ALAN KROPP
& ASSOCIATES, INC.
GEOTECHNICAL
CONSULTANTS

ALAN KROPP, CE, GE
JAMES R. LOTT, CE, GE
JEROEN VAN DEN BERG, CE
THOMAS M. BRENCIC, CE

September 12, 2019
1853-3, L-31862

Mr. John Calise
Executive Director of Facilities, Maintenance, and Operations
Berkeley Unified School District
1707 Russell Street
Berkeley, CA 94703

RE: Landslide Deformation Hazard Study Report
Oxford Elementary School
Berkeley Unified School District
Berkeley, California

Dear Mr. Calise:

We have attached six copies of our landslide deformation study report for the Oxford Elementary School site in Berkeley, California. Our services on this project are being provided in general accordance with our modified contract with the Berkeley Unified School District approved on January 30, 2019.

As presented in the report, our study confirmed the Oxford Elementary School site is located within the actively-moving Keith Avenue Landslide Complex. An extensive compilation of past data indicates this landslide mass generally moves at an average rate of about one inch per year, with significant variations related to annual rainfall patterns; this movement will continue in the future. Based on our calculations of the additional magnitude of landslide movements that would occur during an earthquake, we have calculated that the Oxford School campus would likely have a total movement which might range from as little as 2 feet to as much as 20 feet or more in the design event. Without major site reconstruction, a high safety hazard would result at the school site. With some substantial remedial schemes, it may be possible for an entirely reconstructed school campus to achieve reasonable performance, but still experience localized, non-structural damage. If the school were to be rebuilt, it will be important to consider that the neighborhood may become a disaster area as a result of the landslide activities, isolating the school from its surroundings. This report provides details regarding all of our investigation, calculations, and conclusions. We encourage you to read the report in its entirety.

If you have any questions regarding the attached report, please do not hesitate to call us.

Very truly yours,

Alan Kropp, C.E., G.E.
Principal Engineer

REGISTERED PROFESSIONAL ENGINEER
ALAN LEE KROPP
GE 487
EXP. 12/31/19
GEOTECHNICAL
STATE OF CALIFORNIA

James Joyce, R.G., C.E.G., C.H.G.
Certified Engineering Geologist

PROFESSIONAL GEOLOGIST
JAMES M. JOYCE
No. 1517
CERTIFIED
ENGINEERING
GEOLOGIST
STATE OF CALIFORNIA

M. Jeroen van den Berg, C.E.
Senior Engineer

Copies: Addressee (6+PDF) - johncalise@berkeley.net
Mr. William Savidge (PDF) - bsavidge@k12schoolfacilities.org
Ms. Maria Denny (PDF) - maria@k12schoolfacilities.org

TABLE OF CONTENTS

Letter of Transmittal
Table of Contents

1.0 INTRODUCTION 1
2.0 PURPOSE 1
3.0 SCOPE 2
4.0 SITE INVESTIGATION 2
4.1 Site Development History 2
4.2 Review of Historic Data for Site/Area 3
4.3 Review of Published Geologic Maps 3
4.4 Compilation of Past Alan Kropp & Associates (AKA) Maps & Datasets 3
4.5 Review of Aerial Photographs 3
4.6 Site Reconnaissance 4
4.7 Field Explorations 4
4.7.1 Conventional Small Diameter Borings 4
4.7.2 Large Diameter Borings 4
4.7.3 Cone Penetrometer Tests 5
4.7.4 Geophysics (Downhole Shear Wave Logging) 5
4.7.5 Piezometers 6
4.8 Laboratory Testing 6
5.0 SITE CONDITIONS 6
5.1 Geologic Setting 6
5.1.1 Regional Geology 6
5.1.2 Site Area Geology 6
5.1.3 Site Area Landslides 7
5.1.4 Regional Landslide History 7
5.1.5 Keith Avenue Landslide Location and Composition 8
5.1.6 Keith Avenue Landslide Movement Magnitude and Rate 9
5.1.7 Regional Seismicity 11
5.1.8 Earthquake Probabilities 12
5.1.9 Historic Seismicity 12
5.2 Site Reconnaissance 13
5.3 Aerial Photo Interpretations 14
5.4 Subsurface Data 15
5.4.1 Borings 15
5.4.1.1 Conventional Small Diameter Borings 15
5.4.1.2 Large Diameter Borings 16
5.4.2 Cone Penetrometer Tests 16
5.4.3 Woodward-Clyde Consultants 1977 Geologic Study Report 17
5.4.4 Shear Wave Profile 17
5.4.5 Summary of Soil/Rock Conditions 17
5.4.6 Groundwater Conditions 18
6.0 EVALUATIONS AND CONCLUSIONS 19
6.1 Active Landslide Boundaries 19
6.2 Probabilistic Seismic Hazards Analysis (PSHA) 19
6.3 Calculated Seismic Displacements 19

6.4 Conceptual Mitigation Measures 22
7.0 LIMITATIONS 23

FIGURES

Figure 1 Vicinity Map
Figure 2 Historic Photos
Figure 3 Site Plan
Figure 4 Overview Geologic Maps
Figure 5 Three Landslide Maps
Figure 6 Pre-Development Earthflow Photo
Figure 7 1982 Landslide/Fault Data Map
Figure 8 Landslide Damage Photos
Figure 9 Historic East Bay Municipal Utilities District Pipe Leak Map
Figure 10 Composite Map of Active Landslide Limits
Figure 11 Active Limits of Keith Avenue Landslide – Lidar Base
Figure 12 Geologic Section 1-1'
Figure 13 Boulder Photo
Figure 14 Landslide Outline on 1935 Oblique Photo
Figure 15 News Article
Figure 16 Arch Street Block Movement Survey
Figure 17 Regional Fault Map
Figure 18 CPT Summary
Figure 19 Shear Wave Velocity Overlay Plot
Figure 20 Geologic Section A-A'
Figure 21 Geologic Section B-B'
Figure 22 Geologic Section C-C'
Figure 23 Geologic Section D-D'
Figure 24 Geologic Section E-E'
Figure 25 Geologic Section F-F'
Figure 26 Sample Slope Stability Calculation

APPENDICES

Appendix A Logs of Borings
Appendix B Cone Penetrometer Testing
Appendix C Geophysical Shear Wave Velocity Report
Appendix D Laboratory Test Data
Appendix E Site-Specific Probabilistic Seismic Hazard Analysis (PSHA) Report
Appendix F Previous Geologic Study Report
Appendix G Previous Subsurface Data
Appendix H Landslide Displacement Calculations
Appendix I Reference Materials

1.0 INTRODUCTION

This report presents the results of our seismic landslide hazard study for the Oxford Elementary School (Oxford) campus in Berkeley, California. We are currently providing services for this project in general accordance with our (modified) contract with the Berkeley Unified School District (District) dated January 30, 2019.

Our original scope of work was outlined in a District Request for Qualifications and Proposals (RFQ/RFP) published on July 25, 2018, and included geotechnical services relative to the planned replacement of the Multi-Purpose Building on the Oxford campus. Our initial proposal dated August 22, 2018, which responded to the RFQ/RFP, provided a detailed scope of services for a conventional geotechnical evaluation of the site.

During contract negotiations, we notified the District that based on our landslide mitigation experience in the North Berkeley area and on California Seismic Hazard Zone mapping, the entire Oxford site is located within a larger, existing active landslide zone encompassing over 120 acres. It was decided that a landslide hazard study of the entire Oxford campus is warranted prior to performing a detailed geotechnical evaluation for the Multi-Purpose building replacement. Consequently, we provided an expanded scope and cost to perform a seismic landslide hazard study which was approved on January 30, 2019. The purpose of the expanded study was to evaluate the static and seismic landslide hazard to the existing Oxford site as it is currently configured. As the study would contribute to the feasibility analysis of overall future site development, our scope would not include an evaluation of designs or layouts for planned buildings.

Oxford Elementary School is located in North Berkeley at the base of the Berkeley/East Bay Hills, about 2½ miles east of the San Francisco Bay margin. The school address is 1130 Oxford Street in North Berkeley. The school property is bounded on the northwest and southeast by single-family residences, by Walnut Street to the southwest and by Oxford Street to the northeast. The approximate location of the school property is indicated on the attached Vicinity Map, Figure 1.

During the course of our investigation, we collaborated with several outside consultants who contributed their expertise to the study. These consultants included:

- Norcal Geophysical Consultants, Inc., who performed geophysical seismic shear wave interpretation and modeling;
- Lettis Consultants International, Inc., who performed a site-specific, probabilistic seismic hazard analysis for the site;
- Rune Storesund of Storesund Consulting, who provided landslide modeling and analytical expertise; and
- Professor Jonathan Bray of UC Berkeley, who acted as an advisory and review consultant.

2.0 PURPOSE

The primary purposes of this seismic landslide hazard study were to: (1) explore geologic conditions at the site; (2) conduct preliminary geologic and geotechnical engineering analyses to evaluate slope stability, especially during a design seismic event; and (3) develop conceptual mitigation alternatives to address slope stability concerns, if warranted.

This initial document is intended to provide information to the District, local decision makers, and project team members regarding potential site development alternatives for Oxford School. For this reason, we have not included some of the more extensive discussions that we normally include as part of a full design-level document subject to DSA review. We also note that additional services could be warranted to further explore and develop the preliminary conceptual alternatives discussed herein. It is our intent to continue our discussions with project team members and to provide geotechnical and geologic input, when needed, to assist the District in identifying a preferred site development alternative.

We also note that the preliminary opinions, interpretations, and conclusions presented herein are not intended for use in final design. Additional investigation and study will be required following the selection of a preferred site development alternative prior to preparing final design-level recommendations for the Oxford site.

3.0 SCOPE

The scope of work performed in this investigation to accomplish our stated purposes included:

- A review of historic data for the Oxford site and surrounding area;
- A review of published materials with data relevant to the site, along with data from other projects in the area;
- A compilation of past AKA maps and datasets;
- A review and interpretation of historic aerial photographs;
- A reconnaissance of the site and portions of the immediate surrounding properties;
- A subsurface exploration program consisting of conventional small-diameter borings, large diameter borings, cone penetrometer testing (CPT), and geophysical explorations;
- Laboratory index, classification, and strength tests on subsurface samples from the site, as required;
- Development of a site-specific probabilistic seismic hazard analysis (PSHA), performed by Lettis Consultants, Inc. (LCI);
- Identification of active landsliding boundaries at the Oxford area;
- Quantitative evaluation of landslide-related hazards at Oxford, and;
- Preparation of this landslide hazard report for the site which presents the results of our studies and provides geologic and geotechnical input for future development of the site.

The scope of our services did not include an environmental assessment or investigation for the presence of hazardous or toxic materials in the soil, groundwater, or air on, below, or around this site. An evaluation of the potential presence of sulfates in the soil, or other possibly corrosive, naturally occurring elements was beyond our scope.

4.0 SITE INVESTIGATION

4.1 Site Development History

Based on our review of historic photographs and news articles, we have concluded the Oxford site was originally developed in 1909 when the first Oxford School building was constructed along the northwestern property boundary. Following the Long Beach Earthquake in 1933, the building was condemned in accordance with the California State Field Act, enacted on April 10, 1933, and mandating that school buildings must be

earthquake-resistant (which the Oxford school building was not). The building was subsequently structurally upgraded to conform to the Field Act. In 1964, the original Oxford School building was demolished and new classroom and multi-purpose room buildings were constructed on the site. The classroom building was remodeled around 1998 to install an elevator and other improvements. Photos of the now demolished original Oxford school building taken in 1922 and in 1933 after the addition of a cafeteria/shop annex are presented on Figure 2.

4.2 Review of Historic Data for Site/Area

Several documents were made available to us during our study, including plans from previous site developments provided by the District, historic photos and news articles obtained from local historical societies, geotechnical reports performed by other consultants, our own library of geologic and geotechnical reports, and other sources. A key report provided to us was a comprehensive fault trench study of the Oxford site performed in 1977 by Woodward-Clyde Consultants. The entire Woodward-Clyde report is included in Appendix F and sections of other reports are included in Appendix G.

4.3 Review of Published Geologic Maps

We reviewed published geologic maps and literature pertaining to geologic and seismic conditions in the project vicinity. These references included regional geologic maps, landslide maps, regional and localized fault maps, and seismic hazard maps.

A list of selected references is presented in Appendix I. Information obtained from the map and geologic literature review is discussed in Section 5.0, “Site Conditions.”

4.4 Compilation of Past Alan Kropp & Associates (AKA) Maps & Datasets

AKA has had extensive experience working with landslides in the Berkeley Hills over the past 40 years. We reviewed numerous datasets we have compiled which have relevancy to the Oxford site. These sources of information included:

- Our area damage and active slide location maps;
- Our subsurface exploration database;
- East Bay Municipal Utility District pipe leak maps from 1985;
- Surveyed measurements of movement of houses and improvements;
- Technical articles that discuss the landslides in the area; and
- Satellite-based Interferometric Remote Synthetic Aperture Radar (InSAR) measurements.

4.5 Review of Aerial Photographs

Eleven sets of single and stereo-paired, black and white aerial photographs were reviewed as a part of this study. The photographs we reviewed were taken in the years 1930, 1935, 1939, 1946, 1947, 1949, 1953, 1957, 1959, 1969, and 1983 and ranged in scale from about 1:7,200 to 1:24,000. Descriptions of our observations are included in Section 5.3, “Aerial Photo Interpretations,” and a complete listing of the photographs is attached in Appendix I.

4.6 Site Reconnaissance

As a part of our investigation, we performed a reconnaissance of the entire mapped landslide area and portions of the surrounding neighborhood. Our reconnaissance was confined to roads and public areas and the portions of private property that is visible from the street, along with the Oxford site. The results of the geologic reconnaissance are discussed in Section 5.2, "Site Reconnaissance."

4.7 Field Explorations

4.7.1 Conventional Small Diameter Borings

Between December 26, 2018, and January 2, 2019, we drilled five borings to evaluate the subsurface conditions at various locations throughout the Oxford campus. The test borings were drilled by Britton Exploration of Los Gatos, California using a track-mounted auger/rotary wash combination drill rig. The drill rig was also equipped to advance continuous sampling apparatus. During drilling, our Geologist monitored the soil cuttings and made notes of any changes in drilling conditions that were observed or commented on by the driller. Soil samples were obtained using a 2-inch O.D. Standard Penetration Test (SPT), 3-inch O.D. California Modified, 3-inch I.D. continuous core and Pitcher-Barrel samplers. The SPT and California Modified samplers were driven by a 140-pound hammer falling 30 inches using an automatic-trip hammer. The hammer blows required to drive the samplers the final 12 inches of each 18-inch drive are presented on the boring logs. Where the sampler met early refusal, the number of hammer blows and the corresponding depth of penetration (in inches) are indicated.

- Boring 1 was drilled using 8-inch diameter, hollow-stem augers with continuous dry core sampling to about 55 feet and switched to 5½-inch diameter, mud-rotary wash with conventional drive sampling from about 55 feet to 118 feet (maximum depth explored).
- Borings 2 and 5 were drilled using 8-inch diameter, hollow-stem augers and conventional drive sampling to the depths explored of about 61½ feet and 43 feet respectively.
- Borings 3 and 4 were started using 8-inch diameter, hollow-stem augers to about 5 to 9 feet, then switched to mud-rotary wash with Pitcher-Barrel and conventional drive sampling to the depths explored of about 38 feet and 54½ feet respectively.

The approximate boring locations are indicated on the Site Plan, Figure 3. Details regarding the conventional small-diameter boring field investigation are discussed below and boring logs are presented in Appendix A.

4.7.2 Large Diameter Borings

Between December 27 and December 29, 2018, we drilled three large-diameter geologic borings to conduct a detailed, in-situ logging of geologic conditions and estimate the depth(s) of landsliding at the site. The approximate locations of our large-diameter borings (identified as LD-1, LD-2, and LD-3) are indicated on the Site Plan, Figure 3. The test borings were drilled by Tri-Valley Drilling Services, Inc. of Ventura, California with a truck-mounted drill rig using a 30-inch diameter bucket auger. Boring LD-1 was extended to a depth of approximately 60 feet; LD-2 was extended to about 50 feet; and LD-3 was extended to about 28 feet.

The large diameter borings were logged by Mr. Joyce, our Certified Engineering Geologist, using down-hole, direct observation techniques. Logs of the large diameter borings are included in Appendix A.

Soils from both the small and large diameter borings were classified in general accordance with ASTM D2488, which is based on the Unified Soil Classification System (USCS). The USCS is described on the Key to Exploratory Boring Logs, Figure A-1. Rock was classified in general accordance with the Physical Properties Criteria for Rock Descriptions described on Figure A-2.

4.7.3 Cone Penetrometer Tests

On December 29, 2018, we advanced three CPT soundings at the approximate locations shown on the Site Plan (Figure 3). The CPTs were advanced using a ConeTec, 30-ton, truck-mounted CPT rig. The CPTs were located to obtain a relatively representative image of the subsurface conditions. The CPTs, designated CPT-1, CPT-2, and CPT-3, were advanced to depths of approximately 28, 48, and 45 feet below the existing site grade, respectively. The depths of the soundings were limited by effective refusal on hard surfaces. ConeTec Industries, Inc. (ConeTec) of San Leandro, California performed the CPT soundings under the observation of Mr. Jeroen van den Berg, C.E., Senior Engineer for AKA.

In addition to estimating interpretive soil parameters, the CPT cones were equipped with geophones and a seismic source to estimate soils and rock shear wave velocities. During cone advancement, seismic shear wave velocities were recorded at about every 5 feet to the final depth of the cone advancement. This data was relayed to LCI as input to their PSHA.

The CPT method involves pushing a 2-inch diameter conical probe into the ground using a hydraulic ram system. The CPT probe is equipped with sensors that produce a continuous record of tip resistance, sleeve friction, and pore pressure as the cone is advanced. During cone advancement, real-time data obtained from the cone sensors are displayed on a computer monitor together with preliminary interpretive logs of soil type. During cone advancement, Mr. van den Berg monitored the real-time cone data and determined the depths to which the probes would extend.

ConeTec's interpretive logs of the CPT soundings are attached in Appendix B. Also included in Appendix B is information obtained from ConeTec describing their equipment and the correlative methods they used in developing their interpretive logs. The attached logs prepared by ConeTec represent their interpretations of the subsurface conditions at the approximate sounding locations indicated on the site plan on the particular date designated on the logs. The sounding location and elevation indicated on the attached materials were determined by measuring from existing fences and buildings shown on the project plans and should be considered approximate.

4.7.4 Geophysics (Downhole Shear Wave Logging)

In addition to the boring explorations, we performed a geophysical investigation of the underlying materials in order to estimate the shear wave velocities of the soil and rock profile. Following drilling of Boring 1, downhole shear wave suspension logging was performed within the evacuated shaft to the total depth of the boring of about 118 feet below grade. The estimated shear wave velocities, methodologies, and detailed results of the downhole shear wave logging are presented in Appendix C. In addition to the seismic CPT cone data, the geophysical shear wave data was used in development of the PSHA by LCI.

4.7.5 Piezometers

Ascertaining the depth to free groundwater during the drilling operations was generally precluded by the rotary wash drilling method. However, vibrating-wire piezometers were installed in Borings 1 and 3 to continuously measure the depth of groundwater over time. All piezometer casings were grouted in accordance with City of Berkeley permit requirements. The results of the piezometer readings are discussed in Section 5.4.6, "Groundwater Conditions."

4.8 Laboratory Testing

Water content, Atterberg Limits, grain size distribution, dry density, triaxial unconsolidated-undrained shear strength tests, and direct torsional shear tests were performed on appropriate subsurface samples obtained during our field investigation. The water content and Atterberg Limits tests were performed to evaluate the variations in soil moisture and the soil's expansive potential, respectively. The results of the grain size tests were used to aid in the classification of the soils. The dry density tests were used to evaluate the weight characteristics of the soil, while the triaxial shear strength tests were used in estimating the undrained strength of the clayey soils. The torsional ring shear tests were performed to evaluate the fully softened and residual strength of slide plane materials. The results of these tests are presented on the boring logs at the appropriate sample depths and in Appendix D.

5.0 SITE CONDITIONS

5.1 Geologic Setting

5.1.1 Regional Geology

The Oxford site is located on the west slope of the Berkeley Hills, east of San Francisco Bay, within the northern portion of the Coast Ranges geomorphic province of California. The region is characterized by northwest-trending mountain ranges and valleys that generally parallel the major geologic structures, such as the San Andreas and Hayward faults. The oldest widespread rocks in the region are highly deformed sedimentary and volcanic rocks of the Mesozoic-age (the period from 225 million to 65 million years before present) Franciscan Assemblage. These rocks are in fault contact with similar-age sedimentary rocks of the Mesozoic-age Great Valley Sequence. The Mesozoic rocks are, in turn, overlain by a diverse sequence of Tertiary-age (the period from 65 million to 1.8 million years before present) sedimentary and volcanic rocks. Since their deposition, the Mesozoic and Tertiary rocks have been extensively deformed by repeated episodes of folding and faulting. In general, upland areas such as the Berkeley Hills have experienced some tectonic uplift over time while the adjacent lowlands, such as San Francisco Bay, have experienced some subsidence.

5.1.2 Site Area Geology

A widely used geologic map of the area (Dibblee, 2005) indicates the surficial deposits in the project area are underlain by bedrock of the Coast Range Ophiolite Complex, described as "Igneous complex intrusive into Franciscan Assemblage." As shown on Figure 4, Overview Geologic Maps, this map describes the bedrock unit underlying the site as "Volcanic rocks, mostly keratophyre andesitic rock, brown, massive, aphanitic, much altered. Includes basaltic rocks in Hayward Fault." The map also shows the site is partially within Franciscan Assemblage mélange; this material is described as a "mixture of Franciscan rock fragments in matrix of pervasively sheared dark claystone or greywacke."

A geologic map of the Hayward Fault Zone prepared by Graymer et al. (2000) also indicates the site is underlain by bedrock belonging to the Arc Volcanics group. Although this map places the keratophyre rock type in a different assemblage than the Dibblee map, it is essentially the same rock type. The text accompanying this map describes the bedrock as follows: "Keratophyre and quartz keratophyre (Late Jurassic). Highly altered intermediate and silicic volcanic and hypabyssal rocks. Feldspars are almost all replaced by albite. In some places, closely associated with (intruded into?) basalt." The portion of the Graymer et al. map which includes the site is also presented on Figure 4 adjacent to the Dibblee map.

5.1.3 Site Area Landslides

Although the Graymer et al. map did not include landslide mapping, the Dibblee map indicates a large landslide is present about 600 feet southeast of the site. Other landslide maps of the area (Nilsen, 1975; CGS Seismic Hazard Compilation map, 2003) show large landslide complexes are present in the North Berkeley hillside areas including the site. Furthermore, on the Quaternary fault mapping of the Hayward fault through this portion of the East Bay Hills, Herd (1978) indicated the entire hillside area from just north of the University of California campus to the southern portion of El Cerrito was one massive landslide complex. All three of these landslide maps are presented on Figure 5. We should point out that all of these landslide maps were based largely on aerial photograph interpretation and limited field reconnaissance; thus, they should be considered preliminary.

5.1.4 Regional Landslide History

Within the region, many valleys have been partially filled with unconsolidated sedimentary deposits of Quaternary age (the last 1.8 million years). These deposits, which include alluvium and colluvium, underlie the gently sloping valley bottoms and consist of interbedded clay, silt, sand, and gravel. This geologic framework has led to the development of landslides in the Berkeley Hills since tectonic uplift began millions of years ago. The larger landslides in the area are earthflows (or earthflow complexes) ranging up to hundreds or thousands of feet in length. Earthflows are typically elongate, slow-moving landslide masses that are shallow to moderately deep. Typically, earthflow deposits consist of colluvium and other soils that have accumulated in hillside swales. Movement typically occurs when these materials reach significant thickness and become saturated. Once earthflow movement begins and a basal shear surface is formed at the bottom of the deposit, movement will typically continue episodically over a long period of time. Within a short period of time such as a year or a decade, individual earthflows may experience no movement or movements ranging from a few inches to a few feet. Movement rates typically increase in response to periods of wet weather. This process has led to the development of a number of large, slow-moving earthflow complexes in the North Berkeley Hills. A historic photograph of one of these slide areas is presented on Figure 6.

Hoexter et al. (1982) was among the earliest attempts to define the general areas of these landslides in their study of the Hayward fault, because the ground movement from landsliding made the location of fault creep very difficult. As shown on Figure 7, they provided general locations and gave names to three primary landslide areas. The southernmost slide complex on the map was divided into the upper and lower area, with the lower portion of the southern landslide complex was termed the "Oxford School Slide." Apparently, they utilized information compiled by the City of Berkeley in the 1950's regarding landslide activity in the area of this southern slide, but we have not been able to acquire the City dataset.

5.1.5 Keith Avenue Landslide Location and Composition

In the 1980's, AKA began accumulating information on the large landslide complexes in the Berkeley Hills because geotechnical design parameters to guide construction of new projects were heavily influenced by whether a site was located on a landslide deposit and the depth of sliding, if present. As work was performed throughout the hills, there were concentrations of damage on private properties and in the streets and sidewalks in certain areas that did not appear to be related to poor construction, settling fill, inadequate drainage, or other factors; in these areas patterns of landslide movement were evident. Examples of such damage are shown on Figure 8. Zones in the hills where landslide damage was and was not likely were plotted on a topographic quadrangle sheet, and compared to the general locations shown on the Hoexter et al. map. Further quantification was established as a database of borings drilled by our firm and by other consultants was assembled, because there were obvious areas where landslide debris was encountered during subsurface exploration while in other areas shallow, competent bedrock was encountered. As a result, starting in 1985 AKA began preparing a map of deep-seated, slow-moving "active" and "potentially active" landslides in the Berkeley Hills for local distribution. (Active landslides were defined as landslides that moved recently enough to damage cultural features, while potentially active landslides were locations where young slide deposits were present but the landslide not seem to caused significantly damage to cultural features.) Copies of key boring logs for projects beyond the Oxford site that we have utilized in our Oxford evaluation are presented in Appendix G. It should also be noted that two investigations by Woodward- Clyde-Sherard and Associates at the school site in 1963 assessed the geological features at the site and concluded a slow-moving landslide was present; however, we do not have copies of these reports so that data was not used in the development of our 1995 map.

An early tool that AKA utilized to further refine the Berkeley Hills landslide map was water supply line leak information provided by the East Bay Municipal Water District (EBMUD). An example of the data supplied by EBMUD in 1985 is presented on Figure 9. Pipe leaks and breaks can result from a large number of factors in addition to landsliding, such as poor road fill, old pipe material, adjacent construction, as well as other conditions. However, as seen on Figure 9, there are areas with a concentration of pipe leaks or breaks, and AKA utilized this concentration of distress to assist in the location of the landslide limits.

Additional refinements of the landslide limits in the Berkeley Hills have more recently come through the use of satellite-based Interferometric Remote Synthetic Aperture Radar (InSAR) measurements by various investigators. Utilizing satellite data recorded as early as 1992, various teams have analyzed data recorded in time periods ranging from 2 to 14 years. The work of each successive team has advanced the sophistication of the datasets, as more advanced satellite recording systems have been utilized. The results of the four most important of these studies, and time period of recording, appear in Hilley et al. (2004), Quigley et al. (2010), Lei and Burgmann (2010), and Cohen-Weber (2018). The limits of landslide movement from each of the time periods of study have been utilized in our mapping of the active slide area. Movement rate information from these studies is presented in the following section of this report.

The Oxford site is within one of the landslides mapped by AKA (1995), as well as previously by Hoexter et al. This landslide has generally come to be referred to locally as the Keith Avenue Landslide (but is called the North Berkeley Slide in some references, especially the InSAR studies). The location of the active Keith Avenue Landslide plotted on the 1995 AKA map, along with the limits detected by the two InSAR studies for which detailed maps of movement for the specific time periods areas of movement, are presented on Figure 10. Utilizing this data and a LiDAR base map, we have developed our estimated limits of the historically active Keith Active Landslide for this study, and it is presented on Figure 11. As shown on Figure 11, the historically

active portion of the Keith Avenue Landslide extends from the vicinity of Miller Avenue downslope to beyond Shattuck Avenue. The landslide crosses the Hayward fault approximately 1,500 feet east of the school site. It should be noted that the limits of sliding on Figure 11 are very similar to the limits of the "Euclid Slide" and "Oxford School Slide" of Hoexter et al. presented on Figure 7. Also, all of the examples of damage on Figure 8 and the EBMUD pipe leak data on Figure 9 are each taken from within the Keith Avenue Slide. It should be noted these conclusions are apparently consistent with those from the two 1963 studies by Woodward-Clyde Sherard because key information from the 1963 studies is presented in the 1977 follow-up report of the school site by Woodward-Clyde Consultants (as the name of the firm that performed the investigation had been changed).

Over the past few decades, our firm has performed dozens of geotechnical investigations within the Berkeley Hills landslides. These investigations generally indicate that earthflows in the Berkeley Hills, including the Keith Avenue Landslide, have a thickness of slide debris in the range of 30 to 60 feet. A section drawn through the Keith Avenue Landslide, illustrating the long, shallow characteristic of the earthflow is presented on Figure 12 and is preceded by a plan view showing the section location (Figure 10). Figure 12 illustrates a number of the points of subsurface exploration we have utilized in the development of our understanding of the depth of sliding along the length of the Keith Avenue Landslide.

As landsliding has progressed in the large Berkeley Hills slides, the composition of the earthflows has been modified as areas of weathered bedrock become incorporated into the landslide mass. An example of a boulder more than 15 feet across encountered in an excavation in the upper Keith Avenue Landslide is shown on the photograph presented on Figure 13. Borings performed on the Oxford property for this investigation indicate that the landslide material is predominately silty to sandy clay with a large amount of incorporated cobbles and boulders. The majority of the larger boulders are composed of keratophyre (a type of volcanic rock similar to rhyolite), which is a part of the Franciscan Assemblage. These boulders range up to several feet or more in diameter. Keratophere crops out extensively in nearby portions the Berkeley Hills and keratophere boulders have become incorporated into the landslide debris over time. Other boulders consist of basalt or graywacke sandstone, which are derived from the Franciscan Assemblage and Moraga Basalt, which underlie the majority of the landslide area.

5.1.6 Keith Avenue Landslide Movement Magnitude and Rate

Some landslides can be divided into two zones, with the upper zone referred to as the "Zone of Depletion" (where material is lost due to downslope transport resulting in concave landforms), and the lower area called the "Zone of Accumulation" (where landslide materials are deposited, resulting in convex, lobate landforms). The Keith Avenue Landslide generally follows this pattern. As seen on Figure 12, the Hayward fault crosses the landslide about 1,500 feet east of the school site, and generally marks the transition between zones. The upper portion of the slide is narrower, and has a steeper gradient. As the slide debris has moved onto the flatter area downhill of the fault, the material has spread out in lobate form. With time, shallow creeks have formed on the margins of the lower area, particularly on the southern flank. Figure 14 presents an oblique view of the hillside in 1935, and we have denoted on the photograph the general outline of the Keith Avenue Landslide.

The Oxford site lies in the lobate toe of the Keith Avenue Landslide, within the zone of accumulation. In the geologic past, landslide movement has overridden the ground surface that existed at the time in localized areas. This was especially the case in the most downslope toe region. In some areas, the surficial soils (paleosols) are preserved beneath the landslide deposit. Boring 1 at the site encountered a dark, organic rich soil, which appeared to be a paleosol, at a depth of about 56 feet directly beneath the landslide deposit. A radiocarbon date

obtained from that zone was dated at 8,400 +/- 30 years before present (YBP). A similar paleosol was encountered on a previous project on Shattuck Avenue downslope of the school site and that soil was dated at 5,180 +/- 30 YBP. We should caution that soil dates can be subject to contamination by older or younger carbon and therefore should be considered only as a general indication of age.

Historically, the fastest area of movement of the Keith Avenue Landslide has occurred in the upper portion, with serious damages occurring to many homes and streets. In 1983, a local civil engineering company was engaged to locate property lines of homes on an aerial photograph base map in the vicinity of Keith Avenue and Euclid Avenue because consideration was being given to property line adjustments as houses seemed to be moving large distances (and crossing property lines!). An article in the San Francisco Chronicle in 2004 described the on-going struggles by homeowners and the litigation that was ensuing over the movements of houses into setback areas or across property lines. A figure attached to the 2004 article is presented on Figure 15. Note that many of the houses along the subject portion of Keith Avenue, constructed between 1910 and 1920, had moved 15 to 20 feet by 1983.

On Arch Street, also located in the upper portion of the Keith Avenue Landslide, AKA was an expert witness in two lawsuits related to the encroachment of homes or easements beyond original setbacks or property lines. A plot of houses in relation to property lines in one city block from a 2005 litigation is presented on Figure 16. As can be seen in the annotations we added to Figure 16, the entire area is not moving as a coherent landslide block, but there are varying magnitudes and directions of movement across the area, commonly with surveyed movement magnitudes up to 5 to 10 feet.

According to the 1977 Woodward-Clyde Consultants fault study, the 1963 study by Woodward-Clyde Sherard apparently estimated the downslope movement of the Oxford site to be about ½ to 1 inch per year. The recent InSAR studies have provided more information regarding the rates of movement in the Keith Avenue Landslide (as well as other Berkeley Hills slides). The rate of movement from the InSAR evaluations in each study period by the various authors can be summarized as follows:

Table 1 – InSAR Studies

Article Title	Authors, Date	Date Range of Satellite Recording	Magnitude of Movement (Inches/Year)
Dynamics of Slow-Moving Landslides from Permanent Scatter Analysis	Hilley, G.E., Burgmann, R., Ferretti, A., Novali, F., & Rocca, F., 2004	1992-2001	1.1-1.5
Seasonal Acceleration and Structure of Slow Moving Landslides in the Berkeley Hills	Quigley, K.C., Burgmann, R., Giannico, C., & Novali, F., 2010	1992-2006	1.0
Application of PSI to Investigate the Berkeley Hills Landslides	Lei, L., & Burgmann, R., 2010	2008-2010	0.8-1.2*
Spatiotemporal Patterns of Seasonality in Landslide Deformation from InSAR and GPS	Julien Cohen-Waeber, 2018	2009-2014	0.9-1.4

*Approximated from figures, not explicitly stated in text

InSAR data has shown that slow downhill creep has continued over the last couple of decades across the broad zone that includes the school site. Within a large earthflow complex such as the landslide that underlies the Oxford property, do not typically occur at the same rate and time throughout the entire landslide complex. Specifically, the work of Quigley et al. and Cohen-Waeber have indicated that the earthflows may move more in heavy rainfall years and may not move or move very small amounts in drought years. Over a many year period, we estimate the Oxford site is moving an average of 1 to 1½ inches per year.

The primary active trace of the Hayward fault crosses the upper portion of the Keith Avenue Landslide approximately 1,500 feet east of the school property. Within the Berkeley Hills, the Hayward fault typically acts as a barrier to groundwater resulting in groundwater seepage near the fault. The fault is buried where it passes through the Keith Avenue landslide and it is likely that substantial groundwater seepage is contributed to the landslide along the fault. On past projects, we have noted that landslide movement appears to be more severe in the vicinity of the fault.

It is worth noting that the existing school buildings appear to be in relatively good condition considering they are approximately 60 years old. The buildings, pavement areas, and the existing retaining wall do not appear to have been significantly distressed by landslide movement. The lack of building distress, and limited observed surficial damage on the school property and in the surrounding area, probably indicate that the school property and the immediate surrounding area are moving as a relatively coherent block since these features were originally constructed. Both the Woodward-Clyde Consultants report of 1977 and our own borings found that scattered internal shears are present within the landslide mass. These shears occur at variable orientations and are likely the result of past compression or differential movement within the slide mass. We found no evidence that current movement is occurring on these shears within the school site or the immediate surrounding area, but such shears may lead to differential site movement and distress in the future.

It should be noted that both Youd and Hoose (1978) and Lawson (1908) report no earthquake-induced landslide movement, or ground failures in the Berkeley Hills or within or near the Oxford site. However, the area was largely undeveloped at the time of the past major earthquakes studied by these authors.

Based on the above information, it is apparent that the school site lies within a large earthflow complex called the Keith Avenue Landslide that has experienced slow downhill creep historically. This movement is expected to continue under the current environmental conditions at a long-term rate averaging 1 to 1½ inches per year.

5.1.7 Regional Seismicity

Seismic activity within the northern Coast Ranges is generally associated with active faults of the San Andreas system, including major active faults both east and west of the site (Figure 17). The principal active faults in the region are the Hayward fault, mapped approximately 1,500 feet east of the site; the San Andreas fault, about 18.5 miles to the west; and the Calaveras fault, about 14 miles to the east. Other major active faults in the region include the San Gregorio fault, about 21 miles to the west; the Greenville fault, about 18.5 miles east; the Rodgers Creek fault, about 20 miles north; and the Concord-Green Valley fault, about 14 miles northeast. It should be noted that we are using the primary, active trace of the Hayward fault to guide our seismicity input; a minor, queried second trace located about 550 feet to the southwest of the main trace was not used to generate our seismic demand. Table 1 summarizes the fault parameters of selected known active faults closest to the site.

Table 2 – Fault Parameters

Fault	Distance and Direction from Site	Maximum Moment Magnitude
Hayward (total length)	1,500 feet east	7.1
Calaveras (north of Calaveras Reservoir)	17 miles southeast	6.8
Concord - Green Valley	14 miles northeast	6.9
San Andreas (1906 rupture)	18.5 miles southwest	7.9
San Gregorio	21 miles west	7.3
Rodgers Creek	20 miles northwest	7.0
Greenville	18.5 miles east	6.9
West Napa	15 miles north	6.5

The active Hayward fault is located approximately 1,500 feet east of the site. The term "active fault" as used herein, refers to a fault that has experienced movement during Holocene time (about the last 11,000 years). The Hayward fault is a northwest-trending zone about 51 miles long, which extends from southeastern San Jose, through the East Bay communities, into San Pablo Bay. Beneath San Pablo Bay, it probably steps right (east) to the Rodgers Creek fault. To the south, near San Jose, the Hayward fault merges with the Calaveras fault.

During historical times, well-documented surface creep has occurred along the Hayward fault at average rates ranging from about 0.2 to 0.4 inches per year (Lienkaemper et al. 1991).

The Oxford site is not within the Alquist Priolo Earthquake Fault Zone (APEFZ) associated with the Hayward fault. The western boundary of the Hayward fault APEFZ is approximately 500 feet east of the school. Lienkaemper (1992) shows the main active trace of the Hayward fault to lie approximately 1,500 feet east of the Oxford site.

5.1.8 Earthquake Probabilities

Studies by the United States Geological Survey's Working Group on California Earthquake Probabilities (Aagaard et al. 2016) have estimated a 72 percent probability that at least one magnitude 6.7 or greater earthquake will occur in the San Francisco Bay Region before the year 2043. As part of their prediction, they estimated the probability to be 33 percent for a magnitude 6.7 or greater earthquake to occur on the Hayward-Rodgers Creek fault, 22 percent for a magnitude 6.7 or greater earthquake to occur on the Northern San Andreas fault, and 16 percent for a magnitude 6.7 or greater earthquake to occur on the Concord fault during that same period.

5.1.9 Historic Seismicity

The San Francisco Bay Region has experienced several large earthquakes during historical time (Figure 17). A summary of the more significant earthquakes in the region is given below.

The Hayward Earthquake of October 21, 1868

On October 21, 1868, an earthquake of about M 6.8 occurred on the southern segment of the Hayward fault, causing significant damage throughout the region. Surface ground rupture occurred over a length of approximately 30 miles. The northern limit of ground rupture was in the vicinity of Mills College. The epicenter of the 1868 earthquake was located in the Castro Valley area (Figure 17).

The 1858 and 1911 Earthquakes

Two other earthquakes greater than M 6 are thought to have occurred on the Hayward fault (Steinbrugge et al. 1987). These occurred in 1858 (M 6.1) and 1911 (M 6.6). Both of these earthquakes were centered in or near the southern portion of the Hayward fault.

The San Francisco Earthquake of April 18, 1906

The largest historical earthquake in the region was the great San Francisco earthquake of April 18, 1906 (M 7.9) that occurred on the San Andreas fault near San Francisco. This earthquake caused strong to violent ground shaking throughout much of west central California and caused widespread damage.

The Loma Prieta Earthquake of October 17, 1989

On October 17, 1989, the M 7.1 Loma Prieta earthquake occurred near the San Andreas fault in the Santa Cruz Mountains (Figure 17). The earthquake resulted in 63 deaths and approximately $6 billion dollars in damage over a wide area (McNutt and Sydnor, 1990). Moderate ground shaking was felt in the Berkeley area (McNutt and Toppozada, 1990).

The Napa Earthquake Of August 24, 2014

A magnitude 6.0 earthquake occurred on morning of August 24, 2014, near the City of Napa (Figure 17). Although the earthquake was felt widely throughout the region, no fatalities occurred. Damage in the city of Napa was estimated at $360,000,000. Ground shaking in the Berkeley area was relatively light.

5.2 Site Reconnaissance

As a part of our investigation, we performed a reconnaissance of the entire mapped landslide area and portions of the surrounding neighborhoods. Our reconnaissance was confined to roads and public areas and the portions of private properties visible from the street. In general, below Spruce Street evidence of landslide movement is somewhat indistinct. Because most of the houses are in the range of 80 to 100 years old, distress such as cracks to buildings and pavements could be the result of age and poor foundations, landslide movement, or both.

Along Spruce Street near the intersection with Los Angeles Avenue, horizontal and vertical displacement of the sidewalk is visible that appears to be the result of landslide movement. Evidence of similar movement was not observed along the nearby portions of Oxford Street or Walnut Street; it appears that the movement along Spruce Street may not extend down to these areas.

As discussed previously, the upper portions of the landslide mass above Spruce Street in general show more significant evidence a landslide movement than the area below Spruce Street. Previous studies done by our firm have shown that areas on Keith Avenue, Spruce Street, Arch Street, Cragmont Avenue, High Court, and Corona Court have experienced extensive landslide movement historically, causing damage to residences, roadways, and sidewalks in those areas.

The landslide margins are well defined by offset cultural features from Spruce Street uphill within the Keith Avenue Landslide. In addition, geomorphic features are generally obscured by development except in the areas uphill of Cragmont Avenue, where clear geomorphic forms related to landsliding are evident.

5.3 Aerial Photo Interpretations

Eleven sets of single and stereo-paired black-and-white aerial photographs were reviewed as a part of our investigation. These photos were taken during the period from 1930 to 1983 and ranged in scale from 1:7,200 to 1:24,000. A complete listing of photographs reviewed is included in Appendix I.

The 1930 photographs show that the school site is already developed and two large school buildings are present along the north and east sides of the campus. The lots immediately to the north are undeveloped. By this time, roughly 90% of the entire landslide area and surrounding area has been developed as residential properties. Vegetation on most of the lots is fairly mature suggesting that most of the houses were built 2 to 3 decades before 1930. The margins of landslide area are obscured by development. The uppermost portions of the Keith Avenue Landslide were undeveloped and covered with a heavy growth of vegetation.

No significant changes in site conditions were observed on the 1935 photograph. This photograph was introduced earlier and is presented as Figure 14.

By 1939, the lots to the north had been developed, and two residential structures are apparently present on those lots. Development has continued in the area surrounding the school site such that approximately about 90% of the lots in the Keith Avenue Landslide area have been developed. The general shape of the landslide is visible on the aerial photographs; however, development has obscured landslide features to a great extent and the margins of the landslide are not clearly defined. A retaining wall is visible in the central portion of the school campus.

The 1946 photographs show that conditions on the site are unchanged. An area of pavement patches is visible on Spruce Street between Los Angeles Avenue and Eunice Street, in the highly active upper portion of the Keith Avenue Landslide. However, no pavement patches are visible on the portions of Oxford Street or Walnut Street adjacent to the site. No significant changes were observed on the 1947, 1949, 1953, or 1957 aerial photographs. The 1959 aerial photographs show that new pavement patches have been placed on Spruce Street in the area described above.

The 1969 photographs show that the old school buildings have been removed and new buildings, which are still present on the site today, have been constructed. As a part of this construction, the old retaining wall has been removed and a new retaining wall has been built which is still present today. No significant changes were observed on the 1983 aerial photographs.

In summary, the aerial photographs indicate that the school site lies in the lower portion of a large landslide that extends several blocks in all directions. The general shape of the landslide can be observed on the aerial photographs; however, most of the land surface is largely covered by roads, buildings, and vegetation that mask the risk original landslide features.

5.4 Subsurface Data

5.4.1 Borings

5.4.1.1 Conventional Small Diameter Borings

Borings performed on the Oxford property for this investigation indicate that the landslide material is predominately silty to sandy clay with a large amount of incorporated cobbles and boulders.

Five conventional, small-diameter borings were performed as a part of our investigation using a truck-mounted drill rig provided by Britton Exploration. All the borings were hampered to some degree by the presence of cobbles and boulders in the landslide debris.

Boring 1, located in the upper portion of the school property near the buildings, was drilled to a depth of about 118 feet using hollow stem auger/dry core and rotary wash drilling techniques. The boring encountered approximately 10 feet of clayey sand fill. Below the fill, landslide debris consisting principally of clay with intermixed sand, gravel, and boulders was encountered to a depth of about 54½ feet, where we observed a potential landslide plane. Below the landslide debris, the boring encountered black clay, which is interpreted to be a paleosol to a depth of about 59 feet, where bedrock was encountered. Below about 59 feet, the boring encountered sandstone and shale to the bottom of the boring.

Boring 2, located in the north-central portion of the school property, was drilled to a depth of about 61 feet using hollow stem auger and rotary wash drilling techniques. The boring encountered fill consisting of very stiff sandy clay to a depth of about 9 feet. Below that depth, the boring encountered landslide debris consisting of sandy clay, silty sand, and clay and to a depth of about 49 feet. We observed a potential landslide plane at about 49 feet. Below 49 feet, the boring encountered silty claystone to the bottom of the boring at about 61 feet.

Boring 3, located near the top of the eastern access ramp, was drilled to a depth of about 38 feet using hollow stem auger and rotary wash drilling techniques with Pitcher Barrel sampling. The boring encountered about 13 feet of fill consisting of medium dense sandy clay and very stiff fat sandy clay. Below the fill, the boring encountered landslide debris consisting of stiff to very stiff, sandy lean to fat clay, and clayey gravel to a depth of about 25 feet, with a potential landslide plane at the base of the landslide debris. Greenstone and rhyolite bedrock was encountered below the landslide debris to the bottom of the boring at about 38 feet.

Boring 4 was drilled on the lower playground near the west end of the main building using hollow stem auger/dry core and rotary wash drilling techniques. Medium dense clayey sand fill was encountered to a depth of about 9½ feet, and landslide debris consisting of medium dense to very dense clayey sand and gravel was then encountered to a depth of about 46 feet. A potential landslide plane was observed at about 49 feet. Clayey sand was encountered from about 46 to about 49 feet. Below that depth, the boring encountered shale bedrock to the bottom of the boring at about 55 feet.

Boring 5 was drilled on the lower playground near the northwest corner of the school property using hollow stem auger/dry core and rotary wash drilling techniques. Medium dense, clayey sand fill was encountered to a depth of 5½ feet, and landslide debris consisting of loose to dense clayey sand, clay, and gravel was then encountered to the bottom of the boring at 43 feet. We did not observe a potential landslide plane in B-5 and the boring did not reach bedrock.

5.4.1.2 Large Diameter Borings

Three large diameter borings were drilled within the school property as a part of this investigation. These borings were drilled using a bucket auger drill rig provided by TriValley Drilling Company equipped with a 24-inch diameter bucket. The borings were logged by direct downhole observation by the engineering geologist. All three borings encountered groundwater seepage and some caving, which made logging difficult.

Boring LD–1, located in the southwestern portion of the lower playground, encountered approximately 8 feet of fill consisting of sandy clayey silt to a depth of about 8 feet. Below that depth, landslide debris consisting of silty clay with gravel was encountered to a depth of 28 feet. From 28 feet to approximately 55 feet, the landslide debris consisted of highly sheared serpentinite. Below 55 feet, serpentinite, which appeared to be in place, was encountered to a depth of 57½ feet; this was, in turn, underlain by silty claystone to the bottom of the boring at 62 feet. We observed what may be a landslide plane at about 31 feet; a ½-inch thick seam of greenish gray clay within the serpentinite rock.

Boring LD-2, located in the northwestern part of the campus below the retaining wall, encountered landslide debris consisting of clay with intermixed sand gravel and silt to a depth of 31½ feet. From that depth to 34 feet, the boring encountered serpentinite. Below 34 feet, greenstone was encountered to the full depth explored, which was 50 feet. We observed a shear zone, which may also be a landslide plane, at about 30½ feet deep.

Boring LD-3 was drilled in the playground area between the main building and the northern addition. The boring encountered approximately 2 feet of sandy clay fill underlain by landslide debris consisting of clay within a mixed silt, sand, and gravel to a depth of 16 feet. Below 16 feet, the boring encountered a large boulder of rhyolite (keratophere) to the full depth explored. Groundwater was encountered at approximately 19 feet and below that depth, the boring experienced extensive caving and was not entered. We did not observe a potential landslide plane in LD-3.

5.4.2 Cone Penetrometer Tests

In general, CPT testing revealed highly variable subsurface conditions consistent with the borings and the mapped geologic description of the Franciscan mélange and Coast Range Ophiolite Complex assemblies. CPT-1 was advanced to refusal at about 28 feet deep and encountered a variable profile of intermixed sands, sand mixtures, clays, silt mixtures, and clayey sands. CPT-2 met refusal at about 48 feet deep and generally encountered clays and silt mixtures to the depth explored. CPT-3 was advanced to about 45 feet deep and encountered about 15 feet of clay over about 30 feet of sand.

One of the most useful correlated interpretations provided by the CPT analysis software is the soil behavior type (SBT) which labels individual estimated soil types based on the recorded sounding data. As the SBT ‘value’ is intended to characterize soil types and not necessarily rock, some of the weaker, weathered rock types (as encountered in the borings) are likely to be interpreted as soil. For example, LD-1 encountered weathered serpentinite bedrock at about 28 feet deep and the adjacent CPT-2 interpreted this material to be a clay. Serpentinite rock can behave as a clay if highly weathered as the rock degrades or ‘weathers’ into primarily clay minerals.

Figure 18 presents some of the basic CPT correlated interpretations including:

- Recorded tip resistance (qt);
- Recorded skin friction (fs),
- Soil behavior type index (Ic); and
- Soil behavior type (SBT).

The plots illustrate the highly variable nature of the subsurface underlying the Oxford site.

5.4.3 Woodward-Clyde Consultants 1977 Geologic Study Report

We were provided with a report by the District that explored the possibility of a splay of the active Hayward fault underlying the Oxford site. The investigation included a field exploration program consisting of about 247 linear feet of fault trenching. The trenches extended about 5 to 10 feet deep and about 3 feet wide. The report concluded that the Hayward fault did not encroach into the school site but that "the Oxford site is located within an area subject to earth movements" and that "there is evidence of slow (on the order of ½ to 1 inch, or less, per year) deep seated earth movement." The fault trenching also revealed chaotic subsurface soil and rock conditions with inclusions of large boulders and shear zones inclined at differing dip angles. Three of the shear planes are labelled as "slide planes." The report goes on to state that "the area of earth movement is a large complex mass, with many planes that may move independently of the larger area." The 1977 Woodward Clyde report is included in Appendix F.

5.4.4 Shear Wave Profile

As part of our characterization of the subsurface materials, we performed a seismic shear wave analysis at various locations across the Oxford site. As previously discussed, we performed geophysical downhole suspension logging within Boring 1 and recorded shear wave velocities during CPT soundings. In general, the shear wave velocities correlated reasonably well between the B-1 suspension logging and the seismic CPTs. From the ground surface to about 50 feet deep (approximate bedrock contact), the velocities ranged from about 700 feet per second up to about 2,000 feet per second. Below 50 feet, the shear wave velocities increased with depth to about 3,700 feet per second at about 100 feet deep. The overlaid shear wave velocities are presented on Figure 19.

5.4.5 Summary of Soil/Rock Conditions

Based on our explorations and background material, the soil profile underlying the Oxford site is highly varied both vertically and laterally with inclusions of large rocks and boulders of varying composition. We encountered lean to fat clays, typically with some amount of silts, sands, and gravels in a highly sheared landslide mass. The Woodward-Clyde Consultants fault trench study also clearly illustrates the chaotic nature of the composition of the near surface soil profile. Where bedrock was reached in our borings, at about 34 to 55 feet, the bedrock beneath the landslide debris typically consists of claystone, serpentinite, or greenstone of the Franciscan Assemblage. Because of the highly variable nature of the soil strata above the bedrock, it is extremely difficult to coherently characterize the site lithology.

In preparing a model on which to base our landslide analyses and based on all of the compiled data (including borings, CPTs, shear wave testing, and previous site studies), we have developed an idealized conceptual section consisting of four major material types; artificial fill, landslide mass, landslide plane material, and bedrock. We developed average values for unit weight and unconfined shear strengths from laboratory testing results and parameters calculated from the CPT data. We used laboratory torsional shear testing to help

characterize the residual strength along the slide plane, but the slide plane was very thin and collection of samples without introducing sand particles was very difficult. We therefore relied primary on samples which were least contaminated with sand particles, and concluded our best characterization was to provide a range of values for this critical parameter. The basic material properties of these sections used in our analyses are presented below in Table 3.

Table 3 – Section Properties

Unit	Unit Weight (pcf)	Shear Strength (psf)
Artificial Fill	125	2,000
Landslide Mass	130	1,500
Landslide Plane Material	-	13-15 degrees
Bedrock	140	3,300

In addition to developing material properties for the landslide model, we prepared seven idealized geologic cross sections to illustrate subsurface geologic conditions and provide a geometric basis for the landslide analyses. The cross section locations are shown on Figure 3 and the cross sections are presented in Figures 20 through 25. Cross sections A-A' through F-F' illustrate geologic conditions within the school site and the immediate surroundings. These cross sections were based primarily on subsurface information gained during this investigation.

5.4.6 Groundwater Conditions

During drilling of small and large diameter borings, we encountered several instances of perched groundwater at various depths throughout the soil/rock columns including in LD-3 where groundwater and loose soil caused caving of the large diameter boring shaft. The small diameter borings were drilled using mud-rotary wash methods, which precluded measurement of groundwater in those borings.

During advancement of the CPTs, we attempted to perform pore pressure dissipation tests at various depths with no conclusive results.

As discussed previously, we installed five vibrating-wire piezometers to continuously monitor groundwater depths over time. We installed three in Boring 1 (at 13 feet, 33 feet, and 77 feet below the surface) and 2 in Boring 3 (at 17 feet and 37 feet below the surface). Based on the most recent data collection for groundwater levels measured from January 3, 2019, to July 15, 2019, the groundwater readings fluctuated between 12.4 feet deep and 14.7 feet deep in the B-1 piezometers and between 13.4 feet deep and 18.2 feet deep in the B-3 piezometers. We judge that a groundwater level of 13 feet is appropriate for modeling in landslide hazard analyses. It should be noted, however, that fluctuations in the perched and groundwater level may occur due to variations in rainfall, temperature, and other factors not evident at the time the measurements were made.

6.0 EVALUATIONS AND CONCLUSIONS

6.1 Active Landslide Boundaries

The Oxford site is located within the active limits of the Keith Avenue Landslide, and historic movement of the site has been documented by InSAR evaluations as well as other techniques. Subsurface exploration on the site has determined that slide debris underlies the school property; this is the primary material that is undergoing deformation. Under the current environmental conditions, the school buildings and other improvements will continue to move in the future at varying rates (depending primarily on rainfall conditions) but averaging about 1 to 1½ inches per year. There has been relatively modest damage in the buildings to date, but this may be in part the result of the 1963 Woodard-Clyde-Sherard reports apparently recommending the new school buildings be supported by a rigid foundation system to minimize the impacts of the actively-moving landslide mass. Nonetheless, numerous shears were logged in our large diameter borings and also documented in the trenches excavated by Woodward-Clyde Consultants in 1977; some were labelled as slide planes. With progressive movement, pressure distributions within the slide mass under the school site will occur and ruptures to the ground surface extending from the existing shear surfaces may result.

The school site is located in the highly seismic Bay Area, and is only 1,500 feet from the active Hayward fault (the fault with the highest probability of causing a magnitude 6.7 or greater earthquake in Northern California). Significant landslide deformations can occur during strong earthquake shaking. In response to this statewide concern, the California Geological Society has created seismic hazard maps where potential earthquake-induced landsliding seismic hazard are shown, and where CGS requires a site-specific study of the hazard be performed for new projects. The school site is located within the potential earthquake-induced landslide zone on the map of the area, which is not surprising because the site is already undergoing landslide deformations during non-earthquake conditions. Therefore, to evaluate the potential magnitude of earthquake-induced landslide movements at the site, we have performed the deformation analyses described in the following section.

6.2 Probabilistic Seismic Hazards Analysis (PSHA)

LCI conducted a PSHA and developed recommended site-specific earthquake ground motions for the project. The PSHA was based on data obtained from the shear wave analysis performed by Norcal and the seismic cone data obtained by ConeTec. Based on the results of the LCI report, the site-specific peak ground acceleration, PGA_M (based on risk-targeted, maximum considered earthquake, MCE_R) for design (5% damped, 2,475-year return period) is 1.1g for rock outcrop (at the base of the soil profile) and 1.5g for soil surface accelerations (where g is the acceleration of gravity). The detailed LCI report and the results of the site-specific PSHA are included in Appendix E.

6.3 Calculated Seismic Displacements

The potential for seismic slope displacements at the project site was evaluated considering California Geological Survey (CGS) Special Publication 117A dated September 2008, CGS Note 48 dated October 2013, and ASCE 7-10, which forms the basis of the current California Building Code. The LCI (2019) Site-Specific Seismic Hazard Analyses forms the primary basis of the seismic demands at the Oxford Elementary School site. The Bray et al. (2009) ground motion model was used to estimate the peak ground velocity (PGV) of the fault-normal component of ground motion due to the special characteristics of pulse motions in the near-fault region of a major fault. The predominant direction of the movement of the slope is roughly perpendicular to the strike of the Hayward fault, which is at a distance of only 0.46 km.

Slope stability modeling was completed using the computer program SLIDE2 by *RocScience*. SLIDE2 is a two-dimensional (2D) slope stability program for calculating the static factor of safety (FS) and seismic yield coefficient (k_y), which is the maximum dynamic resistance of potential sliding masses with circular or non-circular failure surfaces. The Spencer and Morgenstern-Price established slope stability procedures were used because these procedures satisfy all conditions of equilibrium for 2D slope stability (i.e. vertical and horizontal force and moment equilibrium equations).

Seismic slope displacements (D) were calculated using the Bray and Macedo (2019) procedure. This procedure is an update of the widely used Bray and Travasarou (2007) seismic slope displacement procedure. Whereas the Bray and Travasarou (2007) procedure was based on 688 recorded ground motions from the Pacific Earthquake Engineering Research (PEER) Center NGA-West1 ground motion database; the Bray and Macedo (2019) procedure is based on 6,711 two-component horizontal ground motion recordings from the updated NGA-West2 database (Bozorgnia et al. 2014). The NGA-West2 database also includes 197 near-fault pulse two-component records.

Slope stability analyses focused on calculation of the static FS and seismic k_y values of the Keith Avenue Landslide centered about the Oxford site. Local slope stability within the school parcel was also analyzed, but the lowest slope stability factors of safety were found to occur within the Keith Avenue Landslide; thus, it governed the static and seismic stability assessment of the Oxford site.

Boundary conditions for the slope stability modeling were developed as a result of available topographic information (both site-specific topographic surveys as well as Aerial LiDAR-based contours), subsurface stratigraphy from the field exploration data, material properties from the field exploration data as well as geotechnical laboratory testing, and groundwater conditions based on site-specific instrumentation installed during the field exploration program. The slope stability modeling was situated within the larger debris flow extents, but with search limits constrained to several hundred feet downslope and upslope of the Oxford site to be consistent with the anticipated deformation behavior of the Keith Avenue Landslide.

To reflect the uncertainty associated with groundwater conditions, friction angle of the surface of rupture, and surface of rupture geometries, sensitivity analyses were performed to characterize the impacts to the calculated static FS and seismic k_y values. Based on site-specific geotechnical laboratory testing and experience working on similar sites in the Berkeley Hills, the residual effective friction angle of the surface of rupture material (i.e. failure surface or sliding surface) was estimated to vary from 10 to 20 degrees, with the most representative values being on the order of 13 to 15 degrees.

The calculated static FS and seismic k_y values for a suite of groundwater (GW) conditions for the representative residual effective friction angles (ϕ'_{Qls}) of the surface of rupture of 13 and 15 degrees are presented in Table 4 (see Appendix H); a sample calculation for one iteration is visually presented in Figure 26. It is not likely for the groundwater level to be below the surface of rupture or to be at the ground surface at the time of the design earthquake, which is a rare event. The groundwater is currently estimated to be at a depth of about 13 feet. This depth is judged to be most representative of the groundwater conditions at the time of the earthquake, as the primary groundwater measurements were obtained during the winter months of a slightly above normal rainfall year. Thus, the cases with groundwater at a depth of 13 feet with a residual effective friction angle of the surface of rupture of 13 or 15 degrees are the basis for calculating seismic slope displacements (D). For these cases, the static FS varied from 1.9 to 2.1 and k_y varied from 0.09 to 0.12 (Table 4).

Table 4. Oxford Slope Stability (Spencer Procedure)

ϕ°_{Qls}	GW @ Surface		GW @ 13 ft		No GW	
	FS	Ky	FS	Ky	FS	Ky
13	1.6	0.06	1.9	0.09	2.6	0.17
15	1.8	0.08	2.1	0.12	2.7	0.18

The Bray and Macedo (2019) seismic slope stability procedure requires specification of the yield coefficient (k_y), the initial fundamental period of the potential sliding mass (T_s, estimated as $4H/V_s$, where H is its representative height and V_s is its average shear wave velocity), the 5%-damped pseudo-acceleration response spectral value of the underlying material at a period of $1.3T_s$ ($S_a(1.3T_s)$), the peak ground velocity of the underlying material (PGV), and the moment magnitude of the earthquake event (M_w). The seismic slope displacement is calculated as the maximum component seismic slope displacement (D100) for this project because the predominant slope movement is oriented perpendicular to the strike of the Hayward fault and near-fault pulse motions are likely to occur (Hayden et al. 2014).

As noted previously, $k_y = 0.09$ or 0.12. Using a representative sliding mass height of H = 50 feet with a range of 45-55 feet and an average V_s profile based on the site-specific measured Vs data in the slide mass of V_s = 670 feet/s over a depth of 0-28 feet and V_s = 860 feet/s over a depth of 28 to 55 feet, T_s = 0.26 s, with a range of T_s = 0.24-0.29 s. The characteristic earthquake event is M_w = 7.2 (LCI 2019).

The seismic demand at the 84% deterministic hazard level, which is recommended to be used by LCI (2019) and consistent with our interpretation of ASCE 7-10, is defined for the baseline case of T_s = 0.26 s by $S_a(1.3T_s)$ = S_a(0.34s) = 1.92 g (interpolated from Table 2 of LCI (2019)) for the maximum component direction, which is aligned with the predominant direction of slope movement. The calculated seismic displacement was found to be insensitive to varying the value of T_s within the range of 0.24 s to 0.29 s and the corresponding value of $S_a(1.3T_s)$. Thus, results are presented only for the baseline case of T_s = 0.26 s. The 84% estimate of the PGV for rock outcrop for a M_w = 7.2 earthquake at a source-to-site distance (R) of 0.46 km is 4.7 feet/s (Bray et al. 2009). Using these input parameters (see Appendix H), the 16% to 84% calculated seismic slope displacement (D) range is 6 feet to 20 feet for k_y = 0.12 and D is 8 feet to 30 feet for k_y = 0.09.

CGS (2013) Note 48 recommends using design-level ground motions based on the geometric mean component value, which would be at the 50% deterministic hazard level, for evaluating seismic slope stability for a public school project. Thus, seismic slope stability calculations are also performed for the seismic demand defined at the design-level. The seismic demand at the 50% deterministic hazard level is defined for the baseline case of T_s = 0.26 s by $S_a(1.3T_s)$ = S_a(0.34s) = 1.04 g (interpolated from Table 2 of LCI (2019)) at two-thirds of the 84% deterministic spectrum values without the maximum component factor of 1.22). The 50% deterministic hazard level estimate of the PGV for rock outcrop for a M_w = 7.2 earthquake at R = 0.46 km is 3.1 feet/s (Bray et al. 2009). Using these input parameters (see Appendix H), the 16% to 84% calculated seismic slope displacement (D) range is 2 feet to 7 feet for k_y = 0.12 and D is 3 feet to 10 feet for k_y = 0.09.

The calculated seismic slope displacement should be considered an index of the likely seismic performance of the landslide. CGS (2008) Special Publication 117a states: "*Calculated displacements greater than 100 cm* [i.e. about 3 feet] *are very likely to correspond to damaging landslide movement, including possible catastrophic failure, and such slopes should be considered unstable*." The seismic slope displacement is

calculated to be within a range of 2 feet to 30 feet for representative values of k_y from 0.09 to 0.12 considering both the 84% and 50% deterministic ground motion levels. As the calculated seismic displacements are generally greater than 3 feet, the earthquake-induced landslide movement at the Oxford Elementary School site at either hazard level is judged to be large and potentially damaging.

6.4 Conceptual Mitigation Measures

Should earthquake-induced landslide movements occur at the Oxford site, serious damage may result in the buildings and facilities on the property. Given the age of the current structures, a structural assessment is likely to conclude it would be difficult to retrofit the buildings to accommodate significant ground deformations, even if they were originally designed to be robust by 1963 standards. Therefore, reconstruction of the school site may be necessary; this would provide the opportunity to not only update all the facilities, but also to utilize ground improvement, structural techniques, and use of specialized materials to minimize future damage.

Given the size of the Keith Avenue Landslide, it would be impossible to stop the landslide from moving by work entirely within the school property. Therefore, employing techniques to accommodate the ground movement is the more reasonable approach to rebuilding at the site. When considering how ground movements from landsliding may impact the buildings, it should be noted differential ground movement is more damaging than total ground movement. The current facilities are performing reasonably well while undergoing landslide movements because the design was intended to be robust (by 1963 standards) and during the recent historic period, the site is generally displacing as a coherent block. Although this type of coherent block movement may or may not continue during non-earthquake conditions, it is likely differential ground deformation will occur at the site during a strong, nearby earthquake. Such movement may be characterized by an abrupt shear reaching the ground surface with differential displacements on either side of the shear. This type of movement is somewhat similar to a building being located over a fault rupture at the ground surface, and a significant amount of research has been performed recently to develop techniques to accommodate such movements. At the forefront of the activities has been Professor Jonathan Bray at the University of California, Berkeley, who summarized many of these techniques in his 2013 Joyner Lecture and in papers such as Bray (2009). His work has also been recently published along with his colleague Nicolas Oettle (Oettle and Bray, 2013a; Oettle and Bray, 2013b; Oettle and Bray, 2015). Two of the key elements presented in Oettle and Bray, 2013b are:

- Ductile engineered fill; and
- Thick mat foundation.

Several possible remedial schemes could be used to improve site survivability, but some of the approaches developed for improving building performance on fault rupture discussed above may be valuable. A conceptual scheme that would improve school building performance could utilize the two elements noted in the previous paragraph. The first element would be to spread out any ruptures from differential movement across slide-related shears over a broad area to minimize local movement differences. At the Oxford site, after the site is cleared and the new building areas are created, the upper 5 to 10 feet of soil could be placed and compacted in layers with periodic geogrid. The geogrid would spread out and minimize the magnitude of any significant differential movement across the geogrid from a shear surface that would otherwise extend to the ground with a localized expression. The second element of the remedial work scheme would be to create a robust mat foundation for the buildings to accommodate the remaining differential movements that occur at the surface of the engineered fill without incurring major structural damage. By constructing a thick, robust mat foundation under new buildings, serious structure damage can likely be avoided. Nonetheless, non-structural damage may occur (e.g., building tilt) as well as damage to the building contents.

In addition to the school buildings, other key improvements needing better design elements to accommodate seismic displacement on the site would include buried utility lines and retaining walls. The utilities within the school property could be constructed with sections of ductile pipeline and flexible connections and joints at critical areas. With the presence of the ductile engineered fill below the pipelines, along with these other elements, most pipelines could likely survive, and replacement of some sections would not be too difficult. In the locations where the pipelines exit the school property, performance may degrade, even if highly flexible and movement-accommodating details are employed at the property line boundaries. New retaining walls being built could potentially be located on the ductile fill as well. Use of such techniques as modular block elements with geogrid in the wall backfill for the retaining walls, would generally help the walls perform in a survivable condition, although localized repairs or replacement may be necessary.

The specific details of these approaches will depend on the new layout of the school, but it is our judgment that it is possible relatively good performance of the school may be achieved during landslide movements at the site, even during a strong, nearby earthquake. However, the likelihood of a successful outcome is uncertain, given the large magnitude of the calculated total displacements. Significant engineering analyses would be required to support the design of a new school facility within a large landslide where the calculated total seismic slope displacements are still likely to exceed 3 feet. Considering the sentence quoted previously from CGS (2008) Special Publication 117a, approval by the State agencies may not be granted.

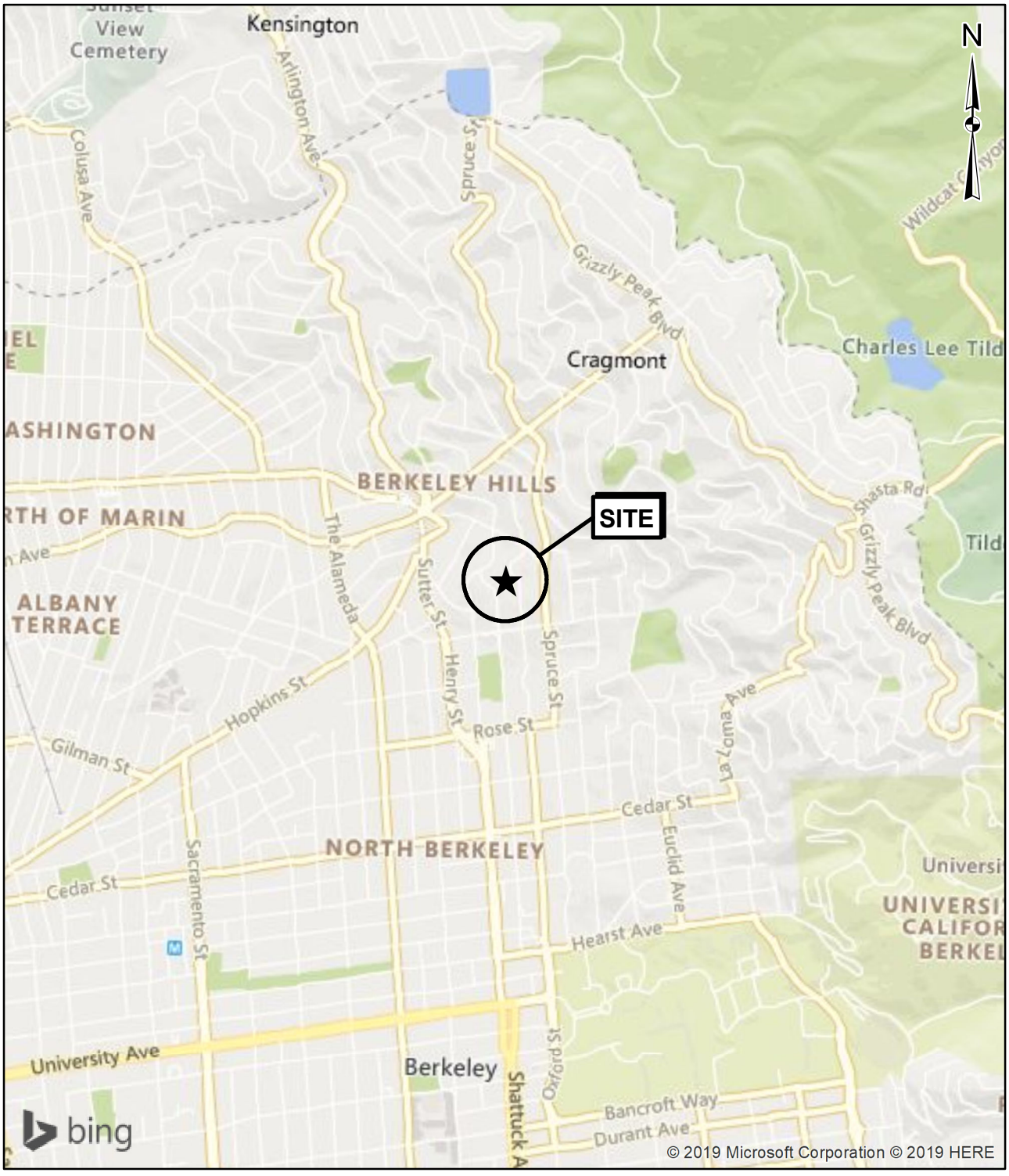
Importantly, even if the Oxford site performs reasonably well, the impact on the surrounding neighborhood during a major earthquake will likely be substantial. A nearby major earthquake event may lead to large displacements throughout the area, resulting in rupture of utilities and offsets in roadways. Utility ruptures may also result in ignition and spread of fires and the lack of water to fight fires. Significant roadway offsets may render them impassable, precluding ingress of emergency personnel and evacuation of residents and students. It will be important to consider this broader context when considering the reasonableness of reconstructing the Oxford site for a new school.

In summary, we calculate that total seismic displacements at the site are likely to exceed 3 feet during the design earthquake, and perhaps may move 20 feet or more. Three feet is a threshold at which it is often concluded that without major remedial activities, facilities at a site will experience serious damage. Using ductile engineered fill, mat foundations for buildings, and other specialized materials will likely significantly reduce the distress at the site compared to conventional construction and may result in generally acceptable performance. However, detailed additional investigation techniques would have to be performed for the specific development scheme for a new school facility, including all the individual campus elements. Other conceptual remedial schemes may also be considered other than those discussed above. Furthermore, the neighborhood is likely to experience a high level of distress, and numerous serious injuries, which may isolate the school from meaningful connections with the surrounding area for an extended period after the earthquake.

7.0 LIMITATIONS

This report has been prepared for the exclusive use of the District and their consultants for specific application to the Oxford Elementary School in accordance with generally accepted geologic and geotechnical engineering practices. No other warranty, expressed or implied, is made. In the event that any changes in the nature or design of the building are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing.

The findings of this report are valid as of the present date. However, the passing of time will likely change the conditions of the existing property due to natural processes or the works of man. In addition, due to legislation or the broadening of knowledge, changes in applicable or appropriate standards may occur. Accordingly, the findings of this report may be invalidated, wholly or partly, by changes beyond our control. Therefore, this report should not be relied upon after a period of three years without being reviewed by this office.



0 2,000 4,000

SCALE FEET

Original figure produced in color.

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

VICINITY MAP

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**1**

Oxford School, 1922

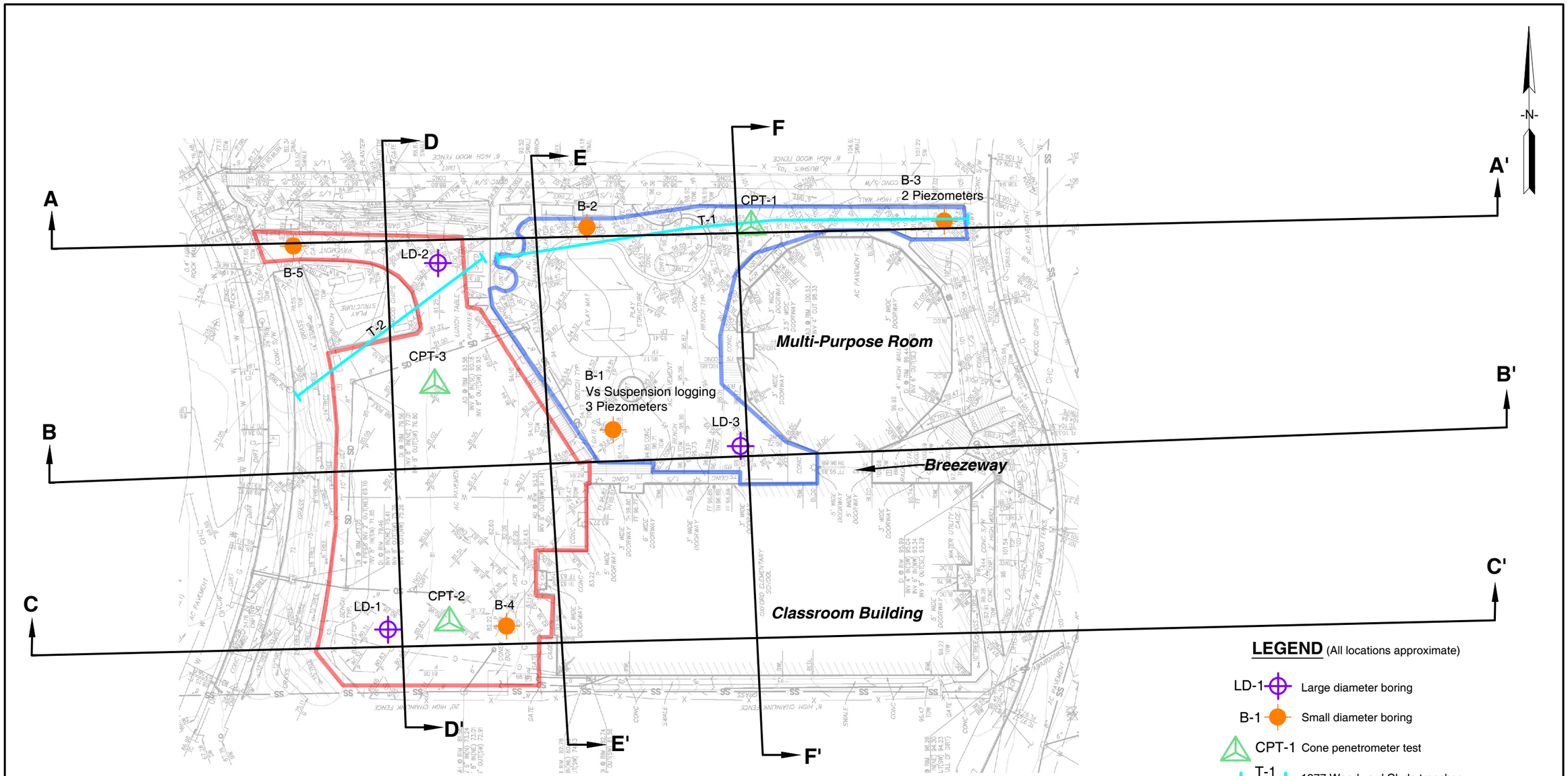
Oxford School, 1933

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

HISTORIC PHOTOS

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE **2**
1853-3	**September 2019**	



Original figure produced in color.

Source: "Topographic Survey 1130 Oxford Elementary School," drawn by Sandis, dated 7/10/18.

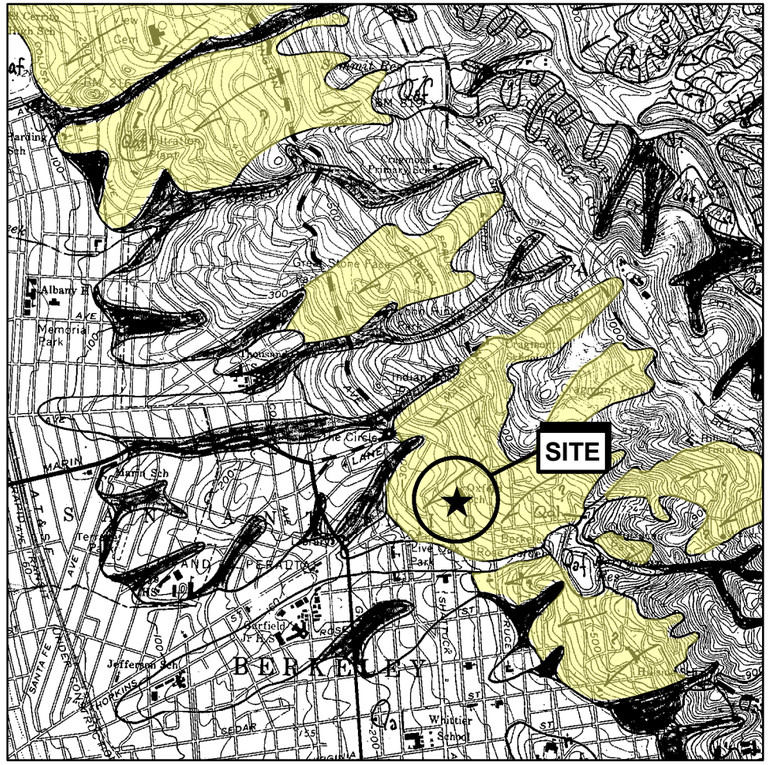
20 0 40 80
APPROXIMATE SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

SITE PLAN

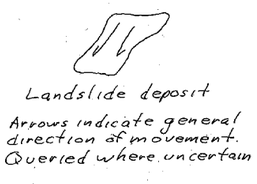
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**3**

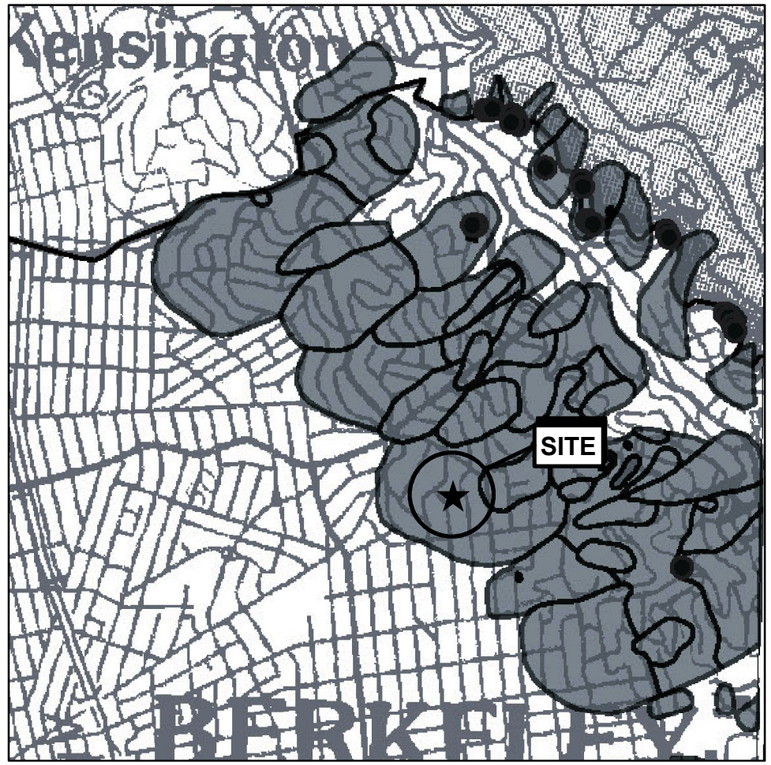


Source: "Preliminary Photointerpretation Map of Landslide and Other Surficial Deposits of the Richmond 7 1/2' Quadrangle, Contra Costa and Alameda Counties," Nilsen, 1975

LEGEND



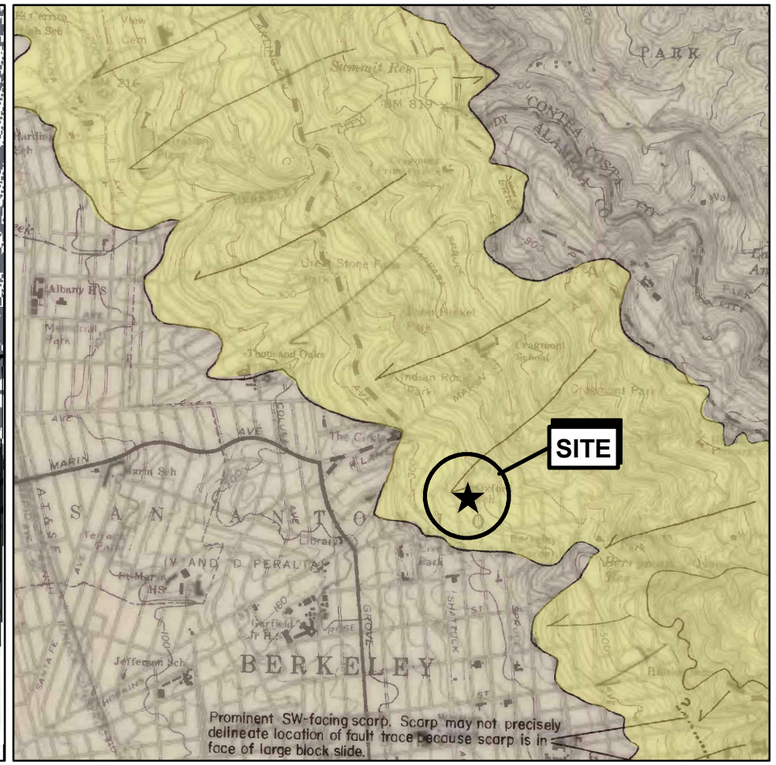
Note: Primary landslides highlighted for emphasis on this figure.



Source: CGS Seismic Hazard Map, Richmond Quad, 2003.

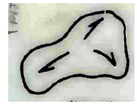
LEGEND

Landslide



Source: "Map of Quaternary Faulting Along the Northern Hayward Fault Zone," Herd, 1978,

LEGEND



Landslide; arrows show direction of past movement of slide block. Slide may be locally active. Landslides shown only where cut by or obscuring faults showing Quaternary displacement.

Note: Massive slide complex highlighted for emphasis on this figure.

Original figure produced in color.

0 2,400 4,800

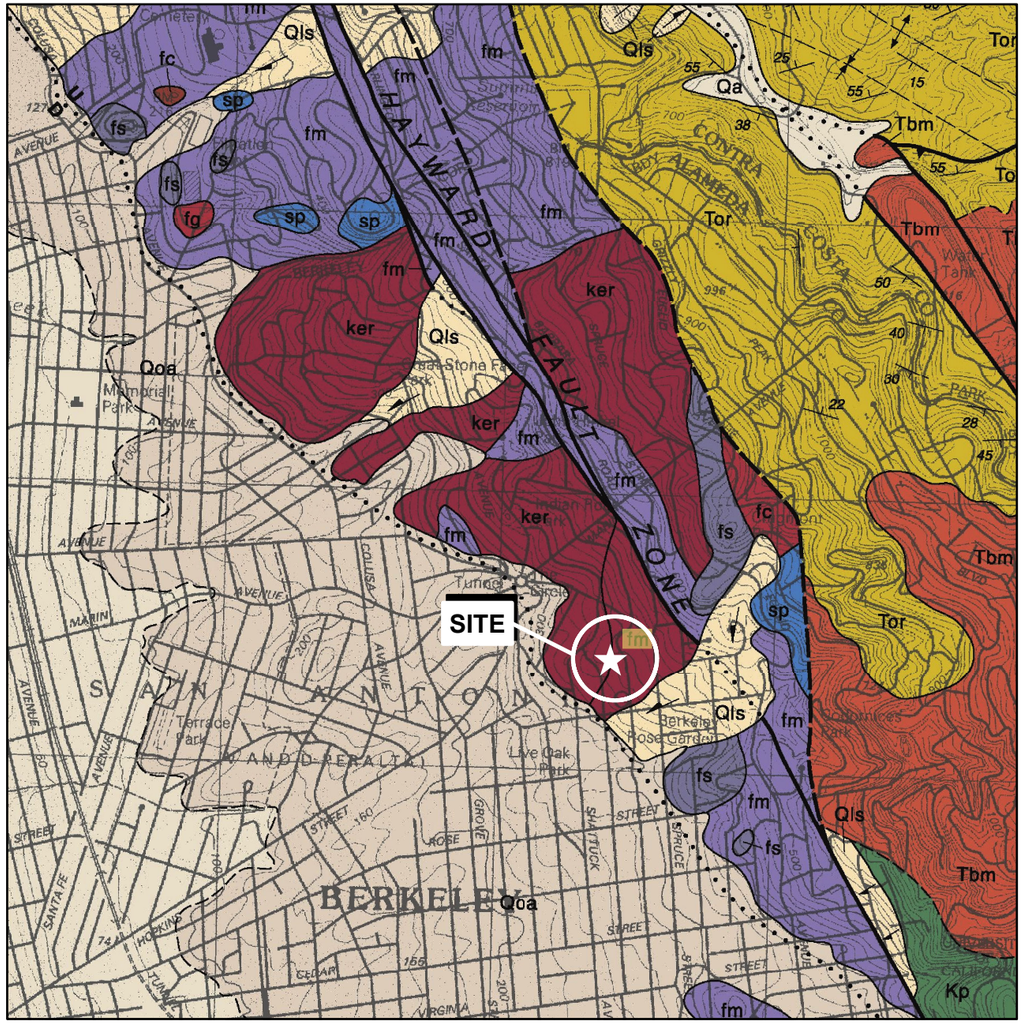
SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

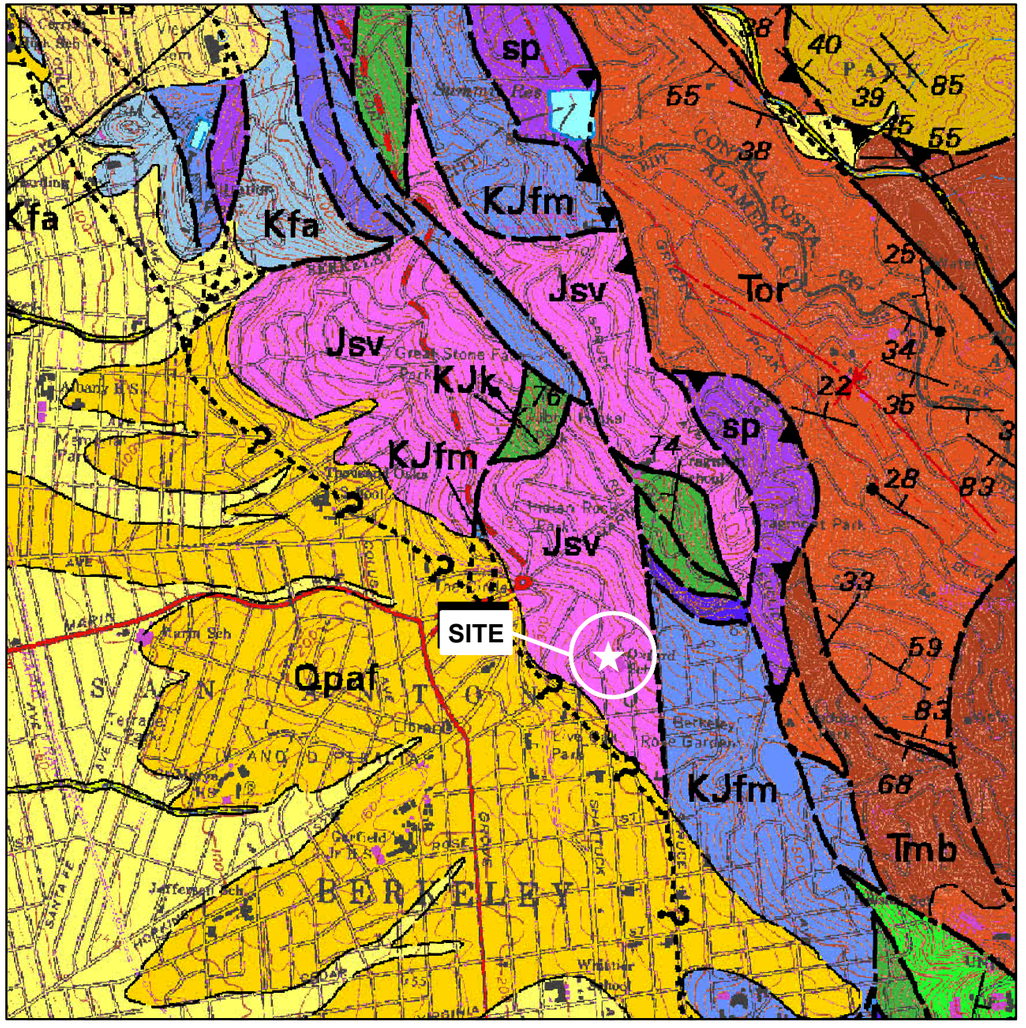
THREE LANDSLIDE MAPS

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**5**



Source: "Geologic Map of the Richmond Quadrangle," Dibblee, 2005.



Source: "Geologic Map and Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, California," Graymer, 2000.

LEGEND

fs fm fg fc gl

FRANCISCAN ASSEMBLAGE

Submetamorphosed eugeosynclinal marine sedimentary and mafic igneous rocks; age Jurassic and Cretaceous

fs *Graywacke sandstone, gray, massive, fine grained, hard*
fm *Melange (mixture) of Franciscan rock fragments in matrix of pervasively sheared dark claystone and greywacke*
fg *Greenstone (metabasalt) (may be in part of the Coast Range ophiolite complex)*
fc *Chert or metachert, thin bedded, varicolored red and green, brittle, contorted*
gl *Glaucophane blue-schist*

sp ker

COAST RANGE OPHIOLITE COMPLEX

Igneous complex intrusive into Franciscan Assemblage; age Jurassic to Cretaceous

sp *Serpentinite, hydrothermally metamorphosed from ultramafic igneous rocks, such as dunite, hydrous magnesium silicate, massive, amorphous, blue-green gray, much fractured, sheared, slickensided*
Ker *Volcanic rocks, mostly keratophyre andesitic rock, brown, massive, aphanitic, much altered, Includes basaltic rocks in Hayward Fault*

Qls

LANDSLIDE RUBBLE

Qoa

OLDER SURFICIAL SEDIMENTS

Qoa *Dissected older alluvial gravel and sand, undeformed; age late Pleistocene*

Original figure produced in color.

0 1,800 3,600
SCALE FEET

LEGEND

Jsv Keratophyre and quartz keratophyre (Late Jurassic)

KJfs Franciscan complex sandstone, undivided (Late Cretaceous to Late Jurassic)

KJfm Franciscan complex, mélange (Cretaceous Late Jurassic), includes mapped locally: Graywacke and meta-graywacke blocks

fs

sp Chert blocks

Qpaf Alluvial fan and fluvial deposits (Pleistocene)

KJk Knoxville Formation (Early Cretaceous and Late Jurassic)

Tsgl Limestone

Tmb Moraga Formation (late Miocene)

Tor Orinda Formation (late Miocene)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

OVERVIEW GEOLOGIC MAPS

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	September 2019	4

NORTH BRANCH CORDONICES CREEK

TAKEN FROM LOS ANGELES AND MARIPOSA STS SHOWING GROTTO ROCK ON SANTA BARBARA DAVIS FARM HOUSE AND BARNS DAVIS SALOON AT MARIN AND SPRUCE AND CHRIS BOREN SALOON ACROSS THE STREET.

