engineering	PA17.1039.00	**4324B**

Project Name:	Sample ID	Report Date:
San Mateo Scenic Drive Landslide	I-1 @ 6'	January 15, 2018



Test No.	Initial Water Content %	Initial Dry Density pcf	Description	UNCONFINED COMPRESSIVE STRENGTH q_u, psi	UNCONFINED COMPRESSIVE STRENGTH shear, psi
1	36.8	82	Dark Gray Brown Clay	**12.4**	**6.2**

NOTE:

Sample Diameter = 2.4 in.

Sample Height = 5.0 in.

Height / Dia. Ratio = 2.1

Strain Rate: 0.050 in./ min.

Strain % : 1.00 % / min.

Test Date : January 10, 2018

This testing is based upon accepted industry practice as well as the test method listed. These results apply only to the samples supplied and tested for the above referenced job.

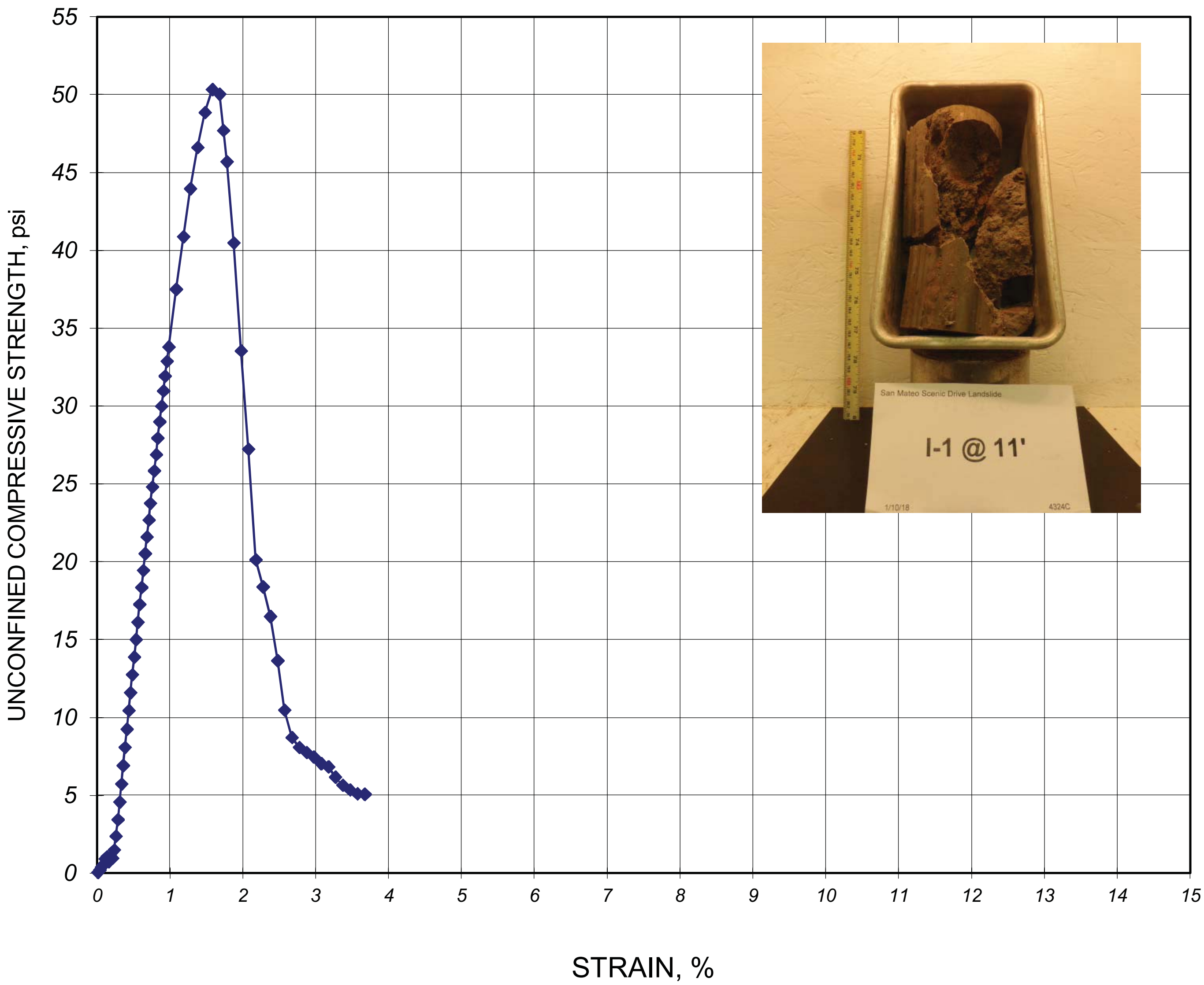
Geo-Logic ASSOCIATES

UNCONFINED COMPRESSIVE STRENGTH

ASTM D-2166

Client / Project Name:	Project No:	Lab Log:
Pacific Geotechnical Engineering	PA17.1039.00	**4324C**

Project Name:	Sample ID	Report Date:
San Mateo Scenic Drive Landslide	I-1 @ 11'	January 15, 2018



Test No.	Initial Water Content %	Initial Dry Density pcf	Description	UNCONFINED COMPRESSIVE STRENGTH q_u, psi	UNCONFINED COMPRESSIVE STRENGTH shear, psi
1	35.1	82	Gray Brown Clay	**50.3**	**25.2**

NOTE:

Sample Diameter =	2.4 in.		Strain Rate:	0.027	in./ min.
Sample Height =	5.4 in.		Strain % :	0.50	% / min.
Height / Dia. Ratio =	2.2		Test Date :	January 10, 2018	

This testing is based upon accepted industry practice as well as the test method listed. These results apply only to the samples supplied and tested for the above referenced job.

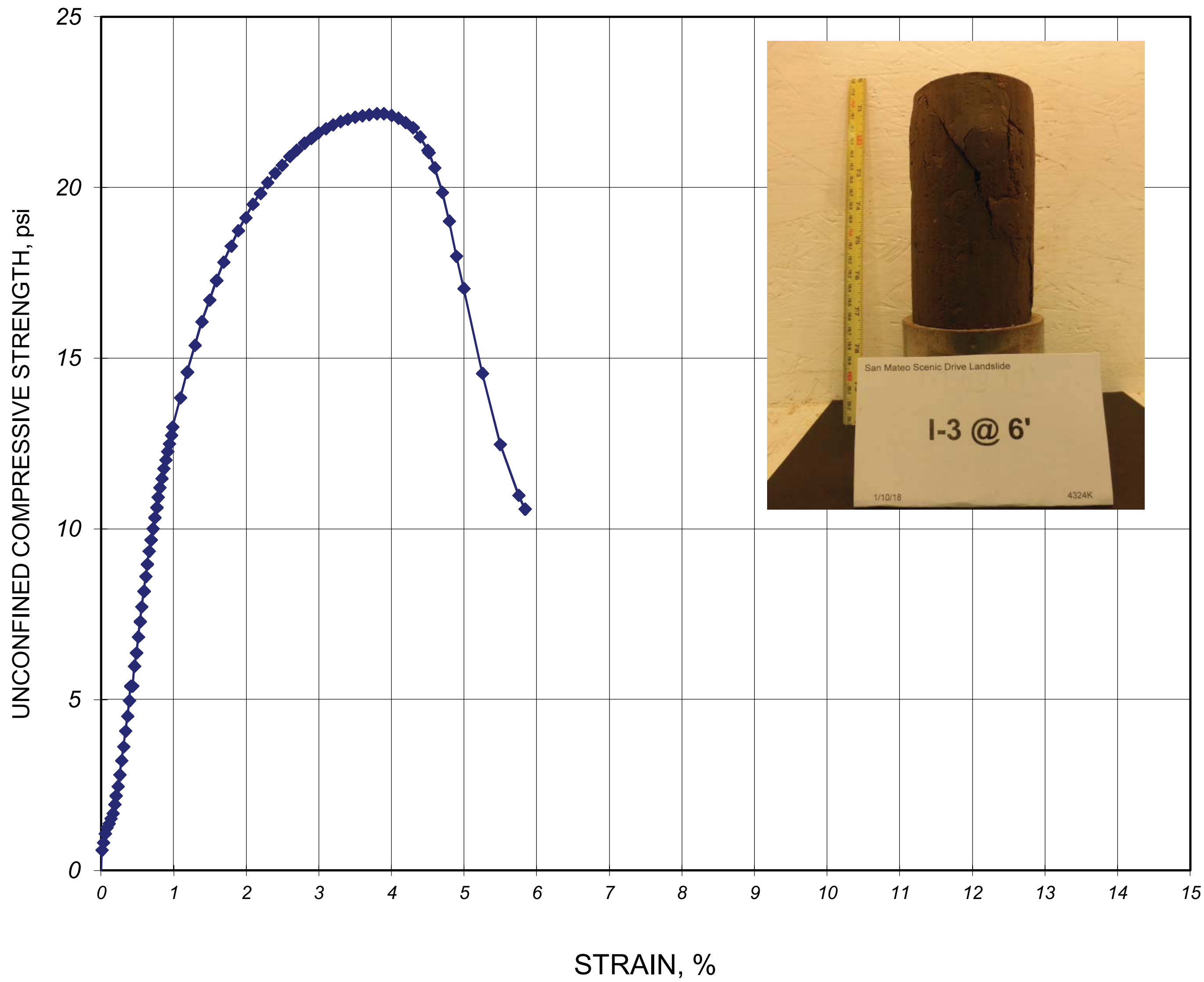
UNCONFINED COMPRESSIVE STRENGTH

Geo-Logic ASSOCIATES

ASTM D-2166

Client / Project Name:	Project No:	Lab Log:
Pacific Geotechnical Engineering	PA17.1039.00	**4324K**

Project Name:	Sample ID	Report Date:
San Mateo Scenic Drive Landslide	I-3 @ 6'	January 15, 2018



Test No.	Initial Water Content %	Initial Dry Density pcf	Description	UNCONFINED COMPRESSIVE STRENGTH q_u, psi	UNCONFINED COMPRESSIVE STRENGTH shear, psi
1	31.4	87	Brown Clay	**22.2**	**11.1**

* Water content determined on total sample after test.

NOTE:

Sample Diameter = 2.4 in.

Sample Height = 5.0 in.

Height / Dia. Ratio = 2.1

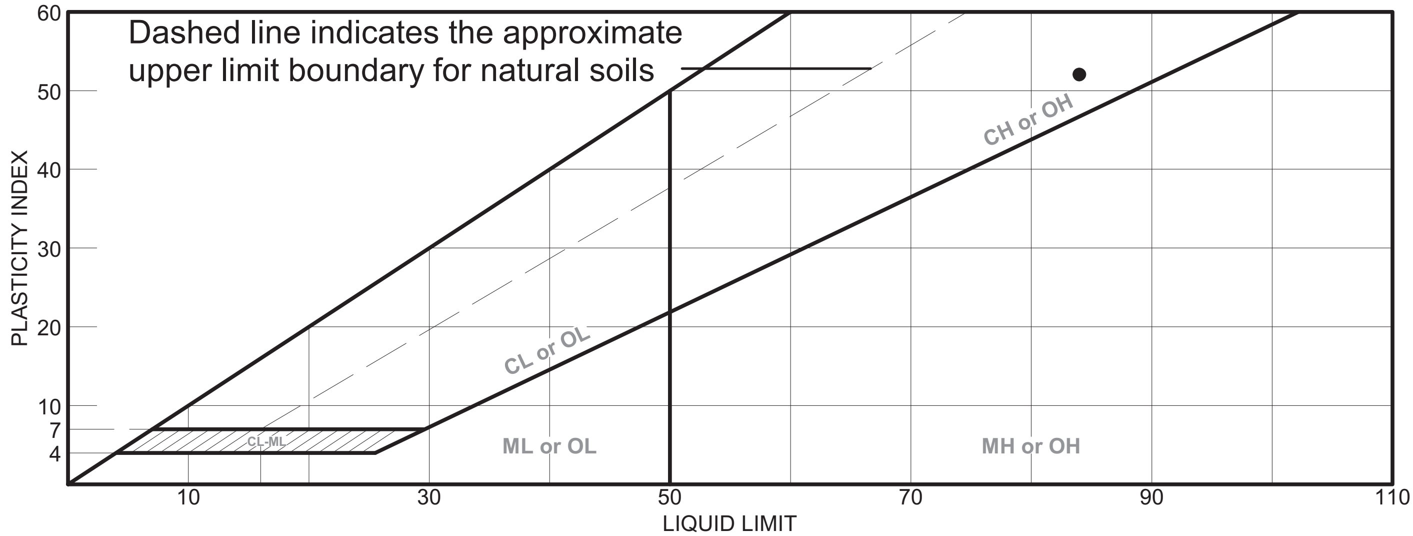
Strain Rate: 0.050 in./ min.

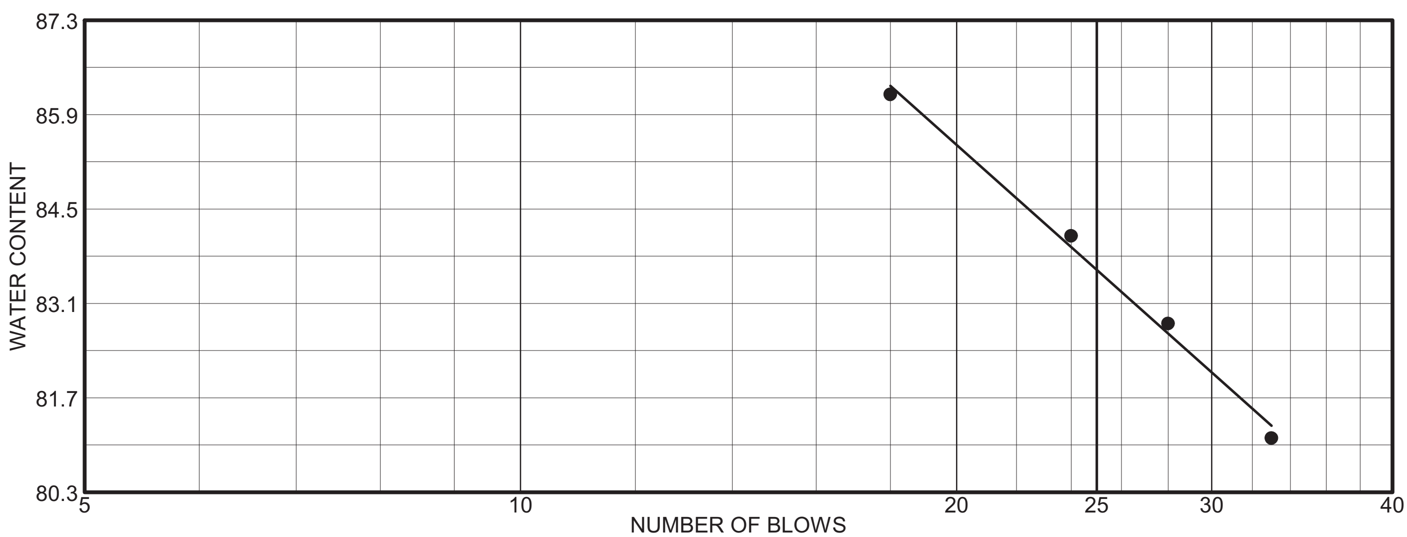
Strain % : 1.00 % / min.

Test Date : January 10, 2018

This testing is based upon accepted industry practice as well as the test method listed. These results apply only to the samples supplied and tested for the above referenced job.

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish Gray Fat CLAY	84	32	52	99.4	96.6	CH

Project No. 516-035 **Client:** Geo-Logic Associates

Project: Scenic Drive LS - PA17.1039

● **Source:** DH-1 **Elev./Depth:** 25.7'

Remarks:

●

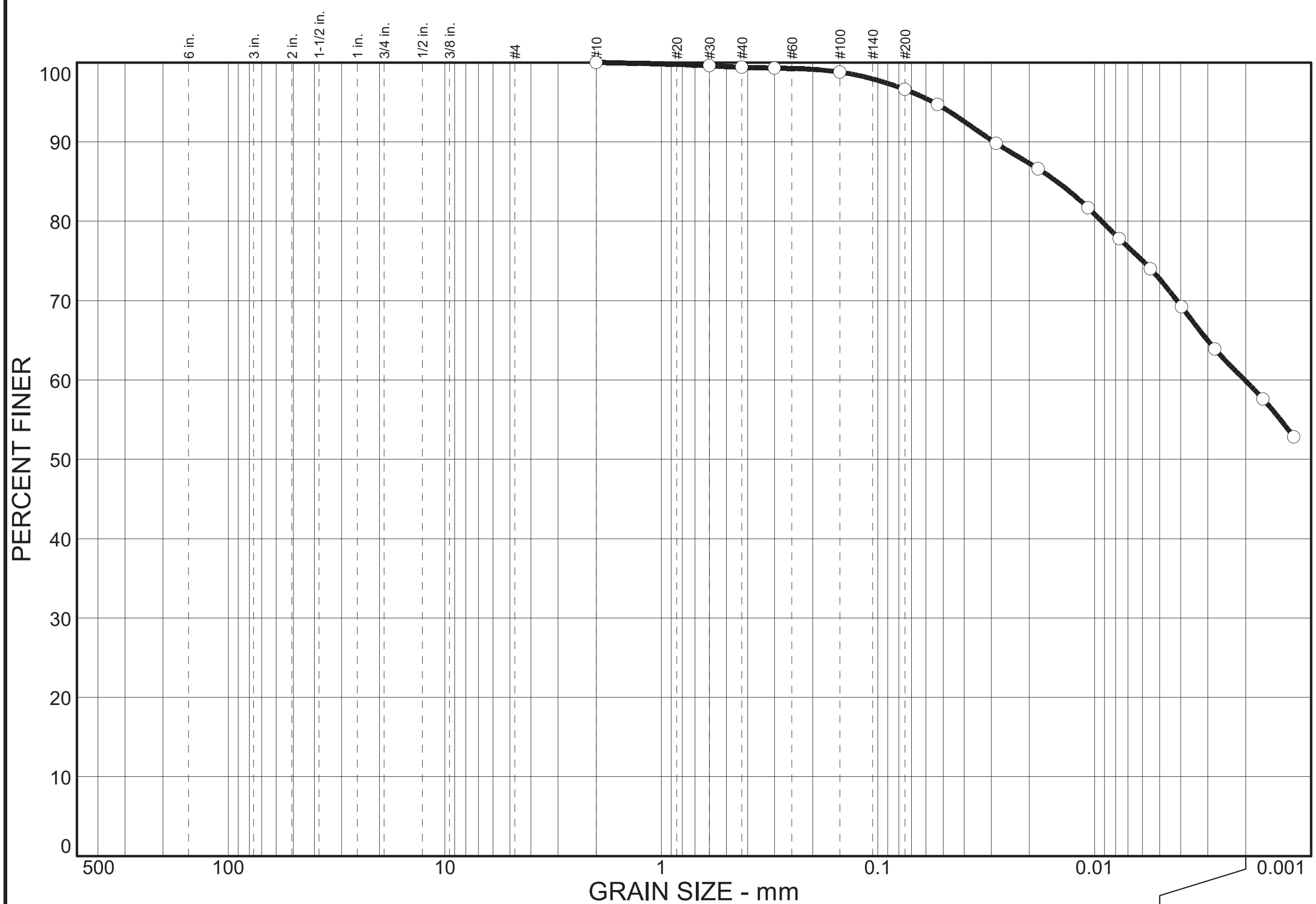
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

Figure B-5

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	3.4	36.8	59.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.6		
#40	99.4		
#50	99.3		
#100	98.8		
#200	96.6		
#270	94.7		
0.0284 mm.	89.8		
0.0182 mm.	86.6		
0.0107 mm.	81.7		
0.0077 mm.	77.8		
0.0055 mm.	74.0		
0.0040 mm.	69.2		
0.0028 mm.	63.9		
0.0017 mm.	57.6		
0.0012 mm.	52.8		

* (no specification provided)

Soil Description

Greenish Gray Fat CLAY

Atterberg Limits

PL= 32 LL= 84 PI= 52

Coefficients

D_{85}= 0.0149 D_{60}= 0.0020 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CH AASHTO=

Remarks

Sample No.: **Source of Sample:** DH-1 **Date:** 1/10/18
Location: **Elev./Depth:** 25.7'

COOPER TESTING LABORATORY

Client: Geo-Logic Associates
Project: Scenic Drive LS - PA17.1039
Project No: 516-035 **Figure**

Figure B-6

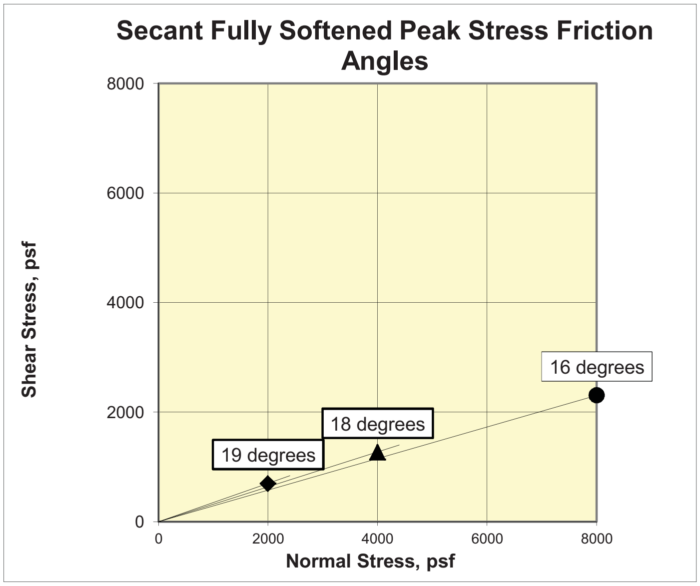
Drained Fully Softened Peak Torsional Shear Strength (ASTM D7608)

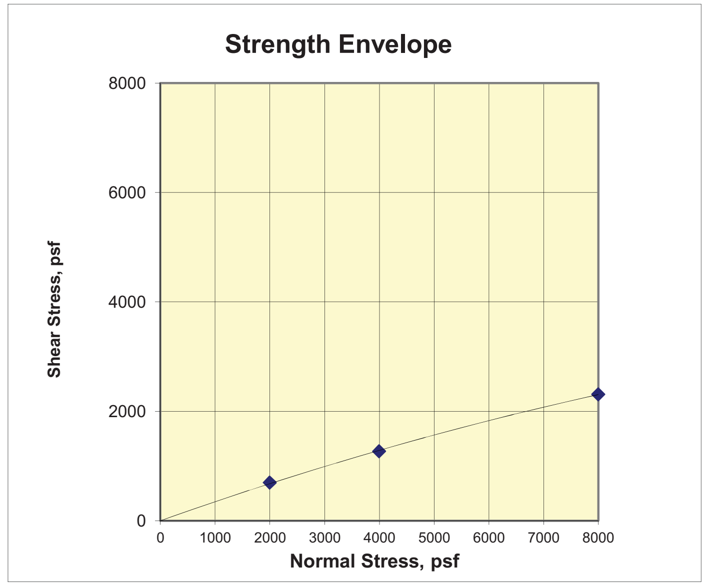
CTL Job No.:	516-035	Boring:	D-1	Date:	1/23/2018	Clay, %:	59.8
Client:	Geo-Logic Associates	Sample:		By:	PJ	LL:	84
Project Name:	Scenic Drive LS	Depth (ft):	25.7	Checked:	DC	PL:	32
Project Number:	PA17.1039	Test Type:	Fully Softened Peak				

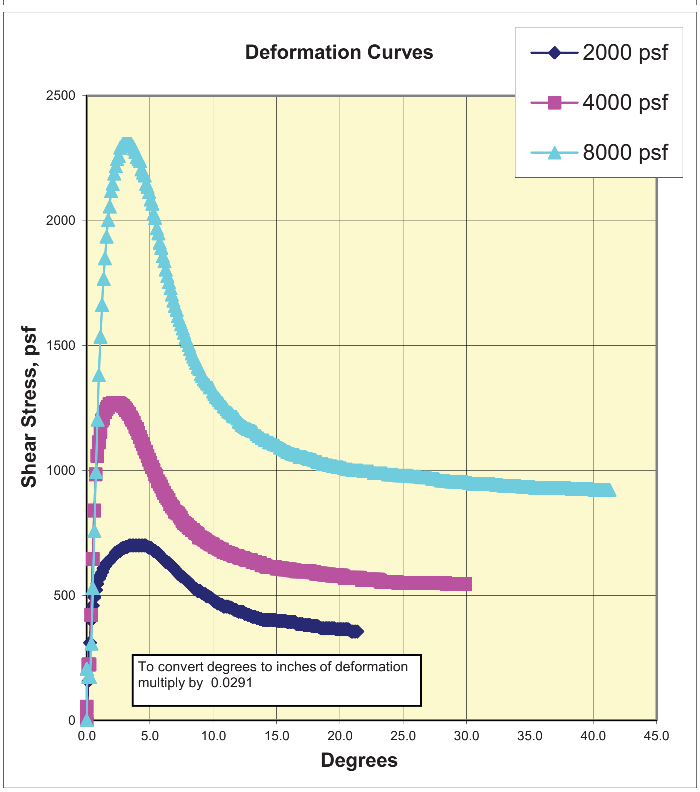
Soil Type: Greenish Gray Fat CLAY

Remarks:

Normal Stress, psf:	2000	4000	8000
Secant Phi, deg.:	19	18	16







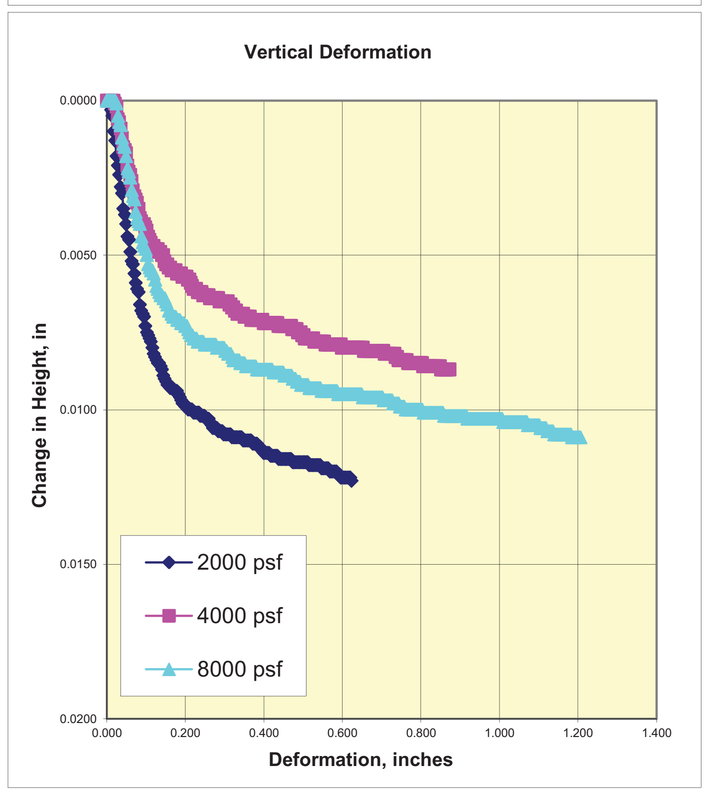


Figure B-7

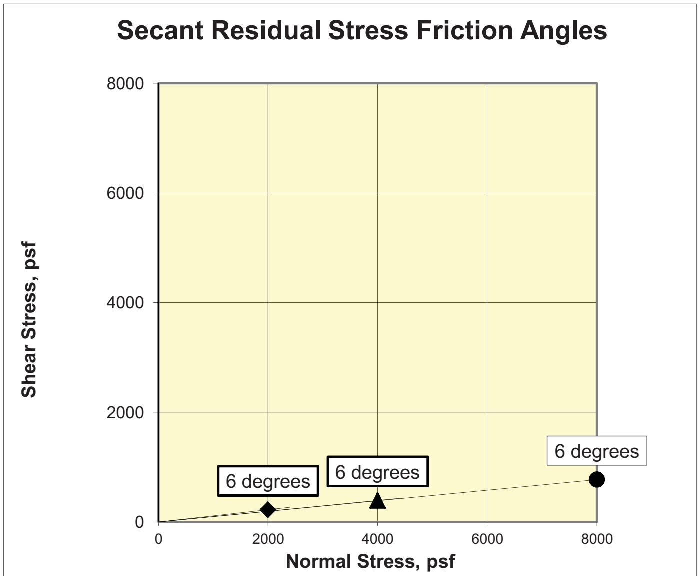
Drained Residual Torsional Shear Strength (ASTM D6467)