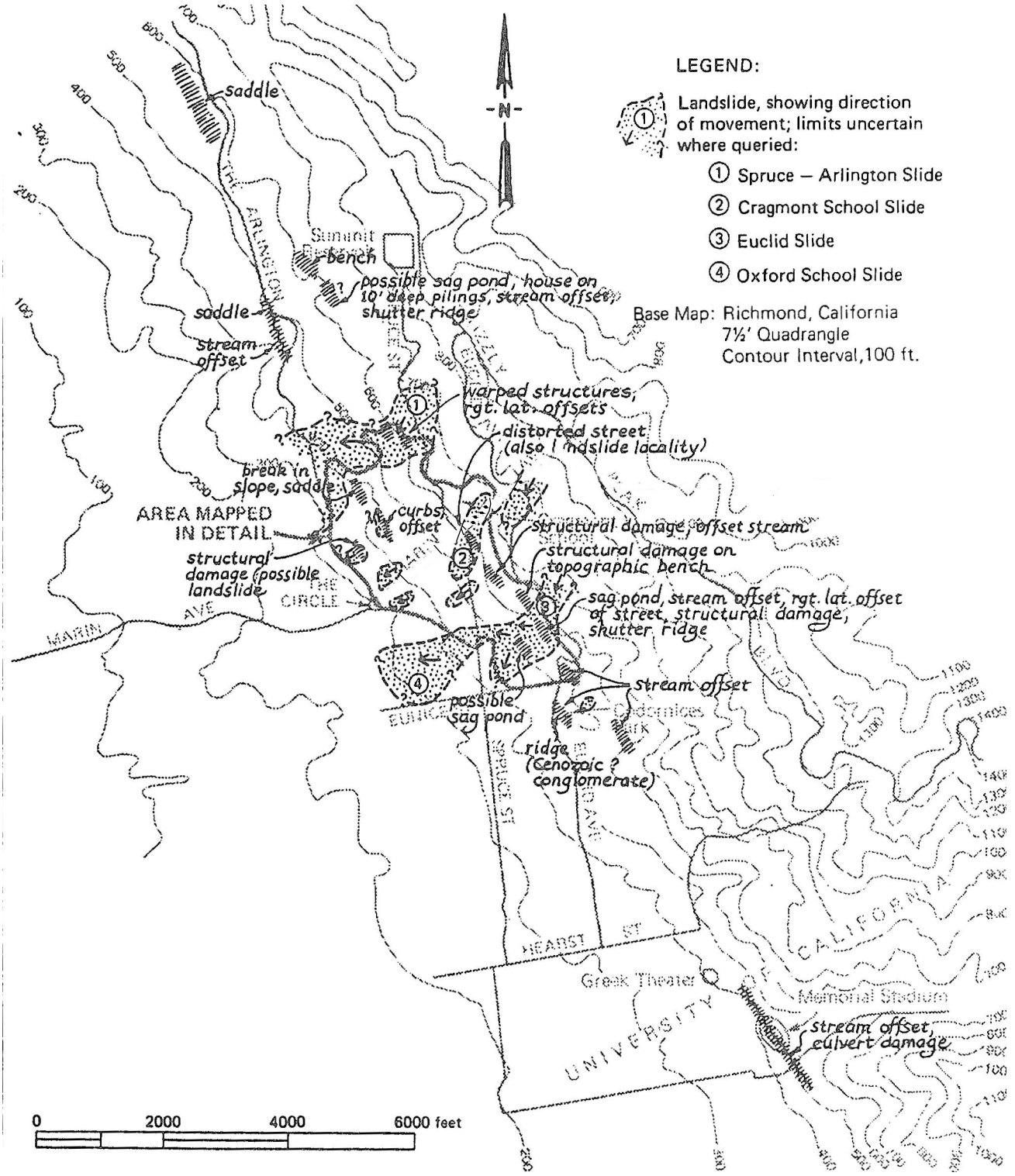
Source: Berkeley Historical Society.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

PRE-DEVELOPMENT EARTHFLOW PHOTO

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**6**



Source: Figure 5: Landslides and features indicative of active faulting along Hayward fault zone, North Berkeley area, taken from Hoexter, D.F., Levine, C.R., Hecht, B., and Collier, G., "Deformation Along the Hayward Fault Zone, North Berkeley: Fault Creep and Landsliding," Proceedings, Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, California Division of Mines and Geology, Special Publication 62.

ALAN KROPP & ASSOCIATES *Geotechnical Consultants*	**1982 LANDSLIDE/FAULT DATA MAP** OXFORD ELEMENTARY SCHOOL Berkeley, California	
	PROJECT NO. **1853-3**	DATE **September 2019**
		FIGURE **7**

Photo 1: Corona Court building distress

Photo 2: Spruce Avenue house foundation distress

Photo 3: Hummocky topography and Spruce Avenue deflection

Photo 4: Distress along Arch Street

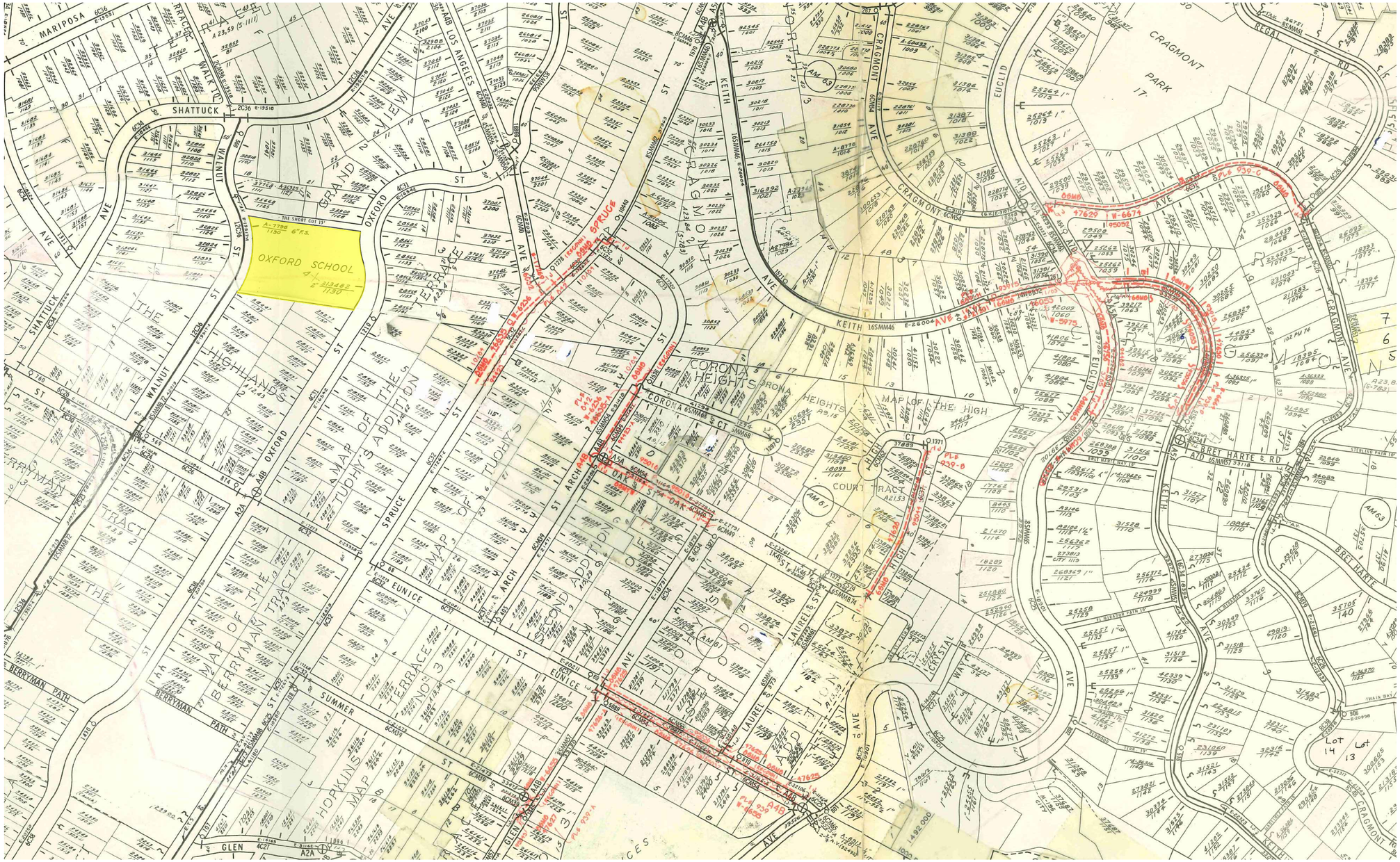
Note: Locations of photographs are presented on Figure 16.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

LANDSLIDE DAMAGE PHOTOS

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**8**



Source: EBMUD, 1985.

Original figure produced in color.

125 0 250 500

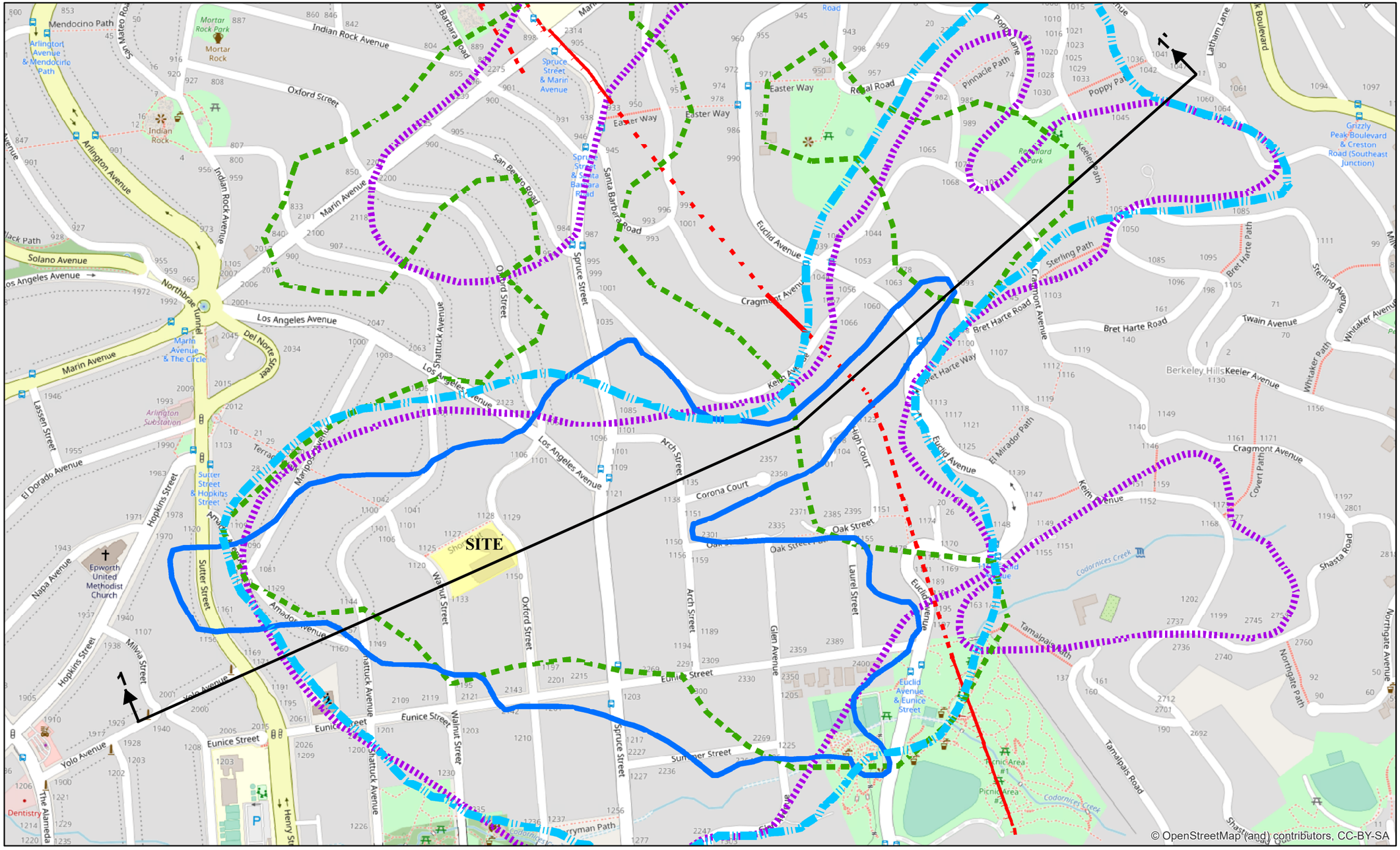
APPROXIMATE SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

HISTORIC EAST BAY MUNICIPAL UTILITIES DISTRICT PIPE LEAK MAP

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**9**



LEGEND (All locations approximate)

- Limits of active slide area (AKA, 1995)
- Limits of active movement - 1992-2001 (Hilley, 2004)
- Limits of active movement - 2009-2014 (Cohen - Waeber, 2018)
- Limits of active Keith Avenue slide (this study)

Hayward Fault (Lienkaemper, 2006)
- <= 20 m uncertainty
- <= 20 m uncertainty, down
- <= 40 m uncertainty

1 1' Location of cross section (See Figure 12)

0 200 400 800 Feet

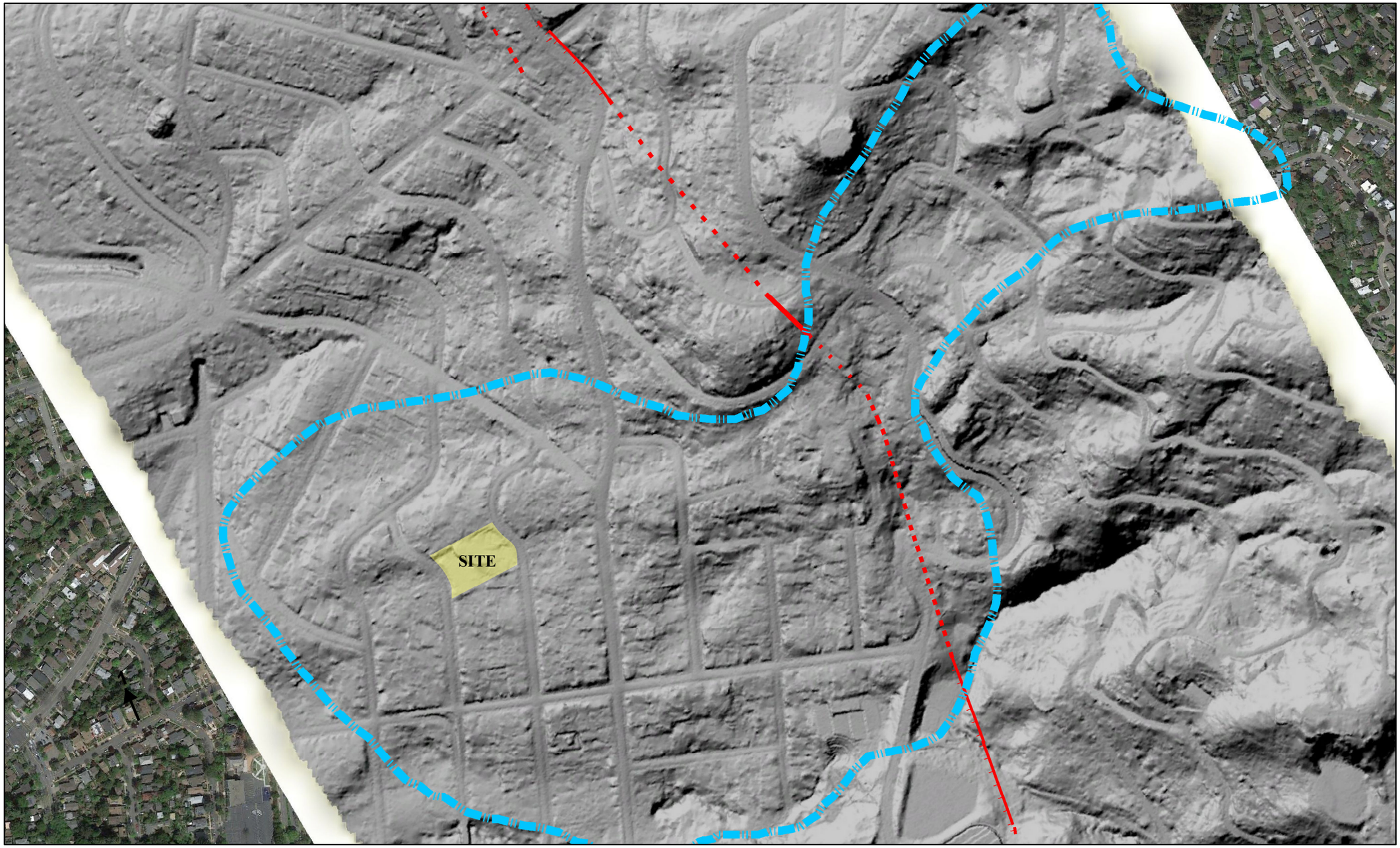
Original figure produced in color.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

COMPOSITE MAP OF ACTIVE LANDSLIDE LIMITS

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	September 2019	10



N

LEGEND (All locations approximate)

Limits of active Keith Avenue landslide (this study, from Figure 10)

Hayward Fault (Lienkaemper, 2006)
- <= 20 m uncertainty
- <= 20 m uncertainty, down
- <= 40 m uncertainty

0 200 400 800 Feet

Original figure produced in color.

LiDAR Base: This material is based on services provided to the Plate Boundary Observatory by NCALM (http://www.ncalm.org). PBO is operated by UNAVCO for EarthScope (http://www.earthscope.org) and supported by the National Science Foundation (No. EAR-0350028 and EAR-0732947).

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

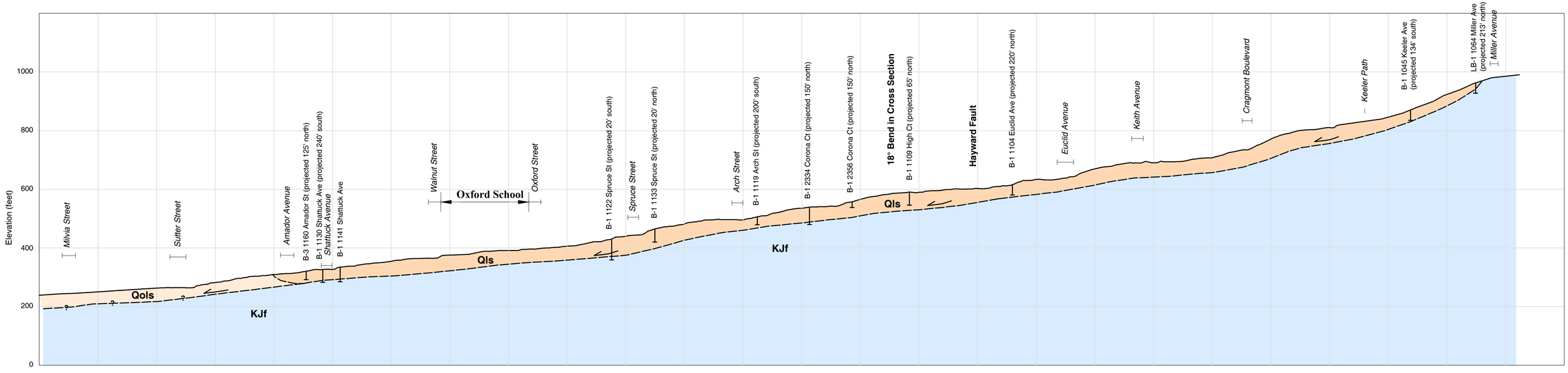
ACTIVE LIMITS OF KEITH AVENUE LANDSLIDE - LIDAR BASE

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**11**

1
(Southwest)

1'
(Northeast)



LEGEND

Qls	Landslide Debris
Qols	Older Landslide Debris
KJf	Franciscan Assemblage
I	Location and depth of boring

NOTES:
1. See Figure 10 for location of cross section.
2. Cross section represents idealized conditions based on limited subsurface data. Significant variations may be encountered during construction.
3. Area of fill not located.

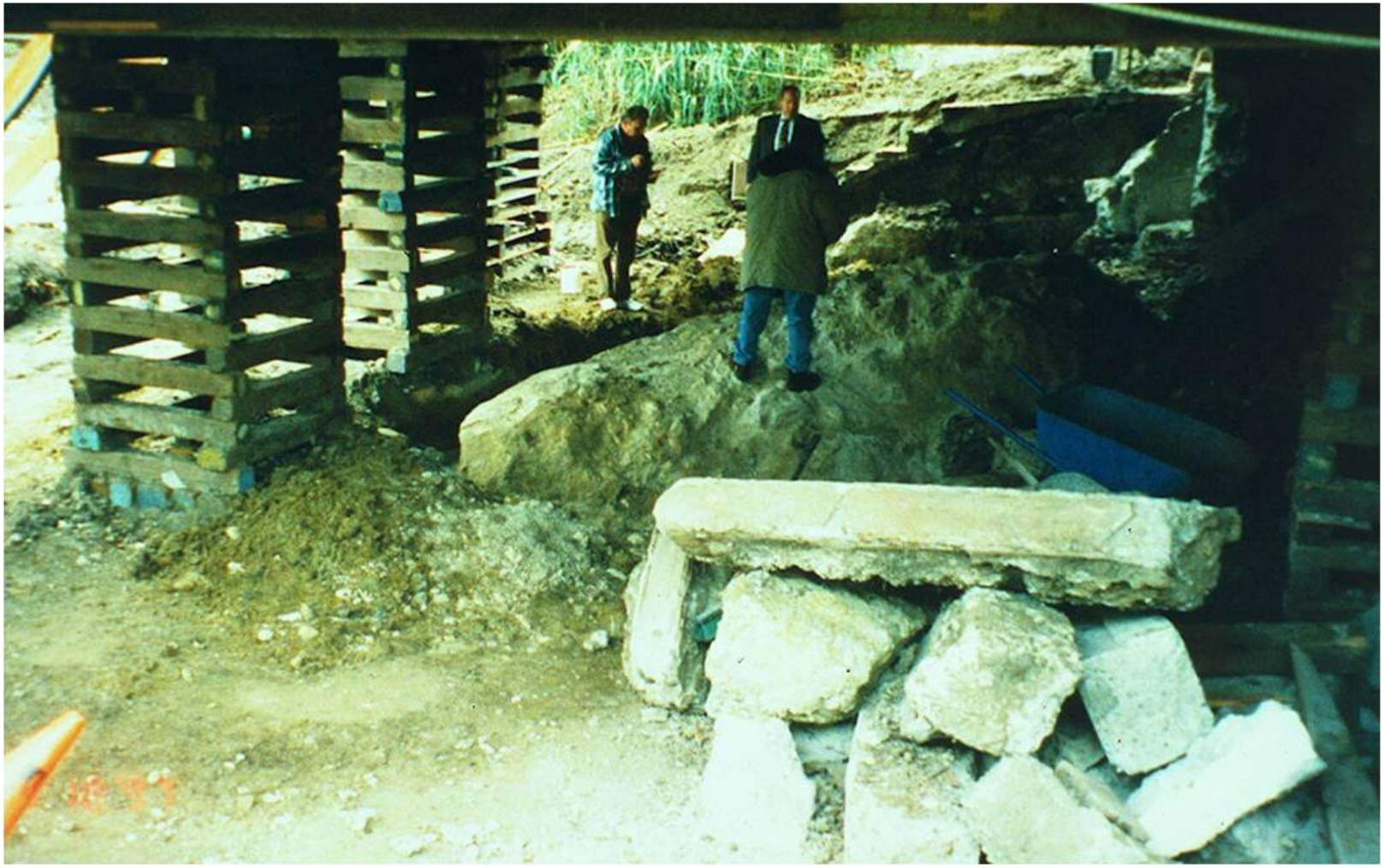
100 0 200 400
APPROXIMATE HORIZONTAL SCALE FEET

Base: Alameda County LiDAR, 2007

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

GEOLOGIC SECTION 1-1'
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	September 2019	12



Laurel Avenue Residence Foundation Replacement,
Large Boulder in Foundation Area

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

BOULDER PHOTO

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**13**

Source: United States Park Service, 1935.

LEGEND (All locations approximate)

Outline of active Keith Avenue landslide (from Figure 10)

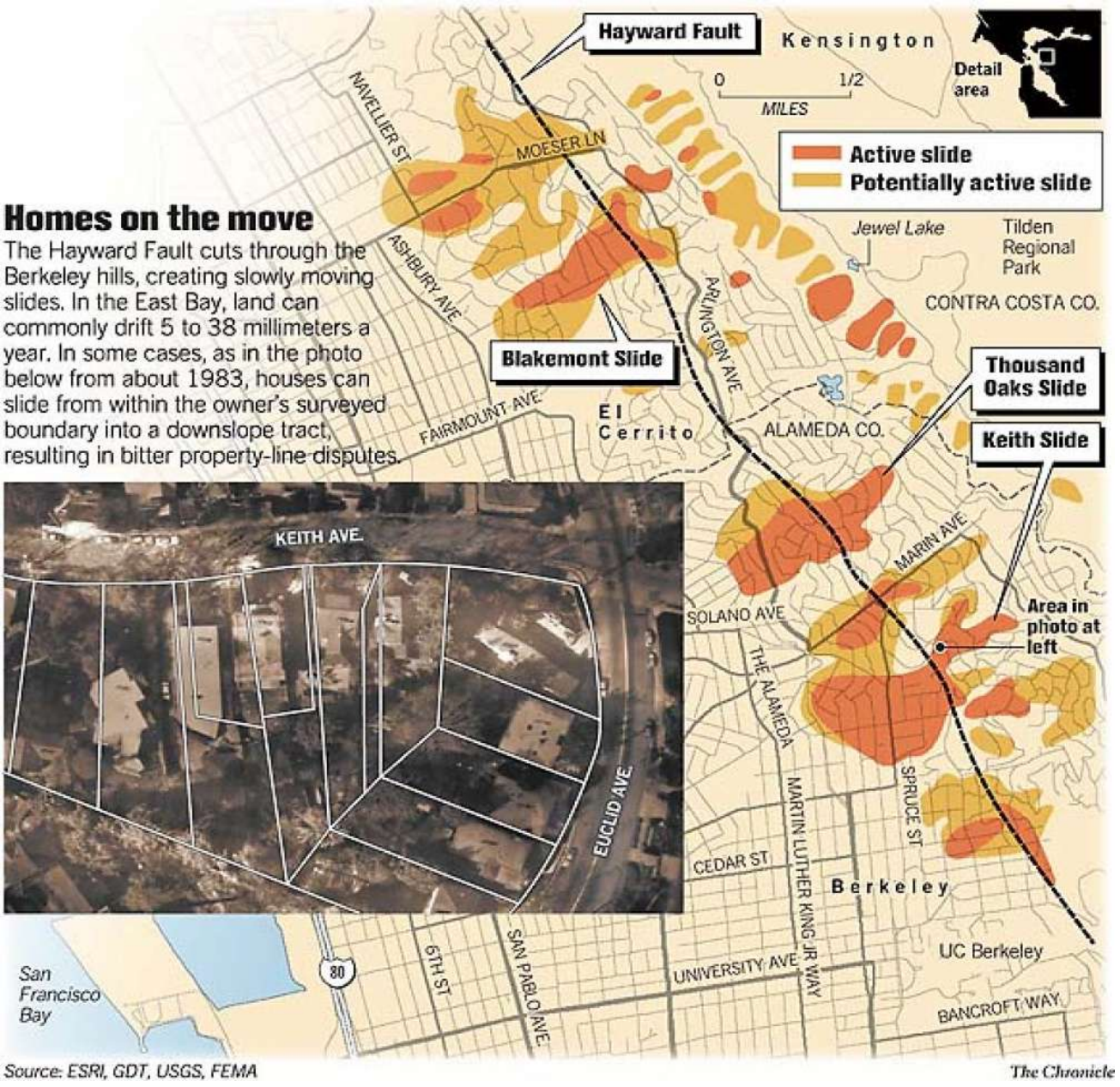
Original figure produced in color.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

LANDSLIDE OUTLINE ON 1935 OBLIQUE PHOTO

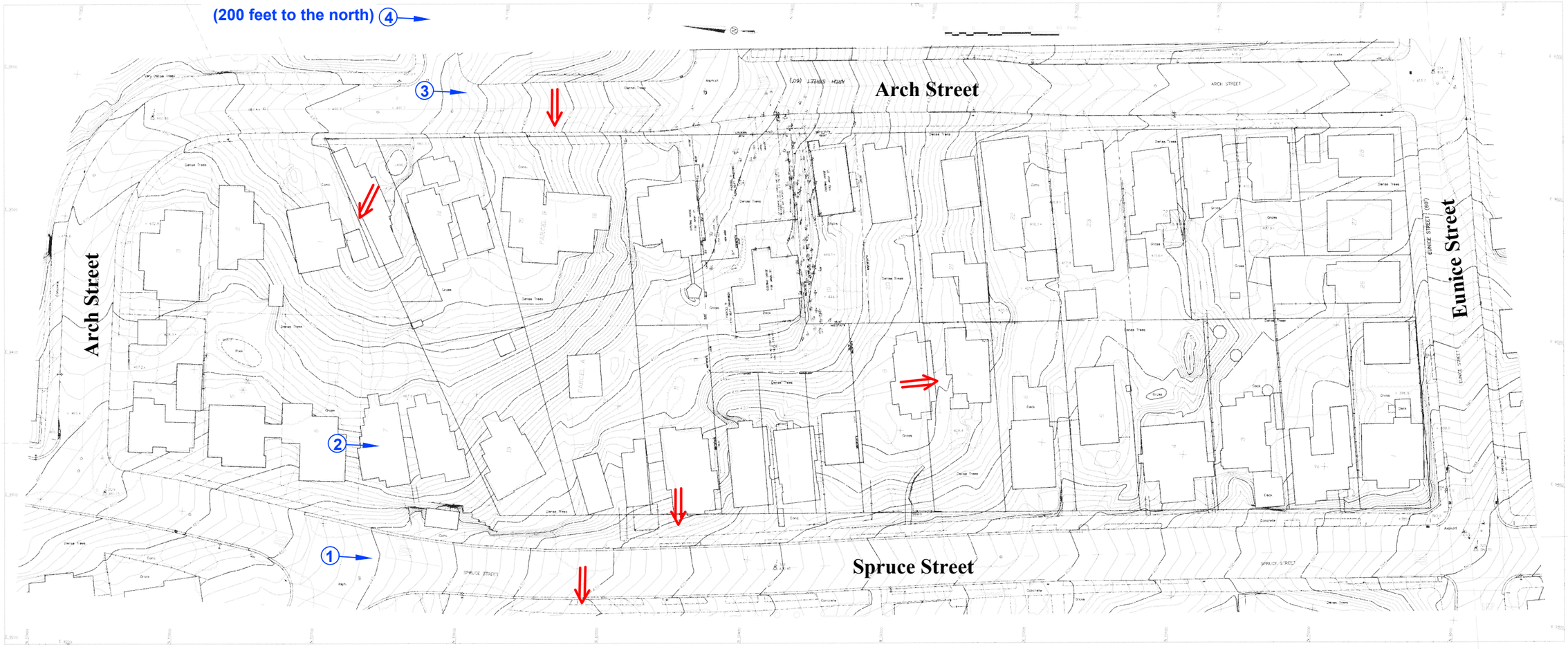
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**14**



Source: "When property lines run through the front door / The slowly shifting ground in the Berkeley hills area means the land that's yours today may be your neighbor's tomorrow," Patrick Hoge, San Francisco Chronicle, 12/20/04.

ALAN KROPP & ASSOCIATES Geotechnical Consultants	BERKELEY HILLS SLIDES NEWS ARTICLE		
	OXFORD ELEMENTARY SCHOOL Berkeley, California		
	PROJECT NO.	DATE	FIGURE **15**
	1853-3	**September 2019**	



Source: "Arch Street, Berkeley Site," drawn by HJW, 2005.

LEGEND

Direction of movement

2 Location and orientation of photograph on Figure 8

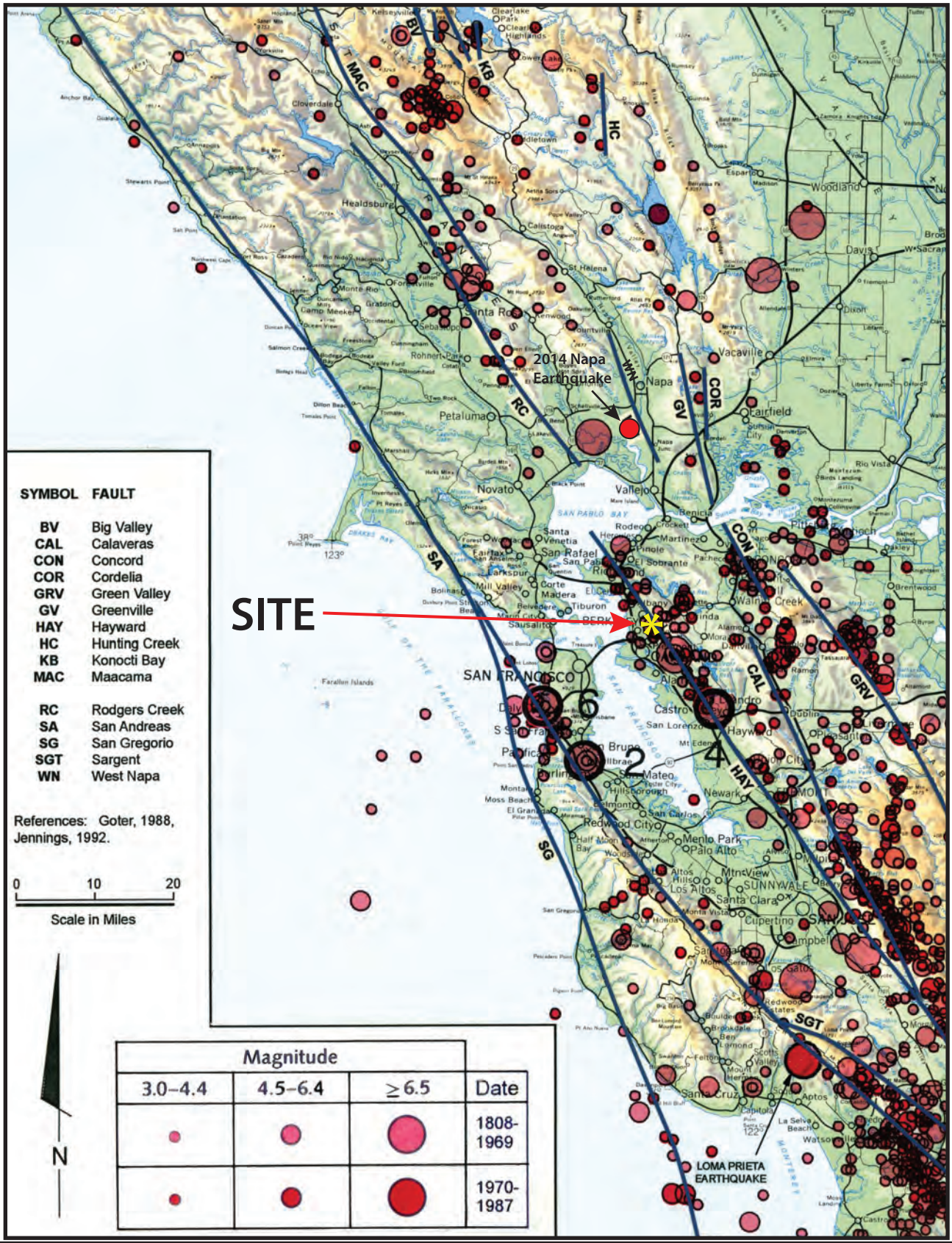
Original figure produced in color.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

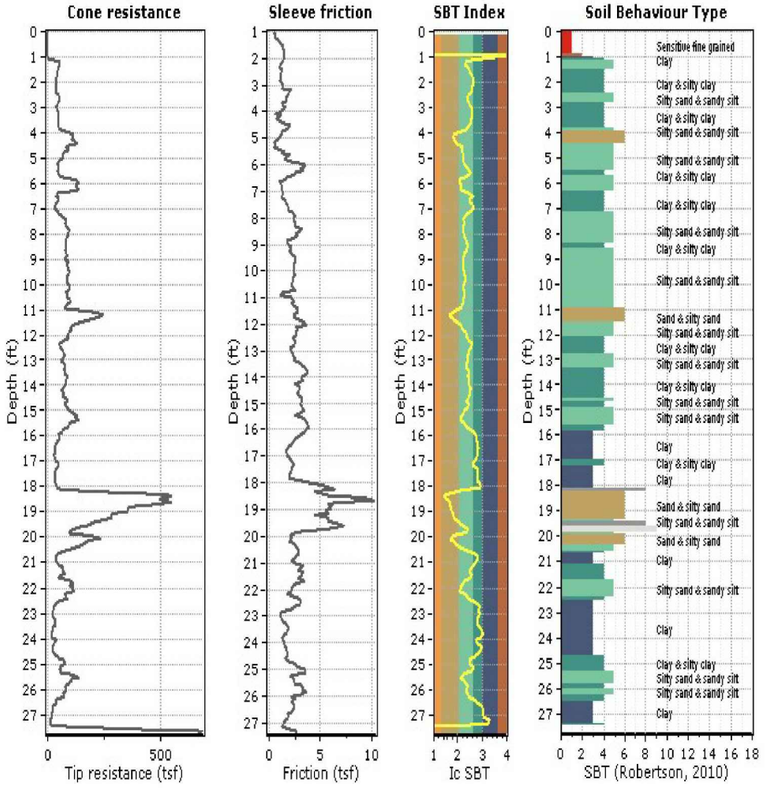
ARCH STREET BLOCK MOVEMENT SURVEY

OXFORD ELEMENTARY SCHOOL
Berkeley, California

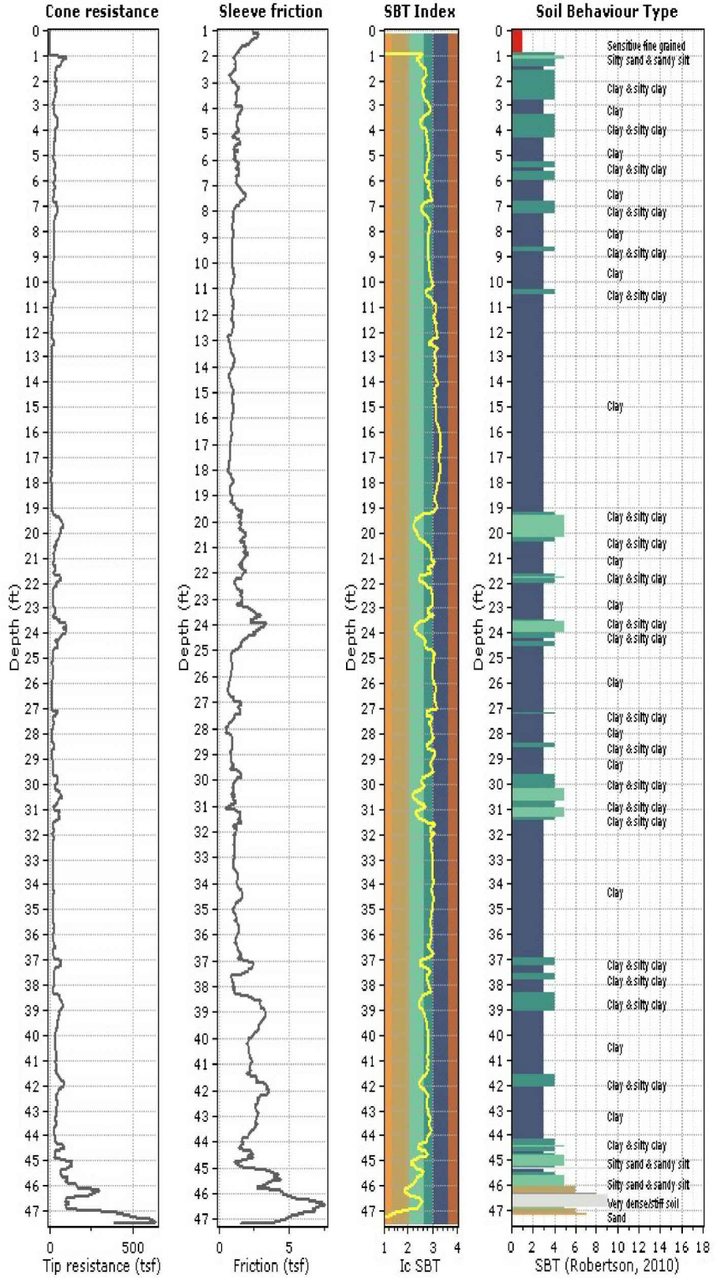
PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**16**


SYMBOL FAULT
BV Big Valley
CAL Calaveras
CON Concord
COR Cordelia
GRV Green Valley
GV Greenville
HAY Hayward
HC Hunting Creek
KB Konocti Bay
MAC Maacama
RC Rodgers Creek
SA San Andreas
SG San Gregorio
SGT Sargent
WN West Napa
References: Goter, 1988, Jennings, 1992.
0 10 20
Scale in Miles
N
Magnitude
3.0–4.4
4.5–6.4
≥6.5
Date
1808-1969
1970-1987
SITE
2014 Napa Earthquake
LOMA PRIETA EARTHQUAKE
SAN FRANCISCO
Healdsburg
Santa Rosa
Petaluma
Novato
Vallejo
Napa
Fairfield
Vacaville
Woodland
Davis
Dixon
Rohnert Park
Sebastopol
Cloverdale
Calistoga
St Helena
Middletown
Clearlake Park
Clearlake Highlands
Kelseyville
Cotati
Sonoma
Glen Ellen
Boyes Hot Springs
Fulton
Forestville
Guerneville
Monte Rio
Occidental
Camp Meeker
Duncans Mills
Jenner
Bodega
Bodega Bay
Tomales
Dillon Beach
Point Reyes
Inverness
Olema
Bolinas
Fairfax
San Anselmo
Ross
Kentfield
Larkspur
Corte Madera
Mill Valley
Belvedere
Tiburon
Sausalito
Marin City
Strawberry
Alameda
Oakland
Berkeley
Emeryville
Piedmont
Albany
El Cerrito
Richmond
San Pablo
El Sobrante
Pinole
Hercules
Rodeo
Crockett
Martinez
Benicia
Pacheco
Concord
Walnut Creek
Danville
San Ramon
Dublin
Pleasanton
Livermore
Brentwood
Oakley
Antioch
Pittsburg
Rio Vista
Suisun City
Fairfield
Vacaville
Elmira
Dixon
Davis
Woodland
Esparto
Madison
Winters
Capay
Knights Landing
Colusa
Williams
Arbuckle
Maxwell
Willows
Orland
Chico
Oroville
Gridley
Yuba City
Marysville
Colusa
Sutter
Yuba
Butte
Glenn
Tehama
Shasta
Trinity
Mendocino
Lake
Napa
Sonoma
Marin
Solano
Yolo
Contra Costa
Alameda
San Francisco
San Mateo
Santa Clara
Santa Cruz
San Benito
Monterey
Merced
Stanislaus
San Joaquin
Sacramento
Amador
Calaveras
Tuolumne
Mariposa
Madera
Fresno
Kings
Tulare
Kern
Inyo
Mono
Alpine
Modoc
Lassen
Plumas
Sierra
Nevada
Placer
El Dorado
Alpine
Mono
Inyo
Kern
Tulare
Kings
Fresno
Madera
Mariposa
Tuolumne
Calaveras
Amador
Sacramento
San Joaquin
Stanislaus
Merced
San Benito
Monterey
Santa Cruz
Santa Clara
San Mateo
San Francisco
Alameda
Contra Costa
Solano
Yolo
Marin
Sonoma
Napa
Lake
Mendocino
Trinity
Shasta
Tehama
Glenn
Butte
Yuba
Sutter
Colusa
Willows
Orland
Chico
Oroville
Gridley
Yuba City
Marysville
Arbuckle
Maxwell
Williams
Colusa
Winters
Capay
Knights Landing
Esparto
Madison
Woodland
Davis
Dixon
Fairfield
Vacaville
Elmira
Suisun City
Rio Vista
Montezuma
Collinsville
Birds Landing
Oakley
Antioch
Pittsburg
Brentwood
Byron
Tracy
Lathrop
Manteca
Ripon
Escalon
Oakdale
Riverbank
Modesto
Turlock
Ceres
Hughson
Waterford
Patterson
Newman
Gustine
Los Banos
Dos Palos
Firebaugh
Mendota
Coalinga
Huron
Avenal
Lemoore
Hanford
Corcoran
Kingsburg
Selma
Fowler
Parlier
Reedley
Sanger
Dinuba
Visalia
Tulare
Porterville
Lindsay
Exeter
Farmersville
Woodlake
Orosi
Kingsburg
Selma
Fowler
Parlier
Reedley
Sanger
Dinuba
Visalia
Tulare
Porterville
Lindsay
Exeter
Farmersville
Woodlake
Orosi
Delano
Wasco
Shafter
Arvin
Lamont
Weedpatch
Bakersfield
Oildale
Rosedale
Buttonwillow
Taft
Maricopa
Fellows
McKittrick
Derby Acres
Lost Hills
Kettleman City
Avenal
Coalinga
Huron
Firebaugh
Mendota
Los Banos
Dos Palos
Gustine
Newman
Patterson
Waterford
Hughson
Ceres
Turlock
Modesto
Riverbank
Oakdale
Escalon
Ripon
Manteca
Lathrop
Tracy
Byron
Brentwood
Oakley
Antioch
Pittsburg
Rio Vista
Suisun City
Fairfield
Vacaville
Elmira
Dixon
Davis
Woodland
Esparto
Madison
Winters
Capay
Knights Landing
Colusa
Williams
Arbuckle
Maxwell
Willows
Orland
Chico
Oroville
Gridley
Yuba City
Marysville
Colusa
Sutter
Yuba
Butte
Glenn
Tehama
Shasta
Trinity
Mendocino
Lake
Napa
Sonoma
Marin
Solano
Yolo
Contra Costa
Alameda
San Francisco
San Mateo
Santa Clara
Santa Cruz
San Benito
Monterey
Merced
Stanislaus
San Joaquin
Sacramento
Amador
Calaveras
Tuolumne
Mariposa
Madera
Fresno
Kings
Tulare
Kern
Inyo
Mono
Alpine
Modoc
Lassen
Plumas
Sierra
Nevada
Placer
El Dorado
Alpine
Mono
Inyo
Kern
Tulare
Kings
Fresno
Madera
Mariposa
Tuolumne
Calaveras
Amador
Sacramento
San Joaquin
Stanislaus
Merced
San Benito
Monterey
Santa Cruz
Santa Clara
San Mateo
San Francisco
Alameda
Contra Costa
Solano
Yolo
Marin
Sonoma
Napa
Lake
Mendocino
Trinity
Shasta
Tehama
Glenn
Butte
Yuba
Sutter
Colusa
Willows
Orland
Chico
Oroville
Gridley
Yuba City
Marysville
Arbuckle
Maxwell
Williams
Colusa
Winters
Capay
Knights Landing
Esparto
Madison
Woodland
Davis
Dixon
Fairfield
Vacaville
Elmira
Suisun City
Rio Vista
Montezuma
Collinsville
Birds Landing
Oakley
Antioch
Pittsburg
Brentwood
Byron
Tracy
Lathrop
Manteca
Ripon
Escalon
Oakdale
Riverbank
Modesto
Turlock
Ceres
Hughson
Waterford
Patterson
Newman
Gustine
Los Banos
Dos Palos
Firebaugh
Mendota
Coalinga
Huron
Avenal
Lemoore
Hanford
Corcoran

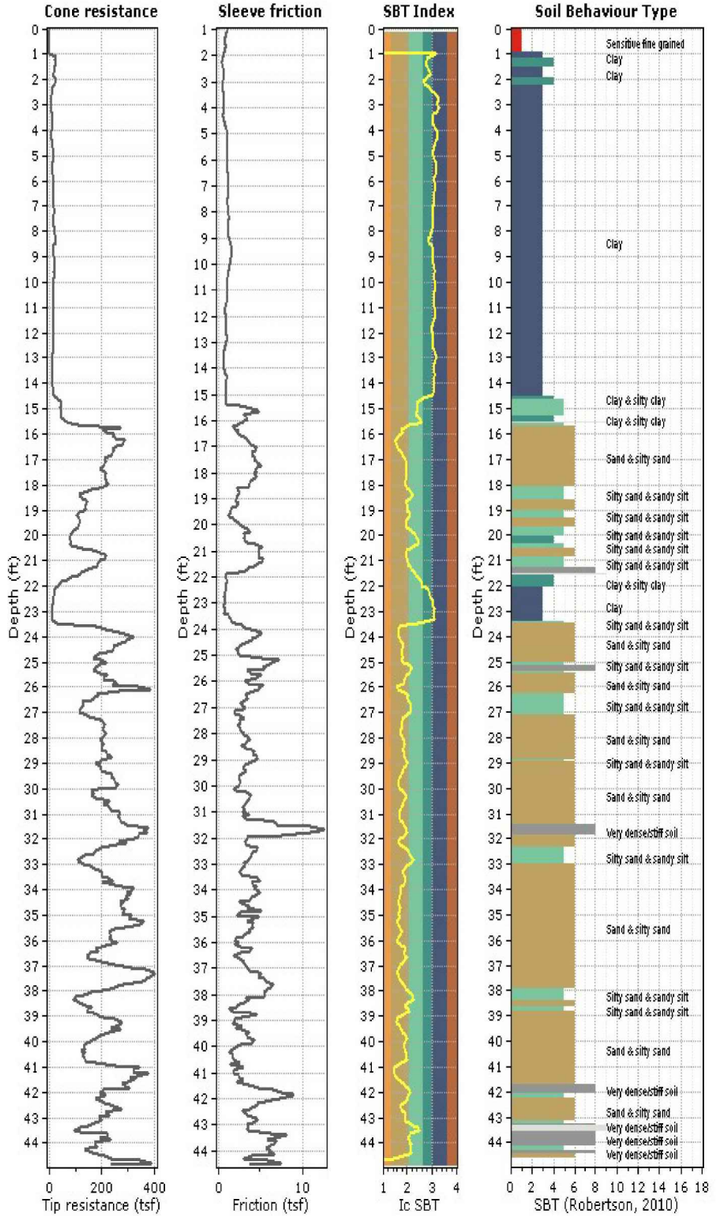
CPT-1



CPT-2



CPT-3



LEGEND

SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

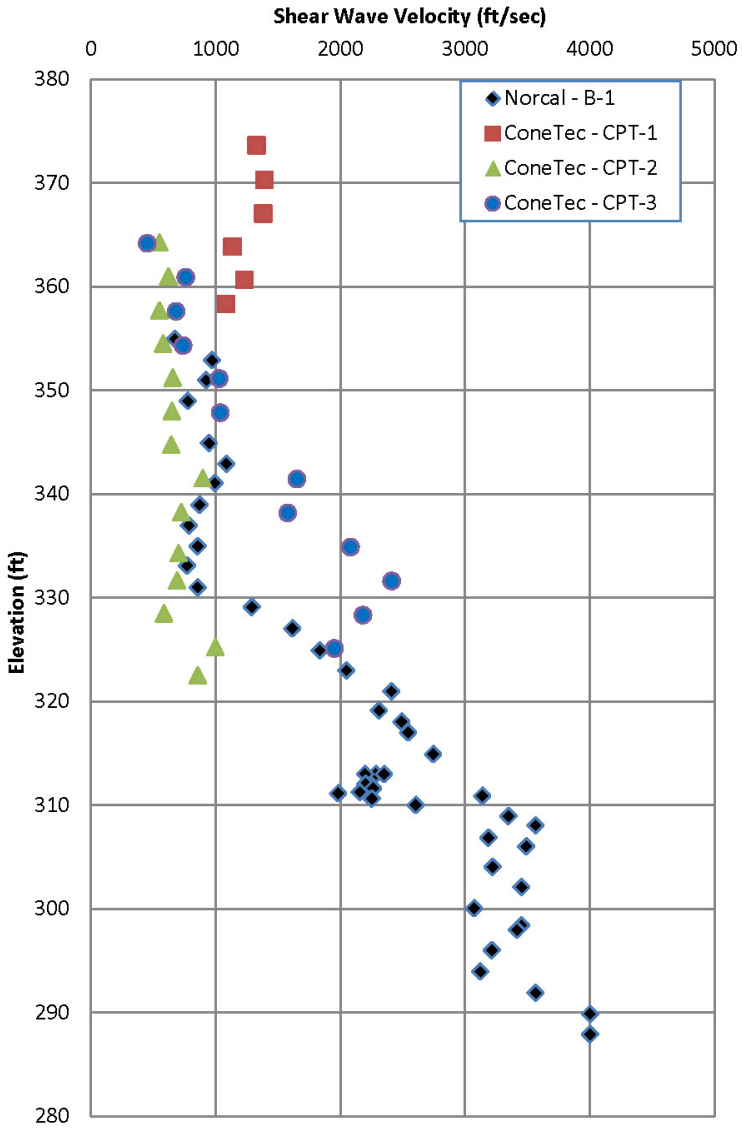
Original figure produced in color.

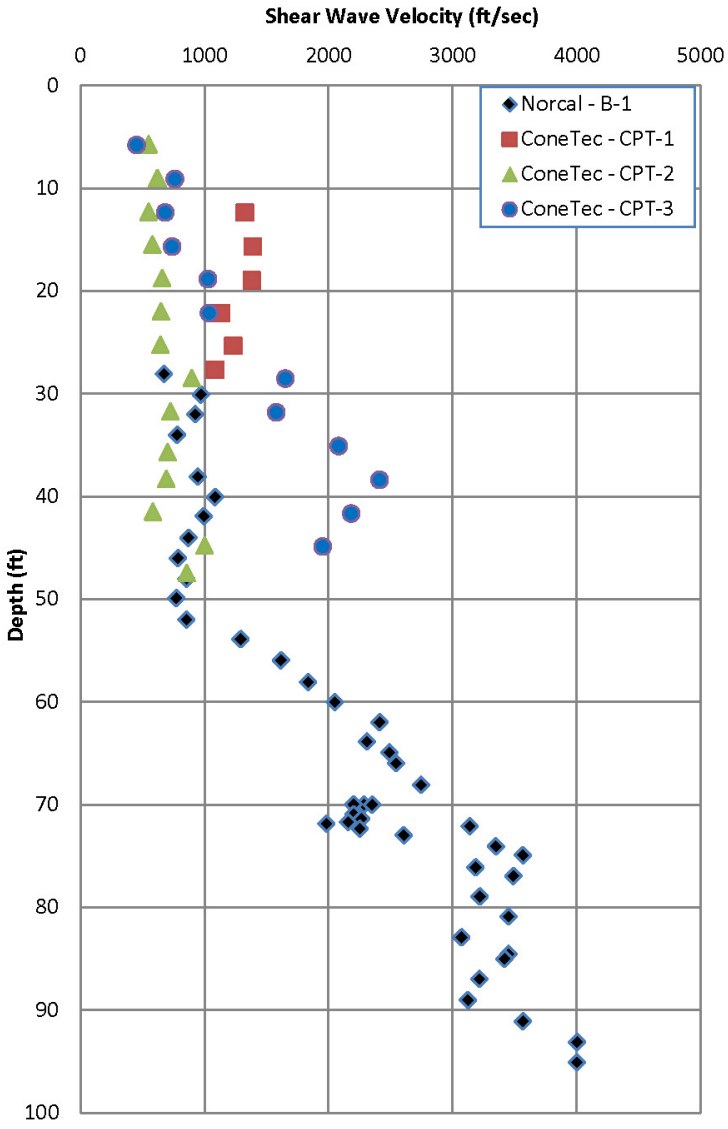
ALAN KROPP & ASSOCIATES
Geotechnical Consultants

CPT SUMMARY

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**18**





ALAN KROPP & ASSOCIATES
Geotechnical Consultants

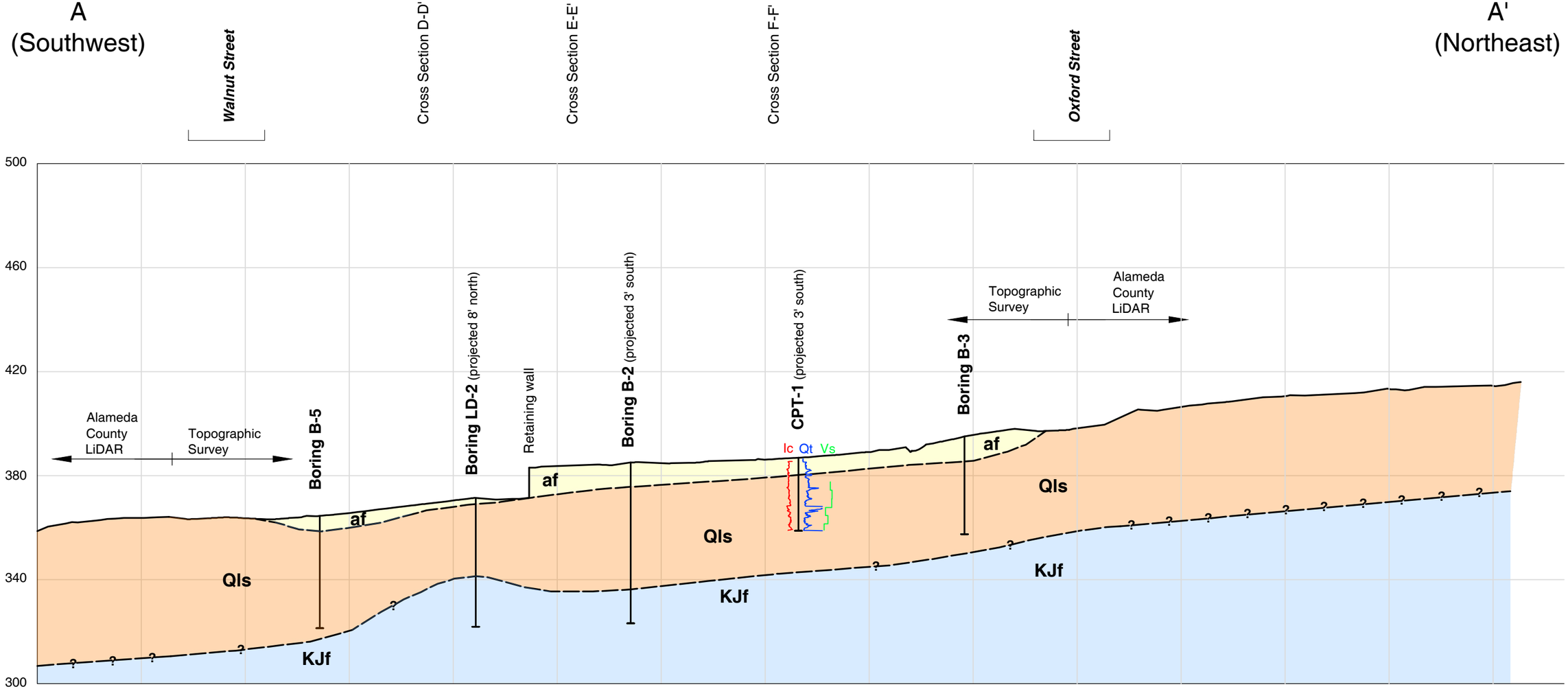
SHEAR WAVE VELOCITY OVERLAY PLOT

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**19**

A (Southwest)

A' (Northeast)



Base: This material is based on "Topographic Survey 1130 Oxford Elementary School," drawn by Sandis, dated 7/10/18. Note: Elevations have been adjusted +289' and Alameda County LiDAR, 2007 adjusted -6'.

LEGEND

af	Artificial Fill
Qls	Landslide Debris
KJf	Franciscan Assemblage
	Location and depth of boring

Ic Qt Vs

Ic - Soil Behavior Type Index, (unitless value)
Qt - Recorded Tip Resistance, (tsf)
Vs - Shear Wave Velocity (ft/sec)
(See details on Figure 18)

Original figure produced in color.

NOTES:
1. See Figure 3 for location of cross section.
2. Cross section represents idealized conditions based on limited subsurface data. Significant variations may be encountered during construction.
3. CPT data for graphical purposes only. See Appendix B for actual values.

20 0 40 80
APPROXIMATE HORIZONTAL SCALE FEET

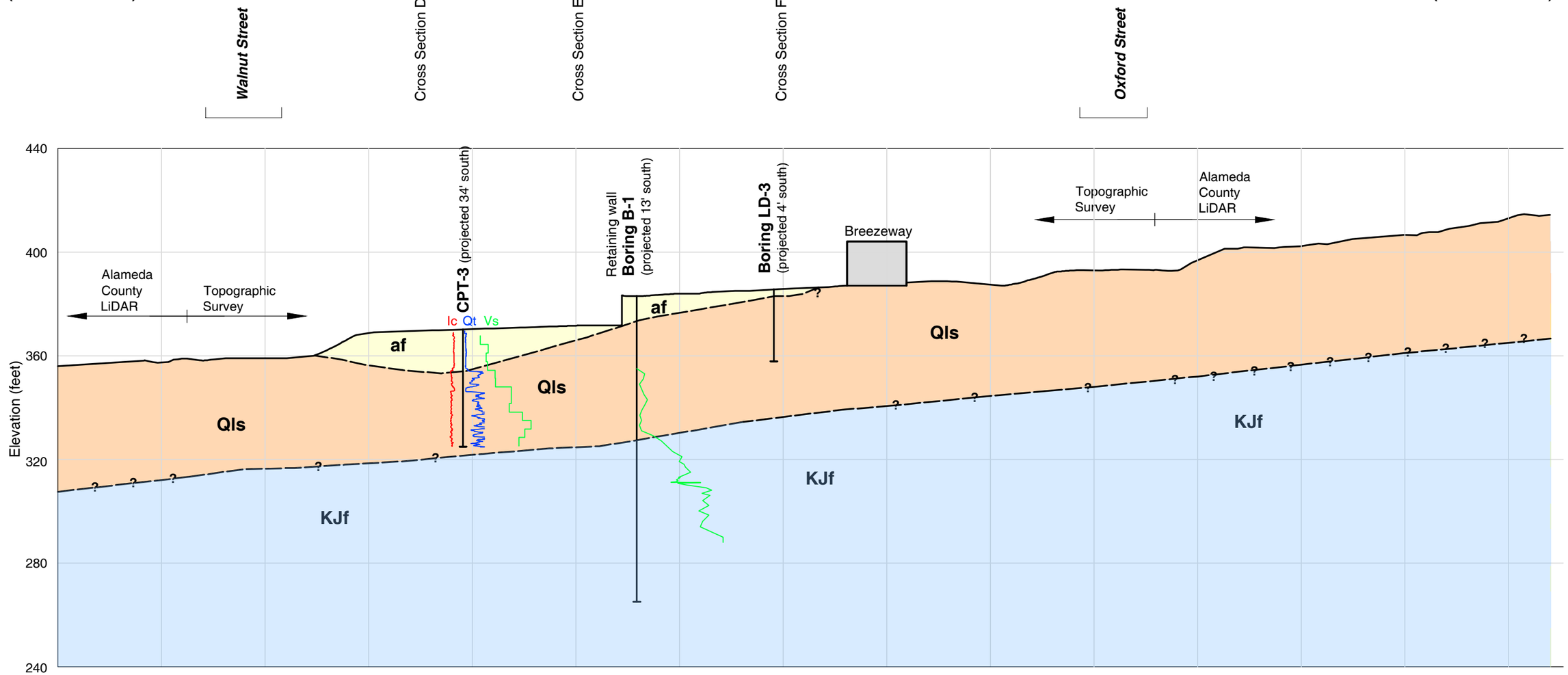
ALAN KROPP & ASSOCIATES
Geotechnical Consultants

GEOLOGIC SECTION A-A'
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	September 2019	20

B
(Southwest)

B'
(Northeast)



Base: This material is based on "Topographic Survey 1130 Oxford Elementary School," drawn by Sandis, dated 7/10/18. Note: Elevations have been adjusted +289' and Alameda County LiDAR, 2007 adjusted -6'.

LEGEND

af	Artificial Fill
Qls	Landslide Debris
KJf	Franciscan Assemblage
⊥	Location and depth of boring

Ic Qt Vs

Ic - Soil Behavior Type Index, (unitless value)
Qt - Recorded Tip Resistance, (tsf)
Vs - Shear Wave Velocity (ft/sec)
(See details on Figure 18)

Original figure produced in color.

NOTES:
1. See Figure 3 for location of cross section.
2. Cross section represents idealized conditions based on limited subsurface data. Significant variations may be encountered during construction.
3. CPT data for graphical purposes only. See Appendix B for actual values.

20 0 40 80
APPROXIMATE HORIZONTAL SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

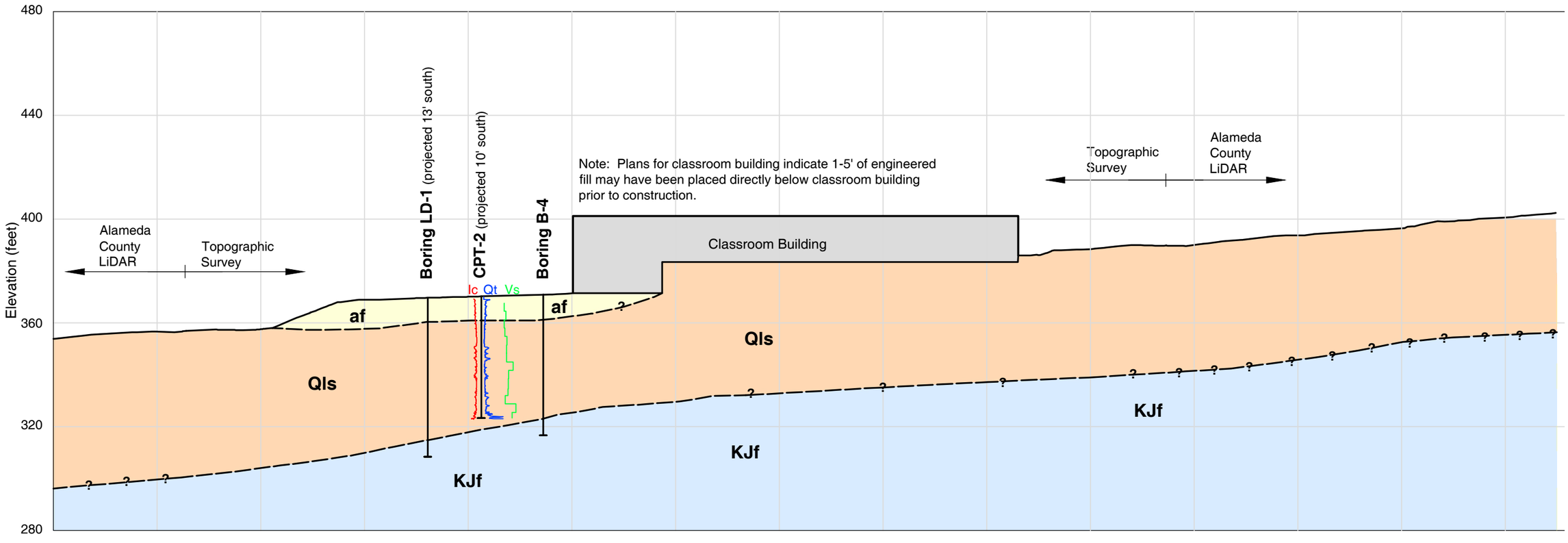
GEOLOGIC SECTION B-B'
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**21**

C
(Southwest)

C'
(Northeast)

Walnut Street | Cross Section D-D' | Cross Section E-E' | Cross Section F-F' | **Oxford Street**



Base: This material is based on "Topographic Survey 1130 Oxford Elementary School," drawn by Sandis, dated 7/10/18. Note: Elevations have been adjusted +289' and Alameda County LiDAR, 2007 adjusted -6'.

LEGEND

af	Artificial Fill
QIs	Landslide Debris
KJf	Franciscan Assemblage
⊥	Location and depth of boring

Ic Qt Vs

Ic - Soil Behavior Type Index, (unitless value)
Qt - Recorded Tip Resistance, (tsf)
Vs - Shear Wave Velocity (ft/sec)
(See details on Figure 18)

Original figure produced in color.

NOTES:
1. See Figure 3 for location of cross section.
2. Cross section represents idealized conditions based on limited subsurface data. Significant variations may be encountered during construction.
3. CPT data for graphical purposes only. See Appendix B for actual values.

20 0 40 80
APPROXIMATE HORIZONTAL SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

GEOLOGIC SECTION C-C'
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**22**

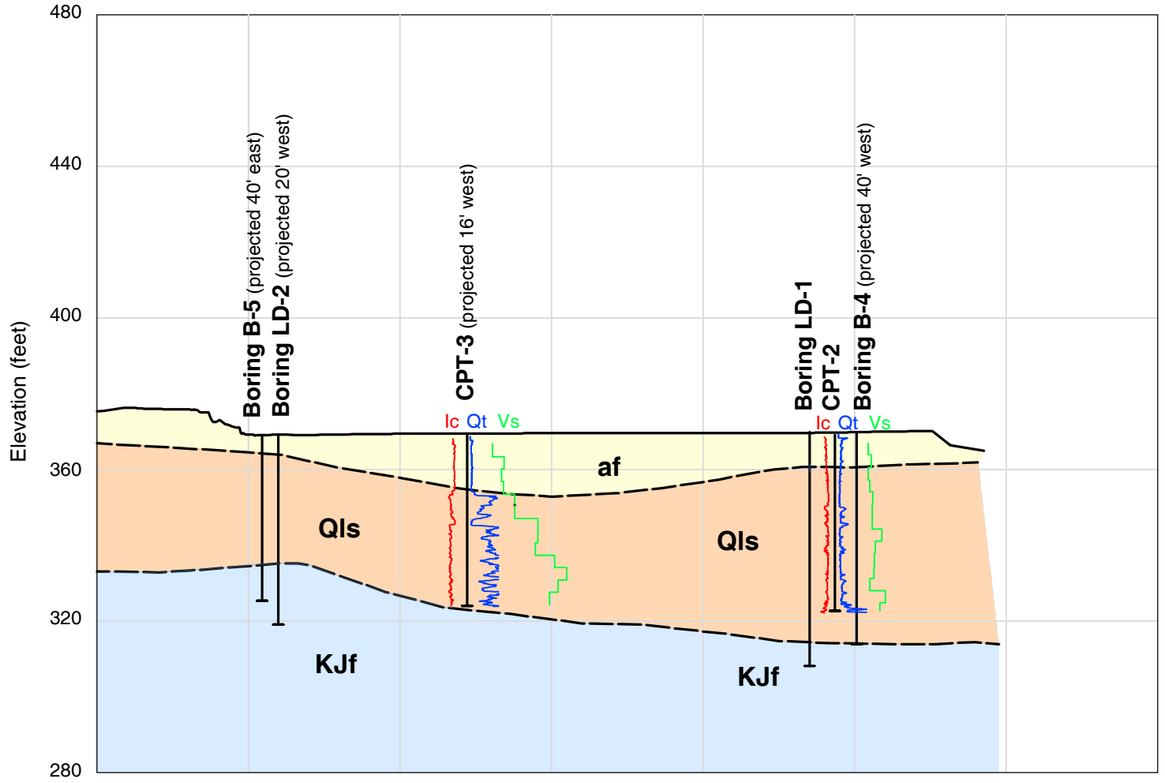
D
(North)

Cross Section A-A'

Cross Section B-B'

Cross Section C-C'

D'
(South)



Base: This material is based on "Topographic Survey 1130 Oxford Elementary School," drawn by Sandis, dated 7/10/18. Note: Elevations have been adjusted +289'.

LEGEND

af	Artificial Fill
Qls	Landslide Debris
KJf	Franciscan Assemblage
⊥	Location and depth of boring

Ic Qt Vs

Ic - Soil Behavior Type Index, (unitless value)
Qt - Recorded Tip Resistance, (tsf)
Vs - Shear Wave Velocity (ft/sec)
(See details on Figure 18)

Original figure produced in color.

NOTES:
1. See Figure 3 for location of cross section.
2. Cross section represents idealized conditions based on limited subsurface data. Significant variations may be encountered during construction.
3. CPT data for graphical purposes only. See Appendix B for actual values.

20 0 40 80
APPROXIMATE HORIZONTAL SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

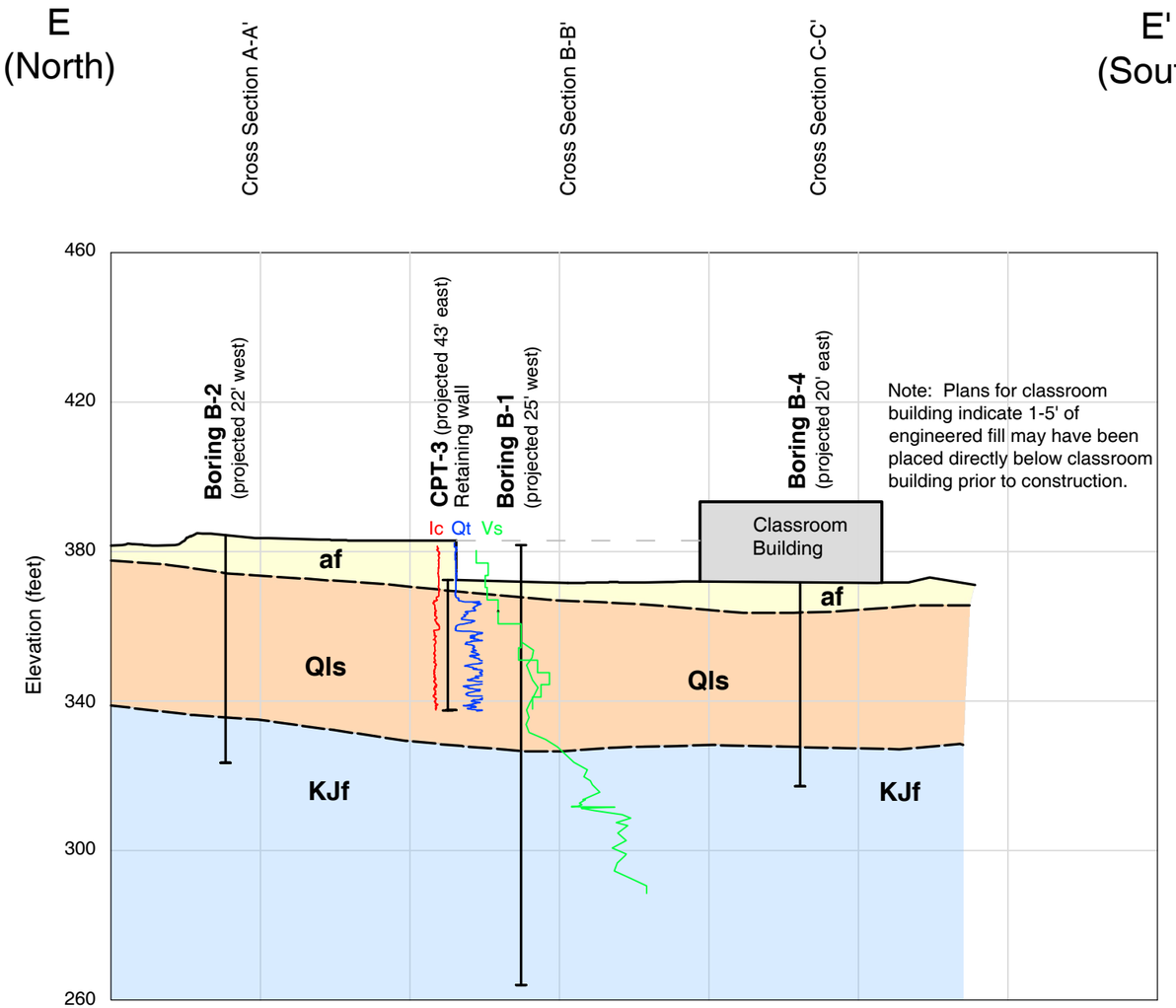
GEOLOGIC SECTION D-D'

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**23**

E
(North)

E'
(South)



Base: This material is based on "Topographic Survey 1130 Oxford Elementary School," drawn by Sandis, dated 7/10/18. Note: Elevations have been adjusted +289'.

LEGEND

af	Artificial Fill
Qls	Landslide Debris
KJf	Franciscan Assemblage
⊥	Location and depth of boring

Ic Qt Vs

Ic - Soil Behavior Type Index, (unitless value)
Qt - Recorded Tip Resistance, (tsf)
Vs - Shear Wave Velocity (ft/sec)
(See details on Figure 18)

Original figure produced in color.

NOTES:
1. See Figure 3 for location of cross section.
2. Cross section represents idealized conditions based on limited subsurface data. Significant variations may be encountered during construction.
3. CPT data for graphical purposes only. See Appendix B for actual values.

20 0 40 80
APPROXIMATE HORIZONTAL SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

GEOLOGIC SECTION E-E'
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**24**

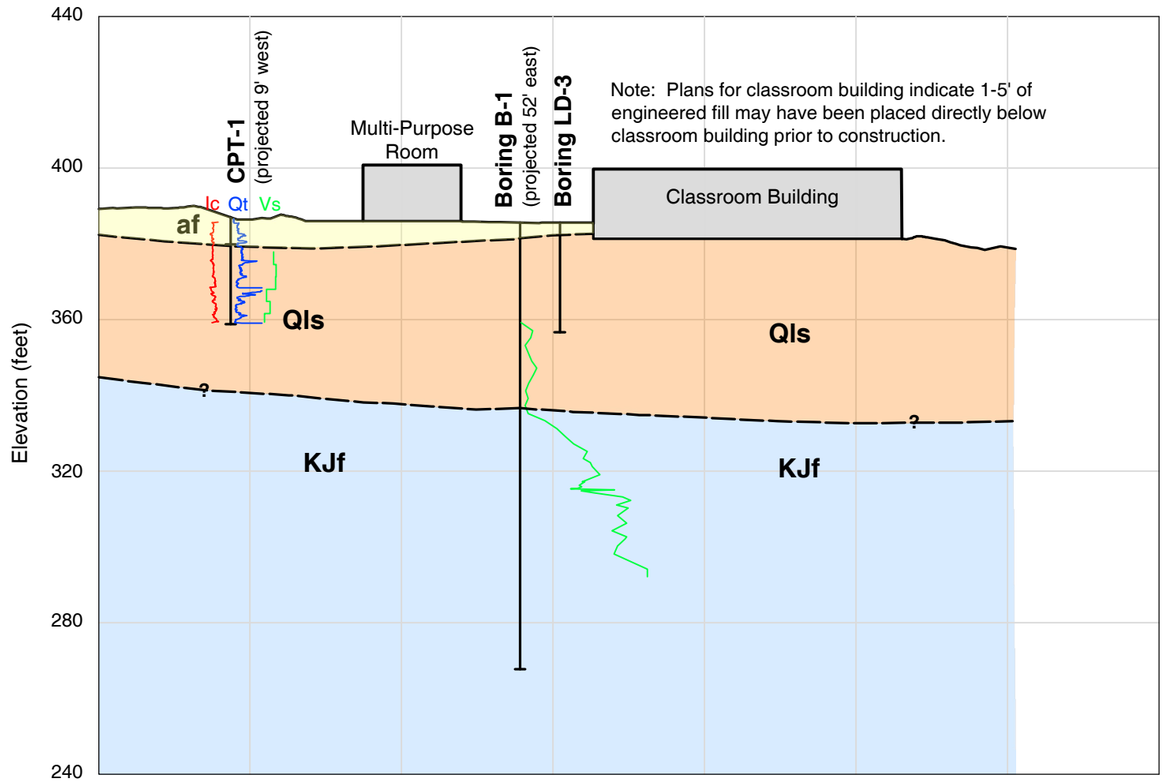
F
(North)

Cross Section A-A'

Cross Section B-B'

Cross Section C-C'

F'
(South)

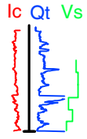


Base: This material is based on "Topographic Survey 1130 Oxford Elementary School," drawn by Sandis, dated 7/10/18. Note: Elevations have been adjusted +289'.

LEGEND

af	Artificial Fill
Qls	Landslide Debris
KJf	Franciscan Assemblage
⊥	Location and depth of boring

Ic Qt Vs



Ic - Soil Behavior Type Index, (unitless value)
Qt - Recorded Tip Resistance, (tsf)
Vs - Shear Wave Velocity (ft/sec)
(See details on Figure 18)

Original figure produced in color.

NOTES:
1. See Figure 3 for location of cross section.
2. Cross section represents idealized conditions based on limited subsurface data. Significant variations may be encountered during construction.
3. CPT data for graphical purposes only. See Appendix B for actual values.

20 0 40 80
APPROXIMATE HORIZONTAL SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

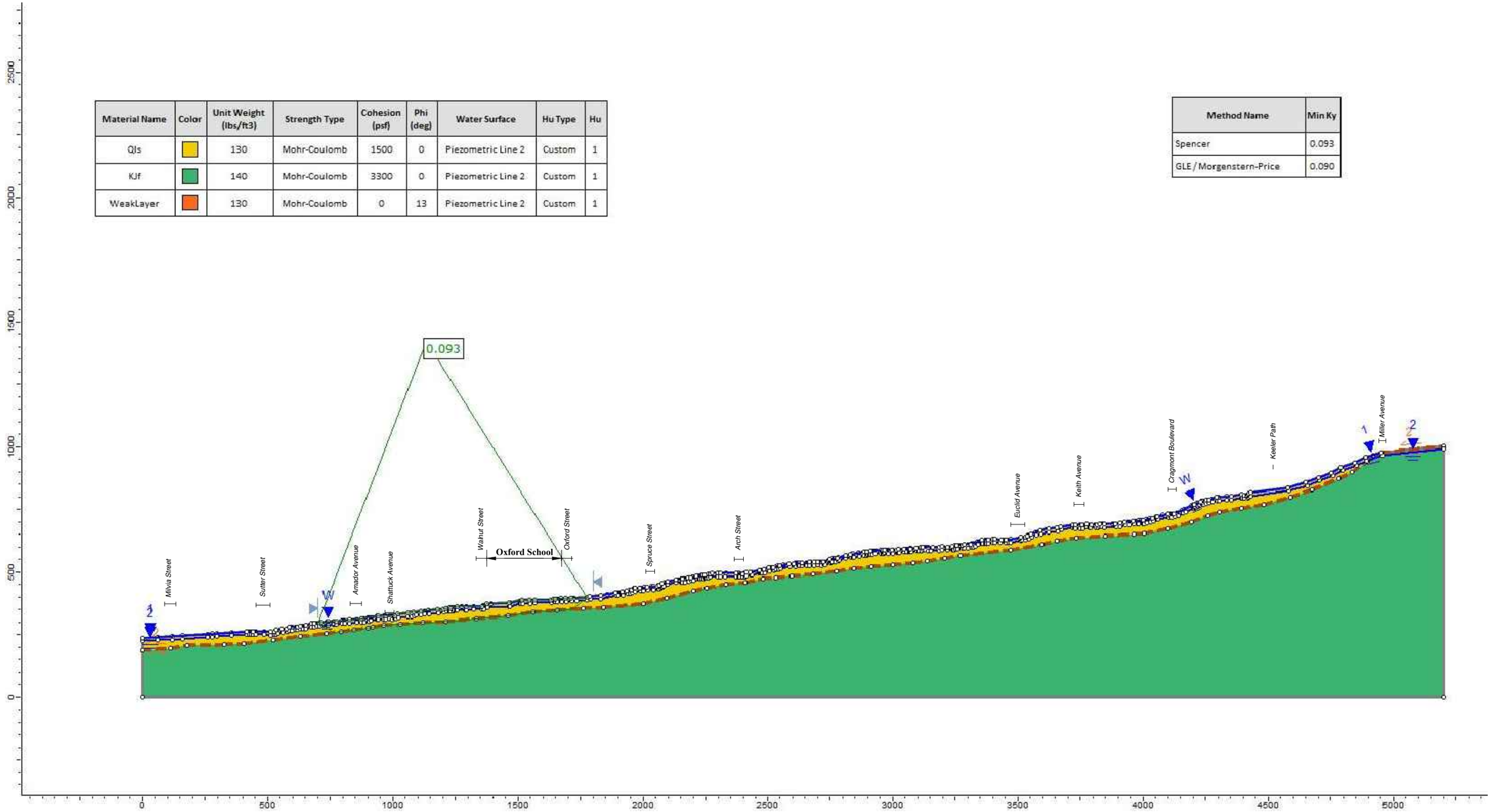
GEOLOGIC SECTION F-F'

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**25**

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Qls		130	Mohr-Coulomb	1500	0	Piezometric Line 2	Custom	1
Kjf		140	Mohr-Coulomb	3300	0	Piezometric Line 2	Custom	1
WeakLayer		130	Mohr-Coulomb	0	13	Piezometric Line 2	Custom	1

Method Name	Min Ky
Spencer	0.093
GLE / Morgenstern-Price	0.090



200 0 400 800
APPROXIMATE HORIZONTAL SCALE FEET

Original figure produced in color.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

SAMPLE SLOPE STABILITY CALCULATION

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**26**

APPENDIX A

LOGS OF BORINGS

SOIL CLASSIFICATION CHART

PRIMARY DIVISIONS			SECONDARY DIVISIONS		
			CRITERIA *	GROUP SYMBOL	GROUP NAME
COARSE-GRAINED SOILS (MORE THAN 50% RETAINED ON NO.200 SIEVE)	GRAVELS (MORE THAN 50% OF COARSE FRACTION RETAINED ON NO.4 SIEVE)	CLEAN GRAVELS (LESS THAN 5% FINES)	$Cu \geq 4$ AND $1 \leq Cc \leq 3$ [A]	GW	Well-graded gravel
			$Cu < 4$ AND/OR $1 > Cc > 3$	GP	Poorly-graded gravel
		GRAVELS WITH FINES - MORE THAN 12% FINES	FINES CLASSIFY AS ML OR MH	GM	Silty gravel
			FINES CLASSIFY AS CL OR CH	GC	Clayey gravel
	SANDS (50% OR MORE OF COARSE FRACTION PASSES NO. 4 SIEVE)	CLEAN SANDS (LESS THAN 5% FINES)	$Cu \geq 6$ AND $1 \leq Cc \leq 3$	SW	Well-graded sand
			$Cu < 6$ AND/OR $1 > Cc > 3$	SP	Poorly-graded sand
		SANDS WITH FINES - MORE THAN 12% FINES	FINES CLASSIFY AS ML OR MH	SM	Silty sand
			FINES CLASSIFY AS CL OR CH	SC	Clayey sand
FINE-GRAINED SOILS (50% OR MORE PASSES THE NO.200 SIEVE)	SILTS AND CLAYS (LIQUID LIMIT LESS THAN 50%)	INORGANIC	PI > 7 AND PLOTS ON OR ABOVE "A" LINE	CL	Lean clay
			PI < 4 OR PLOTS BELOW "A" LINE	ML	Silt
		ORGANIC	$\frac{\text{LIQUID LIMIT - OVEN DRIED}}{\text{LIQUID LIMIT - NOT DRIED}} < 0.75$	OL	Organic Clay & Organic Silt
	SILTS AND CLAYS (LIQUID LIMIT 50% OR MORE)	INORGANIC	PI PLOTS ON OR ABOVE "A" LINE	CH	Fat clay
			PI PLOTS BELOW "A" LINE	MH	Elastic silt
		ORGANIC	$\frac{\text{LIQUID LIMIT - OVEN DRIED}}{\text{LIQUID LIMIT - NOT DRIED}} < 0.75$	OH	Organic Clay & Organic Silt
	HIGHLY ORGANIC SOILS		PRIMARILY ORGANIC MATTER, DARK IN COLOR, AND ORGANIC ODOR	PT	Peat

REFERENCE: Unified Soil Classification System (ASTM D2487-11)

* Criteria may be done on visual basis, not necessarily based on lab testing

$A - C_u = D_{60}/D_{100}$ & $C_c = (D_{30})^2 / (D_{10} \times D_{60})$

GRAIN SIZES

U. S. STANDARD SERIES SIEVE				CLEAR SQUARE SIEVE OPENINGS			
200	40	10	4	3/4"	3"	12"	
SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

ABBREVIATIONS

INDEX TESTS

LL - Liquid Limit (%) (ASTM D4318-17)

PI - Plasticity Index (%) (ASTM D4318-17)

-200 - Passing No. 200 Sieve (%) (ASTM D1140-17)

STRENGTH TESTS

PP - Field Pocket Penetrometer test of unconfined compressive strength (tsf)

TV - Field Torvane test of shear strength (psf)

UC - Laboratory unconfined compressive strength (psf) (ASTM D2166/2166M-16)

TXUU - Laboratory unconsolidated, undrained triaxial test of undrained shear strength (psf) (ASTM D2850-15)

MISCELLANEOUS

ATOD - At time of drilling

psf/tsf - pounds per square foot / tons per square foot

psi - pounds per square inch (indicates relative force required to advance Shelby tube sampler)

SYMBOLS

Standard Penetration Test Split Spoon (2-inch O.D.)

Modified California Sampler (3-inch O.D.)

Thin-walled Sampler Tube (either Pitcher or Shelby) (3-inch O.D.)

Rock Core

Bag Sample

Groundwater Level during drilling

Groundwater Level after drilling

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

KEY TO EXPLORATORY BORING LOGS

OXFORD ELEMENTARY SCHOOL

Berkeley, California

PROJECT NO.	DATE	FIGURE
1853-3	**September 2019**	**A-1**

CONSOLIDATION OF SEDIMENTARY ROCKS; usually determined from unweathered samples. Largely dependent on cementation.

- **U** = unconsolidated
- **P** = poorly consolidated
- **M** = moderately consolidated
- **W** = well consolidated

BEDDING OF SEDIMENTARY ROCK

Splitting Property	Thickness	Stratification
Massive	Greater than 4.0 feet	Very thick-bedded
Blocky	2.0 to 4.0 feet	Thick-bedded
Slabby	0.2 to 2.0 feet	Thin-bedded
Flaggy	0.05 to 0.2 feet	Very thin-bedded
Shaly or platy	0.01 to 0.05 feet	Laminated
Papery	Less than 0.01 feet	Thinly laminated

FRACTURING

Intensity	Size of Pieces in Feet
Very little fractured	Greater than 4.0 feet
Occasionally fractured	1.0 to 4.0 feet
Moderately fractured	0.5 to 1.0 feet
Closely fractured	0.1 to 0.5 feet
Intensely fractured	0.05 to 0.1 feet
Crushed	Less than 0.05 feet

HARDNESS

1. **Soft** - Reserved for plastic material alone.
2. **Low Hardness** - Can be gouged deeply or carved easily by a knife blade.
3. **Moderately Hard** - Can be readily scratched by a knife blade; scratch leaves a heavy trace of dust and is readily visible after the powder has been blown away.
4. **Hard** - Can be scratched by a knife blade with difficulty; scratch produces little powder and is often faintly visible.
5. **Very Hard** - Cannot be scratched by a knife blade; leaves a metallic streak

STRENGTH

1. **Plastic -** Very low strength.
2. **Friable** - Crumbles easily by rubbing with fingers.
3. **Weak** - An unfractured specimen of such material will crumble under light hammer blows.
4. **Moderately Strong** - Specimen will withstand a few heavy hammer blows before breaking.
5. **Strong** -Specimen will withstand a few heavy ringing hammer blows and will yield with difficulty only dust and small flying fragments.
6. **Very Strong** -Specimen will resist heavy ringing hammer blows and will yield with difficulty only dust and small flying fragments.

WEATHERING - the physical and chemical disintegration and decomposition of rocks and minerals by natural processes such as oxidation, reduction, hydration, solution, carbonation, and freezing and thawing.

- **D. Deep** - Moderate to complete mineral decomposition; extensive disintegration; deep and thorough discoloration; many fractures, all extensively coated or filled with oxides, carbonates and/or clay or silt.
- **M. Moderate** - Slight change or partial decomposition of minerals; little disintegration; cementation little to unaffected. Moderate to occasionally intense discoloration. Moderately coated fractures.
- **L. Little** - No megascopic decomposition of minerals; little or no effect on normal cementation. Slight and intermittent, or localized discoloration. Few stains on fracture surfaces.
- **F. Fresh** - Unaffected by weathering agents. No disintegration or discoloration. Fractures usually less numerous than joints.

CONVENTIONAL SMALL DIAMETER BORINGS

DRILL RIG: CME Track-mounted	SURFACE ELEVATION: 383 feet +/- MSL	LOGGED BY: PB
DEPTH TO GROUNDWATER: Not Observed	BORING DIAMETER: 8, 3.5 inches	DATE DRILLED: 12/26/18

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
ASPHALT PAVEMENT - 2 1/2 inches AC									
SAND, Clayey - with fine to coarse-grained sand and fine to coarse gravel, red brick fragments (FILL)	Brown to Dark Brown	Dense	SC	1 2 3 4 5 6 7 8 9					LL = 40 PI = 22 -200 = 45%
FILL									
SAND, Clayey - fine to coarse-grained, chaotic, no visible layering, gravels are angular rock fragment of Franciscan Assemblage including greenstone, rhyolite, sandstone and shale (LANDSIDE DEBRIS)	Brown	Very Dense	SC	10 11 12 13 14					LL = 35 PI = 16 -200 = 25%
GRAVEL, Clayey, Sandy, Silty - chaotic, no visible layering, gravels are angular rock fragment of Franciscan Assemblage including greenstone, rhyolite, sandstone and shale (LANDSIDE DEBRIS) -mainly decomposed rock with some intermixed clay	Brown	Very Dense	GC	15 16 17 18 19					

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**1 of 6**	**1**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
GRAVEL, Clayey, Sandy, Silty - chaotic, no visible layering, gravels are angular rock fragment of Franciscan Assemblage including greenstone, rhyolite, sandstone and shale (LANDSIDE DEBRIS)	Brown	Very Dense	GC	21 22 23 24 25 26 27 28 29					LL = 34 PI = 13 -200 = 6%
CLAY, Lean, Sandy, Silty - mainly decomposed rock fragment (LANDSLIDE DEBRIS)	Brownish Gray	Very Stiff to Hard	CL	30 31 32					
CLAY, Lean, Sandy, Silty - with some serpentinite (LANDSLIDE DEBRIS) -polished parting with 30 degree dip in serpentinite -becomes wet to saturated -graded to mostly gravelly clay	Mainly Gray with Patches of Greenish Gray	Very Stiff to Hard	CL	33 34 35 36 37 38 39 40 41 42					LL = 35 PI = 19 -200 = 51%

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**2 of 6**	**1**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean, Sandy, Silty - with some serpentinite (LANDSLIDE DEBRIS)	Mainly Gray with Patches of Greenish Gray	Very Stiff to Hard	CL	43 44 45 46 47 48 49					
CLAY, Fat, Silty - high plasticity, wet (LANDSLIDE DEBRIS)	Dark Olive Gray	Very Stiff	CH	50 51 52 53 54		[40]			LL = 60 PI = 37 -200 = 61%
LANDSLIDE DEBRIS									
CLAY, Fat, Silty - with sand, high plasticity, fine-grained sand, some coarse-grained sand, trace fine gravel, moist	Black	Very Stiff	CH	55 56 57 58		[30] 21			PP = 2.3 tsf
SANDSTONE - low hardness, deeply weathered, closely fractured, some clayey streaks	Yellowish Brown with Mottled Bluish Gray	Weak to Friable Weak	BR	59 60 61 62		42 83			
SHALE - moderately hard, deeply weathered, intensely fractured, with quartz veins	Dark Gray to Black with Yellowish Brown	Weak	BR	63 64 65		50/5"			

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**3 of 6**	**1**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
SHALE - moderately hard, deeply weathered, intensely fractured, with quartz veins	Dark Gray to Black with Yellowish Brown	Weak	BR	66					
				67					
				68					
-with some intensely fractured zones				69		50/6"			
				70					
				71					
				72					
				73					
				74					
				75					
				76					
				77					
				78					
SANDSTONE - hard compacted, closely fractured	Black and Dark Gray	Moderately Strong	BR	79		50/3"			
				80					
				81					
				82					
				83					
				84					
				85					
				86					
				87					
				88					

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**4 of 6**	**1**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)			BR						
SANDSTONE and SHALE - hard, cemented, closely fractured, moderately weathered	Dark Gray	Moderately Strong	BR	89		50/3"			
				90					
				91					
				92					
				93					
				94					
				95					
				96					
				97					
				98					
SANDSTONE - hard, little weathering, intensely fractured, well-cemented sandstone with white quartz veins	Dark Gray with White	Strong	BR	99		50/1"			
				100					
				101					
				102					
				103					
				104					
				105					
				106					
				107					
				108					
	Dark Gray with White Veins			109		50/1"			
				110					
				111					

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**5 of 6**	**1**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
SANDSTONE - hard, little weathering, intensely fractured, well-cemented sandstone with white quartz veins	Dark Gray with White	Strong	BR	112 113 114 115 116 117 118					

Bottom of boring at 118.0 feet.