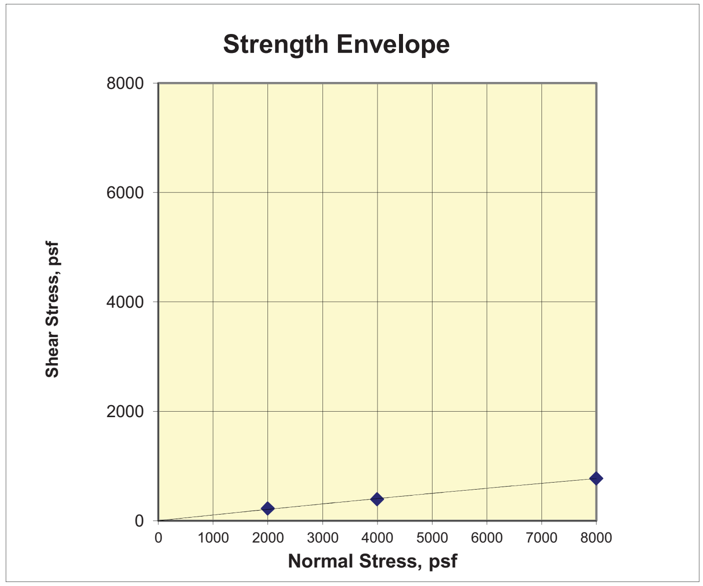
CTL Job No.:	516-035	**Boring:**	D-1	**Date:**	1/19/2018	**Clay, %:**	59.8
Client:	Geo-Logic Associates	**Sample:**		**By:**	PJ	**LL:**	84
Project Name:	Scenic Drive LS	**Depth (ft):**	25.7	**Checked:**	DC	**PL:**	32
Project Number:	PA17.1039	**Test Type:**	Fully Softened Residual				

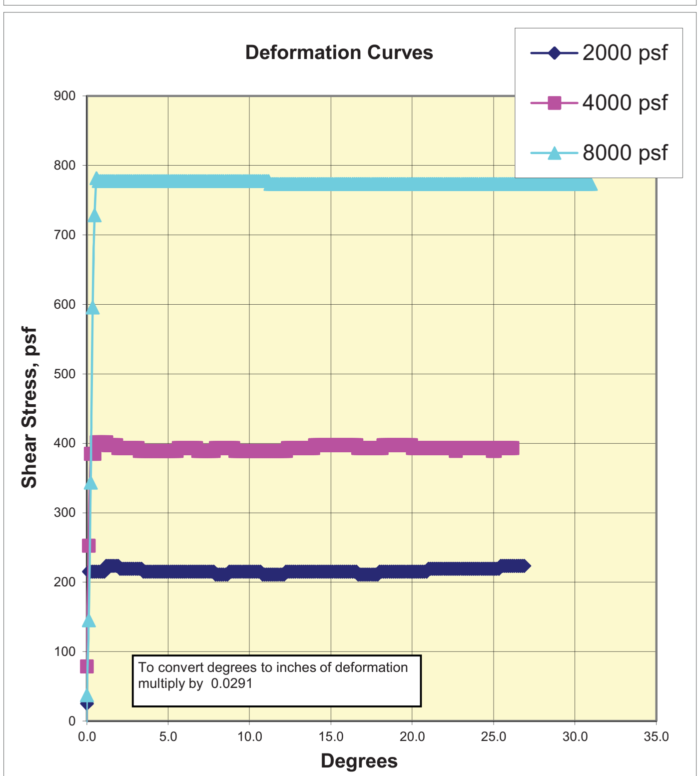
Soil Type: Greenish Gray Fat CLAY

Normal Stress, psf:	2000	4000	8000
Secant Phi, deg.:	6	6	6

Remarks: A small friction correction was applied to each point.







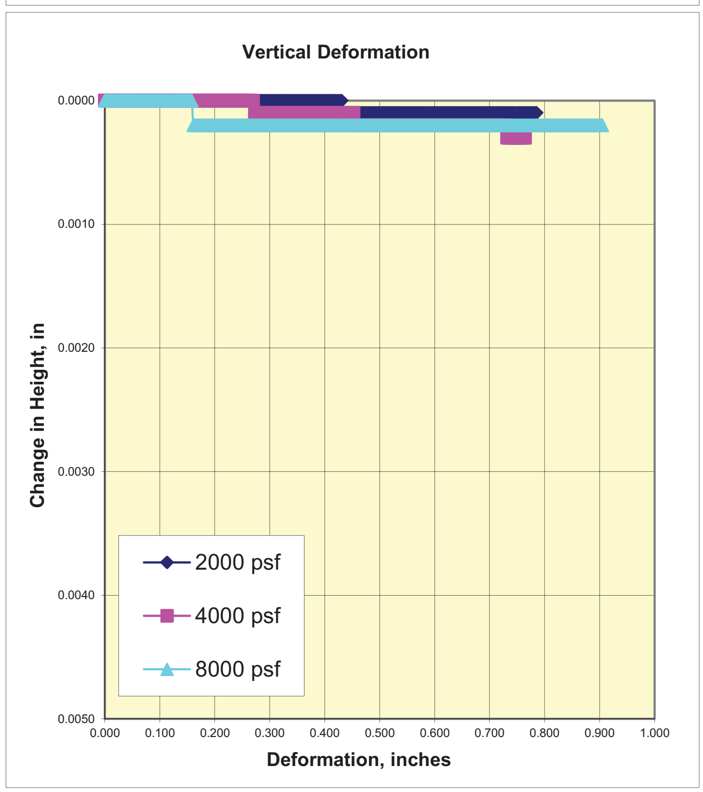


Figure B-8

Drained Fully Softened Peak Torsional Shear Strength (ASTM D7608)

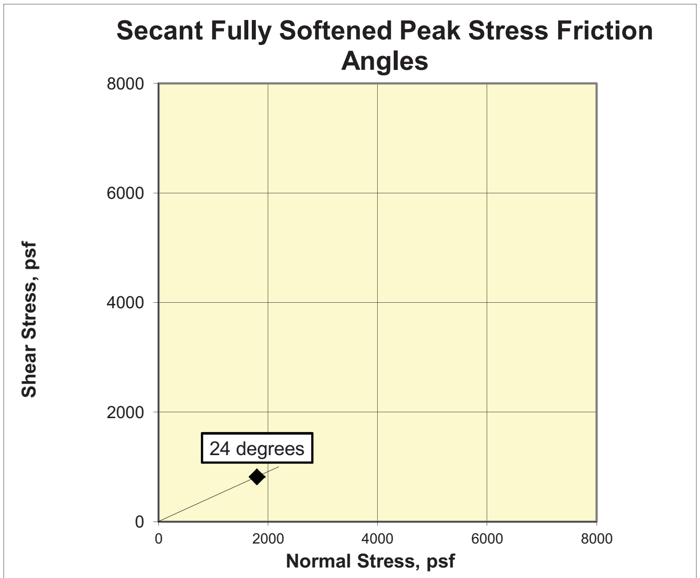
CTL Job No.:	516-035	**Boring:**	I-3	**Date:**	1/29/2018	**Clay, %:**	
Client:	Geo-Logic Associates	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Scenic Drive LS	**Depth (ft):**	14.5	**Checked:**	DC	**PL:**	
Project Number:	PA17.1039	**Test Type:**	Fully Softened Peak				

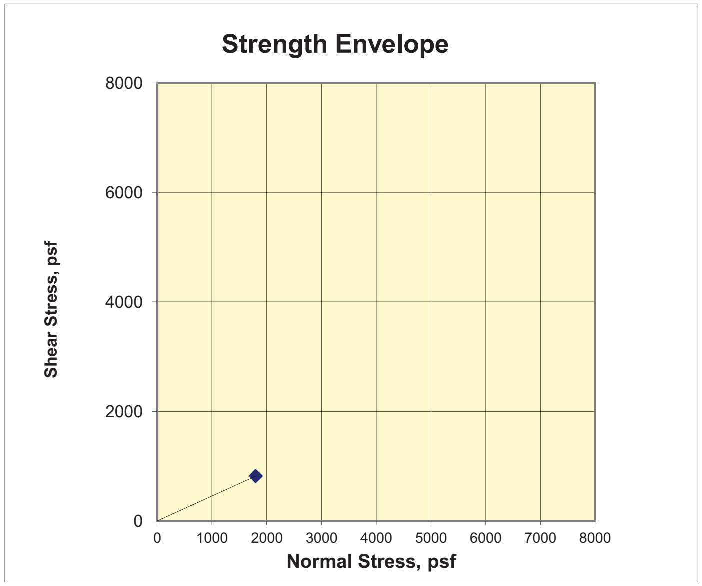
Soil Type: Yellowish Brown CLAY

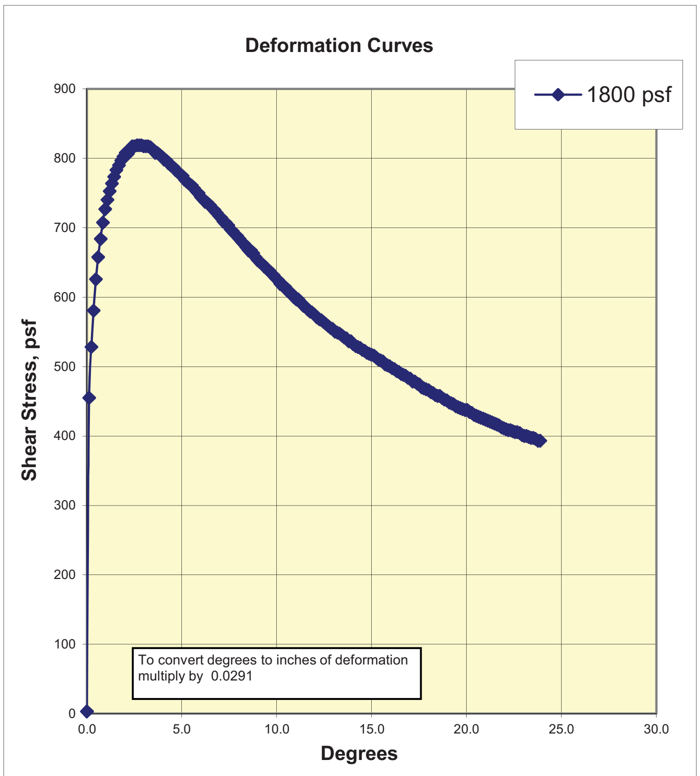
Normal Stress, psf: 1800

Secant Phi, deg.: 24

Remarks:







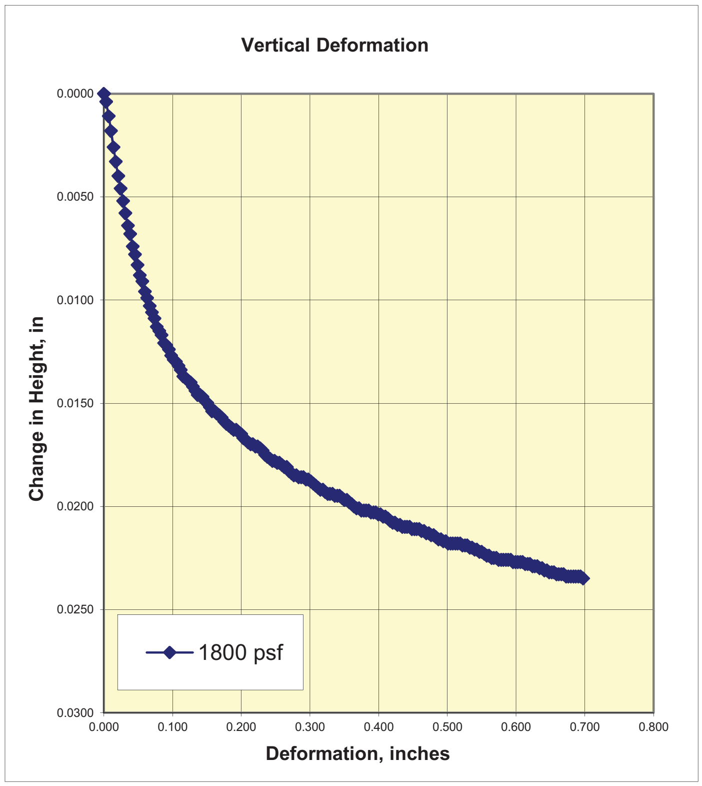


Figure B-9

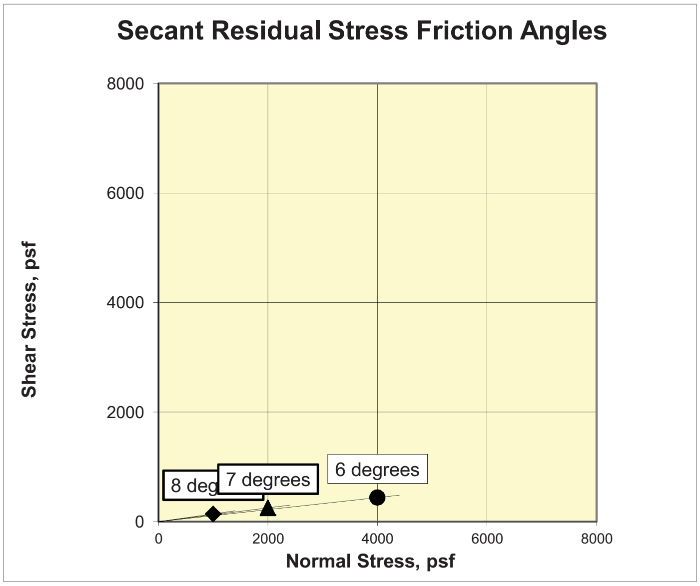
Drained Residual Torsional Shear Strength (ASTM D6467)