NOTES:

1. Groundwater was not observed at the time of drilling due to mud rotary drilling method and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were estimated from "Topographic Survey Map, Oxford School," drawn by Telamon Engineering Consultant, dated 5/28/97.
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**6 of 6**	**1**

DRILL RIG: CME Track-mounted	**SURFACE ELEVATION:** 383 feet +/- MSL	**LOGGED BY:** PB
DEPTH TO GROUNDWATER: 38 feet (see notes)	**BORING DIAMETER:** 8 inches	**DATE DRILLED:** 12/27/18

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
ASPHALT PAVEMENT - 2 1/2 inches AC over 4 inches aggregate base									
CLAY, Fat, Sandy, Silty - with gravel, fine to coarse-grained sand, with up to 25% angular fine-gravel, dry (FILL)	Dark Brown	Very Stiff	CH	1 2 3 4 5 6 7 8		[30]	17	96	LL = 51 PI = 30 -200 = 58% PP = 3.5 tsf
FILL				9					
CLAY, Lean, Sandy, Silty - with gravel, moderate plasticity, some silt, fine-grained sand, with 20% angular fine-gravel, dry (LANDSLIDE DEBRIS)	Brown	Stiff to Very Stiff	CL	10 11		15			PP = 2.5 tsf
		Stiff		12 13 14 15 16		[15]	23	103	LL = 44 PI = 24 -200 = 52% PP = 2.5 tsf
				17 18					
SAND, Silty - fine to coarse-grained, some clay, dry (LANDSLIDE DEBRIS)	Yellowish Brown Mottled with Olive Brown	Medium Dense	SM	19					

(Continued on Next Page)

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
SAND, Silty - fine to coarse-grained, some clay, dry (LANDSLIDE DEBRIS)	Yellowish Brown Mottled with Olive Brown	Medium Dense	SM	21		15			
				22					
				23					
				24					
SAND, Silty - fine to coarse-grained, with some very fine gravel, dry (LANDSLIDE DEBRIS)	Gray with Yellowish Brown	Medium Dense	SM	25					
				26		[40]	10	126	-200 = 33%
				27					
				28					
				29					
SAND, Silty - fine to medium-grained sand, trace fine gravel, dry (LANDSLIDE DEBRIS)	Dark Gray	Medium Dense	SM	30					
				31		23			
				32					
				33					
SAND, Clayey - moderate plasticity, very fine to medium-grained sand, with silt, moist to wet (LANDSLIDE DEBRIS)	Dark Gray	Medium Dense	SC	34					
				35					
				36		[19]	18	114	LL = 37 PI = 21 -200 = 44% TXCU = 1468 psf PP = 1.3 tsf
				37					
				38					▽
CLAY, Fat, Sandy - very fine to medium-grained sand, with silt, moist to wet (LANDSLIDE DEBRIS)	Dark Gray with Olive Gray Patches	Stiff	CH	39					
				40					
				41		14			PP = 1.5 tsf
				42					

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**2 of 4**	**2**

AKA BORING LOG 1853-3 BORING LOGS.GPJ AKA_TEMPLATE.GDT 9/10/19

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Fat, Sandy - very fine to medium-grained sand, with silt, moist to wet (LANDSLIDE DEBRIS)	Dark Gray with Olive Gray Patches	Stiff	CH	43 44 45 46 47 48 49		[24]	23	103	LL = 51 PI = 32 -200 = 69%
LANDSLIDE DEBRIS									
CLAYSTONE - friable to plastic, deeply weathered, wet	Dark Olive Gray	Moderately Strong	BR	50 51 52 53 54		21			
-becomes friable, intensely fractured, moist		Strong		55 56 57 58 59 60 61		[37] 30			PP = 3.7 tsf PP = 3.7 tsf

Bottom of boring at 61.5 feet.

NOTES:

1. Groundwater was encountered at approximately 38 feet at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**3 of 4**	**2**

AKA BORING LOG 1853-3 BORING LOGS.GPJ AKA_TEMPLATE.GDT 9/10/19

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									

sampler; these are not standard penetration resistance values.

4. Elevations were estimated from "Topographic Survey Map, Oxford School," drawn by Telamon Engineering Consultant, dated 5/28/97.

5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

DRILL RIG: CME Track-mounted	**SURFACE ELEVATION:** 397 feet +/- MSL	**LOGGED BY:** PB
DEPTH TO GROUNDWATER: Not Observed	**BORING DIAMETER:** 5-8 inches	**DATE DRILLED:** 12/28/18

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
ASPHALT PAVEMENT - 2 inches AC over 4 inches aggregate base **SAND, Clayey** - some silt, fine to medium-grained sand, trace coarse sand and fine gravel, dry (FILL) **FILL**	Yellowish Brown	Medium Dense	SC	1 2 3 4 5 6 7 8 9 10		[18]			
CLAY, Fat, Sandy, Silty - with gravel, includes smeared serpentinite, with apparent slicken sides (LANDSLIDE DEBRIS)		Very Stiff	CH	10 11 12			23	107	LL = 52 PI = 22 -200 = 68%
SAND, Silty - with gravel, fine to coarse-grained sand, some clay, intermixed very fine gravel fragments (LANDSLIDE DEBRIS)	Olive Gray	Medium Dense	SM	13		21			
CLAY, Fat, Silty - with sand and gravel, high plasticity, sticky, fine to coarse-grained sand, mixed fine gravel, moist (LANDSLIDE DEBRIS)	Olive Brown with Yellowish Brown Mottling	Very Stiff	CH	14 15 16			25	102	LL = 57 PI = 35 TXCU = 1411 psf
CLAY, Fat, Silty - with sand and gravel, fine to coarse-grained sand, abundant intermixed angular fine gravel fragments, serpentinite and rhyolite deeply weathered fragments, moist (LANDSLIDE DEBRIS)	Dark Gray with Light Olive Gray and Greenish Streaks	Stiff	CH	17 18 19		11			PP = 1.75 tsf

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**1 of 3**	**3**

AKA BORING LOG 1853-3 BORING LOGS.GPJ AKA_TEMPLATE.GDT 9/10/19

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Fat, Silty - with sand and gravel, fine to coarse-grained sand, abundant intermixed angular fine gravel fragments, serpentinite and rhyolite deeply weathered fragments, moist (LANDSLIDE DEBRIS)	Dark Gray with Light Olive Gray and Greenish Streaks	Stiff	CH	21			26	103	LL = 56 PI = 34 -200 = 74%
GRAVEL, Clayey - with sand, fine gravel angular hard and soft rock fragments, with variable clay and sand matrix, very moist to wet (LANDSLIDE DEBRIS)	Dark Gray with Light Olive Gray and Greenish Streaks	Dense	GC	22					
		Hard	CL	23		40			PP = 3.2 tsf
CLAY, Lean, Sandy, Silty - fine to coarse-grained sand, trace fine gravel, some serpentinite smears, moist (LANDSLIDE DEBRIS) **LANDSLIDE DEBRIS**	Dark Gray with Olive Gray Streaks			24					
SANDSTONE - fine to very coarse-grained sand, angular hard rock fragments up to fine-gravel, some clay, some cemented core fragments	Dark Gray	Friable	BR	25			7	131	LL = 43 PI = 26 -200 = 9% TXCU = 1161 psf
				26		50/3"			
				27					
				28					
GREENSTONE - moderate hardness, deeply weathered, closely to intensely fractured, with quartz veins	Olive Brown to Dark Green	Weak	BR	29					
				30		81			
				31					
				32					
				33					
RHYOLITE - low to moderate hardness, deeply weathered, intensely fractured, includes dark gray shale and greenstone fragments	Dark Olive Brown with Orange and Black Patches	Weak	BR	34		50/4"			
				35					
				36					
				37					
				38		50/6"			

Bottom of boring at 38.0 feet.

NOTES:

1. Groundwater was not observed at the time of drilling due to mud rotary drilling method and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**2 of 3**	**3**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									

4. Elevations were estimated from "Topographic Survey Map, Oxford School," drawn by Telamon Engineering Consultant, dated 5/28/97.

5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**3 of 3**	**3**

DRILL RIG: CME Track-mounted	**SURFACE ELEVATION:** 370 feet +/- MSL	**LOGGED BY:** PB
DEPTH TO GROUNDWATER: Not Observed	**BORING DIAMETER:** 5.5-6.5 inches	**DATE DRILLED:** 1/2/19

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
ASPHALT PAVEMENT - 2 1/2 inches AC over 3 1/2 inches aggregate base									
CLAY, Fat, Gravelly - high plasticity, with fine to medium-grained sand and silt, with scattered angular fine gravel, dry (FILL)	Brown	Stiff	CH	1					
				2					
				3					
				4					
				5					
				6		[13]			PP = >4.5 tsf
				7					
				8					
FILL				9					
GRAVEL, Clayey - with sand, moist (LANDSLIDE DEBRIS)	Light Brown	Medium Dense	GC	10					
				11					
				12					
-sampler driven on large, cobble-size or larger fragments/clast of rhyolite				13					
				14		13			
				15					
				16					
-highly oxidized, weathered, clayey, coarse-grained, sandy matrix	Yellowish to White			17			11	129	-200 = 21%
GRAVEL, Clayey - with sand, highly oxidized, stained, weathered, coarse-grained sandy matrix, moist to wet (LANDSLIDE DEBRIS)	Light Gray with White and Pink	Dense	GC	18					
				19		46			

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**1 of 3**	**4**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
GRAVEL, Clayey - with sand, highly oxidized, stained, weathered, coarse-grained sandy matrix, moist to wet (LANDSLIDE DEBRIS)	Light Gray with White and Pink	Dense	GC	21					
SAND, Coarse - with clay and gravel, fine to very coarse-grained sand, with rock fragments, angular, hard, moist to wet (LANDSLIDE DEBRIS)	Light Gray with Yellow and Rusty Brown	Very Dense	SM	22					
				23		50/5"			
				24					
				25					
				26		38			
		Dense		27					
				28			10	134	-200 = 27%
				29					
		Medium Dense to Dense		30					
SAND, Well-Graded - with clay, fine to very coarse-grained sand, some fine gravel, angular rock fragments, moist (LANDSLIDE DEBRIS)	Gray with Yellow-Orange and White Mottling	Medium Dense to Dense	SW/SC	31		30			
				32					
SAND, Clayey, Silty - fine to very coarse-grained sand, with angular rhyolite fragments, trace fine gravel (LANDSLIDE DEBRIS)	Light Brown with Rusty Orange Brown	Dense	SC	33					
				34					
				35		36			
				36					
				37					
GRAVEL, Clayey - with sand, angular fine gravel, rhyolite fragments in moderately plastic clay, moist (LANDSLIDE DEBRIS)	Dark Gray	Very Dense	GC	38					
				39					
GRAVEL, Well-Graded - with sand, gravels are rhyolite, trace clay (LANDSLIDE DEBRIS)	Dark Gray	Very Dense	GW	40		52			
				41					
				42					

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**2 of 3**	**4**

AKA BORING LOG 1853-3 BORING LOGS.GPJ AKA_TEMPLATE.GDT 9/10/19

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
	Dark Gray	Very Dense	GW	43					
				44					
SAND, Clayey - fine to very coarse-grained sand, some fine gravel, with angular fragments, moist (LANDSLIDE DEBRIS)	Gray with Pink and Green Streaks	Medium Dense	SC	45			19	115	-200 = 48%
LANDSLIDE DEBRIS				46					
SAND, Clayey - with fine to coarse-grained sand, with intermixed clayey sand, moist	Dark Gray	Medium Dense	SC	47		12			PP = 1.75 tsf
				48					
	Dark Olive Green	Very Dense					17	119	TXCU = 3324 psf -200 = 47%
SHALE - low to moderate hardness, shaly parings, moderately-weathered, closely fractured	Olive Brown	Weak to Moderately Strong	BR	49		[52]			
				50					
				51					
				52					
				53					
				54		[50/2"]			
						50/6"			

Bottom of boring at 54.7 feet.

NOTES:

1. Groundwater was not observed at the time of drilling due to mud rotary drilling method and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were estimated from "Topographic Survey Map, Oxford School," drawn by Telamon Engineering Consultant, dated 5/28/97.
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

DRILL RIG: CME Track-mounted	**SURFACE ELEVATION:** 364 feet +/- MSL	**LOGGED BY:** PB
DEPTH TO GROUNDWATER: Not Observed	**BORING DIAMETER:** 8 inches	**DATE DRILLED:** 1/2/19

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
ASPHALT PAVEMENT - 2 inches AC over 4 inches aggregate base									
SAND, Clayey, Silty - fine to medium-grained sand, with silt, trace fine gravel, dry (FILL)	Yellowish Brown	Medium Dense	SC	1 2 3 4 5					
FILL									
CLAY, Lean, Silty - with sand, moderate plasticity, some fine-grained sand and silt, with intermixed angular to subangular fine gravel, dry (LANDSLIDE DEBRIS)	Olive Brown	Stiff	CL	6 7 8 9		[19]	18	113	LL = 45 PI = 28 -200 = 73%
SAND, Clayey - moderate plasticity, fine-grained sand and silt, with ~40% fine to coarse gravel, mostly angular, dry (LANDSLIDE DEBRIS)	Dark Yellowish Brown with Olive Brown	Loose	SC	10 11 12		[10]	14	108	LL = 34 PI = 15 -200 = 24% TXCU = 2143 psf PP = 3.0 tsf
GRAVEL, Well-Graded - with sand, fine to very coarse gravel, up to >2.5" (larger than sampler) likely cobble-size, all angular to subangular, hard rhyolite and weathered greenstone rock fragments, with fine to coarse-grained sand, dry (LANDSLIDE DEBRIS)	Olive Brown with Yellowish Brown Patches	Medium Dense	GW	13 14 15 16 17 18 19		[25]	5		-200 = 4%

(Continued on Next Page)

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
GRAVEL, Well-Graded - with sand, fine to very coarse gravel, up to >2.5" (larger than sampler) likely cobble-size, all angular to subangular, hard rhyolite and weathered greenstone rock fragments, with fine to coarse-grained sand, dry (LANDSLIDE DEBRIS)	Olive Brown with Yellowish Brown Patches Yellowish Brown to Olive Brown	Medium Dense	GW	21		[23]			
				22					
				23					
				24					
	Dark Yellowish Olive Brown			25					
				26		[18]	12	112	
				27					
				28					
				29					
	Dark Yellowish Brown with Olive Gray Patches			30					
				31		[44]	7	118	
				32					
				33					
				34					
-with fine gravel, dry	Yellowish Brown with Rusty Brown	Dense		35					
				36		50/4"			
				37					
				38					
SAND, Clayey - some fine gravel, angular rock fragments, fine-grained sand with silt (LANDSLIDE DEBRIS)	Dark Gray to Black	Medium Dense	SC	39					
				40					
				41			5		LL = 30 PI = 15 -200 = 18%
				42		21			

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**2 of 3**	**5**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)				43		35			
Bottom of boring at 43.0 feet.									

NOTES:

1. Groundwater was not observed at the time of drilling due to mud rotary drilling method and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were estimated from "Topographic Survey Map, Oxford School," drawn by Telamon Engineering Consultant, dated 5/28/97.
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**3 of 3**	**5**

LARGE DIAMETER BORINGS

DRILL RIG: Bucket Auger	**SURFACE ELEVATION:** 369 feet +/- MSL	**LOGGED BY:** JJ
DEPTH TO GROUNDWATER: 60 feet (see notes)	**BORING DIAMETER:** 30 inches	**DATE DRILLED:** 12/27/18

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
ASPHALT PAVEMENT - 2 inches AC over 4 inches aggregate base									
SILT, Sandy, Clayey - with numerous rock fragments, moist (FILL)	Mottled Brown to Olive Brown	Hard	ML	1					
FILL				2					
				3					
				4					
				5					
				6					
				7					
				8					
CLAY, Fat, Silty - with numerous rock fragments, wet (LANDSLIDE DEBRIS)	Dark Brownish Gray	Very Stiff	CH	9					
				10					
				11					
				12					
CLAY, Lean, Silty - with rock fragments, wet (LANDSLIDE DEBRIS)	Olive Brown to Greenish Gray	Very Stiff to Stiff	CL	13					
-substantial seepage from rocky zones				14					
				15					
				16					
				17					
				18					
				19					

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**1 of 4**	**LD-1**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean, Silty - with rock fragments, wet (LANDSLIDE DEBRIS) -moderate seepage	Olive Brown to Greenish Gray	Very Stiff to Stiff	CL	21 22 23 24 25 26 27					
SERPENTINITE - clay with some intermixed rock fragments, wet (LANDSLIDE DEBRIS) -slide plane, 1/2" seam greenish gray clay, with polished parting, wet	Greenish Gray to Rusty Brown	Plastic	BR	28 29 30					
SERPENTINITE - with occasional rounded pebbles, intensely fractured, wet (LANDSLIDE DEBRIS)	Greenish Gray to Rusty Brown	Plastic to Friable	BR	31 32 33 34 35 36 37 38 39 40					
SERPENTINITE - moderately weathered, closely to intensely fractured, wet (LANDSLIDE DEBRIS) -with occasional seams of greenish gray	Olive Brown with some Rusty Brown and Greenish Gray Patches	Friable	BR	41 42					

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**2 of 4**	**LD-1**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
clay, tight with diffuse shears dipping north at approximately 80 degrees **SERPENTINITE** - moderately weathered, closely to intensely fractured, wet (LANDSLIDE DEBRIS)	Olive Brown with some Rusty Brown and Greenish Gray Patches	Friable	BR	43 44 45					
SERPENTINITE - consisting of mainly clay, tight, ultramafic rock fragments, wet (LANDSLIDE DEBRIS) -6" zone of pale greenish gray clay within serpentinite **LANDSLIDE DEBRIS**	Greenish Gray to Rusty Brown	Plastic to Friable	BR	46 47 48 49 50 51 52 53 54					
SERPENTINITE - tight with zones of very stiff to hard greenish gray clay, moderately weathered, intensely fractured, wet	Gray and Green	Plastic to Friable	BR	55 56 57					
SILTSTONE, Clayey - tight, moderately weathered, wet	Brown	Friable to Weak	BR	58 59 60 61					▽
Bottom of boring at 62.0 feet.				62					

NOTES:

1. Groundwater was encountered at approximately 60 feet at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**3 of 4**	**LD-1**

AKA BORING LOG 1853-3 BORING LOGS.GPJ AKA_TEMPLATE.GDT 9/10/19

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									

3. Elevations were estimated from "Topographic Survey Map, Oxford School," drawn by Telamon Engineering Consultant, dated 5/28/97.

DRILL RIG: Bucket Auger	SURFACE ELEVATION: 370 feet +/- MSL	LOGGED BY: JJ
DEPTH TO GROUNDWATER: 40 feet (see notes)	BORING DIAMETER: 30 inches	DATE DRILLED: 12/28/18

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
ASPHALT PAVEMENT - 3 inches AC									
CLAY, Lean, Silty - wet (FILL) **FILL**	Brown	Stiff							
CLAY, Sandy, Silty - with few rock fragments, wet (LANDSLIDE DEBRIS)	Reddish Brown	Very Stiff	CL	1 2 3 4 5					
CLAY, Sandy, Gravelly - seepage, with angular 2-3" diameter, wet (LANDSLIDE DEBRIS) -with patches of black clay and streaks of black organics -with zones of light rusty brown silty clay -shear zone with polished parting	Olive Brown to Rusty Brown Gray with Intermixed Rusty Brown	Very Stiff	CL	6 7 8 9 10 11 12 13 14					
CLAY, Silty, Sandy - with included rock fragments, moist (LANDSLIDE DEBRIS)	Medium Gray	Hard	CL	15 16 17 18 19					

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG
OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**1 of 3**	**LD-2**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Silty, Sandy - with included rock fragments, moist (LANDSLIDE DEBRIS)	Medium Gray	Very Stiff to Hard	CL						
-becomes tight, moist to wet				21					
				22					
				23					
				24					
				25					
-with inclusions of serpentinite rock fragments, serpentinite inclusions becoming abundant	Greenish Gray			26					
				27					
				28					
-shear zone, few rock inclusions, several polished partings along clay seams ranging from subhorizontal to N20W60NE probable slide plane		Stiff to Very Stiff		29					
LANDSLIDE DEBRIS				30					
SERPENTINITE - with scattered pebbles, irregular subhorizontal no visible shearing, serpentinite and ultramafic inclusions in a matrix of greenish gray to black silty clay		Friable	BR	31					
				32					
-occasional subrounded pebbles				33					
				34					
GREENSTONE - closely fractured, strong, tight, saturated with strong seepage with few discontinuous clay seams and clay filled fractures	Dark Gray	Moderately Strong	BR	35					
				36					
-tight, articulated little or no clay matrix, slight seepage with light and orange quartz veins				37					
				38					
-hole caving				39					
-moderate seepage				40					▽
				41					
				42					

(Continued on Next Page)

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
GREENSTONE - closely fractured, strong, tight, saturated with strong seepage with few discontinuous clay seams and clay filled fractures	Dark Gray	Moderately Strong	BR	43 44 45 46 47 48 49 50					

Bottom of boring at 50.0 feet.

NOTES:

1. Groundwater was encountered at approximately 40 feet at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Elevations were estimated from "Topographic Survey Map, Oxford School," drawn by Telamon Engineering Consultant, dated 5/28/97.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**3 of 3**	**LD-2**

DRILL RIG: Bucket Auger	**SURFACE ELEVATION:** 385 feet +/- MSL	**LOGGED BY:** JJ
DEPTH TO GROUNDWATER: 19.5 feet (see notes)	**BORING DIAMETER:** 30 inches	**DATE DRILLED:** 12/29/18

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
ASPHALT PAVEMENT - 2 1/2 inches AC over 2 inches aggregate base									
CLAY, Lean, Gravelly, Sandy, Silty - with horizontal stratification (FILL) **FILL**	Grayish Brown to Black	Very Stiff	CL	1					
CLAY, Lean, Silty - with gravels, wet (LANDSLIDE DEBRIS)	Reddish Brown	Very Stiff	CL	2					
				3					
				4					
				5					
	Olive Brown			6					
				7					
				8					
				9					
				10					
				11					
CLAY, Sandy, Silty - occasional gravels, with some intermixed serpentinite fragments, wet (LANDSLIDE DEBRIS)	Olive Brown	Stiff to Very Stiff	CL	12					
-shear zone				13					
				14					
				15					
-slide plane at contact with rhyolite boulder orientation N55E21NW, 1.5" very stiff clay with polished parting along the contact, very sharp contact		Very Stiff		16					
RHYOLITE - strong, moderately fractured (LANDSLIDE DEBRIS)	Light Yellowish Brown	Strong	BR	17					
				18					
				19					▽

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

OXFORD ELEMENTARY SCHOOL
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1853-3	**September 2019**	**1 of 2**	**LD-3**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
RHYOLITE - strong, moderately fractured (LANDSLIDE DEBRIS) -heavy seepage enters at 20', rhyolite becomes occasional fractured, strong -extensive caving below 20', very hard drilling in rhyolite boulder, heavy seepage	Light Yellowish Brown	Friable to Weak	BR	21 22 23					
-not logged below water line and collapsed zone				24 25 26 27					
-bucket advanced before caving				28					
Bottom of boring at 28.0 feet.									

NOTES:

1. Groundwater was encountered at approximately 60 feet at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Elevations were estimated from "Topographic Survey Map, Oxford School," drawn by Telamon Engineering Consultant, dated 5/28/97.

APPENDIX B

CONE PENETROMETER TESTING:

(CPT) REPORT
CONETEC INVESTIGATIONS, LTD.

PRESENTATION OF SITE INVESTIGATION RESULTS

Oxford School

Prepared for:

Alan Kropp & Associates

CPT Inc. Job No: 18-56216

Project Start Date: 29-Dec-2018
Project End Date: 29-Dec-2018
Report Date: 02-Jan-2019

Prepared by:

California Push Technologies Inc.
820 Aladdin Avenue
San Leandro, CA 94577

Tel: (510) 357-3677

Email: cpt@cptinc.com
www.cptinc.com

Introduction

The enclosed report presents the results of the site investigation program conducted by CPT Inc. for Alan Kropp & Associates at Oxford Elementary School, Berkeley, CA. The program consisted of 3 seismic cone penetration tests (SCPT).

Project Information

Project	
Client	Alan Kropp & Associates
Project	Oxford School
CPT Inc. project number	18-56216

A map from Google Earth including the SCPT test locations is presented below.

Rig Description	Deployment System	Test Type
CPT truck rig (C17)	30 ton rig cylinder	SCPT

Coordinates		
Test Type	Collection Method	EPSG Reference
SCPT	Consumer Grade GPS	32610

Cone Penetration Test (CPT)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Tip and sleeve data offset	0.1 meter This has been accounted for in the CPT data files.
Additional plots	Standard CPT Plots with Expanded Scales, Advanced Plots, Soil Behavior Type (SBT) Scatter Plots, and Seismic Shear Wave (Vs) Plots are included in the release files.

Cone Penetrometers Used for this Project						
Cone Description	Cone Number	Cross Sectional Area (cm^2)	Sleeve Area (cm^2)	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (psi)
448:T1500F15U500	448	15	225	1500	15	500
Cone 448 was used for all SCPT soundings.						

CPT Calculated Parameters	
Additional information	The Normalized Soil Behavior Type Chart based on Q_{tn} (SBT Qtn) (Robertson, 2009) was used to classify the soil for this project. A detailed set of calculated CPT parameters have been generated and are provided in Excel format files in the release folder. The CPT parameter calculations are based on values of corrected tip resistance (q_t) sleeve friction (f_s), and pore pressure (u_2). Effective stresses are calculated based on unit weights that have been assigned to the individual soil behavior type zones and the assumed equilibrium pore pressure profile. Soils were classified as either drained or undrained based on the Q_{tn} Normalized Soil Behavior Type Chart (Robertson, 2009). Calculations for both drained and undrained parameters were included for materials that classified as silt mixtures (zone 4).

Limitations

This report has been prepared for the exclusive use of Alan Kropp & Associates (Client) for the project titled “Oxford School”. The report’s contents may not be relied upon by any other party without the express written permission of CPT Inc. CPT Inc. has provided site investigation services, prepared the factual data reporting, and provided geotechnical parameter calculations consistent with current best practices. No other warranty, expressed or implied, is made.

The information presented in the report document and the accompanying data set pertain to the specific project, site conditions and objectives described to CPT Inc. by the Client. In order to properly understand the factual data, assumptions and calculations, reference must be made to the documents provided and their accompanying data sets, in their entirety.

Cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd., a subsidiary of ConeTec.

ConeTec's piezocone penetrometers are compression type designs in which the tip and friction sleeve load cells are independent and have separate load capacities. The piezocones use strain gauged load cells for tip and sleeve friction and a strain gauged diaphragm type transducer for recording pore pressure. The piezocones also have a platinum resistive temperature device (RTD) for monitoring the temperature of the sensors, an accelerometer type dual axis inclinometer and a geophone sensor for recording seismic signals. All signals are amplified down hole within the cone body and the analog signals are sent to the surface through a shielded cable.

ConeTec penetrometers are manufactured with various tip, friction and pore pressure capacities in both 10 cm^2 and 15 cm^2 tip base area configurations in order to maximize signal resolution for various soil conditions. The specific piezocone used for each test is described in the CPT summary table presented in the first appendix. The 15 cm^2 penetrometers do not require friction reducers as they have a diameter larger than the deployment rods. The 10 cm^2 piezocones use a friction reducer consisting of a rod adapter extension behind the main cone body with an enlarged cross sectional area (typically 44 mm diameter over a length of 32 mm with tapered leading and trailing edges) located at a distance of 585 mm above the cone tip.

The penetrometers are designed with equal end area friction sleeves, a net end area ratio of 0.8 and cone tips with a 60 degree apex angle.

All ConeTec piezocones can record pore pressure at various locations. Unless otherwise noted, the pore pressure filter is located directly behind the cone tip in the "u_2" position (ASTM Type 2). The filter is 6 mm thick, made of porous plastic (polyethylene) having an average pore size of 125 microns (90-160 microns). The function of the filter is to allow rapid movements of extremely small volumes of water needed to activate the pressure transducer while preventing soil ingress or blockage.

The piezocone penetrometers are manufactured with dimensions, tolerances and sensor characteristics that are in general accordance with the current ASTM D5778 standard. ConeTec's calibration criteria also meet or exceed those of the current ASTM D5778 standard. An illustration of the piezocone penetrometer is presented in Figure CPTu.

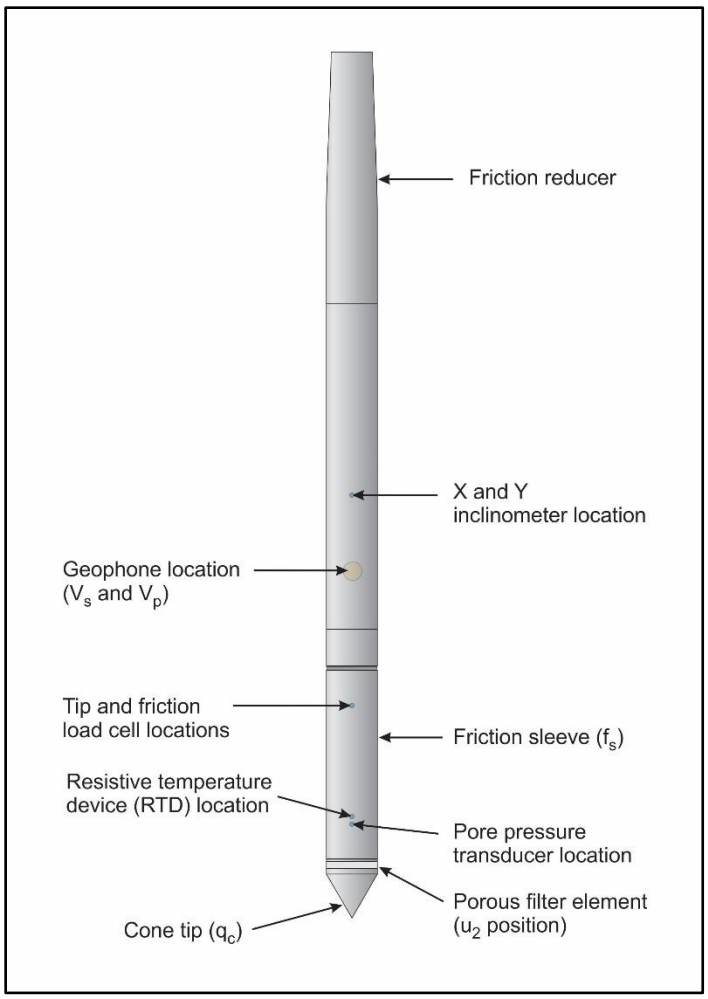


Figure CPTu. Piezocone Penetrometer (15 cm^2)

The ConeTec data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a 16 bit (or greater) analog to digital (A/D) converter. The data is recorded at fixed depth increments using a depth wheel attached to the push cylinders or by using a spring loaded rubber depth wheel that is held against the cone rods.

The typical recording interval is 2.5 cm; custom recording intervals are possible. The system displays the CPTu data in real time and records the following parameters to a storage media during penetration:

- Depth
- Uncorrected tip resistance (q_c)
- Sleeve friction (f_s)
- Dynamic pore pressure (u)
- Additional sensors such as resistivity, passive gamma, ultra violet induced fluorescence, if applicable

All testing is performed in accordance to ConeTec's CPT operating procedures which are in general accordance with the current ASTM D5778 standard.

Prior to the start of a CPTu sounding a suitable cone is selected, the cone and data acquisition system are powered on, the pore pressure system is saturated with either glycerin or silicone oil and the baseline readings are recorded with the cone hanging freely in a vertical position.

The CPTu is conducted at a steady rate of 2 cm/s, within acceptable tolerances. Typically one meter length rods with an outer diameter of 1.5 inches are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to ConeTec's cone penetration testing procedures:

- Each filter is saturated in silicone oil under vacuum pressure prior to use
- Recorded baselines are checked with an independent multi-meter
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards

The interpretation of piezocone data for this report is based on the corrected tip resistance (q_t), sleeve friction (f_s) and pore water pressure (u). The interpretation of soil type is based on the correlations developed by Robertson et al. (1986) and Robertson (1990, 2009). It should be noted that it is not always possible to accurately identify a soil behavior based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behavior type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al. (1986):

$$q_t = q_c + (1\text{-}a) \bullet u_2$$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the piezocone (0.8 for ConeTec probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all ConeTec piezocones have equal end area friction sleeves, pore pressure corrections to the sleeve data are not required.

The dynamic pore pressure (u) is a measure of the pore pressures generated during cone penetration. To record equilibrium pore pressure, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this occurs is predominantly a function of the permeability of the soil and the diameter of the cone.

The friction ratio (Rf) is a calculated parameter. It is defined as the ratio of sleeve friction to the tip resistance expressed as a percentage. Generally, saturated cohesive soils have low tip resistance, high friction ratios and generate large excess pore water pressures. Cohesionless soils have higher tip resistances, lower friction ratios and do not generate significant excess pore water pressure.

A summary of the CPTu soundings along with test details and individual plots are provided in the appendices. A set of files with calculated geotechnical parameters were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the methods used is also included in the data release folder.

For additional information on CPTu interpretations and calculated geotechnical parameters, refer to Robertson et al. (1986), Lunne et al. (1997), Robertson (2009), Mayne (2013, 2014) and Mayne and Peuchen (2012).

Shear wave velocity (Vs) testing is performed in conjunction with the piezocone penetration test (SCPTu) in order to collect interval velocities. For some projects seismic compression wave velocity (Vp) testing is also performed.

ConeTec's piezocone penetrometers are manufactured with a horizontally active geophone (28 hertz) that is rigidly mounted in the body of the cone penetrometer, 0.2 meters behind the cone tip.

Shear waves are typically generated by using an impact hammer horizontally striking a beam that is held in place by a normal load. In some instances an auger source or an imbedded impulsive source maybe used for both shear waves and compression waves. The hammer and beam act as a contact trigger that initiates the recording of the seismic wave traces. For impulsive devices an accelerometer trigger may be used. The traces are recorded using an up-hole integrated digital oscilloscope which is part of the SCPTu data acquisition system. An illustration of the shear wave testing configuration is presented in Figure SCPTu-1.

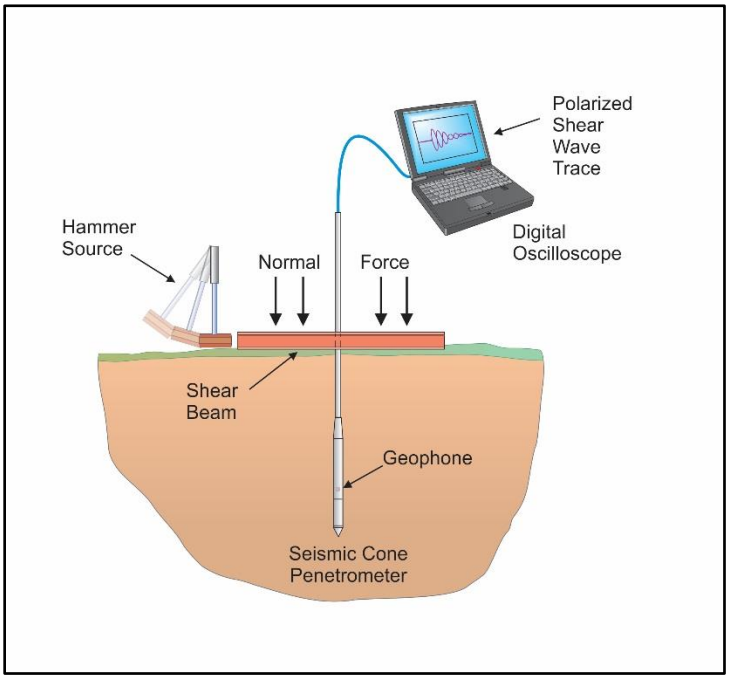


Figure SCPTu-1. Illustration of the SCPTu system

All testing is performed in accordance to ConeTec's SCPTu operating procedures which are in general accordance with the current ASTM 5778 and ASTM D7400 standards.

Prior to the start of a SCPTu sounding, the procedures described in the Cone Penetration Test section are followed. In addition, the active axis of the geophone is aligned parallel to the beam (or source) and the horizontal offset between the cone and the source is measured and recorded.

Prior to recording seismic waves at each test depth, cone penetration is stopped and the rods are decoupled from the rig to avoid transmission of rig energy down the rods. Typically, five wave traces for each orientation are recorded for quality control purposes and uncertainty analysis. After reviewing wave traces for consistency the cone is pushed to the next test depth (typically one meter intervals or as requested by the client). Figure SCPTu-2 presents an illustration of a SCPTu test.

For additional information on seismic cone penetration testing refer to Robertson et. al. (1986).

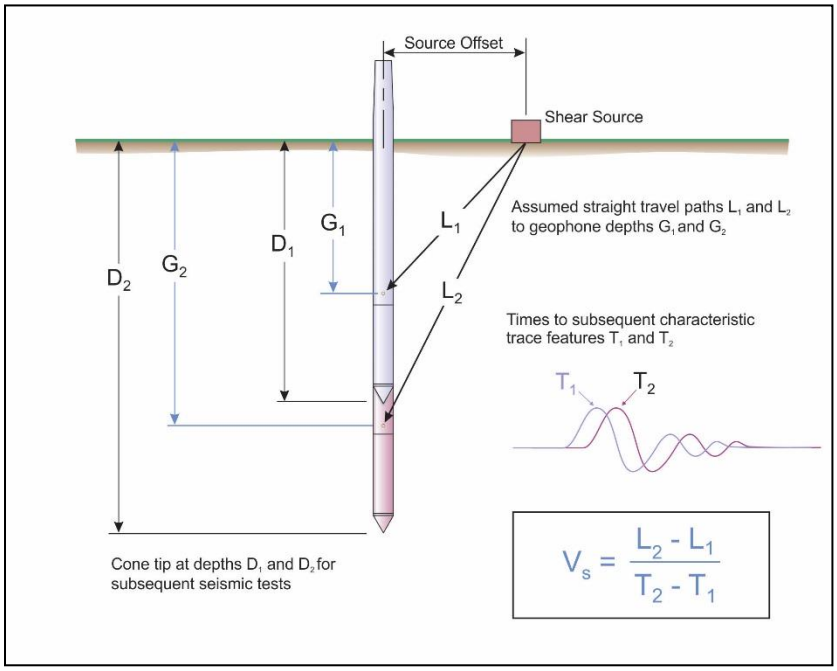


Figure SCPTu-2. Illustration of a seismic cone penetration test

Calculation of the interval velocities are performed by visually picking a common feature (e.g. the first characteristic peak, trough, or crossover) on all of the recorded wave sets and taking the difference in ray path divided by the time difference between subsequent features. Ray path is defined as the straight line distance from the seismic source to the geophone, accounting for beam offset, source depth and geophone offset from the cone tip.

The average shear wave velocity to a depth of 100 feet (30 meters) ($\bar{v}_s$) has been calculated and provided for all applicable soundings using the following equation presented in ASCE (2010).

$$\bar{v}_s = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{v_{si}}}$$

where: $\bar{v}_s$ = average shear wave velocity ft/s (m/s)
d_i = the thickness of any layer between 0 and 100 ft (30 m)
v_{si} = the shear wave velocity in ft/s (m/s)
$\sum_{i=1}^{n} d_i$ = 100 ft (30 m)

Average shear wave velocity, $\bar{v}_s$ is also referenced to V_{s100} or V_{s30}.

The layer travel times refers to the travel times propagating in the vertical direction, not the measured travel times from an offset source.

Tabular results and SCPTu plots are presented in the relevant appendix.

The cone penetration test is halted at specific depths to carry out pore pressure dissipation (PPD) tests, shown in Figure PPD-1. For each dissipation test the cone and rods are decoupled from the rig and the data acquisition system measures and records the variation of the pore pressure (u) with time (t).

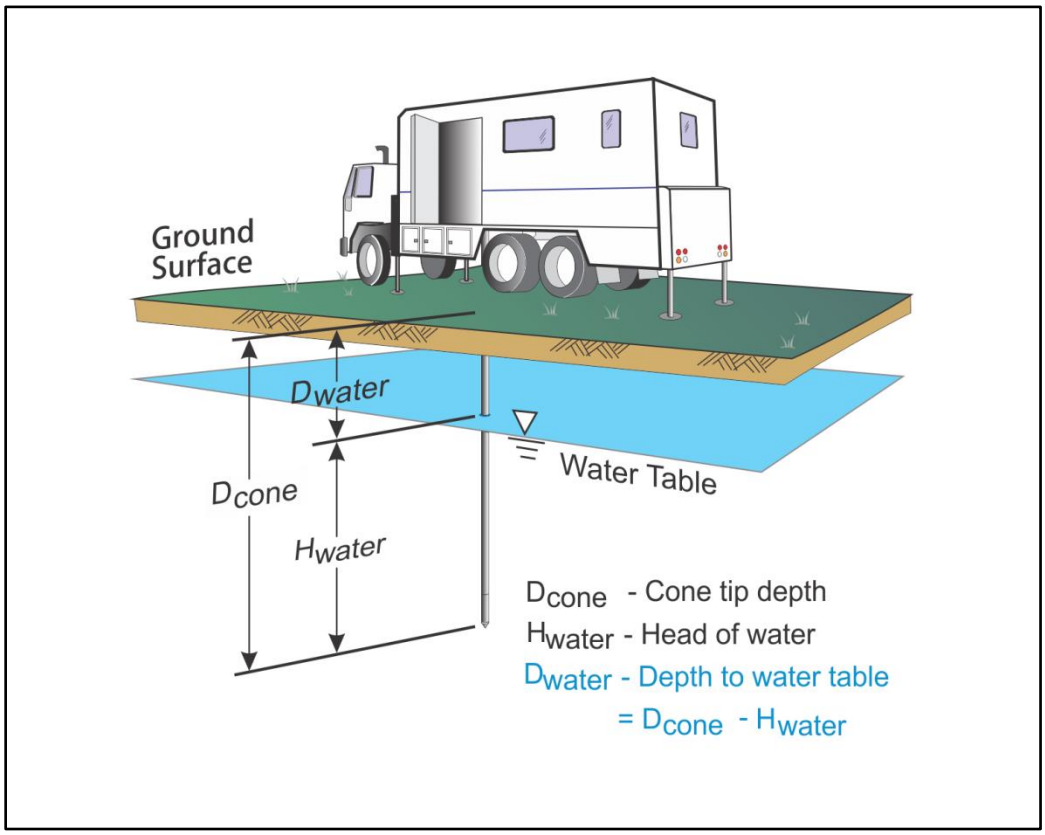


Figure PPD-1. Pore pressure dissipation test setup

Pore pressure dissipation data can be interpreted to provide estimates of ground water conditions, permeability, consolidation characteristics and soil behavior.

The typical shapes of dissipation curves shown in Figure PPD-2 are very useful in assessing soil type, drainage, in situ pore pressure and soil properties. A flat curve that stabilizes quickly is typical of a freely draining sand. Undrained soils such as clays will typically show positive excess pore pressure and have long dissipation times. Dilative soils will often exhibit dynamic pore pressures below equilibrium that then rise over time. Overconsolidated fine-grained soils will often exhibit an initial dilatory response where there is an initial rise in pore pressure before reaching a peak and dissipating.

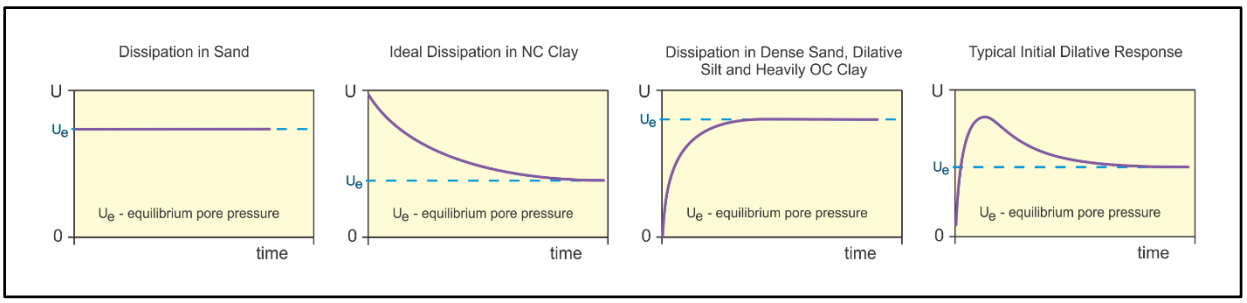


Figure PPD-2. Pore pressure dissipation curve examples

In order to interpret the equilibrium pore pressure (u_{eq}) and the apparent phreatic surface, the pore pressure should be monitored until such time as there is no variation in pore pressure with time as shown for each curve in Figure PPD-2.

In fine grained deposits the point at which 100% of the excess pore pressure has dissipated is known as t_{100}. In some cases this can take an excessive amount of time and it may be impractical to take the dissipation to t_{100}. A theoretical analysis of pore pressure dissipations by Teh and Houlsby (1991) showed that a single curve relating degree of dissipation versus theoretical time factor (T*) may be used to calculate the coefficient of consolidation (c_h) at various degrees of dissipation resulting in the expression for c_h shown below.

$$c_h = \frac{T^* \cdot a^2 \cdot \sqrt{I_r}}{t}$$

Where:

T* is the dimensionless time factor (Table Time Factor)
a is the radius of the cone
I_r is the rigidity index
t is the time at the degree of consolidation

Table Time Factor. T* versus degree of dissipation (Teh and Houlsby (1991))

Degree of Dissipation (%)	20	30	40	50	60	70	80
T* (u_2)	0.038	0.078	0.142	0.245	0.439	0.804	1.60

The coefficient of consolidation is typically analyzed using the time (t_{50}) corresponding to a degree of dissipation of 50% (u_{50}). In order to determine t_{50}, dissipation tests must be taken to a pressure less than u_{50}. The u_{50} value is half way between the initial maximum pore pressure and the equilibrium pore pressure value, known as u_{100}. To estimate u_{50}, both the initial maximum pore pressure and u_{100} must be known or estimated. Other degrees of dissipations may be considered, particularly for extremely long dissipations.

At any specific degree of dissipation the equilibrium pore pressure (u at t_{100}) must be estimated at the depth of interest. The equilibrium value may be determined from one or more sources such as measuring the value directly (u_{100}), estimating it from other dissipations in the same profile, estimating the phreatic surface and assuming hydrostatic conditions, from nearby soundings, from client provided information, from site observations and/or past experience, or from other site instrumentation.

For calculations of c_h (Teh and Houlsby (1991)), t_{50} values are estimated from the corresponding pore pressure dissipation curve and a rigidity index (I_r) is assumed. For curves having an initial dilatory response in which an initial rise in pore pressure occurs before reaching a peak, the relative time from the peak value is used in determining t_{50}. In cases where the time to peak is excessive, t_{50} values are not calculated.

Due to possible inherent uncertainties in estimating I_r, the equilibrium pore pressure and the effect of an initial dilatory response on calculating t_{50}, other methods should be applied to confirm the results for c_h.

Additional published methods for estimating the coefficient of consolidation from a piezocone test are described in Burns and Mayne (1998, 2002), Jones and Van Zyl (1981), Robertson et al. (1992) and Sully et al. (1999).

A summary of the pore pressure dissipation tests and dissipation plots are presented in the relevant appendix.

American Society of Civil Engineers (ASCE), 2010, “Minimum Design Loads for Buildings and Other Structures”, Standard ASCE/SEI 7-10, American Society of Civil Engineers, ISBN 978-0-7844-1085-1, Reston, Virginia.

ASTM D5778-12, 2012, "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils", ASTM, West Conshohocken, US.

ASTM D7400-14, 2014, "Standard Test Methods for Downhole Seismic Testing", ASTM, West Conshohocken, US.

Burns, S.E. and Mayne, P.W., 1998, “Monotonic and dilatory pore pressure decay during piezocone tests”, Canadian Geotechnical Journal 26 (4): 1063-1073.

Burns, S.E. and Mayne, P.W., 2002, “Analytical cavity expansion-critical state model cone dissipation in fine-grained soils”, Soils & Foundations, Vol. 42(2): 131-137.

Jones, G.A. and Van Zyl, D.J.A., 1981, “The piezometer probe: a useful investigation tool”, Proceedings, 10th International Conference on Soil Mechanics and Foundation Engineering, Vol. 3, Stockholm: 489-495.

Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, “Cone Penetration Testing in Geotechnical Practice”, Blackie Academic and Professional.

Mayne, P.W., 2013, “Evaluating yield stress of soils from laboratory consolidation and in-situ cone penetration tests”, Sound Geotechnical Research to Practice (Holtz Volume) GSP 230, ASCE, Reston/VA: 406-420.

Mayne, P.W., 2014, “Interpretation of geotechnical parameters from seismic piezocone tests”, CPT’14 Keynote Address, Las Vegas, NV, May 2014.

Mayne, P.W. and Peuchen, J., 2012, “Unit weight trends with cone resistance in soft to firm clays”, Geotechnical and Geophysical Site Characterization *4,* Vol. 1 (Proc. ISC-4, Pernambuco), CRC Press, London: 903-910.

Robertson, P.K., 1990, “Soil Classification Using the Cone Penetration Test”, Canadian Geotechnical Journal, Volume 27: 151-158.

Robertson, P.K., 2009, “Interpretation of cone penetration tests – a unified approach”, Canadian Geotechnical Journal, Volume 46: 1337-1355.

Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, “Use of Piezometer Cone Data”, Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.

Robertson, P.K., Campanella, R.G., Gillespie D and Rice, A., 1986, “Seismic CPT to Measure In-Situ Shear Wave Velocity”, Journal of Geotechnical Engineering ASCE, Vol. 112, No. 8: 791-803.

Robertson, P.K., Sully, J.P., Woeller, D.J., Lunne, T., Powell, J.J.M. and Gillespie, D.G., 1992, “Estimating coefficient of consolidation from piezocone tests”, Canadian Geotechnical Journal, 29(4): 551-557.

Sully, J.P., Robertson, P.K., Campanella, R.G. and Woeller, D.J., 1999, “An approach to evaluation of field CPTU dissipation data in overconsolidated fine-grained soils”, Canadian Geotechnical Journal, 36(2): 369-381.

Teh, C.I., and Houlsby, G.T., 1991, “An analytical study of the cone penetration test in clay”, Geotechnique, 41(1): 17-34.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Standard Cone Penetration Test Plots with Expanded Scales
- Advanced Cone Penetration Test Plots with Ic, Su(Nkt), Phi and N1(60)Ic
- Soil Behavior Type (SBT) Scatter Plots
- Seismic Cone Penetration Test Plots
- Seismic Cone Penetration Test Tabular Results
- Seismic Cone Penetration Test Shear Wave (Vs) Traces
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

Cone Penetration Test Summary and Standard Cone Penetration Test Plots

CONETEC

Job No:	18-56216
Client:	Alan Kropp & Associates
Project:	Oxford School
Start Date:	29-Dec-2019
End Date:	29-Dec-2019

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface[1] (ft)	Final Depth (ft)	Northing[2] (m)	Easting (m)	Refer to Notation Number
SCPT-01	18-56216_SP01	29-Dec-2018	448:T1500F15U500		27.64	4193606	564315	3
SCPT-02	18-56216_SP02	29-Dec-2018	448:T1500F15U500	9.3	47.49	4193550	564305	4
SCPT-03	18-56216_SP03	29-Dec-2018	448:T1500F15U500	9.3	44.87	4193572	564290	

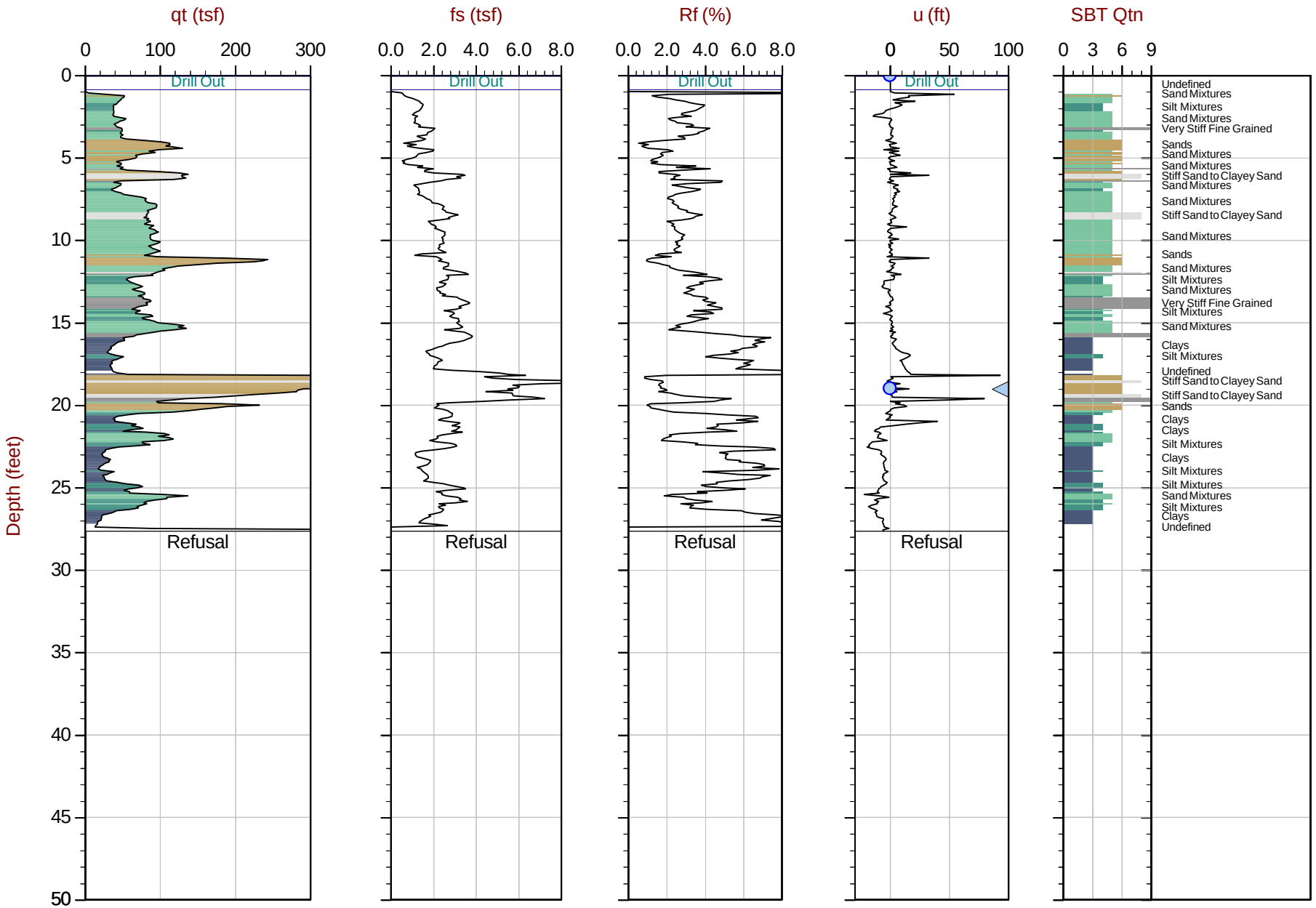
1. The assumed phreatic surface was based on pore pressure dissipation tests unless otherwise noted. Hydrostatic conditions were assumed for the calculated parameters.
2. Coordinates were collected with a consumer grade GPS device with datum WGS84/UTM Zone 10 North.
3. No clear phreatic surface detected.
4. The assumed phreatic surface was based on an adjacent SCPT.

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 08:43
Site: Oxford School

Sounding: SCPT-01
Cone: 448:T1500F15U500



Max Depth: 8.425 m / 27.64 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP01.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193606m E: 564315m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

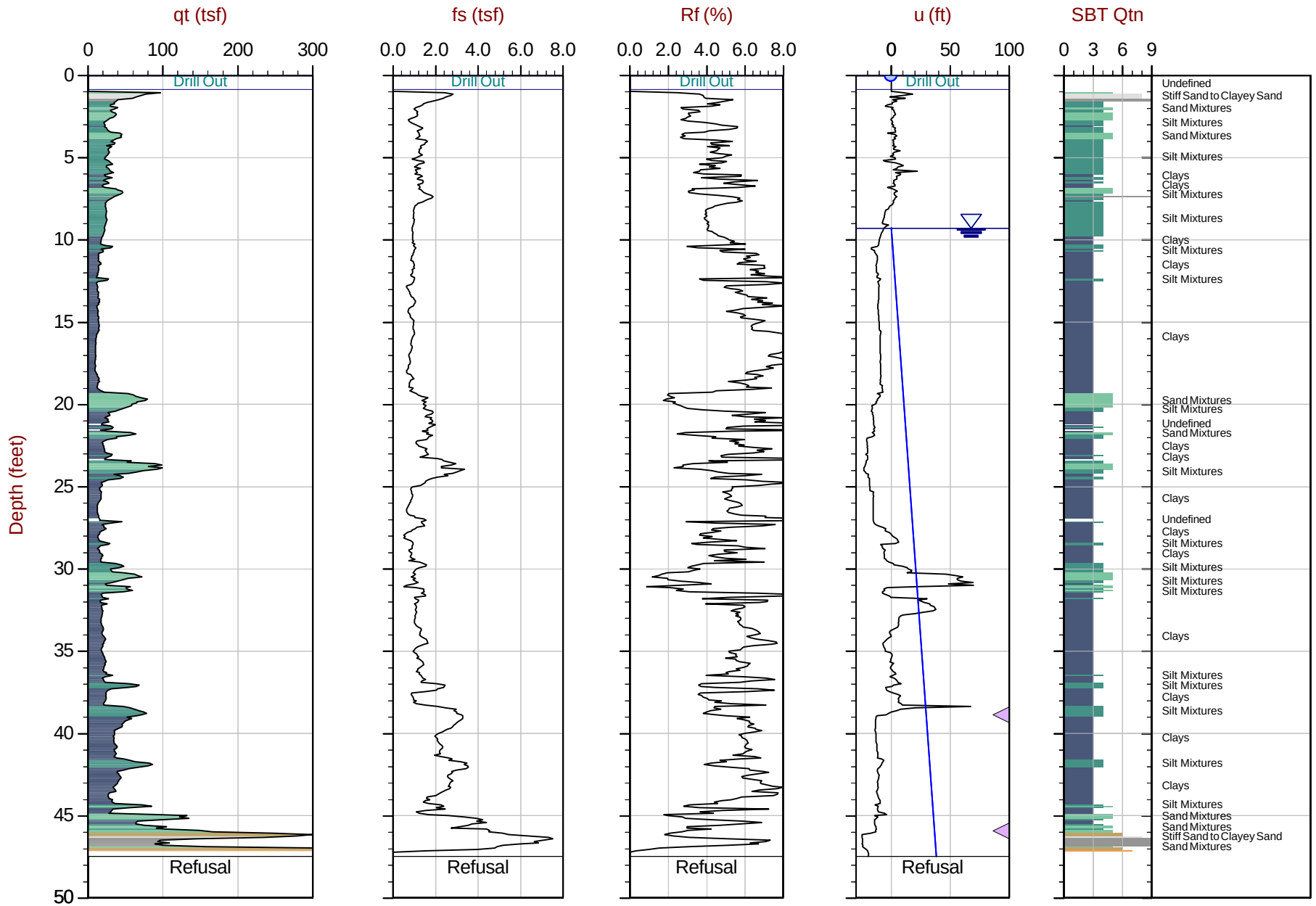
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 10:19
Site: Oxford School

Sounding: SCPT-02
Cone: 448:T1500F15U500



Max Depth: 14.475 m / 47.49 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP02.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193550m E: 564305m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

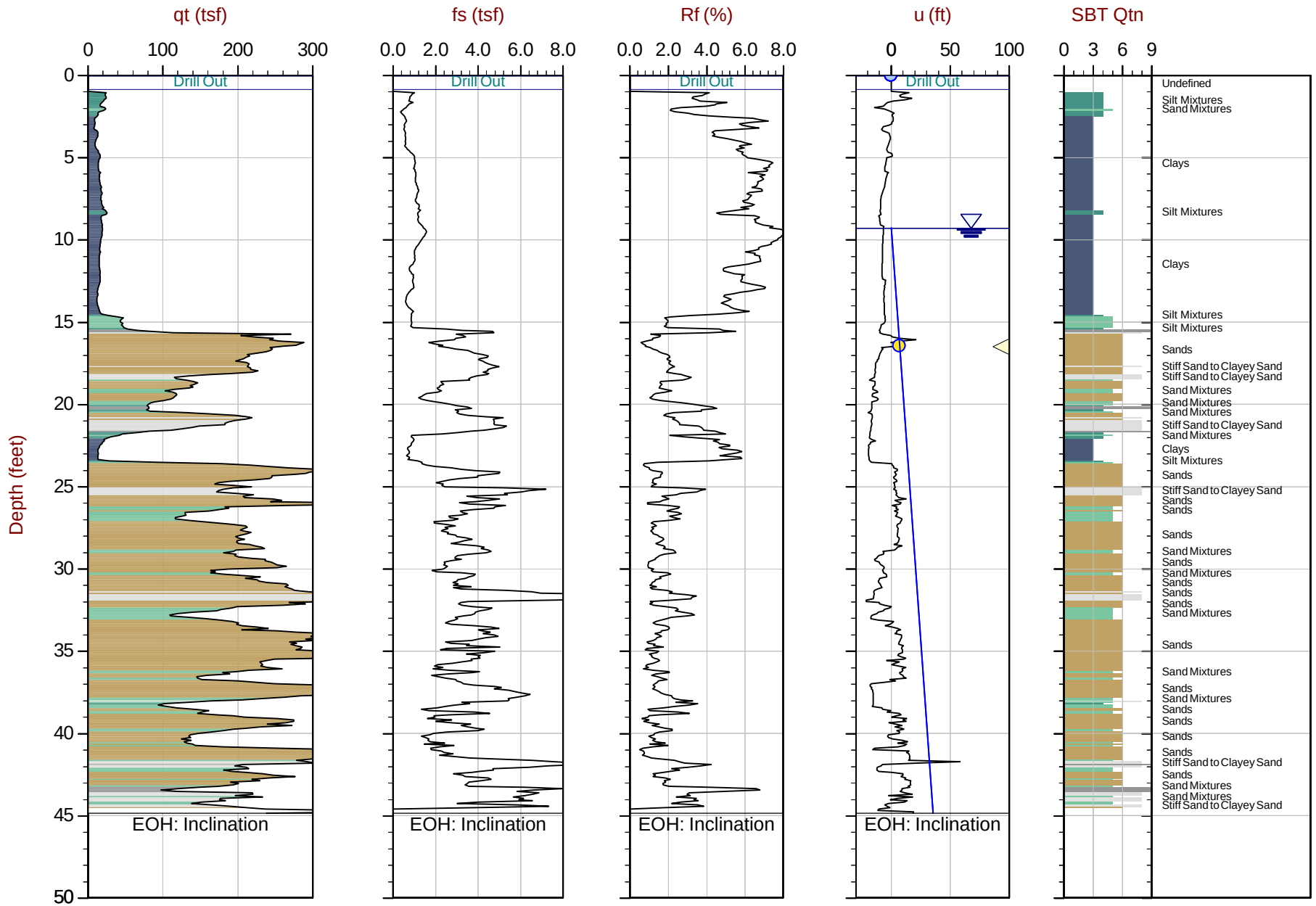
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 11:47
Site: Oxford School

Sounding: SCPT-03
Cone: 448:T1500F15U500



Max Depth: 13.675 m / 44.86 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP03.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193572m E: 564290m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Standard Cone Penetration Test Plots with Expanded Scales

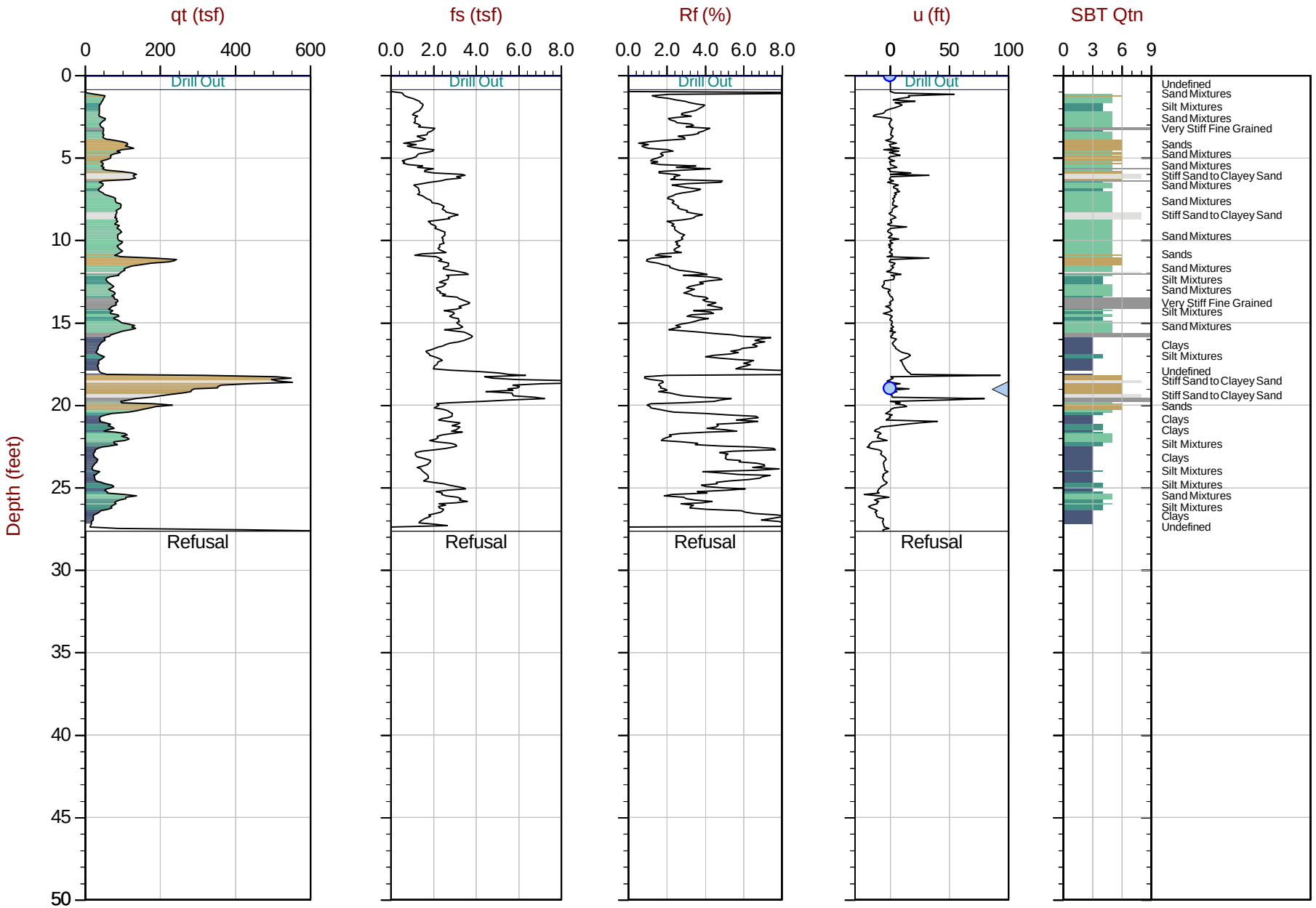
CONETEC

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 08:43
Site: Oxford School

Sounding: SCPT-01
Cone: 448:T1500F15U500



Max Depth: 8.425 m / 27.64 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP01.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193606m E: 564315m
Sheet No: 1 of 1

Overplot Item: Ueq | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

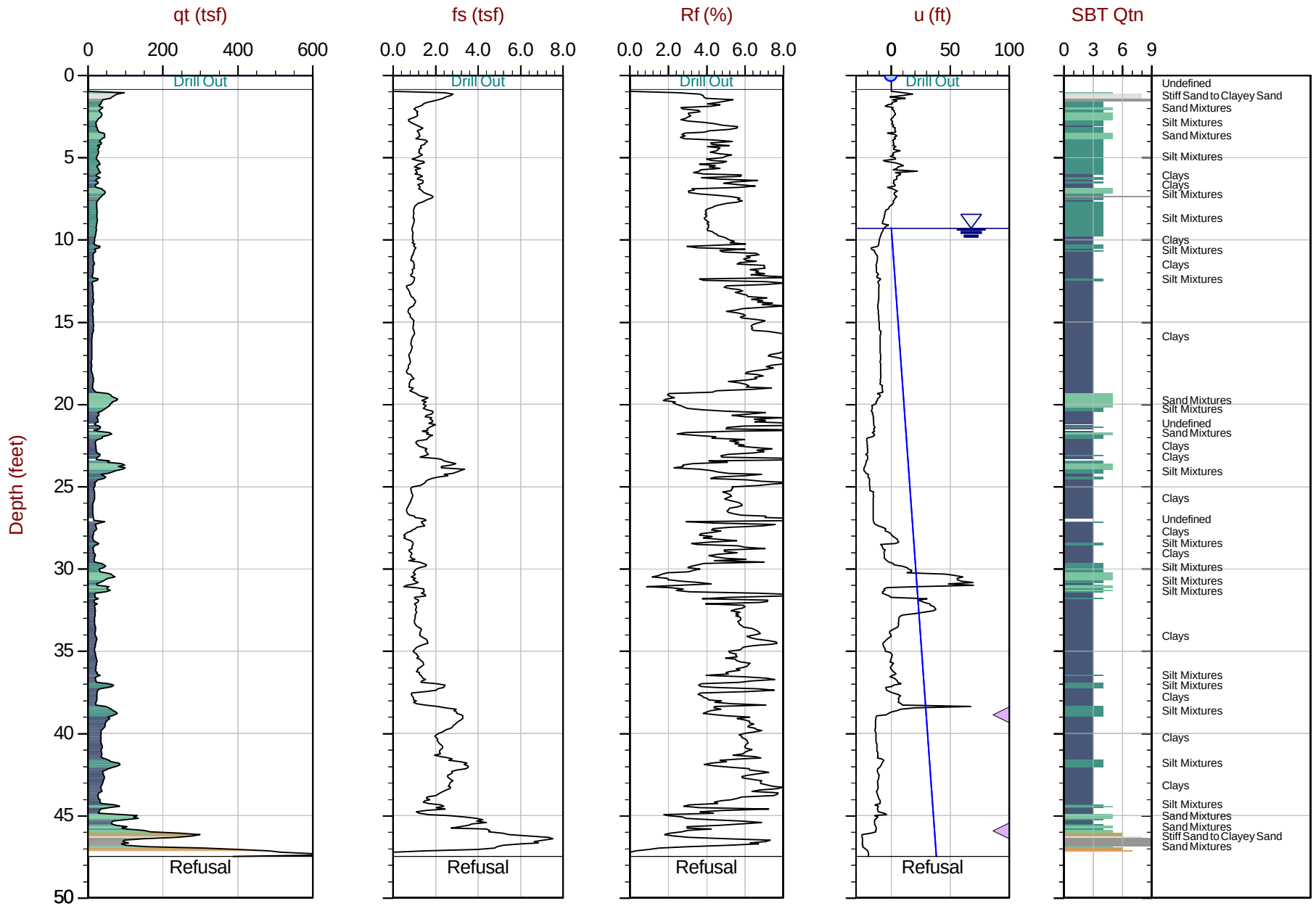
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 10:19
Site: Oxford School

Sounding: SCPT-02
Cone: 448:T1500F15U500



Max Depth: 14.475 m / 47.49 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP02.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193550m E: 564305m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

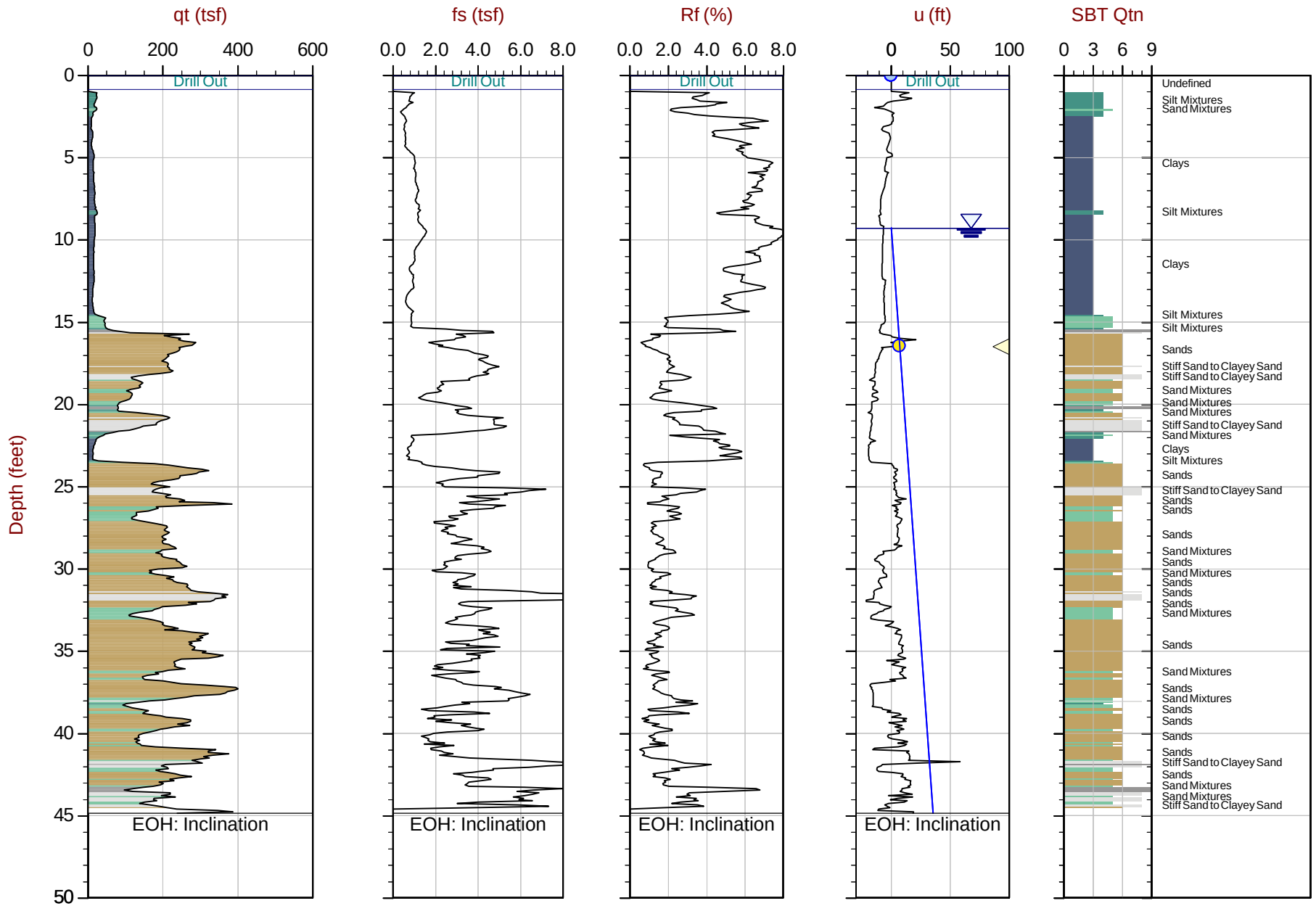
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 11:47
Site: Oxford School

Sounding: SCPT-03
Cone: 448:T1500F15U500



Max Depth: 13.675 m / 44.86 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP03.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193572m E: 564290m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Advanced Cone Penetration Test Plots with Ic, Su(Nkt), Phi and N1(60)Ic

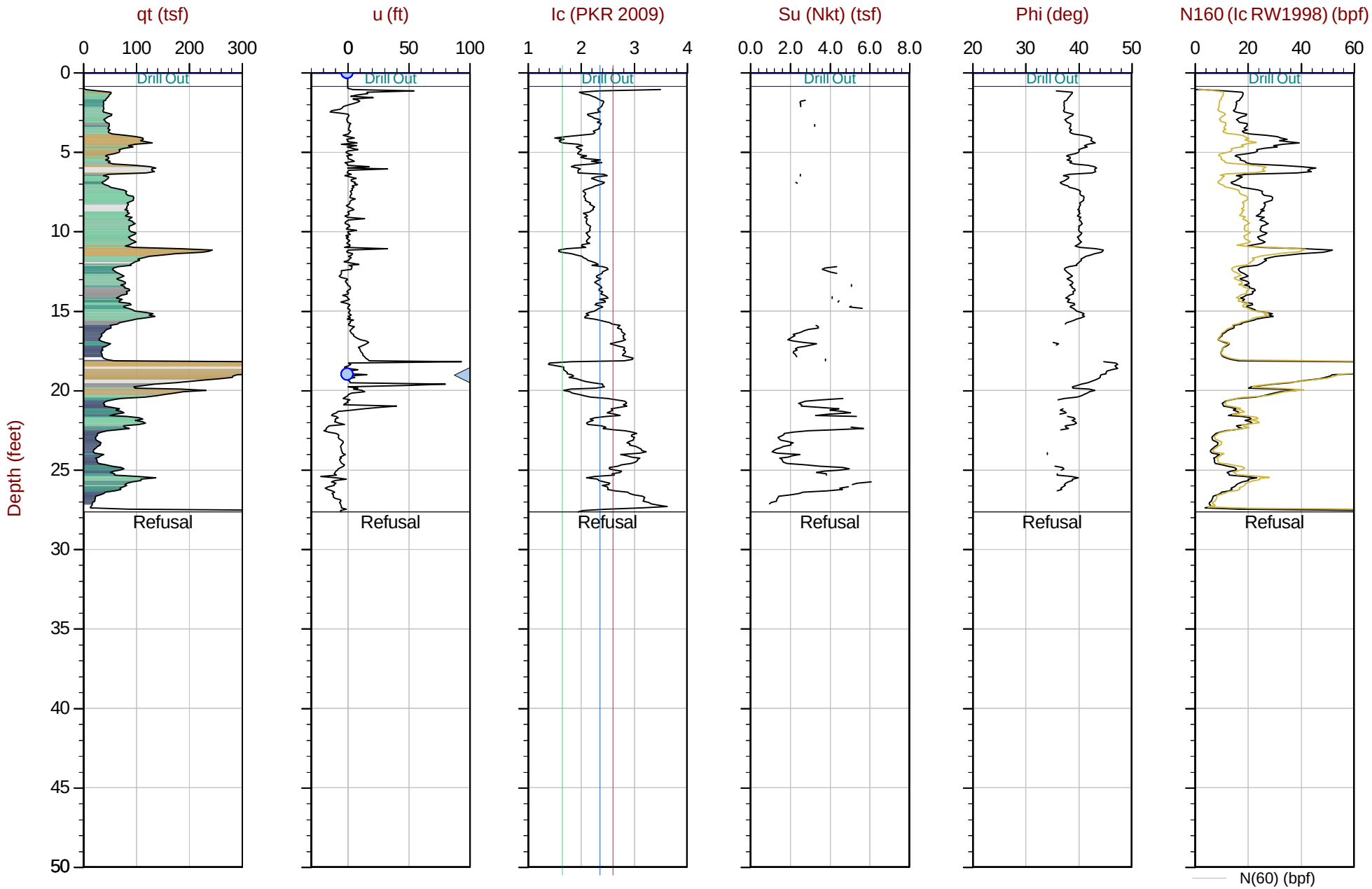
CONETEC

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 08:43
Site: Oxford School

Sounding: SCPT-01
Cone: 448:T1500F15U500



Max Depth: 8.425 m / 27.64 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP01.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193606m E: 564315m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

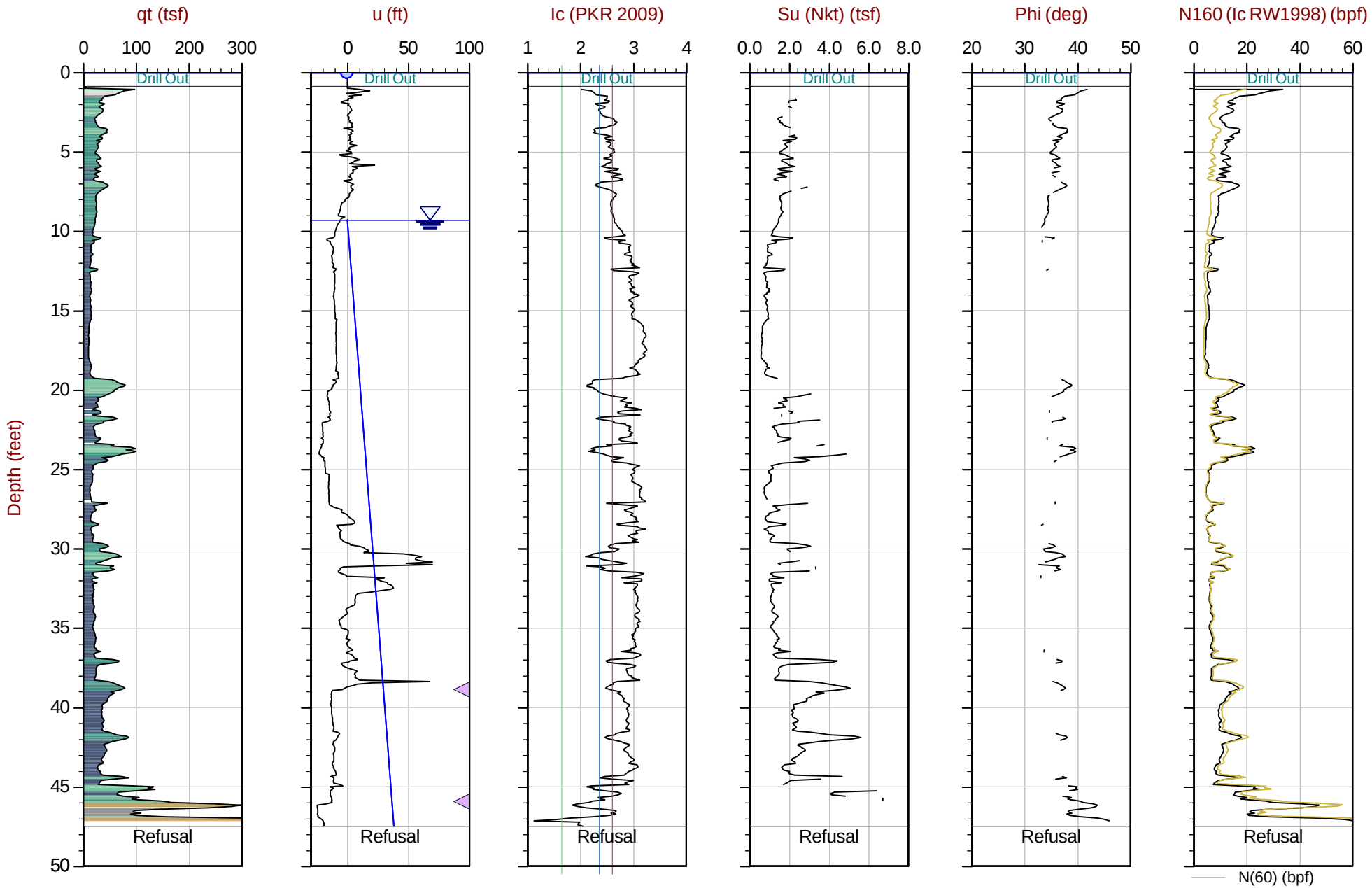
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 10:19
Site: Oxford School

Sounding: SCPT-02
Cone: 448:T1500F15U500



Max Depth: 14.475 m / 47.49 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP02.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193550m E: 564305m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

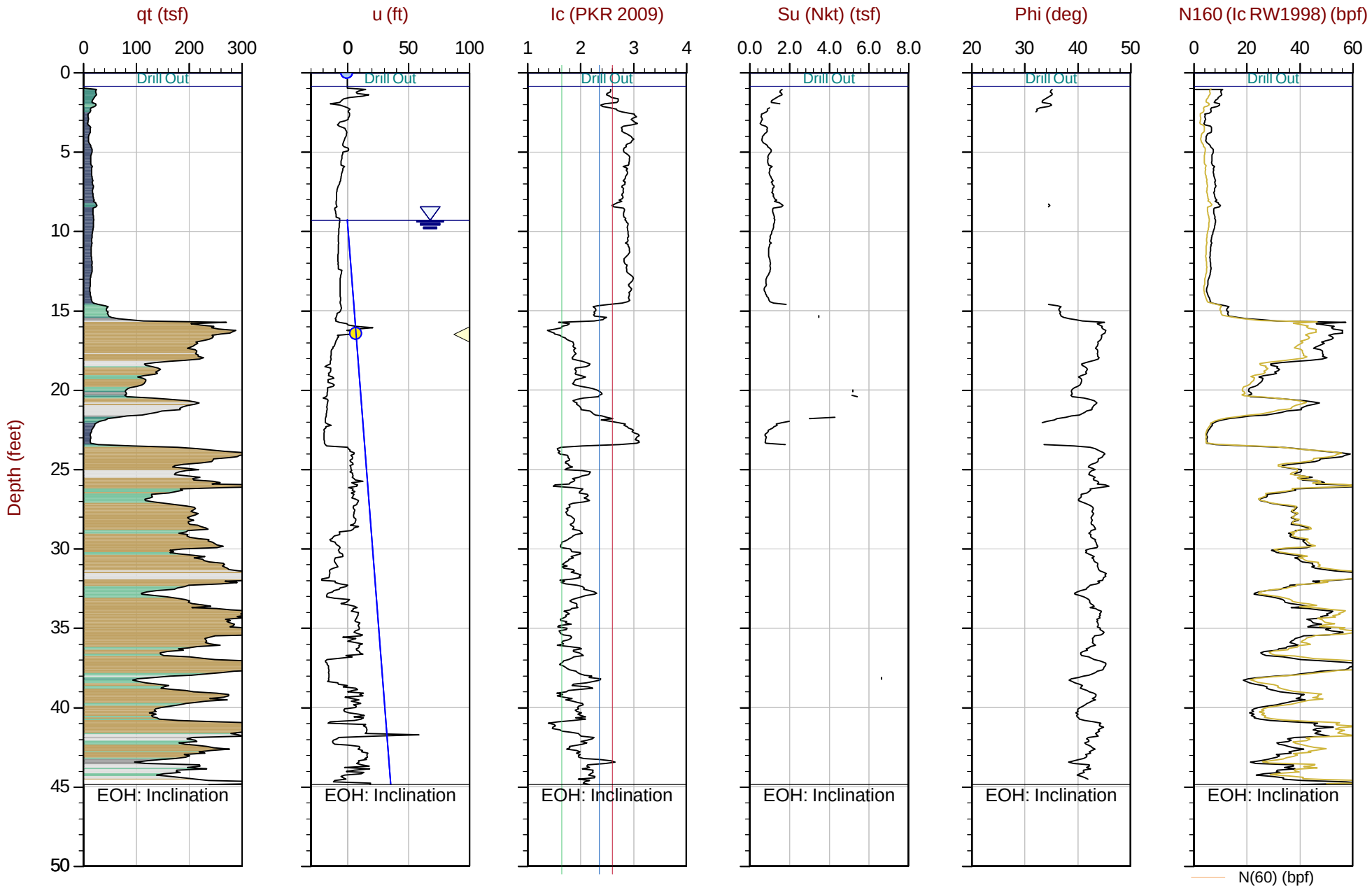
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 11:47
Site: Oxford School

Sounding: SCPT-03
Cone: 448:T1500F15U500



Max Depth: 13.675 m / 44.86 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP03.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193572m E: 564290m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Soil Behavior Type (SBT) Scatter Plots

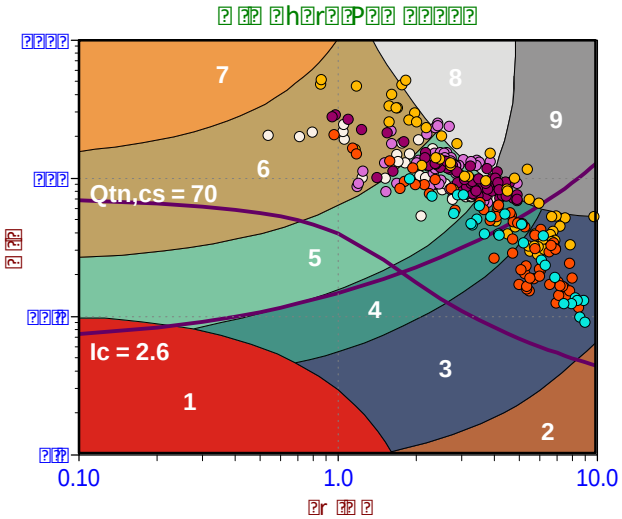
CONETEC

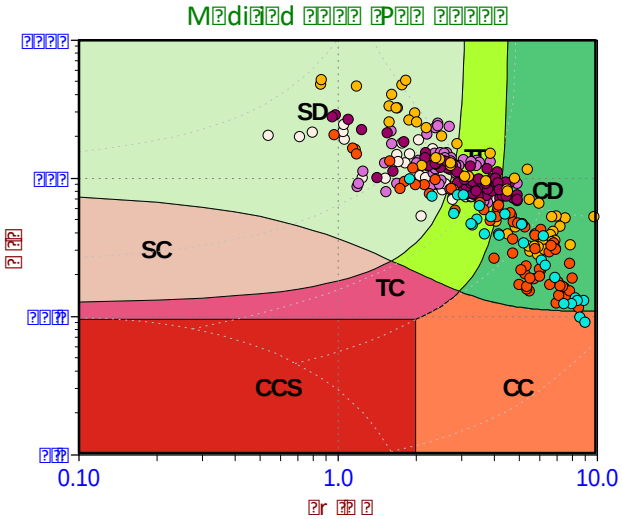
CONETEC

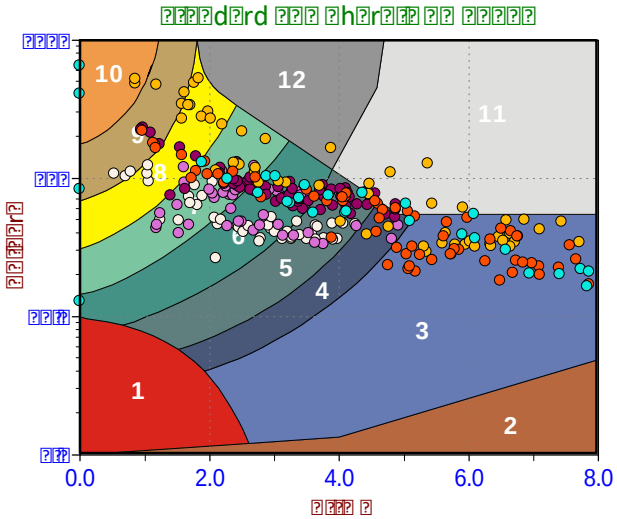
Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 08:43
Site: Oxford School

Sounding: SCPT-01
Cone: 448:T1500F15U500







Depth Ranges

- >0.0 to 5.0 ft
- >5.0 to 10.0 ft
- >10.0 to 15.0 ft
- >15.0 to 20.0 ft
- >20.0 to 25.0 ft
- >25.0 to 30.0 ft
- >30.0 to 35.0 ft
- >35.0 to 40.0 ft
- >40.0 to 45.0 ft
- >45.0 to 50.0 ft
- >50.0 ft

Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

Legend

- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

Legend

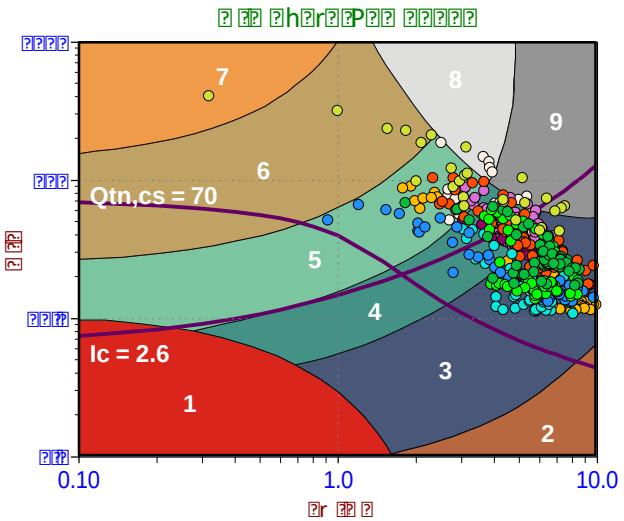
- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

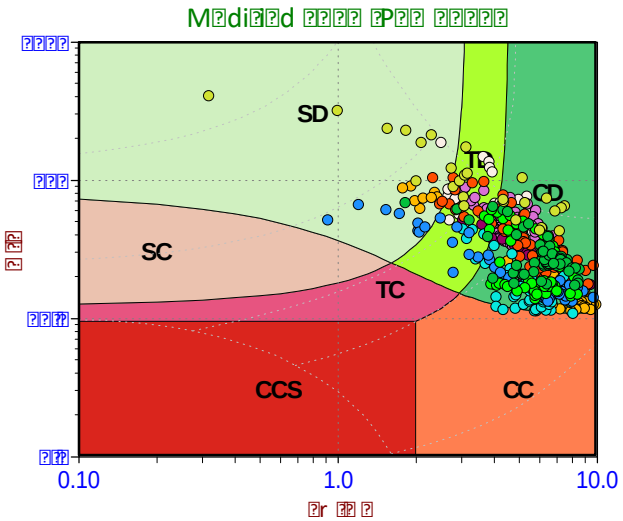
CONETEC

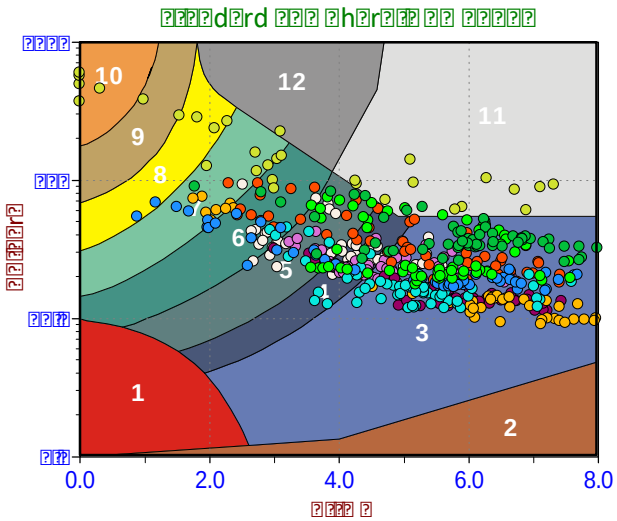
Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 10:19
Site: Oxford School

Sounding: SCPT-02
Cone: 448:T1500F15U500







Depth Ranges

- >0.0 to 5.0 ft
- >5.0 to 10.0 ft
- >10.0 to 15.0 ft
- >15.0 to 20.0 ft
- >20.0 to 25.0 ft
- >25.0 to 30.0 ft
- >30.0 to 35.0 ft
- >35.0 to 40.0 ft
- >40.0 to 45.0 ft
- >45.0 to 50.0 ft
- >50.0 ft

Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

Legend

- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

Legend

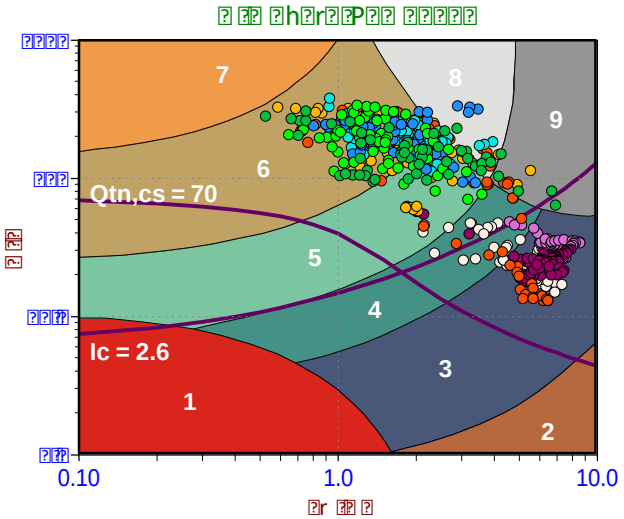
- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

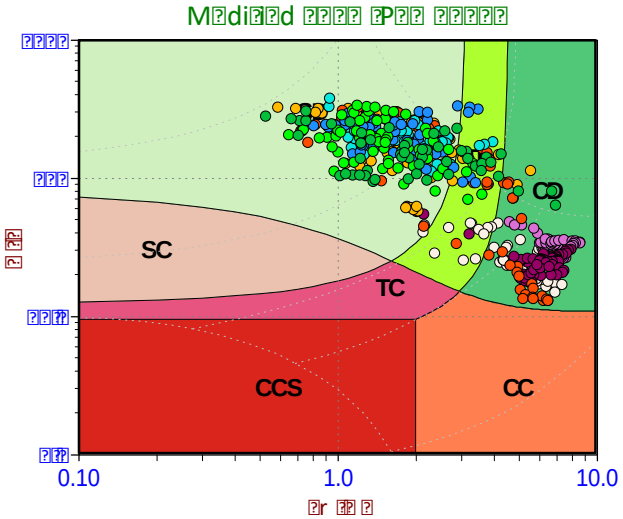
CONETEC

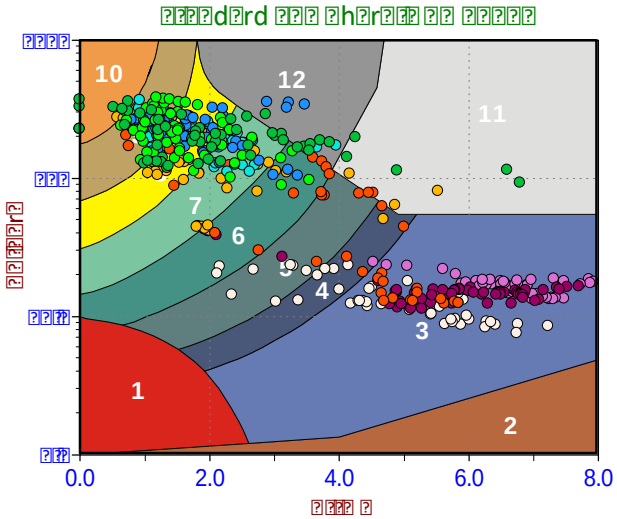
Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 11:47
Site: Oxford School