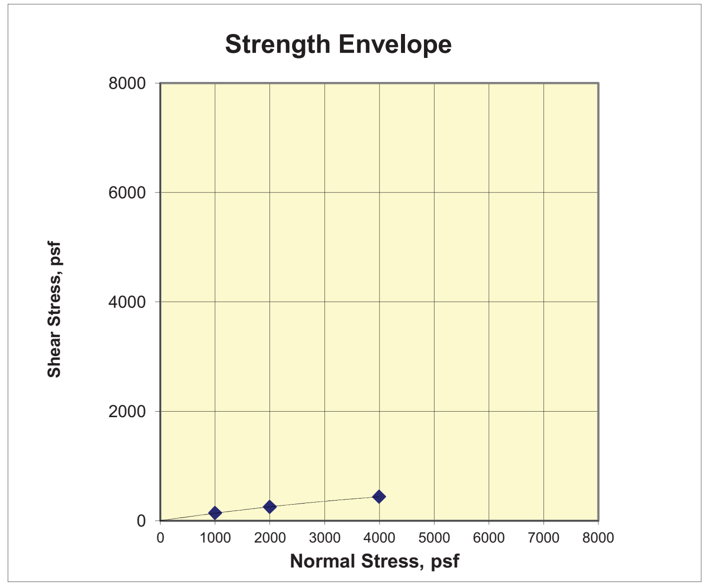
CTL Job No.:	516-035	**Boring:**	I-3	**Date:**	1/29/2018	**Clay, %:**	
Client:	Geo-Logic Associates	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Scenic Drive LS	**Depth (ft):**	14.5	**Checked:**	DC	**PL:**	
Project Number:	PA17.1039	**Test Type:**	Fully Softened Residual				

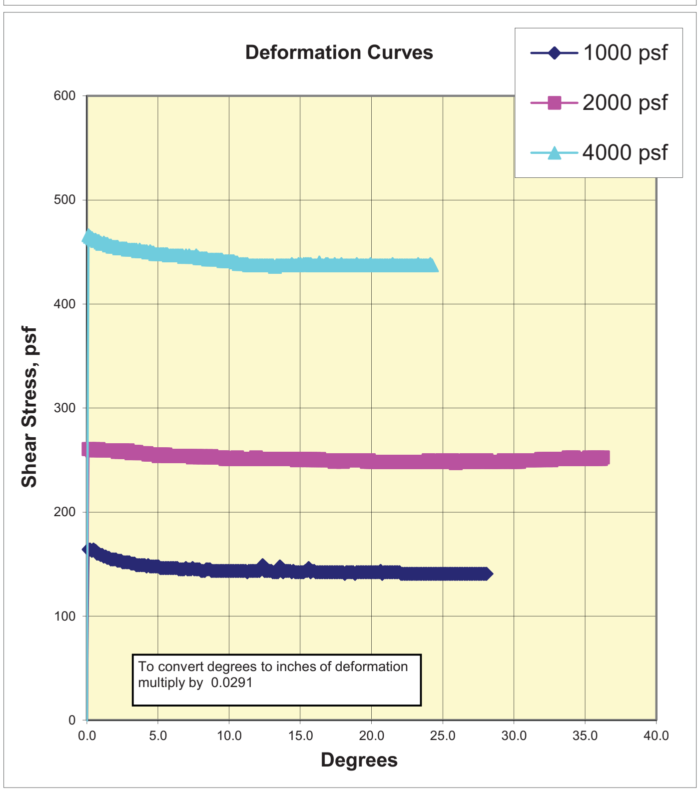
Soil Type: Yellowish Brown CLAY

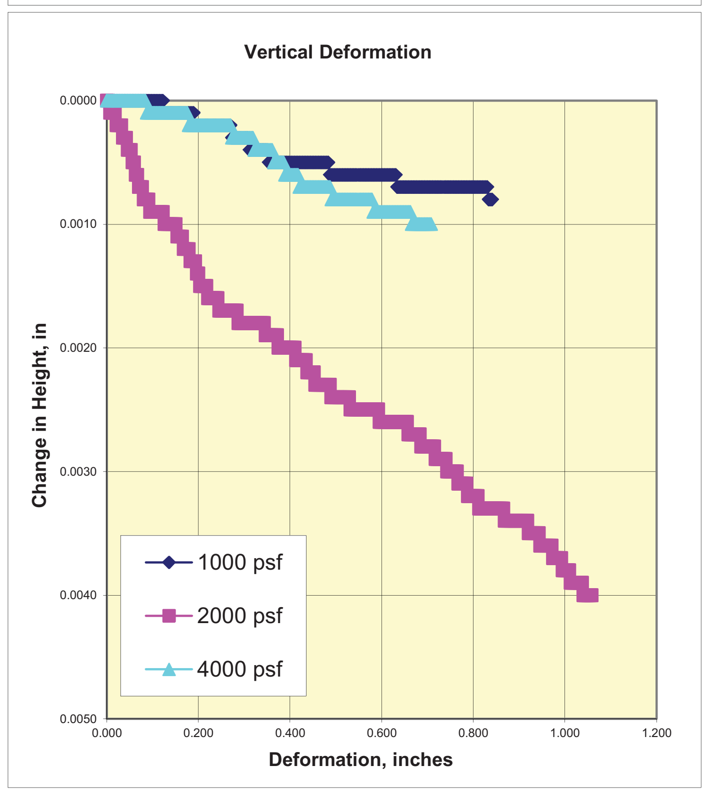
Normal Stress, psf:	1000	2000	4000
Secant Phi, deg.:	8	7	6

Remarks: A small friction correction was applied to each point.