Sounding: SCPT-03
Cone: 448:T1500F15U500







Depth Ranges

- >0.0 to 5.0 ft
- >5.0 to 10.0 ft
- >10.0 to 15.0 ft
- >15.0 to 20.0 ft
- >20.0 to 25.0 ft
- >25.0 to 30.0 ft
- >30.0 to 35.0 ft
- >35.0 to 40.0 ft
- >40.0 to 45.0 ft
- >45.0 to 50.0 ft
- >50.0 ft

Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

Legend

- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

Legend

- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

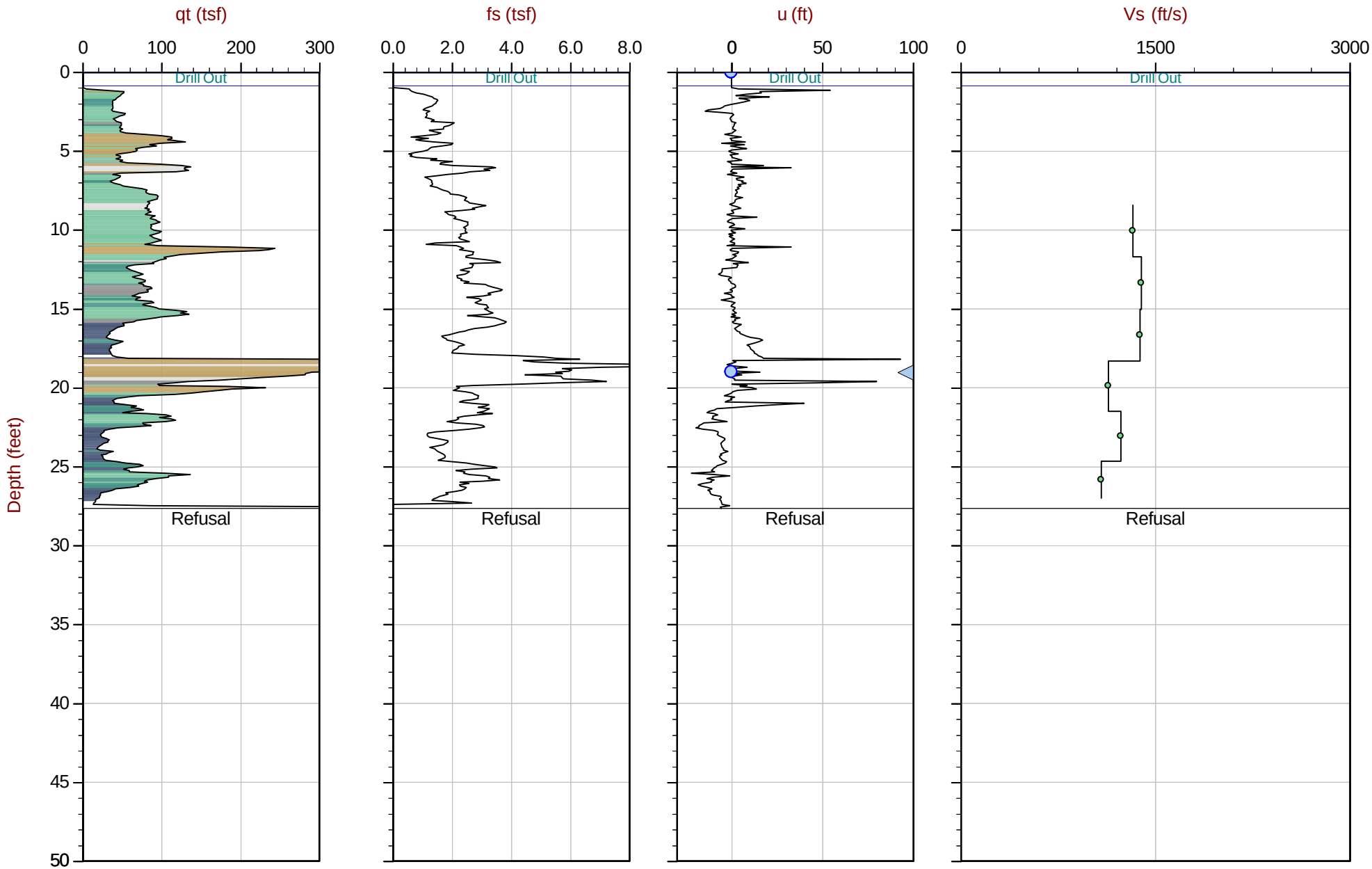
Seismic Cone Penetration Test Plots

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 08:43
Site: Oxford School

Sounding: SCPT-01
Cone: 448:T1500F15U500



Max Depth: 8.425 m / 27.64 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP01.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193606m E: 564315m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

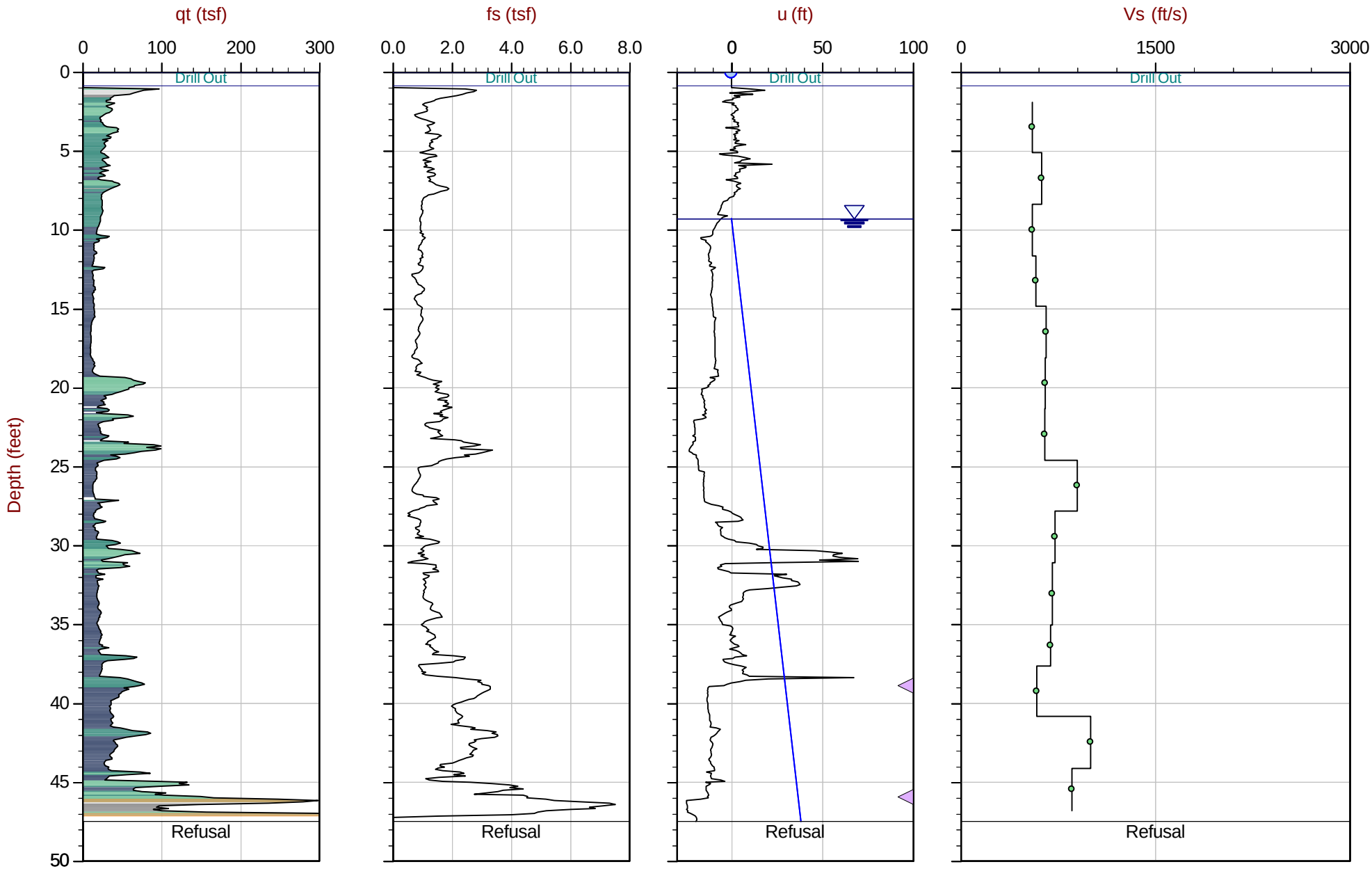
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 10:19
Site: Oxford School

Sounding: SCPT-02
Cone: 448:T1500F15U500



Max Depth: 14.475 m / 47.49 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP02.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193550m E: 564305m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

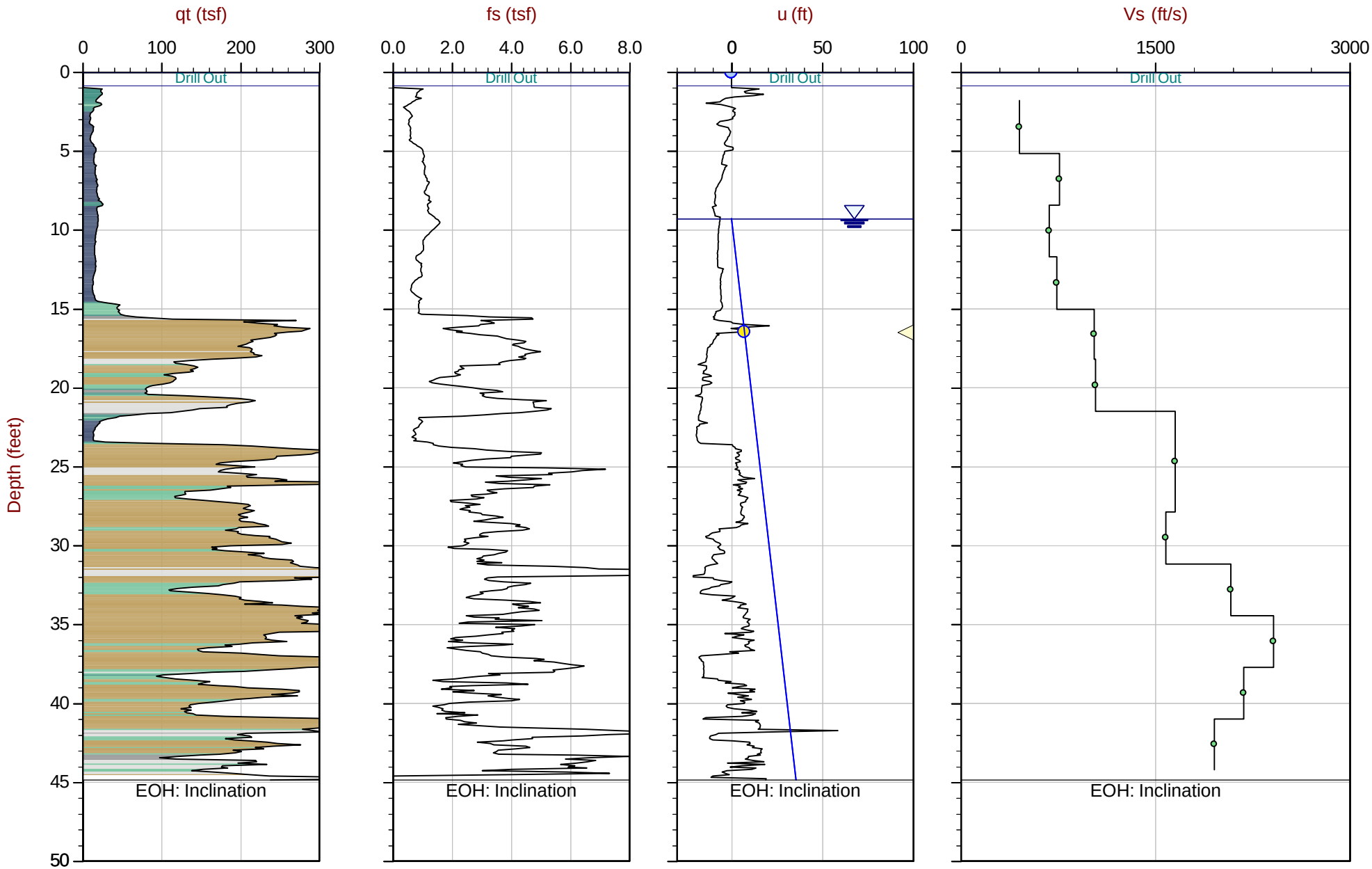
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 2018-12-29 11:47
Site: Oxford School

Sounding: SCPT-03
Cone: 448:T1500F15U500



Max Depth: 13.675 m / 44.86 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56216_SP03.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4193572m E: 564290m
Sheet No: 1 of 1

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Seismic Cone Penetration Test Tabular Results

CONETEC

Job No:	18-56216
Client:	Alan Kropp & Associates
Project:	Oxford School
Sounding ID:	SCPT-01
Date:	29-Dec-2018

Seismic Source:	Beam
Source Offset (ft):	1.87
Source Depth (ft):	0.00
Geophone Offset (ft):	0.66

SCPTu SHEAR WAVE VELOCITY TEST RESULTS - Vs

Tip Depth (ft)	Geophone Depth (ft)	Ray Path (ft)	Ray Path Difference (ft)	Travel Time Interval (ms)	Interval Velocity (ft/s)
9.09	8.43	8.64			
12.37	11.71	11.86	3.22	2.43	1327
15.68	15.03	15.14	3.28	2.36	1391
18.96	18.31	18.40	3.26	2.36	1382
22.15	21.49	21.57	3.17	2.79	1137
25.33	24.67	24.74	3.17	2.57	1233
27.66	27.00	27.07	2.32	2.14	1084

Job No:	18-56216
Client:	Alan Kropp & Associates
Project:	Oxford School
Sounding ID:	SCPT-02
Date:	29-Dec-2018

Seismic Source:	Beam
Source Offset (ft):	1.87
Source Depth (ft):	0.00
Geophone Offset (ft):	0.66

SCPTu SHEAR WAVE VELOCITY TEST RESULTS - Vs

Tip Depth (ft)	Geophone Depth (ft)	Ray Path (ft)	Ray Path Difference (ft)	Travel Time Interval (ms)	Interval Velocity (ft/s)
2.56	1.90	2.67			
5.74	5.09	5.42	2.75	5.00	550
9.02	8.37	8.57	3.15	5.08	622
12.30	11.65	11.80	3.22	5.86	550
15.49	14.83	14.95	3.15	5.43	580
18.77	18.11	18.21	3.26	4.95	658
21.98	21.33	21.41	3.20	4.93	650
25.26	24.61	24.68	3.27	5.06	646
28.48	27.82	27.88	3.21	3.57	898
31.76	31.10	31.16	3.27	4.50	727
35.70	35.04	35.09	3.93	5.58	704
38.32	37.66	37.71	2.62	3.78	693
41.50	40.85	40.89	3.18	5.43	585
44.78	44.13	44.17	3.28	3.27	1001
47.47	46.82	46.85	2.69	3.14	857

Job No:	18-56216
Client:	Alan Kropp & Associates
Project:	Oxford School
Sounding ID:	SCPT-03
Date:	29-Dec-2018

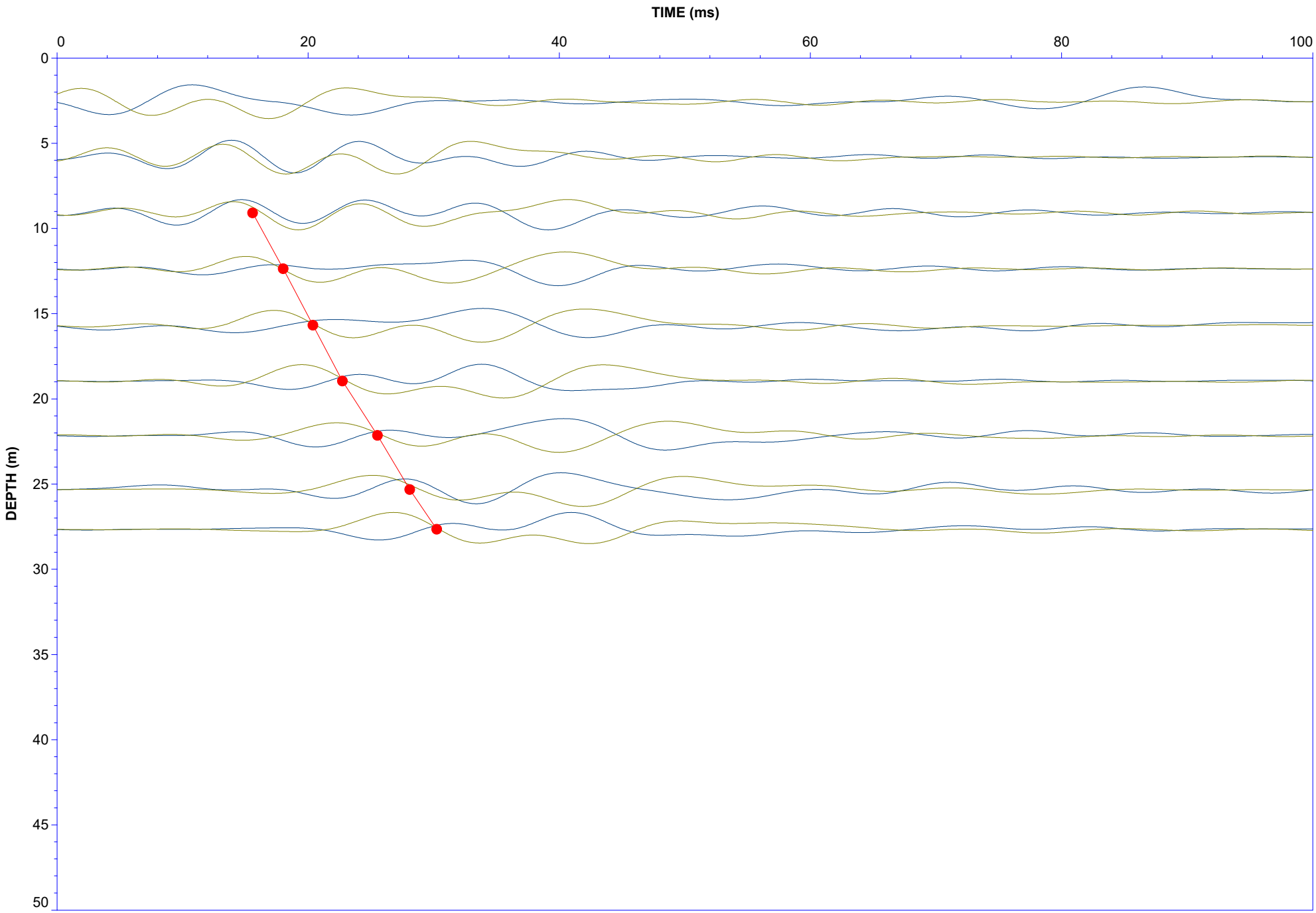
Seismic Source:	Beam
Source Offset (ft):	1.87
Source Depth (ft):	0.00
Geophone Offset (ft):	0.66

SCPTu SHEAR WAVE VELOCITY TEST RESULTS - Vs

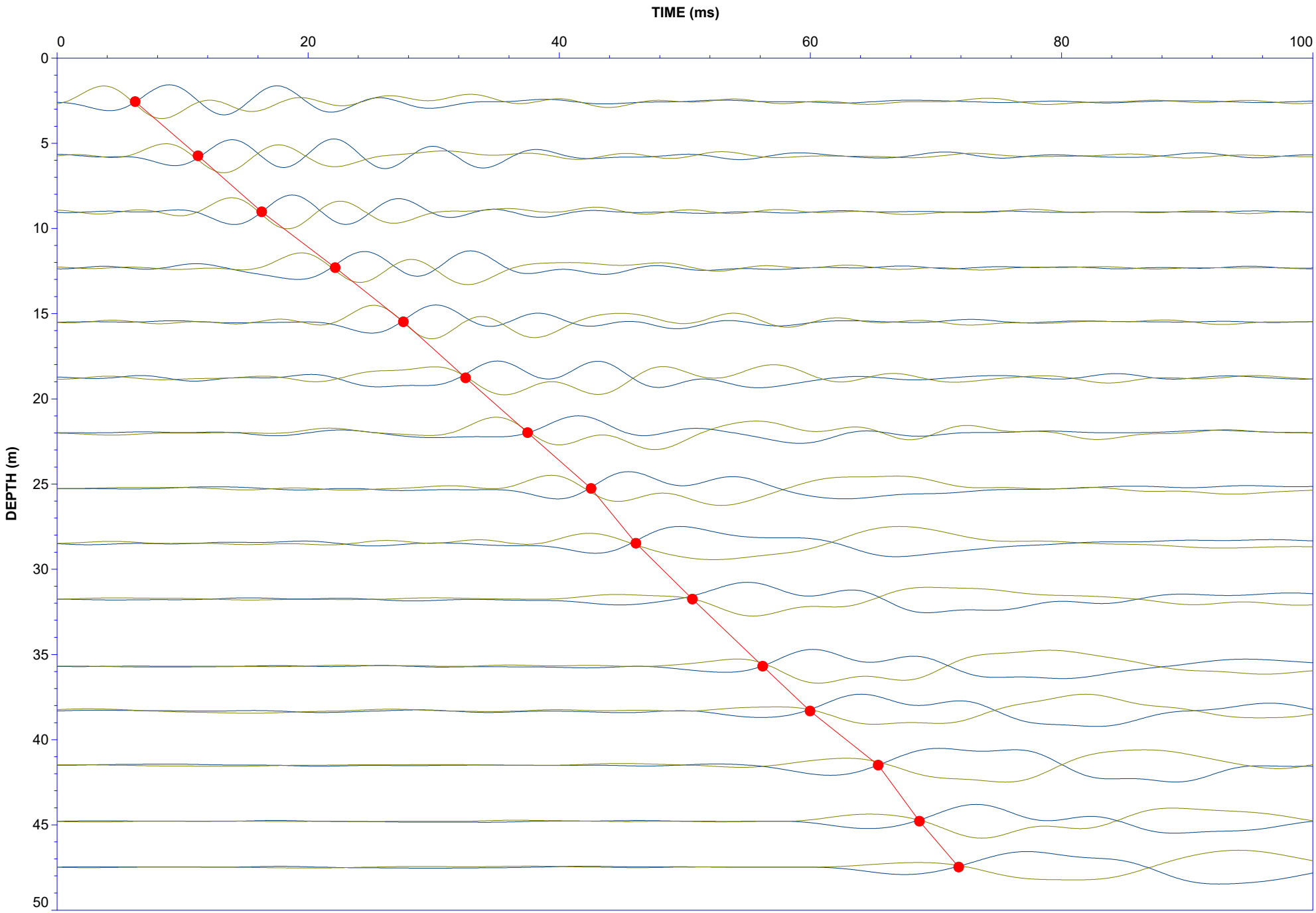
Tip Depth (ft)	Geophone Depth (ft)	Ray Path (ft)	Ray Path Difference (ft)	Travel Time Interval (ms)	Interval Velocity (ft/s)
2.46	1.80	2.60			
5.81	5.15	5.48	2.88	6.36	453
9.09	8.43	8.64	3.16	4.15	761
12.37	11.71	11.86	3.22	4.72	683
15.68	15.03	15.14	3.28	4.43	740
18.86	18.21	18.30	3.16	3.07	1029
22.15	21.49	21.57	3.27	3.15	1039
28.54	27.89	27.95	6.38	3.86	1653
31.82	31.17	31.22	3.27	2.07	1580
35.10	34.45	34.50	3.28	1.57	2083
38.39	37.73	37.78	3.28	1.36	2412
41.67	41.01	41.05	3.28	1.50	2183
44.88	44.23	44.27	3.21	1.64	1954

Seismic Cone Penetration Test Shear Wave (Vs) Traces

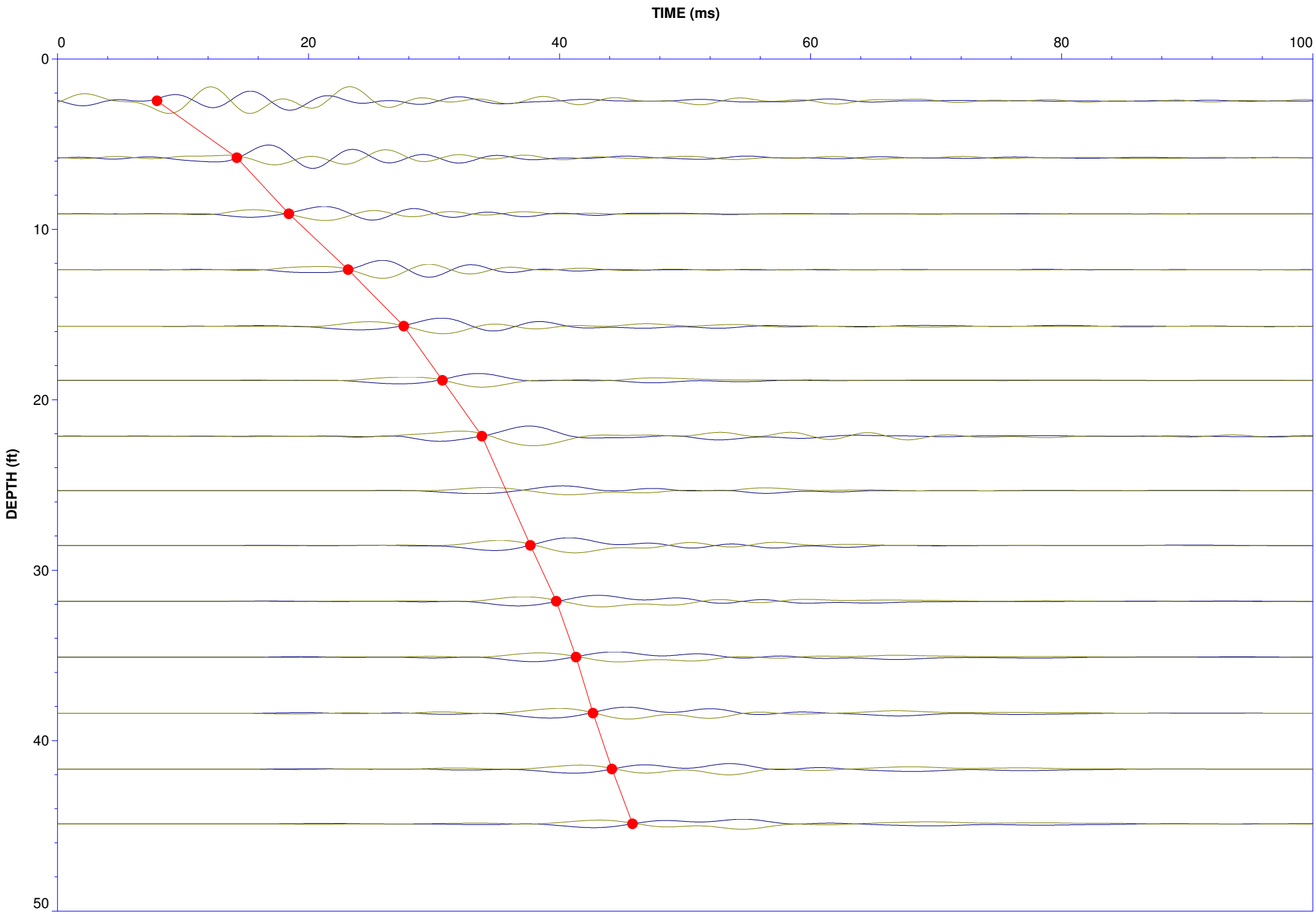
Job No: 18-56216 | Client: Alan Kropp & Associates | Project Title: Oxford School | Filter: 0 -125 hz | Sounding ID: SCPT-01 | Date: 12:29:18



Job No: 18-56216	Client: Alan Kropp & Associates	Project Title: Oxford School	Filter: 0 -150 hz	Sounding ID: SCPT-02	Date: 12:29:18



Job No: 18-56216 | Client: Alan Kropp & Associates | Project Title: Oxford School | Filter: 0 - 200 hz | Sounding ID: SCPT-03 | Date: 12:29:18



Pore Pressure Dissipation Summary and
Pore Pressure Dissipation Plots

Job No:	18-56216
Client:	Alan Kropp & Associates
Project:	Oxford School
Start Date:	29-Dec-2018
End Date:	29-Dec-2018

CPTu PORE PRESSURE DISSIPATION SUMMARY

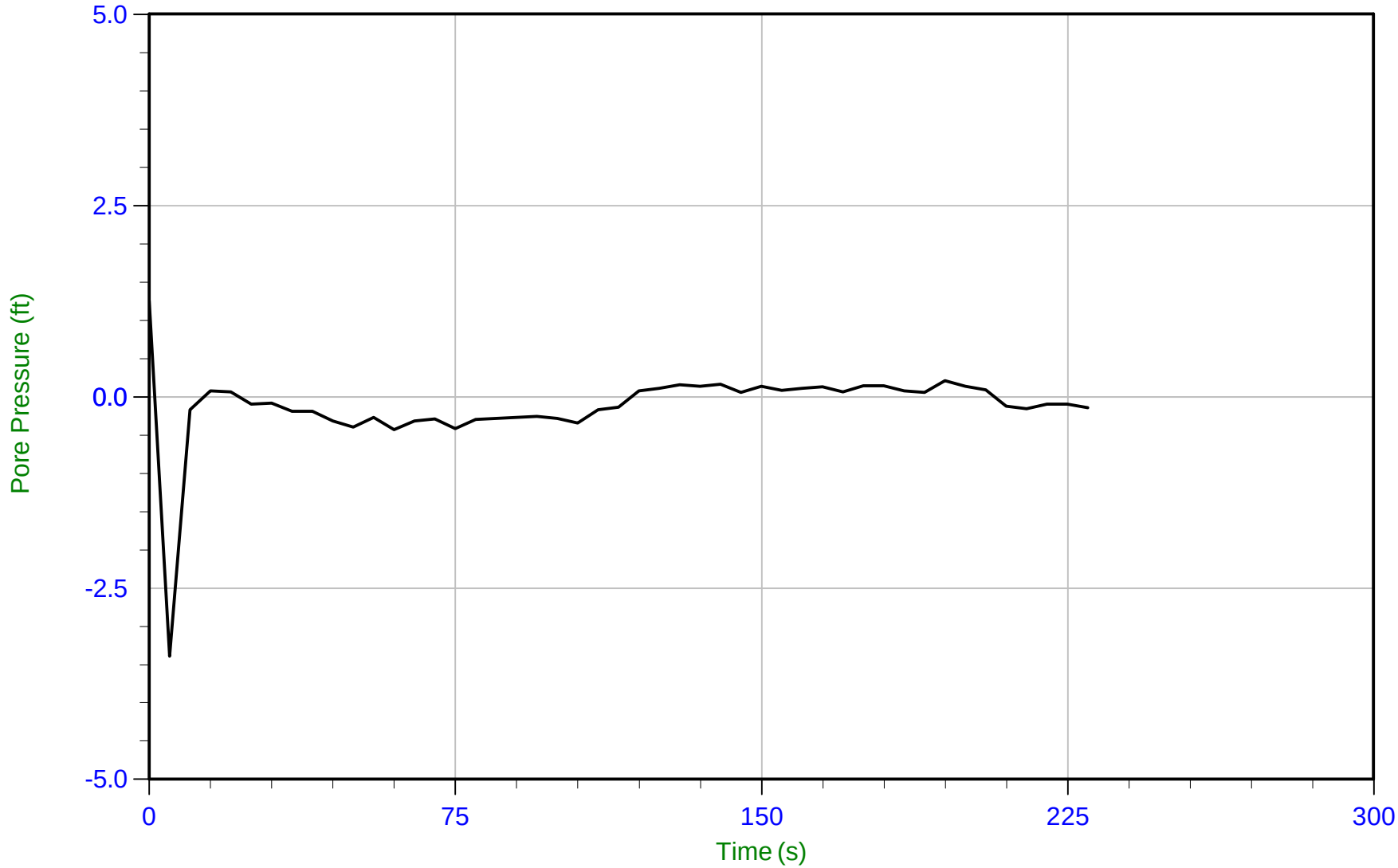
Sounding ID	File Name	Cone Area (cm^2)	Duration (s)	Test Depth (ft)	Estimated Equilibrium Pore Pressure U_{eq} (ft)	Calculated Phreatic Surface (ft)
SCPT-01	18-56216_SP01	15	230	19.03	0.0	
SCPT-02	18-56216_SP02	15	295	38.88	Not Achieved	
SCPT-02	18-56216_SP02	15	960	45.93	Not Achieved	
SCPT-03	18-56216_SP03	15	360	16.49		9.3

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 12/29/2018 08:43
Site: Oxford School

Sounding: SCPT-01
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 18-56216_SP01.PPF
Depth: 5.800 m / 19.029 ft
Duration: 230.0 s

U Min: -3.4 ft
U Max: 1.3 ft

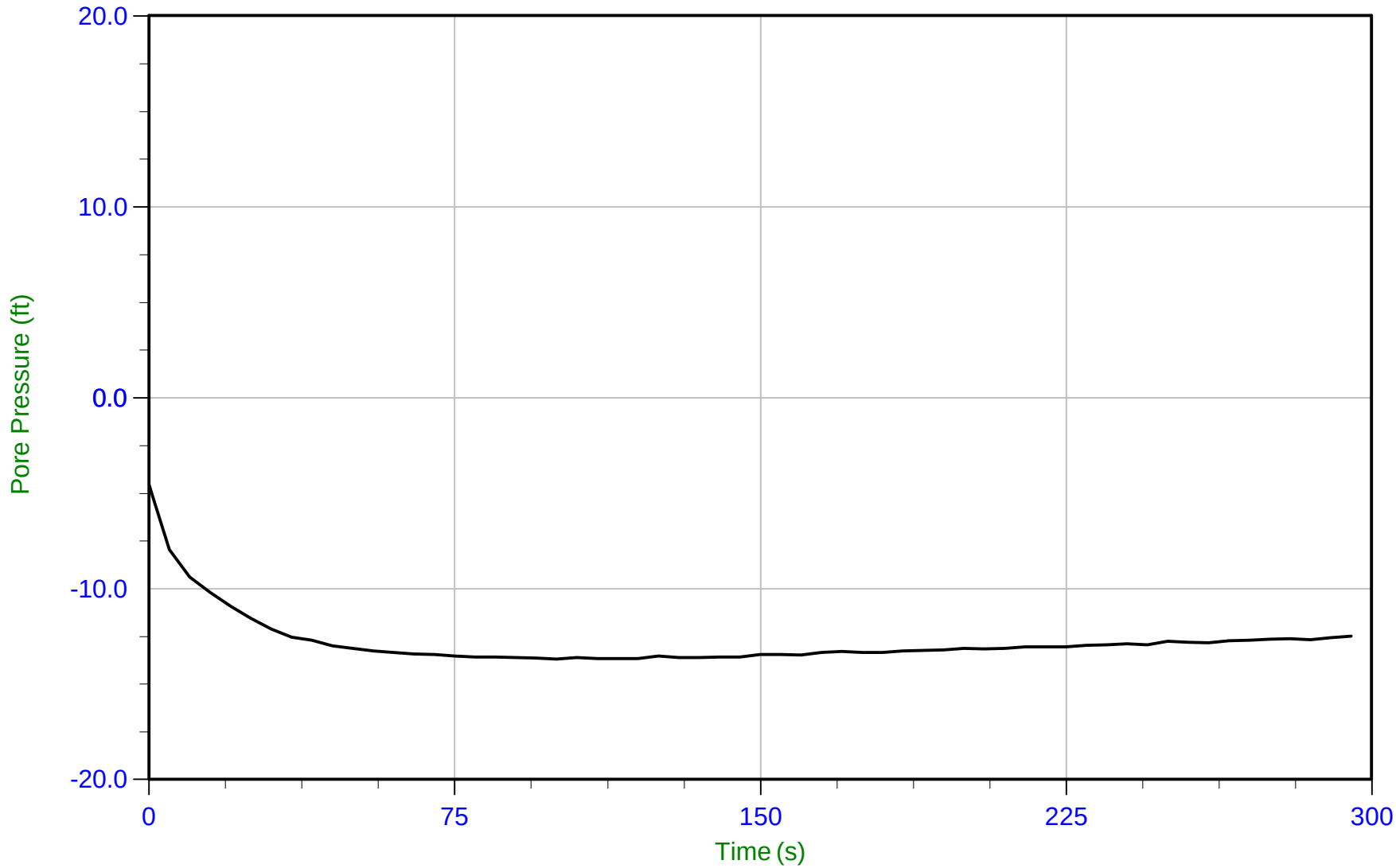
WT: N/A
Ueq: 0.0 ft

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 12/29/2018 10:19
Site: Oxford School

Sounding: SCPT-02
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 18-56216_SP02.PPF
Depth: 11.850 m / 38.877 ft
Duration: 295.0 s

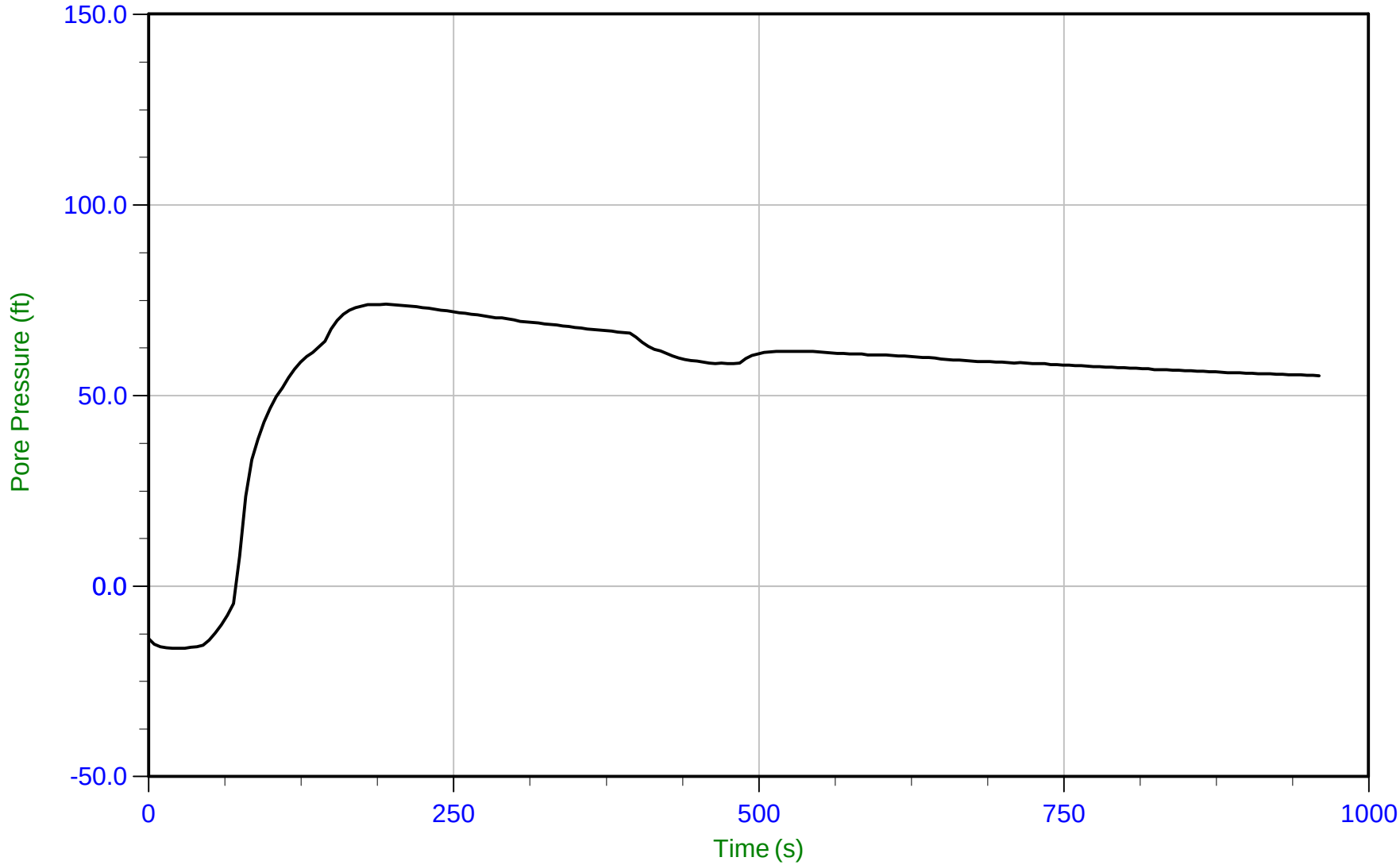
U Min: -13.7 ft
U Max: -4.5 ft

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 12/29/2018 10:19
Site: Oxford School

Sounding: SCPT-02
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 18-56216_SP02.PPF
Depth: 14.000 m / 45.931 ft
Duration: 960.0 s

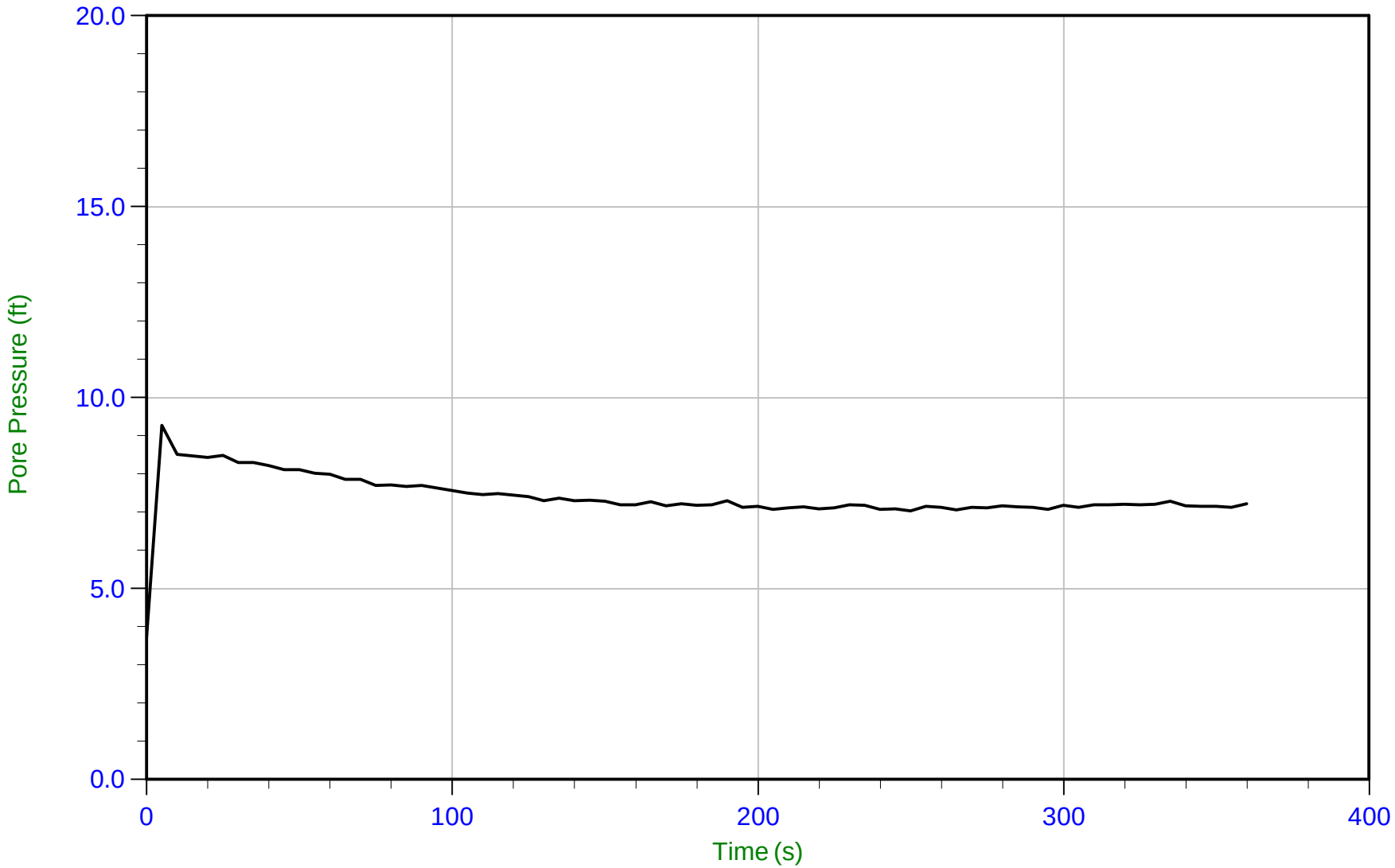
U Min: -16.4 ft
U Max: 73.9 ft

CONETEC

Alan Kropp & Associates

Job No: 18-56216
Date: 12/29/2018 11:47
Site: Oxford School

Sounding: SCPT-03
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 18-56216_SP03.PPF
Depth: 5.025 m / 16.486 ft
Duration: 360.0 s

U Min: 3.7 ft
U Max: 9.3 ft

WT: 2.843 m / 9.328 ft
Ueq: 7.2 ft

APPENDIX C

GEOPHYSICAL SHEAR WAVE VELOCITY REPORT:

NORCAL GEOPHYSICAL CONSULTANTS, INC.

NORCAL GEOPHYSICAL CONSULTANTS INC.
A Terracon COMPANY

January 25, 2019

Alan Kropp and Associates
2140 Shattuck Ave., Suite 910
Berkeley, CA 94704

Subject: Borehole Geophysical PS-wave Logging Survey
Oxford Elementary School
1130 Oxford Street
Berkeley, CA

NORCAL Job No: NS185097

Attention: Mr. Jeroen Van den Berg

1.0 INTRODUCTION

This report presents the findings of a borehole geophysical investigation performed by NORCAL Geophysical Consultants, Inc. in support of a geotechnical landslide evaluation being conducted by Alan Kropp and Associates. The study site was located at Oxford Elementary School located at 1130 Oxford Street Berkeley, California. The survey was performed on December 27, 2018 by NORCAL Geophysical Technician Travis Black. Logistical support and safety information were provided onsite by Alan Kropp and Associates Geologist Mr. Paul Bertucci. Geophysical borehole logging was conducted in one geotechnical borehole labeled as B-1. The borehole was situated in the school yard behind the main school building (see Figure 1). The purpose of the geophysical logging was to measure compressional (P-) and shear (S-) wave velocities in the alluvium and bedrock and relate these velocities to the vertical extent of the slide debris.

Figure 1: *Borehole Location Map*

2.0 SCOPE OF SERVICES

Our scope of services for this project consisted of conducting Suspension P- and S-wave velocity and caliper surveys in one open geotechnical boring and including data processing, data interpretation and presentation of the results in a written report.

3.0 BOREHOLE – GEOLOGIC CONDITIONS

Borehole B-1 was advanced with an 8-inch diameter hollow stem auger to 36-feet below ground surface (bgs) followed by 5 inch-diameter rotary dry coring drilling method that extend to a total depth of 118-ft bgs. At the time of the geophysical logging the borehole appeared to have sloughed-in, losing about 9-10 feet of the once available open borehole. Static water in the borehole at the time of the geophysical logging was 27-ft bgs. Caliper washouts in the upper 35 feet indicate very loose unconsolidated soils that may have contributed to the borehole infilling.

The geotechnical boring encountered alluvial deposits of clay and gravel that overlie Franciscan Formation Complex sandstone greywacke and shale. Preliminary geologic logging of the core suggests that the alluvial deposits have been disturbed by slide movement down to 55-feet bgs. The alluvium-bedrock contact was indicated at 59-ft bgs. The bedrock consists of sandstone, greywacke and shale and was reported to be weak, deeply weathered and highly fractured from the contact boundary to about 70-feet bgs. Below this depth the rock becomes moderately hard, moderately strong and less weathered.

4.0 GEOPHYSICAL LOGGING METHODOLOGY

4.1 P- AND S-WAVE SUSPENSION LOG SURVEY

Complete descriptions of the methodology, data acquisition and data analysis procedures for the PS-logging Surveys are presented in Appendix A.

4.2 CALIPER SURVEY

Caliper logs were conducted to measure borehole diameter versus depth. Variations in borehole diameter can help quantify the relative consolidation/compaction of the alluvial layers. We also used the tool to assess borehole stability and potential hazards (constrictions) prior to conducting the suspension logger surveys.

The caliper tool consists of three interconnected mechanical arms that are spring loaded to extend against the borehole wall. The horizontal deflections of the arms gauge the borehole diameter in units of inches versus depth. Our procedure was to obtain caliper logging measurements in the up hole direction at a speed of approximately 16-ft per minute. This resulted in a data sample interval of about 0.2-ft.

4.3 BOREHOLE LOGGING EQUIPMENT

NORCAL conducted geophysical borehole logging using a digital ***MICROLOGGER2*** System manufactured by **Robertson Geologging, Ltd.** This system consisted of the following components:

- control console
- computer
- motorized cable winch
- P- and S-Wave Suspension logger
- 3-arm caliper tool

5.0 RESULTS

5.1 CALIPER SURVEYS

The results of the caliper survey conducted in Borehole B-1 is illustrated by the Borehole Diameter Plot shown on the right side of the velocity profile in Plate 1. The caliper log shows variations in borehole diameter from 4-inches to as much as 12 inches. Zones with relatively large diameters, i.e. greater than 8 inches in diameter are present in the upper 35-ft of the borehole. They are considered "washouts" and typically correlate with either poorly consolidated, loose sand or clay alluvial layers.

5.2 SUSPENSION LOGGER SURVEY

The results of the suspension logging survey are also illustrated on Plate 1. This plate depicts the variation in S-wave velocity (Vs) and P-wave velocity (Vp) versus depth. Vs are indicated by the red triangles and Vp are indicated by the blue squares. These are interval velocities (see Appendix A) and, as such, are the values that should be used in any evaluation of the alluvial soil or bedrock foundation characteristics. We have added a generalized lithologic column to the right of the velocity profiles. This draft geologic information was supplied by ALAN KROPP and Associates. The purpose of the lithologic column was to compare changes in the geologic units to variations in P and S-wave velocity profile.

6.0 DISCUSSION

As shown on Plate 1, the suspension velocities measured in Borehole B-1 range from 6,000 to 10,000 feet per second (fps) for Vp and 800 to 4,000 fps for Vs. The velocity profile on Plate 1 shows that Vs velocities of approximately 1,000 fps are present in a vertical zone from 28- to

53-ft bgs. Using Vs as a proxy for both the P- and S-wave velocities, Vs velocities gradually increase from 1,000-fps beginning at 53-ft bgs to approximately 3,200 fps at 75-ft bgs. The increase in Vs is related to changes in geology from alluvium to bedrock. When in the bedrock, the increase in Vs is due to the degree of consolidation and rigidity of the bedrock as the Vs profile increases in depth. The highest Vs measured at 4,000 fps below 93-ft bgs represents moderate strong, moderately hard sandstone.

7.0 STANDARD CARE

The scope of NORCAL's services for this project consisted of using geophysical methods to characterize the subsurface. The accuracy of our findings is subject to specific site conditions and limitations inherent to the techniques used. We performed our services in a manner consistent with the standard of care ordinarily exercised by members of the profession currently employing similar methods. No warranty, with respect to the performance of services or products delivered under this agreement, expressed or implied, is made by NORCAL.

We appreciate the opportunity to provide our services to Alan Kropp and Associates for this project. If you have any questions or require additional geophysical services, please do not hesitate to contact us.

Sincerely,

NORCAL Geophysical Consultants, Inc.

William J Henrich
Professional Geophysicist PGp 893

REGISTERED GEOPHYSICIST
WILLIAM J. HENRICH
01/25/19
No. 893
STATE OF CALIFORNIA

Donald J. Kirker
Professional Geophysicist PGP 997

PROFESSIONAL GEOPHYSICIST
DONALD KIRKER
No. 997
1-25-19
STATE OF CALIFORNIA

WJH/DJK/tt

Enclosures:
Plate 1: Suspension PS-wave Velocity Profiles, Borehole B-1
Appendix A: PS-wave Suspension Logging

NORCAL
GEOPHYSICAL CONSULTANTS INC.
A Terracon COMPANY

Appendix A:

PS-wave Suspension Logging

APPENDIX A

PS-WAVE SUSPENSION VELOCITY SURVEY

The Suspension logger is a highly specialized downhole tool that measures P- and S-wave velocities at discrete depths. The following presents a narrative on its operation and the data reduction procedures we used in analyzing the data. Also presented are the velocity profiles and tabulated velocity data table interpreted for the suspension logging survey in Borehole B-1.

1.0 METHODOLOGY

We measured downhole compressional (P-) and shear (S-) wave velocities using a Robertson Geologging, Ltd. digital suspension logging system. A schematic diagram depicting the probe configuration and equipment attachment is shown in Figure A-1. The suspension logging tool is equipped with a dipole seismic energy source located near the base of the probe and a pair of detectors (receivers) designated as R-1 and R-2, located within the middle to the upper sections of the probe. The distance from the energy source to the closest receiver was 7.04 feet (2.15 meters) when assembled with a detachable 1-meter isolation tube. The in-line distance between the receiver pair was 3.28-feet (1.0 meter). Each receiver contains one horizontal and one vertical oriented element. The horizontal receiver elements preferentially record shear wave motion. The vertical receiver elements preferentially record first arriving P-wave energy.

Suspension seismic data are collected at discrete depths in the fluid-filled portion of the borehole. At each measurement depth, the energy source is activated via commands from the surface control console. This activation causes a metal solenoid to strike a plate (anvil) mounted inside the probe housing. This energy transmits through the fluid to the borehole wall, which produces a seismic wave ("flexure") in the adjacent formation. As this wave propagates radially into the formation a physical interaction between the seismic wave and the borehole wall creates tube waves together with a refracted compressional P-wave that travels up the borehole to the two receivers.

When assembled with a 1-meter isolation tube, the suspension logging tool is approximately 20-ft long (Figure A-1). By definition, the depth reference point of the tool is half-way between the two receivers. Since this point is approximately 12-ft from the probe tip, the maximum depth of a suspension logging survey, given a non-sloughing borehole, will always be reported as 12 feet less than the total depth of the borehole. When in operation, the probe is centralized in the borehole with flexible rubber rings positioned just below the source and just above the receiver section. This is necessary in order to maintain a gap between the probe housing and borehole wall.

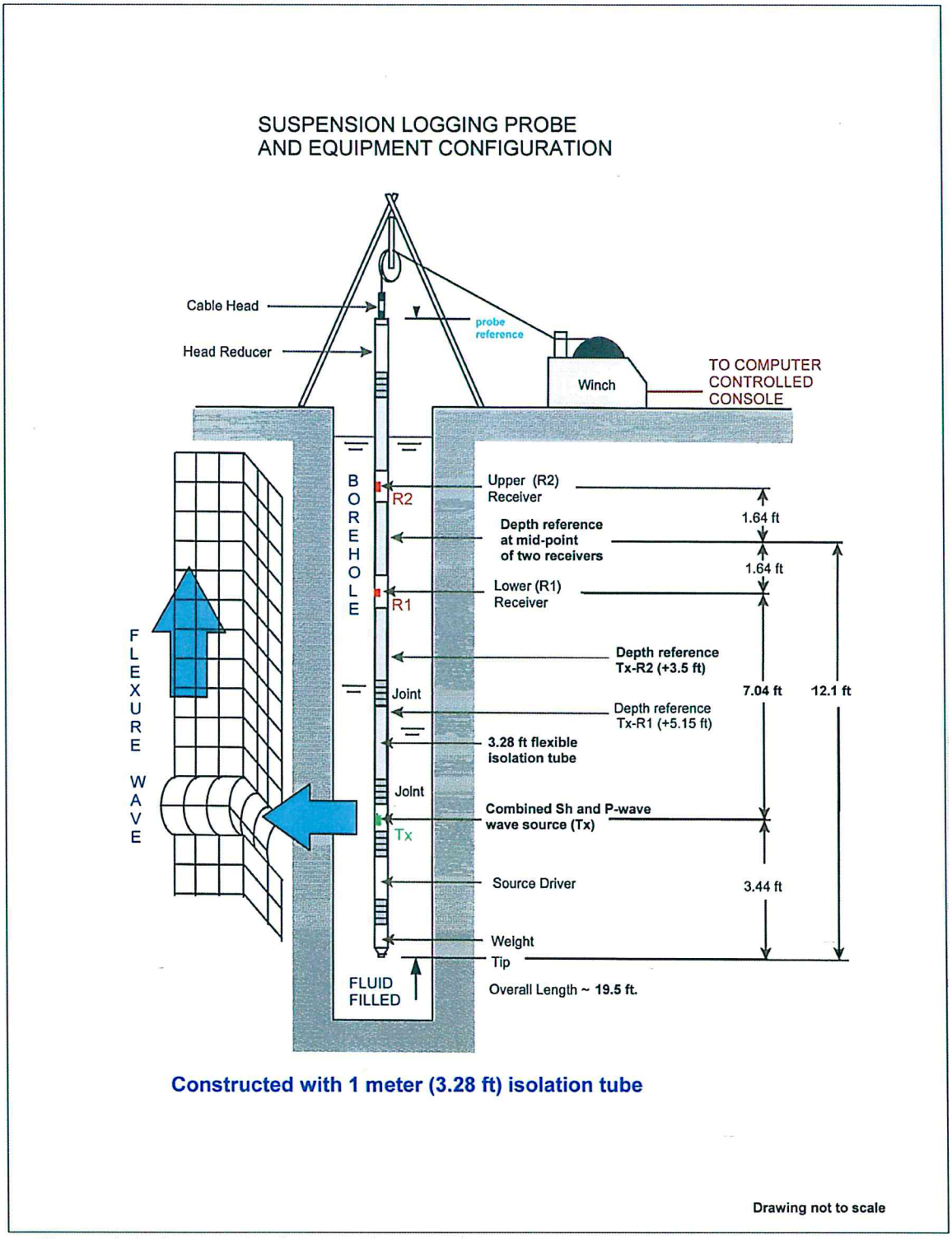


Figure A-1: *Suspension logger schematic diagram*

2.0 DATA ACQUISITION

We measured seismic suspension velocities at stationary positions distributed at 2-foot intervals in a depth range from 8-feet to 96-feet bgs; then reduced the station spacing to approximately 0.5 to 1.0 foot from the depth at select intervals from 60 to 75-ft bgs. The reason for the finer spacing in the mid borehole section was due to the interpolation of additional stations in which related data files with different time windows and gain settings were employed to improve the recognition of the Vs arrivals in relatively poor signal conditions that characterized this section of the borehole. The depth reference point of the probe was positioned near the bottom of the borehole, at a depth of approximately 96-feet below ground surface (bgs). The survey then proceeded upward to a depth of 8-ft bgs. At each measurement station, we cycled the energy source to fire 2 times in succession into each of the receiver elements. This cycling stacked the seismic energy resulting in an improved signal-to-noise ratio. We recorded S-wave by applying a 1.2 KHz low pass filter to the signals detected by the horizontal receiver elements. This filtering reduces high frequency interference from the onset of earlier arriving P-wave energy on the S-wave channels. We recorded P-wave waveforms using a 20 KHz low pass filter.

It should be noted that PS-wave data recorded from 27 feet to within 8 feet of the ground surface were of poor quality and deemed uninterpretable. Conditions impacting the suspension method included borehole wall rugosity, partially saturated, poorly consolidated soils. Therefore, the shallow most PS-wave measurement we present is 28-ft bgs.

3.0 DATA ANALYSIS

3.1 SEISMIC RECORDS

Suspension P- and S-wave velocities were calculated with the interpretation computer software programs ***PSLogger Application*** Version 1.121 and ***PSLOG Analysis*** Version 1.0.001. Both programs are published by ***Robertson Geologging, Ltd.*** (2009). Sample suspension logger seismic records are presented in Figures A-2 and A-3. These samples were recorded at a depth of 25- and 90-ft bgs. The record displays six seismic wave-traces. The upper four traces were detected by the horizontal receiver elements and were used to identify S-wave arrivals. These traces are labeled according to the wave type (s=shear), the direction of impact (l=left and r=right) and the relative distance from the source (n=near and f=far). For example, the top wave trace is labeled "srf" because it was recorded to identify S-waves using a right strike and was detected by the far receiver. The seismic wave traces produced by a right-hand strike of the source (Cycle 1) are red. Those resulting from a left-hand strike (Cycle 2) are green.

The lower two traces were detected by the vertical receiver elements and are used to identify P-wave arrivals. These traces are labeled according to the wave type (p=primary) and the relative

distance from the source (n=near and f=far). For example, the bottom wave trace is labeled "pn" because it was recorded to identify P-waves by the near receiver. These seismic wave traces produced during Cycle 3 are colored blue. Since they were detected by the vertical elements in the receivers, the direction of impact is inconsequential and is not addressed by separate waveforms.

Figure A-2: *Sample seismic record from Borehole B-1 at depth 76-ft bgs*

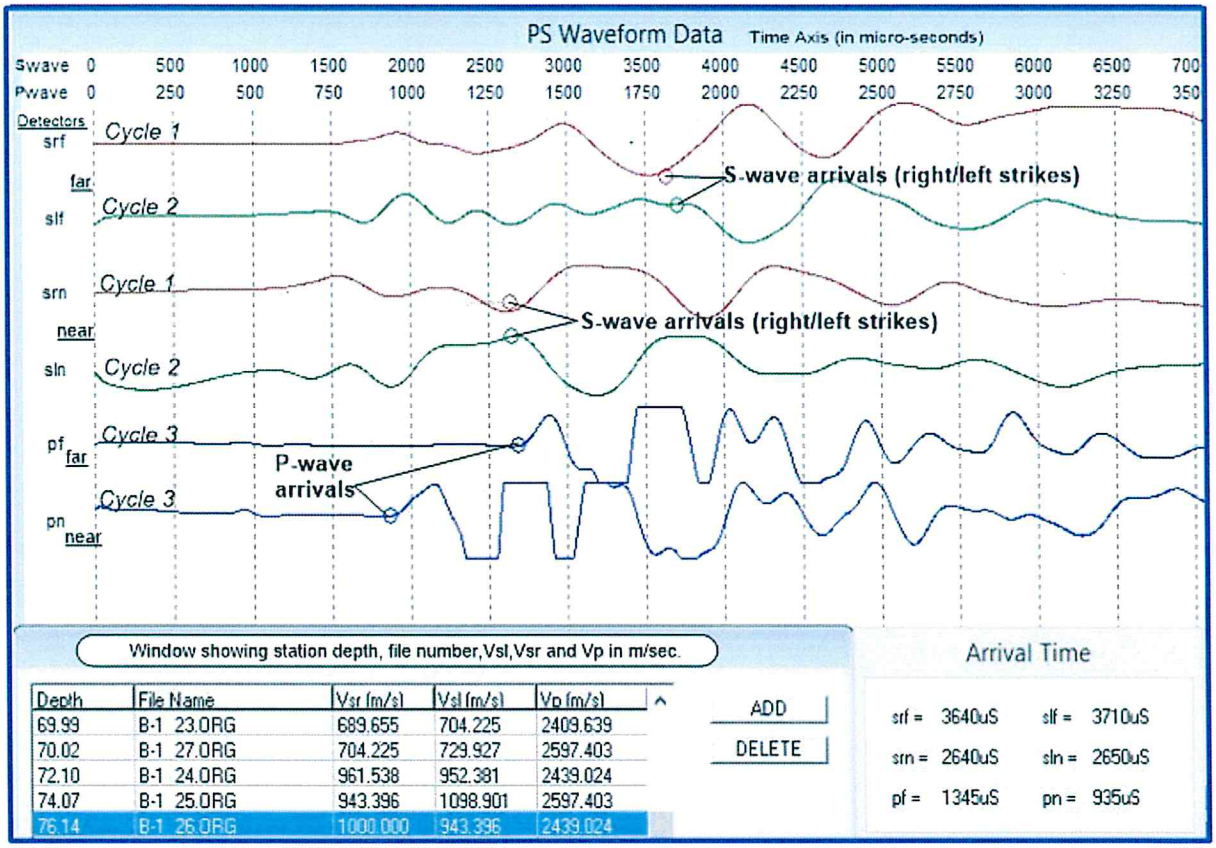
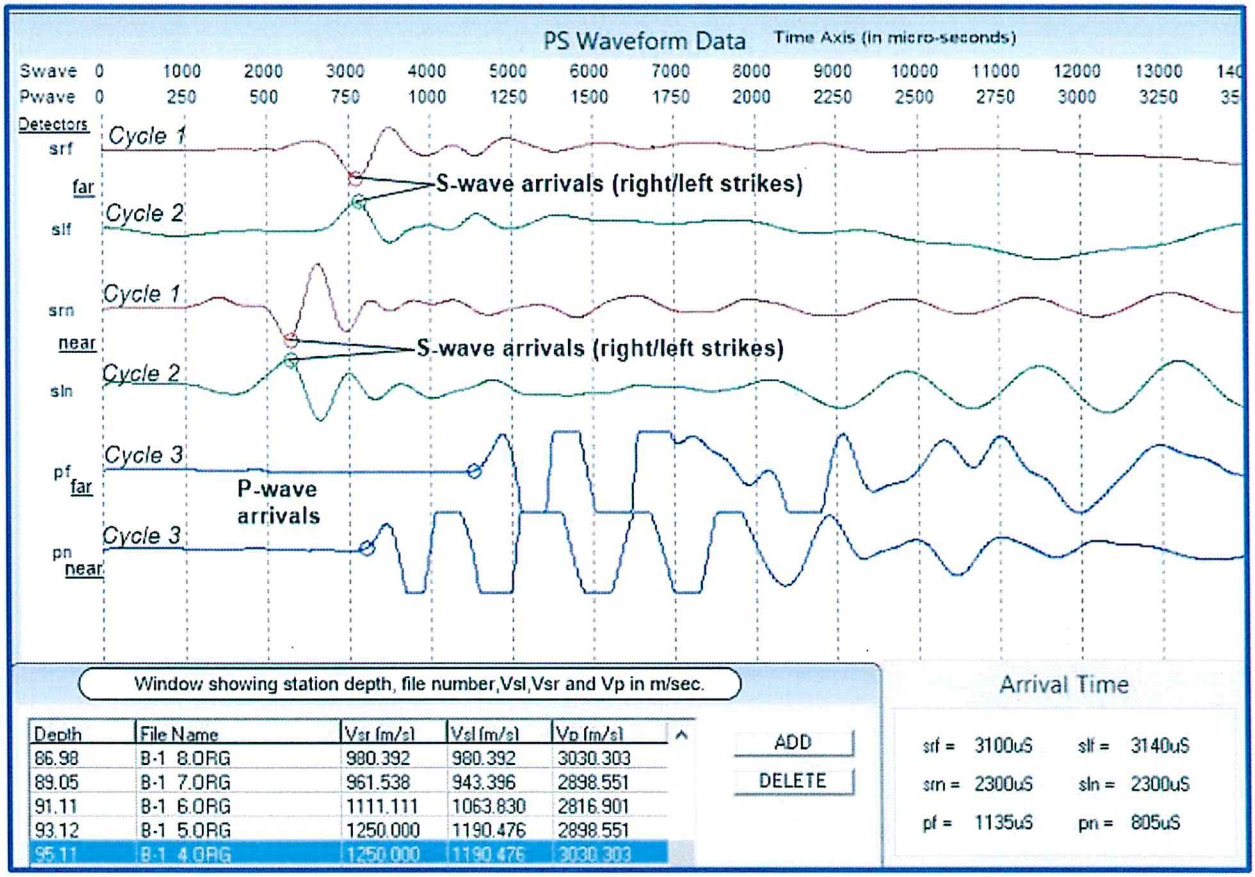


Figure A-3: *Sample seismic record from Borehole B-1 at depth 95-ft bgs*



3.2 S-WAVE ARRIVALS

On the suspension seismic records shown in Figure A-2 and A-3, the red traces (Cycle 1) were created by right strikes or impacts and the green traces (Cycle 2) were created by left strikes. Pairing the traces produced by opposite directions of impact reveals a phase reversal that is associated with the onset (arrival) of S-wave energy. However, because there can be slight discrepancies in timing between Cycle 1 and Cycle 2, the reversal point may not occur at the same exact time on both traces. Therefore, the onset of S-wave energy is further defined as the point where there is also a significant increase in amplitude within the phase reversal time window. These arrival times are depicted by open dots on the upper four wave traces.

3.3 P-WAVE ARRIVALS

P-wave arrivals are identified as the point where the wave traces produced by Cycle 3 (blue) change from straight lines to sinusoidal wave forms. These points, referred to as a “first breaks” are represented by blue circles on the lower two wave traces.

3.4 SEISMIC VELOCITY CALCULATIONS

Seismic wave velocities (V) are calculated by dividing the distance (X) from the source to a given receiver by the time required (T) for the seismic wave to reach that receiver. Hence, (V) = X/T. This is referred to as a direct path seismic velocity. However, velocities can also be calculated by dividing the distance between the two receivers (R1 and R2) by the difference in travel time to those receivers (T2-T1). This is considered an interval velocity. For example:

$V_{(R2-R1)} = (X_{R2}-X_{R1})/(T_{R2}-T_{R1})$

Where X_{R1} and T_{R1} are the distance and travel time to the first receiver (R1); and X_{R2} and T_{R2} are the distance and time to the second receiver (R2).

3.5 INTERVAL SEISMIC VELOCITIES

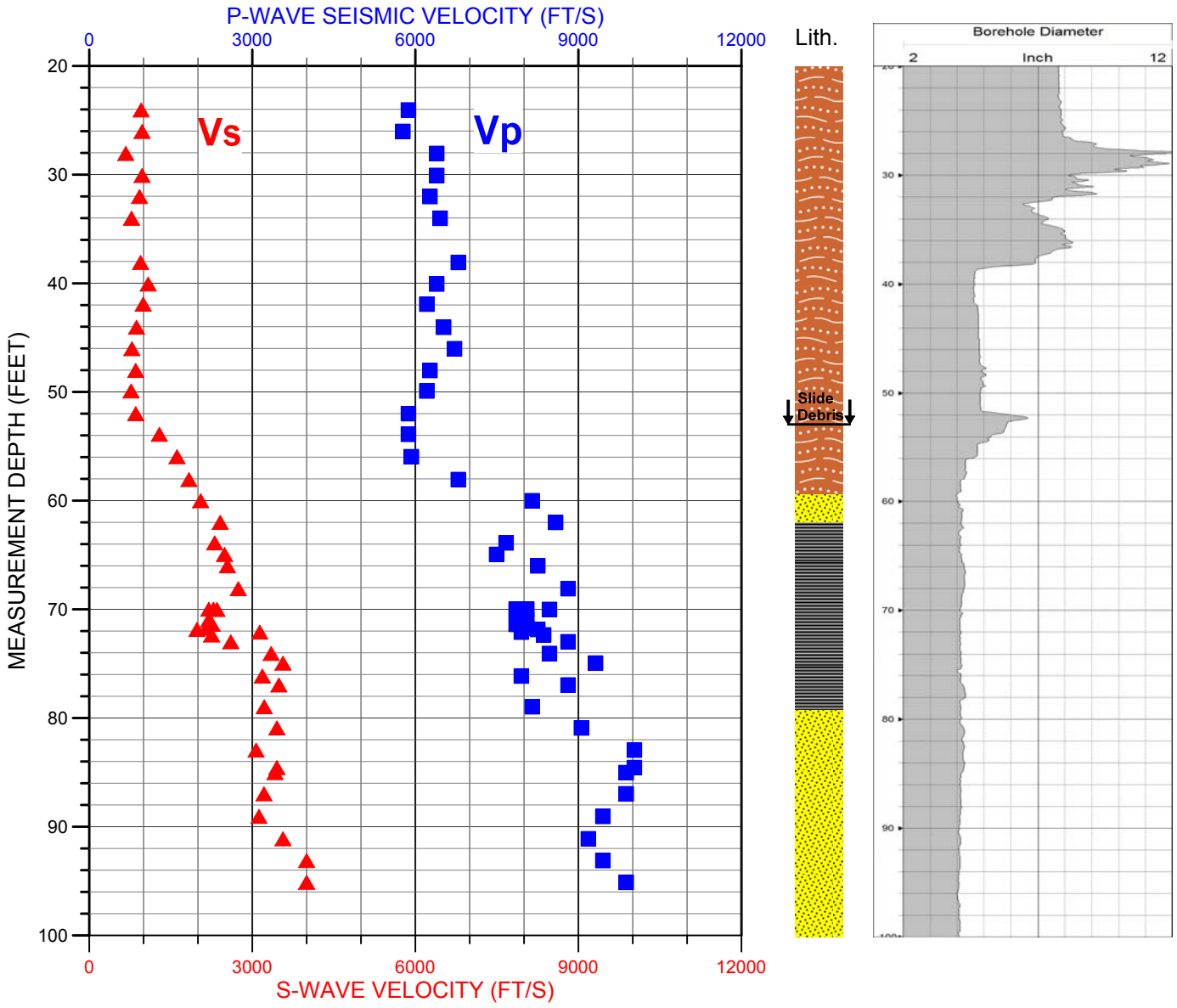
We used the travel times measured in Borehole B-1 to compute four interval velocities; three S-wave (Vs) and one P-wave (Vp). The interval Vs were computed using the Cycle 1 (VsRight) and Cycle 2 (VsLeft) travel times and their average. The interval Vp were computed using the Cycle 3 travel times. All of the velocities are listed, in meters per second, in Table A-1. We have also listed the average Vs and average Vp interval velocities (blue shaded columns) in feet per second. These values are displayed graphically on Plate 1 in the main body of the report. We have emphasized the interval velocities because they are immune to variations in triggering and/or coupling errors. The depths of the measurements are based on a probe reference point that is half-way between the near and far receivers.

Table A-1: *B-1 PS-wave Interval Seismic Velocities*

METRIC UNITS DEPTHS & INTERVAL VELOCITIES					IMPERIAL UNITS DEPTHS & INTERVAL VELOCITIES				
Depth	**VsLeft**	VsRight	VsAvg	Vp	Depth	VsLeft	VsRight	VsAvg	Vp
Meters	M/sec.	M/sec.	M/sec.	M/sec.	Feet	Ft./sec.	Ft./sec.	Ft./sec.	Ft./sec.
8.55	208	203	206	1961	28.06	685	667	675	6394
9.17	298	296	297	1961	30.09	979	971	974	6394
9.76	282	282	282	1923	32.02	929	927	927	6271
10.37	242	234	238	1980	34.03	795	767	780	6457
11.61	289	289	289	2083	38.09	951	948	948	6794
12.22	313	350	331	1961	40.08	1028	1147	1086	6394
12.78	314	292	303	1905	41.93	1035	959	996	6211
13.43	263	269	266	2000	44.05	866	882	873	6522
14.03	240	239	240	2062	46.03	791	785	787	6724
14.64	260	262	261	1923	48.03	857	859	857	6271

NORCAL
GEOPHYSICAL CONSULTANTS INC.
A Terracon COMPANY

METRIC UNITS DEPTHS & INTERVAL VELOCITIES					IMPERIAL UNITS DEPTHS & INTERVAL VELOCITIES				
Depth	**VsLeft**	VsRight	VsAvg	Vp	Depth	VsLeft	VsRight	VsAvg	Vp
Meters	M/sec.	M/sec.	M/sec.	M/sec.	Feet	Ft./sec.	Ft./sec.	Ft./sec.	Ft./sec.
15.21	228	243	236	1905	49.91	751	796	773	6211
15.85	259	263	261	1802	52.00	852	863	857	5875
16.43	391	397	394	1802	53.90	1285	1302	1292	5875
17.06	481	505	493	1818	55.96	1582	1657	1617	5929
17.70	588	532	560	2083	58.06	1935	1745	1838	6794
18.29	610	641	625	2500	60.01	2006	2103	2052	8152
18.90	741	730	735	2632	62.00	2437	2395	2413	8581
19.47	709	699	704	2353	63.89	2333	2294	2311	7673
19.80	800	719	760	2299	64.95	2632	2360	2493	7496
20.12	800	752	776	2532	66.00	2632	2467	2546	8255
20.76	833	840	837	2703	68.10	2741	2757	2746	8813
21.33	704	690	697	2410	69.99	2317	2263	2287	7858
21.34	730	704	717	2597	70.02	2401	2310	2353	8470
21.98	952	962	957	2439	72.10	3133	3155	3140	7953
22.58	1099	943	1021	2597	74.07	3615	3095	3350	8470
23.21	943	1000	972	2439	76.14	3104	3281	3188	7953
21.33	725	617	671	2469	69.99	2384	2025	2201	8052
21.63	658	685	671	2469	70.96	2164	2247	2203	8052
21.76	667	714	690	2410	71.39	2193	2344	2265	7858
21.86	667	649	658	2469	71.73	2193	2130	2159	8052
21.90	568	641	605	2532	71.85	1869	2103	1984	8255
22.05	649	725	687	2564	72.36	2136	2377	2254	8361
22.25	820	769	794	2703	72.99	2697	2524	2607	8813
22.84	1064	1111	1087	2857	74.95	3500	3645	3568	9317
23.46	1042	1087	1064	2703	76.97	3427	3566	3492	8813
24.07	943	1020	982	2500	78.96	3104	3348	3222	8152
24.66	1042	1064	1053	2778	80.91	3427	3490	3454	9058
25.28	980	893	937	3077	82.95	3225	2929	3073	10034
25.78	1042	1064	1053	3077	84.57	3427	3490	3454	10034
25.92	1064	1020	1042	3030	85.03	3500	3348	3419	9882
26.51	980	980	980	3030	86.98	3225	3217	3217	9882
27.14	943	962	952	2899	89.05	3104	3155	3125	9452
27.77	1064	1111	1087	2817	91.11	3500	3645	3568	9186
28.38	1190	1250	1220	2899	93.12	3916	4101	4003	9452
28.99	1190	1250	1220	3030	95.11	3916	4101	4003	9882



LEGEND

▲	Vs (R1-R2 INTERVAL)
■	Vp (R1-R2 INTERVAL)

GENERAL LITHOLOGY

	CLAY WITH GRAVEL (SLIDE MATERIAL)
	SANDSTONE GREYWACKE
	SHALE

NORCAL GEOPHYSICAL CONSULTANTS INC.
A Terracon COMPANY

321A BLODGETT STREET
COTATI, CA 94931
PH. (707) 796-7170
FAX. (707) 796-7175
www.norcalgeophysical.com

REGISTERED GEOPHYSICIST
WILLIAM J. HENRICH
No. 893
STATE OF CALIFORNIA

SUSPENSION P- & S-WAVE VELOCITY PROFILE BOREHOLE B-1

LOCATION: 1130 OXFORD STREET, BERKELEY, CALIFORNIA

CLIENT: ALAN KROPP & ASSOCIATES

JOB #: NS185097	DATE: JANUARY 2019	PLATE 1
DRAWN BY: G.RANDALL	APPROVED BY: WJH	

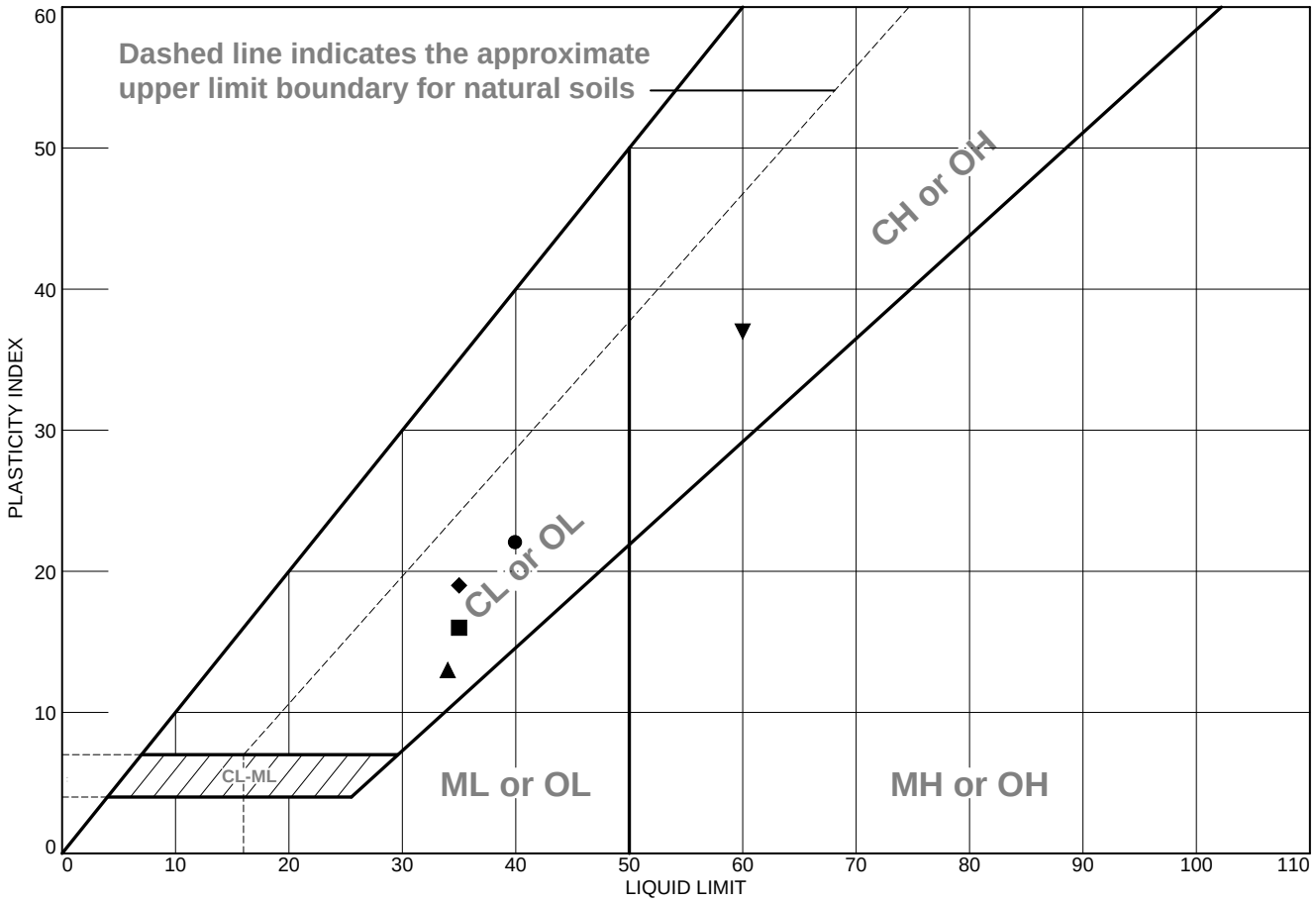
1/28/2019

APPENDIX D

LABORATORY TEST DATA:

BENCHMARK GEOLABS, LLC
B.HILLEBRANDT SOILS TESTING, INC.

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Yellowish brown clayey SAND with gravel	40	18	22	64.4	44.5	SC
■	Yellowish brown sandy lean CLAY	35	19	16	37.0	25.0	SC
▲	Yellowish brown clayey SABD with gravel	34	21	13	8.9	5.7	GW-GC
◆	Gray sandy lean CLAY	35	16	19	63.4	51.4	CL
▼	Gray sandy fat CLAY	60	23	37	79.4	61.4	CH

Project No. **Client:**

Project:

Remarks:

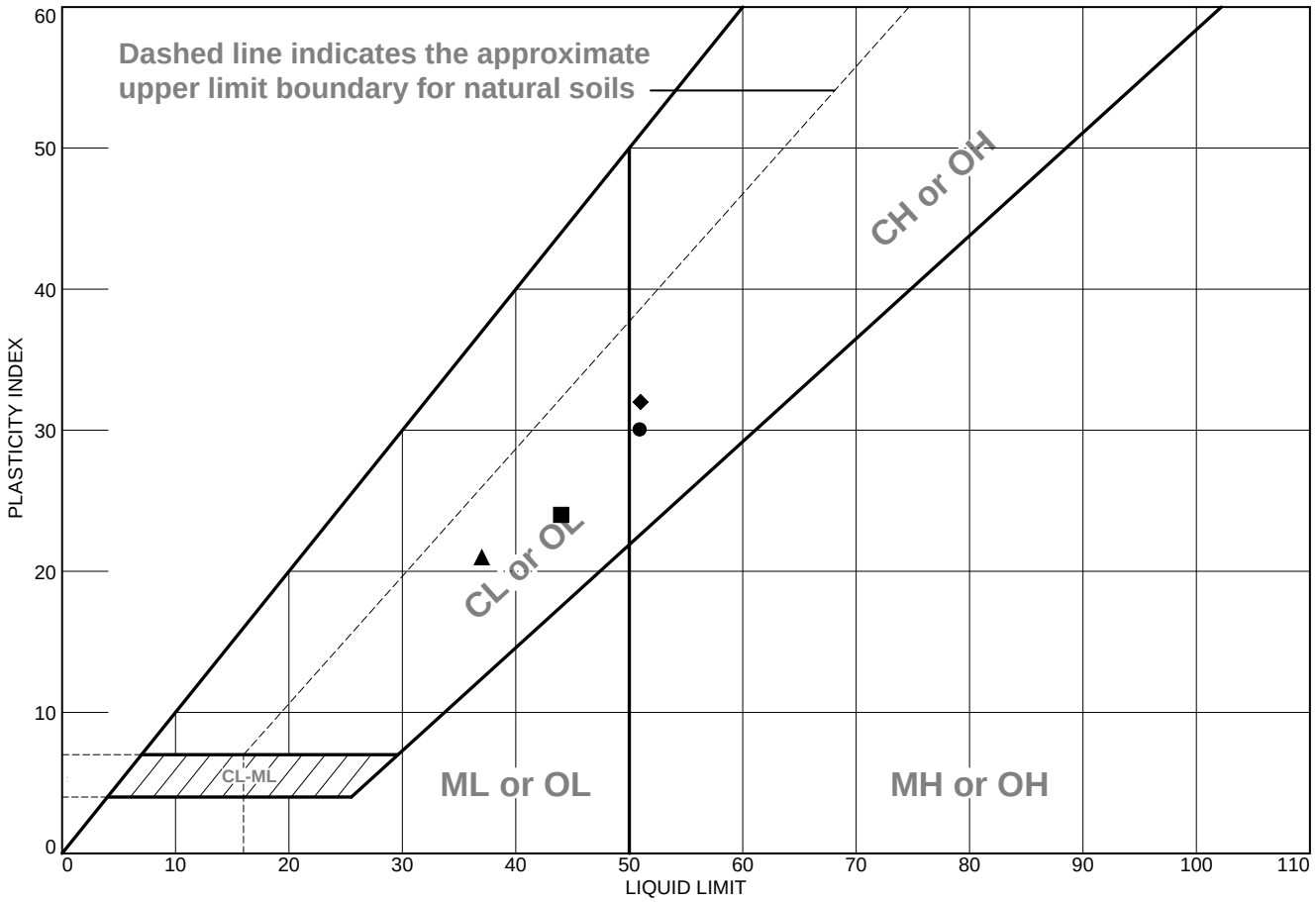
●**Source of Sample:** B-1 **Depth:** 2.5 - 4.0'
■**Source of Sample:** B-1 **Depth:** 10.5 - 13.0'
▲**Source of Sample:** B-1 **Depth:** 23.0 - 25.0'
◆**Source of Sample:** B-1 **Depth:** 30.0 - 35.0'
▼**Source of Sample:** B-1 **Depth:** 51.2 - 51.5'

B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Figure

Tested By: BH

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Very dark brown sandy fat CLAY	51	21	30	74.1	58.2	CH
■	Grayish brown sandy lean CLAY	44	20	24	64.5	52.0	CL
▲	Bluish gray clayey SAND	37	16	21	65.4	43.5	SC
◆	Dark brown and gray sandy fat CLAY	51	19	32	81.7	69.4	CH

Project No. **Client:**

Project:

●**Source of Sample:** B-2 **Depth:** 6.0 - 6.5'
■**Source of Sample:** B-2 **Depth:** 15.5 - 16.0'
▲**Source of Sample:** B-2 **Depth:** 35.5 - 36.0'
◆**Source of Sample:** B-2 **Depth:** 45.5 - 46.0'

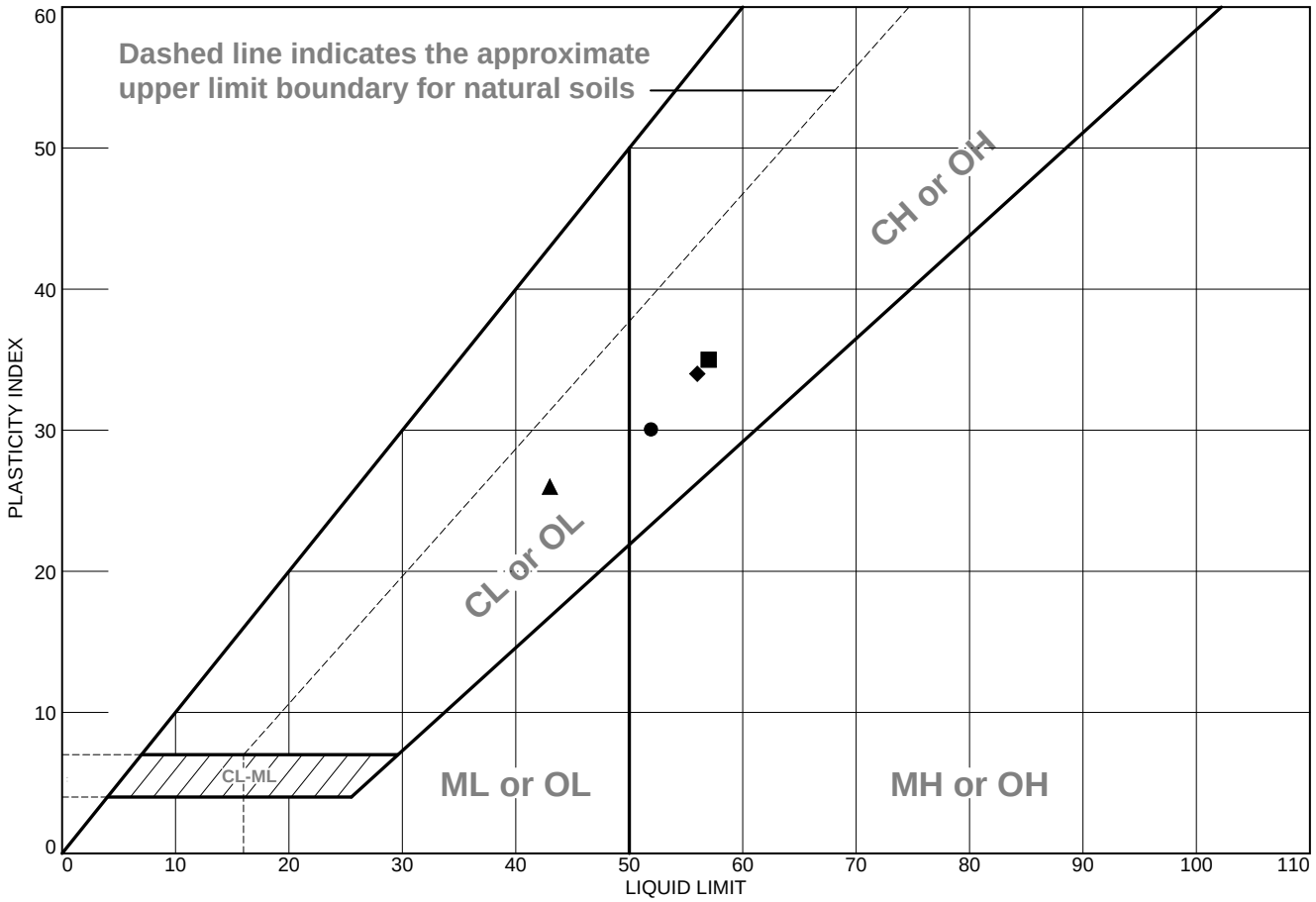
B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Remarks:

Figure

Tested By: BH

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish gray sandy fat CLAY	52	22	30	78.9	67.5	CH
■	Greenish gray fat CLAY with sand	57	22	35	86.5	78.3	CH
▲	Brown poorly graded GRAVEL with clay and sand	43	17	26	14.6	9.2	GP-GC
◆	Dark greenish gray fat CLAY with sand	56	22	34	86.4	74.3	CH

Project No. **Client:**

Project:

●**Source of Sample:** B-3 **Depth:** 10.7 - 12.0'
■**Source of Sample:** B-3 **Depth:** 15.3 - 16.5'
▲**Source of Sample:** B-3 **Depth:** 24.5 - 25.0'
◆**Source of Sample:** B-3 **Depth:** 19.6 - 21.5'

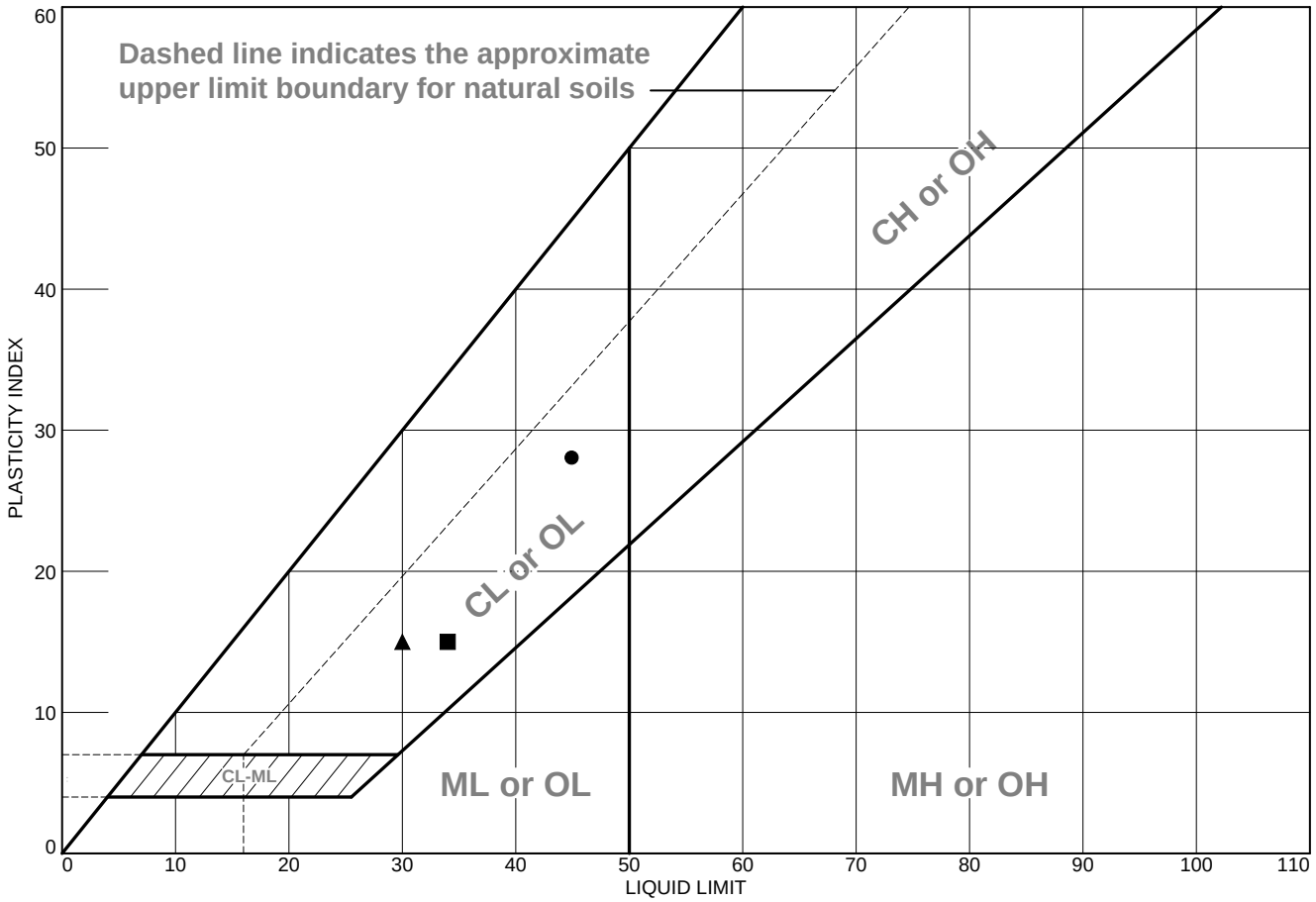
Remarks:

B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Figure

Tested By: BH

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Brownish gray lean CLAY with sand	45	17	28	82.4	72.8	CL
■	Brown clayey SAND	34	19	15	34.5	24.4	SC
▲	Gray clayey SAND with gravel	30	15	15	32.6	17.9	SC

Project No. **Client:**

Project:

●**Source of Sample:** B-5 **Depth:** 6.0 - 6.5'
■**Source of Sample:** B-5 **Depth:** 11.0 - 11.5'
▲**Source of Sample:** B-5 **Depth:** 40.5 - 41.0'

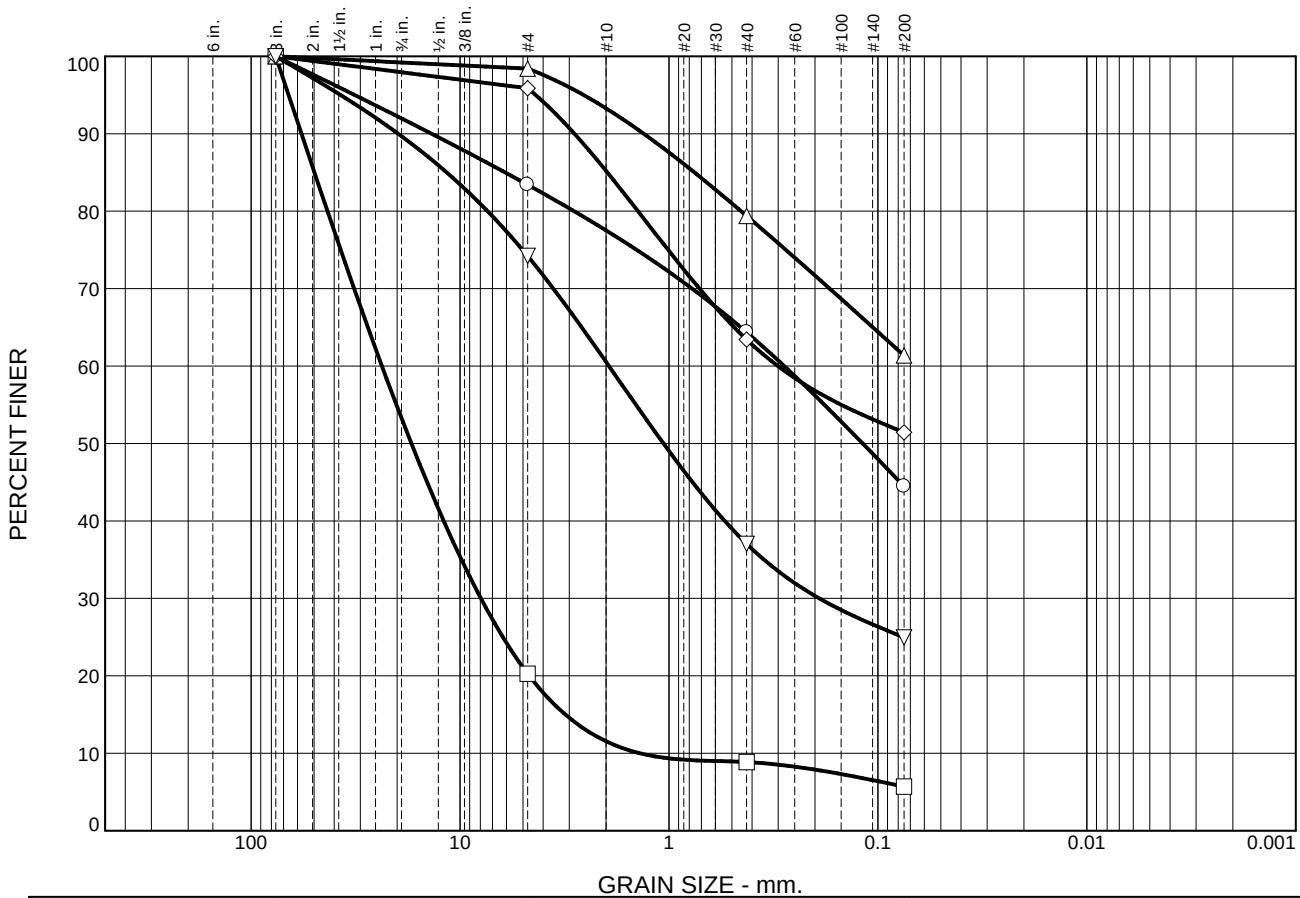
B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Remarks:

Figure

Tested By: BH

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	8.0	8.6	5.9	13.1	19.9	44.5	
□	0.0	46.7	33.0	8.8	2.6	3.2	5.7	
△	0.0	0.8	0.8	5.1	13.9	18.0	61.4	
◇	0.0	2.1	2.0	10.7	21.8	12.0	51.4	
▽	0.0	10.3	15.5	13.7	23.5	12.0	25.0	

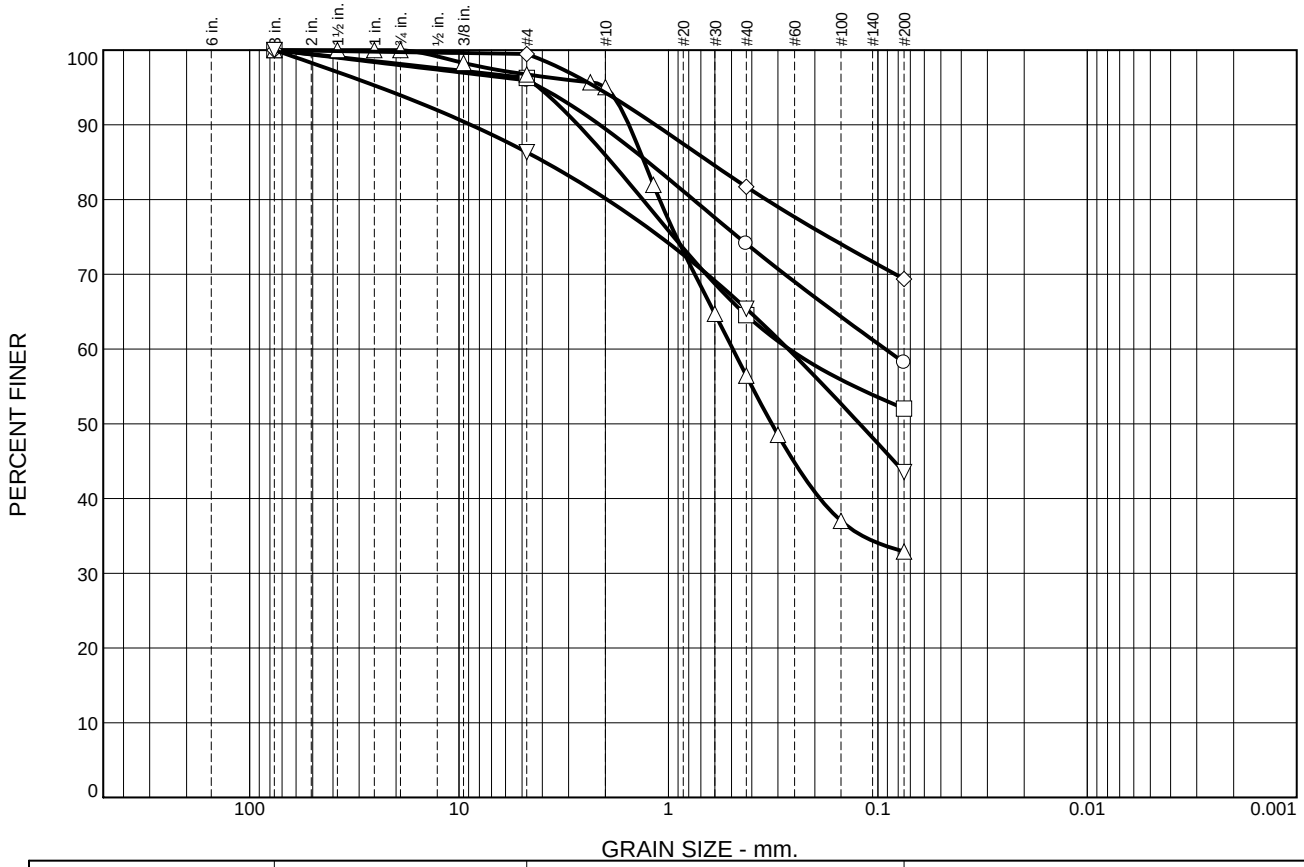
SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	Material Description	USCS
○	B-1		2.5 - 4.0'	Yellowish brown clayey SAND with gravel	SC
□	B-1		23.0 - 25.0'	Yellowish brown clayey SABD with gravel	GW-GC
△	B-1		51.2 - 51.5'	Gray sandy fat CLAY	CH
◇	B-1		30.0 - 35.0'	Gray sandy lean CLAY	CL
▽	B-1		10.5 - 13.0'	Yellowish brown sandy lean CLAY	SC

B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Client:
Project:
Project No.: **Figure**

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	2.0	2.0	6.5	15.4	15.9	58.2	
□	0.0	1.9	1.8	10.4	21.4	12.5	52.0	
△	0.0	0.0	3.3	1.7	38.5	23.6	32.9	
◇	0.0	0.3	0.2	5.2	12.6	12.3	69.4	
▽	0.0	6.0	7.7	6.2	14.7	21.9	43.5	

SOIL DATA

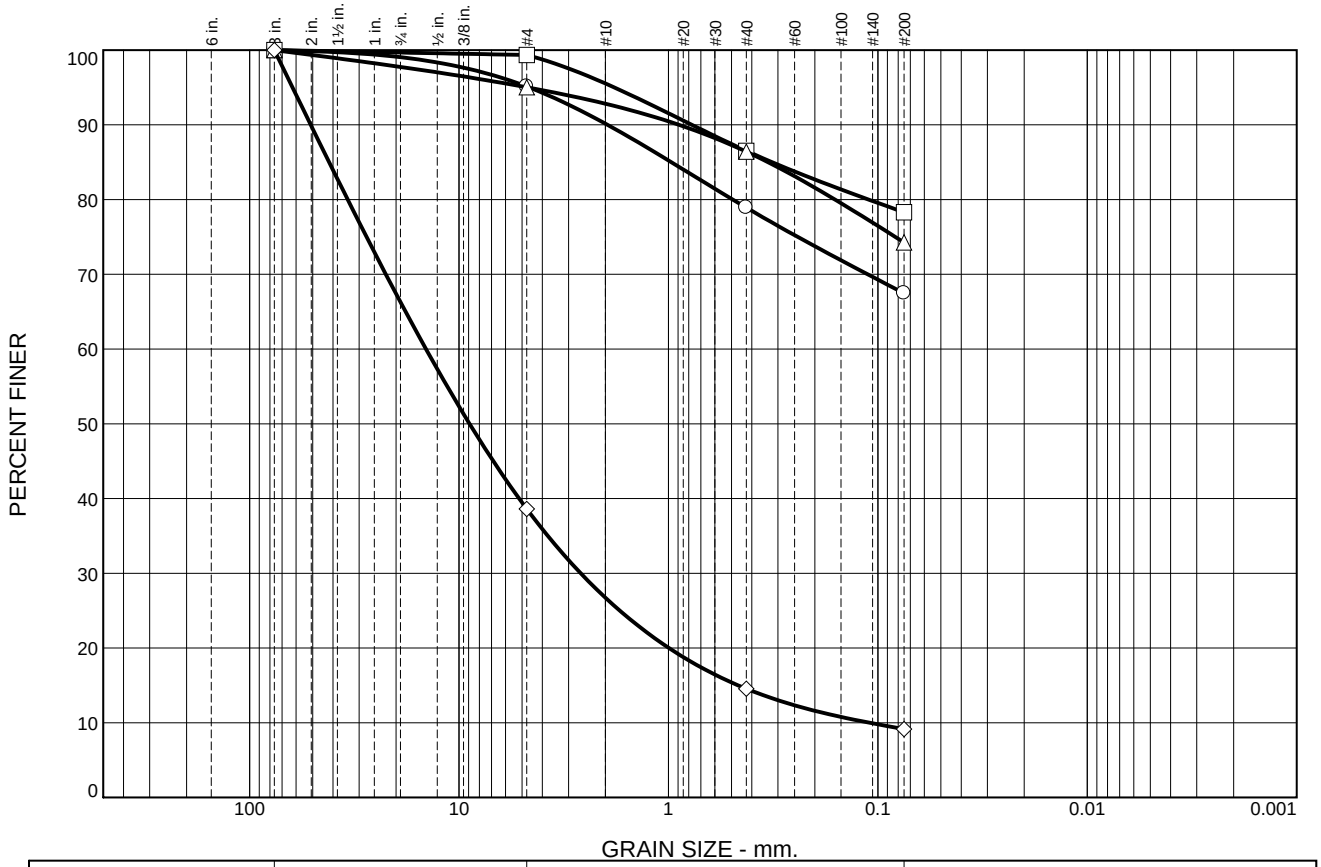
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	Material Description	USCS
○	B-2		6.0 - 6.5'	Very dark brown sandy fat CLAY	CH
□	B-2		15.5 - 16.0'	Grayish brow sandy lean CLAY	CL
△	B-2		25.5 - 26.0'	Yellowish brown silty SAND	SM
◇	B-2		45.5 - 46.0'	Dark brown and gray sandy fat CLAY	CH
▽	B-2		35.5 - 36.0'	Bluish gray clayey SAND	SC

B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Client:
Project:
Project No.: **Figure**

Tested By: BH

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.9	4.0	4.9	11.3	11.4	67.5	
□	0.0	0.3	0.4	3.8	9.0	8.2	78.3	
△	0.0	2.3	2.7	2.2	6.4	12.1	74.3	
◇	0.0	33.7	27.7	11.9	12.1	5.4	9.2	

SOIL DATA

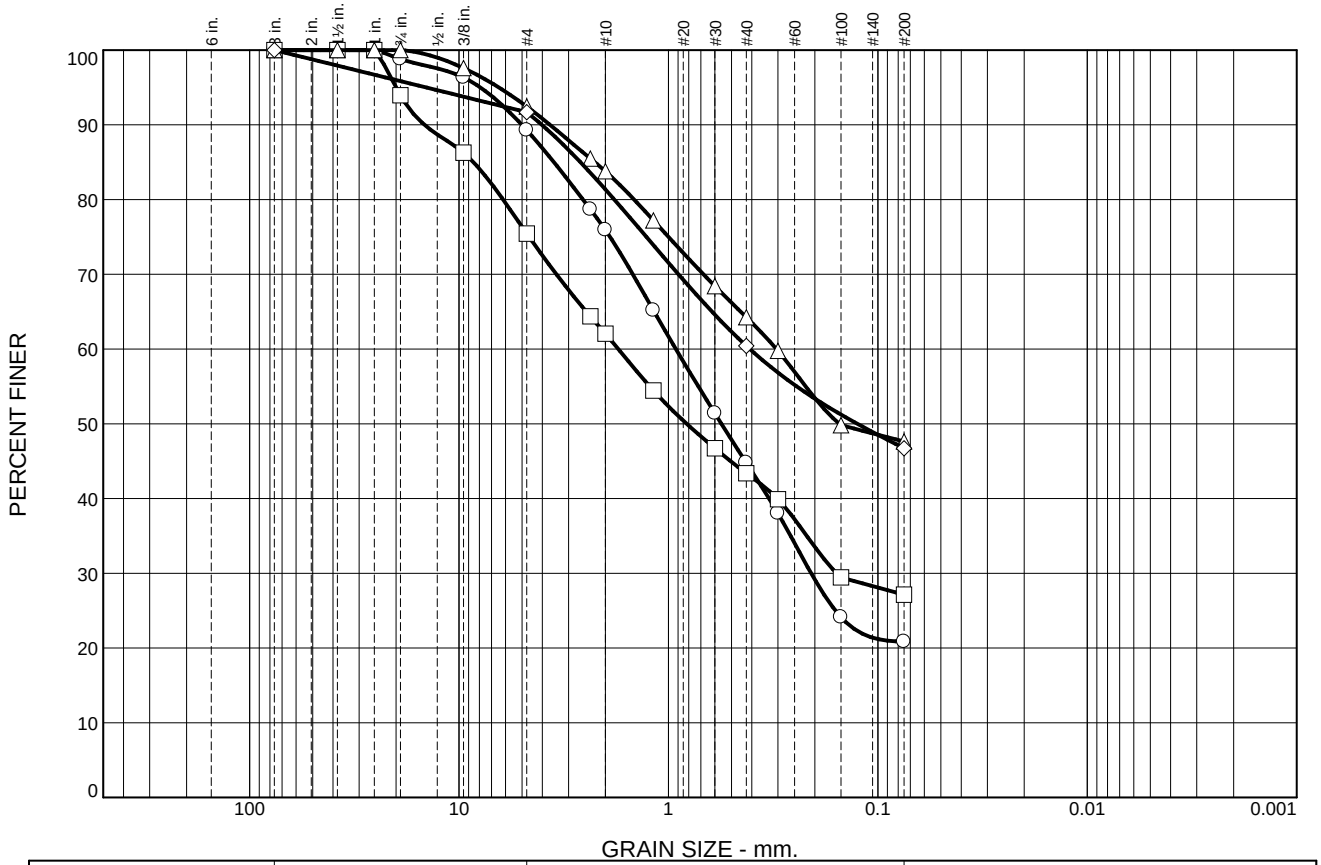
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	Material Description	USCS
○	B-3		10.7 - 12.0'	Greenish gray sandy fat CLAY	CH
□	B-3		15.3 - 16.5'	Greenish gray fat CLAY with sand	CH
△	B-3		19.6 - 21.5'	Dark greenish gray fat CLAY with sand	CH
◇	B-3		24.5 - 25.0'	Brown poorly graded GRAVEL with clay and sand	GP-GC

B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Client:
Project:
Project No.: **Figure**

Tested By: BH

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	1.2	9.5	13.4	31.1	23.9	20.9	
□	0.0	6.0	18.6	13.3	18.7	16.3	27.1	
△	0.0	0.0	7.6	8.6	19.5	16.7	47.6	
◇	0.0	4.2	4.1	10.4	20.9	13.7	46.7	

SOIL DATA

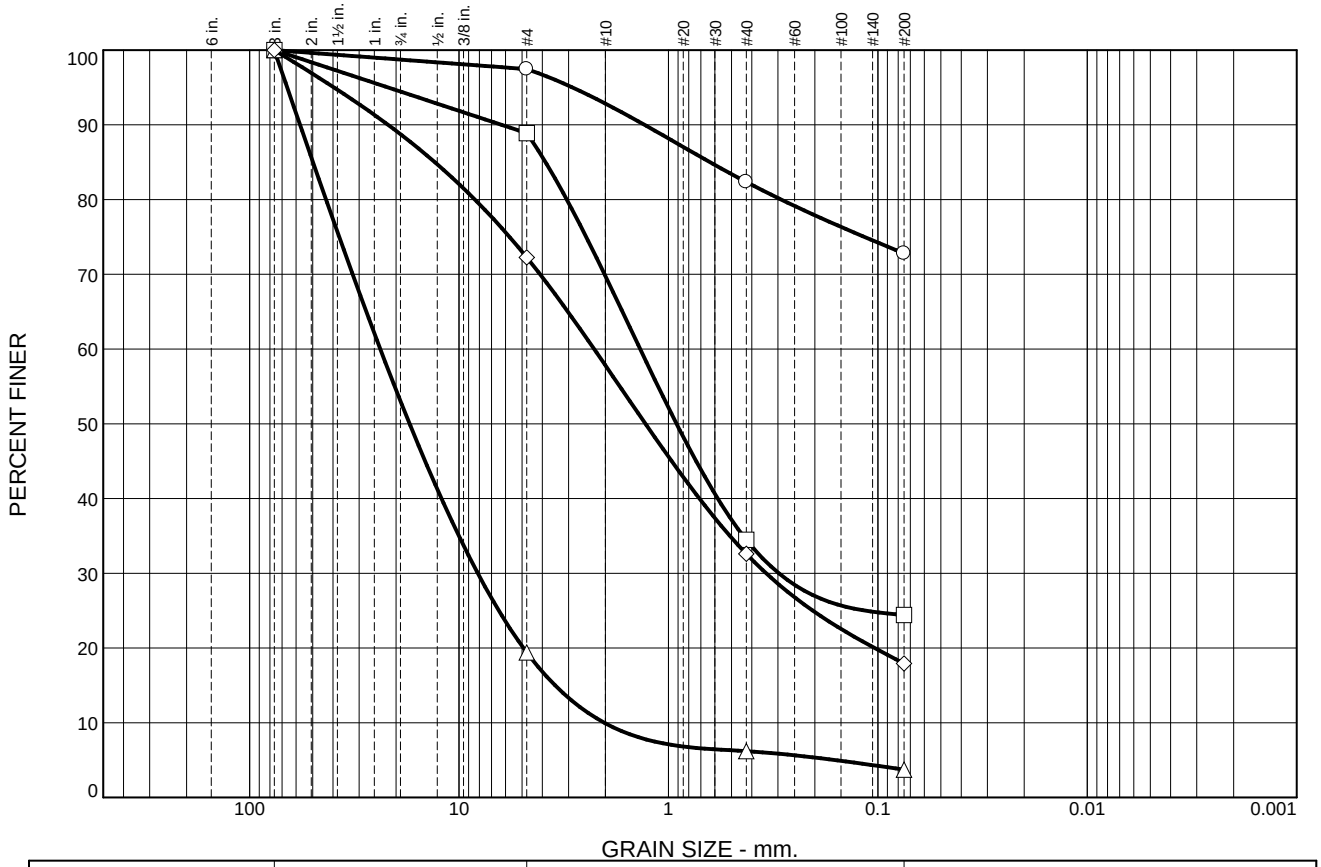
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	Material Description	USCS
○	B-4		16.2 - 17.5'	Yellowish brown to pinkish white silty SAND	SM
□	B-4		27.8 - 29.5'	Brownish yeloow to pinkish white silty SAND with gravel	SM
△	B-4		44.5 - 45.5'	Dusky red and gray clayey SAND	SC
◇	B-4		48.5 - 49.0'	Bluish gray clayey SAND	SC

B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

Client:
Project:
Project No.: **Figure**

Tested By: BH

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	1.3	1.2	4.7	10.4	9.6	72.8	
□	0.0	5.5	5.6	19.1	35.3	10.1	24.4	
△	0.0	46.9	33.7	9.5	3.7	2.5	3.7	
◇	0.0	11.2	16.5	14.5	25.2	14.7	17.9	

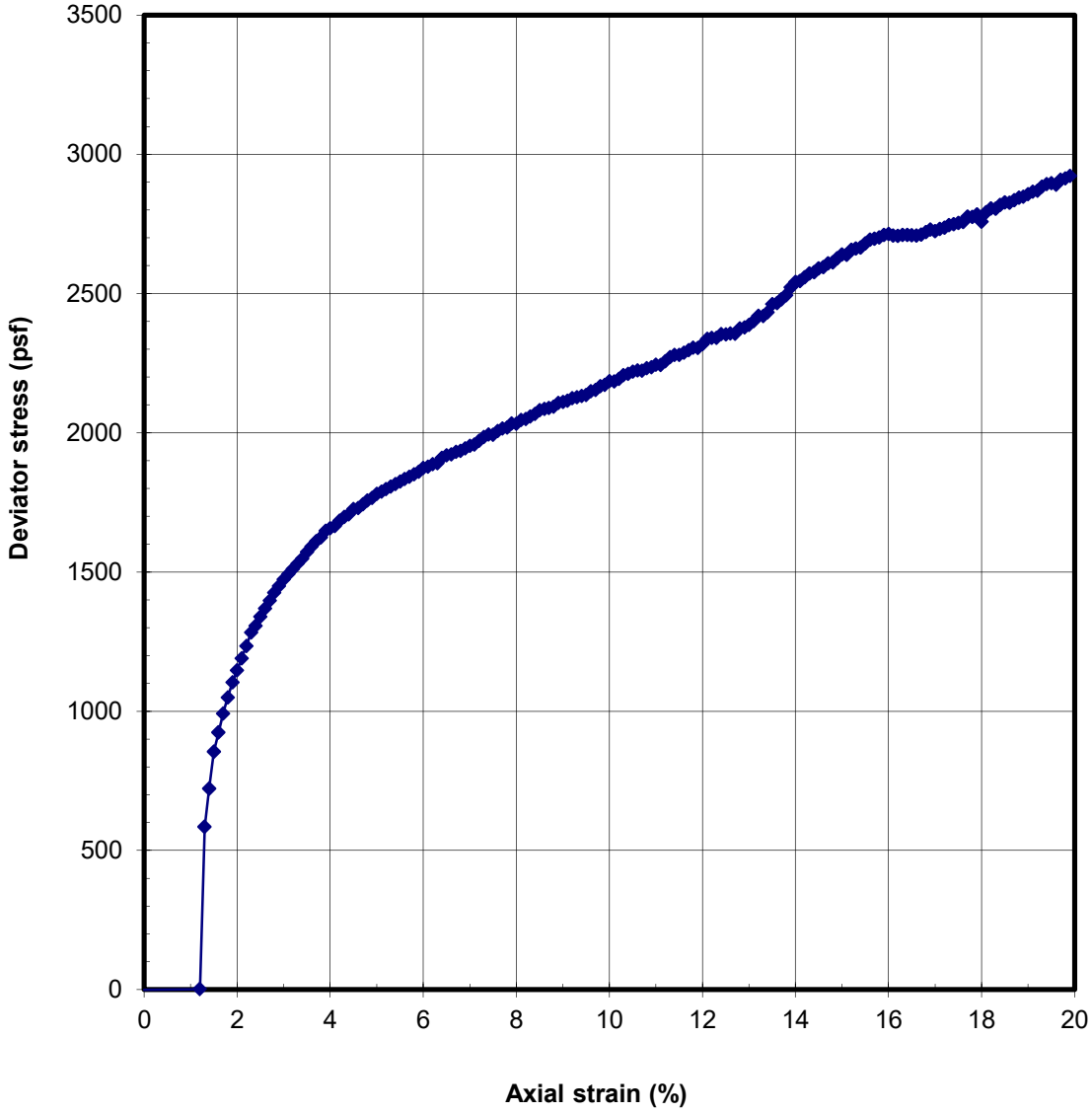
SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	Material Description	USCS
○	B-5		6.0 - 6.5'	Brownish gray lean CLAY with sand	CL
□	B-5		11.0 - 11.5'	Brown clayey SAND	SC
△	B-5		16.0 - 16.5'	Yellowish brown well graded GRAVEL with sand	GW
◇	B-5		40.5 - 41.0'	Gray clayey SAND with gravel	SC

B. HILLEBRANDT SOILS TESTING, INC.
+1 510-409-2816
SoilTesting@aol.com

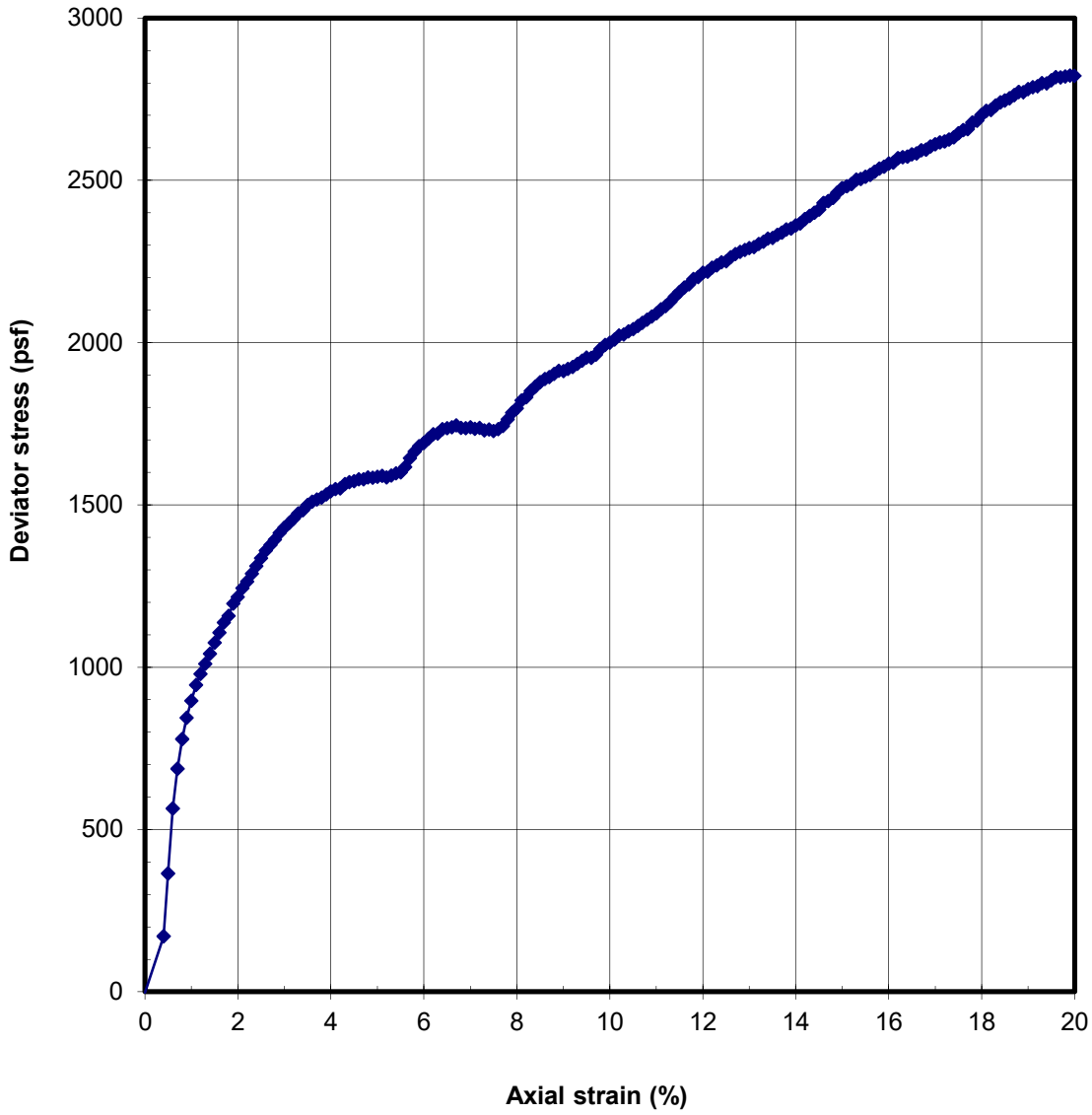
Client:
Project:
Project No.: **Figure**

Tested By: BH



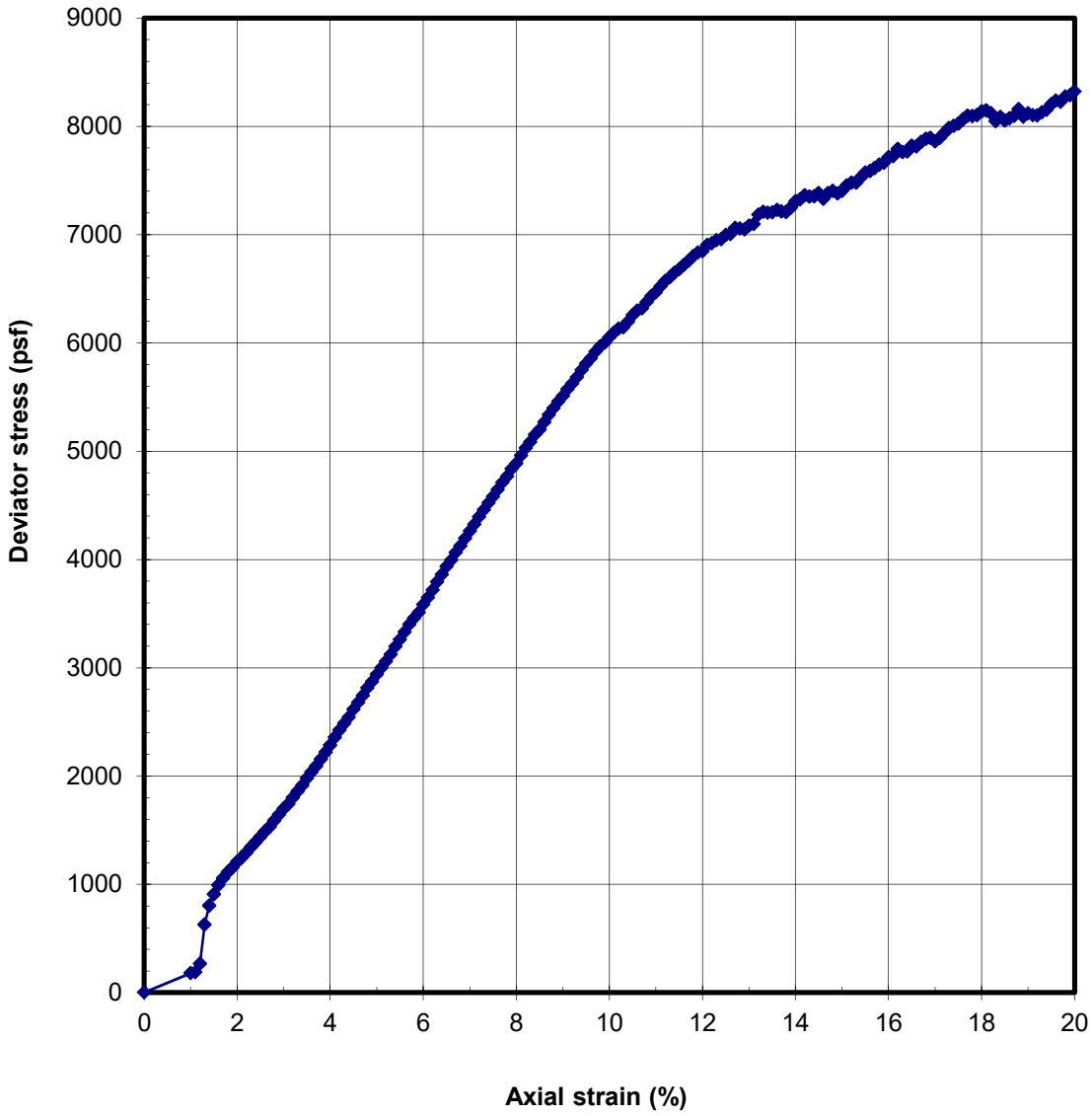
Sampler Type: Mod Cal		Shear Strength:	1468 psf
Diameter (in): 2.39	Height (in): 4.86	Strain at Failure:	20.0%
Moisture Content:	18.2 %	Confining Pressure:	2200 psf
Dry Density:	114 pcf	Strain Rate:	.07%/min
Source: B-2 at 35.5 feet			
Description: Bluish gray clayey SAND			

OXFORD ELEMENTARY SCHOOL BERKELEY, CA		**CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST**	
B. HILLEBRANDT SOILS TESTING, INC	Date: 06/13/19	Project No. 1853.3	Figure



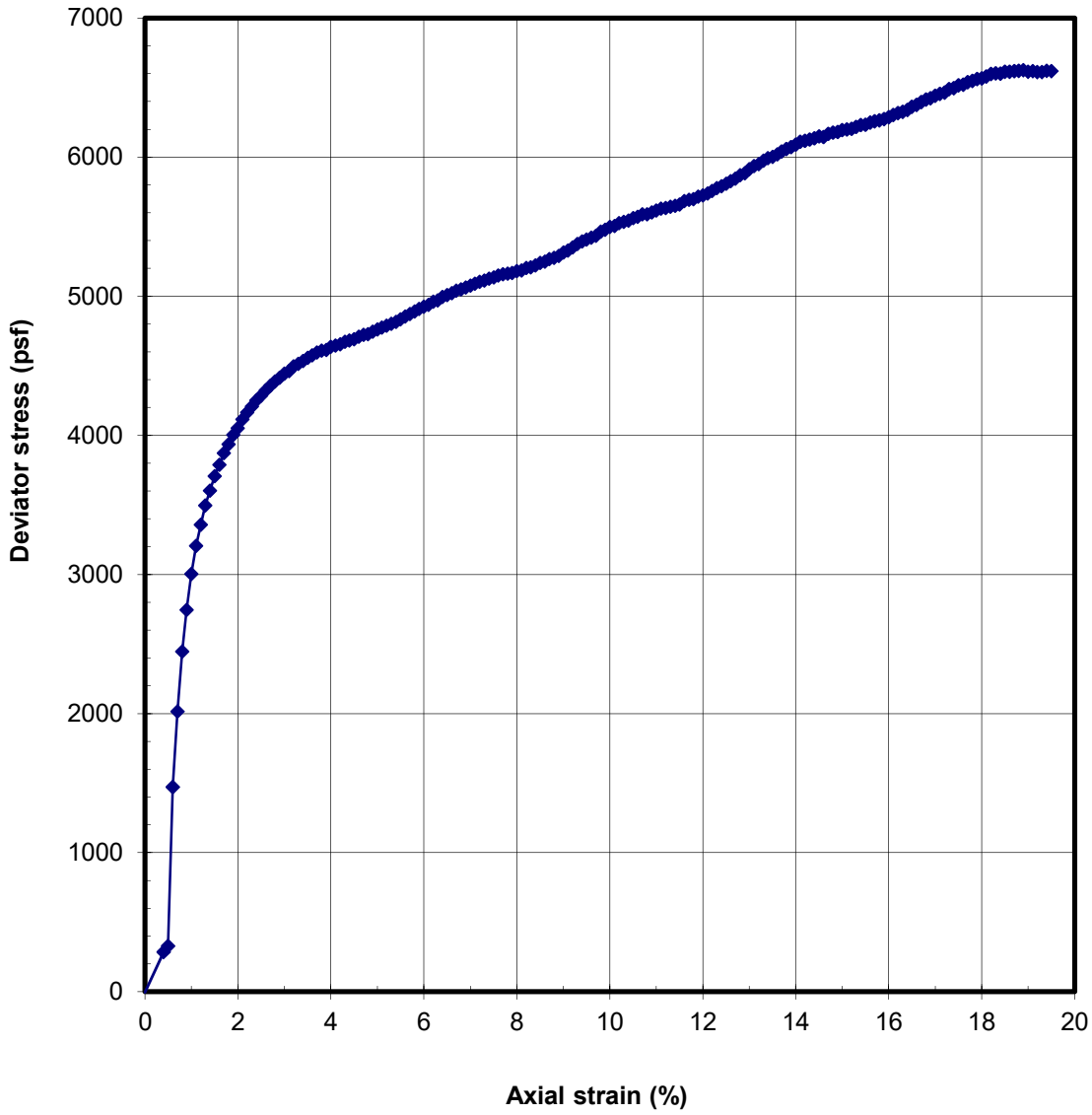
Sampler Type: Shelby		Shear Strength:	1411 psf
Diameter (in): 2.82	Height (in): 6.35	Strain at Failure:	20.0%
Moisture Content:	25.1 %	Confining Pressure:	1000 psf
Dry Density:	102 pcf	Strain Rate:	.07%/min
Source: B-3 at 15.3 feet			
Description: Greenish gray fat CLAY with sand			

OXFORD ELEMENTARY SCHOOL BERKELEY, CA		**CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST**	
B. HILLEBRANDT SOILS TESTING, INC	Date: 06/15/19	Project No. 1853.3	Figure



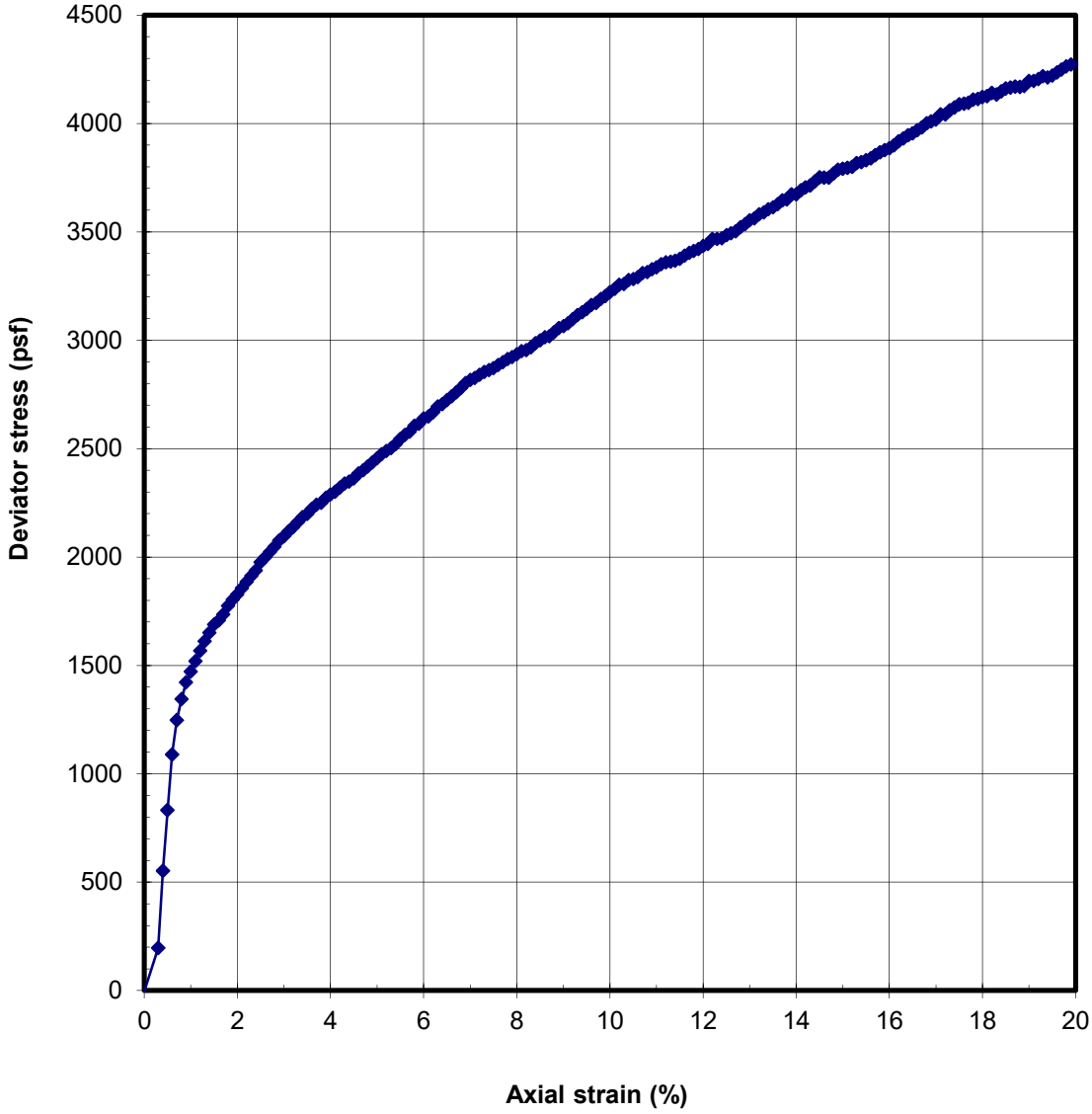
Sampler Type: Shelby		Shear Strength:	4161 psf
Diameter (in): 2.84	Height (in): 7.02	Strain at Failure:	20.0%
Moisture Content:	7.2 %	Confining Pressure:	1600 psf
Dry Density:	131 pcf	Strain Rate:	.07%/min
Source: B-3 at 24.5 feet			
Description: Brown poorly graded GRAVEL with clay and sand			

OXFORD ELEMENTARY SCHOOL BERKELEY, CA		**CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST**	
B. HILLEBRANDT SOILS TESTING, INC	Date: 06/16/19	Project No. 1853.3	Figure



Sampler Type: Mod Cal		Shear Strength:	3324 psf
Diameter (in): 2.40	Height (in): 5.41	Strain at Failure:	20.0%
Moisture Content:	17.4 %	Confining Pressure:	3000 psf
Dry Density:	119 pcf	Strain Rate:	.07%/min
Source: B-4 at 48.5 feet			
Description: Bluish gray clayey SAND			

OXFORD ELEMENTARY SCHOOL BERKELEY, CA		**CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST**	
B. HILLEBRANDT SOILS TESTING, INC	Date: 06/17/19	Project No. 1853.3	Figure



Sampler Type: Mod Cal		Shear Strength:	2143 psf
Diameter (in): 2.39	Height (in): 5.45	Strain at Failure:	20.0%
Moisture Content:	14.4 %	Confining Pressure:	700 psf
Dry Density:	108 pcf	Strain Rate:	.07%/min
Source: B-5 at 11.0 feet			
Description: Brown clayey SAND			

OXFORD ELEMENTARY SCHOOL BERKELEY, CA		**CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST**	
B. HILLEBRANDT SOILS TESTING, INC	Date: 06/18/19	Project No. 1853.3	Figure

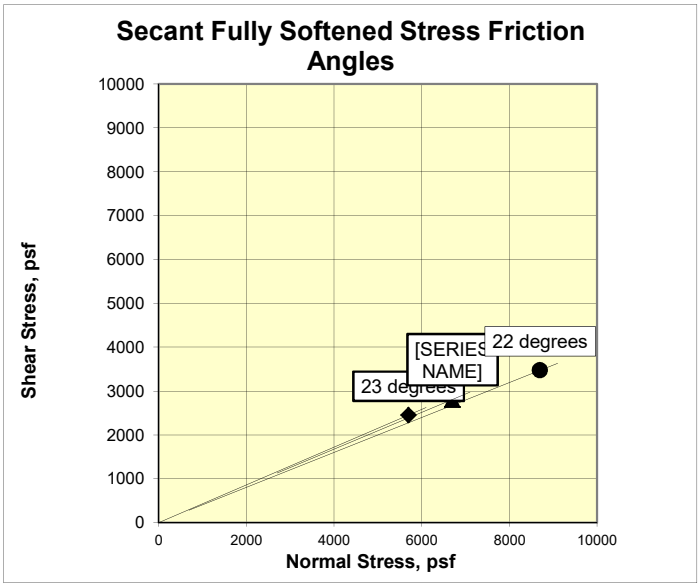
BENCHMARK GEOLABS

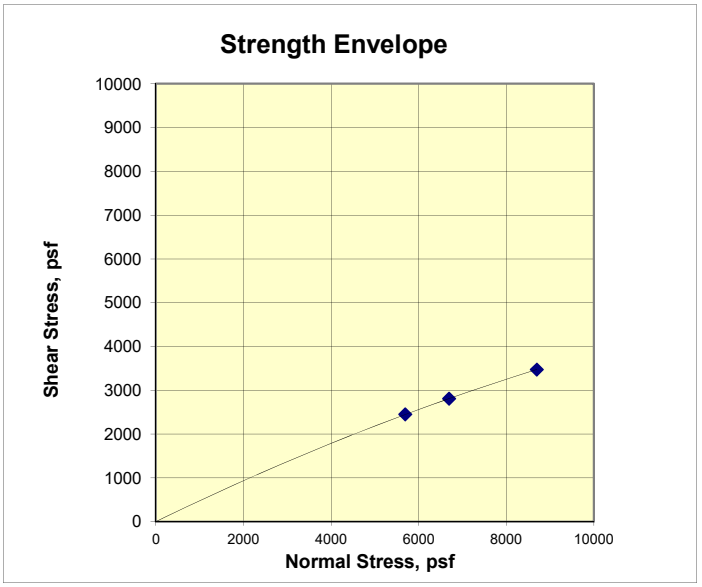
Drained Fully Softened Torsional Shear Strength (ASTM D7608)

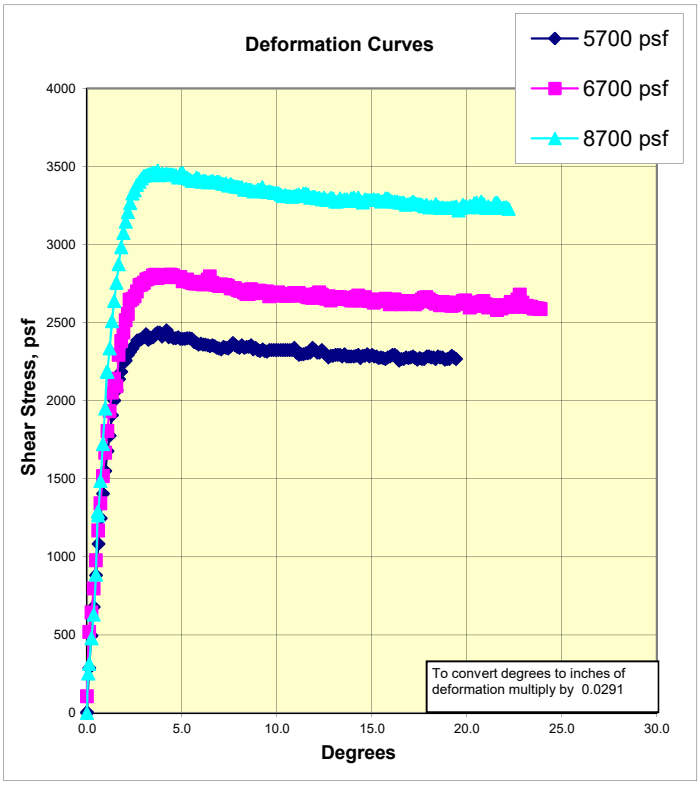
BGL Job No.:	049-001	**Boring:**	B-1	**Date:**	6/28/2019	**Clay, %:**	
Client:	Alan Kropp & Associates	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Oxford	**Depth (ft):**	55.9-56.5	**Checked:**	PJ	**PL:**	
Project Number:	1853-3	**Test Type:**	Reconstituted Fully Softened			**Sample Preparation:**	<#40
Soil Type:	Dark Gray CLAY w/ Sand						

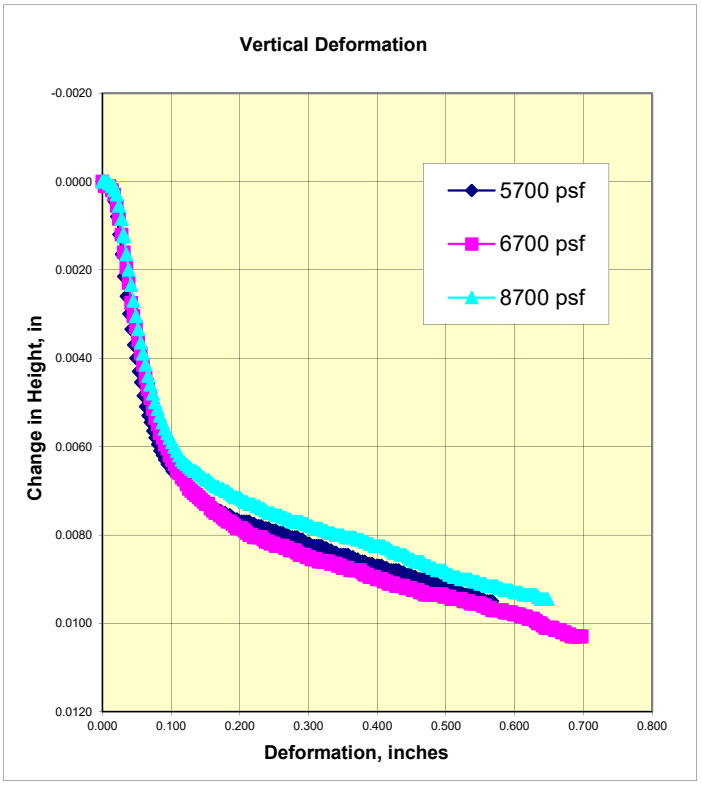
Normal Stress, psf	5700	6700	8700
Secant Phi, deg.:	23	23	22

Remarks:









BENCHMARK GEOLABS

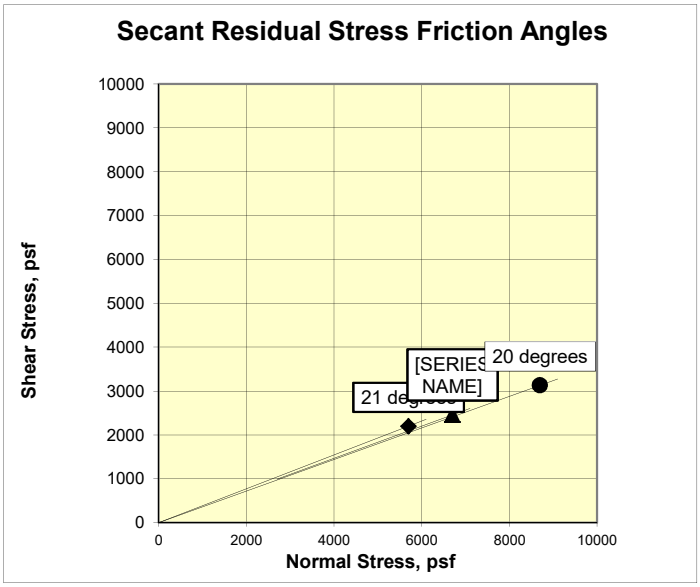
Drained Residual Torsional Shear Strength (ASTM D6467)

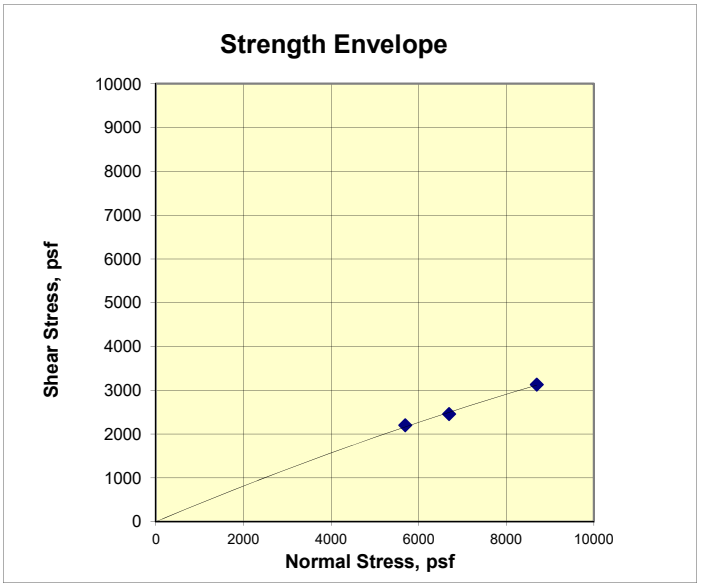
BGL Job No.:	049-001	**Boring:**	B-1	**Date:**	6/28/2019	**Clay, %:**	
Client:	Alan Kropp & Associates	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Oxford	**Depth (ft):**	55.9-56.5	**Checked:**	PJ	**PL:**	
Project Number:	1853-3	**Test Type:**	Reconstituted Residual			**Sample Preparation:**	<#40

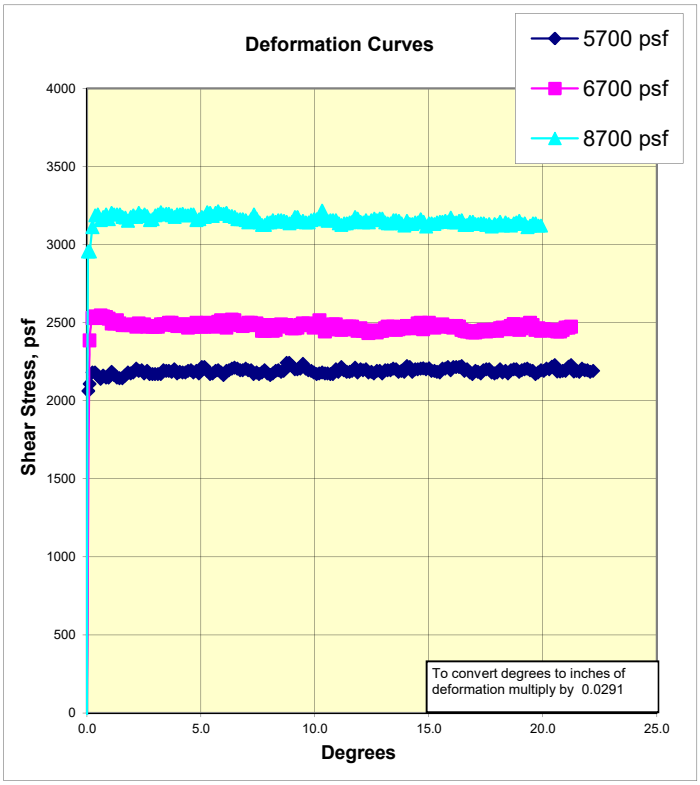
Soil Type: Dark Gray CLAY w/ Sand

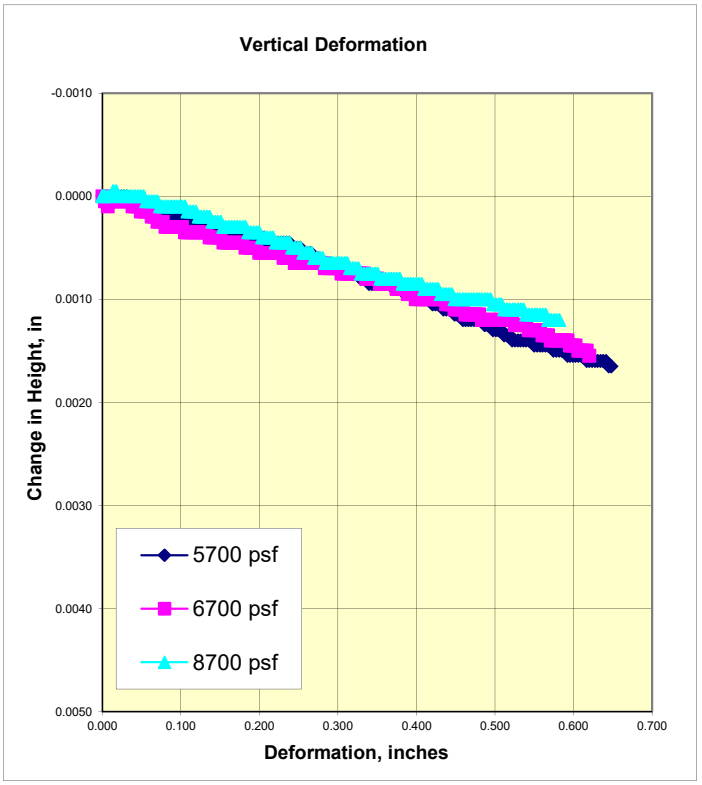
Normal Stress, psf	5700	6700	8700
Secant Phi, deg.:	21	20	20

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









BENCHMARK GEOLABS

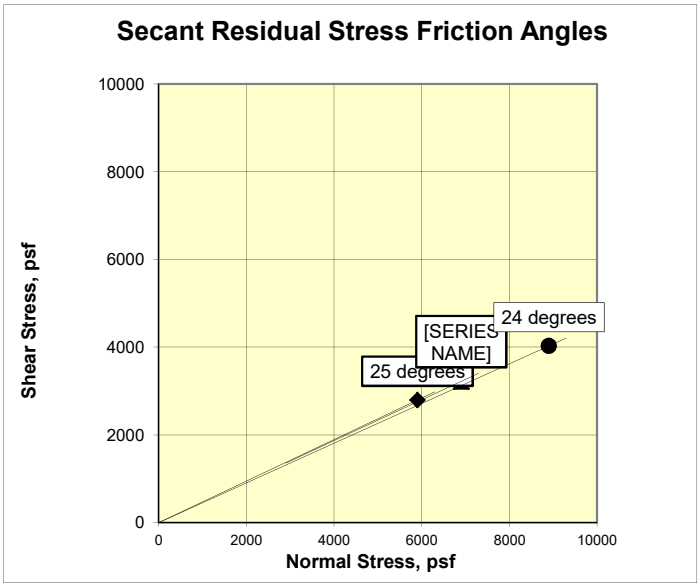
Drained Residual Torsional Shear Strength (ASTM D6467)

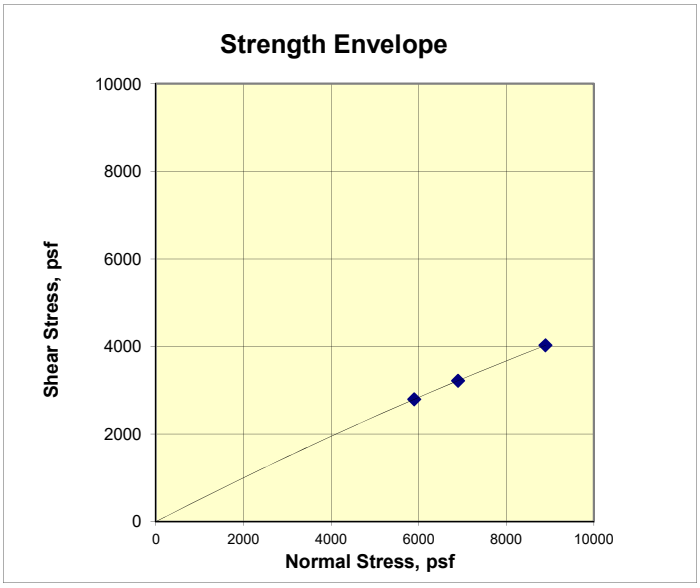
BGL Job No.:	049-001	**Boring:**	B-1	**Date:**	7/5/2019	**Clay, %:**	
Client:	Alan Kropp & Associates	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Oxford	**Depth (ft):**	57.5-58.0	**Checked:**	PJ	**PL:**	
Project Number:	1853-3	**Test Type:**	Reconstituted Residual			**Sample Preparation:**	<#40

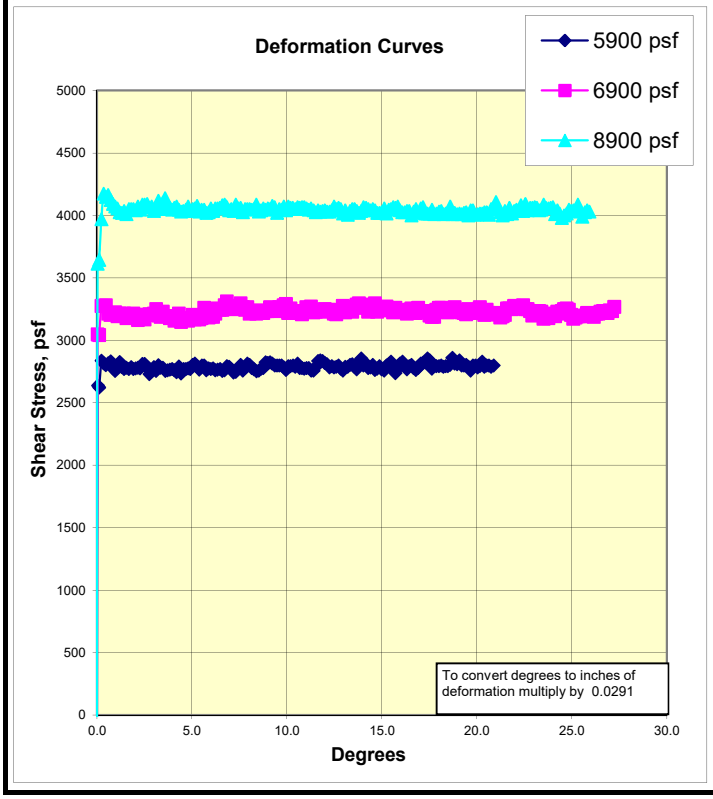
Soil Type: Very Dark Gray CLAY w/ Sand

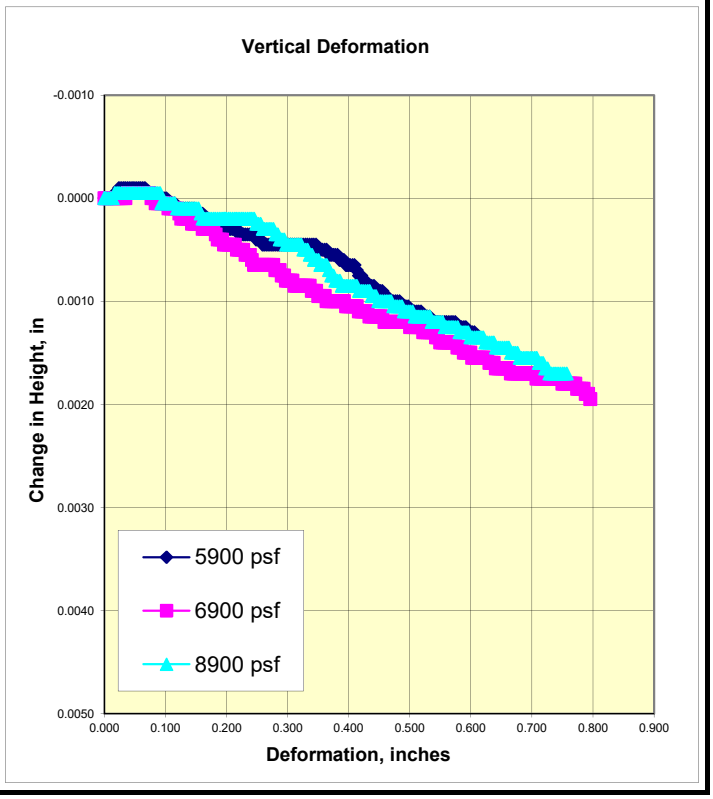
Normal Stress, psf	5900	6900	8900
Secant Phi, deg.:	25	25	24

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









BENCHMARK GEOLABS

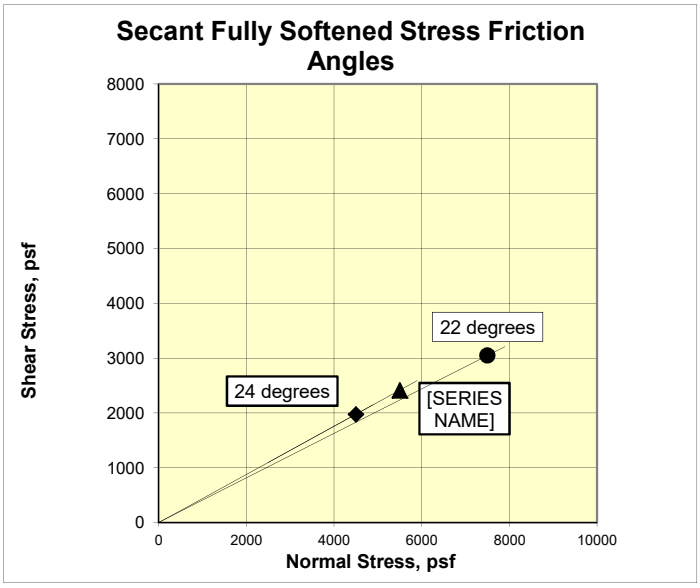
Drained Fully Softened Torsional Shear Strength (ASTM D7608)

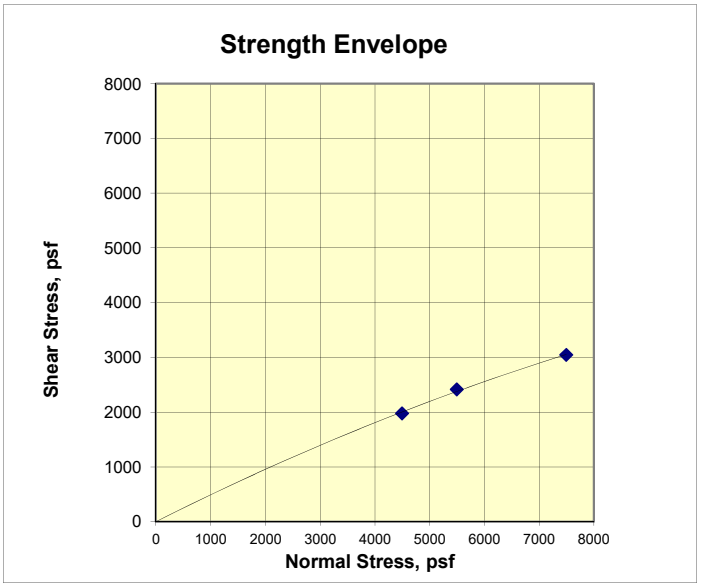
BGL Job No.:	049-001	**Boring:**	B-2	**Date:**	7/16/2019	**Clay, %:**	
Client:	Alan Kropp & Associates	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Oxford	**Depth (ft):**	46.0-46.5	**Checked:**	PJ	**PL:**	
Project Number:	1853-3	**Test Type:**	Reconstituted Fully Softened			**Sample Preparation:**	<#40

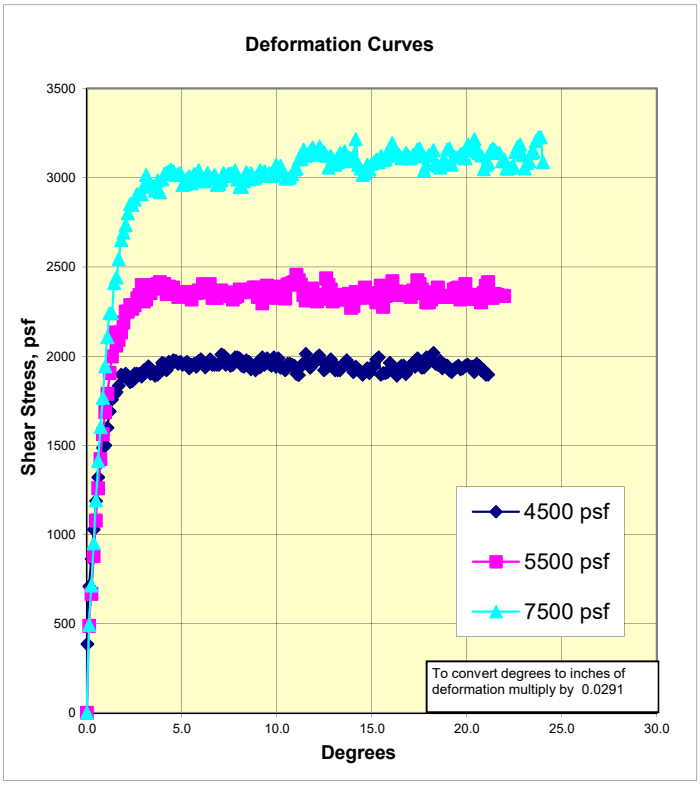
Soil Type: Dark Bluuish Gray Sandy CLAY

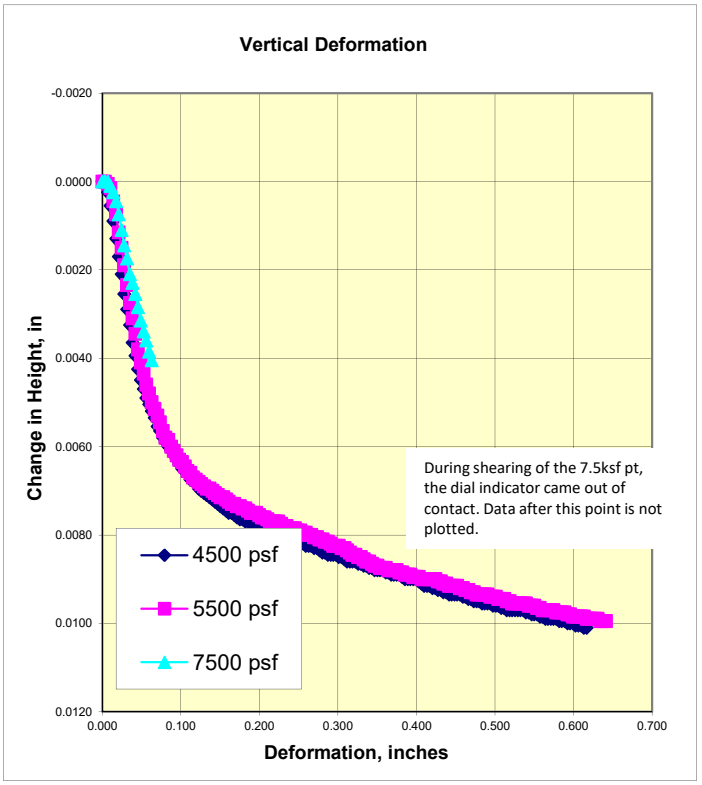
Normal Stress, psf	4500	5500	7500
Secant Phi, deg.:	24	24	22

Remarks: It appears that some fricton developed during shearing. Because of this, strengths were evaluated before 5 degrees of deformation.









BENCHMARK GEOLABS

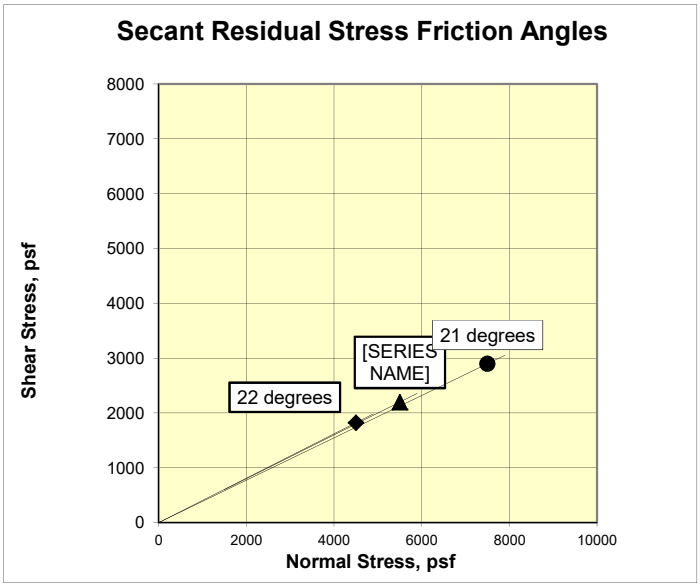
Drained Residual Torsional Shear Strength (ASTM D6467)

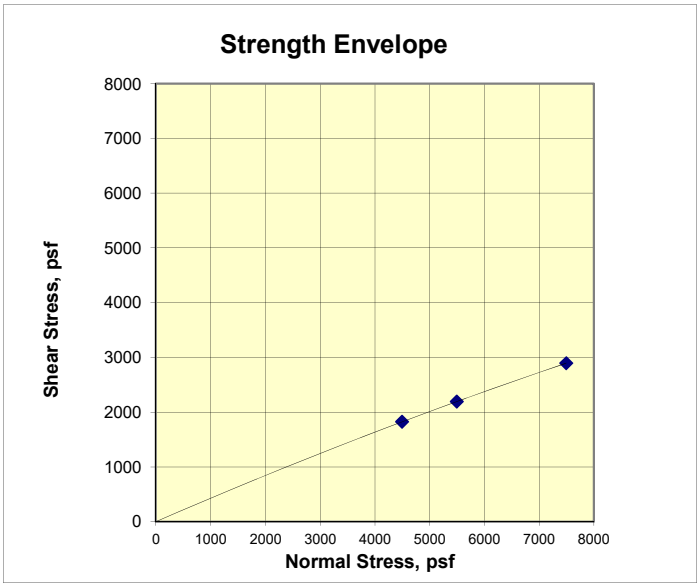
BGL Job No.:	049-001	**Boring:**	B-2	**Date:**	7/16/2019	**Clay, %:**	
Client:	Alan Kropp & Associates	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Oxford	**Depth (ft):**	46.0-46.5	**Checked:**	PJ	**PL:**	
Project Number:	1853-3	**Test Type:**	Reconstituted Residual			**Sample Preparation:**	<#40

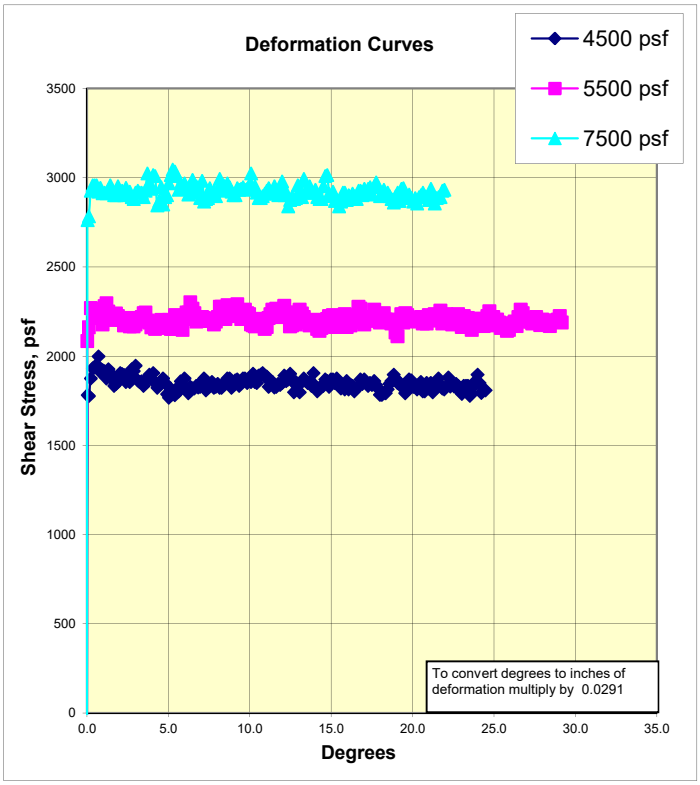
Soil Type: Dark Bluish Gray Sandy CLAY

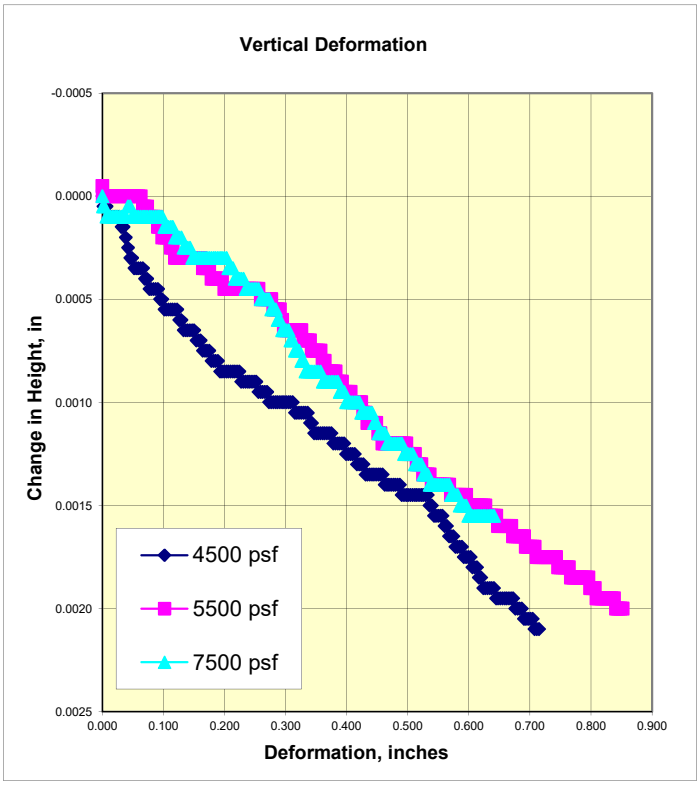
Normal Stress, psf	4500	5500	7500
Secant Phi, deg.:	22	22	21

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









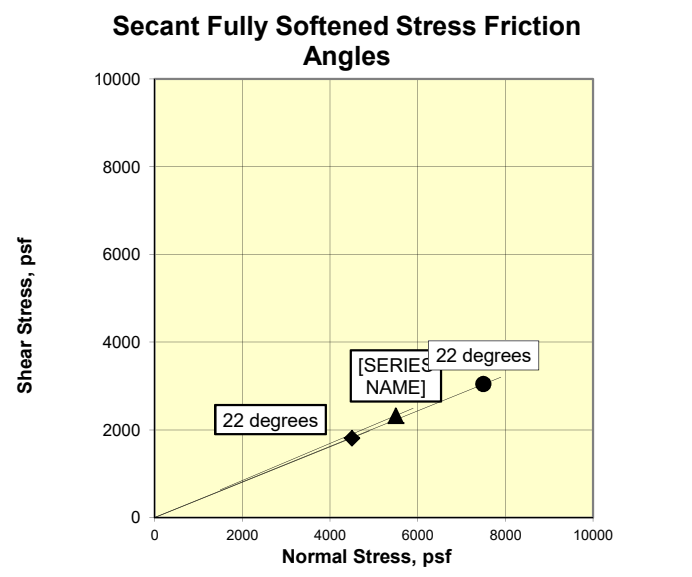
BENCHMARK GEOLABS

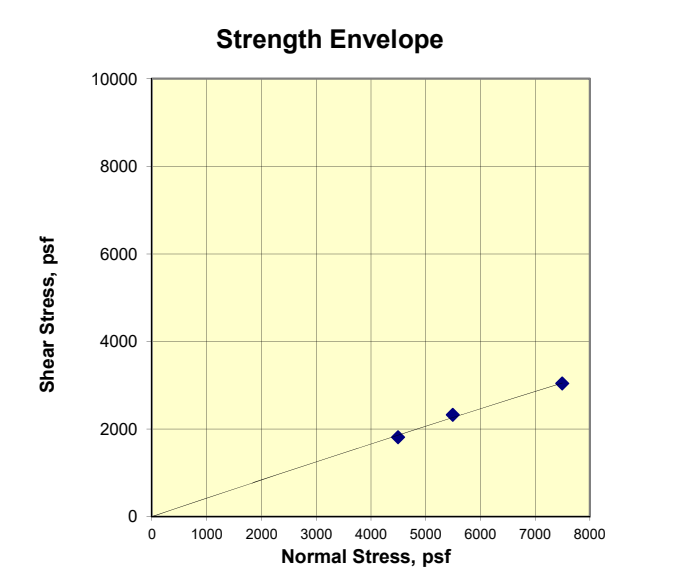
Drained Fully Softened Torsional Shear Strength (ASTM D7608)

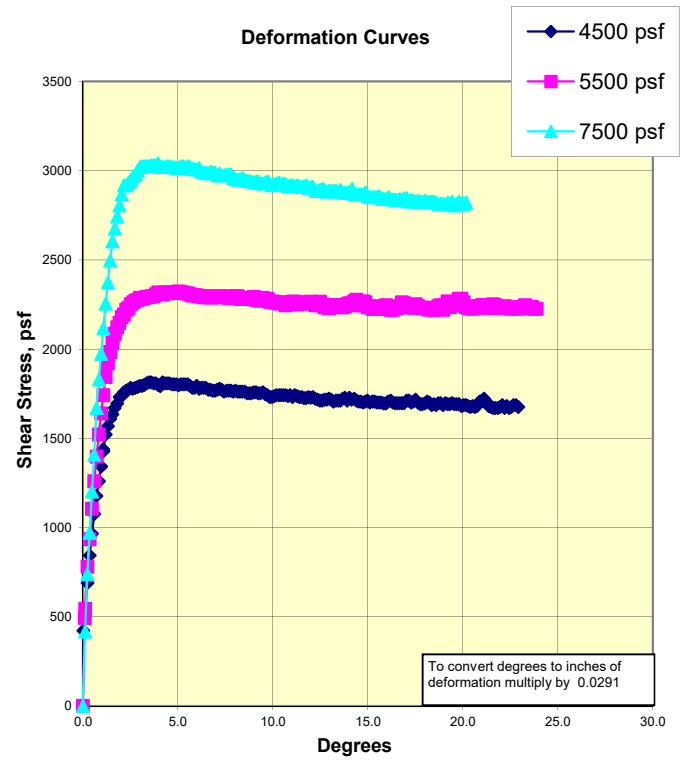
BGL Job No.:	049-001	**Boring:**	B-4	**Date:**	7/24/2019	**Clay, %:**	
Client:	Alan Kropp & Assoc.	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Oxford	**Depth (ft):**	46.4-46.7	**Checked:**	PJ	**PL:**	
Project Number:	1853-1	**Test Type:**	Reconstituted Fully Softened			**Sample Preparation:**	<#40
Soil Type:	Dark Gray CLAY						

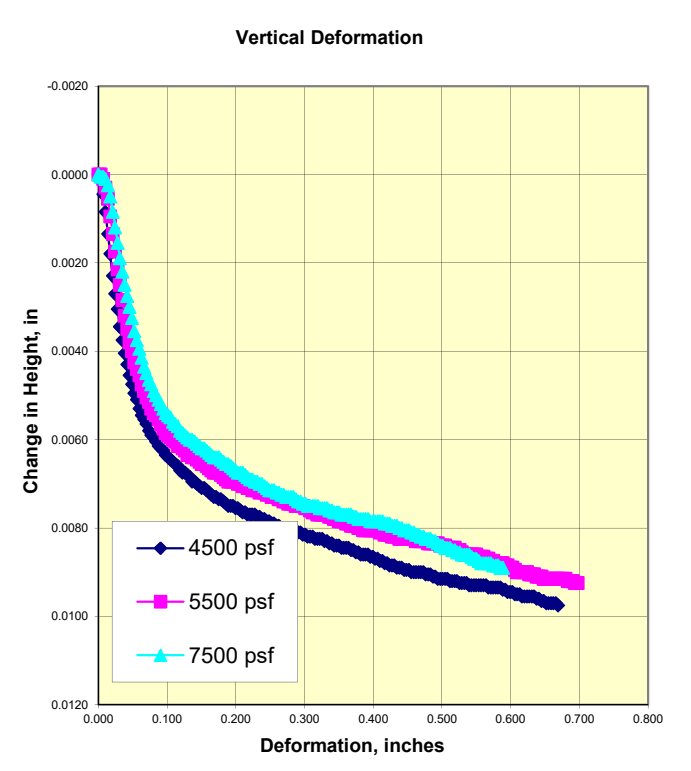
Normal Stress, psf	4500	5500	7500
Secant Phi, deg.:	22	23	22

Remarks:









BENCHMARK GEOLABS

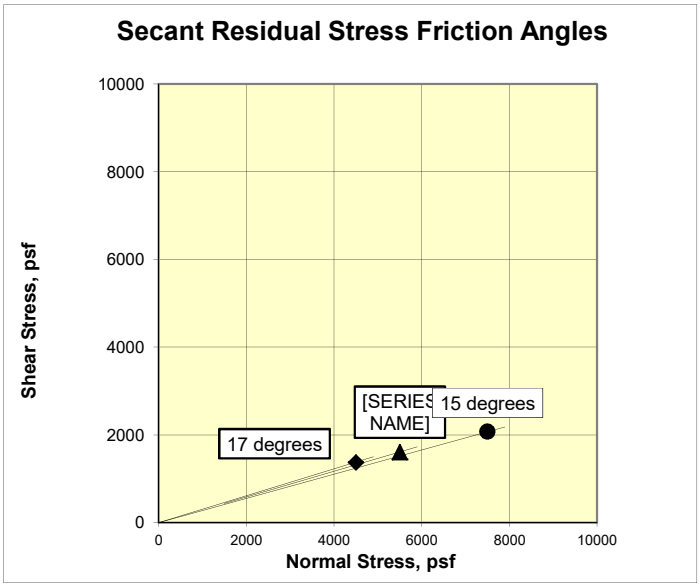
Drained Residual Torsional Shear Strength (ASTM D6467)

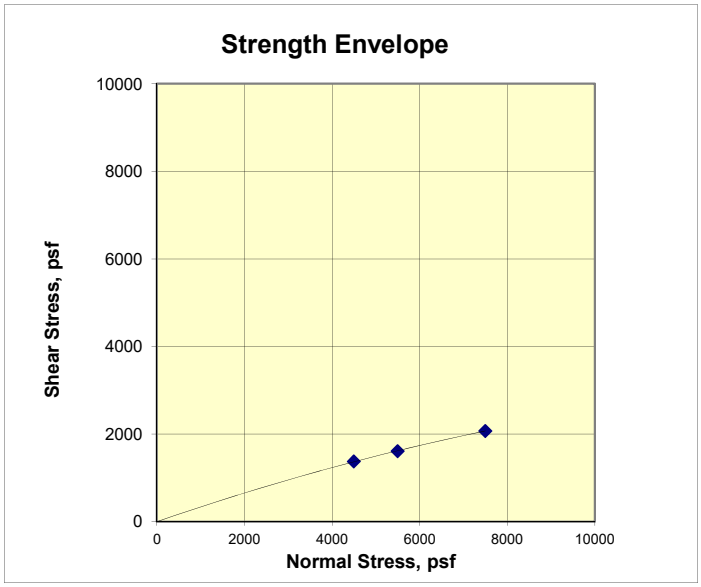
BGL Job No.:	049-001	**Boring:**	B-4	**Date:**	7/24/2019	**Clay, %:**	
Client:	Alan Kropp & Assoc.	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Oxford	**Depth (ft):**	46.4-46.7	**Checked:**	PJ	**PL:**	
Project Number:	1853-1	**Test Type:**	Reconstituted Residual			**Sample Preparation:**	<#40

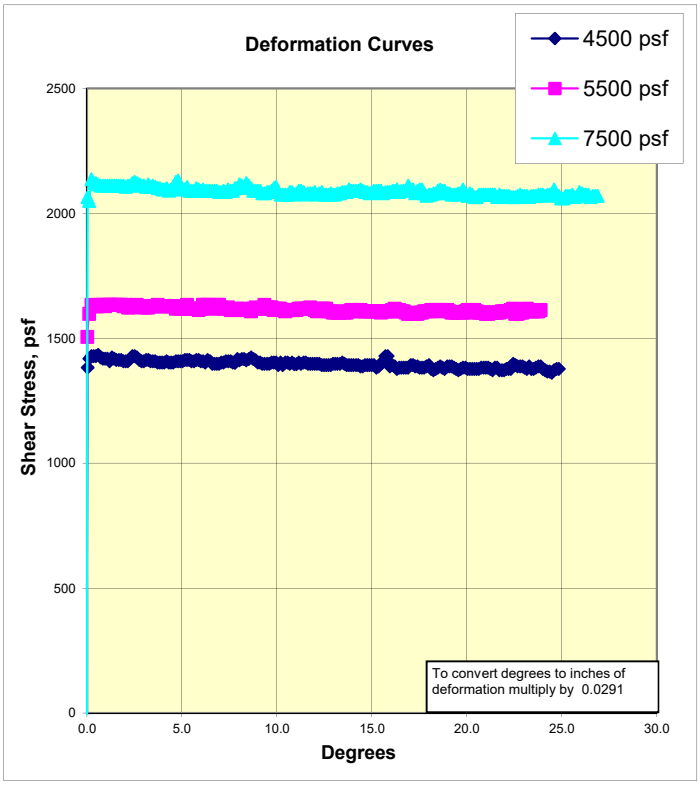
Soil Type: Dark Gray CLAY

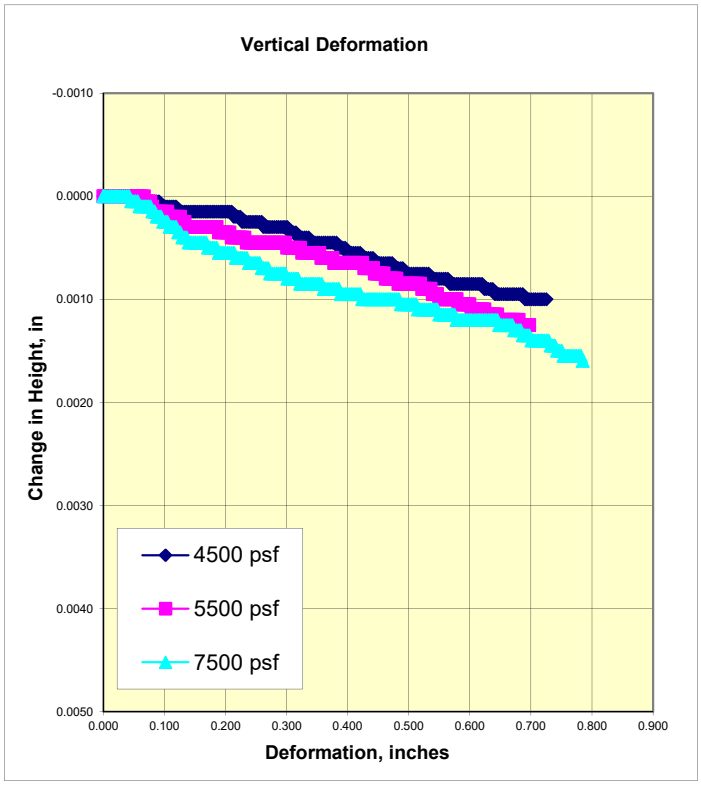
Normal Stress, psf	4500	5500	7500
Secant Phi, deg.:	17	16	15

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









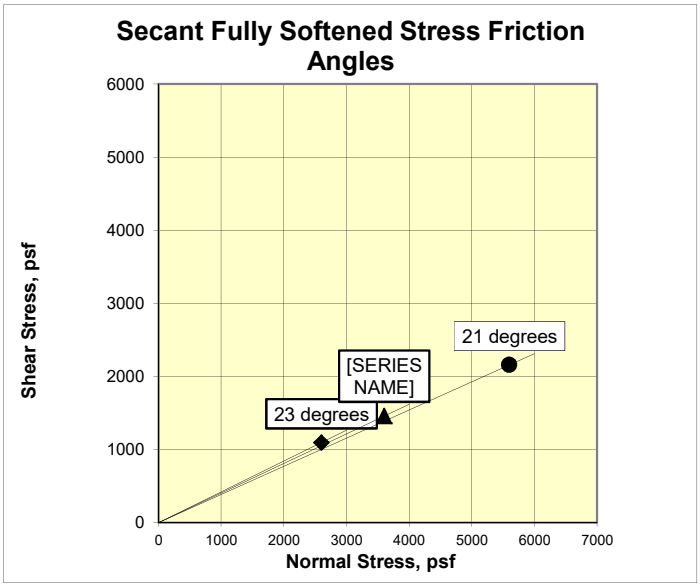
BENCHMARK GEOLABS

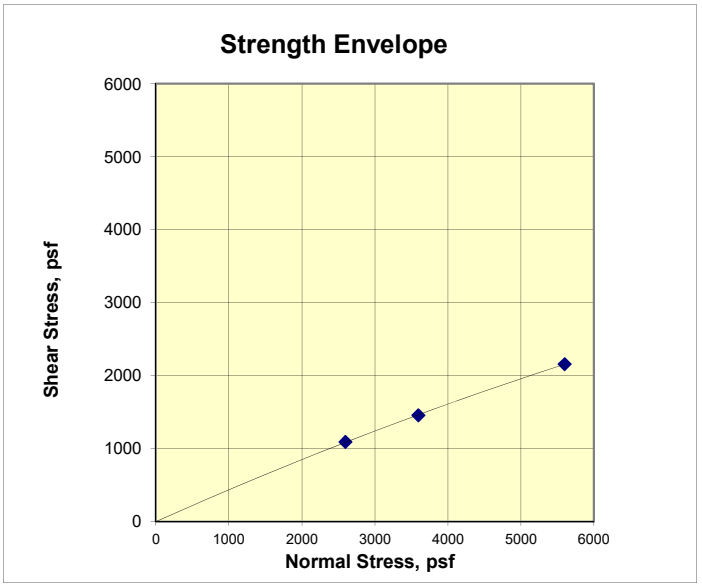
Drained Fully Softened Torsional Shear Strength (ASTM D7608)

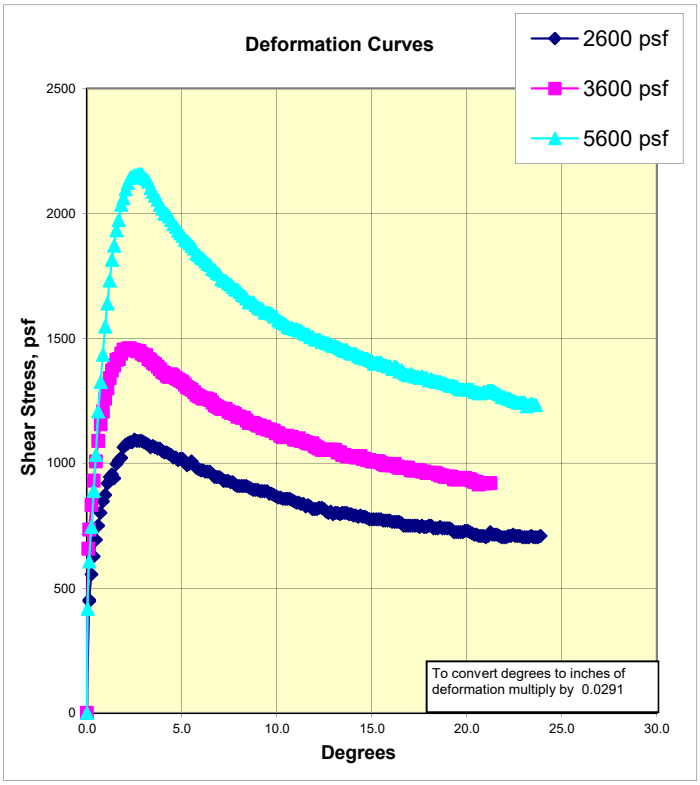
BGL Job No.:	049-001	**Boring:**	LD-2	**Date:**	8/1/2019	**Clay, %:**	
Client:	Alan Kropp & Associates	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Oxford	**Depth (ft):**	30.2-30.5	**Checked:**	PJ	**PL:**	
Project Number:	1853-3	**Test Type:**	Reconstituted Fully Softened			**Sample Preparation:**	<#40
Soil Type:	Dark Gray CLAY, trace Sand						

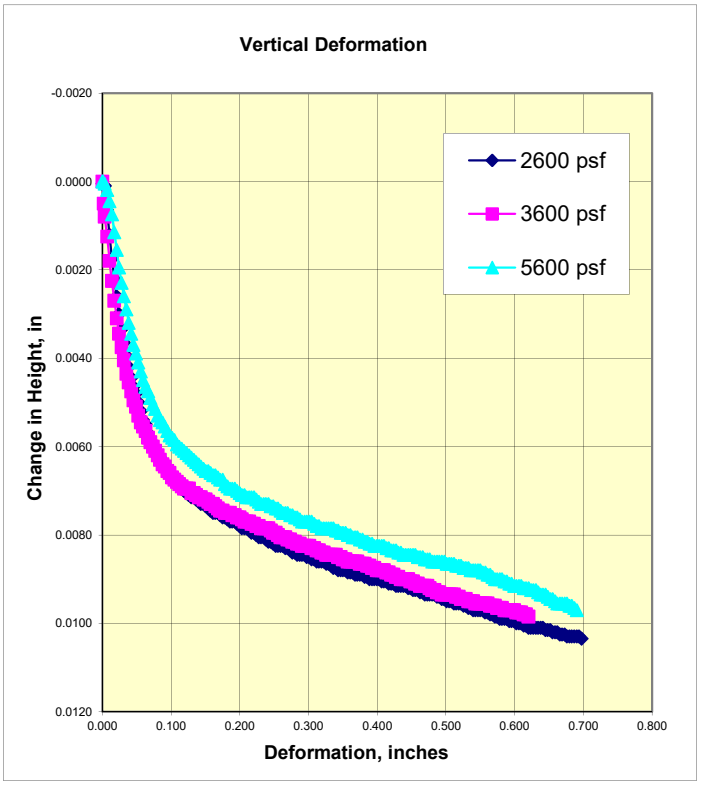
Normal Stress, psf	2600	3600	5600
Secant Phi, deg.:	23	22	21

Remarks:









BENCHMARK GEOLABS

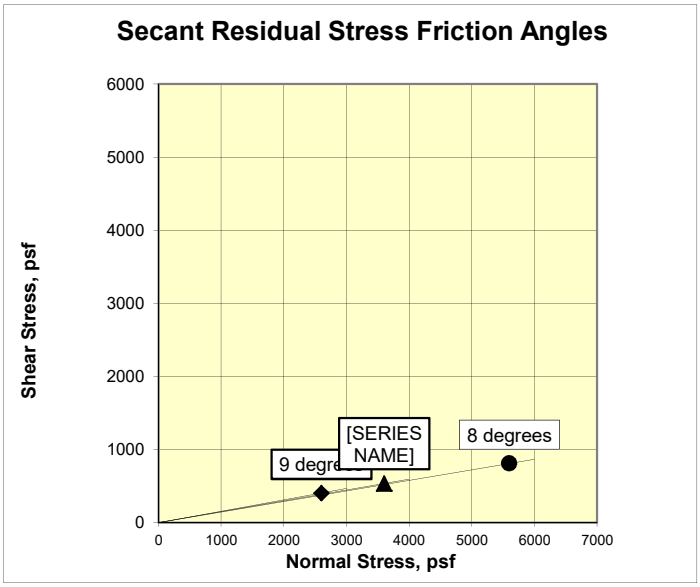
Drained Residual Torsional Shear Strength (ASTM D6467)

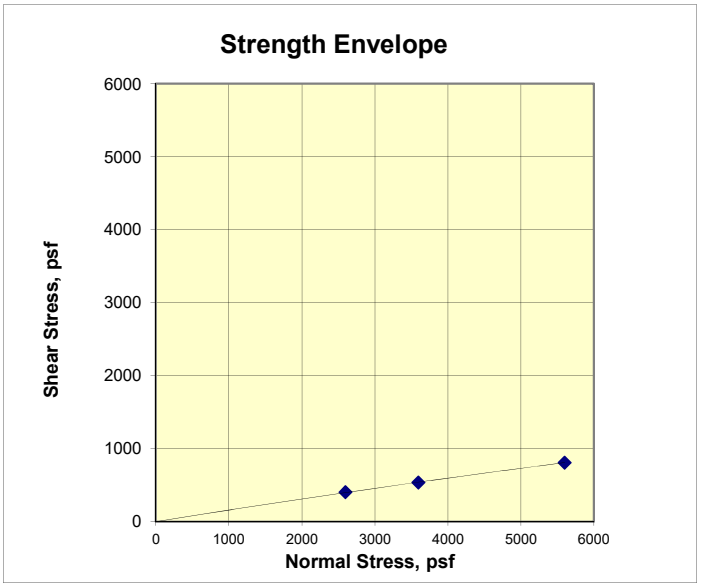
BGL Job No.:	049-001	**Boring:**	LD-2	**Date:**	8/1/2019	**Clay, %:**	
Client:	Alan Kropp & Associates	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Oxford	**Depth (ft):**	30.2-30.5	**Checked:**	PJ	**PL:**	
Project Number:	1853-3	**Test Type:**	Reconstituted Residual			**Sample Preparation:**	<#40

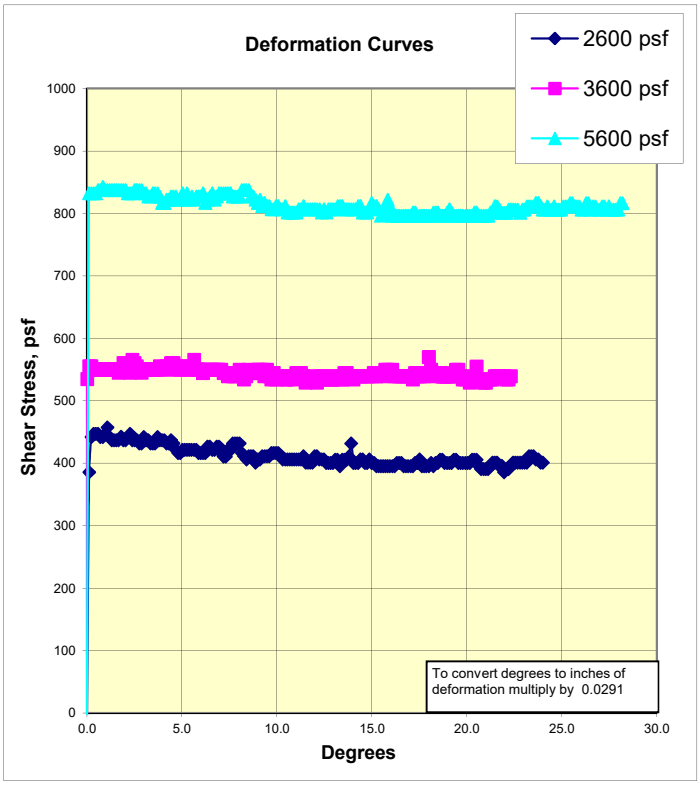
Soil Type: Dark Gray CLAY, trace Sand

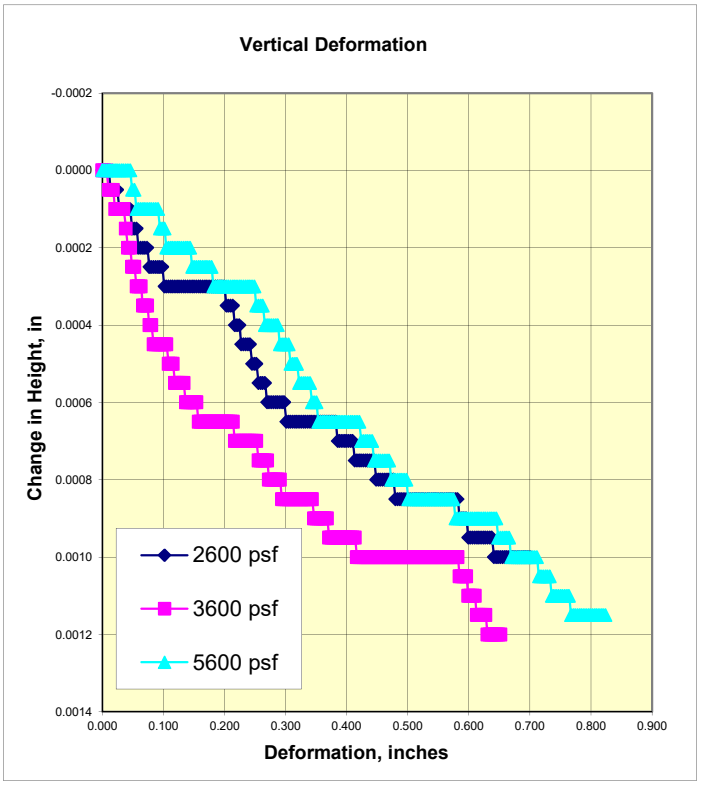
Normal Stress, psf	2600	3600	5600
Secant Phi, deg.:	9	8	8

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









APPENDIX E

SITE-SPECIFIC PROBABILISTIC SEISMIC HAZARD ANALYSIS (PSHA) REPORT:

LETTIS CONSULTANTS INTERNATIONAL, INC.