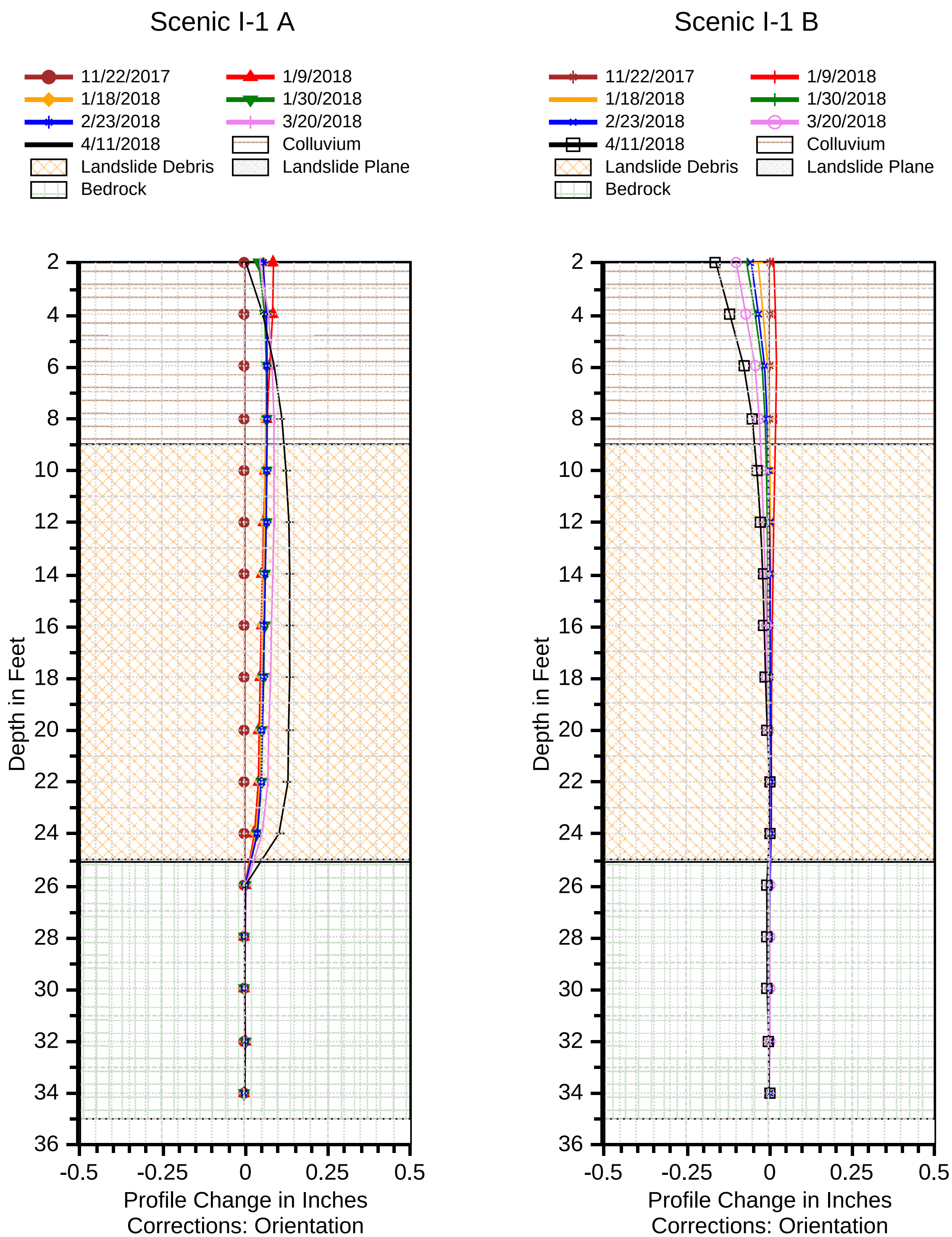






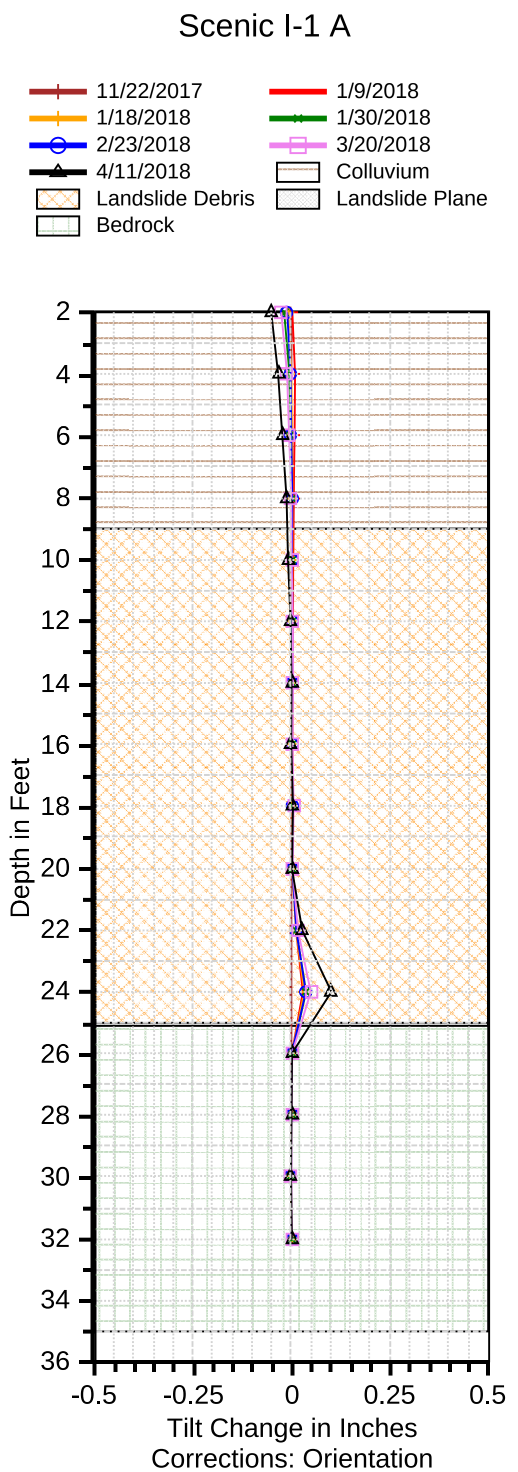
APPENDIX C

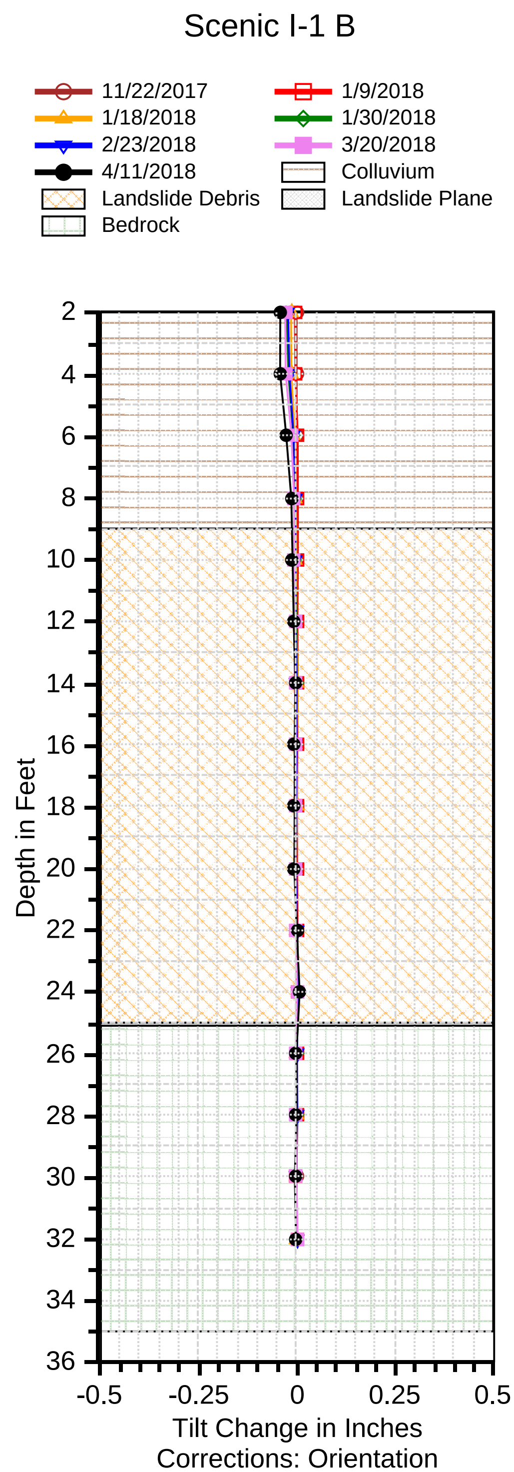
SLOPE INCLINOMETER PLOTS



A0 Direction = 250
Orientation Correction = 018

Figure C-1

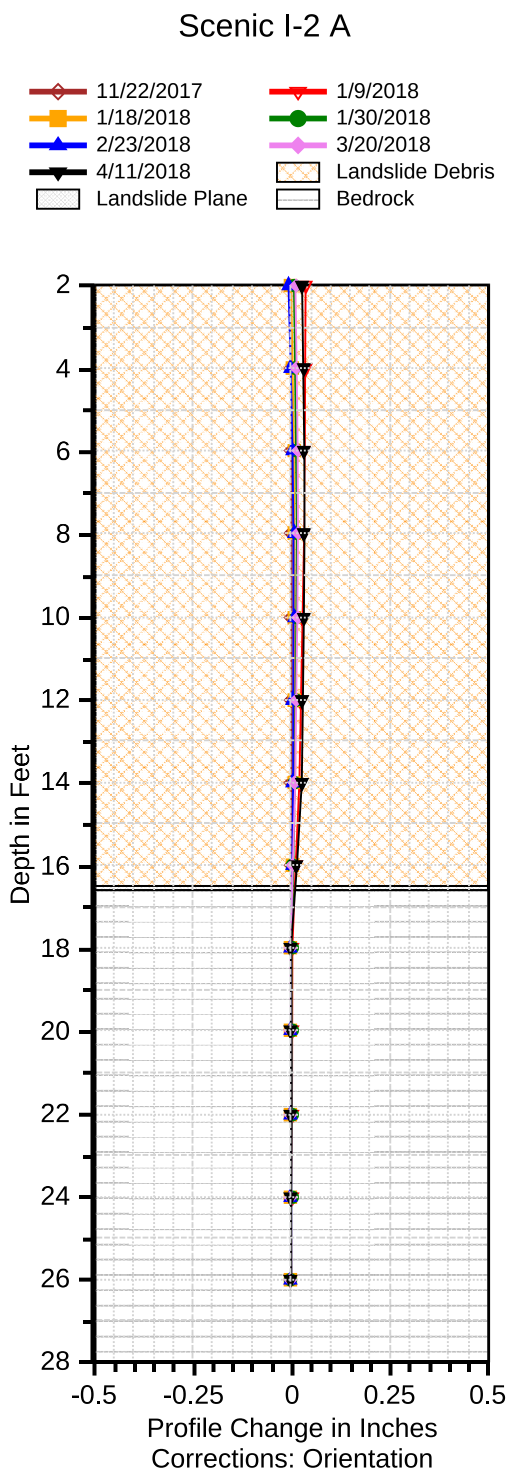


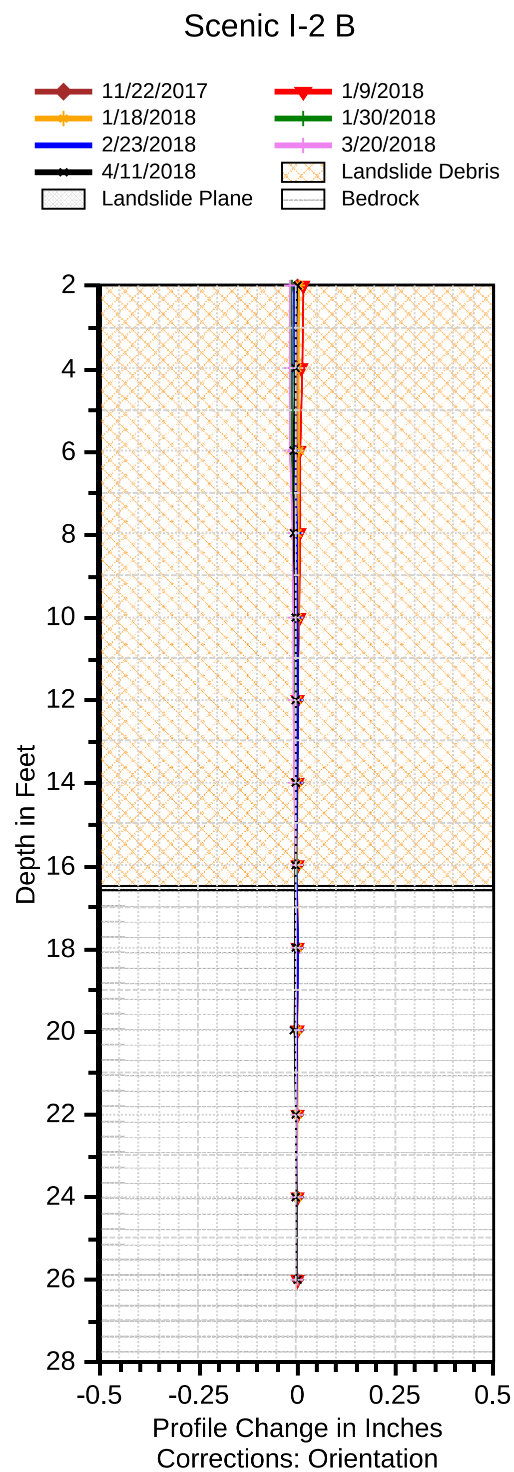


Geo-Logic ASSOCIATES

A0 Direction = 250
Orientation Correction = 018

Figure C-2

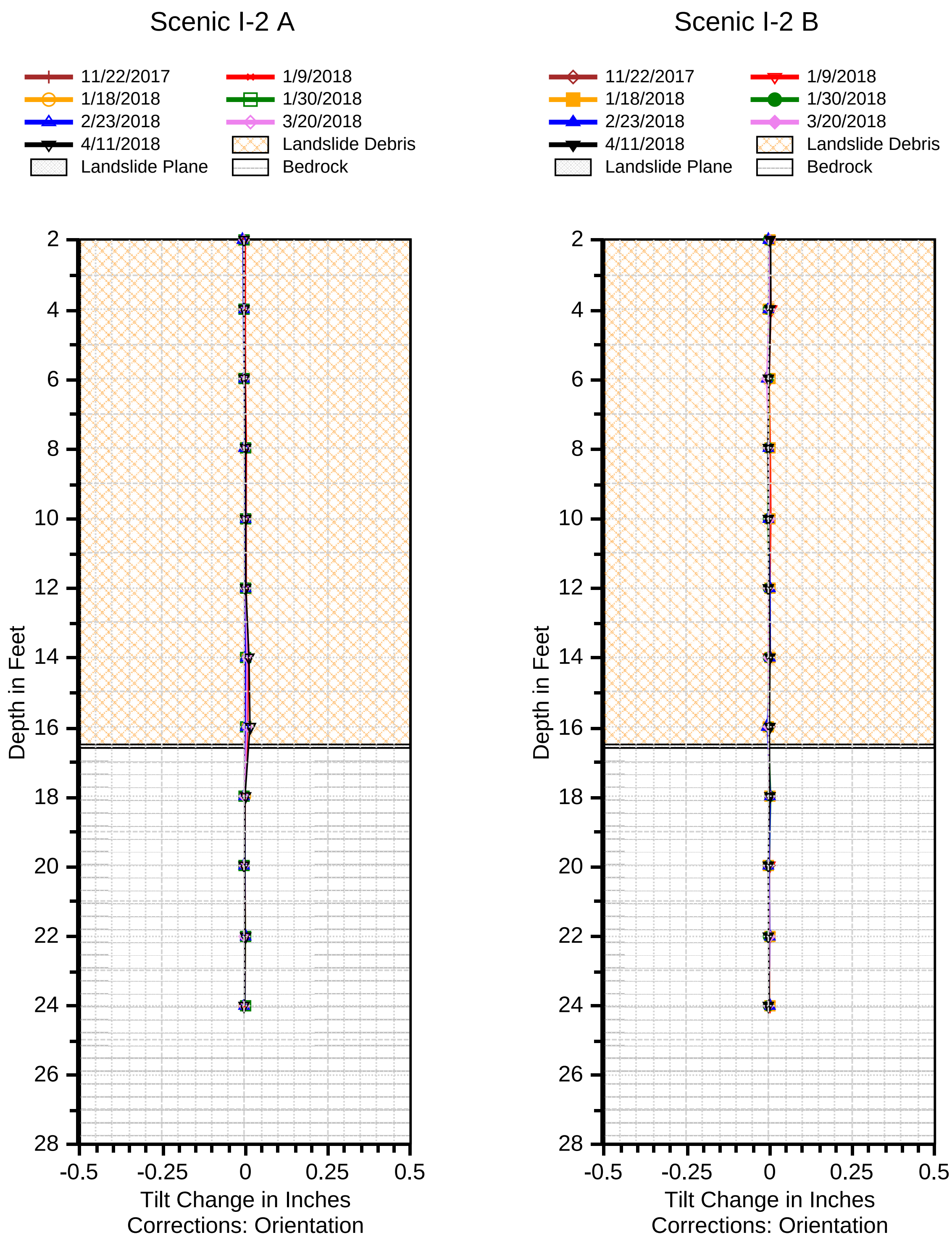




Geo-Logic ASSOCIATES

A0 Direction = 244
Orientation Correction =

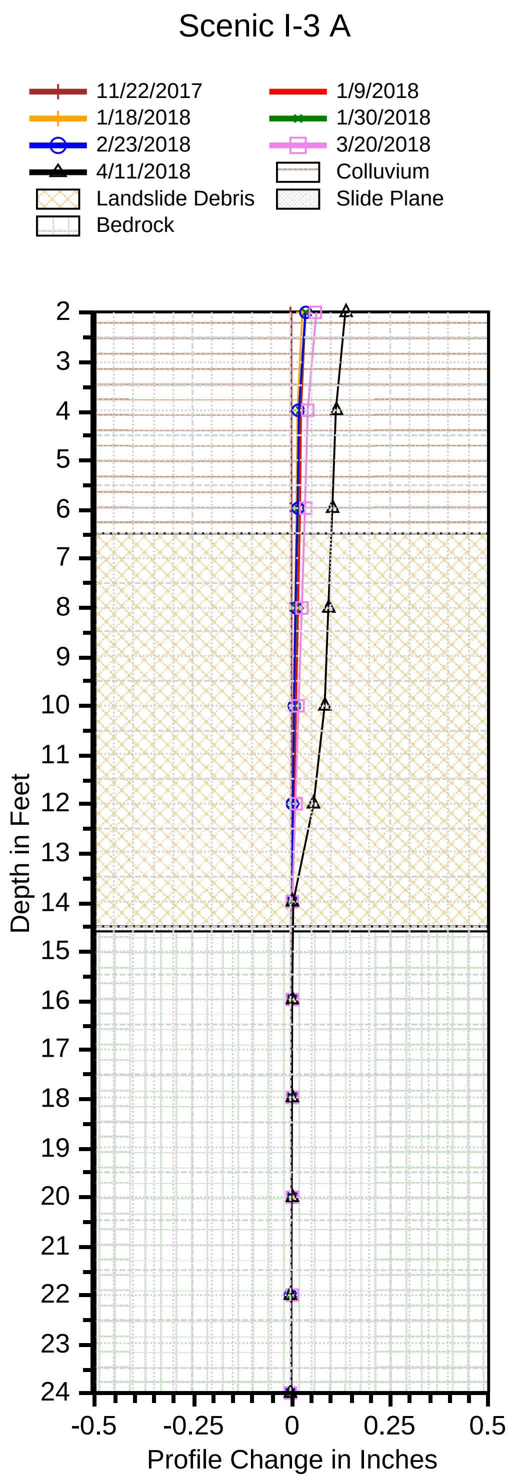
Figure C-3

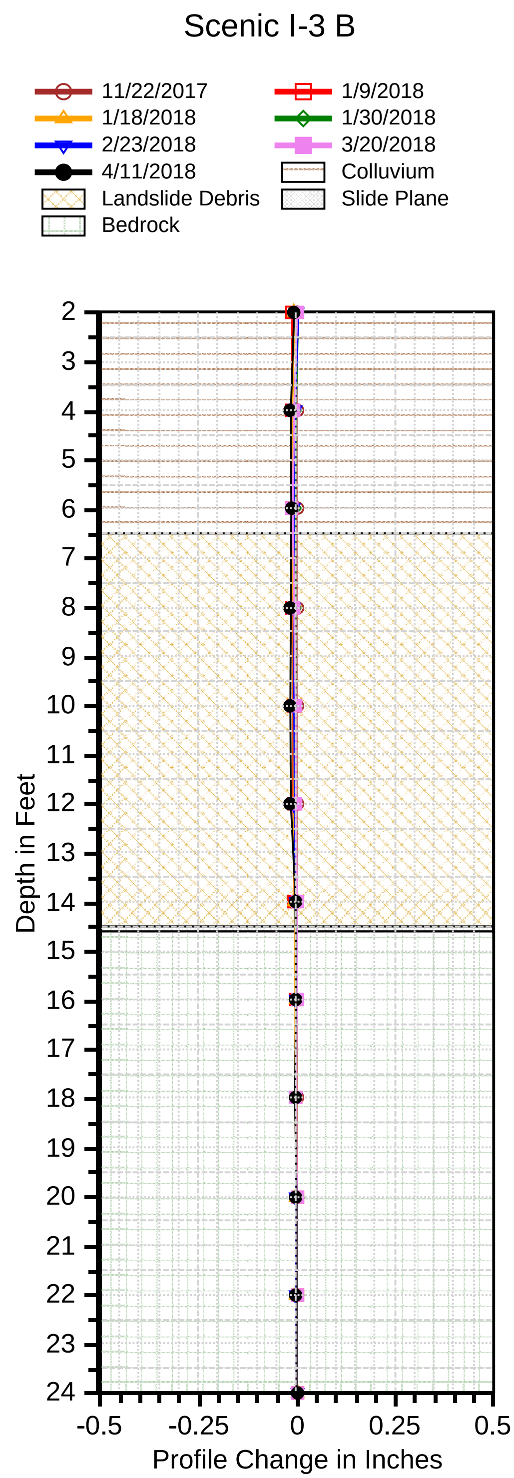


Geo-Logic ASSOCIATES

A0 Direction = 244
Orientation Correction = 025

Figure C-4



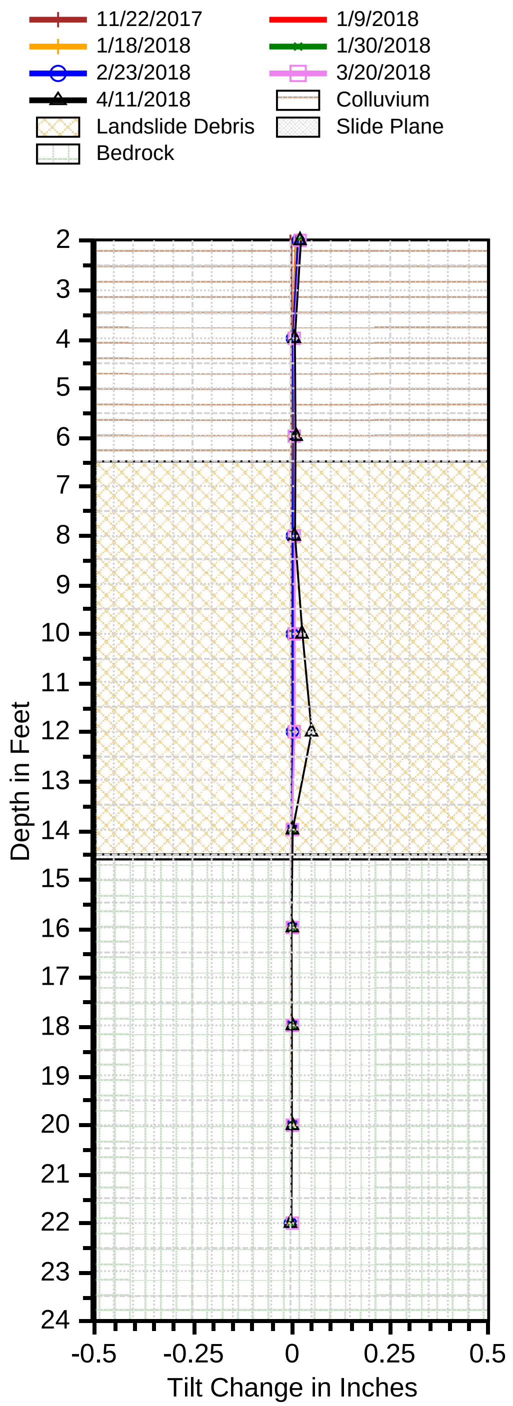


Geo-Logic ASSOCIATES

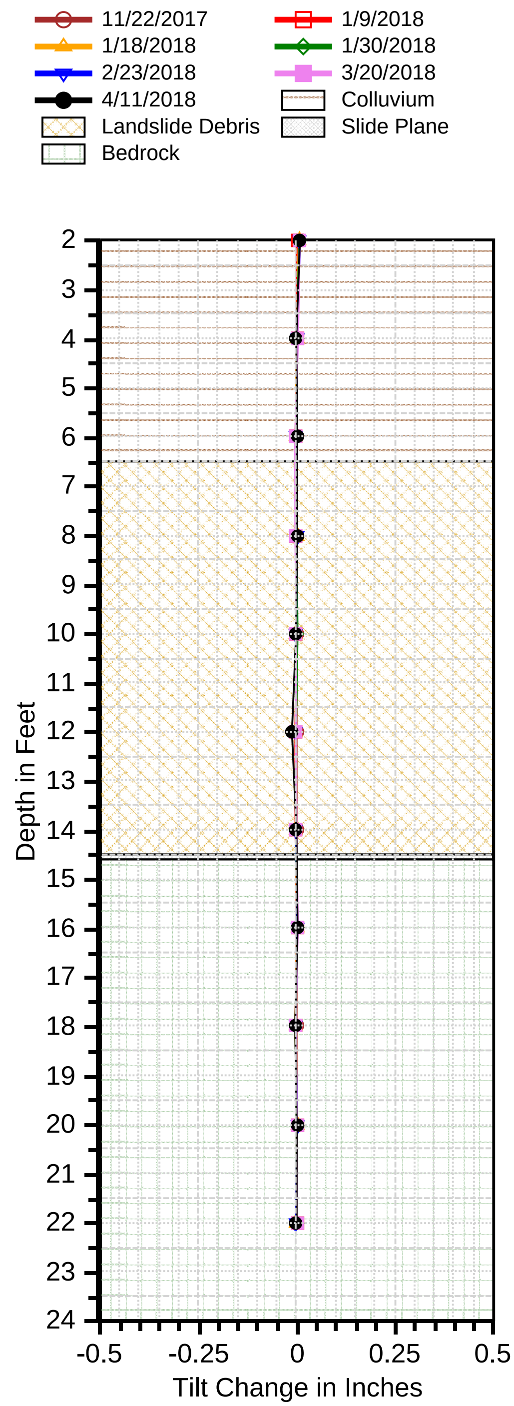
A0 Direction = 274
Orientation Correction = NA

Figure C-5

Scenic I-3 A



Scenic I-3 B



Geo-Logic ASSOCIATES

A0 Direction = 274
Orientation Correction = NA

Figure C-6

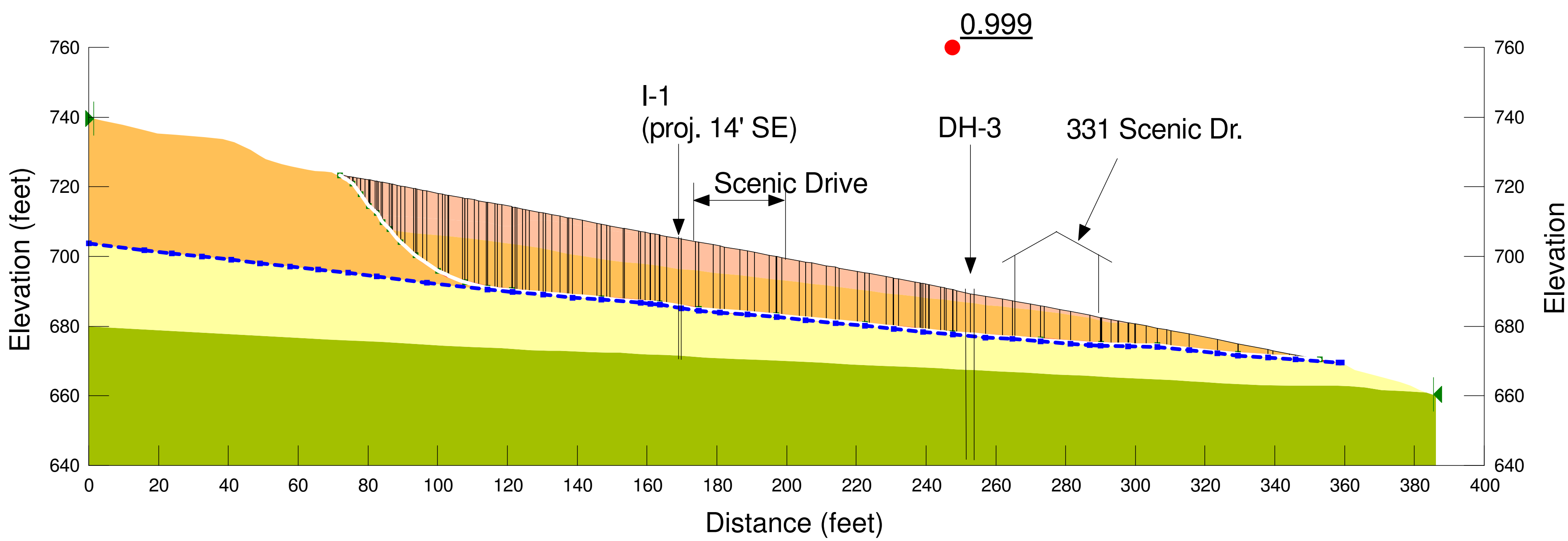
APPENDIX D

SLOPE STABILITY PLOTS

Scenic Drive Slope Stability
Back-Analysis