Draft Report

Site-Specific Seismic Hazard Analyses and Development of Seismic Design Ground Motion for the Oxford Elementary School Berkeley, California

Prepared for:
Alan Kropp & Associates
2140 Shattuck Ave., Suite 910
Berkeley, CA 94704

Prepared by:
Patricia Thomas, Ivan Wong, and Nora Lewandowski
Lettis Consultants International, Inc. (LCI)
1000 Burnett Ave., Suite 350
Concord, CA 94520

Bob Darragh and Walt Silva
Pacific Engineering & Analysis (PE&A)
856 Sea View Drive, El Cerrito, CA 94530

12 September 2019

Lettis Consultants International, Inc.
1000 Burnett Avenue, Suite 350
Concord, CA 94520
(925) 482-0360; fax (925) 482-0361

EARTH SCIENCE CONSULTANTS

12 September 2019

Mr. M. Jeroen van den Berg, C.E.
Alan Kropp & Associates
2140 Shattuck Ave., Suite 910
Berkeley, CA 94704

SUBJECT: **Site-Specific Seismic Hazard Analyses and Development of Seismic Design Ground Motions for the Oxford Elementary School, Berkeley, California**

Dear Jeroen:

Lettis Consultants International, Inc. (LCI) is pleased to submit this report that presents our site-specific seismic hazard evaluation and seismic design ground motions for the Oxford Elementary School in Berkeley, CA. Please do not hesitate to contact us with any questions or comments that you may have regarding this report. You may contact us directly at (925) 482-0360.

Respectfully,
Lettis Consultants International, Inc.

Patricia A. Thomas

Patricia Thomas, Ph.D., Senior Engineering Seismologist
thomas@lettisci.com

Ivan G. Wong

Ivan Wong, Senior Principal Seismologist
wong@lettisci.com

TABLE OF CONTENTS

1.0 Introduction 1
1.1 Scope of Work 1
1.2 Acknowledgements 1
2.0 Historical Seismicity 2
3.0 Inputs To Seismic Hazard Analyses 4
3.1 Seismic Source model 4
3.1.1 Faults 4
3.1.2 Background Seismicity 6
3.2 Ground Motion Models 7
3.3 Site Characterization 8
4.0 PSHA Results 9
5.0 DSHA Results 10
6.0 Site Response Analysis 11
6.1 Methodology and Inputs 11
6.1.1 Rock Ground Motions 11
6.1.2 Site Conditions 12
6.2 Site Response Results 13
7.0 Site-Specific Design Spectra 14
8.0 References Cited 15

List of Tables

Table 1. Background Zone Recurrence Parameters....19
Table 2. Calculation of Deterministic Rock MCE as per ASCE 7-10, Chapter 21 19
Table 3. Calculation of Probabilistic Rock MCE_R as per ASCE 7-10, Chapter 21 20
Table 4. Calculation of Site-Specific Rock MCE_R as per ASCE 7-10, Chapter 21....21
Table 5. Scaled Input Time Histories for Site Response Analysis....22
Table 6. Weights for Basecase Properties in Site Response Analysis....22
Table 7. Site-Specific Surface MCE_R and DE Spectra as per ASCE 7-10, Chapter 21....23
Table 8. Site-Specific Ground Motion Parameters as per ASCE 7-10, Chapter 21....24

List of Figures

Figure 1 Historical Seismicity (**M** > 3.0), 1800 – 2018 and Quaternary Faults in the San Francisco Bay Region

Figure 2 Site-Specific V_S Measurements

Figure 3 Seismic Hazard Curves for Peak Horizontal Acceleration for V_S30 1,000 m/sec

Figure 4 Seismic Hazard Curves for 0.2 Sec Horizontal Spectral Acceleration for V_S30 1,000 m/sec

Figure 5 Seismic Hazard Curves for 1.0 Sec Horizontal Spectral Acceleration for V_S30 1,000 m/sec

Figure 6 Seismic Source Contributions to Mean Peak Horizontal Acceleration Hazard for V_S30 1,000 m/sec

Figure 7 Seismic Source Fractional Contributions to Mean Peak Horizontal Acceleration Hazard for V_S30 1,000 m/sec

Figure 8 Seismic Source Contributions to Mean 0.2 Sec Horizontal Spectral Acceleration Hazard for V_S30 1,000 m/sec

Figure 9 Seismic Source Fractional Contributions to Mean 0.2 Sec Horizontal Spectral Acceleration Hazard for V_S30 1,000 m/sec

Figure 10 Seismic Source Contributions to Mean 1.0 Sec Horizontal Spectral Acceleration Hazard for V_S30 1,000 m/sec

Figure 11 Seismic Source Fractional Contributions to Mean 1.0 Sec Horizontal Spectral Acceleration Hazard for V_S30 1,000 m/sec

Figure 12 Magnitude, Distance, and Epsilon Contributions to the Mean Peak Horizontal Acceleration Hazard at 2,475-Year Return Period for V_S30 1,000 m/sec

Figure 13 Magnitude, Distance, and Epsilon Contributions to the Mean 0.2 Sec Horizontal Spectral Acceleration Hazard at 2,475-Year Return Period for V_S30 1,000 m/sec

Figure 14 Magnitude, Distance, and Epsilon Contributions to the Mean 1.0 Sec Horizontal Spectral Acceleration Hazard at 2,475-Year Return Period for V_S30 1,000 m/sec

Figure 15 5%-Damped Uniform Hazard Spectra at Return Period of 2,475 Years for V_S30 1,000 m/sec

Figure 16 Comparison of Uniform Hazard Spectra at 2,475-year Return Period Using NGA-W1 and NGA-W2 GMMs for V_S30 1,000 m/sec

Figure 17 5%-Damped 84th Percentile Deterministic Horizontal Acceleration Response Spectra for **M** 7.2 Hayward Event for V_S30 1,000 m/sec

Figure 18 Median and 84th Percentile Deterministic Horizontal Acceleration Response Spectra for **M** 7.2 Hayward Event for V_S30 1,000 m/sec

Figure 19 Comparison of Median and 84th Percentile Deterministic Horizontal Acceleration Response Spectra for **M** 7.2 Hayward Event for V_S30 1,000 m/sec Using NGA-W1 and NGA-W2 GMMs

Figure 20 Calculation of Site-Specific Deterministic Rock MCE Spectrum as per ASCE 7-10, Chapter 21

Figure 21 Calculation of Site-Specific Probabilistic Rock MCE_R Spectrum as per ASCE 7-10, Chapter 21

Figure 22 Site-Specific Rock MCE_R Spectrum as per ASCE 7-10, Chapter 21

Figure 23 Scaled Input Time History Response Spectra for Site Response Analysis

Figure 24 Basecase V_S Profiles for Site Response Analysis

Figure 25 Randomized V_S Profiles for Basecase V_S Profile P1

Figure 26 Shear Modulus Reduction (G/G_{MAX}) and Damping Ratio Curves

Figure 27 Site-Specific Amplification Factors Based on 1999 Duzce, Turkey – Lamont 1059 (N) Seed

Figure 28 Site-Specific Amplification Factors Based on 1980 Irpinia, Italy-01 – Bagnoli Irpinio (000) Seed

Figure 29 Site-Specific Amplification Factors Based on 1989 Loma Prieta – Gilroy-Gavilan Coll. (067) Seed

Figure 30 Site-Specific Amplification Factors Based on 1995 Kobe, Japan – Nishi-Akashi (000) Seed

Figure 31 Site-Specific Amplification Factors Based on 1978 Tabas, Iran – Tabas (L1) Seed

Figure 32 Surface MCE_R Spectrum

Figure 33 Calculation of Site-Specific MCE_R Spectrum as per ASCE 7-10, Chapter 21
Figure 34 Calculation of Site-Specific DE Spectrum as per ASCE 7-10, Chapter 21

1.0 INTRODUCTION

At the request of Alan Kropp & Associates (AKA), we have performed site-specific seismic hazard analyses and developed seismic design ground motion spectra for the Oxford Elementary School in Berkeley, California. The site is located in the seismically active San Francisco Bay region within the San Andreas fault system (Figure 1). The Hayward fault, with a characteristic earthquake of moment magnitude (**M**) 7.2, lies 460 m to the east of the school site.

The strong ground motion hazard at the site was estimated by performing a site-specific probabilistic seismic hazard analysis (PSHA), deterministic seismic hazard analysis (DSHA), and a site-response analysis. The seismic hazard analysis and design ground motion parameters were developed in accordance with ASCE 7-10 *Minimum Design Loads for Buildings and Other Structures* as described in items 12 through 17 of California Geological Survey (CGS) Note 48. Two levels of ground motions were developed for the building following ASCE 7-10: (1) Risk-Adjusted Maximum Considered Earthquake (MCE_R); and (2) Design Earthquake (DE). Also at the request of AKA, ground motions were also calculated at the top of rock for input into the landslide analysis.

1.1 Scope of Work

As stated in our proposal dated 10 October 2018, the scope of work was:

"…to perform a site-specific seismic hazard evaluation of the Oxford Elementary School in Berkeley, California in accordance with California Geological Survey Note 48. Specifically the evaluation will address items 12 to 17 in Note 48. We will perform both site-specific probabilistic and deterministic seismic hazard analyses and a site response analysis."

1.2 Acknowledgements

This work was performed under a contract with Alan Kropp & Associates. Our appreciation to Jeroen van den Berg for his project support and assistance and to Claire Unruh and Åse Mitchell for their assistance in the preparation of this report.

2.0 HISTORICAL SEISMICITY

The earliest written accounts of earthquakes in California come from the logs of the Spanish missions established throughout California in the 1700's. The majority of the historical seismicity in the San Francisco Bay region is associated with the major faults of the San Andreas fault system. There have been 15 earthquakes of approximately **M** 6.0 or greater in the San Francisco Bay region in historical times. The most significant earthquakes to the site are discussed in detail below and shown on Figure 1.

It is likely that most of the significant historical earthquakes discussed below generated strong ground shaking at the school site with the strongest shaking in the 1868 event at Modified Mercalli (MM) intensity VII (Toppazada *et al*., 1981).

10 June 1836 For several decades, this earthquake was thought to be associated with the Hayward fault. However, Toppozada and Borchardt (1998) reevaluated historical evidence and concluded that the 1836 earthquake probably occurred somewhere between Monterey and Santa Clara (south of the area shown in Figure 1). Toppozada and Borchardt (1998) assigned this event a Richter local magnitude (M_L) 6 ¼ ± ½ based on felt reports. Recent trenching studies on the northern Hayward fault found little evidence for movement in the 1800's and corroborate this interpretation. Bakun (1999) supports a location east of Monterey Bay and assigns a magnitude of **M** 6.5.

June 1838 There are very few written records of the June 1838 earthquake, and the exact date is not known. No reports of this earthquake are available from north of San Francisco or south of Santa Clara, except from Monterey (Toppozada *et al*., 1981). Toppozada and Borchardt (1998) reviewed the historical records for this earthquake and found that reported shaking intensities suggest that this earthquake was the result of rupture of more than the 60-km long Peninsula segment of the San Andreas fault as was originally believed, and rather rupture may have extended a distance of 140 km from San Francisco to San Juan Bautista. In contrast, Bakun (1999) believes the 1838 earthquake was confined to the Peninsula segment and assigned a **M** 6.8 to the event.

21 October 1868 This **M** 6.8 earthquake occurred on the southern Hayward fault. It was one of the most destructive in California history. Heavy damage was sustained in towns along the Hayward fault in the eastern San Francisco Bay area, as well as in San Francisco and San Jose. The southern Hayward fault is thought to have ruptured from its southern end, in the eastern Santa Clara Valley, to northern Oakland or southern Berkeley.

31 March 1898 On 31 March 1898, the San Francisco Bay region was shaken by an earthquake that appears to have been centered near Mare Island in San Pablo Bay. The maximum intensity was MM VIII or greater and buildings were damaged in areas around the Bay Area. Toppozada *et al*. (1981) re-evaluated the magnitude of this event through comparisons with other historical earthquakes and assigned it a M_L 6.7. Bakun (1999) assigns a magnitude of only **M** 6.3 and

suggests that the earthquake could have occurred on one of three possible faults: the southern end of the Rodgers Creek fault, the southern end of the West Napa fault, or beneath the fold structures east of Mare Island.

18 April 1906 The **M** 7.8 Great San Francisco earthquake of 1906 was the most destructive earthquake to have occurred in northern California in historical times. The earthquake was felt from southern Oregon to south of Los Angeles, and as far east as central Nevada. It ruptured the northernmost 430 km of the San Andreas fault, from San Juan Bautista to the Mendocino Triple Junction. Damage was widespread in northern California and injury and loss of life was particularly severe. Ground shaking and fire caused the deaths of more than 3,000 people and injured approximately 225,000. Damage from shaking was most severe in areas of saturated or loose, young soils.

24 April 1984 The **M** 6.2 Morgan Hill earthquake occurred on the Calaveras fault about 18 km east of San Jose and 22 km north of Morgan Hill. This earthquake had a focal depth of 8 km and ruptured about 30 km of the fault. It was felt in California and Nevada over an area of 120,000 km^2 and caused damage estimated to be worth $7.5 million. In San Jose, cracks formed in some walls and plaster fell, many items were thrown from store shelves and some chimneys cracked. This earthquake is thought to have been very similar to an earthquake that affected the area in 1911.

17 October 1989 The **M** 6.9 Loma Prieta earthquake occurred on a blind fault adjacent to the Santa Cruz segment of the San Andreas fault (south of the area shown in Figure 1). The cities of Los Gatos, Watsonville, and Santa Cruz were severely damaged, and San Francisco and Oakland were also damaged. Shaking was felt throughout the San Francisco Bay area and as far away as San Diego and Nevada. While the Loma Prieta earthquake was one of the most expensive natural disasters in U.S. history, causing in excess of $6 billion damage, the loss of life was significantly less than in 1906. Sixty-two people died and about 3,500 were injured. About 12,000 people were displaced from their homes. As in the 1906 earthquake, the worst damage from shaking occurred on unconsolidated or saturated soils, or with unreinforced masonry or inadequately designed structures.

24 August 2014 The **M** 6.0 South Napa earthquake occurred on the West Napa fault, which extends along the western margin of the basin underlying Napa Valley. Shaking was felt throughout the San Francisco Bay area and as far away as Reno, NV. The shaking caused damage to many homes and commercial buildings including significant damage to the 1870 courthouse in downtown Napa. The earthquake was unusual in that it had relatively long surface rupture for an event of its magnitude.

3.0 INPUTS TO SEISMIC HAZARD ANALYSES

The following section discusses the characterization of the seismic sources considered in the PSHA and DSHA, the geologic site conditions, and the empirical ground motion models (GMMs) selected and used.

3.1 Seismic Source model

Seismic source characterization for a PSHA is concerned with three fundamental elements: (1) the identification, location and geometry of significant sources of earthquakes; (2) the maximum size of the earthquakes associated with these sources; and (3) the rate at which the earthquakes occur. In the PSHA, we estimated seismic source parameters for the significant faults in the site region, and used two approaches to represent background earthquakes: a uniform seismic source zone and gridded seismicity. These seismic sources and the associated input parameters for the PSHA are described in Sections 3.1.1 and 3.1.2.

In a DSHA, only scenario earthquakes specified by their maximum earthquake and the causative fault are considered. The scenario earthquakes are selected with no consideration of their frequency of occurrence other than they are "reasonably expected to occur" along a specific fault.

3.1.1 Faults

The fault model used in this study is adopted from a model originally developed as part of the California Department of Water Resources' Delta Risk Management Strategy Project (Wong *et al*., 2008). Each seismic source is characterized using the latest available geologic, seismologic, and paleoseismic data and the currently accepted models of fault behavior developed by the Working Group on Northern California Earthquake Potential (WGNCEP, 1996) and the 2002 California Geological Survey's (CGS) seismic source model used in the USGS National Hazard Maps (Cao *et al*., 2003). Characterizations of the major faults in the San Francisco Bay region, including the San Andreas, Hayward/Rodgers Creek, Concord/Green Valley, San Gregorio, Greenville, and Mt. Diablo thrust faults, are adopted from the 1999 and 2002 Working Groups on California Earthquake Probabilities (WGCEP, 2003). These characterizations were updated based on a review of the recent statewide rupture forecast project, UCERF2 and UCERF3.

Figure 1 shows the locations of the faults relative to the site. The faults included in the PSHA are judged to be at least potentially active and may contribute to the probabilistic hazard because of their maximum earthquakes and/or proximity to the site. The most significant fault to the school site is the Hayward-Rodgers Creek fault.

Hayward-Rodgers Creek Fault Zone

The Hayward fault extends for 131 km from the area of Mount Misery, east of San Jose, to Point Pinole on San Pablo Bay (Figure 1). At Point Pinole, the Hayward fault runs into San Pablo Bay. The northern continuation of this fault system is the Rodgers Creek and Healdsburg faults. The Hayward and Rodgers Creek faults are separated by a 5-km-wide right step beneath San Pablo

Bay (Figure 1). Systematic right-lateral geomorphic offsets and creep offset of cultural features have been well documented along the entire length of the fault (Lienkaemper, 1992). In addition to undergoing displacement in earthquake ruptures, the Hayward fault also moves by aseismic creep. Measurements along the fault over the last two decades show that the mean creep rate is 4 to 7 mm/yr (Lienkaemper *et al*., 2012).

The last major earthquake on the Hayward fault, in October 1868, occurred along the southern segment of the fault. This **M** 6.8 event caused toppling of buildings in Hayward and other localities within about 5 km of the fault. The surface rupture associated with this earthquake is thought to have extended for approximately 30 km, from Warm Springs to San Leandro, with a maximum reported displacement of 1 m. Studies by Lienkaemper and Williams (2007) indicate that there have been 10 earthquakes along the southern Hayward fault since about 170 A.D. resulting in an average recurrence interval of 170 years. The last five events have an average recurrence interval of 140 $\pm$ 50 years.Paleoseismic trenching along the northern Hayward fault indicates that the last surface rupturing earthquake along this part of the fault was sometime between 1626 and 1724 (Lienkaemper *et al.*, 1999). This study also indicated at least four surface-rupturing earthquakes in the last 2,250 years.

The Rodgers Creek fault is 44 km long (Figure 1) and its geomorphic expression is similar to that of the Hayward fault. At its northern end, the Rodgers Creek fault is separated from the Healdsburg fault by a 3-km-wide right step, and separated from the Maacama fault by a 10-km-wide right step (Wagner and Bortugno, 1982). Holocene activity along the Rodgers Creek is indicated by a series of fault scarps in Holocene deposits, side-hill benches, right-laterally offset streams, and closed linear depressions. Microseismicity is nearly absent along much of the length of the fault suggesting that it may be a seismic gap and the site of an impending earthquake (Wong, 1991). Paleoseismic investigations by Schwartz *et al.* (1992) revealed three events in 925 to 1,000 years. This gives a preferred recurrence of 230 years for a maximum earthquake of **M** 7.0. Hecker *et al*. (2005) interpreted the most recent earthquake (MRE) on the Rodgers Creek fault occurred sometime between 1715 and 1776. The elapsed time may have reached or exceeded the average recurrence interval of about 230 years. They also speculate that the Rodgers Creek and Hayward faults could have ruptured together in the MRE.

The WGCEP (2008) assigned maximum earthquakes of **M** 6.5 and 6.7, and recurrence intervals of 150 and 158 years, for the northern and southern segments of the Hayward fault, respectively. Rupture of the entire Hayward fault would generate an earthquake of **M** 7.0. Their model also incorporates a scenario where the Hayward fault ruptures with the Rodgers Creek fault. Rupture of the entire length of both faults together would generate a maximum earthquake of **M** 7.3. Rupture of the Rodgers Creek fault and the northern segment of the Hayward fault would generate a maximum event of **M** 7.1. The WGCEP (2003, 2008) considered the Hayward-Rodgers Creek fault system the most likely source of the next **M** 6.7 or larger earthquake in the Bay Area, with a 31 percent probability of occurring in the time period 2002 to 2031.

The most recent analysis of statewide seismic hazard, UCERF3, utilized a different set of empirical relations between rupture geometry and earthquake magnitude to those of earlier working groups (Field *et al*., 2013). These have resulted in magnitudes for specific rupture scenarios that are either the same or about 0.1 magnitude units larger than the WGCEP (2003, 2008) estimated magnitudes. In addition, the Healdsburg fault was added to the Rodgers Creek fault in the Statewide Community Fault Model (SCFM) and UCERF3. As a result, the potential ruptures involving the Rodgers Creek fault increased in length by about 19 km. Furthermore, the segment boundary between the northern Hayward fault and Rodgers Creek fault was relocated farther north, which resulted in a lengthening of the northern Hayward segment from 35 to 53 km. Consequently, without the addition of the Healdsburg fault, the Rodgers Creek fault would have decreased in rupture length. Overall, these changes resulted in 0.1 to 0.2 magnitude unit increases in the Hayward-Rodgers Creek-Healdsburg fault zone rupture scenarios.

UCERF3 has also expanded the range of conceivable ruptures for most faults in California by including the possibility of multi-fault ruptures, wherein fault ruptures can jump from one mapped fault to another in a single earthquake (Field *et al*., 2013). The result of this is that considered earthquake magnitudes can be much larger than those in previous models like WGCEP (2003, 2008). The UCERF3 model permits the Hayward fault to rupture with other faults including the Calaveras fault, as well as a rupture scenario extending from the Rodgers Creek fault through the southern San Andreas fault to the Salton Sea, generating an **M** > 8 earthquake. The frequency of such an event is very low in the model, however, and unlikely to be of concern for the design purposes of most structures.

In a recently-released report, Aargaard *et al*. (2016) now forecast a 72% chance of one or more **M** 6.7 or larger earthquakes occurring in the San Francisco Bay area from 2014 to 2043 and a 33% probability along the Hayward-Rodgers Creek fault zone (including the Healdsburg fault).

The deterministic scenario selected for the site is an **M** 7.2 event, which corresponds to the rupture of the Hayward fault. This scenario is slightly lower than a northern Hayward-Rodgers Creek or a full Hayward-Rodgers Creek rupture, which are given low weight in the PSHA.

3.1.2 Background Seismicity

To account for the hazard from background (floating or random) earthquakes that are not associated with known or mapped faults, regional seismic source zones are used in the PSHA. In most of the western U.S., the maximum magnitude of earthquakes not associated with known faults usually ranges from **M** 6 to 6½ (e.g., dePolo, 1994). Repeated events larger than these magnitudes generally produce recognizable fault-or-fold related features at the earth's surface. Examples of background earthquakes are the 1989 **M** 6.9 Loma Prieta (Section 2.0), the 1986 **M** 5.7 Mt. Lewis, and the 31 October 2007 **M** 5.6 Alum Rock earthquakes, with the latter two having occurred east of San Jose and resulted in no discernable surface rupture.

Earthquake recurrence estimates of the background seismicity within each seismic source zone are required. The site region is divided into two regional seismic source zones: the Coast Ranges and Central Valley. The recurrence parameters for the Coast Ranges source zone are adopted from Youngs *et al.* (1992). They calculated values for background earthquakes based on the historical seismicity record after removing earthquakes within 10-km-wide corridors along each of the major faults. The recurrence values for the Central Valley zone are adopted from URS Corporation/Jack Benjamin & Associates (2007). The a-values are normalized per year and per km^2 (Table 1). Maximum earthquakes for both zones of **M** 6.5 $\pm$ 0.3 are used in the PSHA.

3.2 Ground Motion Models

To estimate the ground motions for crustal earthquakes in the PSHA and DSHA, we have used recently developed GMMs appropriate for tectonically active crustal regions. The models, developed as part of the NGA-West2 Project sponsored by PEER Center Lifelines Program, were published in 2014.

The NGA-West2 models by Chiou and Youngs (2014), Campbell and Bozorgnia (2014), Abrahamson *et al*. (2014), and Boore *et al*. (2014) were used in the PSHA and DSHA. The models were weighted equally in the hazard analyses.

The NGA-West2 models use the parameter V_S30 (time-averaged shear-wave velocity in the top 30 m) as a proxy for site effects. Based on the site characterization (Section 3.3), a site-specific V_S30 value of 1,000 m/sec consistent with the rock at the site was used in the PSHA and DSHA (Sections 4 and 5). This accounts for the effects of the rock at the site. As described in Section 6, a site response analysis was also performed to model site effects of the overlying soil. As part of the site response analysis (Section 6), amplification functions were developed for the ground surface relative to the rock site condition with a V_S30 of 1,000 m/sec.

Other input parameters for the NGA-West2 GMMs include $Z_{2.5}$, the depth to the V_S of 2.5 km/sec (a proxy for basin effects), which is only used in one model, Campbell and Bozorgnia (2014). In addition, Abrahamson *et al*. (2014), Boore *et al.* (2014) and Chiou and Youngs (2014) use $Z_{1.0}$, the depth to the V_S of 1.0 km/sec. In the absence of site-specific information, the default $Z_{1.0}$ and $Z_{2.5}$ based on the equations provided by the NGA-West2 developers were used in the PSHA and DSHA. Other parameters such as depth to the top of rupture (zero for all faults with surface expression unless specified otherwise), dip angle, rupture width, and aspect ratio were specified for each fault or calculated within the PSHA code.

Rupture directivity was not included in the DSHA or PSHA because we believe it is accommodated in the aleatory variability associated with the NGA-West2 GMMs.

As noted by Al Atik and Youngs (2014), the development of the NGA-West2 models was a collaborative effort with many interactions and exchanges of ideas among the developers. The developers indicated that additional epistemic uncertainty needs to be incorporated into the median ground motions in order to more fully represent an appropriate level of epistemic uncertainty. Hence, for each of the four NGA-West2 models, additional epistemic uncertainty on the median ground motion was included. The three-point distribution and model of Al Atik and

Youngs (2014) was applied. The model is a function of magnitude, style of faulting, and spectral period.

The PSHA and DSHA were also performed using the four NGA-West1 models that were predecessors to the four NGA-West2 models used in this study (Abrahamson and Silva, 2008; Boore and Atkinson, 2008; Campbell and Bozorgnia 2008; and Chiou and Youngs, 2008). The NGA-West1 models were used in the 2008 versions of the National Seismic Hazard Maps, which were the basis for the design maps in ASCE 7-10. Due to the requirements of the CBC 2017, the envelope of the hazard results using the NGA-West1 and NGA-West2 models were used to develop design ground motions.

3.3 Site Characterization

To characterize the V_S of materials underlying Oxford Elementary School, site-specific V_S surveys were performed by NorCal and Conetec. NorCal performed P-S suspension logging in borehole B-1 which is located in the school yard behind the main school building. The borehole encountered alluvial landslide deposits down to a depth of 16 to 17 m. The alluvium-bedrock contact was at a depth of 18 m. Rock consisted of weak, highly weathered and fractured sandstone, greywacke, and shale down to about 21 m. Below this depth, the rock was less weathered and moderately hard and strong.

The Vs profile based on the suspension logging is shown in Figure 2. It shows relatively uniform Vs of about 250 m/sec from a depth of 8 to 16 m coinciding with the alluvial deposits. The top 8 m was not measured due to poor borehole conditions. From 16 to 23 m, the Vs increases to about 1,000 m/sec which probably represents the zone of weathered rock (Figure 2). At a depth of 28 m, the Vs begins to increase. Conetec also perfomed seismic CPT measurements at three locations at the school. Those profiles are also shown on Figure 2. They show considerable variability and we addressed that in the development of the basecase Vs profiles used in the site response analysis (Section 6). Based on the V_S30 from the site-specific profile, the site corresponds to a Site Class D in ASCE 7-10.

4.0 PSHA RESULTS

The results of the PSHA at the site for a V_S30 of 1,000 m/sec are presented in terms of ground motion as a function of annual frequency of exceedance (AFE). AFE is the reciprocal of the average return period. Figures 3 through 5 show the mean, median (50th percentile), 5th, 15th, 85th, and 95th percentile hazard curves for peak horizontal ground acceleration (PGA) and 0.2 and 1.0 sec horizontal spectral acceleration (SA). The fractiles indicate the range of uncertainties about the mean hazard. For a return period of 2,475 years, the range of uncertainty is about a factor of 2.0 between the 5th and 95th percentiles for PGA (Figure 3). This factor ranges from 2.0 to 5.5 for periods between 0.01 and 10 sec. This uncertainty is typical of Bay Area sites and is due in large part to the uncertainties in the GMMs.

The contributions of the various seismic sources to the mean PGA are shown in Figure 6. As expected, because of the proximity to the site, the Hayward fault is the dominant contributor to both the short- and long-period ground motion hazard. Figure 7 shows the fractional contributions of significant sources to the total mean PGA hazard. The source contributions for 0.2 and 1.0 sec SA hazard are shown on Figures 8 to 11. For all spectral periods, the Hayward fault dominates at all return periods.

Figures 12 to 14 illustrate deaggregation of the mean PGA and 0.2 and 1.0 sec horizontal SA hazard by magnitude, distance, and epsilon bins at the 2,475-year return period. Epsilon is the difference between the logarithm of the ground motion amplitude and the mean logarithm of ground motion (for that magnitude and distance) measured in units of the standard deviation (σ) of the logarithm of the ground motion. At a 2,475-year return period, the hazard is dominated by events in the magnitude range of **M** 6.4 to 7.6 at distances less than 10 km corresponding to events on the Hayward fault (Figure 12). This is also the case for 0.2 and 1.0 sec SA (Figures 13 and 14.)

The UHS at a 2,475-year return period for the V_S30 of 1,000 m/sec is shown in Figure 15. This UHS reflect the geometric mean of expected horizontal ground motions, as predicted by the NGA-West2 models.

The 2016 California Building Code (CBC), Section 1803A.6 states that the NGA-West1 GMMs that were used in the 2008 USGS National Seismic Hazard Maps be used in site-specific analyses. For this study, hazard curves and UHS have been computed using both NGA-West1 and NGA-West2 GMMs. Figure 16 shows a comparison of the UHS computed based on the NGA-West1 and NGA-West2 GMMs. The UHS developed using NGA-West2 are larger for periods less than 0.2 sec. Although the NGA-West2 GMMs represent the latest science, the envelopes of the NGA-West1 and NGA-West2 UHS were used as input to the site response analysis in order to comply with the 2016 CBC.

5.0 DSHA RESULTS

5%-damped 84th-percentile horizontal acceleration response spectra are calculated for the characteristic earthquake on the Hayward fault (**M** 7.2) using the same NGA-West2 models used in the PSHA and the site-specific V_S30 of 1,000 m/sec.

Figure 17 shows the lognormal average 84th-percentile acceleration response spectrum along with the individual spectra from the four NGA-West2 GMMs. Input parameters are also provided in Figure 17. The range in spectra represent the epistemic uncertainty in the ground motion modeling. Figure 18 shows the lognormal average median and 84th percentile acceleration response spectra. The lognormal average median and 84th percentile PGAs are 0.47 and 0.86 g, respectively.

Figure 19 compares the median and 84th percentile spectra using the NGA-West1 and NGA-West2 GMMs. In comparing the median and 84th percentile spectra, the NGA-West2 models predict larger spectral values than predicted by the NGA-West1 models for periods between approximately 0.03 and 0.15 sec and for periods less than approximately 0.2 sec, respectively. For longer periods, the NGA-West1 models predict larger ground motions. As described in Section 4 for the UHS, the envelope of the deterministic spectra from NGA-West1 and NGA-West2 are used to develop design spectra.

6.0 SITE RESPONSE ANALYSIS

A site response analysis was performed to model the effects of near-surface materials using the site-specific velocity profile provided in Section 3.3. This section describes the site response methodology, inputs and resulting ground motions.

6.1 Methodology and Inputs

The site response analysis was performed in accordance with ASCE 7-10, Chapter 21. The computational formulation that has been most widely employed to evaluate 1D site response assumes vertically-propagating plane S-waves. Departures of soil response from a linear constitutive relation are treated in an approximate manner through the use of the equivalent-linear formulation. The equivalent-linear formulation, in its present form, was introduced by Idriss and Seed (1968). A stepwise analysis approach was formalized into a 1D, vertically propagating S-wave code called SHAKE (Schnabel et al., 1972). Subsequently, this code has become the most widely used and validated analysis package for 1D site response calculations. The site response analysis for this study was performed using the computer program RASCALS (Silva et al., 1987), which, similar to SHAKE, propagates the input ground motions at the bedrock level up through the soil column using an equivalent-linear approach. Period-dependent amplification factors are computed as the ratio of surface response spectra to input bedrock response spectra.

6.1.1 Rock Ground Motions

In accordance with ASCE 7-10, Chapter 21.1.1, an MCE_R response spectrum was developed for rock. The site-specific V_S measurements indicate a relatively uniform Vs in the alluvial material, a Vs gradient in the weathered rock increasing to more competent rock with a Vs of about 1,000 m/sec at a depth of 23 m (Figure 2; Section 3.3). Hence, the site-specific PSHA and DSHA were performed for a V_S30 of 1,000 m/sec and the results used to develop the rock MCE_R response spectrum.

The horizontal MCE_R spectrum is defined in ASCE 7-10 Chapter 21 as the lesser of the deterministic MCE and probabilistic MCE_R ground motions. The deterministic MCE response spectrum is the 84th percentile response spectrum from the characteristic event on the controlling active fault, but not less than a minimum deterministic motion as defined in ASCE 7-10 Figure 21.2-1. Figure 20 shows the 84th percentile deterministic response spectrum for the **M** 7.2 event on the Hayward fault at a distance of 0.46 km (V_S30 1000 m/sec) and the adjustment from RotD50 (geometric mean) ground motions predicted by the NGA-West2 (and NGA-West1) GMMs to maximum-direction ground motions using the factors of Shahi and Baker (2014). Also shown on Figure 20 is the deterministic minimum as per ASCE 7-10. The site-specific deterministic rock MCE spectrum is the 84^{th} percentile maximum direction spectrum as it exceeds the minimum deterministic spectrum at all periods (Figure 20; Table 2).

The probabilistic MCE_R spectrum was calculated using Method 1 in ASCE 7-10, Chapter 21 (Figure 21; Table 3). The 2,475-year return period rock UHS was adjusted to maximum-direction ground motions and also adjusted using a risk coefficient to obtain a spectrum that is expected to

achieve a 1% probability of collapse within a 50-year period. The risk coefficient, C_R is equal to C_{RS} at periods less than or equal to 0.2 sec and equal to C_{R1} at periods greater or equal to 1.0 sec. The values of C_{RS} and C_{R1} for this site, obtained from the USGS website (https://seismicmaps.org/ accessed 5 February 2019) are 1.002 and 0.978, respectively.

Figure 22 compares the probabilistic rock MCE_R (risk-adjusted 2,475-year rock UHS) and the deterministic rock MCE spectra. The site-specific rock MCE_R is the lesser of these spectra, but not less than 80% of the general code MCE_R spectrum for Site Class B. For this site, the rock MCE_R is the 84th percentile deterministic spectrum for periods less than 0.3 sec and the 80% general code MCE_R spectrum for Site Class B at longer periods. The site-specific rock MCE_R is provided in Table 4.

Five recorded horizontal time histories were selected from the NGA-West2 database (Ancheta *et al*., 2013) from events of similar magnitude and distance as the earthquake scenario controlling the rock MCE_R spectrum (**M** 7.2 at 0.46 km) and most importantly, having a similar spectral shape as the rock MCE_R spectrum. The response spectra of these input time histories, scaled to the rock MCE_R spectrum, are shown in Figure 23 and listed in Table 5.

6.1.2 Site Conditions

The near-surface material dynamic behavior is modeled using a V_S profile, shear modulus reduction and damping curves, and unit weights. Both epistemic uncertainty and aleatory variability in V_S and shear modulus and damping curves were accommodated in the site response analysis.

A best-estimate V_S profile (P1) was developed based on the site-specific V_S measurements (Section 3.3; Figure 24). Epistemic uncertainty in the V_S profile was included by developing lower-range (P2) and upper-range (P3) basecase V_S profiles. These V_S profiles were computed based on the range of variability in the Vs for the alluvium and weathered rock (Figure 2). To address the variability in the depth of competent rock beneath the school property, the depth was varied from about 16 to 22 m (Figure 24). Hence, there were a total of three basecase profiles used in the site response analysis (Figure 24). In developing amplification factors the lower range, best-estimate and upper range basecase profiles are weighted 0.3, 0.4 and 0.3, respectively (Table 6).

For each of the basecase V_S profiles, 30 randomized V_S profiles were generated using the soil correlation model (Toro, 1996). These randomized V_S profiles accommodate aleatory variability in the soil properties. Figure 25 illustrates the 30 randomized profiles for the best-estimate basecase profile (P1).

For the dynamic material properties, the EPRI (1993) curves (Revision 1) and Peninsular Range curves for cohesionless soils (Silva *et al.*, 1997) were used to cover the possible range of nonlinear behavior of the alluvium and weathered rock beneath the site. The EPRI (1993) model (M1) curves are depth-dependent. The Peninsular Range curves (M2), which are a subset of the EPRI (1993) curves, use the EPRI (1993) 51 to 120 ft curves for 0 to 50 ft and the 501 to 1,000 ft curves for deeper materials and reflect much more linear response than the EPRI curves. The two dynamic material models, shown on Figure 26, were weighted equally (Table 6) when

combining the site response analyses results obtained from the three basecase V_S models. As with the V_S profiles, a suite of 30 randomized curves about each of these basecase curves is generated.

6.2 Site Response Results

For each of the five input time histories, RASCALS was used to compute surface spectra using the suites of randomized V_S profiles and dynamic material properties. For each combination of basecase V_S profile (P1, P2, and P3) and basecase material property curves (M1 and M2), an input time history is propagated through the 30 randomized soil columns and a surface spectrum is computed. Amplification factors are computed as the ratios of surface spectra to input spectra and average amplification factors are calculated. Figures 27 to 31 show the period-dependent amplification factors. Each of the six curves on these figures are the average from the 30 randomizations about the basecase properties. In general, the stiffer profile P3 results in larger amplification for periods less than 0.2 to 0.3 sec. At longer periods, the softest profile P2 results in the largest amplification. For each of the five input time histories, weighted average amplification factors are computed using the weights described in Section 6.1 (Table 6). The average of these five amplification factors is applied to the rock MCE_R response spectrum to obtain the surface MCE_R response spectrum. Figure 32 compares the rock and surface MCE_R response spectra. There is significant amplification for spectral periods greater than approximately 0.11 sec, as well as at very short spectral periods (< 0.05 sec). The amplification over a wide spectral period range is due to the significant uncertainty and aleatory variability in the site velocity profile.

7.0 SITE-SPECIFIC DESIGN SPECTRA

Design spectra were developed following the requirements of ASCE 7-10, as modified by the 2016 CBC for structures governed by the Division of the State Architect-Structural Safety (DSA-SS). As described in Section 6, the site-specific procedures of ASCE 7-10, Chapter 21 were used to develop rock MCE_R response spectrum. A site response analysis was then performed to develop amplification functions which reflect the effects of the overlying soil on the ground motion. We note following the above procedures where the ground motions from the MCE_R are used in the site response analysis results in potentially unconservative MCE_R at the ground surface. However, that is the requirement in ASCE7-10.

In accordance with ASCE 7-10, Chapter 21, the average amplification factors are applied to the rock MCE_R response spectrum to develop the surface MCE_R response spectrum. This site-specific spectrum must not be less than 80% of the general ASCE 7-10 spectrum for the appropriate site class, which is Site Class D for this site (Section 3.3). For this site, the 80% code minimum controls the site-specific MCE_R spectrum for periods greater than 0.63 sec (Figure 33). The site-specific horizontal MCE_R spectrum is provided in Table 8.

Figure 34 and Table 7 provide the site-specific horizontal DE Spectra, which is defined as 2/3 the MCE_R response spectra, but not less than 80% of the general DE spectrum for Site Class D computed per ASCE 7-10 Chapter 11 (S_S = 2.476 g, S_1 = 1.027 g, F_a = 1.0, F_v = 1.5).

Site-specific spectral acceleration design parameters S_{DS} and S_{D1} were calculated in accordance with ASCE 7-10, Section 21.4 (Table 8). S_{DS} is defined as the site-specific 0.2 sec SA, but not less than 90% the SA for all periods greater than 0.2 sec. For this site, the site-specific S_{DS} is 1.96 g. S_{D1} is defined as the site-specific 1.0 sec SA, but not less than twice the 2.0 sec SA. For this site, the site-specific S_{D1} is 0.82 g. S_{MS} and S_{M1}, defined as 1.5 times S_{DS} and S_{D1}, are 2.94 and 1.23 g, respectively. All spectral design acceleration values are provided in Table 8.

For the landslide analysis, we recommend that the geometric mean deterministic or probabilistic ground motions for rock be used. The 84th percentile horizontal geomean spectrum for rock is listed in Table 2 and the 2,475 year return period geomean UHS for rock is tabulated in Table 3. Use of the maximum-direction and/or risk-adjusted ground motions could result in over-driving the nonlinear behavior of the soil column resulting in ground motions that are too low.

8.0 REFERENCES CITED

Aargaard, B.T., Blair, J.L., Boatwright, J., Garcia, S.H., Harris, R.A., Michael, A.J., Schwartz, D.P., and DiLeo, J.S., 2016, Earthquake Outlook for the San Francisco Bay Region 2014-2043: U.S. Geological Survey Fact Sheet 2016-3020.

Abrahamson, N.A. and Silva, W.J., 2008, Summary of the Abrahamson and Silva NGA ground motion relations. Earthquake Spectra, v. 24, p. 67-97.

Abrahamson, N.A., Silva, W.J., and Kamai, R., 2014, Summary of the ASK14 ground-motion relation for active crustal regions: Earthquake Spectra, v. 30, p. 1025-1055.

American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI), 2010, Minimum design loads for buildings and other structures, ASCE 7-10.

American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI), 2013, Seismic evaluation and retrofit of existing buildings, ASCE 41-13.

Al Atik, L. and Youngs, R., 2014, Epistemic uncertainty for NGA-West2 models: Earthquake Spectra, v. 30, p. 1301-1318.

Bakun, W.H., 1999, Seismic activity of the San Francisco Bay region: Bulletin of the Seismological Society of America, v.89, p. 764-784.

Boore, D.M., and Atkinson, G.M., 2008, Ground motion predictive equations for the average horizontal component of PGA, PGV, and 5% damped PSA at spectral periods between 0.01s to 10.0s: Earthquake Spectra, v. 24, p. 99-138.

Boore, D.M., Stewart, J.P., Seyhan, E., and Atkinson, G.M., 2014, NGA-West2 equations for predicting PGA, PGV, and 5%-damped PSA for shallow crustal earthquakes: Earthquake Spectra, v. 30, p. 1057-1085.

California Building Standards Commission, 2016, California Building Code (CBC), California Code of Regulations, Title 24, Vol. 1 and 2.

Campbell, K.W. and Bozorgnia, Y., 2008, NGA ground motion model for the geometric mean horizontal component of PGA, PGV, PGD, and 5% damped linear elastic response spectra for periods ranging from 0.01 to 10s: Earthquake Spectra, v. 24, p. 139-171.

Campbell, K.W. and Bozorgnia, Y., 2014, NGA-West2 ground motion model for the average horizontal components of PGA, PGV, and 5%-damped linear acceleration response spectra: Earthquake Spectra, v. 30, p. 1087-1115.

Cao, T., Bryant, W.A, Rowshandel, B., Branum, D., Wills, C.J., 2003, The revised 2002 California probabilistic seismic hazard maps, June 2003: California Geological Survey, http://www.consrv.ca.gov/CGS/rghm/psha/fault_parameters/pdf/2002_CA_Hazard_Maps.pdf.

Chiou, B.S.J. and Youngs, R.R., 2008, An NGA model for the average horizontal component of peak ground motion and response spectra: Earthquake Spectra, v. 24, p. 173-215.

Chiou, B-S.J. and Youngs, R.R., 2014, Update of the Chiou and Youngs NGA ground motion model for average horizontal component of peak ground motion and response spectra: Earthquake Spectra, v. 30, p. 1117-1153.

dePolo, C. M., 1994, The maximum background earthquake for the Basin and Range Province, western North America: Bulletin of the Seismological Society of America, v. 84, p. 466-472.

Electric Power Research Institute (EPRI), 1993, Guidelines for determining design basic ground motions, v. 1: Method and guidelines for estimating earthquakes ground motion in eastern North America: EPRI Report TR-102293.

Field, E.H., Biasi, G.P., Bird, P., Dawson, T.E., Felzer, K.R., Jackson, D.D., Johnson, K.M., Jordan, T.H., Madden, C., Michael, A.J., Milner, K.R., Page, M.T., Parsons, T., Powers, P.M., Shaw, B.E., Thatcher, W.R., Weldon, R.J., II, and Zeng, Y., 2013, Uniform California earthquake rupture forecast, version 3 (UCERF3)—The time-independent model: U.S. Geological Survey Open-File Report 2013–1165, 97 p., California Geological Survey Special Report 228, and Southern California Earthquake Center Publication 1792, http://pubs.usgs.gov/of/2013/1165/.

Hecker, S., Pantosti, D., Schwartz, D., Hamilton, J., Reidy, L., and Power, T., 2005, The most recent large earthquake on the Rodgers Creek fault, San Francisco Bay area: Bulletin of the Seismological Society of America, v. 95, p. 844-860.

Idriss, I.M. and Seed, H.B., 1968, Seismic response of horizontal soil layers: Journal of Soil Mechanics and Foundations Division, v. 94, p. 1003-1031.

Lienkaemper, J.J., 1992, Map of recently active traces of the Hayward fault, Alameda and Contra Costa counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2196, 1:24,000.

Lienkaemper, J.J. and Williams, P.L., 2007, A record of large earthquake on the southern Hayward fault for the past 1800 years: Bulletin of the Seismological Society of America, v. 97, p. 1803-1819.

Lienkaemper, J.J., McFarland, F.S., Simpson, R.W., Bilham, R.G., Ponce, D.A., Boatwright, J.J. and Caskey, S.J., 2012, Long-term creep rates on the Hayward fault: Evidence for controls on the size and frequency of large earthquakes: Bulletin of the Seismological Society of America, v. 102, p. 31–41.

Lienkaemper, J.J. Schwartz, D.P., Kelson, K.I., Lettis, W.R., Simpson, G.D., Southon, J.R. Wanket, J.A., Williams, P.L., 1999, Timing of paleoearthquakes on the northern Hayward fault – preliminary evidence in El Cerrito, California: U.S. Geological Survey Open-File Report 99-318, 34 p.

Schnabel, P.B., Lysmer, J., and Seed, H.B., 1972, SHAKE – A computer program for earthquake analysis of horizontally layered sites: Earthquake Engineering Research Center, University of California, Berkeley, Report No. EERC 72-12.

Schwartz, D.P., Pantosti, D., Hecker, S., Okomura, K., Budding, K.E. and Powers, T., 1992, Late Holocene behavior and seismogenic potential of the Rodgers Creek fault zone, Sonoma County, California, in Proceedings of the Second Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, Borchardt, G., Hirschfeld, S.E., Lienkaemper, J.J., McClellan, P., Williams, P.L. and Wong, I.G. (eds.), California Division of Mines and Geology Special Publication 113, p. 393-398.

Shahi, S.K. and Baker, J.W., 2014, NGA-West2 models for ground-motion directionality: Pacific Earthquake Engineering Research Center, PEER Report 2013/10, 73 p.

Silva, W.J., Abrahamson, N.A., Toro, G., and Constantino, C., 1997, Description and validation of the stochastic ground motion model: unpublished report prepared for the Brookhaven National Laboratory.

Silva, W.J. and Lee, K., 1987, WES RASCAL code for synthesizing earthquake ground motions, State-of-the-Art for Assessing Earthquake Hazards in the United States, Report 24, U.S. Corps of Engineers Waterways Experiment Station, Miscellaneous Paper S-73-1, 120 p.

Toppozada, T.R. and Borchardt, G., 1998, Re-evaluation of the 1836 “Hayward Fault” earthquake and the 1838 San Andreas fault earthquake: Bulletin of the Seismological Society of America, v. 88, p. 140-159.

Toppozada, T.R., Real, C.R., and Parke, D.L., 1981, Preparation of isoseismal maps and summaries of reported effects for pre-1900 California earthquakes: California Division of Mines and Geology Open-File Report 81-11, 181 p.

Toro, G.R., 1996, Probabilistic models of site velocity profiles for generic and site-specific ground motion amplification studies. Appendix in Silva et al (1997).

URS Corporation/Jack R. Benjamin & Associates, Inc., 2007, Technical memorandum topical area: seismic hazard, Delta Risk Management Study (DRMS) Phase 1, unpublished report submitted to California Department of Water Resources.

Wagner, D.L. and Bortugno, E.J., 1982, Geologic map of the Santa Rosa quadrangle: California Division of Mines and Geology, Regional Geologic Map Series No. 2A, 1:250,000.

WGCEP (Working Group for California Earthquake Probabilities), 2008, The Uniform Earthquake Rupture Forecast, version 2 (UCERF2): U.S. Geological Survey Open-File Report 2007-1437.

WGCEP (Working Group on California Earthquake Probabilities), 2003, Earthquake probabilities in the San Francisco Bay region: 2002–2031: U.S. Geological Survey Open-File Report 03-214.

WGNCEP (Working Group On Northern California Earthquake Potential), 1996, Database of potential sources for earthquakes larger than magnitude 6 in Northern California: U.S. Geological Survey Open-File Report 96-705.

Wong, I.G., 1991, Contemporary seismicity, active faulting and seismic hazards of the Coast Ranges between San Francisco Bay and Healdsburg, California: Journal of Geophysical Research, v. 96, p. 19891-19904.

Wong, I.G., Thomas, P.A., Unruh, J., Hanson, K., and Youngs, R.R., 2008, characterizing the earthquake ground shaking hazard in the Sacramento-San Joaquin Delta, California: Geotechnical Engineering and Soil Dynamics IV Conference Proceedings, pp. 1-11.

Youngs, R.R, Coppersmith, K.J., Taylor, C.L., Power, M.S., Di Silvestro, L.A., Angell, M.L., Hall, N.T., Wesling, J.R., and Mualchin, L.,1992, A comprehensive seismic hazard model for the San Francisco Bay Region, *in* Proceedings of the Second Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, Borchardt, G., Hirschfeld, S.E., Lienkaemper, J.J., McClellan, P., Williams, P.L. and Wong, I.G. (eds.), California Division of Mines and Geology Special Publication 113, p. 431-441.

Tables

Table 1. Background Zone Recurrence Parameters

Source Zone	b-value	a
Coast Ranges	0.72	-3.68
Central Valley	1.14	-0.73

Table 2. Calculation of Deterministic Rock MCE as per ASCE 7-10, Chapter 21

Period	84th deterministic Rock spectrum, Geomean[1]	Maximum Direction Factor[2]	84th deterministic spectrum, Maximum Direction	Minimum Deterministic Spectrum per ASCE 7-10[3]	Site-Specific Deterministic MCE
(sec)	SA (g)		SA (g)	SA (g)	SA (g)
0.01	0.91	1.19	1.08	0.71	1.08
0.02	0.94	1.19	1.12	0.83	1.12
0.03	1.06	1.19	1.26	0.94	1.26
0.05	1.39	1.19	1.65	1.16	1.65
0.075	1.79	1.19	2.14	1.44	2.14
0.1	2.00	1.19	2.38	1.50	2.38
0.15	2.13	1.20	2.56	1.50	2.56
0.2	2.00	1.21	2.42	1.50	2.42
0.25	1.82	1.22	2.22	1.50	2.22
0.3	1.65	1.22	2.02	1.50	2.02
0.4	1.41	1.23	1.74	1.50	1.74
0.5	1.19	1.23	1.46	1.20	1.46
0.75	0.83	1.24	1.03	0.80	1.03
1	0.65	1.24	0.81	0.60	0.81
1.5	0.44	1.24	0.54	0.40	0.54
2	0.31	1.24	0.38	0.30	0.38
3	0.19	1.25	0.24	0.20	0.24
4	0.14	1.26	0.17	0.15	0.17
5	0.11	1.26	0.14	0.12	0.14
7.5	0.063	1.28	0.081	0.08	0.081
10	0.038	1.29	0.049	0.048	0.049

[1] 84th deterministic spectrum, geomean using V_S30 = 1,000 m/sec (Section 5)
[2] Maximum -direction factors from Shahi and Baker (2014)
[3] Minimum deterministic spectrum for Site Class B (Fa=1.0, Fv = 1.0)

Table 3. Calculation of Probabilistic Rock MCE_R as per ASCE 7-10, Chapter 21

Period	2,475-YR UHS, Geomean[1]	Maximum Direction Factor[2]	2,475-YR UHS, Maximum Direction	risk coefficient[3]	Site-Specific Probabilistic MCE_R
(sec)	SA (g)		SA (g)		SA (g)
0.01	1.07	1.19	1.28	1.002	1.28
0.03	1.32	1.19	1.57	1.002	1.58
0.05	1.88	1.19	2.24	1.002	2.25
0.075	2.41	1.19	2.87	1.002	2.88
0.1	2.64	1.19	3.14	1.002	3.15
0.15	2.69	1.2	3.23	1.002	3.23
0.2	2.54	1.21	3.08	**1.002**	3.08
0.25	2.30	1.22	2.80	1.0005	2.80
0.3	2.06	1.22	2.52	0.999	2.51
0.4	1.74	1.23	2.14	0.996	2.13
0.5	1.44	1.23	1.77	0.993	1.76
0.75	1.00	1.24	1.24	0.9855	1.22
1	0.77	1.24	0.96	**0.978**	0.94
1.5	0.52	1.24	0.64	0.978	0.63
2	0.37	1.24	0.46	0.978	0.45
3	0.23	1.25	0.28	0.978	0.28
4	0.16	1.26	0.20	0.978	0.19
5	0.12	1.26	0.16	0.978	0.15
7.5	0.066	1.28	0.084	0.978	0.082
10	0.036	1.29	0.046	0.978	0.045

[1] 2,475-Yr UHS, geomean using V_S30 = 1,000 m/sec (Section 4)
[2] Maximum-direction factors from Shahi and Baker (2014)
[3] Risk coefficients from https://seismicmaps.org/ accessed 6 February 2019

Table 4. Calculation of Site-Specific Rock MCE_R as per ASCE 7-10, Chapter 21

Period	Site-Specific Probabilistic MCE_R	Site-Specific Deterministic MCE	80% ASCE 7-10 MCE_R, Site Class B[1]	Site-Specific MCE_R
(sec)	SA (g)	SA (g)	SA (g)	SA (g)
0.01	1.28	1.08	0.93	1.08
0.02	NC	1.12	1.08	1.12
0.03	1.58	1.26	1.22	1.26
0.05	2.25	1.6	1.51	1.65
0.075	2.88	2.14	1.86	2.14
0.1	3.15	2.38	1.98	2.38
0.15	3.23	2.56	1.98	2.56
0.2	3.08	2.42	1.98	2.42
0.25	2.80	2.22	1.98	2.22
0.3	2.51	2.02	1.98	2.02
0.4	2.13	1.74	1.98	1.98
0.415	NC	NC	1.98	1.98
0.5	1.76	1.46	1.64	1.64
0.75	1.22	1.03	1.10	1.10
1	0.94	0.81	0.82	0.82
1.5	0.63	0.54	0.55	0.55
2	0.45	0.38	0.41	0.41
3	0.28	0.24	0.27	0.27
4	0.19	0.17	0.21	0.21
5	0.15	0.14	0.16	0.16
7.5	0.082	0.081	0.11	0.11
10	0.045	0.049	0.066	0.066

[1] S_S = 2.473, S_1 = 1.027, Fa = 1.0, Fv = 1.0

Table 5. Scaled Input Time Histories for Site Response Analysis

RSN	YEAR	EARTHQUAKE NAME	STATION NAME	MAG (M)	R_{RUP} (km)	Vs30 (m/sec)	COMP	PGA (g)	PGV (cm/sec)	PGD (cm)	AI (m/sec)	5-95% DURATION (sec)
143	1978	Tabas, Iran	Tabas	7.4	2.1	767	L1	0.83	95.8	36.4	10.0	16.5
285	1980	Irpinia, Italy-01	Bagnoli Irpinio	6.9	8.2	650	000	0.69	125.3	69.7	7.9	19.6
765	1989	Loma Prieta	Gilroy Array #1	6.9	9.6	1428	000	1.61	130.3	31.1	14.4	6.5
879	1992	Landers	Lucerne	7.3	2.2	1369	260	0.93	170.6	145.7	10.3	13.2
8164	1999	Duzce, Turkey	IRIGM 487	7.1	2.7	690	NS	1.20	153.4	79.2	26.0	17.6

RSN – record sequence number in PEER Ground Motion Database
R_{RUP} – rupture distance
COMP - component
PGA = peak ground acceleration
PGV – peak ground velocity
PGD – peak ground displacement
AI – Arias Intensity

Table 6. Weights for Basecase Properties in Site Response Analysis

PROPERTY	BASECASE	WEIGHT
V_S Profile	Best-Estimate, P1	0.6
V_S Profile	Lower-range, P2	0.2
V_S Profile	Upper-range, P3	0.2
G/Gmax, Damping Curves	EPRI (1993), M1	0.5
G/Gmax, Damping Curves	Peninsular Range (Silva *et al.*, 1997), M2	0.5

Table 7. Site-Specific Surface MCE_R and DE Spectra as per ASCE 7-10, Chapter 21

Period	Site-Specific Rock MCE_R * Site AFs[1]	80% ASCE 7-10 MCE_R, Site Class D	Site-Specific MCE_R	2/3 RDS MCE_R	80% ASCE 7-10 DE, Site Class D[2]	Site-Specific DE
(sec)	SA (g)	SA (g)	SA (g)	SA (g)	SA (g)	SA (g)
0.01	1.38	0.89	1.38	0.92	0.59	0.92
0.02	1.40	0.98	1.40	0.93	0.65	0.93
0.03	1.44	1.08	1.44	0.96	0.72	0.96
0.05	1.78	1.27	1.78	1.18	0.85	1.18
0.075	2.09	1.51	2.09	1.39	1.00	1.39
0.1	2.27	1.74	2.27	1.51	1.16	1.51
0.15	2.87	1.98	2.87	1.91	1.32	1.91
0.2	2.92	1.98	2.92	1.95	1.32	1.95
0.25	2.89	1.98	2.89	1.92	1.32	1.92
0.3	2.85	1.98	2.85	1.90	1.32	1.90
0.4	2.79	1.98	2.79	1.86	1.32	1.86
0.415	2.78	1.98	2.78	1.85	1.32	1.85
0.5	2.28	1.98	2.28	1.52	1.32	1.52
0.623	NC	1.98	1.98	1.32	1.32	1.32
0.75	1.49	1.64	1.64	1.10	1.10	1.10
1	1.12	1.23	1.23	0.82	0.82	0.82
1.5	0.69	0.82	0.82	0.55	0.55	0.55
2	0.49	0.62	0.62	0.41	0.41	0.41
3	0.30	0.41	0.41	0.27	0.27	0.27
4	0.22	0.31	0.31	0.21	0.21	0.21
5	0.17	0.25	0.25	0.16	0.16	0.16
7.5	0.11	0.18	0.18	0.12	0.12	0.12
10.0	0.069	0.10	0.10	0.066	0.066	0.066

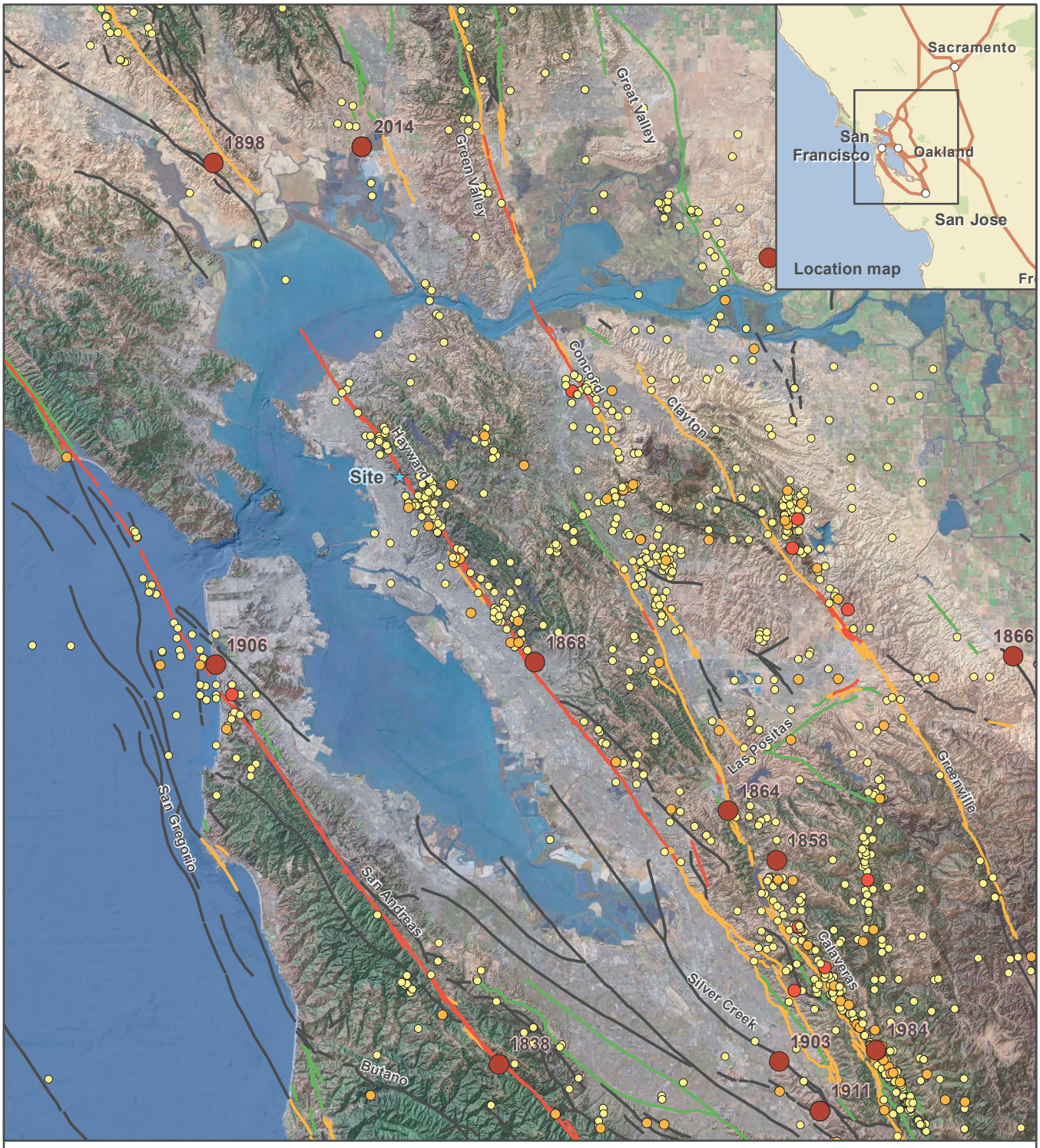
[1] AFs = Amplification factors

[2] S_S = 2.473, S_1 = 1.027, Fa = 1.0, Fv = 1.5

Table 8. Site-Specific Ground Motion Parameters as per ASCE 7-10, Chapter 21

PARAMETER	DESCRIPTION	VALUE
S_S	Mapped Short-Period (0.2 sec) Spectral Acceleration Value (Site Class B)	2.473g
S_1	Mapped Long-Period (1.0 sec) Spectral Acceleration Value (Site Class B)	1.027g
Seismic Design Category	Based on 1.0 sec mapped spectral acceleration, S1, as per 2013 CBC Section 1613A.3.5	E
Site Class	Site Class Based on ASCE 7-10 Chapter 20	D
F_a	Site Class D	1.0
F_v	Site Class D	1.5
C_{RS}	Short-period risk coefficient	1.002
C_{R1}	Long-Period risk coefficient	0.978
S_{DS}, Site-Specific	Spectral value at 0.2 seconds (but not less than 90% SA for all periods greater than 0.2 seconds)	1.95
S_{D1}, Site-Specific	Spectral value at 1.0 seconds (but not less than twice the 2.0 sec SA)	0.82
S_{MS}, Site-Specific	$1.5*S_{DS}$	2.92
S_{M1}, Site-Specific	$1.5*S_{D1}$	1.23
PGA_M	Site-Specific MCE_G peak ground acceleration	1.16 g
M	Magnitude for liquefaction analysis based on deterministic analysis	7.2
R	Distance for liquefaction analysis based on deterministic analysis	0.46 km

Figures



EXPLANATION

Magnitude

- 3.0 - 4.0
- 4.1 - 5.0
- 5.1 - 6.0
- 6.1 - 7.0

- Historic faults
- Holocene faults
- Late Quaternary faults
- Quaternary faults

N W E S

0 10 20 mi

0 20 40 km

Map projection and scale: NAD 1983 UTM Zone 10N, 1:641,964

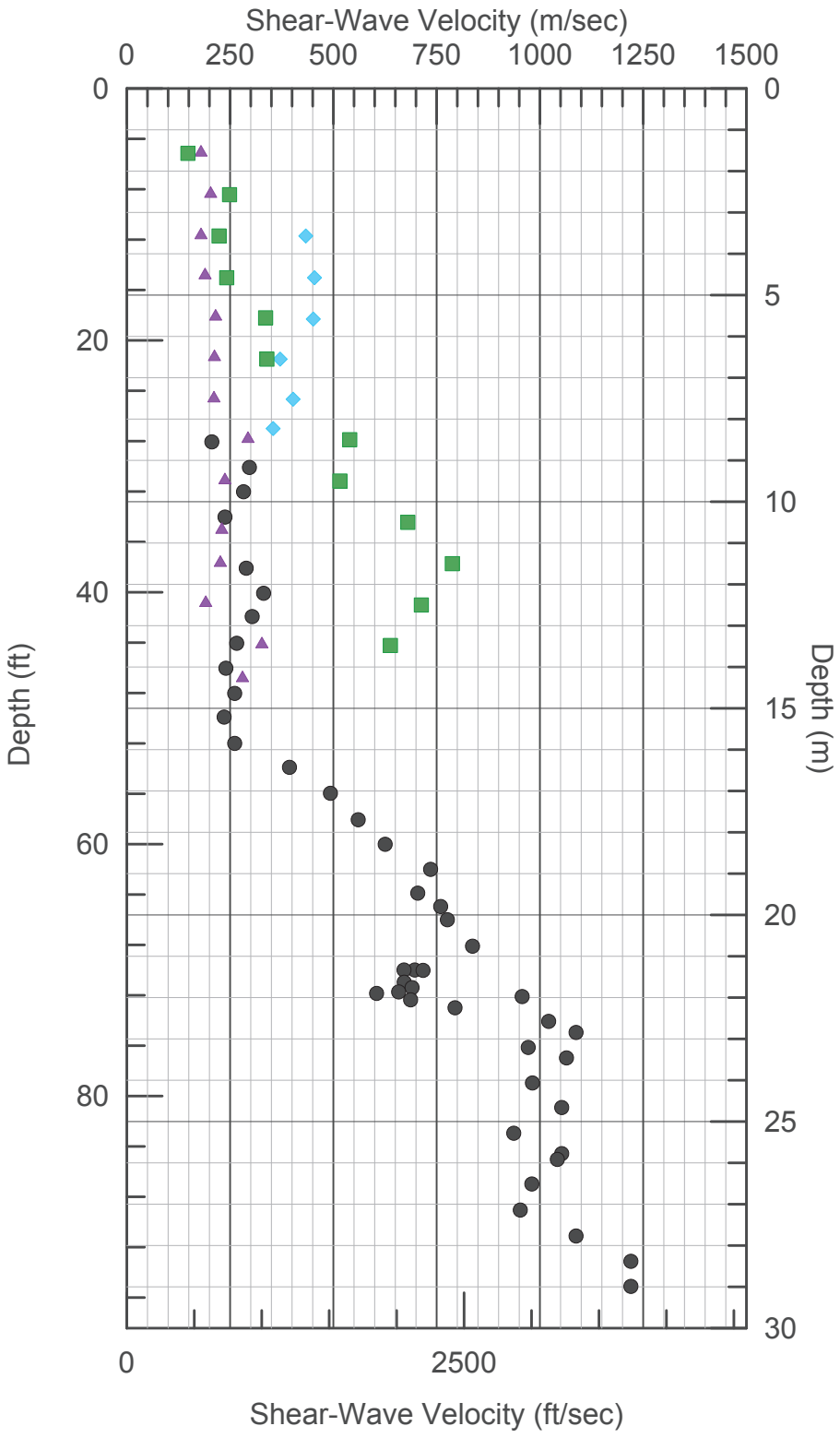
Historical Seismicity (M > 3.0, 1800 - 2018) and Quaternary Faults in the San Francisco Bay Region

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure 1

File path: S:\1770\Figures\Figure_01.mxd; Date: 02/11/2019; User: nora, LCI; Rev.1



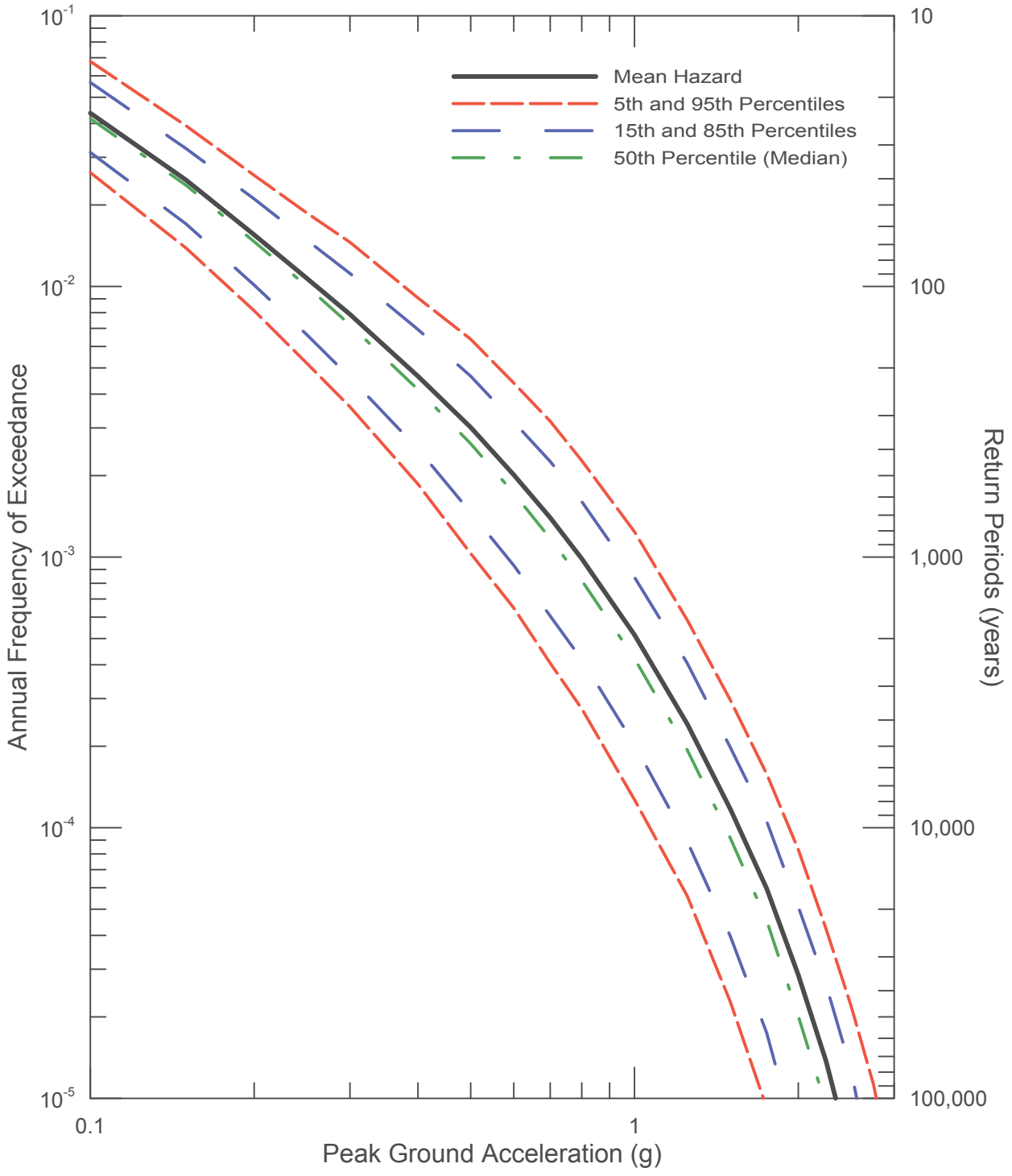
- B-1 Suspension - Norcal 2018
- SP01 sCPT - ConeTec 2018
- SP02 sCPT - ConeTec 2018
- SP03 sCPT - ConeTec 2018

Site-Specific V_s Measurements

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure 2

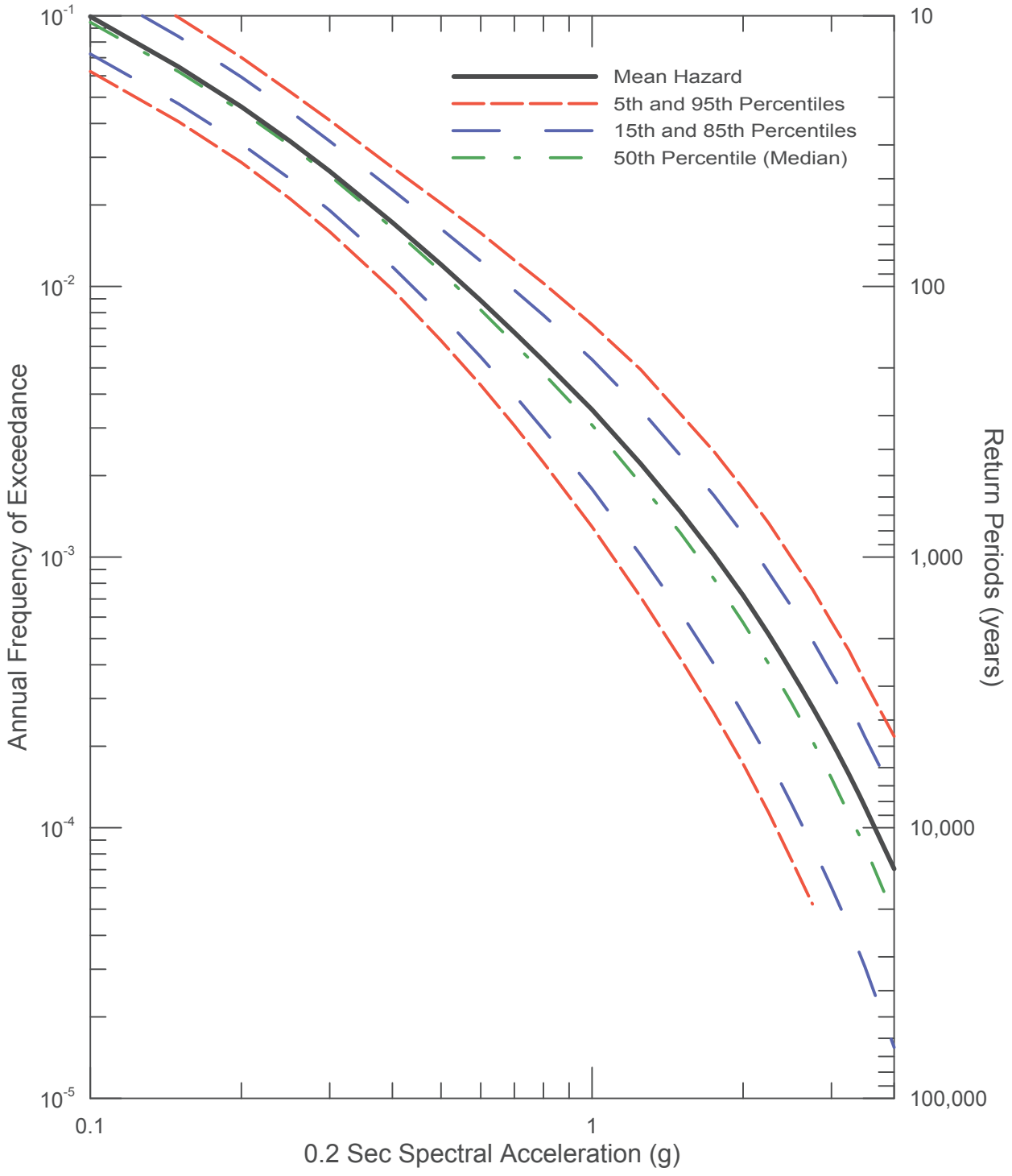


Seismic Hazard Curves
for Peak Horizontal Acceleration
for V_S30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure **3**

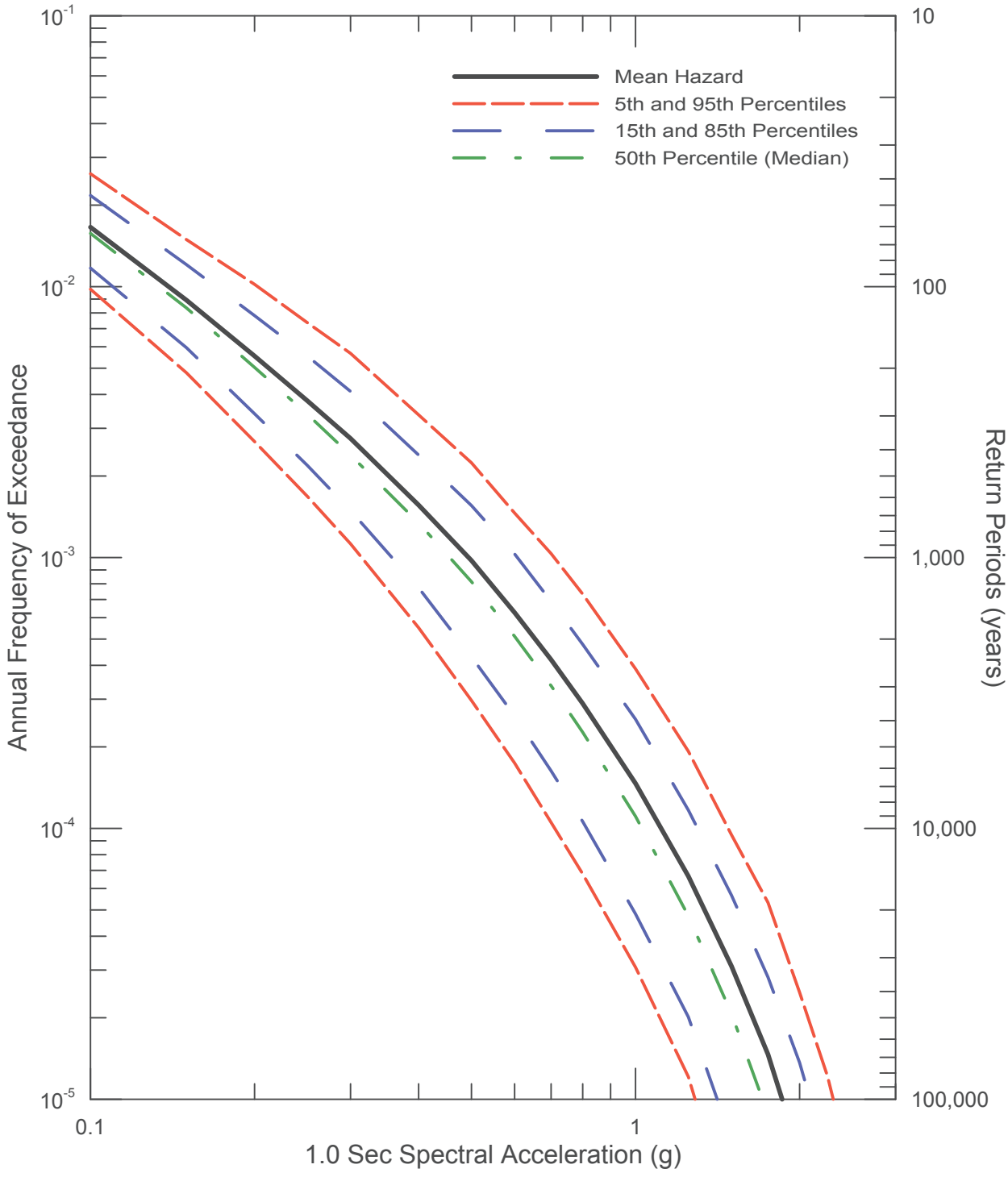


Seismic Hazard Curves
for 0.2 Sec Horizontal Spectral Acceleration
for V_S30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.**

Figure **4**

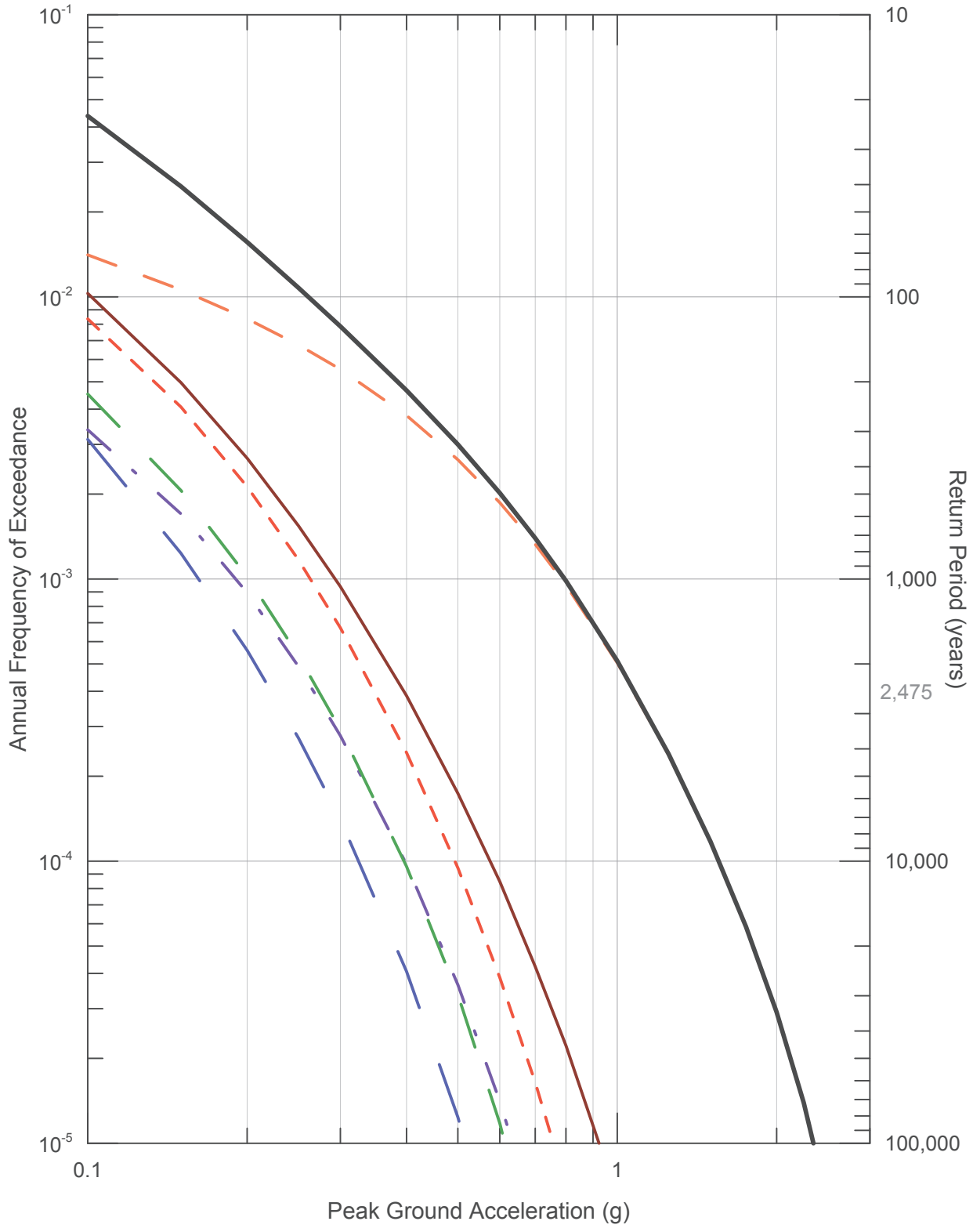


Seismic Hazard Curves
for 1.0 Sec Horizontal Spectral Acceleration
for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.**

Figure **5**

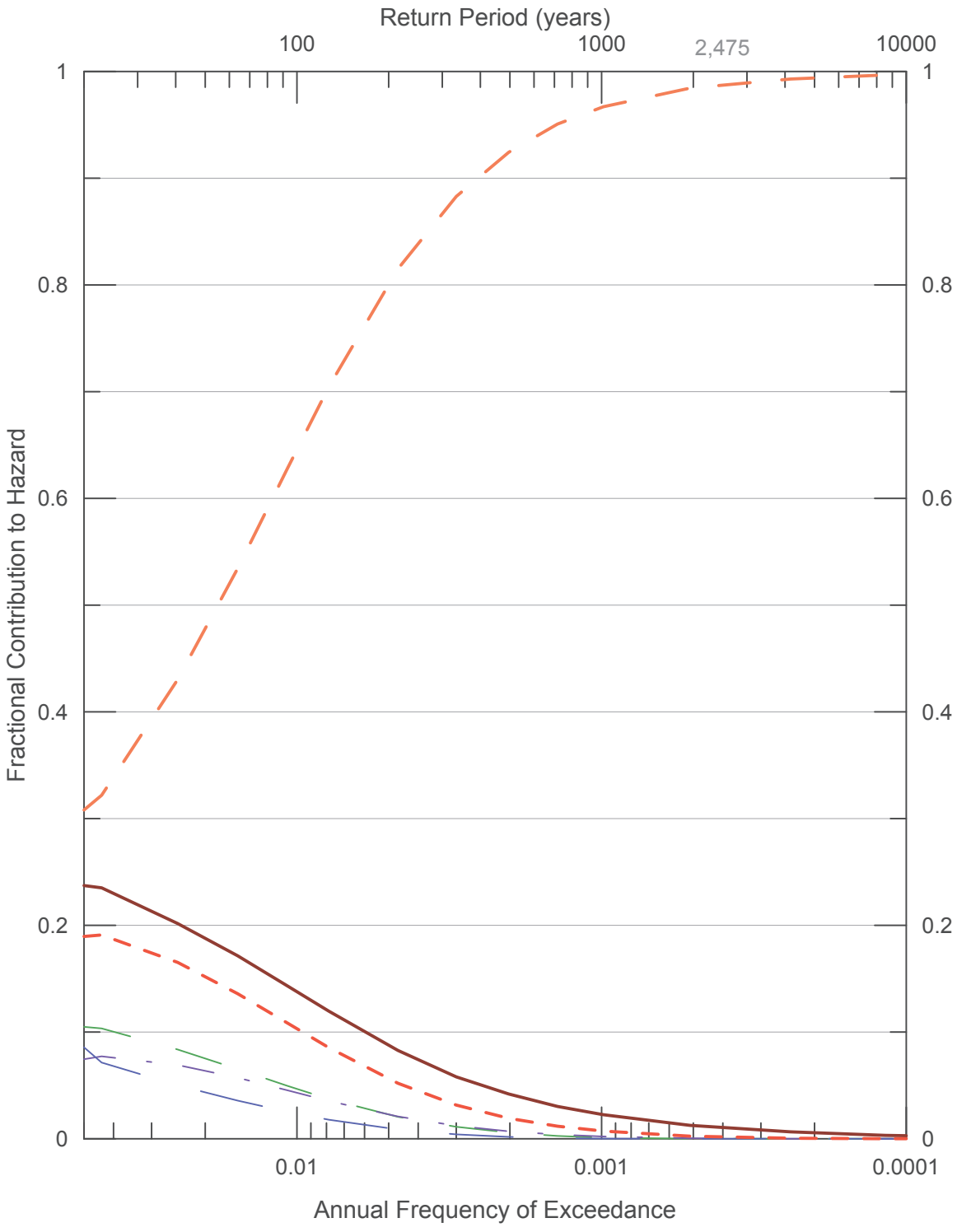


Seismic Source Contributions to Mean Peak Horizontal Acceleration Hazard for V_S30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure **6**