San Mateo Co_Scenic Dr_Section F_Pre-002.gsz
Date: 5/8/2018
Time: 3:44:11 PM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: Yes

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	9.9

Section F-F: Pre-Slide Topo
Groundwater Below Slip Plane



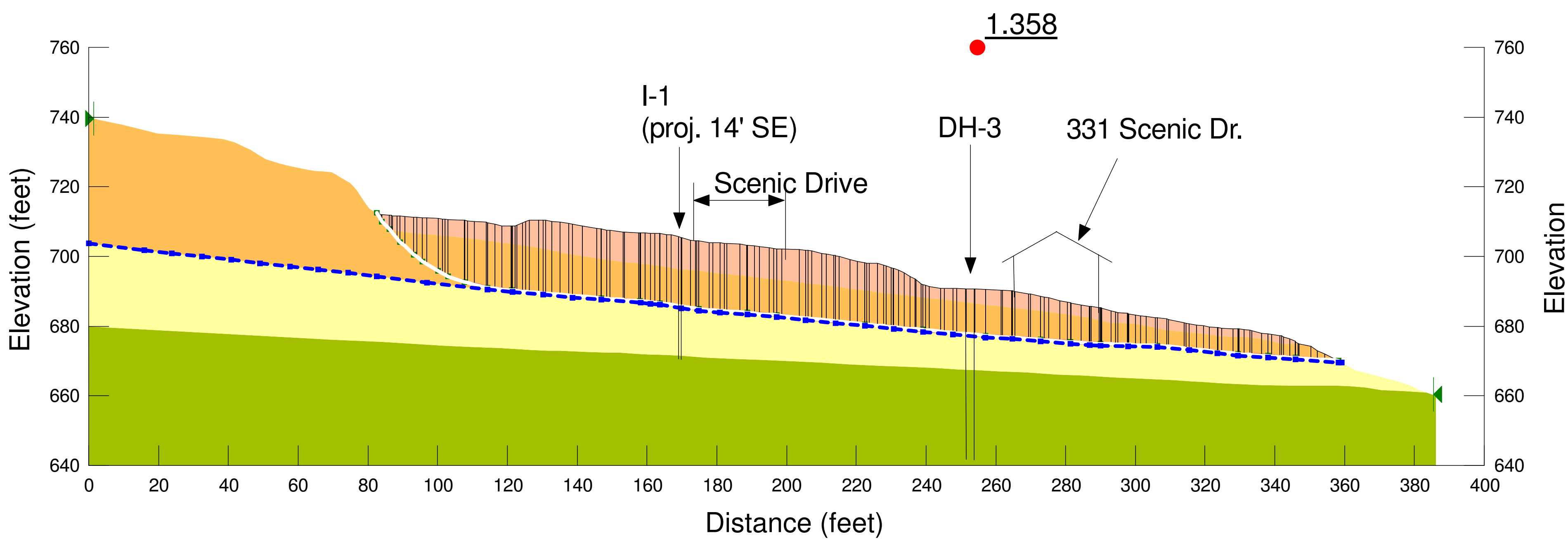
Geo-Logic
ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-010a.gsz
Date: 5/10/2018
Time: 10:29:54 AM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: Yes

Section F-F: Post-Slide Topo
Groundwater Below Slide Plane

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



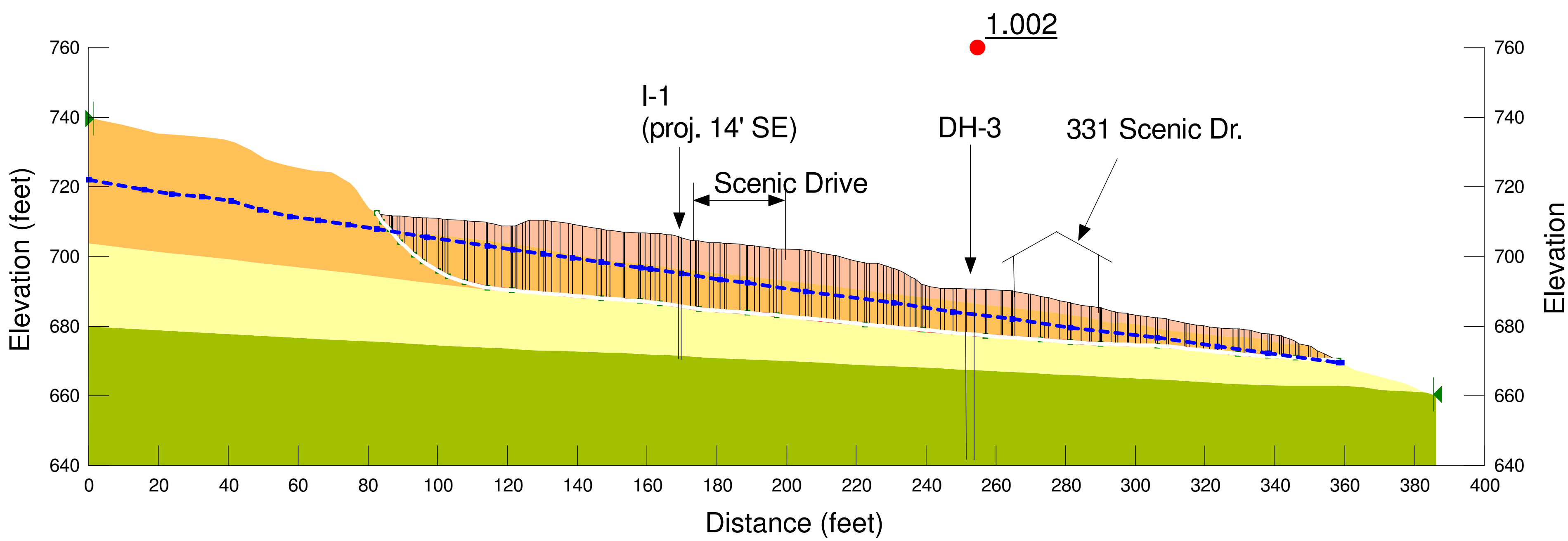
Geo-Logic ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-010b.gsz
Date: 5/10/2018
Time: 10:35:14 AM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: Yes

Section F-F: Post-Slide Topo
Groundwater Midway Between Slide Plane and Surface

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



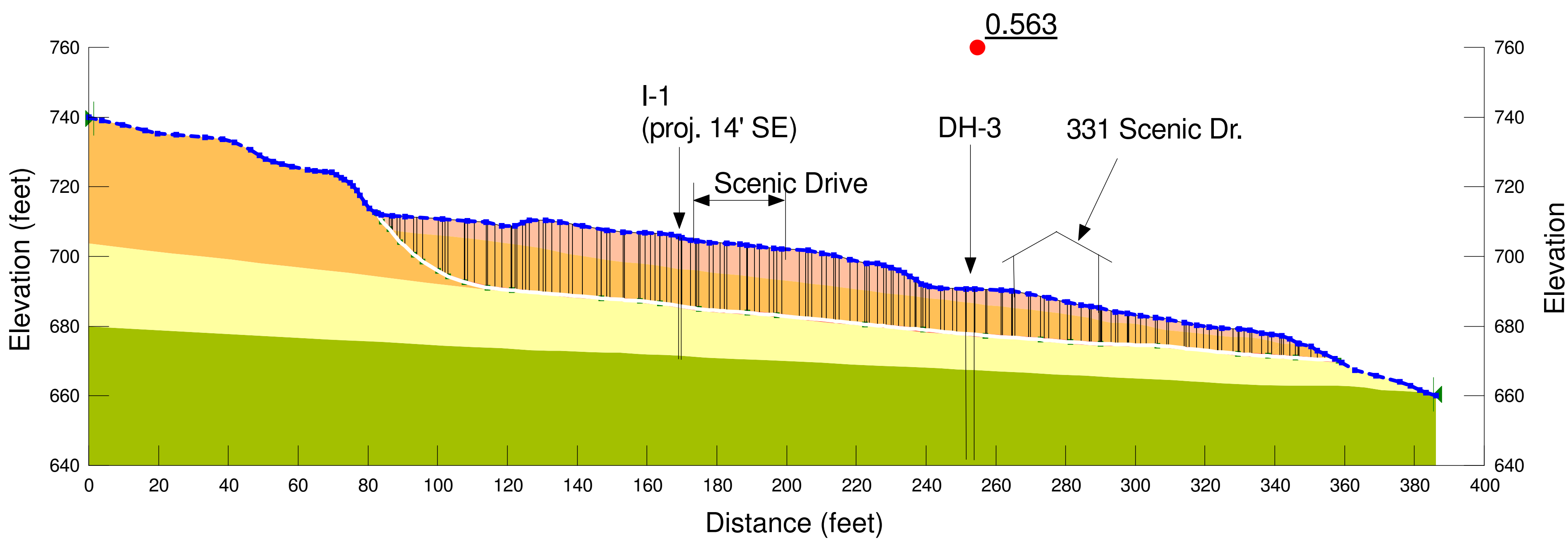
Geo-Logic ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-010c.gsz
Date: 5/10/2018
Time: 10:36:53 AM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: No

Section F-F: Post-Slide Topo
Groundwater At Surface

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



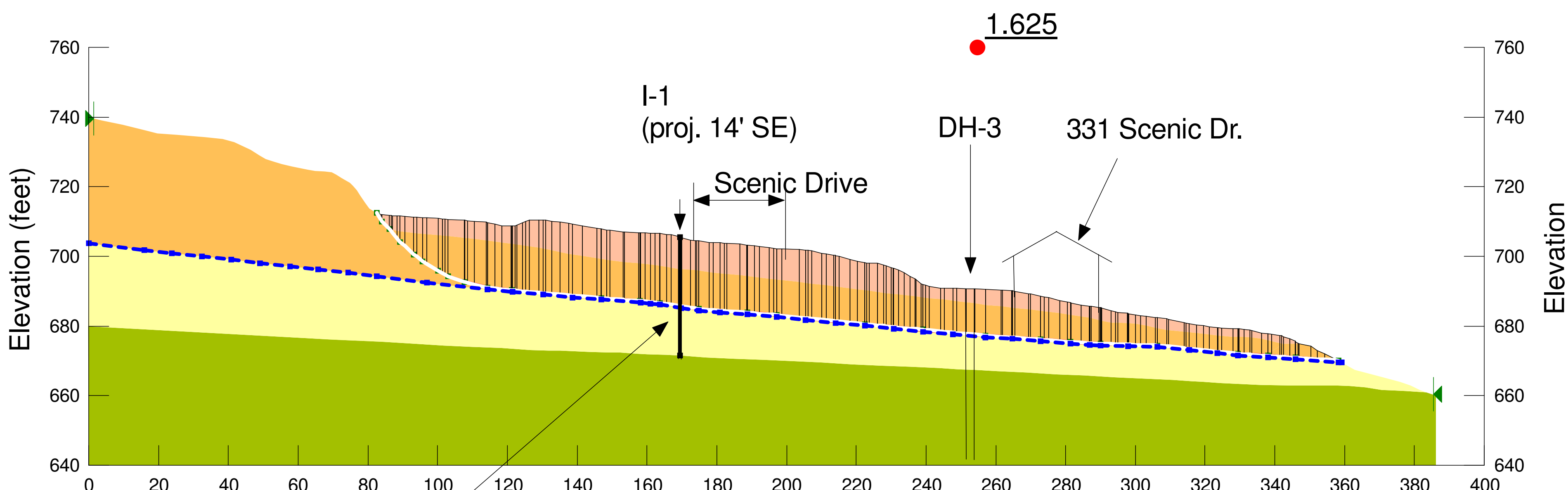
Geo-Logic ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-012a.gsz
Date: 5/10/2018
Time: 2:09:46 PM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: Yes

Section F-F: Post-Slide Topo
Groundwater Below Slide Plane
Remediation Option: Stitch Pier

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



Type: Pile
Shear Force: 45,000 lbs
Shear Reduction Factor: 1
Pile Spacing: 5 ft
Shear Option: Parallel to Slip

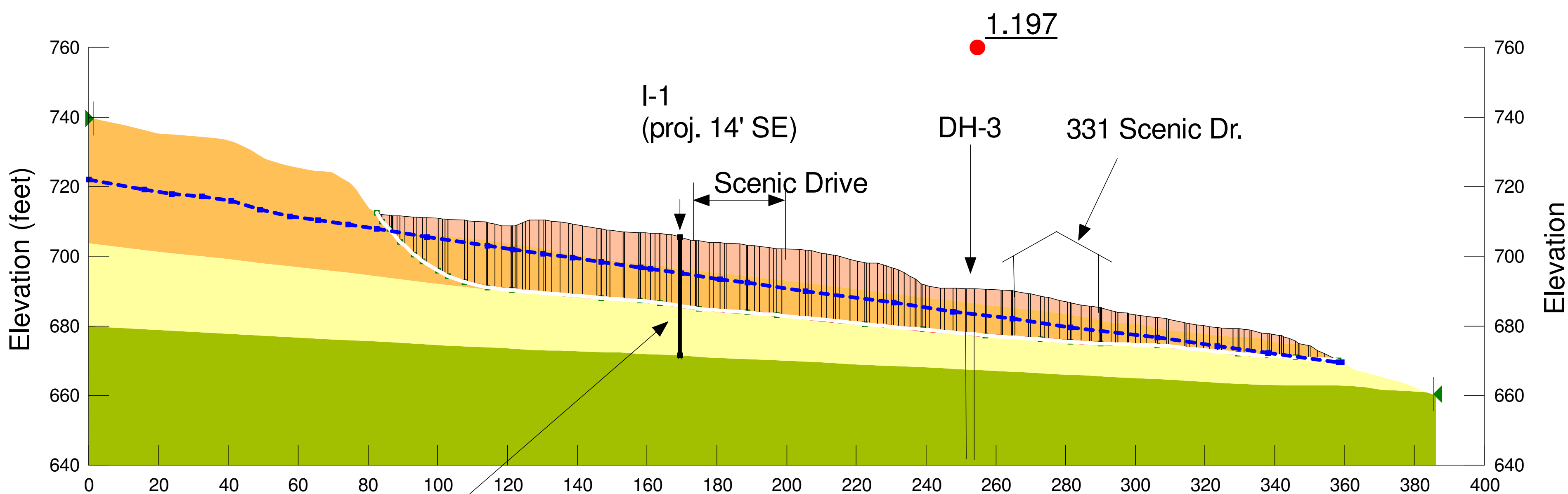
Geo-Logic ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-012b.gsz
Date: 5/10/2018
Time: 2:11:36 PM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: Yes

Section F-F: Post-Slide Topo
Groundwater Midway Between Slide Plane and Surface
Remediation Option: Stitch Pier

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



Type: Pile
Shear Force: 45,000 lbs
Shear Reduction Factor: 1
Pile Spacing: 5 ft
Shear Option: Parallel to Slip

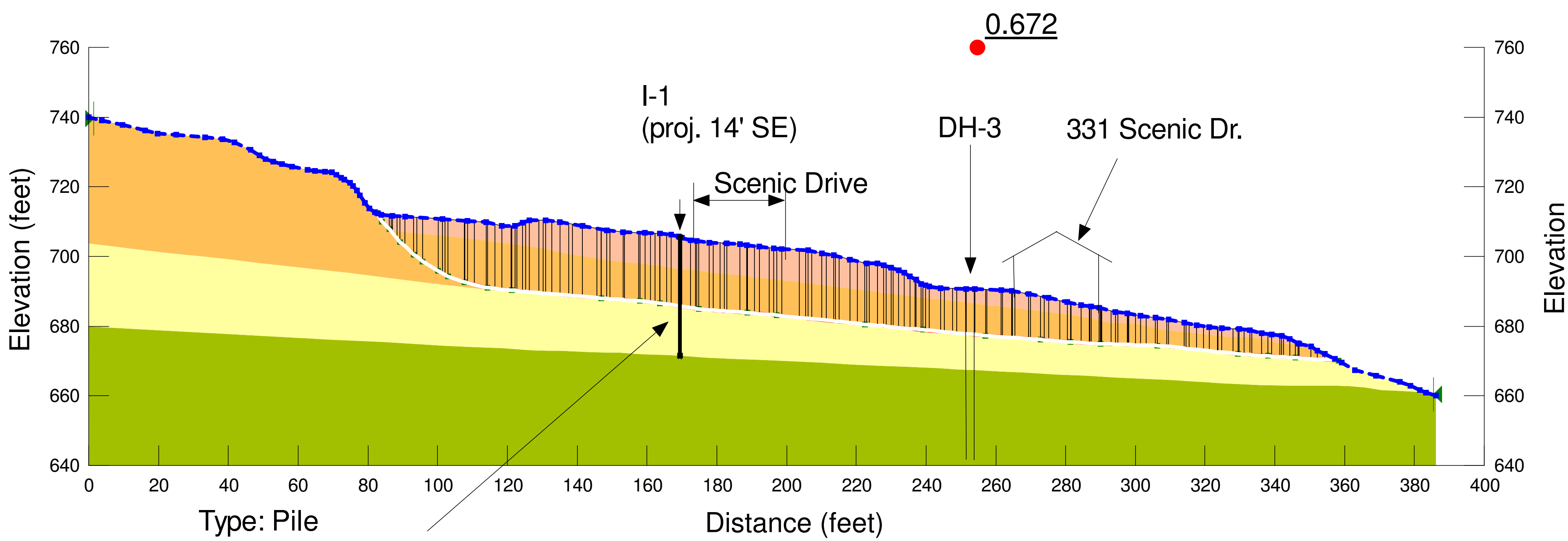
Geo-Logic ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-012c.gsz
Date: 5/10/2018
Time: 2:13:22 PM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: Yes

Section F-F: Post-Slide Topo
Groundwater At Surface
Remediation Option: Stitch Pier

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



Type: Pile
Shear Force: 45,000 lbs
Shear Reduction Factor: 1
Pile Spacing: 5 ft
Shear Option: Parallel to Slip

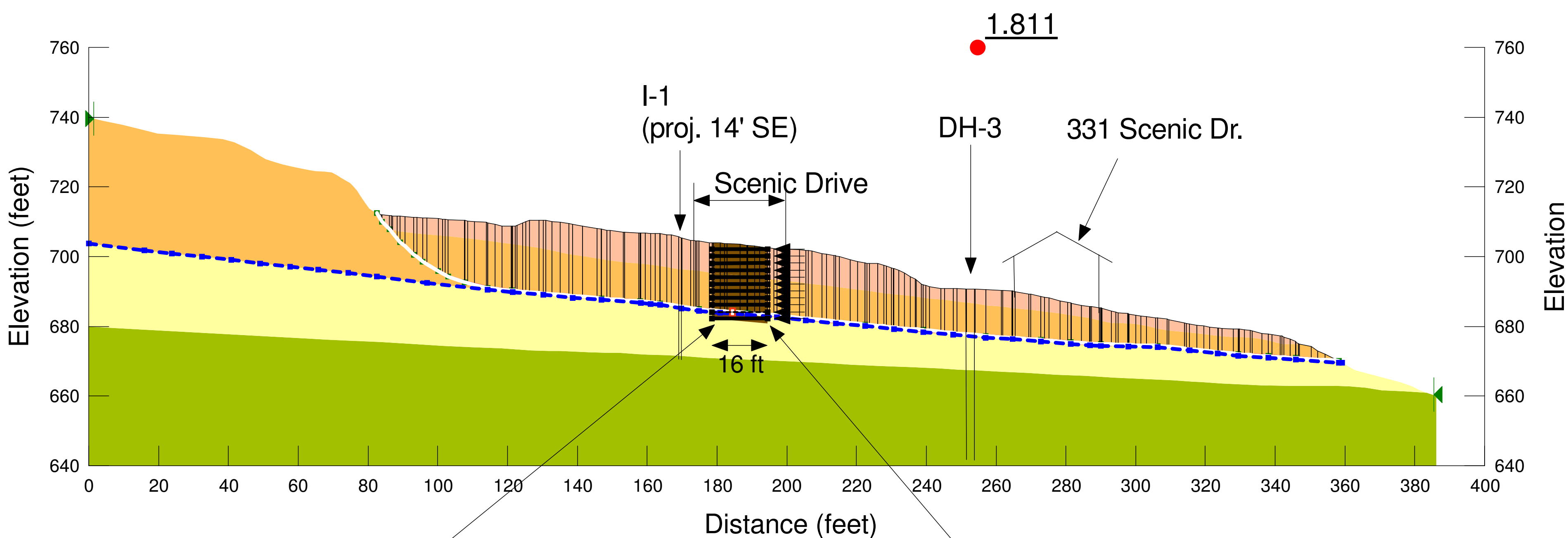
Geo-Logic
ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-011b.gsz
Date: 5/10/2018
Time: 1:44:30 PM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: No

Section F-F: Post-Slide Topo
Groundwater Below Slide Plane
Remediation Option: Excavation Replaced w/ Reinforced Engineered Fill

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Engineered Fill	Mohr-Coulomb	130	0	34
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



Excavate below slide plane,
Replace with compacted engineered fill and
Geosynthetic reinforcement

Type: Geosynthetic
Tensile Capacity: 2,000 lbs
Reduction Factor: 1
Calculate Pullout Resistance: Yes
Vertical Spacing: 2 feet