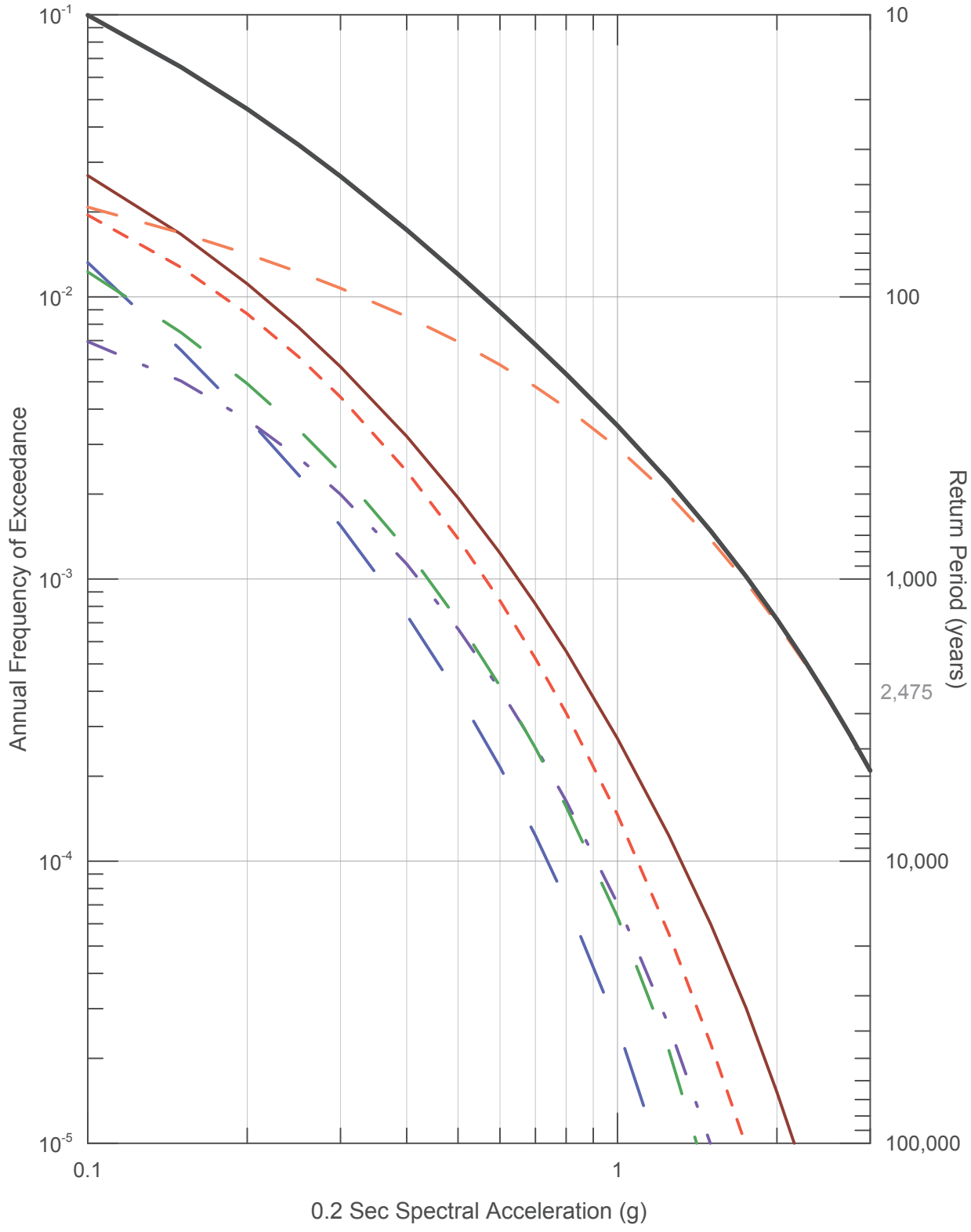


Seismic Source Fractional Contributions to Mean Peak Horizontal Acceleration Hazard for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure 7

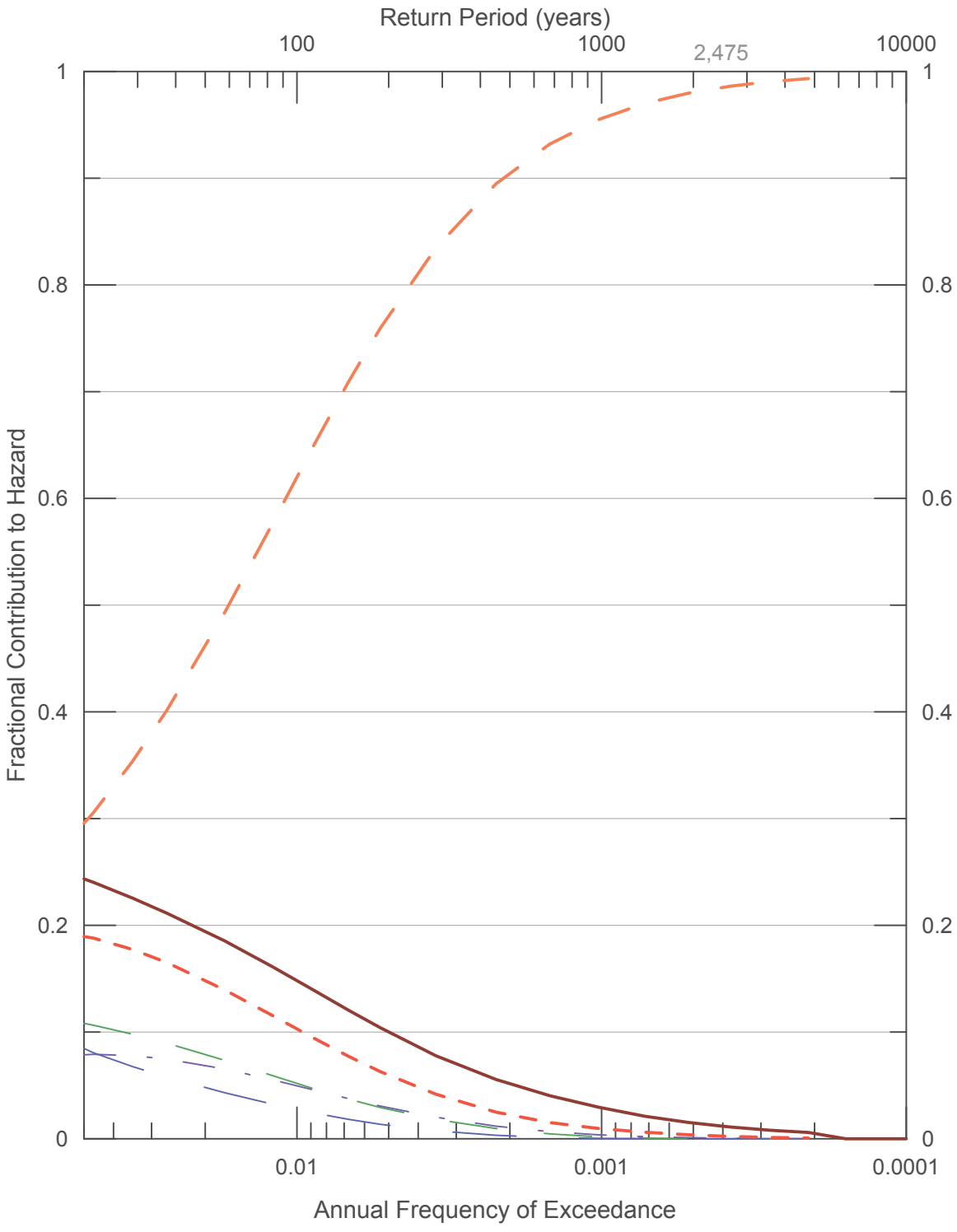


Seismic Source Contributions to Mean 0.2 Sec Horizontal Spectral Acceleration Hazard for V_S30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure 8

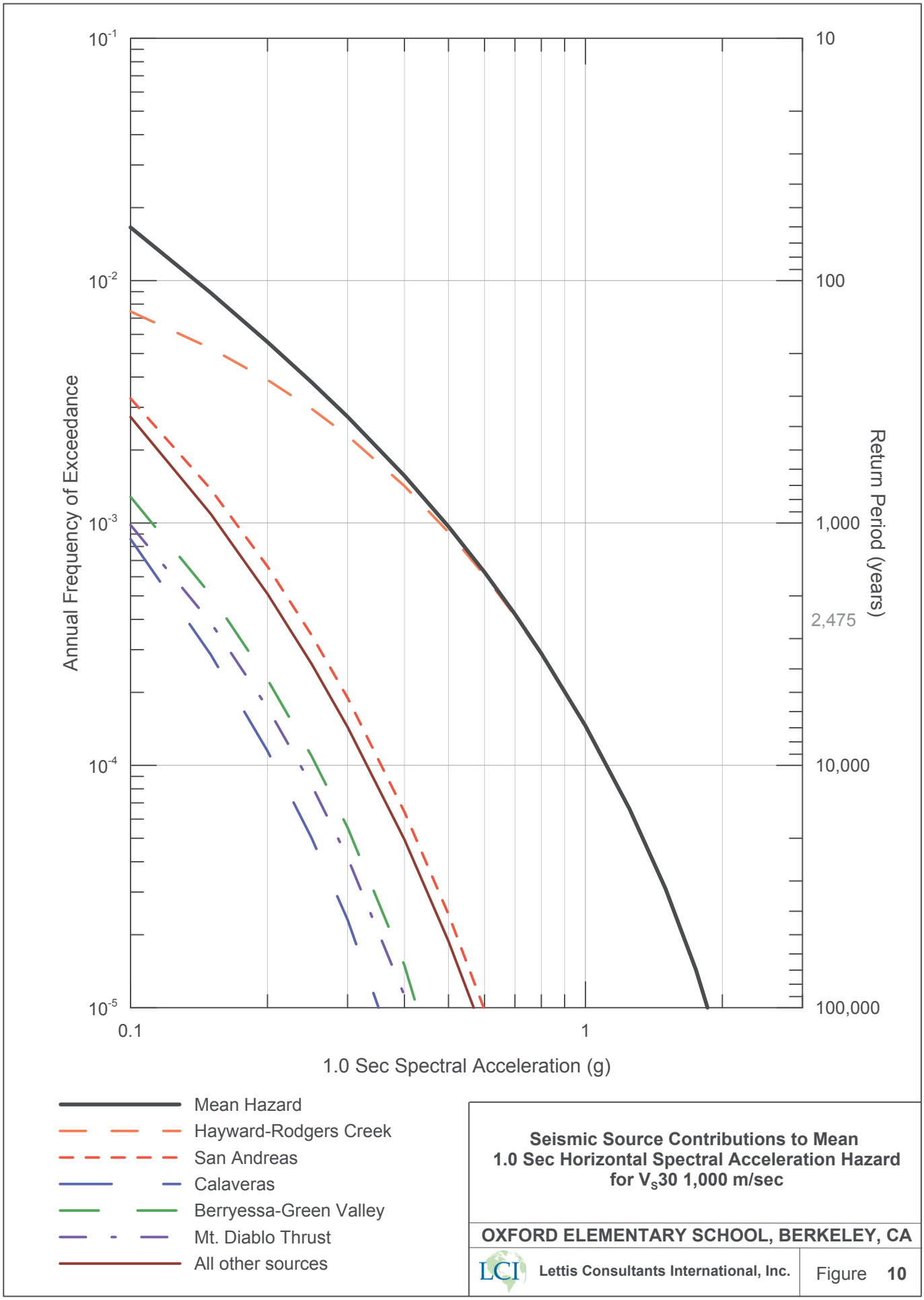


Seismic Source Fractional Contributions to Mean 0.2 Sec Horizontal Spectral Acceleration Hazard for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure **9**

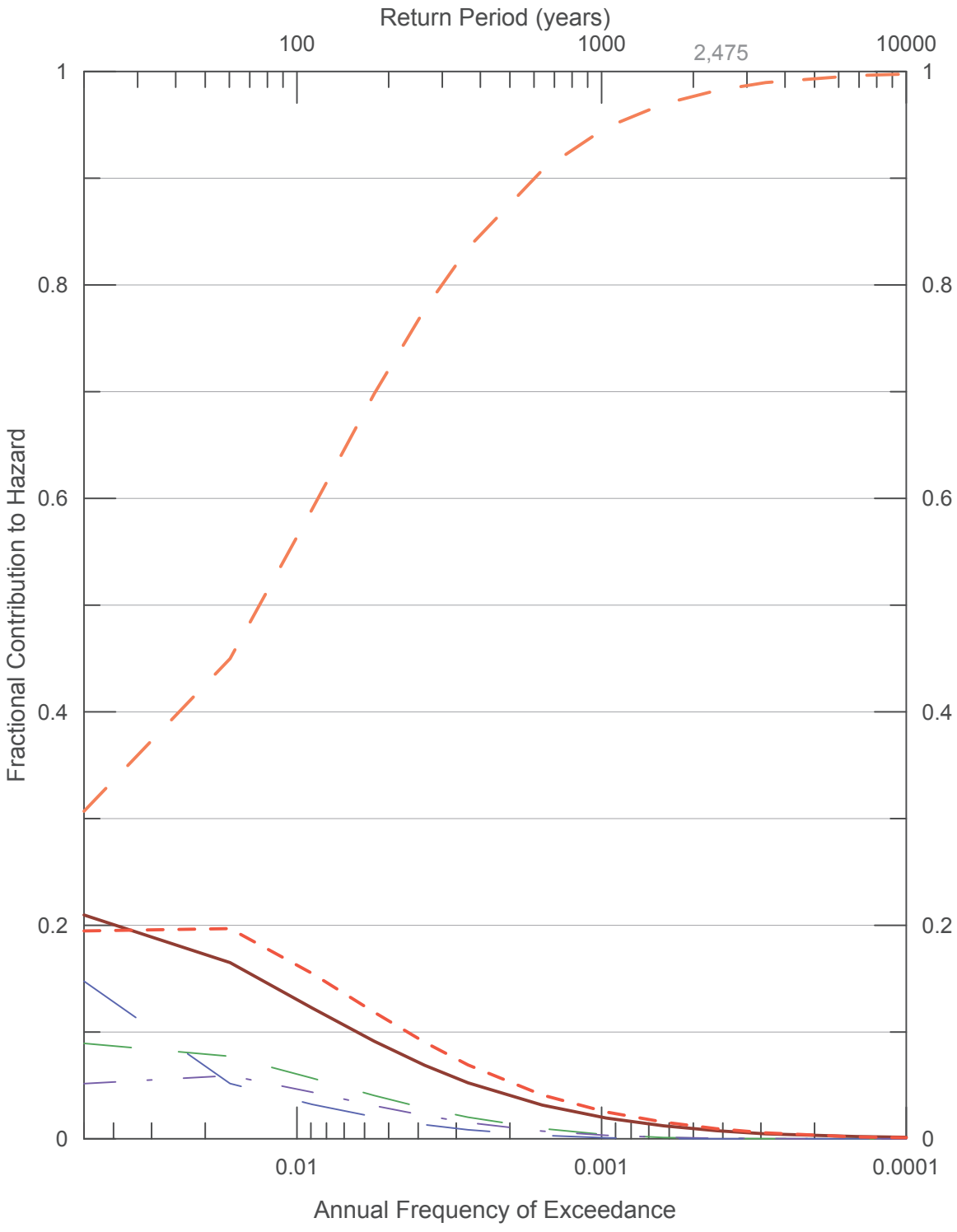


Seismic Source Contributions to Mean 1.0 Sec Horizontal Spectral Acceleration Hazard for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure **10**

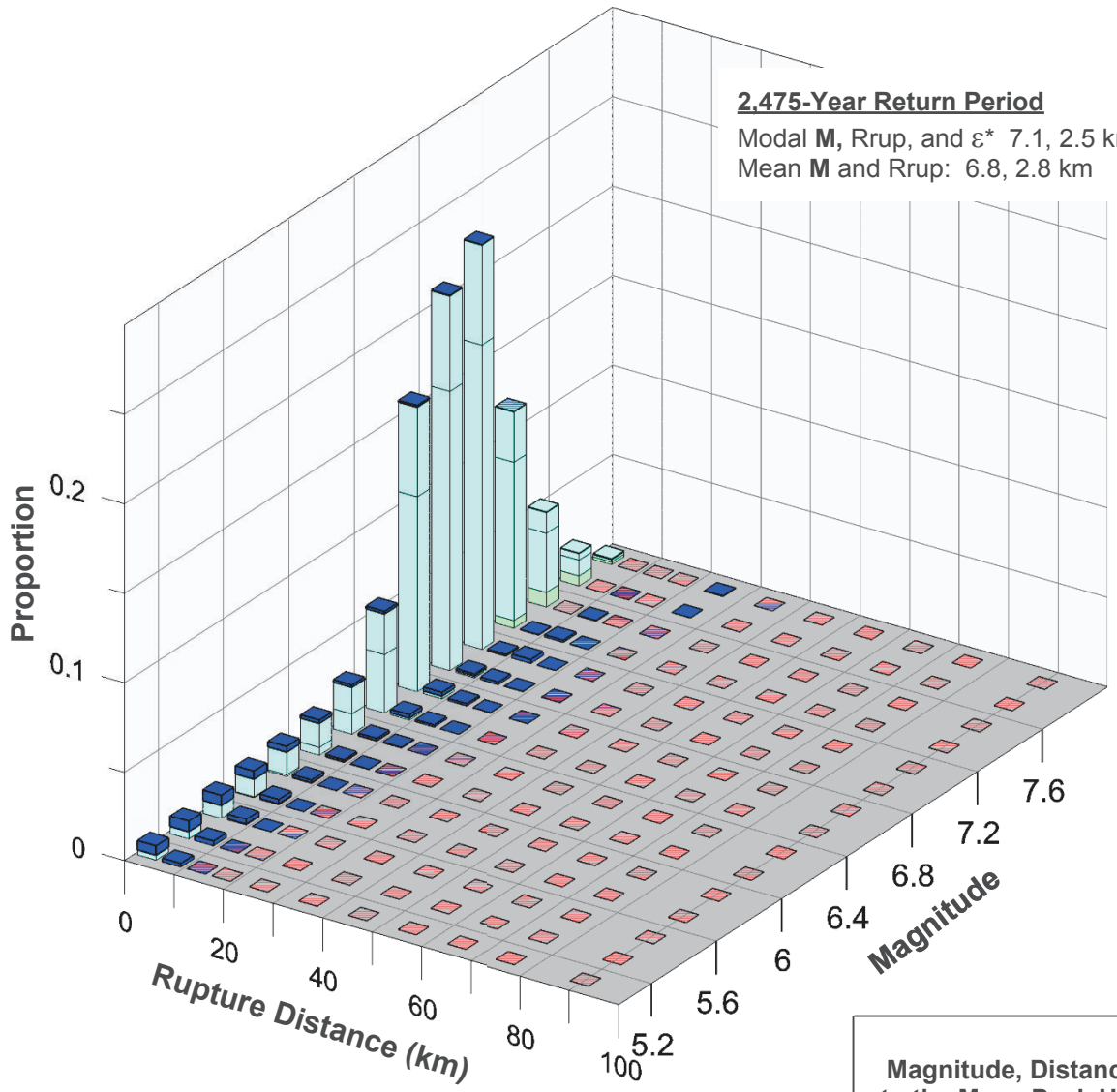


Seismic Source Fractional Contributions to Mean 1.0 Sec Horizontal Spectral Acceleration Hazard for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure **11**



Epsilon

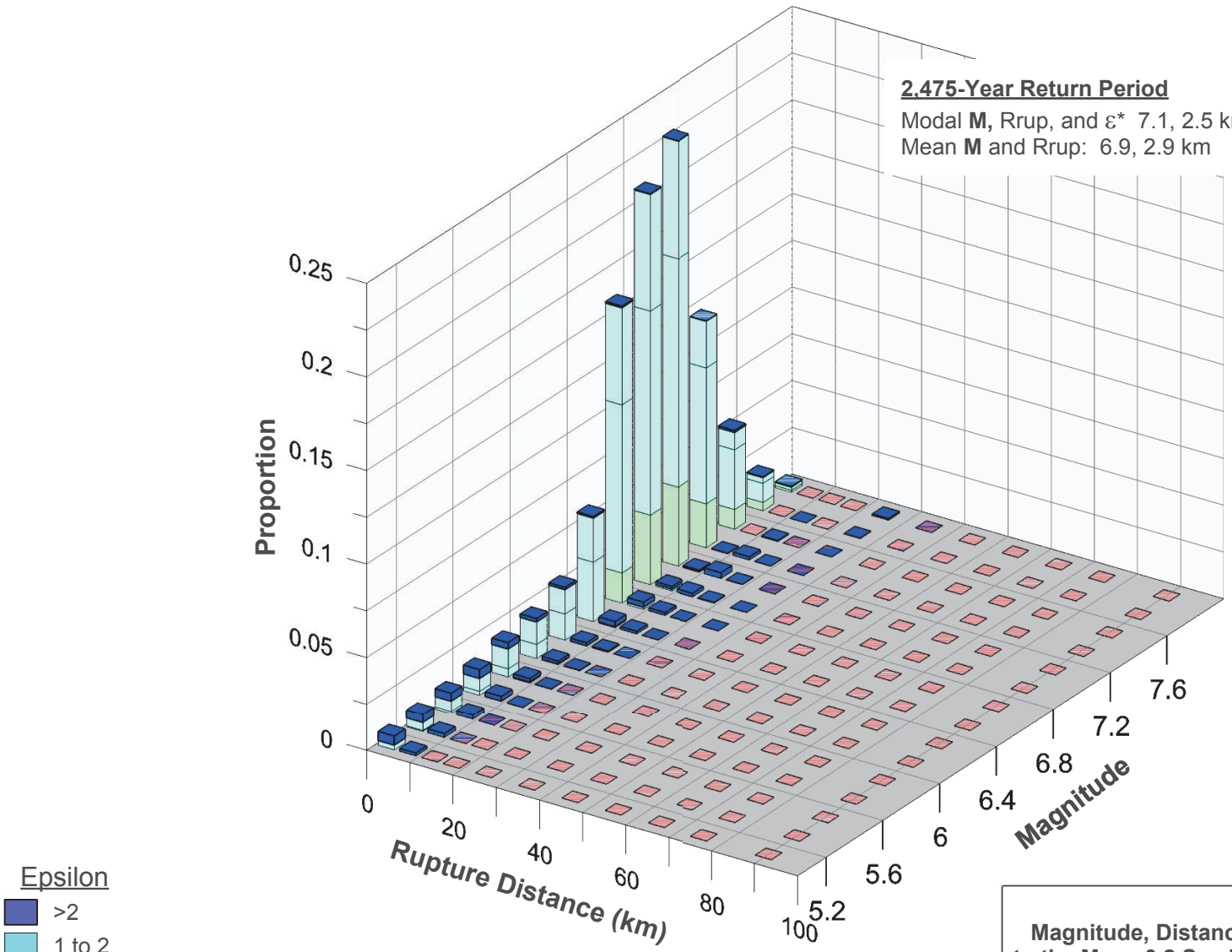
- >2
- 1 to 2
- 0 to 1
- -1 to 0
- -2 to -1
- <-2

Note: ε* is the mean epsilon for the modal M and Rrup bin.

Magnitude, Distance, and Epsilon Contributions to the Mean Peak Horizontal Acceleration Hazard at 2,475-Year Return Period for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.** Figure **12**

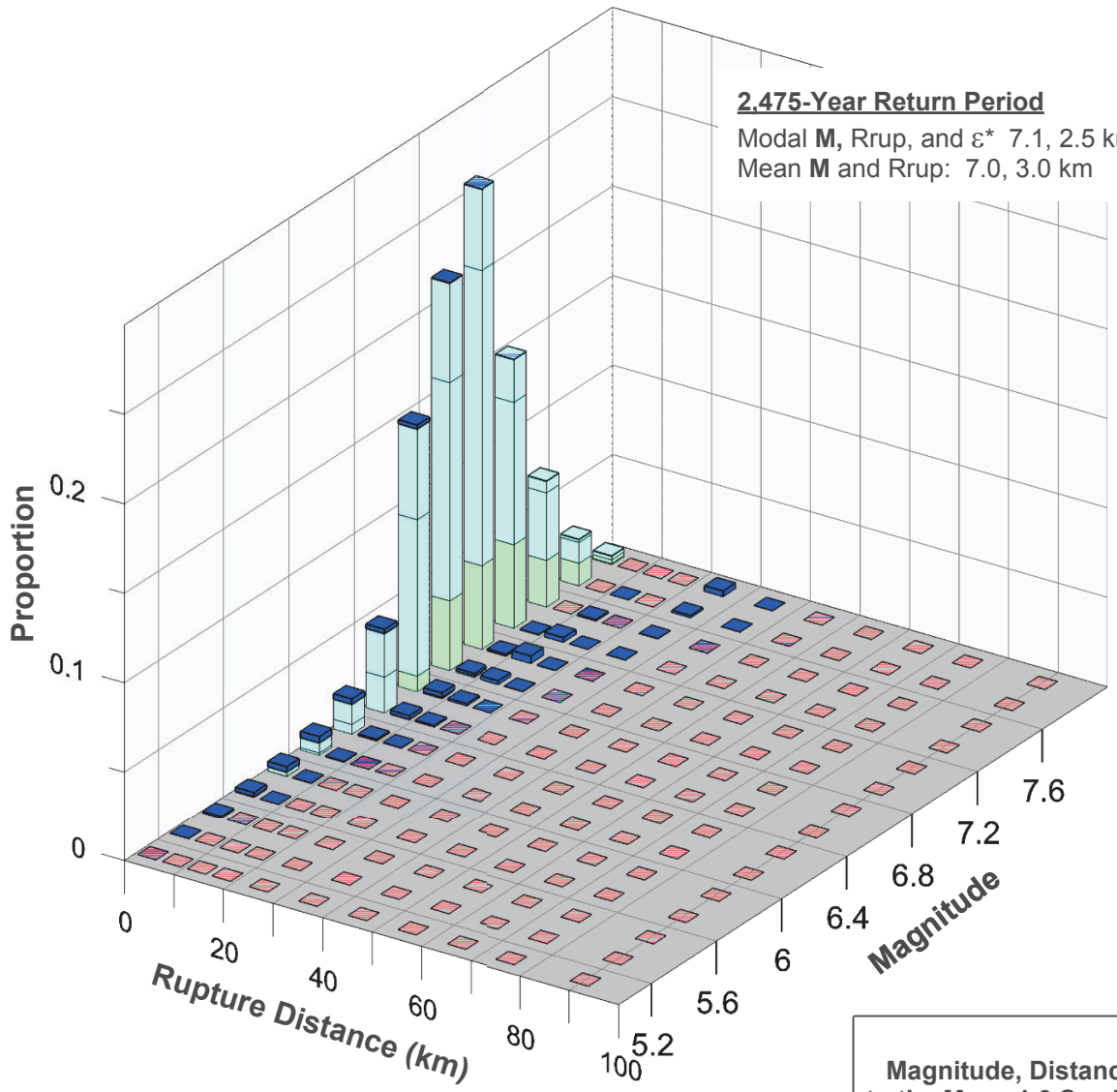


Note: ε* is the mean epsilon for the modal M and Rrup bin.

Magnitude, Distance, and Epsilon Contributions to the Mean 0.2 Sec Horizontal Acceleration Hazard at 2,475-Year Return Period for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.** Figure **13**



Epsilon

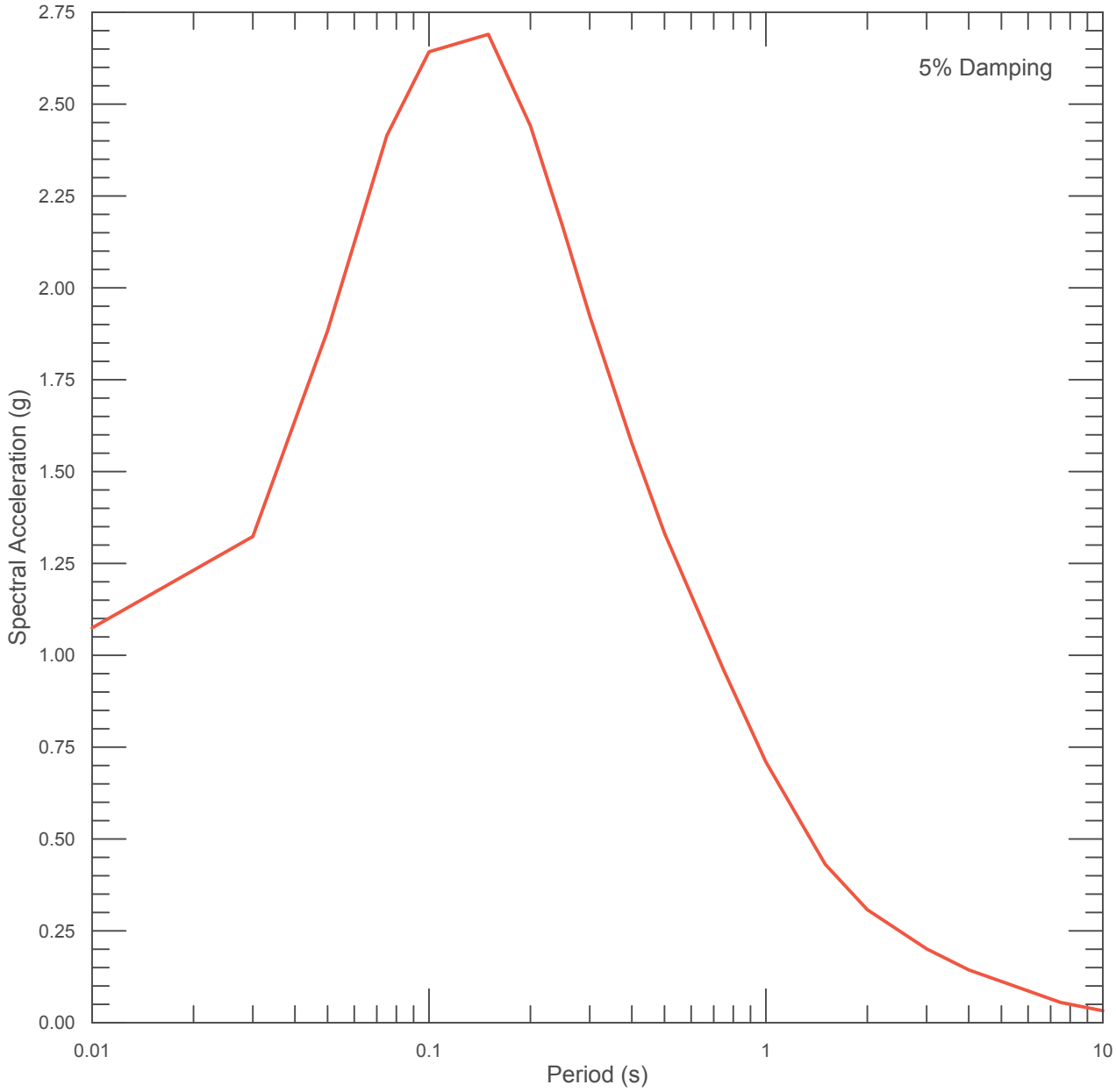
- >2
- 1 to 2
- 0 to 1
- -1 to 0
- -2 to -1
- <-2

Note: ε* is the mean epsilon for the modal M and Rrup bin.

Magnitude, Distance, and Epsilon Contributions to the Mean 1.0 Sec Horizontal Acceleration Hazard at 2,475-Year Return Period for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.** | Figure **14**

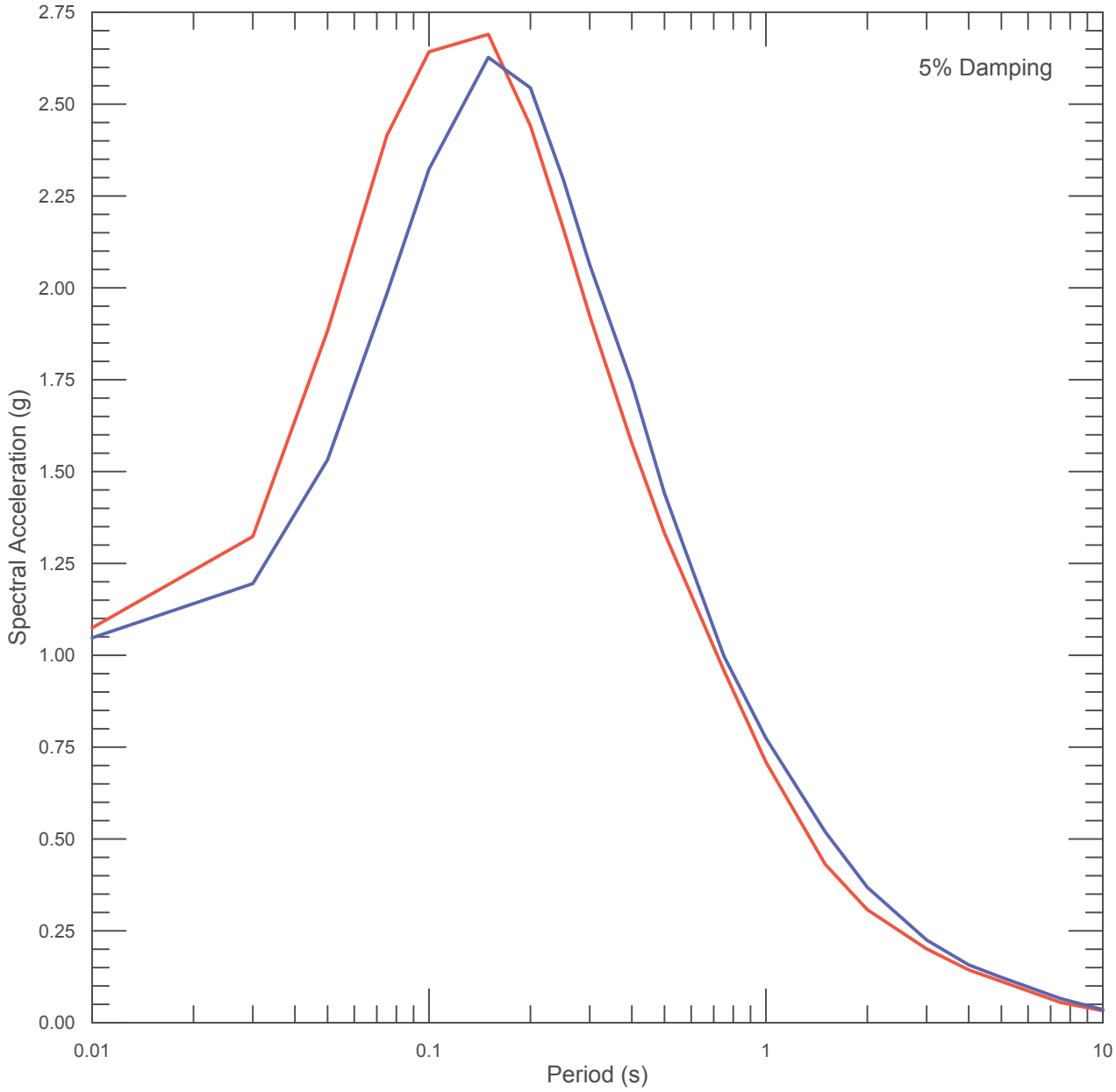


5%-Damped Uniform Hazard Spectra at Return Period of 2,475 Years for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure **15**



2,475-year Return Period, GMM

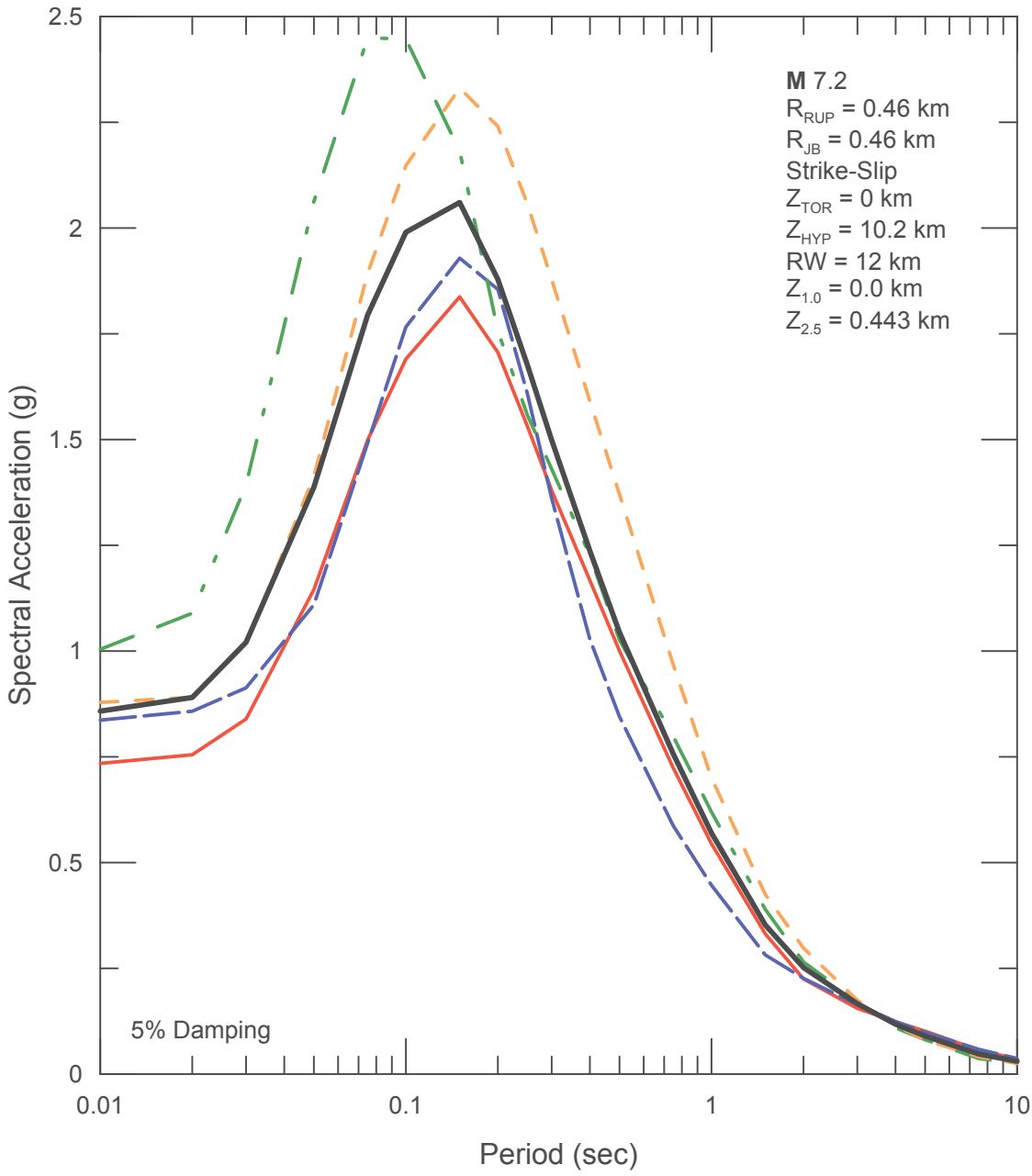
NGA-W2

NGA-W1

Comparison of Uniform Hazard Spectra at 2,475-year Return Period Using NGA-W1 and NGA-W2 for V_s30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BEREKELEY, CA

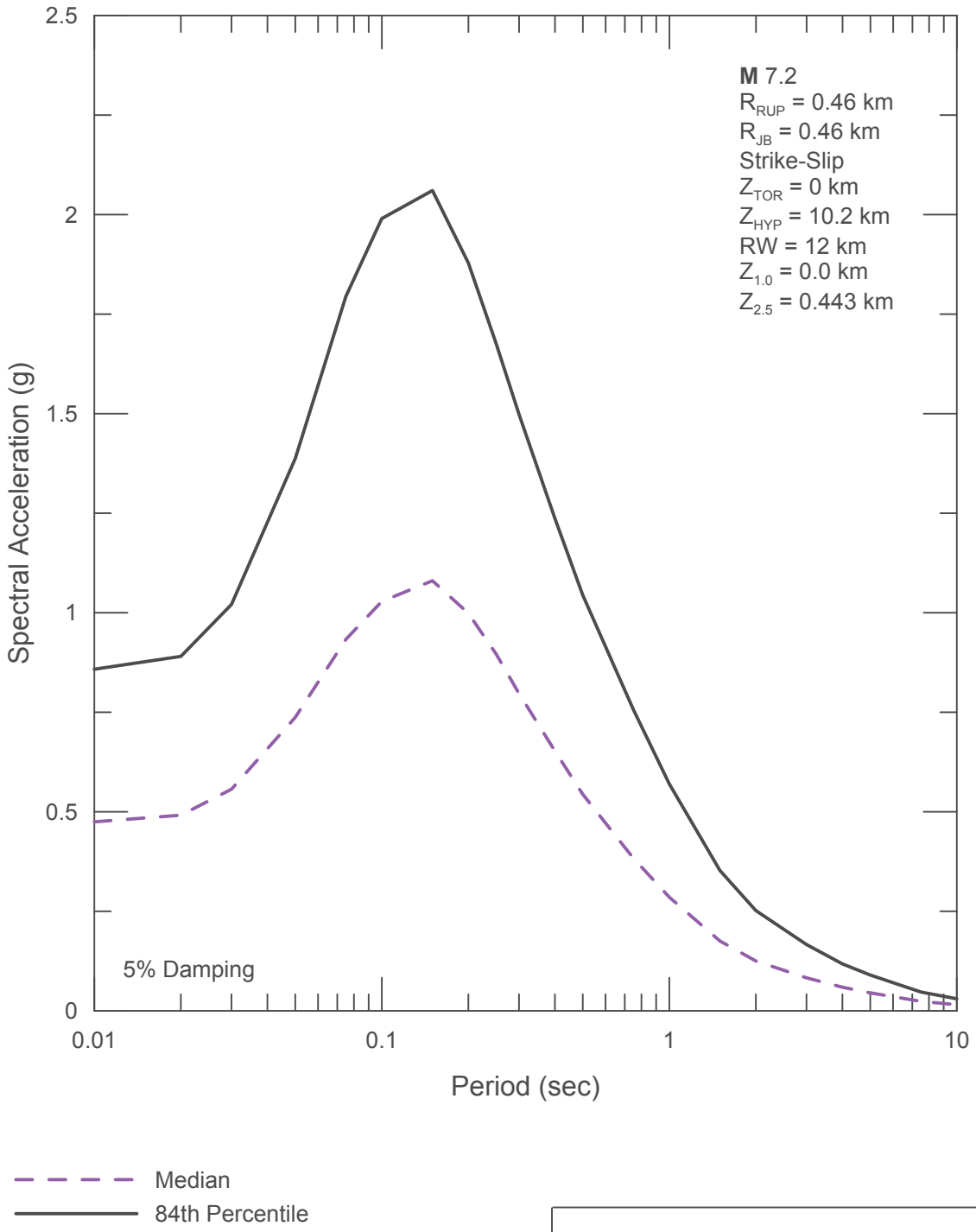
Lettis Consultants International, Inc. | Figure **16**



5%-Damped 84th Percentile Deterministic Horizontal Acceleration Response Spectra for M 7.2 Hayward Event for V_S30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc. | Figure **17**

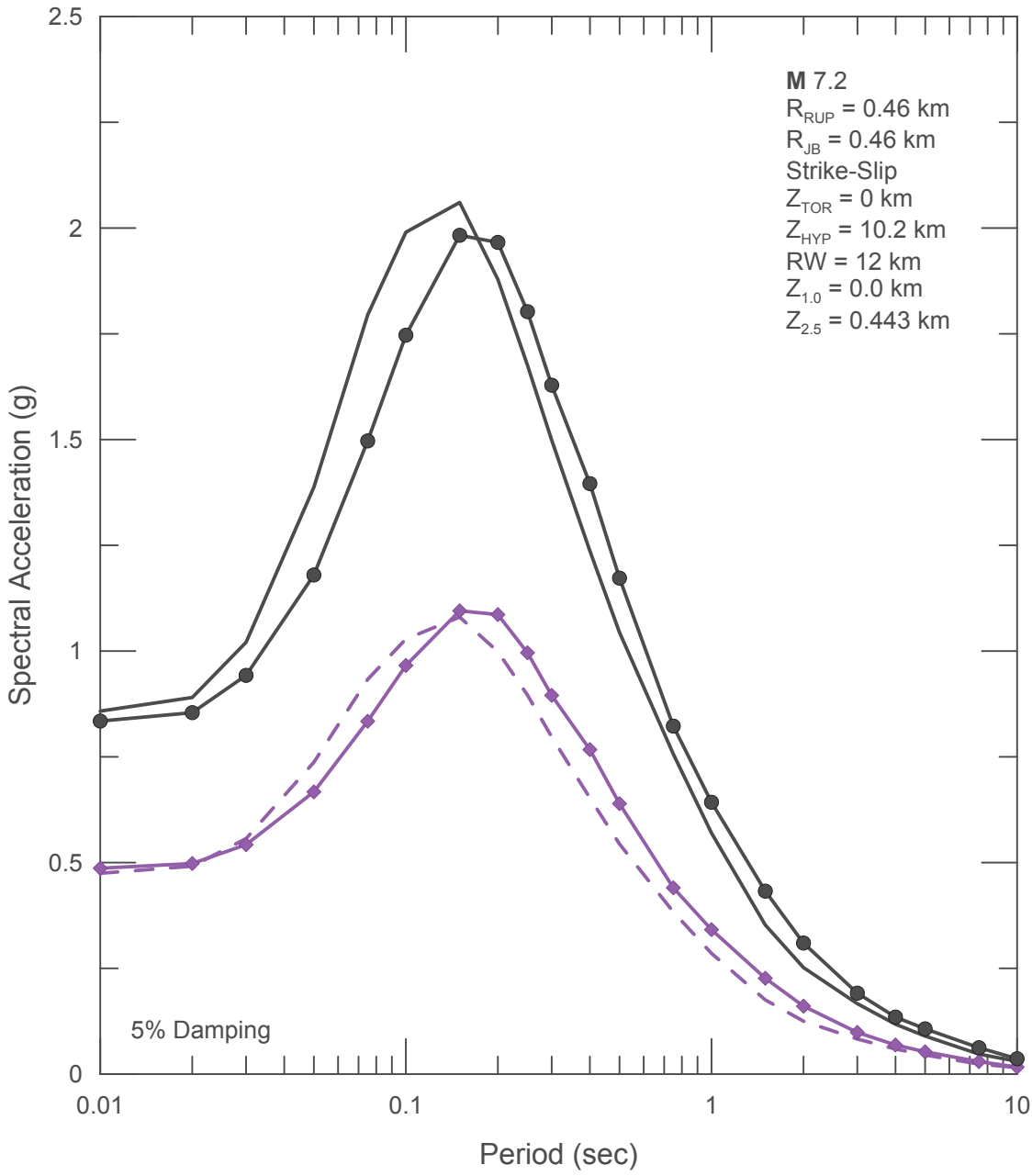


Median and 84th Percentile Deterministic Horizontal Acceleration Response Spectra for M 7.2 Hayward Event for V_S30 1,000 m/sec

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

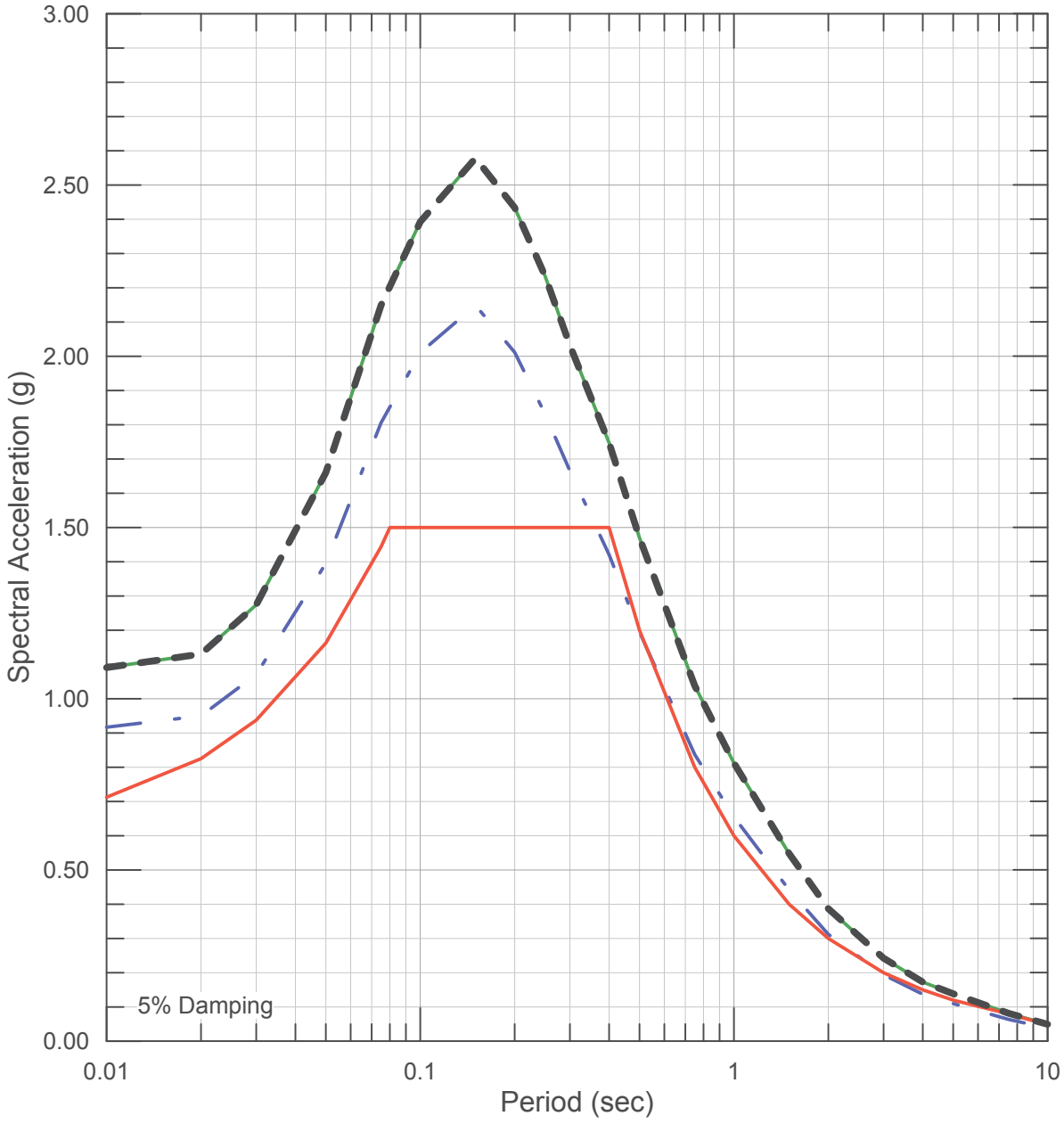
Figure **18**



Comparison of Median and 84th Percentile Deterministic Horizontal Acceleration Response Spectra for M 7.2 Hayward Event for V_S30 1,000 m/sec Using NGA-W1 and NGA-W2

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc. | Figure **19**

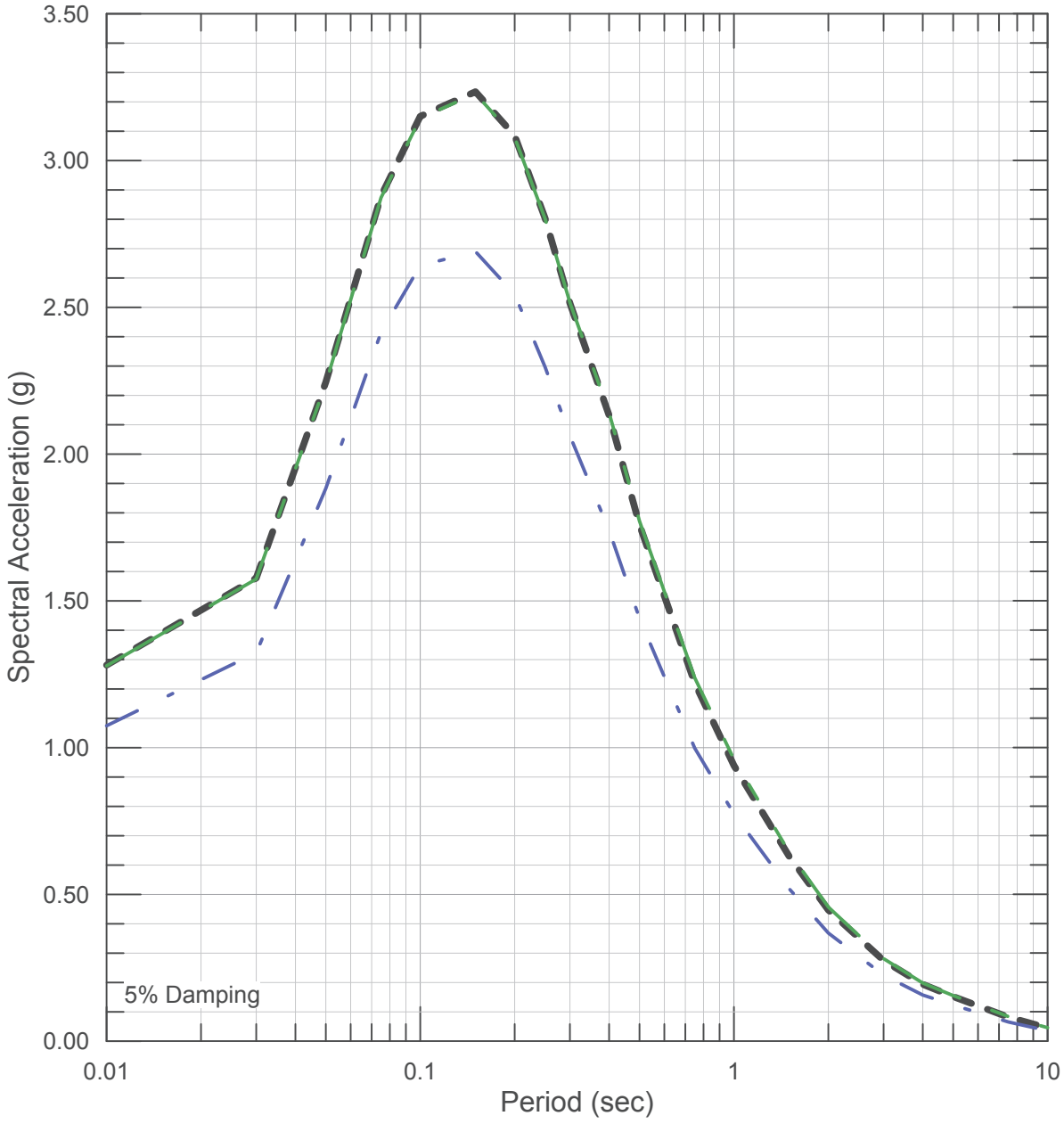


Notes:
Maximum direction factors from Shahi and Baker (2014)

Calculation of Site-Specific Deterministic Rock MCE Spectrum as per ASCE 7-10, Chapter 21

OXFORD ELEMENTARY SCHOOL BERKELEY, CA

LCI **Lettis Consultants International, Inc.** **Figure 20**

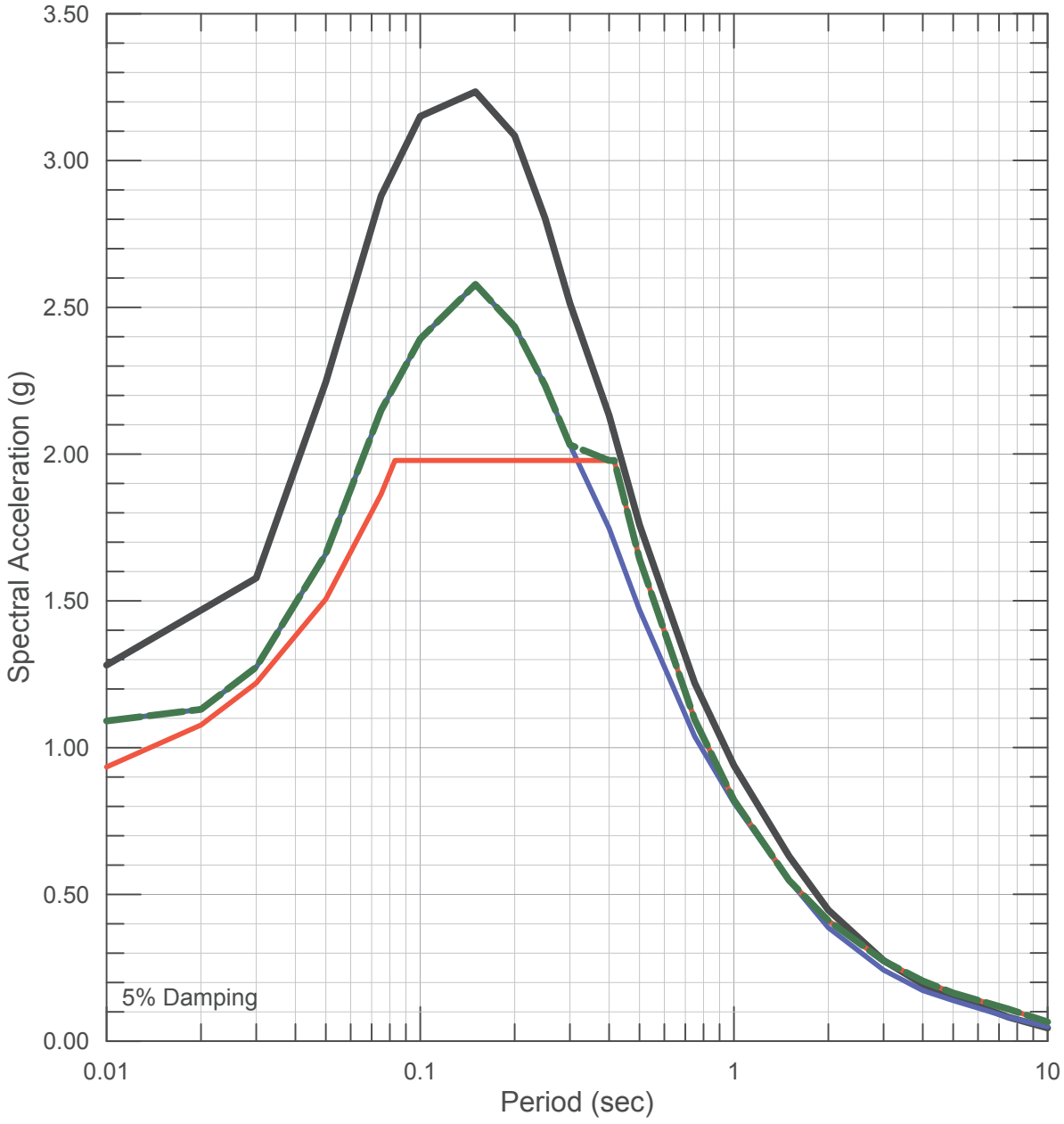


Calculation of Site-Specific Probabilistic Rock MCE$_R$ Spectrum, as per ASCE 7-10, Chapter 21

OXFORD ELEMENTARY SCHOOL BERKELEY, CA

Notes:
Maximum direction factors from Shahi and Baker (2014)
Risk coefficients C_{RS} = 1.002, C_{R1} = 0.978 from USGS Website

LCI **Lettis Consultants International, Inc.** **Figure 21**



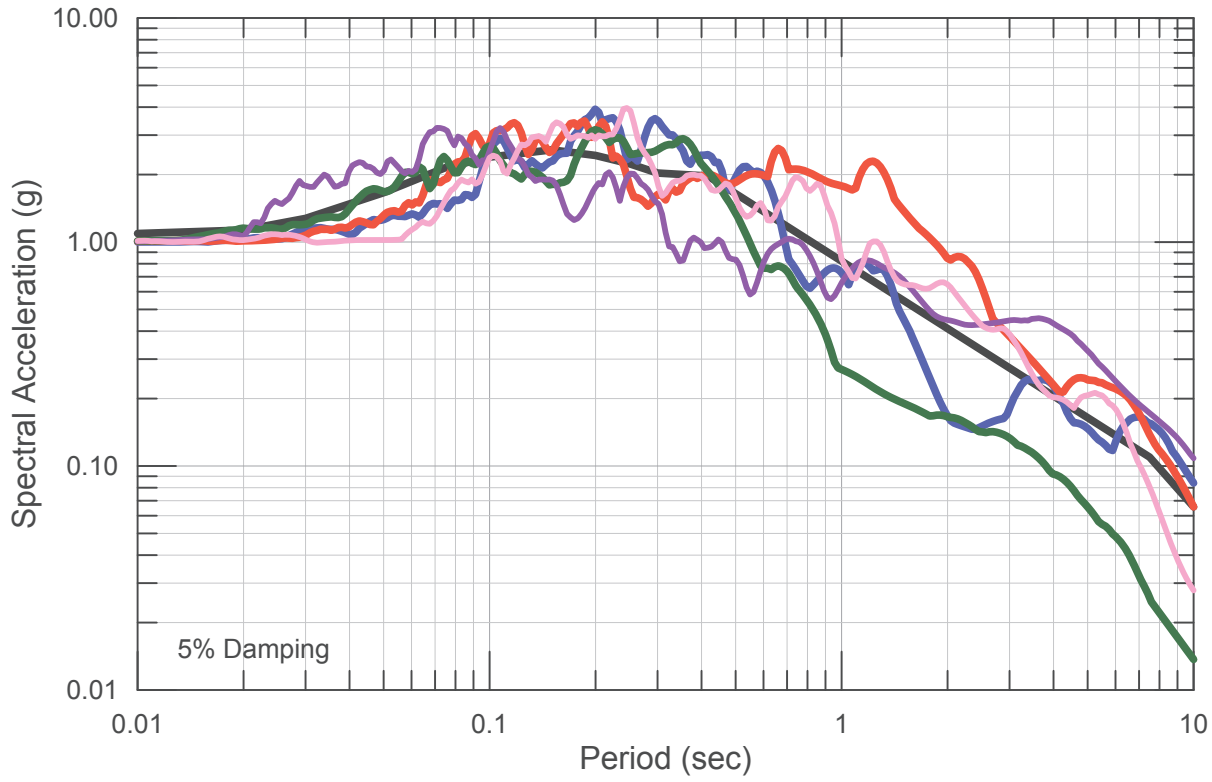
Probabilistic Rock MCE_R
Deterministic Rock MCE
80% ASCE 7-10 MCE_R, Site Class B
Site-Specific Rock MCE_R

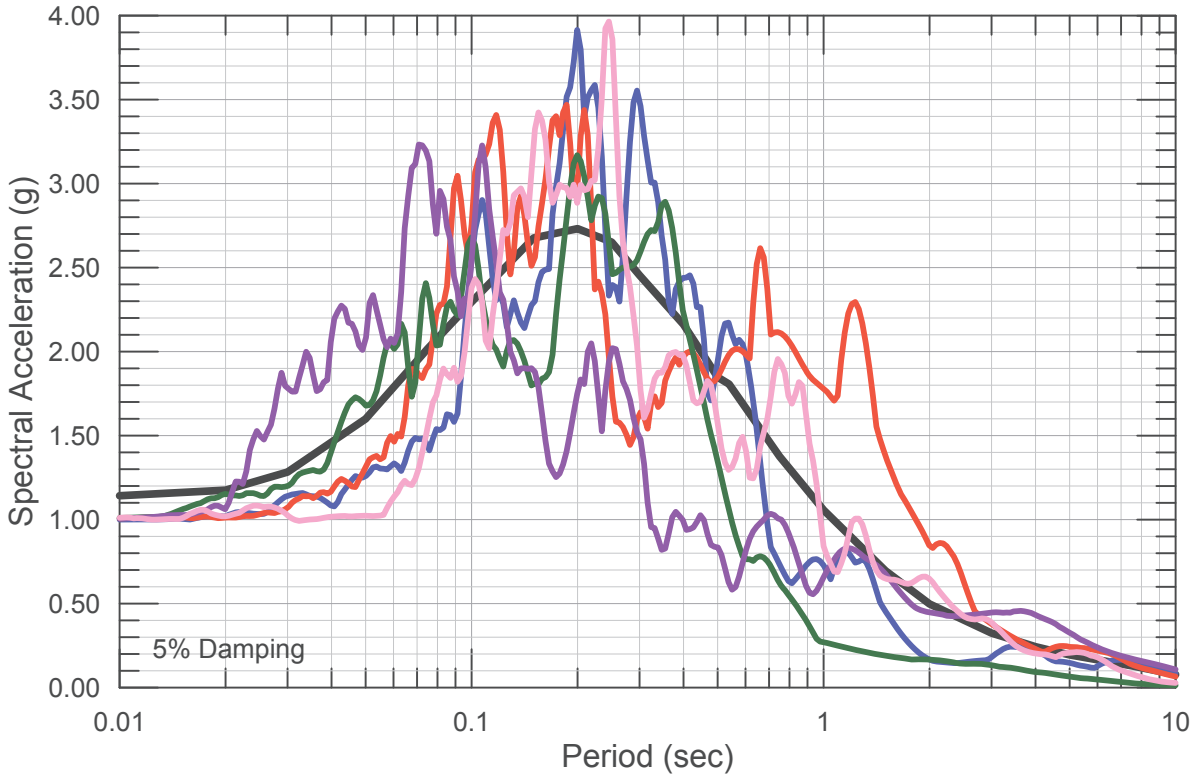
Site-Specific Rock MCE_R Spectrum as per ASCE 7-10, Chapter 21

OXFORD ELEMENTARY SCHOOL BERKELEY, CA

Lettis Consultants International, Inc.

Figure 22



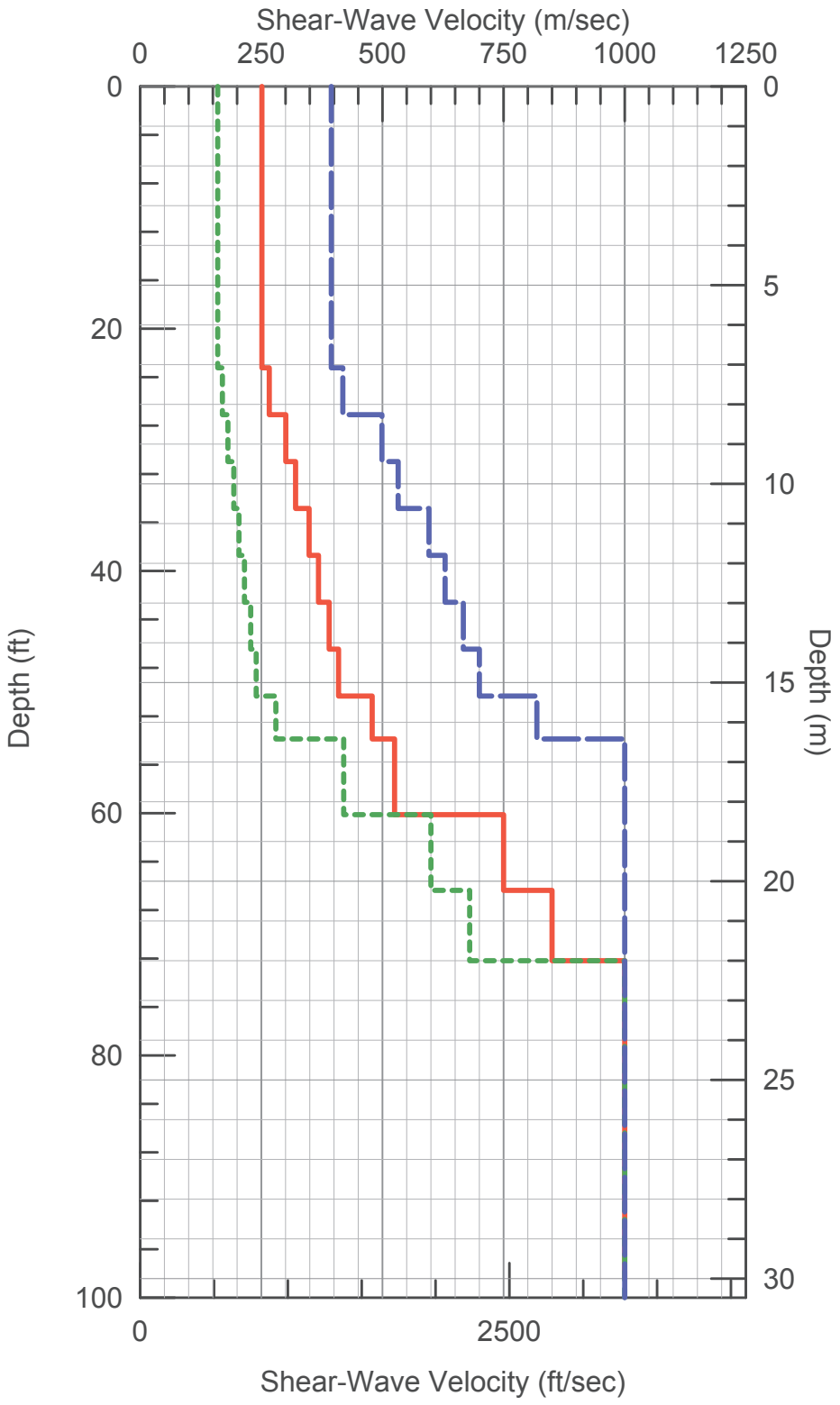


Site-Specific Rock MCE_R
RSN 8164 1999 Duzce, Turkey - IRIGM 487 (NS)
RSN 285 1980 Irpinia, Italy-01 - Bagnoli Irpino (000)
RSN 765 1989 Loma Prieta - Gilroy Array #1 (000)
RSN 879 1992 Landers - Lucerne (260)
RSN 143 1978 Tabas, Iran - Tabas (L1)

Scaled Input Time History Response Spectra for Site Response Analysis

OXFORD ELEMENTARY SCHOOL BERKELEY, CA

LCI **Lettis Consultants International, Inc.** **Figure 23**

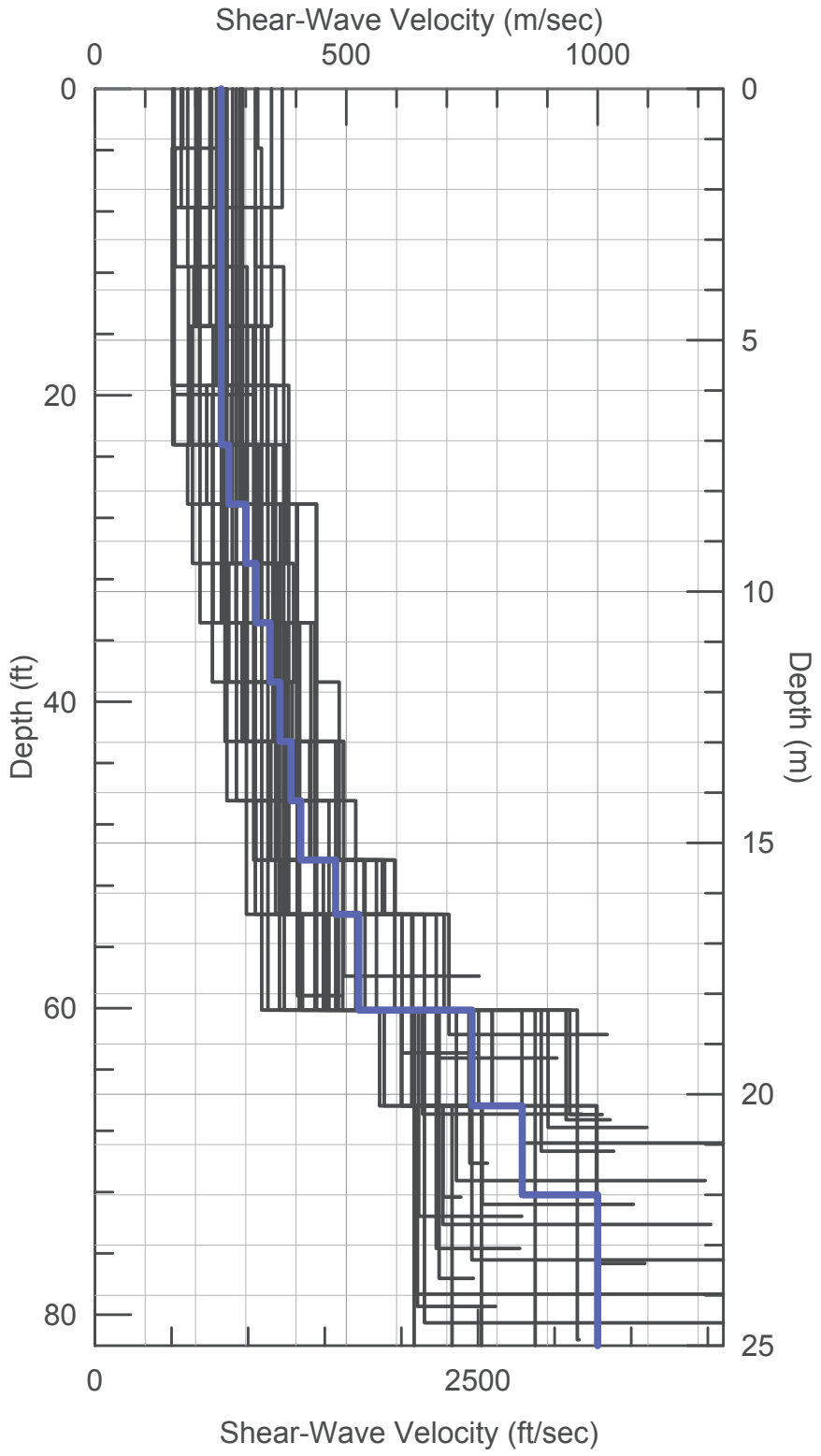


Basecase V_S Profiles for Site Response Analysis

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

Lettis Consultants International, Inc.

Figure 24

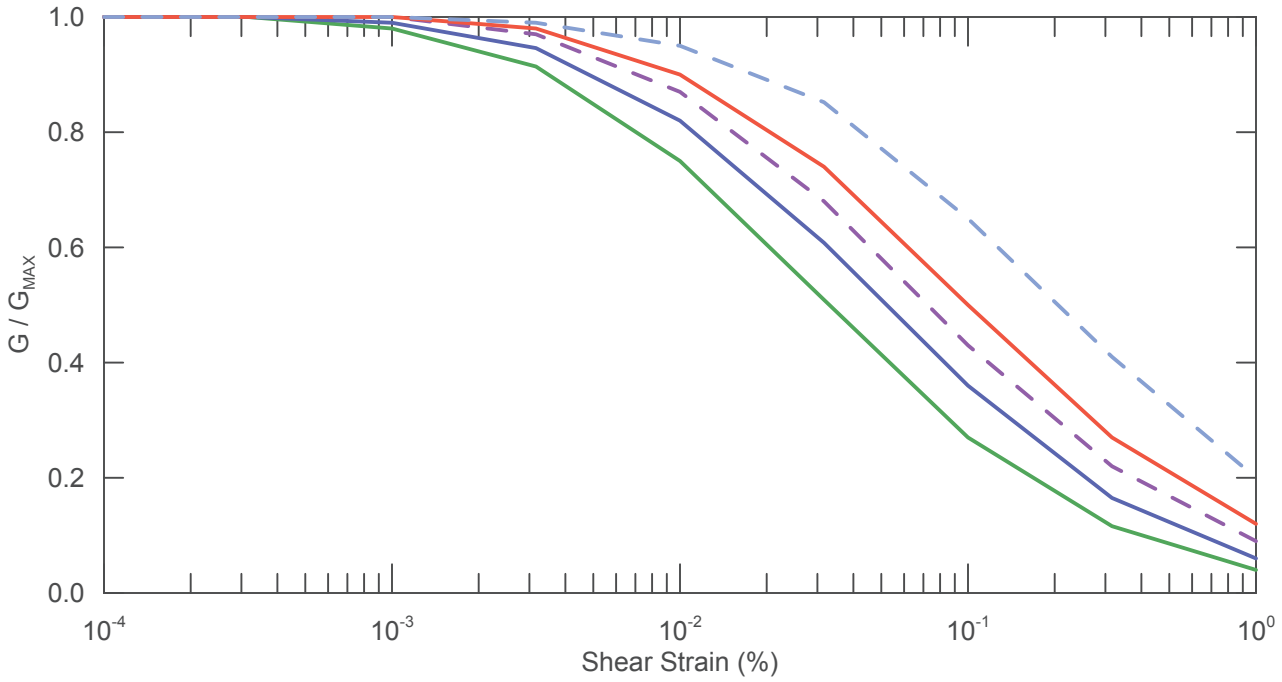


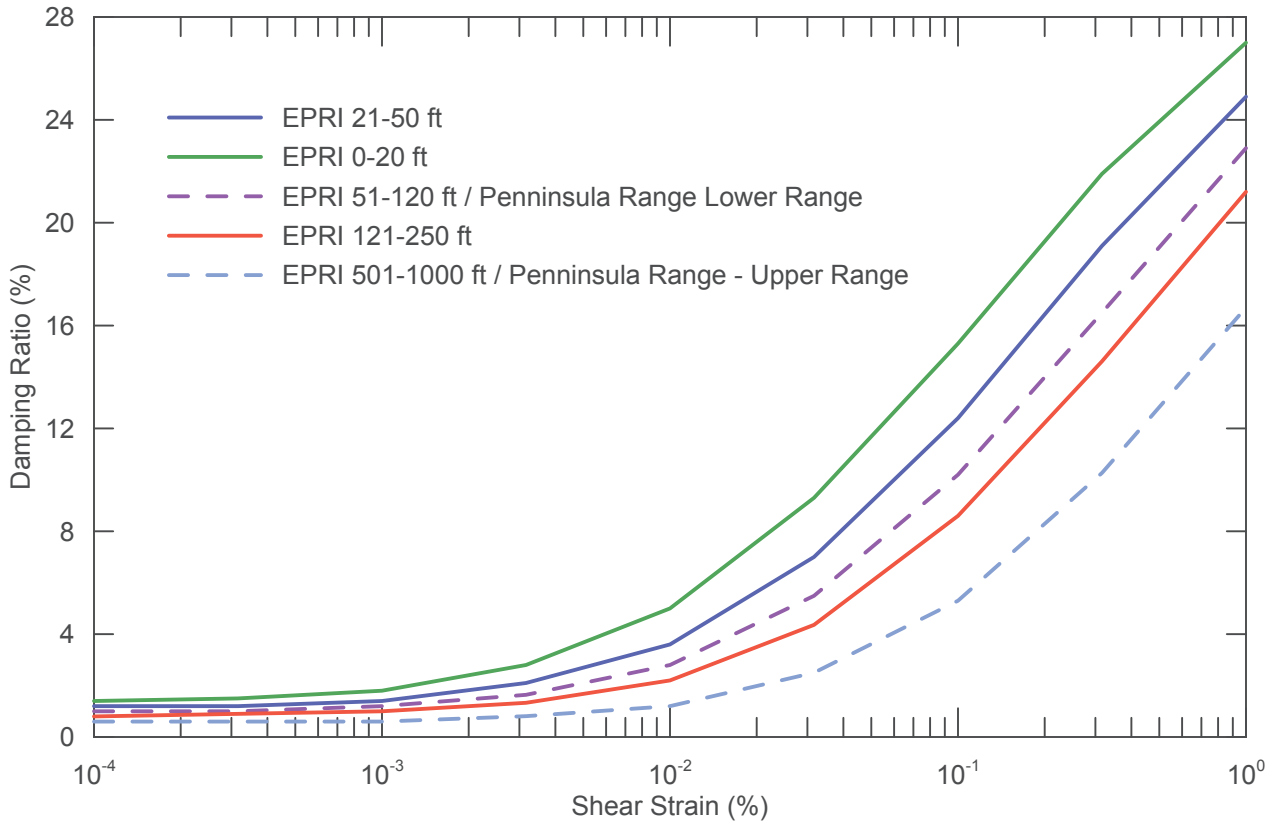
Randomized Profiles (30)
Basecase Profile P1

Randomized V_S Profiles for Basecase Profile P1

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.** **Figure 25**

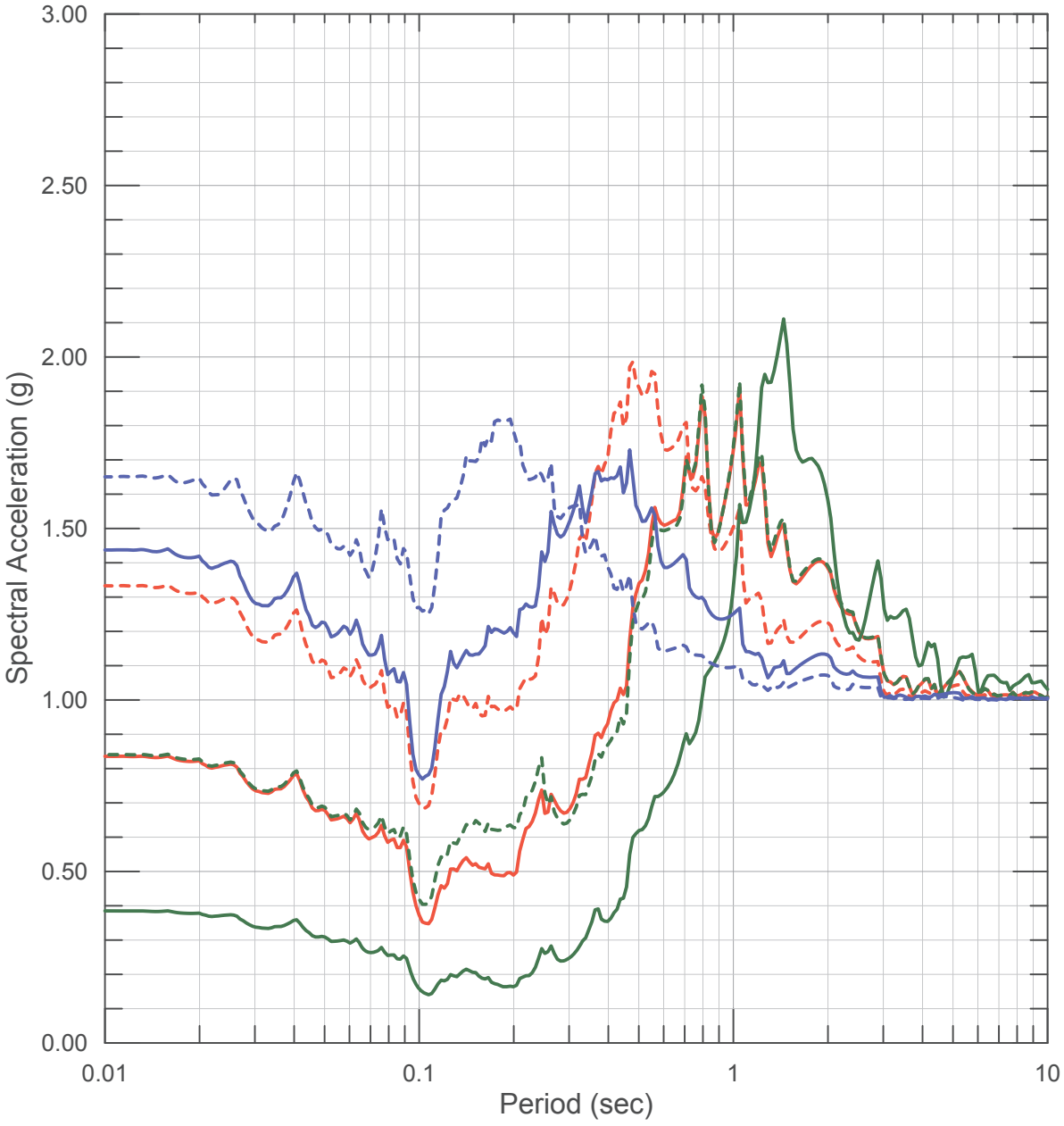




Shear Modulus Reduction (G/G_{MAX}) and Damping Ratio Curves

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.** | **Figure 26**



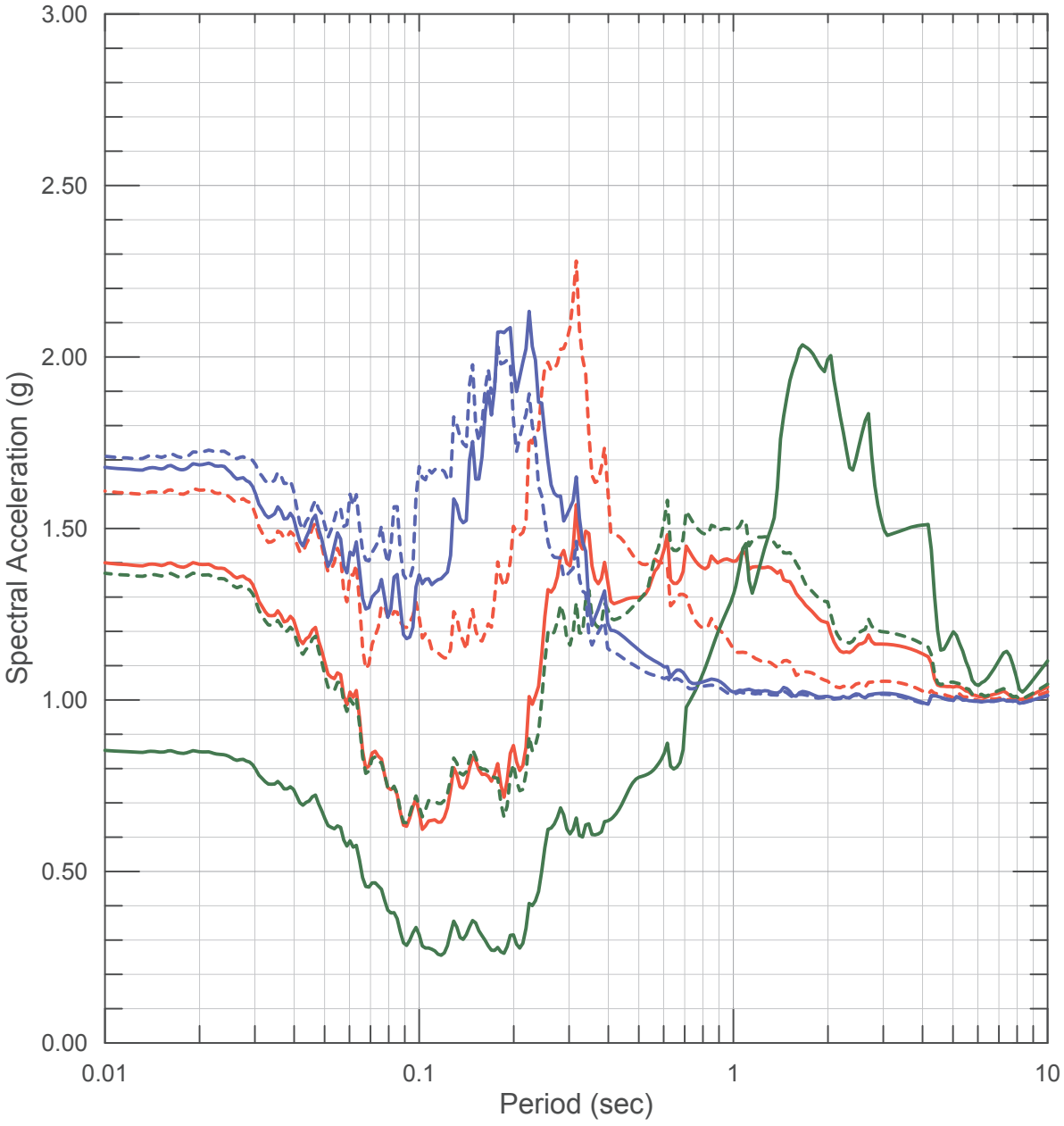
Median Amplification Factors

- M1P1
- M2P1
- M1P2
- M2P2
- M1P3
- M2P3

M1 = EPRI (1993) Curves
M2 = Peninsular Range Curves (Silva et al. 1996)
P1 = Best-estimate Vs Profile
P2 = Lower range Vs Profile
P3 = Upper range Vs Profile

Site-Specific Amplification Factors Based on 1999 Duzce, Turkey - IRIGM 487 (NS) Seed

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA



Median Amplification Factors

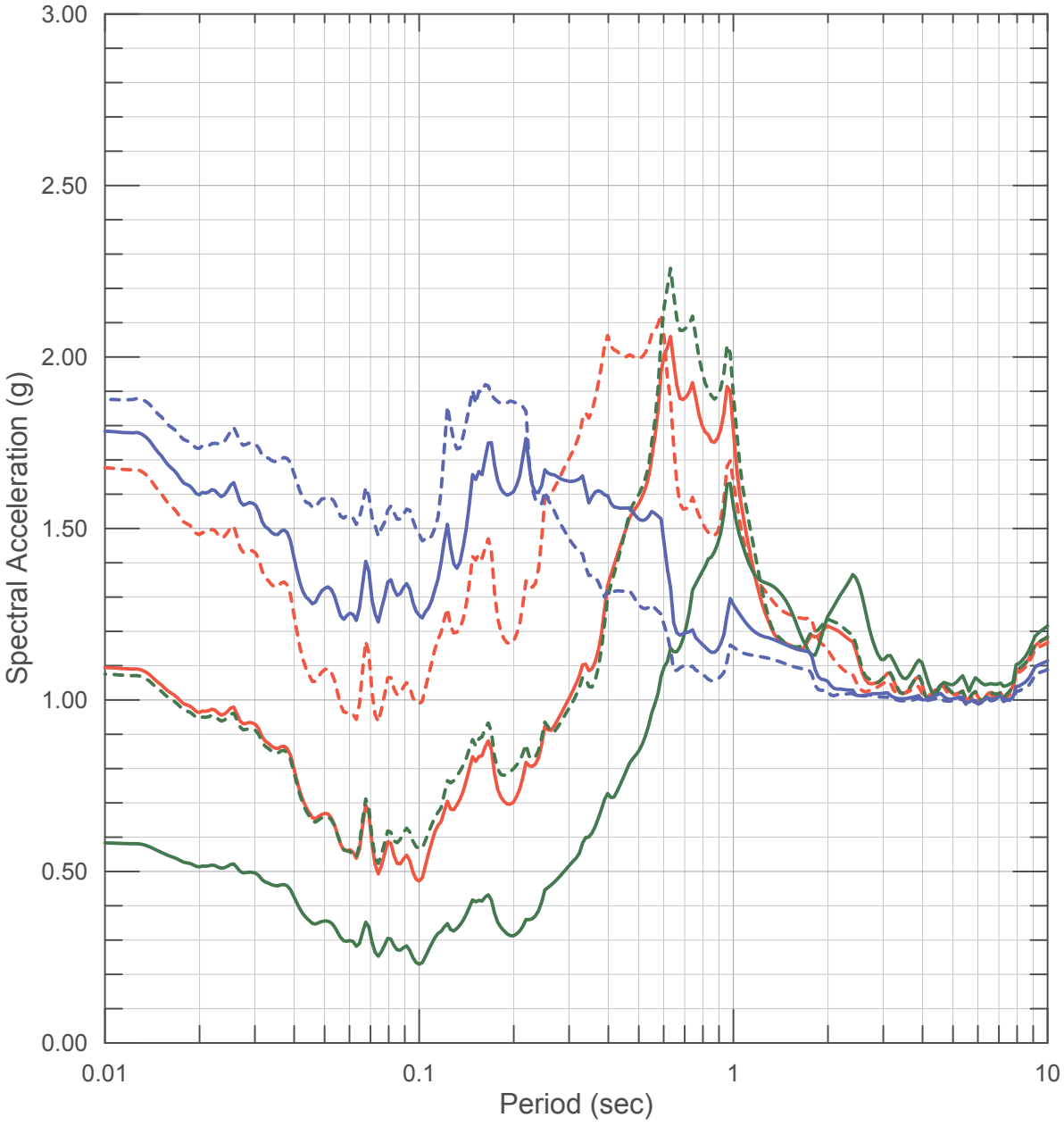
- M1P1
- M2P1
- M1P2
- M2P2
- M1P3
- M2P3

M1 = EPRI (1993) Curves
M2 = Peninsular Range Curves (Silva et al. 1996)
P1 = Best-estimate Vs Profile
P2 = Lower range Vs Profile
P3 = Upper range Vs Profile

Site-Specific Amplification Factors Based on 1980 Irpinia, Italy-01 - Bagnoli Irpino (000) Seed

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.** | **Figure 28**



Median Amplification Factors

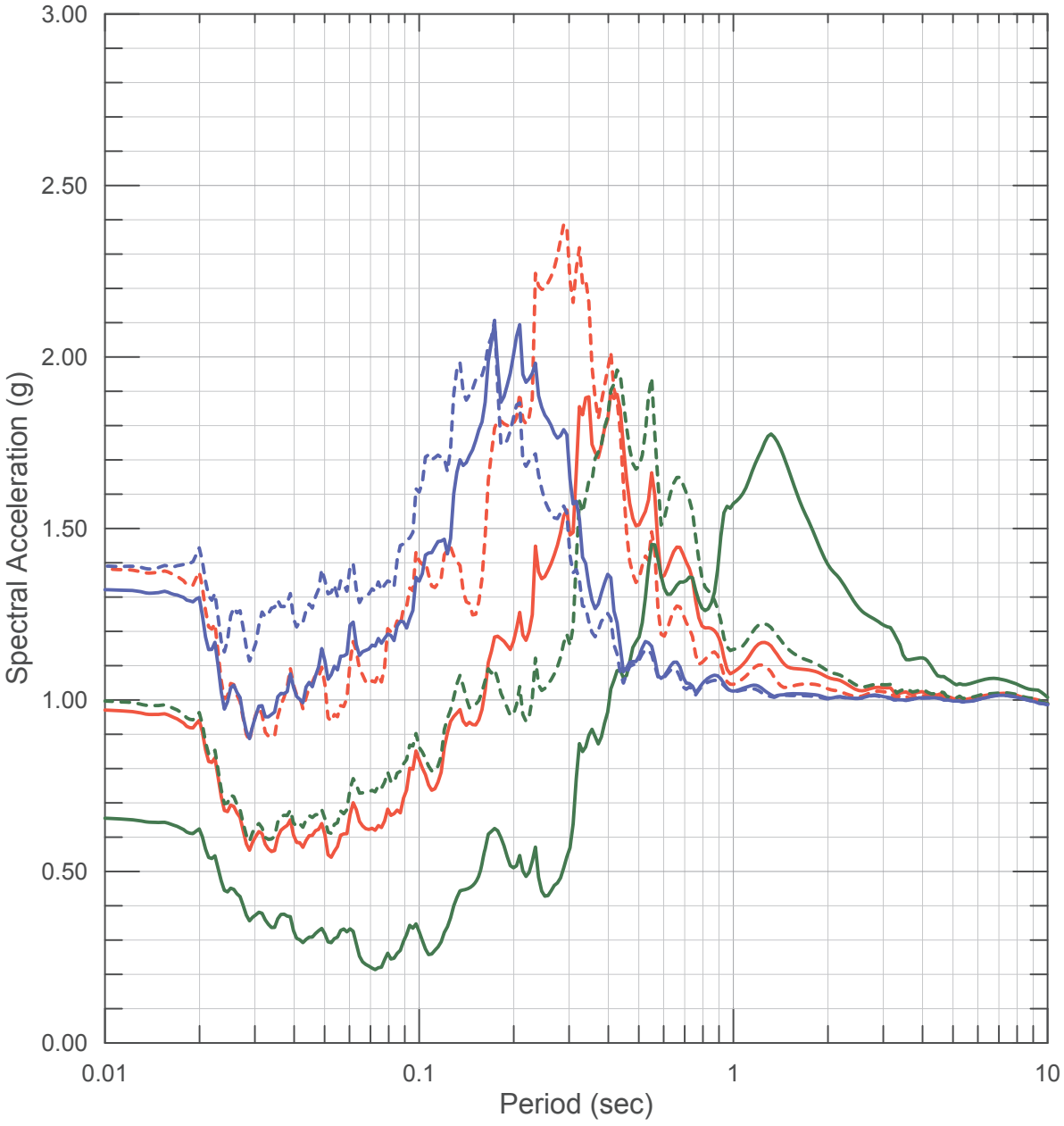
- M1P1
- M2P1
- M1P2
- M2P2
- M1P3
- M2P3