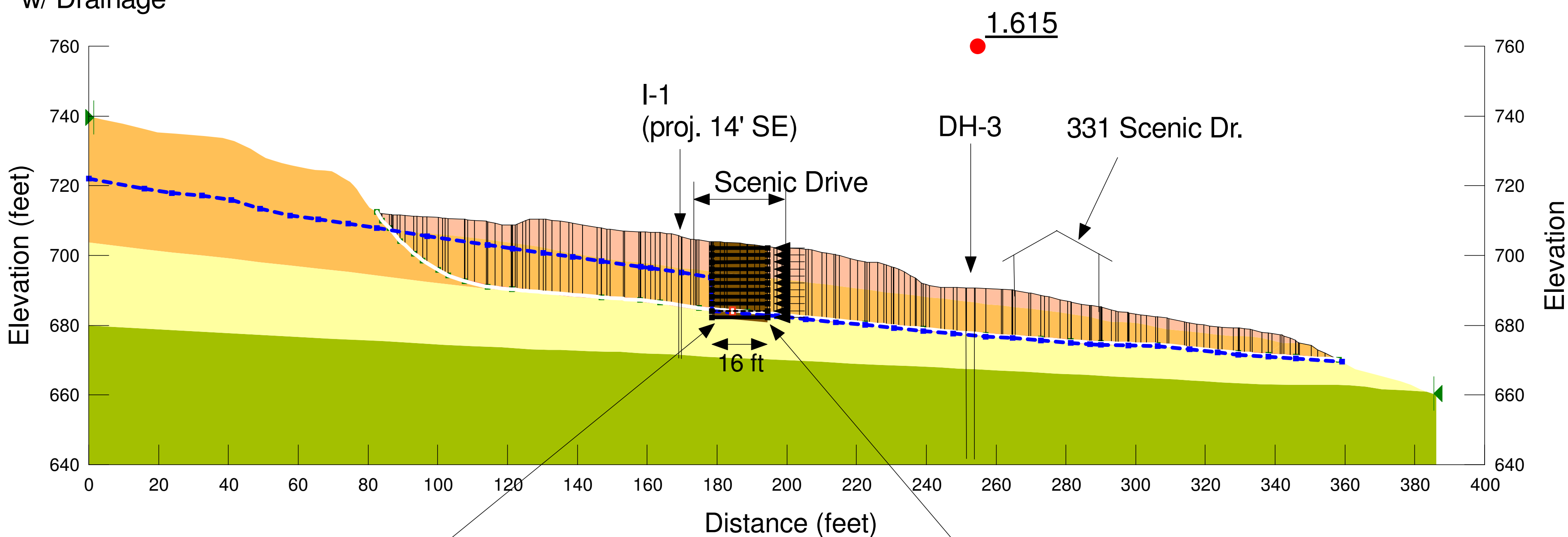
Geo-Logic ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-011e.gsz
Date: 5/10/2018
Time: 3:01:45 PM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: No

Section F-F: Post-Slide Topo
Groundwater Midway Between Slide Plane and Surface
Remediation Option: Excavation Replaced w/ Reinforced Engineered Fill w/ Drainage

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Engineered Fill	Mohr-Coulomb	130	0	34
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



Excavate below slide plane,
Replace with compacted engineered fill and
Geosynthetic reinforcement

Type: Geosynthetic
Tensile Capacity: 2,000 lbs
Reduction Factor: 1
Calculate Pullout Resistance: Yes
Vertical Spacing: 2 feet

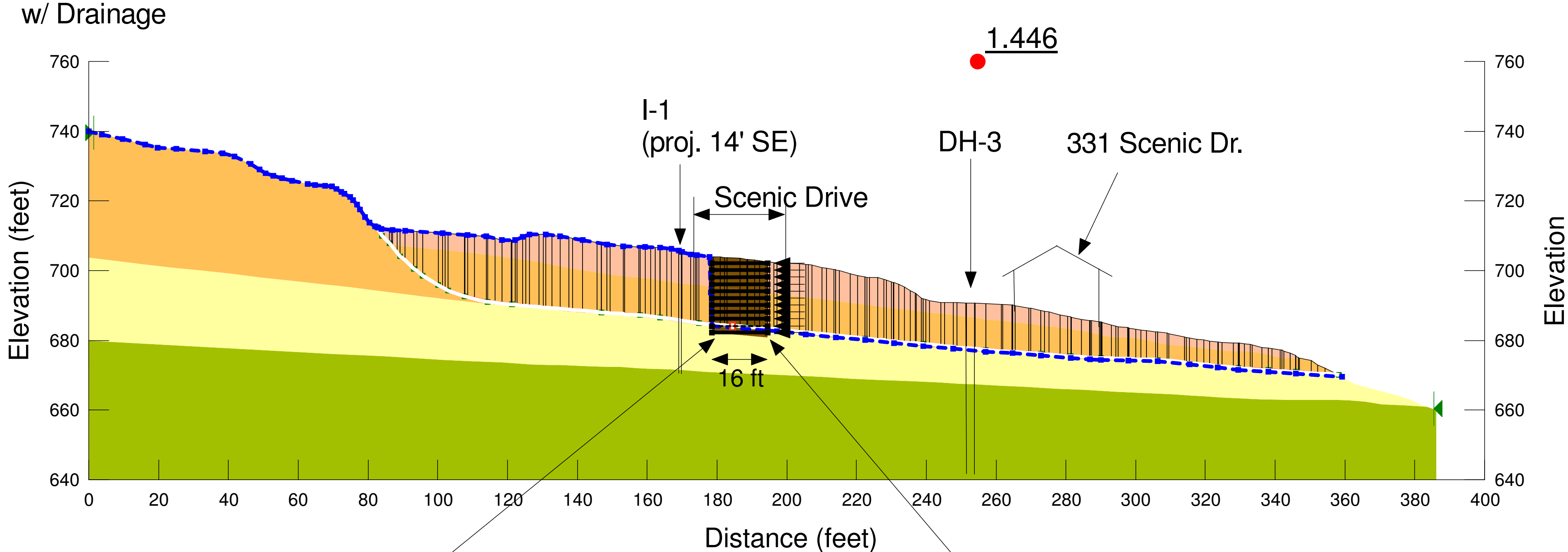
Geo-Logic ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-011f.gsz
Date: 5/10/2018
Time: 3:08:33 PM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: No

Section F-F: Post-Slide Topo
Groundwater at Surface
Remediation Option: Excavation Replaced w/ Reinforced Engineered Fill w/ Drainage

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Engineered Fill	Mohr-Coulomb	130	0	34
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



Excavate below slide plane,
Replace with compacted engineered fill and
Geosynthetic reinforcement

Type: Geosynthetic
Tensile Capacity: 2,000 lbs
Reduction Factor: 1
Calculate Pullout Resistance: Yes
Vertical Spacing: 2 feet

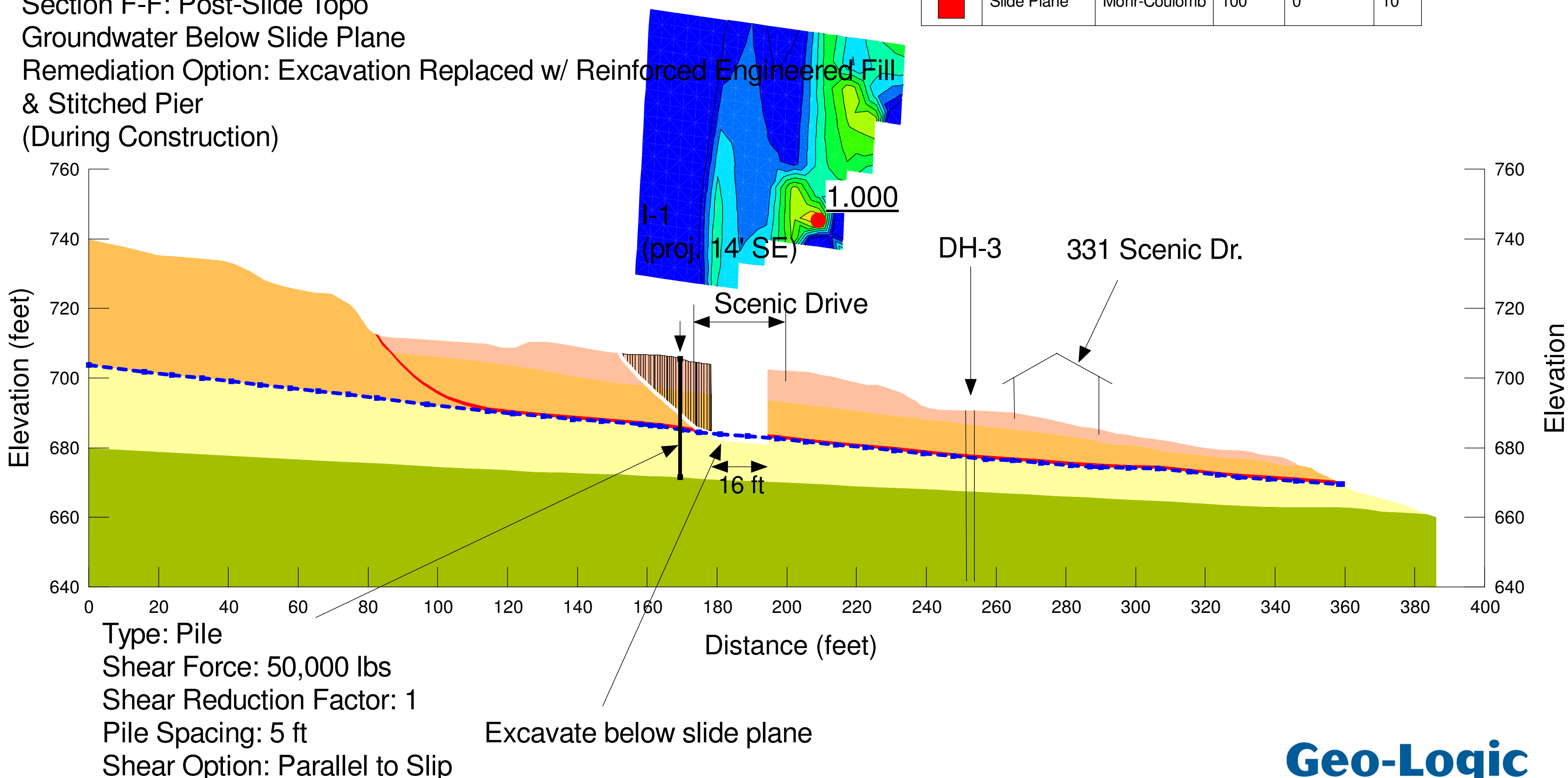
Geo-Logic ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-014c.gsz
Date: 5/11/2018
Time: 8:52:30 AM
Method: Morgenstern-Price
Slip Surface Option: Grid and Radius
Optimize Critical Slip Surface Location: Yes

Section F-F: Post-Slide Topo
Groundwater Below Slide Plane
Remediation Option: Excavation Replaced w/ Reinforced Engineered Fill & Stitched Pier
(During Construction)

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



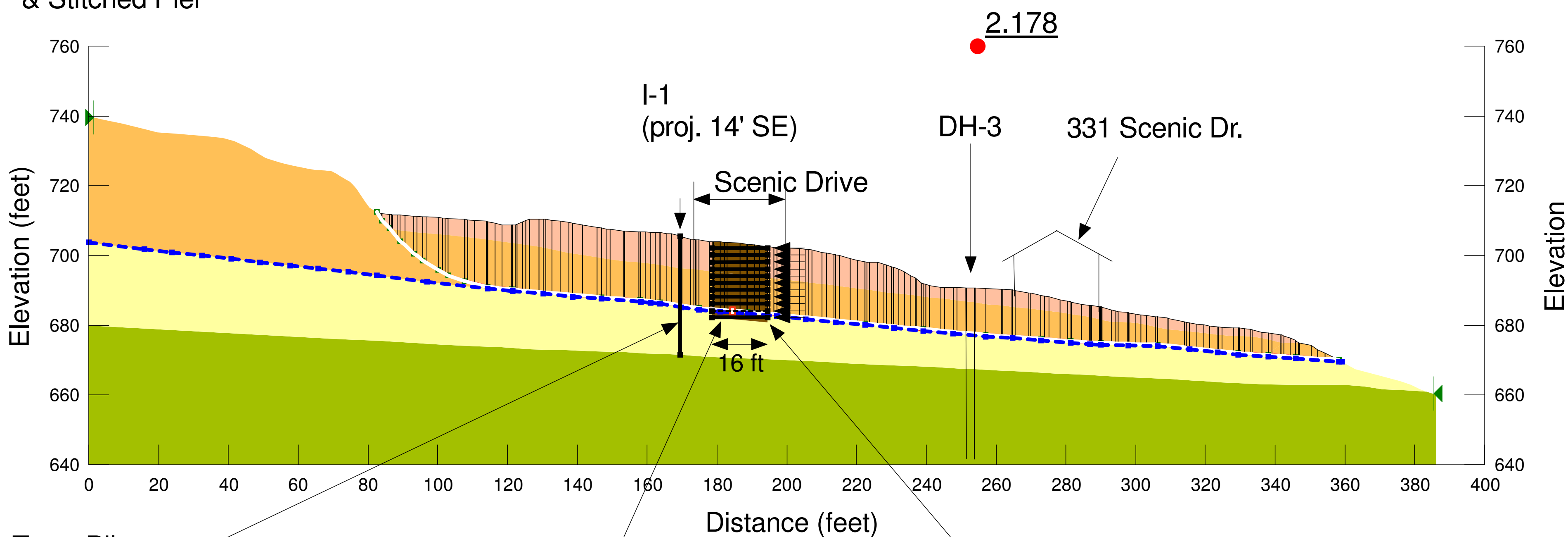
Geo-Logic
ASSOCIATES

Scenic Drive Slope Stability

San Mateo Co_Scenic Dr_Section F_Post-013a.gsz
Date: 5/10/2018
Time: 2:27:25 PM
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Optimize Critical Slip Surface Location: No

Section F-F: Post-Slide Topo
Groundwater Below Slide Plane
Remediation Option: Excavation Replaced w/ Reinforced Engineered Fill & Stitched Pier

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Basalt (Tmb)	Mohr-Coulomb	135	0	35
	Colluvium	Mohr-Coulomb	110	0	25
	Engineered Fill	Mohr-Coulomb	130	0	34
	Purisima (Tpt)	Mohr-Coulomb	119	0	30
	Slide Debris	Mohr-Coulomb	108	0	25
	Slide Plane	Mohr-Coulomb	100	0	10



Type: Pile
Shear Force: 45,000 lbs
Shear Reduction Factor: 1
Pile Spacing: 5 ft
Shear Option: Parallel to Slip

Excavate below slide plane,
Replace with compacted engineered fill and Geosynthetic reinforcement

Type: Geosynthetic
Tensile Capacity: 2,000 lbs
Reduction Factor: 1
Calculate Pullout Resistance: Yes
Vertical Spacing: 2 feet

Geo-Logic
ASSOCIATES