M1 = EPRI (1993) Curves
M2 = Peninsular Range Curves (Silva et al. 1996)
P1 = Best-estimate Vs Profile
P2 = Lower range Vs Profile
P3 = Upper range Vs Profile

Site-Specific Amplification Factors Based on 1989 Loma Prieta - Gilroy Array #1 (000) Seed

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.** **Figure 29**



Median Amplification Factors

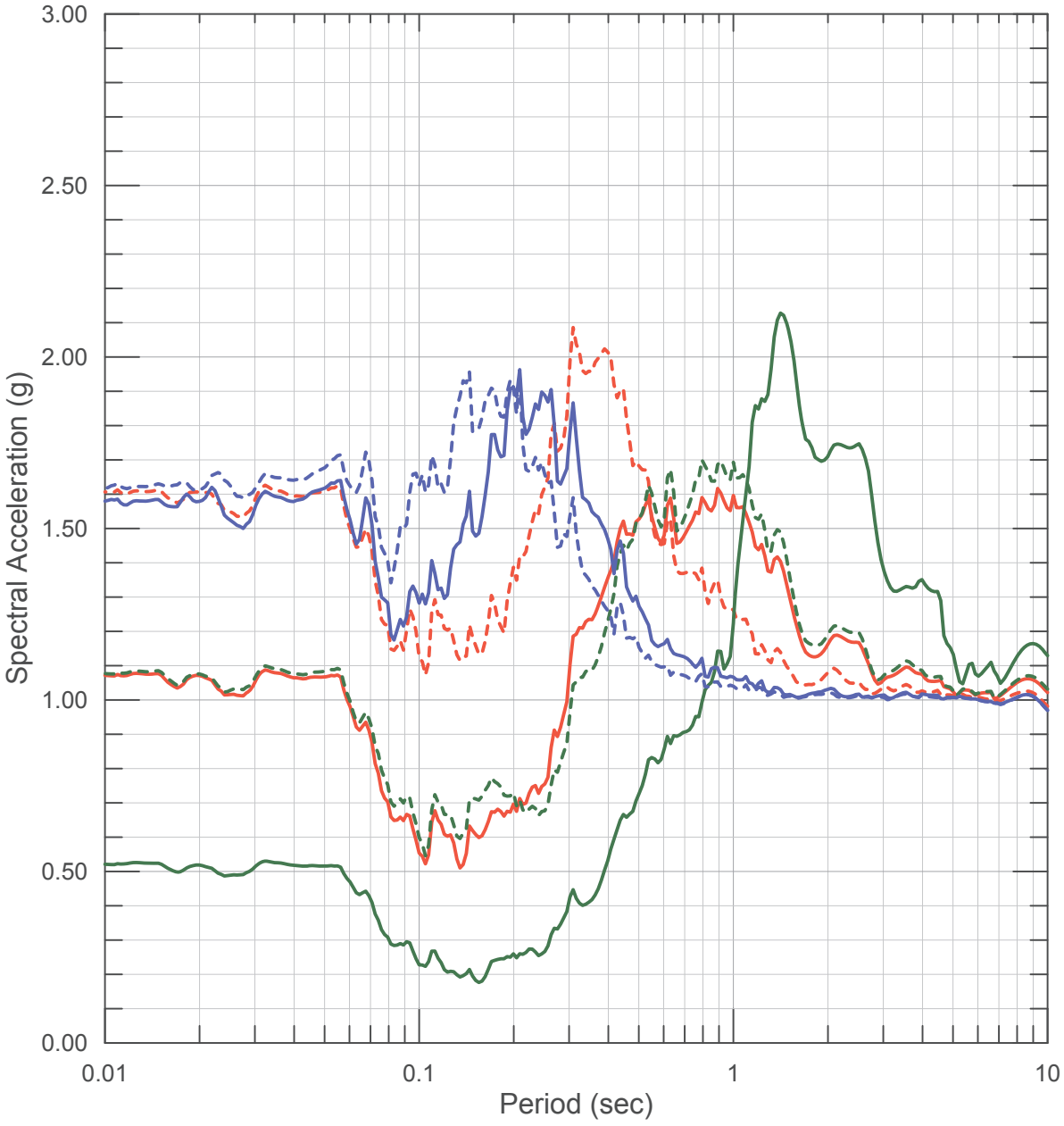
- M1P1
- M2P1
- M1P2
- M2P2
- M1P3
- M2P3

M1 = EPRI (1993) Curves
M2 = Peninsular Range Curves (Silva et al. 1992)
P1 = Best-estimate Vs Profile
P2 = Lower range Vs Profile
P3 = Upper range Vs Profile

Site-Specific Amplification Factors Based on 1992 Landers - Lucerne (260) Seed

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.** **Figure 30**



Median Amplification Factors

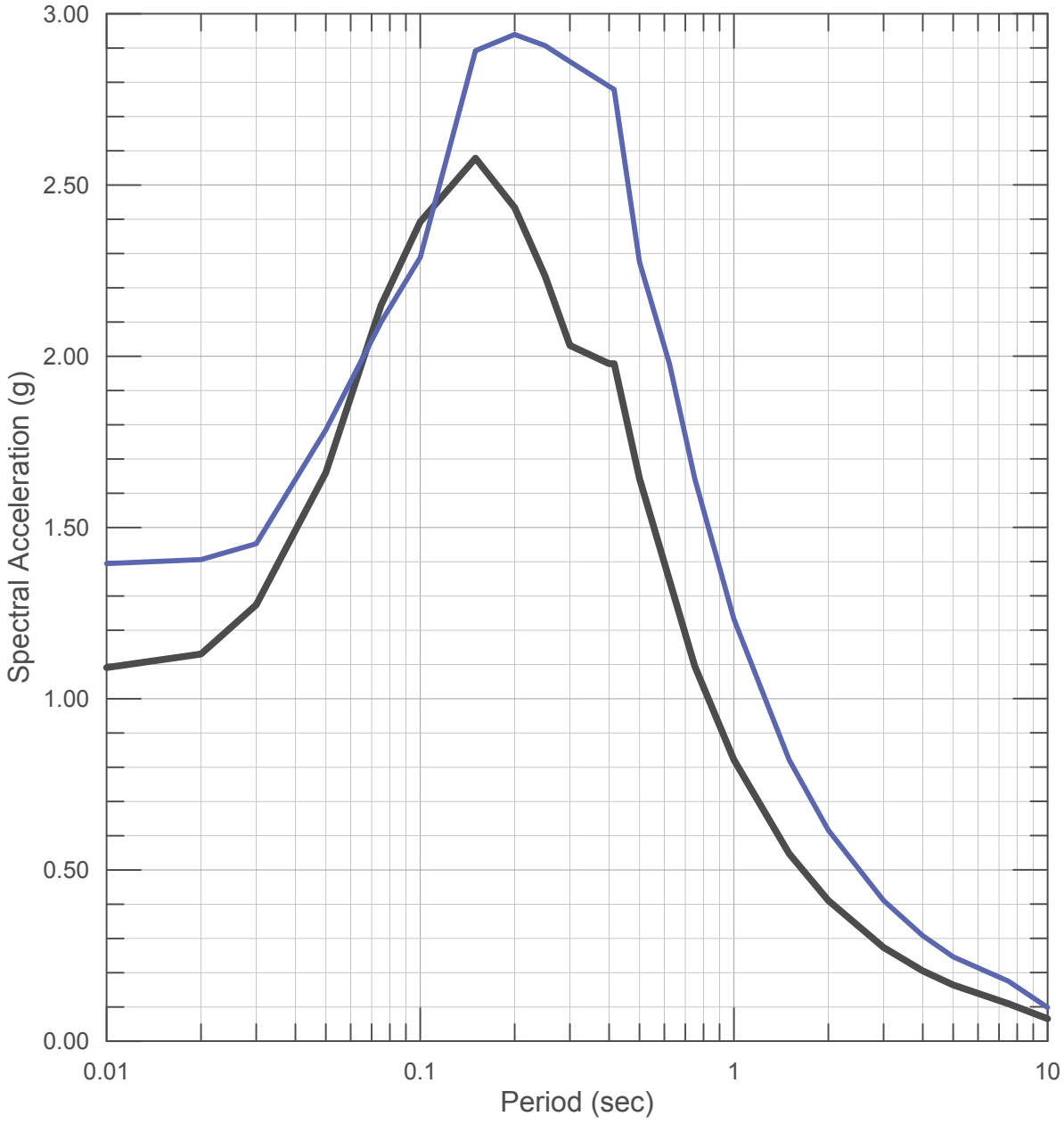
- M1P1
- M2P1
- M1P2
- M2P2
- M1P3
- M2P3

M1 = EPRI (1993) Curves
M2 = Peninsular Range Curves (Silva et al. 1996)
P1 = Best-estimate Vs Profile
P2 = Lower range Vs Profile
P3 = Upper range Vs Profile

Site-Specific Amplification Factors Based on 1978 Tabas, Iran - Tabas (L1) Seed

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.** **Figure 31**



Site-Specific Rock MCE_R

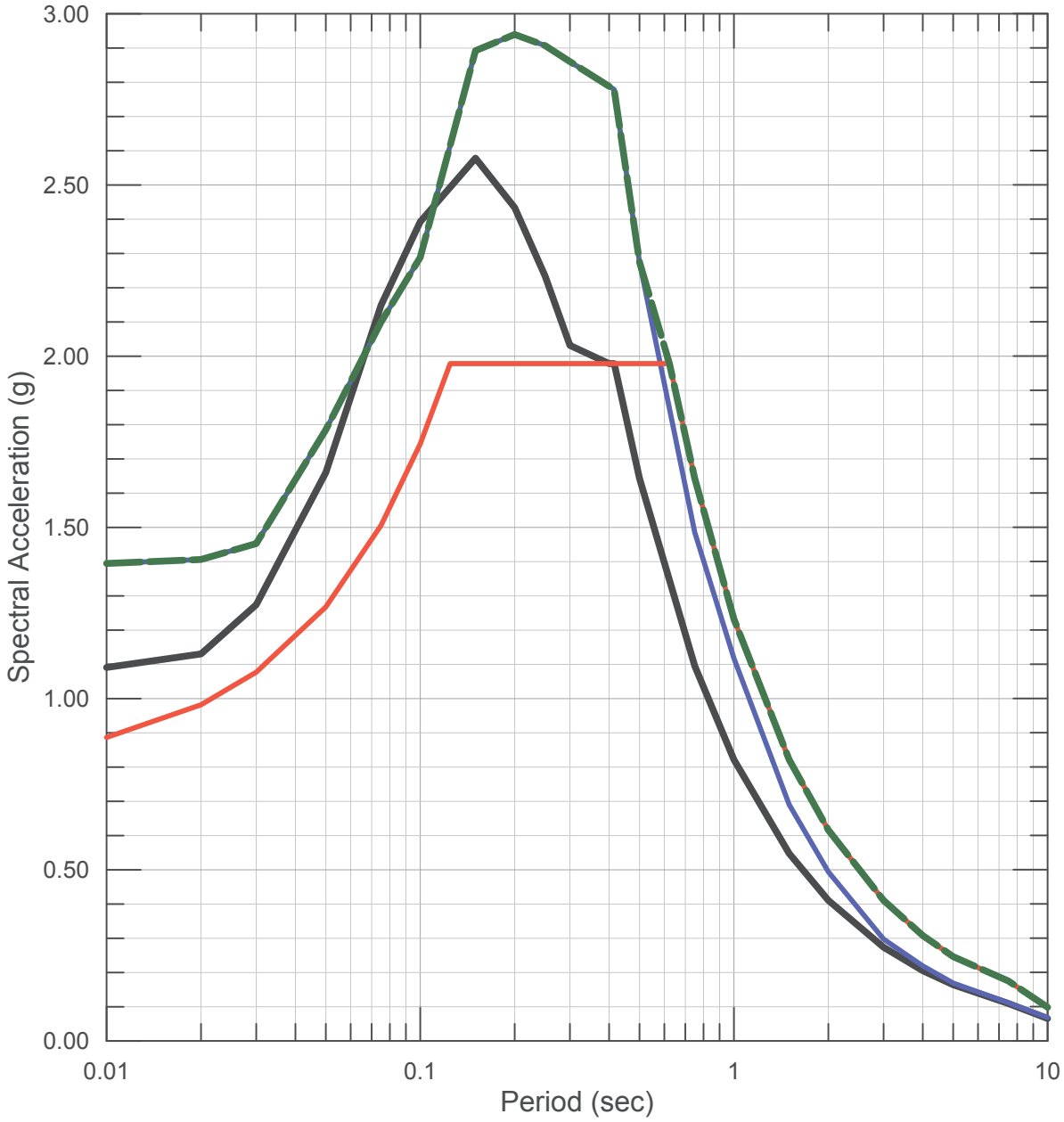
Site-Specific Surface MCE_R

Surface MCE_R Spectrum

OXFORD ELEMENTARY SCHOOL, BERKELEY, CA

LCI **Lettis Consultants International, Inc.**

Figure 32



5% Damping

Site-Specific Rock MCE_R

Site-Specific Surface MCE_R = Site-Specific Rock MCE_R * Average AF

80% ASCE 7-10 MCE_R, Site Class D

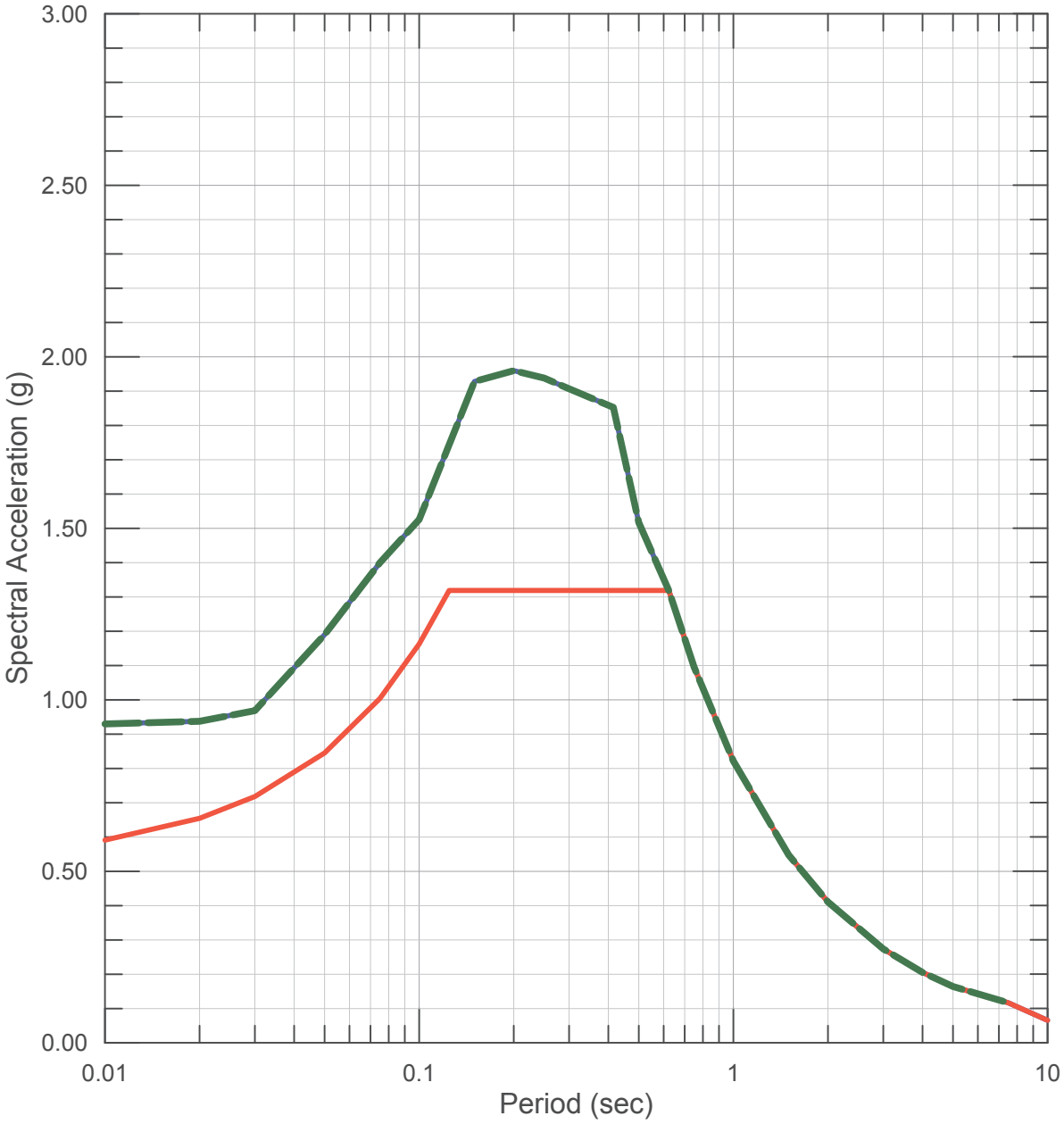
Site-Specific MCE_R

AF = Amplification Factors

Calculation of Site-Specific MCE_R as per ASCE 7-10, Chapter 21

OXFORD ELEMENTARY SCHOOL BERKELEY, CA

LCI **Lettis Consultants International, Inc.** **Figure 33**



2/3rds Site-Specific MCE_R
80% ASCE 7-10 DE, Site Class D
Site-Specific DE

Calculation of Site-Specific DE as per ASCE 7-10, Chapter 21

OXFORD ELEMENTARY SCHOOL BERKELEY, CA

LCI **Lettis Consultants International, Inc.** **Figure 34**

APPENDIX F

PREVIOUS GEOLOGIC STUDY REPORT:

OXFORD ELEMENTARY SCHOOL PHASE II INVESTIGATION WOODWARD CLYDE CONSULTANTS, 1977

PHASE II GEOLOGIC STUDY

OXFORD ELEMENTARY SCHOOL

BERKELEY, CALIFORNIA

For

Berkeley Unified School District
1414 Walnut Street
Berkeley, California 94709

By

Woodward-Clyde Consultants
Consulting Engineers, Geologists, and Environmental Scientists
Suite 700, Two Embarcadero Center
San Francisco, California 94111

Two Embarcadero Center, Suite 700
San Francisco, California 94111
415-956-7070

Woodward-Clyde Consultants

January 25, 1977
Project #70071A

Berkeley Unified School District
1414 Walnut Street
Berkeley, California 94709

Attention: Mrs. Eileen Rygh,
Coordinator of Construction

Gentlemen:

PHASE II GEOLOGIC STUDY
OXFORD ELEMENTARY SCHOOL
Berkeley, California

In accordance with your request and authorization of our proposals dated December 13 and December 21, 1976, we have completed a Phase II geologic study for the Oxford Elementary School site.

The present study has demonstrated that while the school site may be located within the zone designated by others as the Hayward fault zone, our exploratory trenching found no active fault traces traversing the site. Any active fault traces in the vicinity of the school are located either to the east or west of it and not on the school site. The study confirms that the school structures are located within a large area subject to slow deep-seated earth movement. This condition was pointed out prior to the design and construction of the school structures.

If you have any comments or questions, please call the undersigned.

Sincerely yours,

Charles L. Taylor
Senior Project Engineering Geologist

CLT:le

TABLE OF CONTENTS

	Page
LETTER OF TRANSMITTAL	
INTRODUCTION	1
Phase I Geologic Study	1
Previous Studies	3
Purpose of Phase II Geologic Study	4
RESULTS OF STUDY	8
General Statement	5
Exploratory Trenching	8
Interpretation of Exploratory Trenches	7
Other Possible Interpretations	11
Assessment of Stability	13
Static Conditions	14
Earthquake Shaking	14
Potential for Strong Earthquake Shaking	15
Implication of Results	15
CONCLUSIONS	16
APPENDIX A - Review of Previous Work	A-1
REFERENCES	R-1

FIGURES

Figure 1 - Reported Fault Traces	2
Figure 2 - Figure From 1963 Report	6
Figure 3 - Exploration Location Map	8
Figure 4 - Cross-Section Exploration Trench No. 1	9
Figure 5 - Cross-Section Exploration Trench No. 2	10

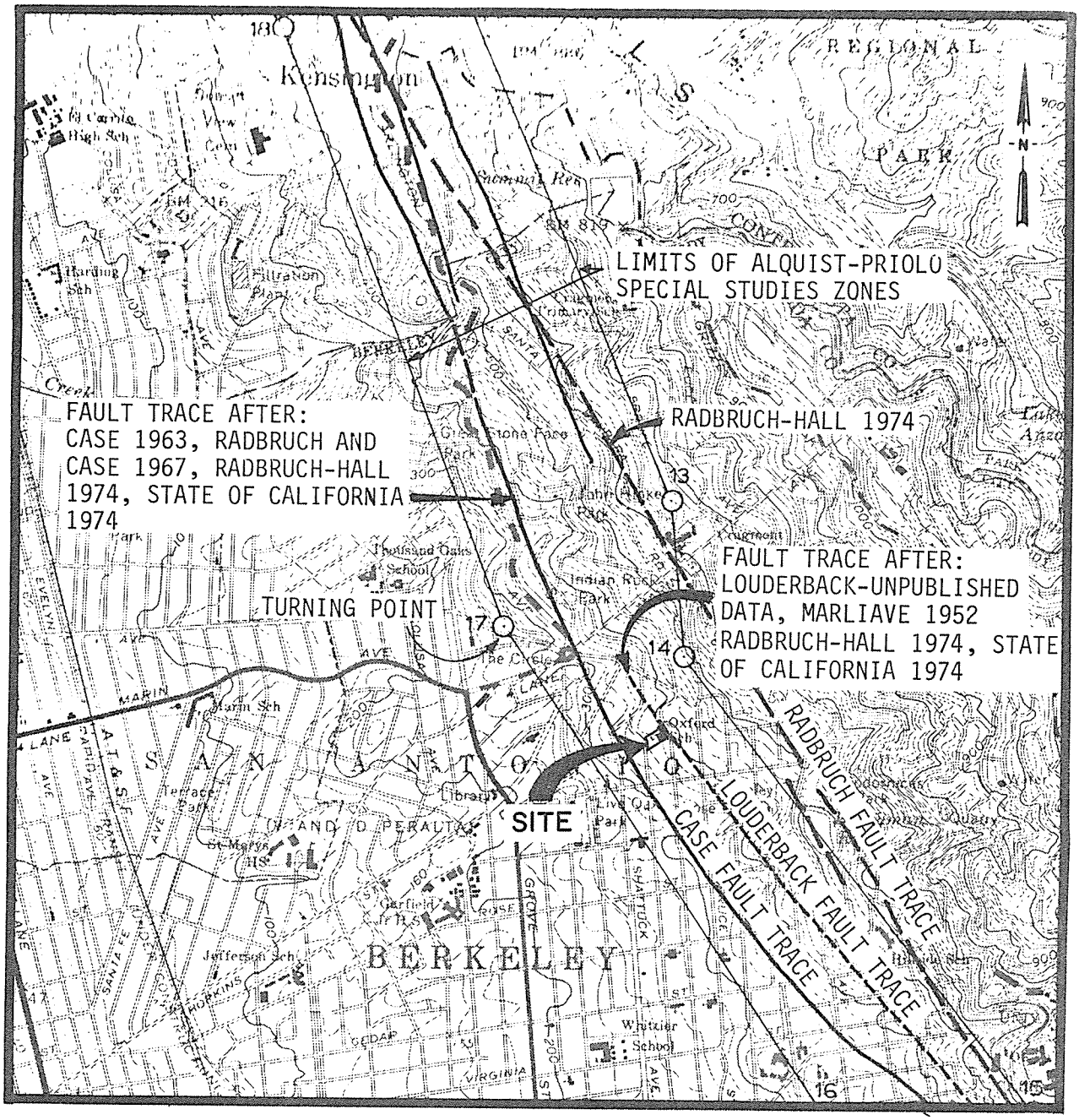
PHASE II GEOLOGIC STUDY
OXFORD ELEMENTARY SCHOOL
Berkeley, California

INTRODUCTION

Oxford Elementary School is located between Oxford and Walnut Streets in Berkeley, California, as shown on Figure 1. Figure 1 also shows the location of the school site with respect to a Special Studies Zone established along the reported location of the active Hayward fault and with respect to the reported location of other mapped fault traces. Special Studies Zones were established by the California Division of Mines and Geology along faults deemed sufficiently active to constitute a potential hazard from surface faulting. The reason for this is that in the event of future faulting within active fault zones, those structures located across active fault traces could be damaged.

Phase I Geologic Study

In October, 1976, the Berkeley Unified School District authorized Woodward-Clyde Consultants to conduct a Phase I geologic study for the Oxford Elementary School. The purposes of the study were: 1) provide a description of the geologic conditions, including the location of faults in the vicinity of Oxford School so that decisions could be made as to the surface faulting hazard at the Oxford School site; 2) assess the impact of the Hayward fault zone on the Oxford School site; and, 3) discuss the implications of the Hayward fault zone to the school site in terms that can be understood by local citizens.



PORTION OF THE SPECIAL STUDIES ZONES, RICHMOND QUADRANGLE,
STATE OF CALIFORNIA 1974

1000 0 1000 2000 3000 4000 ft

REPORTED FAULT TRACES OXFORD ELEMENTARY SCHOOL Berkeley, California	
Project No. 70071B WOODWARD-CLYDE CONSULTANTS	Figure 1

The results of the study are contained in a report entitled "Geological Study, Oxford Elementary School, Berkeley, California", dated November 30, 1976 (Woodward-Clyde Consultants, 1976). The study concludes that while the weight of existing evidence would suggest that the site is located within the zone designated by others as the Hayward fault zone, there is no documented evidence to show that fault traces exist on, or project through, the school site. In fact, there is a good possibility that the active Hayward fault zone could be located elsewhere in the Berkeley Hills. However, based on the presently available data, and considering the land use, the report suggested that it appears reasonable and conservative to assume that the school site is located within the Hayward fault zone and that two possibilities exist: 1) an active fault trace projects through the school site; or, 2) an active fault trace does not project through the site.

The report concluded that should the school district require more documentation that a fault does, or does not, exist on the site, then a subsurface exploration program would be required. On the basis of that November 30, 1976 report, and recommendations contained therein, the present Phase II geologic study was approved.

Previous Studies

The geological study of November 30, 1976 was not the first study conducted for the Oxford Elementary School site. Previous studies include: "Topographical and Geological Features of the Proposed Oxford Elementary School site, Berkeley, California", October 30, 1963 (Woodward-Clyde-Sherard and Associates, 1963a); and "Soil Investigation for the Proposed Oxford Elementary School", December 10, 1963 (Woodward-Clyde-Sherard and Associates, 1963b). These reports

provided significant information for decision making in 1963. Under current legislation, and with the techniques available for investigations, additional information was needed to assess the potential impact to the Oxford Elementary school. Thus, it was recommended that a geological study be conducted to gather the available information and to present it in a form that could be used for making judgment decisions concerning the potential for surface faulting at the Oxford Elementary School. The Woodward-Clyde Consultants' report of November 30, 1976 contained the results of that study.

Purpose of Phase II Geologic Study

The purpose of this Phase II geological study is to: 1) excavate exploratory trenches on the Oxford School site in an attempt to identify whether or not an active fault trace projects through the site, and 2) provide an assessment of the stability of the Oxford School site based on both static conditions and strong earthquake shaking. While the first task is to be based on subsurface trenching, the stability assessment is to be based on existing data and does not include any new borings or test data.

In order to provide a basis for evaulating the results of this Phase II study, it is necessary to review the three previous studies conducted for the Oxford Elementary School site. Therefore, Appendix A, entitled "Review of Previous Work", is included and is intended to provide a summary of the background data used in the present study.

RESULTS OF STUDY

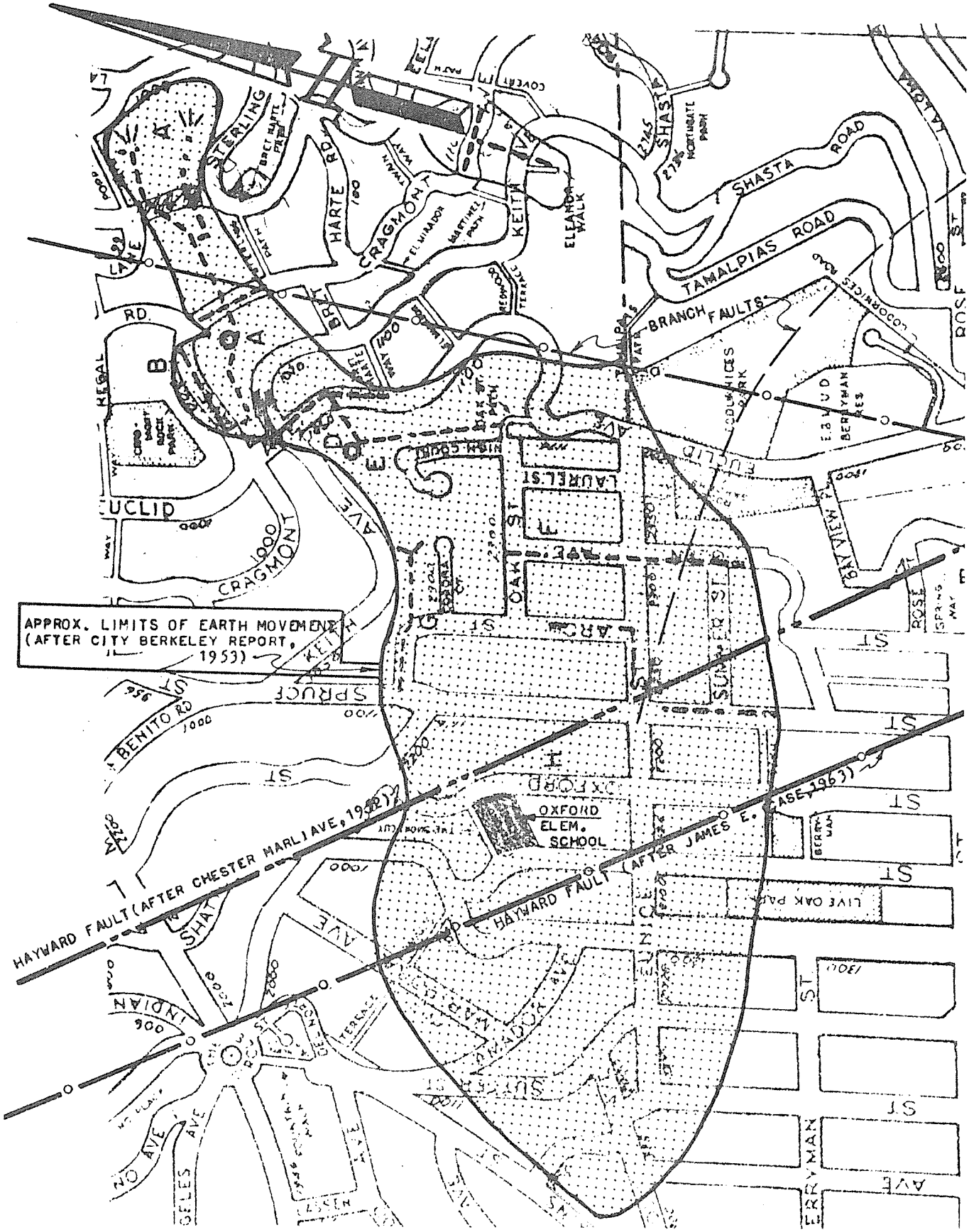
This part of the report is divided into four sections: general statement, exploratory trenching, assessment of stability, potential for strong earthquake shaking, and implication of results.

General Statement

The results of previous studies conducted for the Oxford School site are discussed in Appendix A and are shown on Figures 1 and 2. Figures 1 and 2 show reported fault traces in the vicinity of Oxford Elementary School. These figures show that the school site is located within the reported Hayward fault zone, but no fault traces are shown to pass through the site. Figure 2 also shows that the Oxford School site is within an area identified by the City of Berkeley as subject to earth movements.

Exploratory Trenching

The Hayward fault zone and the reported fault traces in the vicinity of the Oxford Elementary School site trend in a northwesterly direction. The individual fault traces reported in the vicinity of the site are shown on Figures 1 and 2. During this study, two exploratory trenches were excavated across the site at right angles to the strike (trend) of the reported fault traces to detect any evidence of a fault projecting through the school structure. The total length of trenching was approximately 247 feet and the three-foot wide trenches ranged in depth from 5 to 10 feet. The locations of the trenches are shown on Figure 3.



*SOURCE: TOPOGRAPHIC AND GEOLOGICAL FEATURES OF THE PROPOSED OXFORD ELEMENTARY SCHOOL SITE, BERKELEY, CALIFORNIA; OCTOBER 30, 1963; WOODWARD-CLYDE-SHERARD AND ASSOCIATES.

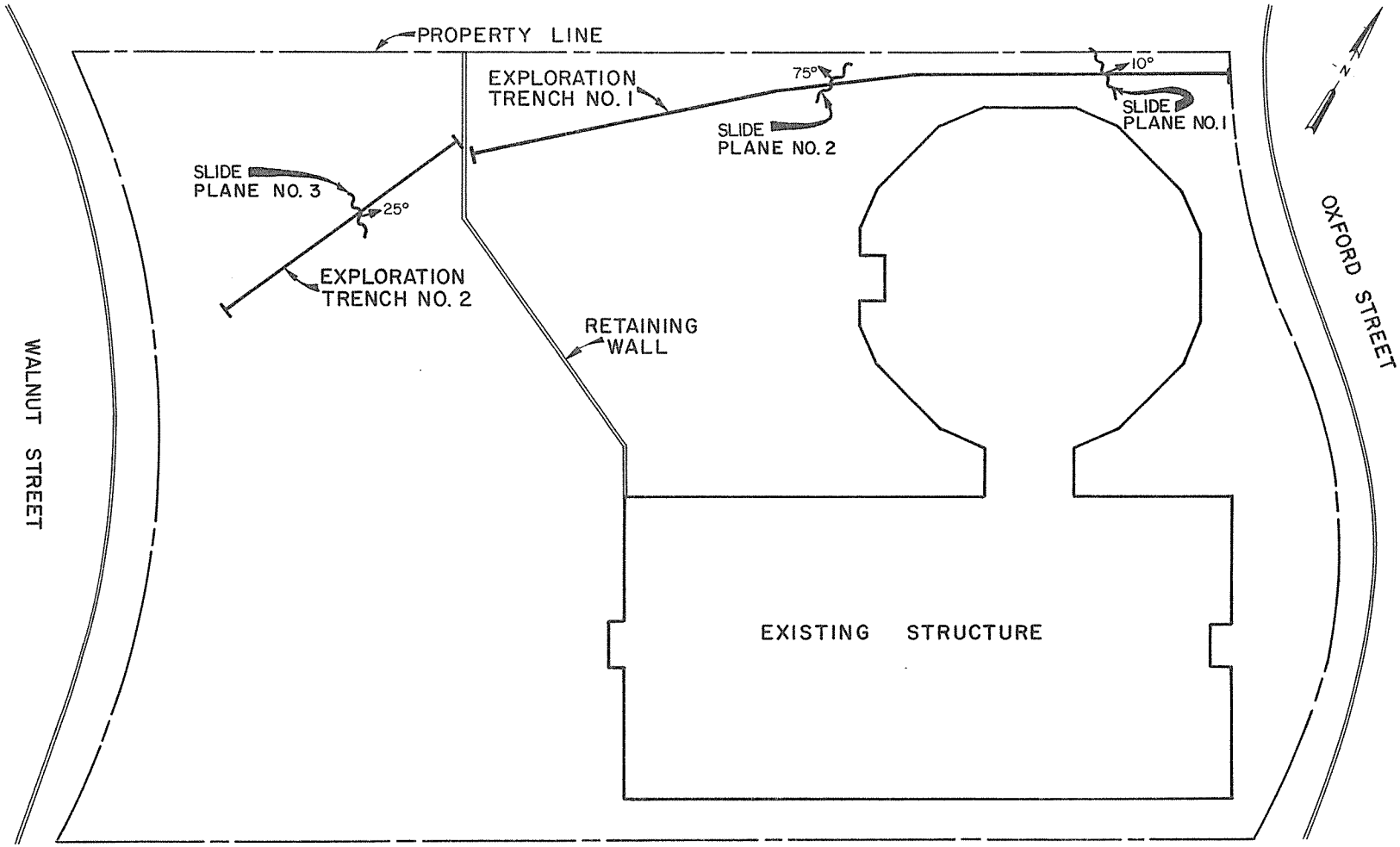
FIGURE FROM 1963 REPORT*
OXFORD ELEMENTARY SCHOOL
Berkeley, California

Project No. 70071B	Figure 2
WOODWARD-CLYDE CONSULTANTS	

After a trench was excavated and hydraulic shoring installed for safety measures, it was inspected and logged by two engineering geologists from our firm experienced in evaluation of active faults. The walls of the trench were cleaned with hand tools to enable the geologist to inspect the soil conditions on the walls of the trench and to examine the walls for any evidence of faulting. The observations of the geologist were logged on a cross-section of the trench to a scale of 1-inch equals 2 feet. The logs were reduced to a more convenient size for this report and the results are shown on Figures 4 (cross-section of exploratory trench 1) and Figure 5 (cross-section of exploratory trench 2). The trenches were excavated through the fill material on the site into native soil materials.

Interpretation of Exploratory Trenches - Three prominent planes were identified in the exploratory trenches. These planes are interpreted to be the result of slide movement. These are identified in Figure 3 as slide plane 1, slide plane 2, and slide plane 3.

Slide plane 1 and slide plane 2 were identified in exploratory trench 1 and are shown on Figure 4, log of exploratory trench 1. Slide plane 1 dips (slopes) into the hill at an angle of about 10^{o} (downward from a horizontal surface). The surface of the plane has grooves, or slickensides, which indicates that the movement has been towards the southwest. This means that the material on the east has moved up and towards the southwest in relation to the material underneath it. This can readily be seen on Figure 4, cross-section of trench 1. Slide plane 2 is shown on Figure 3 to strike (trend) in a northeast-southwest direction with the dip (slope of the plane) towards the northwest. The grooves, or slickensides, on the plane suggest that the movement is along the strike and towards the southwest. Both of these slide planes suggest movement towards the southwest.



EXPLANATION

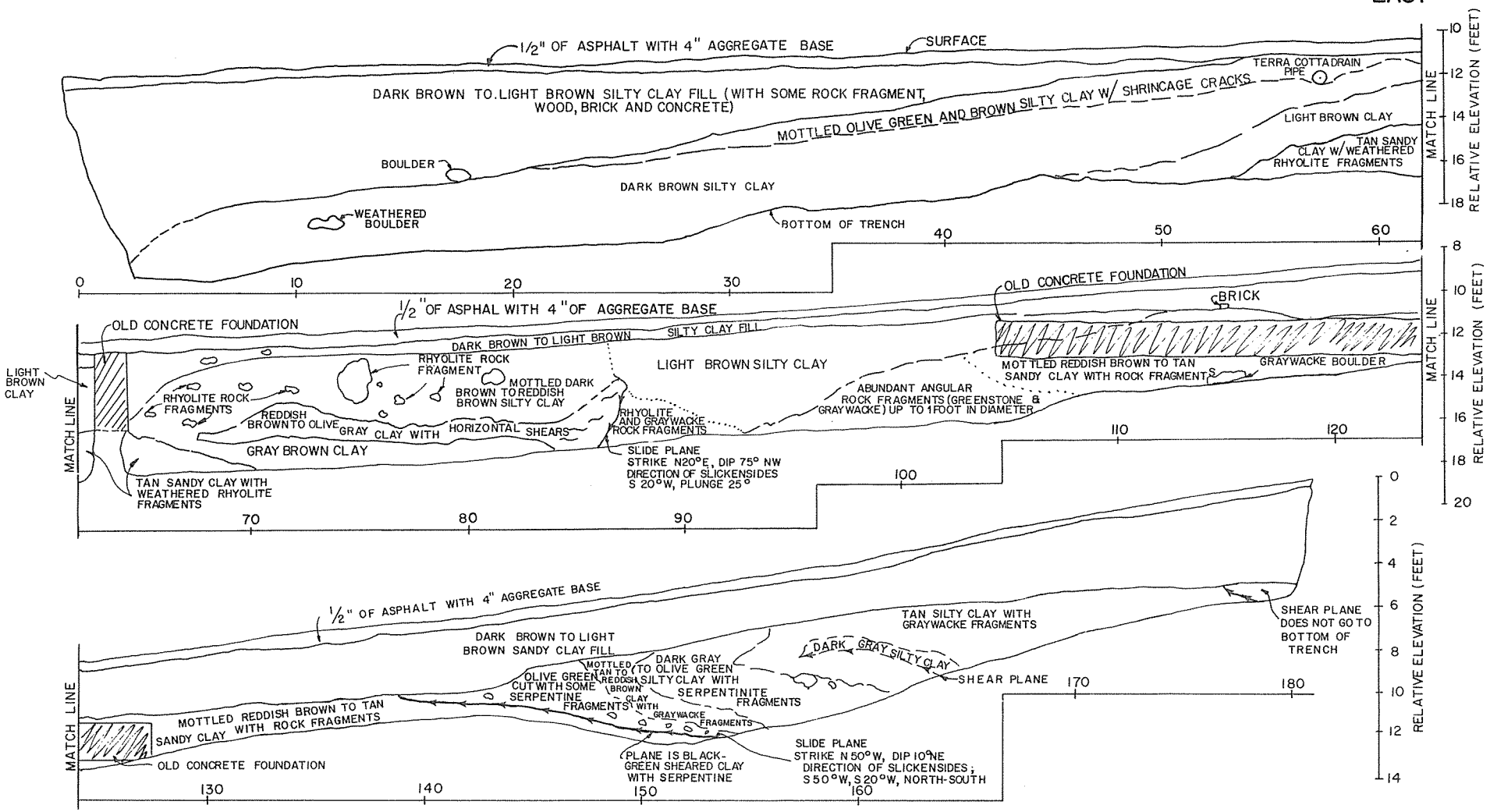
25° GENERAL STRIKE AND DIP OF SLIDE PLANE. (THE STRIKE IS THE DIRECTION OF THE LINE FORMED BY THE INTERSECTION OF THE SURFACE OF THE SLIDE PLANE AND A HORIZONTAL PLANE. THE DIP IS MEASURED AT RIGHT ANGLE TO THE STRIKE AND IS THE DOWNWARD ACUTE ANGLE THAT THE SLIDE PLANE MAKES WITH A HORIZONTAL PLANE).

10 5 0 10 20 30 40feet
APPROXIMATE SCALE

EXPLORATION LOCATION MAP
OXFORD ELEMENTARY SCHOOL
Berkeley, California

Project No. 70071B
WOODWARD-CLYDE CONSULTANTS

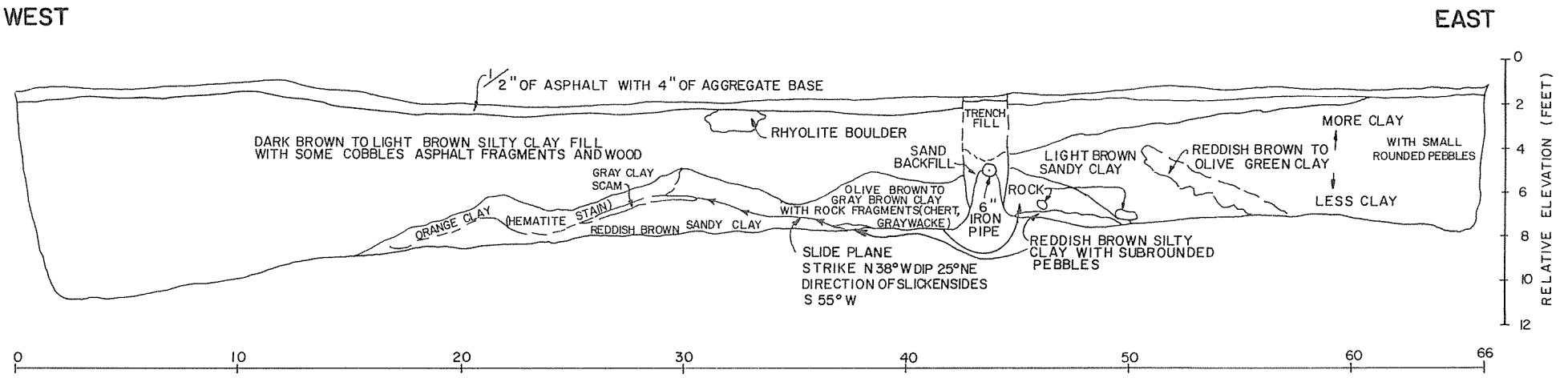
Figure 3



CROSS-SECTION-EXPLORATION TRENCH NO.1
OXFORD ELEMENTARY SCHOOL
Berkeley, California

Project No. 70071B
WOODWARD-CLYDE CONSULTANTS

Figure 4



CROSS-SECTION-EXPLORATION TRENCH NO.2
OXFORD ELEMENTARY SCHOOL
Berkeley, California

Project No. 70071B
WOODWARD-CLYDE CONSULTANTS

Figure 5

Slide plane 1 has a strike (trend) towards the northwest (Figure 3). This strike agrees with the general strike of the Hayward fault zone, but the direction of the slickensides are towards the southwest as would be expected if they were due to slide activity. The strike of slide plane 2 is at right angles to the strike of slide plane 1, has the same type of slickenside features, and its orientation does not suggest faulting. Therefore, it is concluded that the planes have the same origin and sliding is the only reasonable explanation. Since the site is located within a larger area subject to earth movement, it appears very reasonable to assume that these planes are associated with complex earth movements and that these planes tie into a basal slide plane at some greater depth.

Slide plane 3 is identified in exploratory trench 2 as shown on Figure 3 and 5. This feature, like slide plane 1, has a northwest strike and dip (slope) into the hill at about 25^{o} (downward from a horizontal surface). The grooves, or slickensided surfaces suggest movement towards the southwest, like slide plane 1. Therefore, this appears to be consistent with the other two planes and it is also interpreted to be due to landslide activity.

All three planes indicate that the movement is from the east towards the west with the upper materials overriding the lower materials. This is consistent with what would be expected along a slide plane, but it is not consistent with active faulting. Therefore, the planes are interpreted to be related to slide activity as a normal process of earth movement within the area shown on Figure 2, and not related to fault activity.

Other Possible Interpretations - Based on the interpretation presented above, it can be concluded that the planes observed in exploratory trenches 1 and 2 are not associated with active

fault traces of the Hayward fault and there is no evidence of faulting through the school facility. There are two other possible interpretations that must be considered: 1) that a fault trace traverses the site beneath the earth movement, and 2) the planes are, in fact, fault planes.

It might be argued that a fault trace could conceivably traverse the site beneath the earth movement and not be observed within the exploratory trenches. This is conceivable, but not likely. If a fault trace were to traverse the school property beneath the earth movement, and yet does not show up in the exploratory trenches, this would be very strong evidence that surface faulting had not occurred through this area for a considerable period of time. There are two reasons for this statement. First, the origin of the area of earth movement is probably related to slide activity when the climate was much wetter and different from today. This would suggest an age of 10,000 years old or more. Since there is no evidence of faulting through the material exposed in the trenches, this demonstrates a considerable period of time without any evidence of fault movement. Second, the Hayward fault is reported to have been the location of surface faulting in 1836 and the faulting is reported to have occurred through the Berkeley Hills area between Oakland and San Pablo. If this section of the Berkeley Hills experienced surface faulting in 1836 and if the surface faulting projected through the Oxford School site, some evidence should have been observed in the trenches. Yet no such evidence of surface faulting was identified. The Hayward fault zone is very active and is known to have been the location of surface faulting for a very long period of time. Based on its estimated level of activity, the Hayward fault could have been the location of surface faulting from 20 to 40 times in the last 10,000 years. If any such number of fault displacements had taken place through this area, there should be some evidence of faulting, yet no such evidence was identified.

Another argument could be made that the planes identified as slide planes are in fact fault planes. The planes are similar to fault planes, but the direction of the slickenslides suggest movement towards the southwest, not to the northwest as would be expected if they were related to faulting. Based on its strike slide plane 2, is definitely not a fault plane but is a slide plane.

Fault planes associated with the Hayward fault generally have a more vertical orientation than shown by slide plane 1 (10^{o} dip) and slide plane 2 (25^{o} dip). Normally, fault planes on the Hayward fault dip about 70^{o} to 85^{o} towards the east. At some locations along the Hayward fault, fault planes have been observed to "turn over" or "creep downhill", but also associated with those planes are more vertical (on the order of 70^{o} to 85^{o}) planes which break upward to the surface. This would indicate that while some planes can "turn over" due to normal downhill creep, repeated fault movement results in more vertical planes than observed in the exploratory trenches.

If slide planes 1 and 3 were fault planes, this would indicate that the fault is located somewhere east of the school site; since the planes are in the area of earth movement which is moving downhill, they are overturned in the downhill direction, and they would have been displaced from somewhere uphill.

Assessment of Stability

Both of the Woodward-Clyde-Sherard and Associates reports of 1963 (1963a & 1963b) indicate that the Oxford School site is located within an area subject to earth movements. Field reconnaissance and observations in 1976 confirm that disruption and displacement of sidewalks, curbs, and other features are occurring within the limits shown on Figure 2.

At several places within these limits sidewalks are offset horizontally anywhere from four to ten inches; streets and curbs are warped or have a very undulating, or wavy nature; and the sidewalks are buckled and are uplifted due to compression. There is evidence of slow (on the order of 1/2 to 1 inch, or less, per year) deep seated earth movement in the area shown on Figure 2. A previous study conducted for the school site (Woodward-Clyde-Sherard and Associates, 1963b) suggests the possibility that the areal earth movement may be related to a zone which ranges in depth from 20 1/2 to 41 feet beneath the 1963 ground surface at Oxford School. The results of the exploration trenching has identified three slide planes. This suggests that the area of earth movement is a large complex mass, with many individual slide planes that may move independently of the larger area.

Static Conditions - Because of the large area involved and the complex nature of the problem, it is not now possible to predict where, when, or at what rate future earth movements will occur. Future earth movement is a distinct likelihood, and during that movement the general overall area is expected to adjust, deform and move downhill. This movement can be recognized and monitored. If this movement is sufficiently slow, the effects may hardly be noticeable over a short period of time (5 to 10 years). As more time elapses, or the rate of movement increases, there will be more noticeable changes in elevations and possibly some cracks in walls and sidewalks. Under static conditions, the school site, like other lots in the area, should tend to move with the area earth movement. However, it is possible that localized movement could occur along individual slide planes.

Earthquake Shaking - There is a possibility that earth movement could be triggered or accelerated by strong earthquake shaking originating from a major earthquake on the

San Andreas fault or on the Hayward fault. This shaking could accelerate the earth movement and result in more noticeable deformation within the area.

Potential for Strong Earthquake Shaking

The Oxford Elementary School site could, in all probability, be subjected to strong earthquake shaking in the future. Since the structure is a school, it is designed according to the requirements of the Field Act, and meets California earthquake standards in effect at that time. The potential for damage due to earthquake shaking is no greater because of its proximity to the reported Hayward fault zone than if it were located several miles away from the Hayward fault zone. In either event, it will receive strong shaking from an earthquake on the Hayward fault as will all other school sites and residential structures within Berkeley. Therefore, the question of earthquake shaking, with respect to the proximity to the reported Hayward fault zone, should not be given undue consideration as long as the school is not located across an active fault trace, which it is not.

Implication of Results

The results of this study indicate that the most significant consideration at the Oxford School site is areal earth movement and, more specifically, to areal earth movement triggered or accelerated by strong earthquake shaking. Under normal static conditions the earth movement can be monitored, the physical effects to the school property and structures can be observed and repaired, and any potential problems could probably be recognized several months before they become a serious hazard to the school structures and the occupants. An important point to remember is that the Oxford Elementary School was designed and constructed with the knowledge that it

was located within an area subjected to slow earth movement. It was recommended that the building foundation system should be strengthened so that they would act as continuous movement-resistant units and minimize the displacement effects of any possible future earth movements. Therefore, the structure was designed to a higher standard than the normal school structure. The potential for earth movement under static conditions is high; the potential for damage is low to moderate; and the time period available to recognize potential problems and take action is probably several months.

It is not possible for us to predict or estimate where, when, or at what rate earthquake tiggered or accelerated earth movement will occur on the school site; whether or not it will occur; and the results to the existing structure. The potential for earthquake triggered or accelerated earth movement occurring is lower than the potential for movement occurring under static conditions. The potential for damage to the structures is higher, and the time period available to recognize potential problems and take action could vary from several minutes to several hours. The school structures should be evacuated immediately after any strong earthquakes and not used for any purpose until the surrounding area, school yard, and structures are inspected by representatives of the district for potential hazards and structural damage, and decisions are made to utilize the structures.

The potential for earthquake triggered or accelerated earth movement is a condition that needs to be recognized and evaluated by the Berkeley Unified School District and other interested agencies before a final decision can be made concerning the Oxford School site. There is a risk involved in placing a structure within the area of earth movement but no one can say with any degree of certainty that the site will, or will not, ever be damaged by earth movement within

the life of the structure. This information must be considered with other factors in making judgment decisions for the Oxford Elementary School site.

CONCLUSIONS

1. While the existing geological data may show that the Oxford School site is located within the Hayward fault zone, the results of exploratory trenching found no evidence that there are active fault traces traversing the Oxford School site. If there are active fault traces within the vicinity of Oxford School site they would be located east of the site or west of the site. In either case, the potential for surface faulting at the Oxford site is considered low.

2. The Oxford Elementary School is located within a large area subject to slow deep-seated earth movement. The earth movement includes such a large area that there is no way that anything can be done on the Oxford School site to slow down or to stop this movement. These facts were recognized prior to the design and construction of the school site, and at that time it was indicated that design measures should be taken to minimize the potential for damage due to any future deformation associated with the earth movement. There is a potential for accelerated movement during strong earthquakes. Under accelerated earth movement due to eartnquake shaking, there is an increased potential for damage.

3. The Oxford School site will be subjected to strong ground shaking during future earthquakes originating on the San Andreas fault on the other side of the Bay, or on the Hayward fault somewhere within the Berkeley Hills. Thus, the site has a potential for stong earthquake shaking

similar to most other sites within the East Bay area. As far as the potential for surface faulting is concerned, it appears to be fairly remote and the greatest potential hazard, or source of damage, appears to be from strong ground shaking or earth movement.

APPENDIX A
REVIEW OF PREVIOUS WORK

Prior to the present study to which this Appendix is attached, three previous investigations had been conducted for the Oxford School site. The first two studies were conducted in 1963 and the most recent study in 1976. A review of these studies is presented below in order to provide a summary of the background data used in the present study.

1. October 30, 1963a, "Topographical and geological features of the proposed Oxford Elementary School site, Berkeley California", Woodward-Clyde-Sherard and Associates.

   Prior to conducting the soil investigation for the proposed Oxford Elementary School site, Woodward-Clyde-Sherard and Associates (WCSA), studied the available data regarding the prominent topographical and geological features of the subject site. That study indicated that the construction of the proposed structures appeared to involve earth movements and earthquake hazards; and the report provided background information on these features. Figure 1 of that report (WCSA, 1963a), which is shown as Figure 2 of this (1977) report, shows the Oxford Elementary School to be located within the limits of an area designated as being subject to earth movements. The limits of earth movement were defined by the Public Works Department, City of Berkeley, in their report on November 25, 1953, entitled "Report of Underground Drainage System for Control of Earth Movement in Section of the Berkeley Hills". It was pointed out in the WCSA (1963a) report that the areal limits of the earth movement shown on the figure, did not mean that every structure located within those limits had been damaged, or if not, would be damaged in the future. The existing school building in 1963 was

examined for any evidence of differential earth movements. It was concluded that the subject school site did not appear to have been subjected to any appreciable differential earth movements to date, at least not within the life of the then existing structures.

In 1952, prior to the work on their report, the Public Works Department of the City of Berkeley engaged a consulting geologist, Chester Marliave, now deceased, to make a geological study of the subject area. On the geological map submitted by Chester Marliave, the Hayward fault is shown to traverse through the earth movement area. The fault line, as indicated by Marliave, is shown on Figure 2 of this (1977) report. A geologic map prepared by James E. Case, as part of his doctorate thesis at the University of California, was examined during the 1963 study. That map showed the Hayward fault zone passing through the area, and the location of the fault line is shown on Figure 2 of this (1977) report. It can be seen by a comparison of Figure 2, that the Oxford Elementary School is located mid-way between these two fault zones. The WCSA report (1963a) indicates that although the Hayward fault is shown as a single line on the figure, the fault is actually a sheared zone in the bedrock formation having some width. From exposures in the San Pablo Water Tunnel, excavated through the Berkeley Hills, and a tunnel on the Universiy of California grounds, both of which went through the Hayward fault zone, it is concluded that the Hayward fault zone can be about 500-600 feet wide. Therefore, based on this reasoning, it could be concluded that in the vicinity of the Oxford School, the Hayward fault zone, is about 500 to 600 feet wide and, therefore, the Oxford School is located within the rift zone of the Hayward fault.

The October 30, 1963 report presented some prelimnary conclusions regarding earth movements and earthquake hazards. The preliminary conclusions regarding earth movement at the Oxford School site are presented as follows: "No amount of work that can be economically done within the school site would stay the possible future movements of the area shown on Figure 1 (Figure 2 of this 1977 report); however, since the visible evidence of detrimental effects of earth movements within the school site is relatively slight, it is our opinion that it should be feasible to provide some type of a rigid foundation for the proposed buildings, such as a reinforced grid, that would act as a unit and minimize the effects of any possible future movements. Test borings will need to be made to determine the actual foundation requirements for the site."

The preliminary conclusions regarding earthquake hazard (essentially, the potential for surface faulting) are as follows: "The earthquake hazards at the proposed school site is a condition that will need to be recognized and evaluated by you and other interested agencies before a decision is made to go ahead with final design plans. There is a risk involved in placing a structure within the rift zone of a fault but no one can say with any degree of certainty that the site will or will not ever be damaged by earthquakes within the life of the structure. This information must be considered against other factors that would necessitate the construction of the school at the subject site."

2. December 10, 1963b, "Soils Investigation for the Proposed Oxford Elementary School", Woodward-Clyde-Sherard and Associates.

The subject report begins with the following statement: "Our findings on topographical and geological features of the site were presented in our letter of October 30, 1963. In this letter, it was pointed out that the subject site is located within an area subject to possible future earth movements and is possibly within the rift zone of the Hayward fault. Our site investigation was started after you had considered the above two factors and decided to proceed with the proposed construction. The soil investigation made by us was to evaulate the foundation requirements for the proposed structure, considering that the school site is located in an area subject to possible future areal earth movements. A detailed investigation to determine the conditions and problems associated with both the areal movements and the rift zone are beyond the scope of this report."

A total of ten exploratory holes (ranging from 8-1/2 to 60 feet in depth) were drilled for this investigation (WCSA, 1963b). The test borings indicate that some grading work had been done to develop the site to its present condition. Some existing fill was encountered in all the test borings, and varied in thickness from one foot to 11 feet. Bedrock was encountered in three of the holes at depths of 20 1/2, 32 1/2, and 41 feet, respectively. In all three holes, the surface layer of bedrock consisted of shale, siltstone, and serpentine, all completely decomposed and altered to a plastic, silty clay indicating the possibility that the earth movement occurs within this zone. Below this altered zone, the rocks are relatively hard claystones, siltstones and sandstones. An east to west cross-section drawn near the southern property line from Oxford Street to Walnut Street, indicates the earth movement is 40 to 50 feet deep beneath Oxford Street and is approximately 30 feet deep beneath Walnut Street.

The report (WCSA, 1963b) indicates that the site is located within an area subject to possible future earth movements. It indicates that although it is not possible to predict from the limited investigation made for a small area when such movements could take place, or how severe it might be, it is definitely advisable to strengthen the building foundation system so that they would act as rigid units and minimize the effects of any possible future earth movements.

3. November 30, 1976, "Geologic Study, Oxford Elementary School, Berkeley, California", Woodward-Clyde Consultants.

The Oxford School site is reported to be located within the active Hayward fault zone and in close proximity to the Louderback and Case fault traces shown on Figure 1. The results of this study do not conclusively demonstrate that the Oxford School site is located on an active fault trace, nor have the results of the study conclusively shown that the Case fault trace, or the Louderback fault trace, exist where shown (Figure 1), that they are in fact active fault traces, or that they are part of the active Hayward fault zone. However, based on the available data and opinions of the geological community, and in the absence of conclusive evidence to the contrary, it appears reasonable to take the following approach:

a. The Oxford School site is located within the broad Hayward fault zone as mapped by previous investigators (Figures 1 and 2). In other areas along the Hayward fault, the broad fault zone has been shown to be 500 to 600 feet wide and contains several individual fault traces.

b. Due to residential development in the Berkeley Hills and the presence of slope instability, it is not possible to identify the location of individual fault traces with any accuracy utilizing aerial photointerpretation and surface reconnaissance.

c. The Louderback fault trace (Figure 1) is shown on the existing geologic maps to pass through the extreme edge of, or in very close proximity to, the school site. This fault has been inferred to exist by previous workers but its existence has not been confirmed by compelling evidence. Its existence and location are questionable.

d. The weight of the evidence suggests that the site is located in the Hayward fault zone as presently reported, but there is no documented evidence to show that the Louderback fault trace exists on the school site, or that any other fault trace projects through the school site. There is a good possibility that the active Hayward fault zone could be located elsewhere in the Berkeley Hills.

e. Future fault investigations may demonstrate that an active fault trace does not exist on the school site, or that active traces of the Hayward fault exist elsewhere in the Berkeley Hills. However, conclusions of this study must be based on the presence of available data.

The above approach leads to the conclusion that there is some doubt as to the exact location of the Hayward fault zone, of active fault traces in the Hayward fault zone, and specifically the location of active fault traces in the vicinity of the Oxford School

site. However, based on the available data, and considering the land use, it apears reasonable and prudent to assume that the school site is located within the Hayward fault zone and that two possibilities exist: a) an active fault trace projects through the site, or b) an active fault trace does not project through the site.

If the first possibility is correct, it means that surface faulting would have to be considered a distinct and real possibility at the site, and steps would presumably be taken to reduce the hazard. The evidence for the existence, location, and activity of the Louderback fault trace is questionnable enough to make the second possibility worthy of consideration. However, without additional subsurface data, it appears to be reasonable and prudent to assume that an active fault could project through the school site. This assumption would mean acceptance of the possibility of surface faulting at the school site. It appears that exploratory trenching is necessary to resolve the two possibilities. The November 30, 1976 report should be consulted if a more detailed description of the study is desired, and for a discussion of surfaced faulting, earthquakes, and potential hazards in general.

REFERENCES

Case, J. E., 1963, Geology of a portion of the Berkeley and San Leandro Hills, California: California University, Berkeley, Ph.D. Thesis.

City of Berkeley, 1954, Report on proposed drainage system for control of earth movement in the Berkeley area: unsigned copy of an October, 1954 report, John D. Phillips, City Manager.

Louderback, G. D., 1976, Unpublished data, Bancroft Library, University of California, Berkeley, California.

Marliave, C., 1952, Geologic formations and earthquake faults in the Berkeley Hill area: unpublished report and map, Public Works Department, City of Berkeley.

Radbruch, D. and Case, J. E., 1967, Preliminary geologic map and engineering geologic information, Oakland and vicinity, California: United States Geological Survey, Open-File Report.

Radbruch-Hall, D. H., 1974, Map showing recently active breaks along the Hayward fault zone and the southern part of the Calaveras fault zone, California: United States Geological Survey, Miscellaneous Investigations Series, Map I-813.

State of California, 1974, Special Studies Zones, Richmond quadrangle: California Division of Mines and Geology, scale 1:24,000.

Woodward-Clyde-Sherard and Associates, 1963a, Topographical and geological features of the proposed Oxford Elementary School site, Berkeley, California: unpublished consultants' report, October 30, 1963, for Berkeley Unified School District.

Woodward-Clyde-Sherard and Associates, 1963b, Soil investigation for the proposed Oxford Elementary School, Oxford Street and the shortcut, Berkeley, California: unpublished consultants' report, December 10, 1963, for the Berkeley Unified School District.

Woodward-Clyde Consultants, 1976, Geologic study, Oxford Elementary School, Berkeley, California: unpublished consultants' report, November 30, 1976, for Berkeley Unified School District.

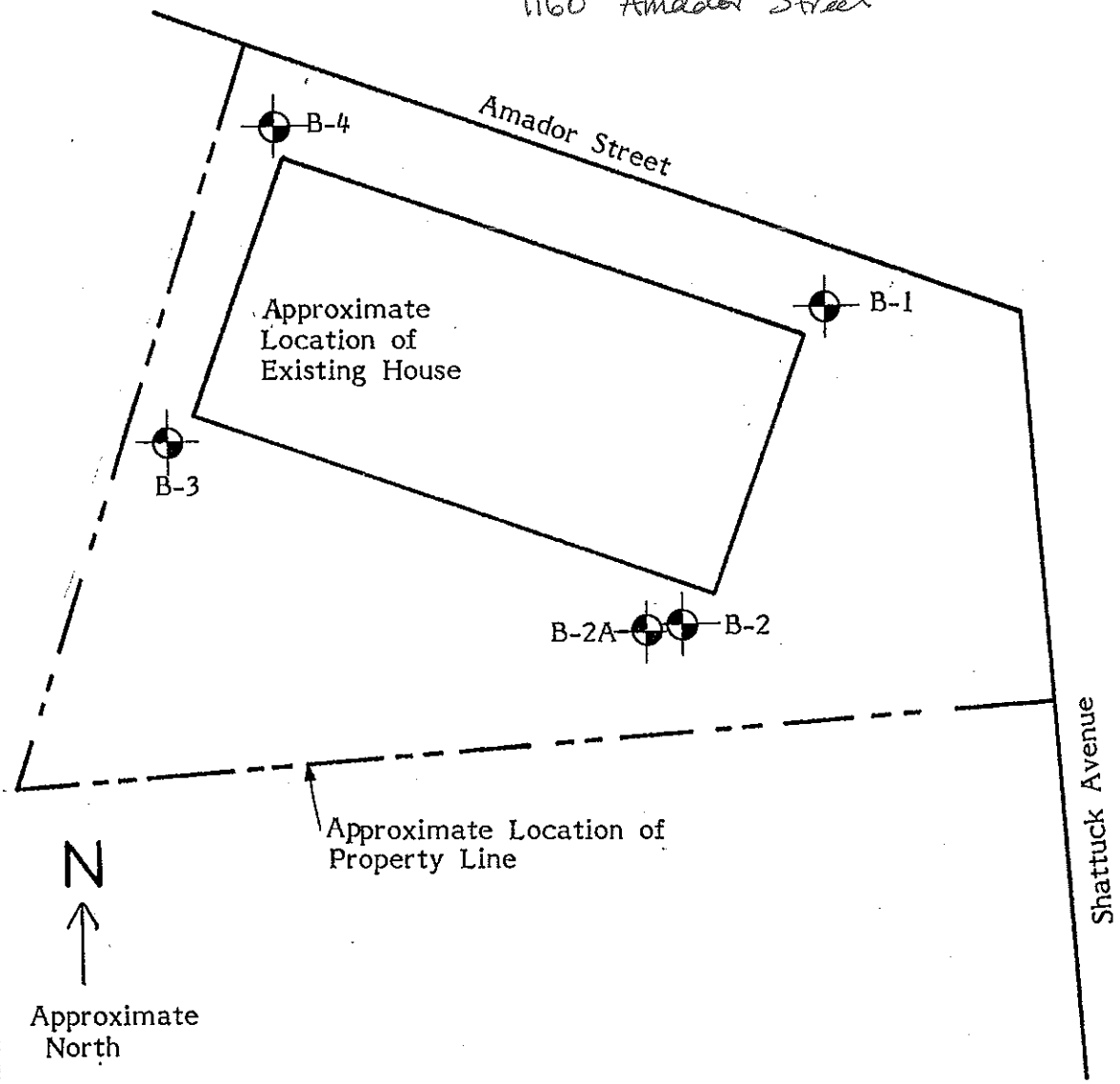
APPENDIX G

PREVIOUS SUBSURFACE DATA

1160 AMADOR STREET
BORING LOGS

417-1 Amador Street Residence

1160 Amador Street



LEGEND

B-1 Approximate Location of Exploratory Borings

NOTE: This is only a rough sketch; it is not drawn to scale.

ALAN KROPP & ASSOCIATES *Geotechnical Consultants*	SITE PLAN		
	1160 AMADOR STREET RESIDENCE Berkeley, California		
	PROJECT NO.	DATE	Figure 1
	417-1	Sept., 1981	

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY PKM
DEPTH TO GROUNDWATER Not Encountered	BORING DIAMETER 3½ inches	DATE DRILLED 9/14/81

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	SHEAR STRENGTH BY TORVANE (KSF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
CLAY, silty, sandy, gravelly Liquid Limit = 58% Plasticity Index = 35% Passing No. 200 Sieve = 78%	Mottled black, very dark gray & dark yellow brown	Stiff	CH	1 2 3 4 5		28* 36* 36*	18 17 18	97 101 101	6.4 Lu
CLAY, silty, sandy	Very dark brown	Stiff Firm	CL-CH	6 7 8 9 10		34* 30* 21*	22 22 21	101 104 101	4.3 Lu
				11 12 13 14 15		12*	22	99	2.5 Lu

Bottom of Boring = 15 Feet

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)
2. The stratification line represents the approximate boundary between material types, and the transition may be gradual.
3. Penetration resistance values marked with an asterisk (*) were recorded with a 70-pound hammer dropping 36 inches (see page A-1 for additional discussion).
4. See page B-1 for explanation of symbol "Lu".

B-1

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

AMADOR STREET RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
417-1	Sept. 1981	1

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY PKM
DEPTH TO GROUNDWATER Not encountered	BORING DIAMETER 3½ inches	DATE DRILLED 9/14/81

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	SHEAR STRENGTH BY TORVANE (KSF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
CLAY, silty, sandy, gravelly Boulders of severely weathered basalt were encountered with a maximum size of approximately 2 feet.	Very dark brown Grading to dark yellow brown	Stiff	CH	1 2 3 4 5		32** 29*/3	23 17	92	
CLAY, silty, sandy, gravelly	Very dark gray	Stiff	CL-CH	6 7 8 9 10		26*/6 26* 21*/6" 27*/6"	12 13 10 11	122 125	
		Very stiff		11 12					
CLAY, silty, sandy, gravelly	Yellow brown	Hard	CL	13 14		30*/3"	13	110	

Bottom of Boring = 14 Feet, 3 Inches

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.
3. Penetration resistance values marked with an asterisk (*) were recorded with a 70-pound hammer dropping 36 inches.

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

AMADOR STREET RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
417-1	Sept. 1981	2

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY PKM
DEPTH TO GROUNDWATER Not encountered	BORING DIAMETER 3½ inches	DATE DRILLED 9/14/81

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	SHEAR STRENGTH BY TORVANE (KSF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
CLAY, silty, sandy, gravelly	Very dark brown Grading to dark yellow brown	Stiff	CH	1 2 3 4 5	X	24*/6	14	110	7.4
CLAY, silty, sandy, gravelly	Very dark gray	Stiff	CL-CH	6 7	X	18*/6	12	115	

Bottom of Boring = 7 Feet

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)
2. The stratification line represents the approximate boundary between material types, and the transition may be gradual.
3. Penetration resistance values marked with an asterisk (*) were recorded with a 70-pound hammer dropping 36 inches.

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

AMADOR STREET RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
417-1	Sept. 1981	2A

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY PKM
DEPTH TO GROUNDWATER See Note 1	BORING DIAMETER 3½ inches	DATE DRILLED 9/14/81

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	SHEAR STRENGTH BY TORVANE (KSF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)
CLAY, silty, with some gravel and roots Liquid Limit = 69% Plasticity Index = 44% Passing No. 200 Sieve = 86%	Black	Stiff	CH	1		25*	23	93	
				2					
				3		26*	23	96	
				4					
		Firm		5		19*	25	108	3.6 Lu
				6					
				7		24*	27	97	
				8					
				9		27*			
CLAY, silty, sandy, gravelly (5-inch diameter cobble at 12½ feet)	Dark grayish brown	Stiff	CL-CH	10			23	103	4.5 Fp
				11					
				12					
				13					
CLAY, sandy, silty	Olive yellow	Soft	CL	14		9*	35	74	2.0 Fp
				15					
	Grading to olive brown			16					
				17					
				18				2 hrs. later	
				19		37*	19	ATOD 112	4.5 Fp
		Stiff	CL	20					

NOTES
1. Groundwater was encountered at a depth of 19 feet at the time of drilling, and was at a depth of 18 feet 2 hours after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.
3. Penetration resistance values marked with an asterisk (*) were recorded with a 70-pound hammer dropping 36 inches.
4. Explanations of the tests used for determining unconfined strengths is found in Appendixes A (for Fp) and B (for Lu).

Bottom of Boring = 20 Feet

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

AMADOR STREET RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
417-1	Sept. 1981	3

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY PKM
DEPTH TO GROUNDWATER Not encountered	BORING DIAMETER 3½ inch	DATE DRILLED 9/15/81

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	SHEAR STRENGTH BY TORVANE (KSF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)
CLAY, silty, sandy, gravelly	Mottled black with yellow brown	Soft	CH	1		10*	24	99	3.6 Lu
				2					
				3		24*	20	101	
		Stiff		4					
				5		32*			
				6			20	103	9.0 Fp
CLAY, silty, with some sand and gravel, also contained, roots	Black	Stiff	CH	7		31*			
				8			24	96	6.9 Lu
				9		24*			
				10			26	98	9.0 Fp
CLAY, silty, gravelly	Gray	Firm	CL-CH	11					
				12					
				13					
				14		15*			6.0 Fp
				15			17	109	

Bottom of Boring = 15 Feet

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.
3. Penetration resistance values marked with an asterisk (*) were recorded with a 70-pound hammer dropping 36 inches.
4. Explanations of the tests used for determining unconfined strengths is found in Appendixes A (for Fp) and B (for Lu).

ALAN KROPP & ASSOCIATES

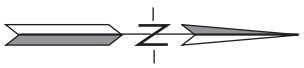
Geotechnical Consultants

EXPLORATORY BORING LOG

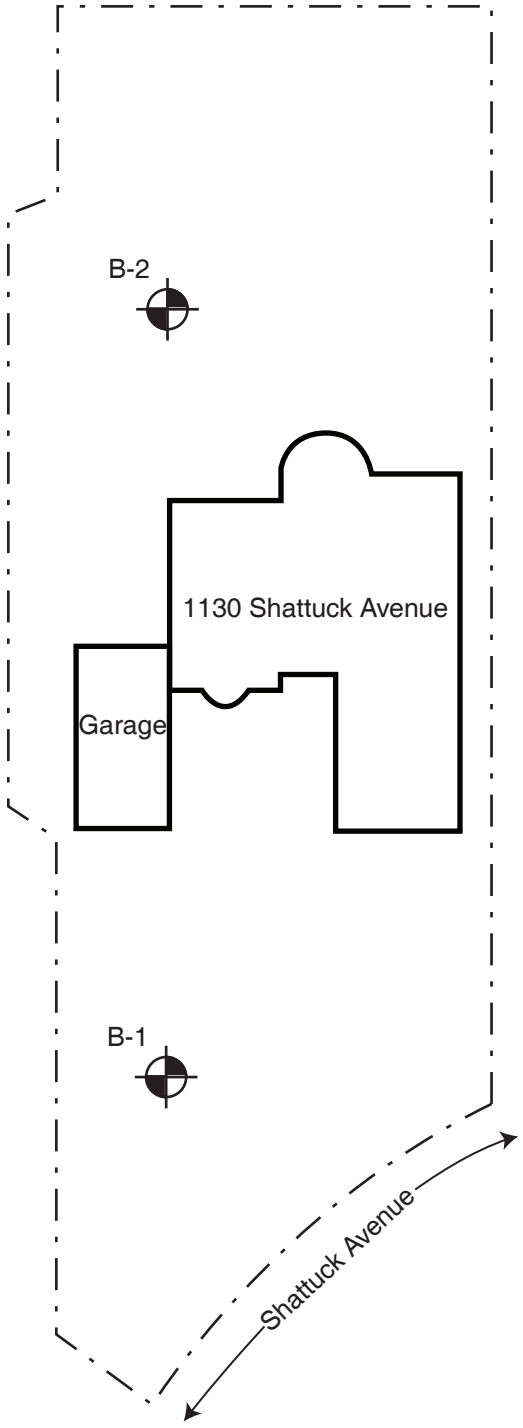
AMADOR STREET RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
417-1	Sept. 1981	4

1130 SHATTUCK AVENUE
BORING LOGS



(REFERENCE)



LEGEND

B-1 — Approximates Location of Exploratory Boring

Approximate Location of' Property Line

Base - Field Sketch

SKETCH: NOT TO SCALE

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

SITE PLAN

POITIER RESIDENCE, 1130 SHATTUCK AVENUE
Berkeley, California

PROJECT NO.	DATE	FIGURE
2033-1	**April 2000**	2

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ± 325 feet	LOGGED BY: JP
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 4-1/2inches	DATE DRILLED: 3-29-00

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
Concrete Driveway ~ 4 inches									
CLAY, silty, sandy, with some fine gravels, subangular; (Fill)	Mottled Yellow Brown	Very Stiff	CL	1 2 3 4 5					
CLAY, silty, sandy, with some rock fragments; (Fill)	Olive Brown	Very Stiff	CL	6		[35]	13	113	
- coarse gravel to cobbles (FILL)				7 8 9 10 11 12 13 14 15		[34]	15		
GRAVEL, clayey, fine to coarse subangular gravels;	Motteled Yellow Brown	Medium Dense	GC	16		[35]	9	115	ATOD
(continued on next sheet)				17 18 19 20					

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ± 325 feet	LOGGED BY: JP
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 4-1/2inches	DATE DRILLED: 3-29-00

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, silty, sandy, with some fine gravels;	Dark Grayish Blue	Stiff	CL	21		[20]			- no recovery
				22					
				23			17		
				24					
				25					
				26					
				27					
				28					
				29					
				30					
	Dark Gray	Very Stiff		31		[43]	18	113	
				32					
				33					
				34					
				35					
				36					
				37					
				38					
				39					
				40					

(continued on next sheet)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

POITIER RESIDENCE, 1130 SHATTUCK AVENUE
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2033-1	**April 2000**	**2 of 3**	1

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ± 325 feet	LOGGED BY: JP
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 4-1/2 inches	DATE DRILLED: 3-29-00

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, silty, with some sand;	Dark Grayish Blue	Stiff	CL	41					
CLAYSTONE, severely weathered;	Gray to Green	Hard	Bed-rock	42 43 44 45 46 47 48 49 50		[50] 2"			

Bottom of boring at 50 feet and 2 inches

NOTES

1. Groundwater was encountered at 17 feet at the time of drilling, and a 2.75-inch O.D. slope inclinometer casing was installed into the boring and grouted in place. (See text for discussion.)

2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.

3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler, and are not standard penetration resistance values.

4. Datum based on City of Berkeley, Department of Public Works, Photo-Contour Map, from photographs dated August, 1956.

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ± 316 feet	LOGGED BY: JP
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 3-1/2inches	DATE DRILLED: 3-29-00

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, silty, sandy, with some fine gravels; (Fill) (FILL)	Dark Grayish Brown	Stiff	CL	1–7		[24*]	19	101	Fp = 4.0 ksf
GRAVEL, clayey, fine to coarse gravels;	Mottled Olive Green to Olive Brown	Medium Dense	GC	8–14		[48*]	15	122	
CLAY, gravelly, fine grained - subangular gravels, clay matrix;	Motteled Olive Brown	Very Stiff	CL	15–20		[46*]	18	113	Fp = 5.0 ksf

(continued on next sheet)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

POITIER RESIDENCE, 1130 SHATTUCK AVENUE
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2033-1	**April 2000**	**1 of 2**	2

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ± 316 feet	LOGGED BY: JP
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 3-1/2inches	DATE DRILLED: 3-29-00

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, gravelly;	Dark Greenish Gray	Hard	CL	21 22		[59*]			-200 = 33%

Bottom of boring at 22 feet and 6 inches

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)

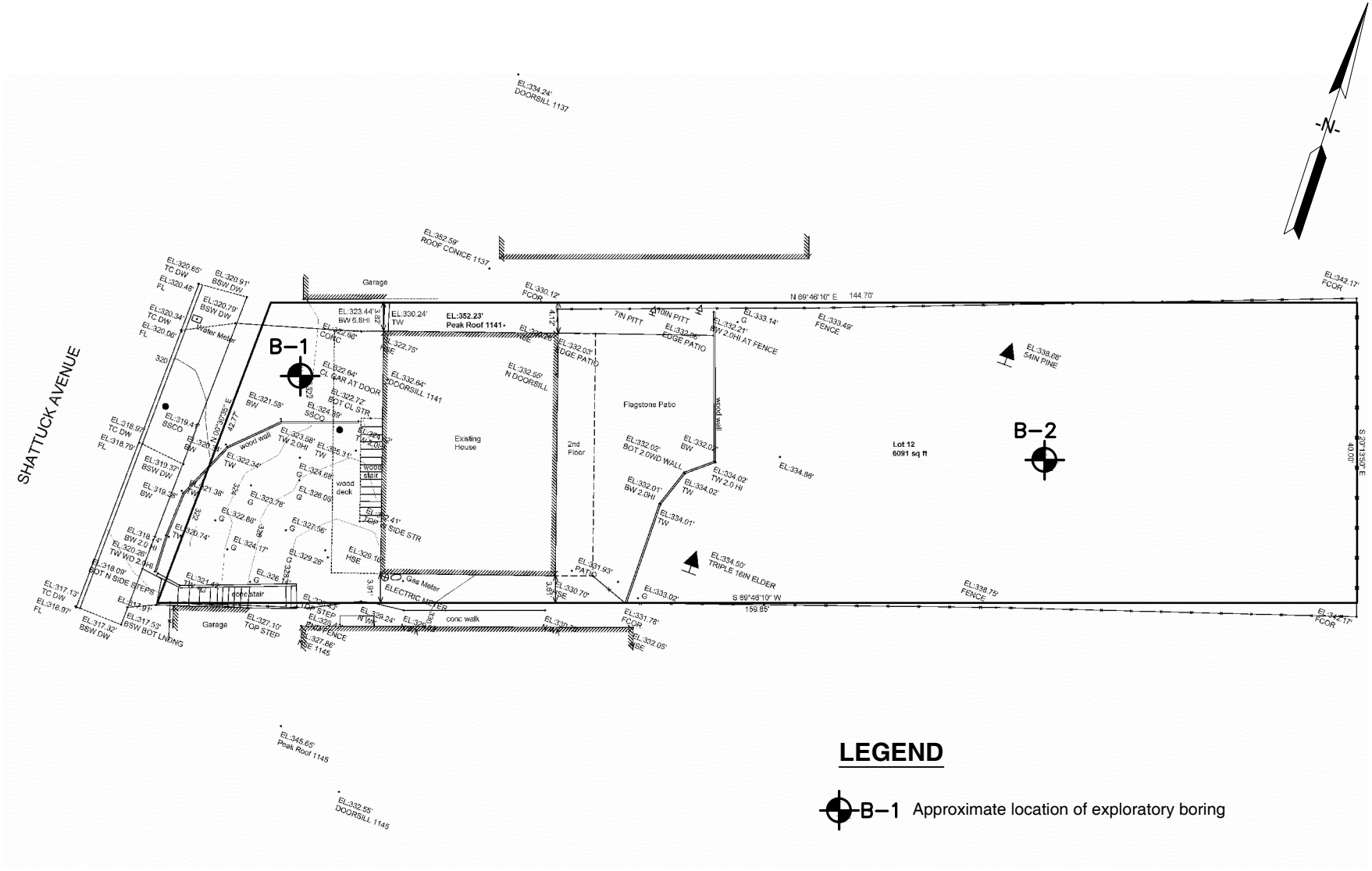
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.

3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler, and are not standard penetration resistance values. Penetration resistance values (blow counts) marked with an asterisk (*) are not standard penetration resistance values.

4. Datum based on City of Berkeley, Department of Public Works, Photo-Contour Map, from photographs dated August, 1956.

5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are followed by the symbol "Fp".

1141 SHATTUCK AVENUE
BORING LOGS



LEGEND

B–1 Approximate location of exploratory boring

Source: Topographic Survey by Paul O. Webb - Licensed Surveyor, dated August 2018.

10 0 20 40
APPROXIMATE SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

SITE PLAN

POLLARD RESIDENCE
Berkeley, California

PROJECT NO.	DATE	FIGURE
2953-1	**November 2018**	**6**

DRILL RIG: B-24, Solid Flight Auger	SURFACE ELEVATION: 322' +/- MSL	LOGGED BY: JJ
DEPTH TO GROUNDWATER: (see notes)	BORING DIAMETER: 4 inches	DATE DRILLED: 10/9/18

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
6" Concrete, 6" Base									
SAND, Lean, Clayey - wet (LANDSLIDE DEBRIS)	Brownish Gray	Medium Dense	SC	1–10		[18]	161	115	LL = 49 PI = 32 -200 = 45
CLAY, Fat - with serpentinite fragments, moist (LANDSLIDE DEBRIS)	Brown and Gray	Stiff	CH	10–15		[17] [15]	22 21	106 105	LL = 55 PI = 27 -200 = 50 LL = 51 PI = 29 -200 = 54
-with gravel, moist to wet	Mottled Brown and Gray			15–20		[23]			
CLAY, Lean, Gravelly - with schist fragments, moist (LANDSLIDE DEBRIS)	Dark Gray	Very Stiff	CL	20–25		[28]			
SAND, Fat, Clayey - wet, with gravels (LANDSLIDE DEBRIS)	Brownish Gray	Medium Dense	SC	25–30		[20]	19	117	LL = 45 PI = 25 -200 = 39
CLAY, Lean - with sand, with gravel, wet	Dark Brown	Very Stiff	CL	30–34			18	114	LL = 44 PI = 25 -200 = 73

(Continued on Next Page)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

POLLARD RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2953-1	**December 2018**	**1 of 2**	**B-1**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean - with sand, with gravel, wet	Dark Brown	Very Stiff	CL	36		[24]			
LANDSLIDE DEBRIS				37					
				38					
CLAY, Silty - wet (PALEOSOL)	Black	Very Stiff	CL	39					
				40		[17]			
				41					
				42					
				43					
SILT, Sandy, Clayey - with few gravels, wet	Yellowish Brown	Dense	SC	44					
				45		[58]	18	117	LL = 36 PI = 17 -200 = 37
				46					
				47					
				48					
SANDSTONE, Silty - closely fractured, moderately weathered, weak, moist (BEDROCK)	Reddish	Hard	BR	49					

Bottom of boring at 49.5 feet.

NOTES:

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were estimated from topographic survey by Paul O. Webb - Surveyor, August, 2018.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG
POLLARD RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2953-1	**December 2018**	**2 of 2**	**B-1**

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 339' +/- MSL	**LOGGED BY:** JJ
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3 inches	**DATE DRILLED:** 10/9/18

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Gravelly - with sand (LANDSLIDE DEBRIS)	Mottled Brown and Black	Very Stiff	CL	1 2 3 4 5 6 7 8 9		[21]			
	Mottled Brown			10		[23]	20	116	LL = 35 PI = 17 -200 = 27
SAND, Lean, Clayey - with gravels (LANDSLIDE DEBRIS)	Brownish Gray	Very Stiff	SC	11 12 13 14 15 16 17 18 19 20 21		18 17			

Bottom of boring at 21.5 feet.

NOTES:

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were estimated from topographic survey by Paul O. Webb - Surveyor, August, 2018.

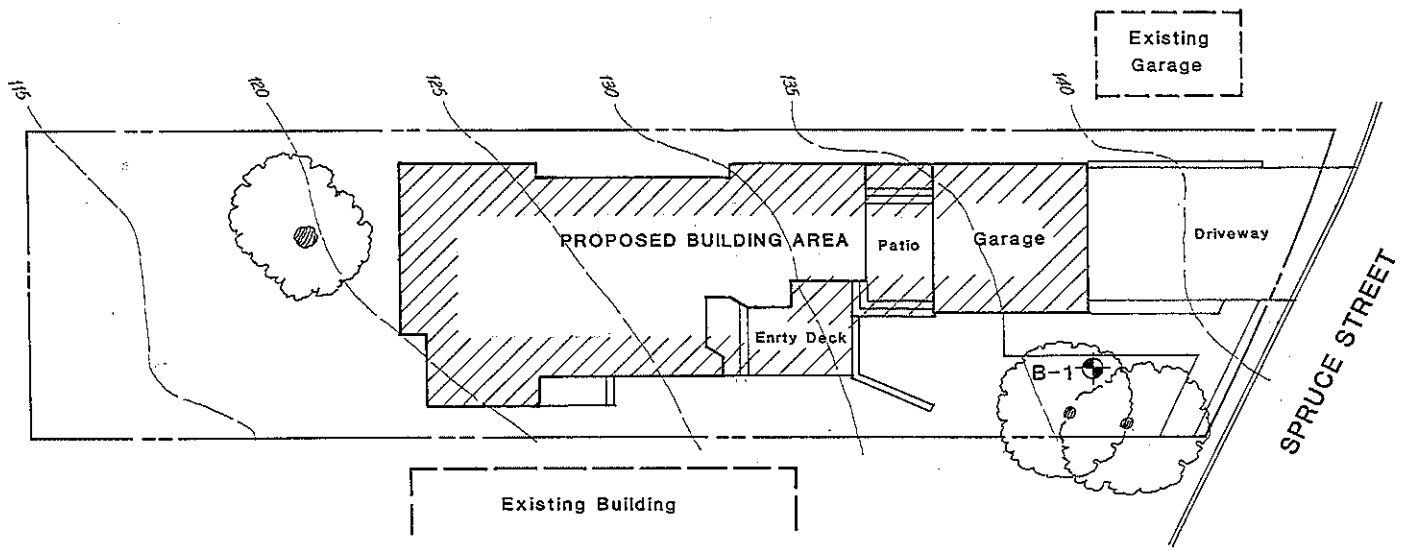
ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

POLLARD RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2953-1	**December 2018**	**1 of 1**	**B-2**

1122 SPRUCE STREET
BORING LOGS



1082-1 Ng Residence
1122 Spruce Street

LEGEND

B-1 Approximate Location of Exploratory Boring

0 20 40
APPROXIMATE SCALE (FEET)

1122 Spruce

BASE: "Residence for Gene and Helen Ng, 1122 Spruce Street, Berkeley, CA.", by Morimoto Architects, dated 20 July 1988.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

SITE PLAN

NG RESIDENCE
Berkeley, California

PROJECT NO.	DATE	FIGURE
1082-1	March 1989	1

DRILL RIG	Continuous Solid Flight Auger	SURFACE ELEVATION	± 137 Feet	LOGGED BY	BL
DEPTH TO GROUNDWATER	68 Feet (See Note 1)	BORING DIAMETER	6 Inches	DATE DRILLED	2/17/89

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
CLAY, very sandy, very silty with numerous variable gravels and rock fragments; FILL (FILL ↑)	Mottled Dark Yellow Brown	STIFF	CL	1–2					
CLAY, very silty, sandy - some woody roots Liquid Limit = 60% Plasticity Index = 38% Passin No. 200 Sieve = 82% - gradual transition	Very Dark Greyish Brown to Very Dark Brown	STIFF VERY STIFF	CH CL	3–7	X	58*	25	93	8.0Fp 4.8Lu
CLAY, silty, sandy with occasional subrounded to angular rock fragments and gravels - very sandy at intervals	Mottled Olive Brown	VERY STIFF	CL	8–12	X	39*	28	90	3.5Fp 2.1Lu
	Olive			13–17					
- sand and gravel lens from 18 to 21 feet Passing No. 200 Sieve = 17%	Mottled Olive Grey	HARD DENSE	SC CL	18–20	X	68*	10	119	
(continued on next sheet)									

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

NG RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
1082-1	March 1989	1

DRILL RIG	Continuous Solid Flight Auger	SURFACE ELEVATION ± 137 Feet	LOGGED BY BL
DEPTH TO GROUNDWATER	68 Feet (See Note 1)	BORING DIAMETER 6 Inches	DATE DRILLED 2/17/89

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
CLAY, very sandy, very silty with numerous to abundant subrounded to angular gravels and rock fragments (continued)	Mottled Olive and Olive Grey	HARD	CL/SC	20					
				21					
				22					
				23					
- varying to a very clayey sand with gravels to cobble size, some clean sand and gravel lenses				24					
				25					
				26					
				27					
				28					
				29					
- dark reddish brown clay layer overlying dense sand and gravel lens at 31 feet	Reddish Brown		CL	30					
	Olive Grey		CL/GC	31					
				32					
				33					
			CL/SC	34					
				35					
				36					
				37					
				38					
				39			14		
				40		65			

(continued on next sheet)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

NG RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
1082-1	March 1989	1 (con't.)

DRILL RIG	Continuous Solid Flight Auger	SURFACE ELEVATION	± 137 Feet	LOGGED BY	BL
DEPTH TO GROUNDWATER	68 Feet (See Note 1)	BORING DIAMETER	6 Inches	DATE DRILLED	2/17/89

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
CLAY, very sandy, very silty with numerous variable gravels and rock fragments (continued) - occasional gravel lenses, varies to clayey sand at intervals	Mottled Olive Grey	HARD	CL/SC	40 41 42 43 44 45 46 47 48 49 50 51 52					
- dense gravel lenses from 53 feet	Mottled Bluish Grey and Olive Grey		CL/GC	53 54 55 56 57 58 59 60					

(continued on next sheet)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

NG RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
1082-1	March 1989	1 (con't.)

DRILL RIG	Continuous Solid Flight Auger	SURFACE ELEVATION	± 137 Feet	LOGGED BY	BL
DEPTH TO GROUNDWATER	68 Feet (See Note 1)	BORING DIAMETER	6 Inches	DATE DRILLED	2/17/89

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
CLAY, very sandy, very silty with numerous variable gravels and rock fragments (continued) - occasional gravel lenses, varies to clayey sand at intervals - brown dense silt layer over sheared serpentine gravels and cobbles in a sheared clay matrix - abundant slickensides in sample at 63½ feet	Bluish Grey and Olive Grey Mottled and Variable	HARD	CL GC	60 61 62 63 64 65		42	23 16		
SERPENTINE and SHEARED ROCK, severely weathered and very severley sheared and fractured, clayey - occasionally harder, some intact boulders	Mottled Olive Grey	SOFT HARDNESS	BED-ROCK	66 67 68 69 70 71 72 73			▽		At time of drilling
Bottom of Boring at 80½ Feet				78 79 80					

NOTES

1. Groundwater was encountered at 68 feet at the time of drilling, and a slope inclinometer casing was installed into the hole and grouted into place immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.
3. Penetration resistance values marked with an asterisk (*) were recorded with a 3.0 inch O.D. Modified California sampler.
4. An explanation of the datum used for the boring elevations is presented on Figure 1.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

NG RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
1082-1	March 1989	1 (con't.)

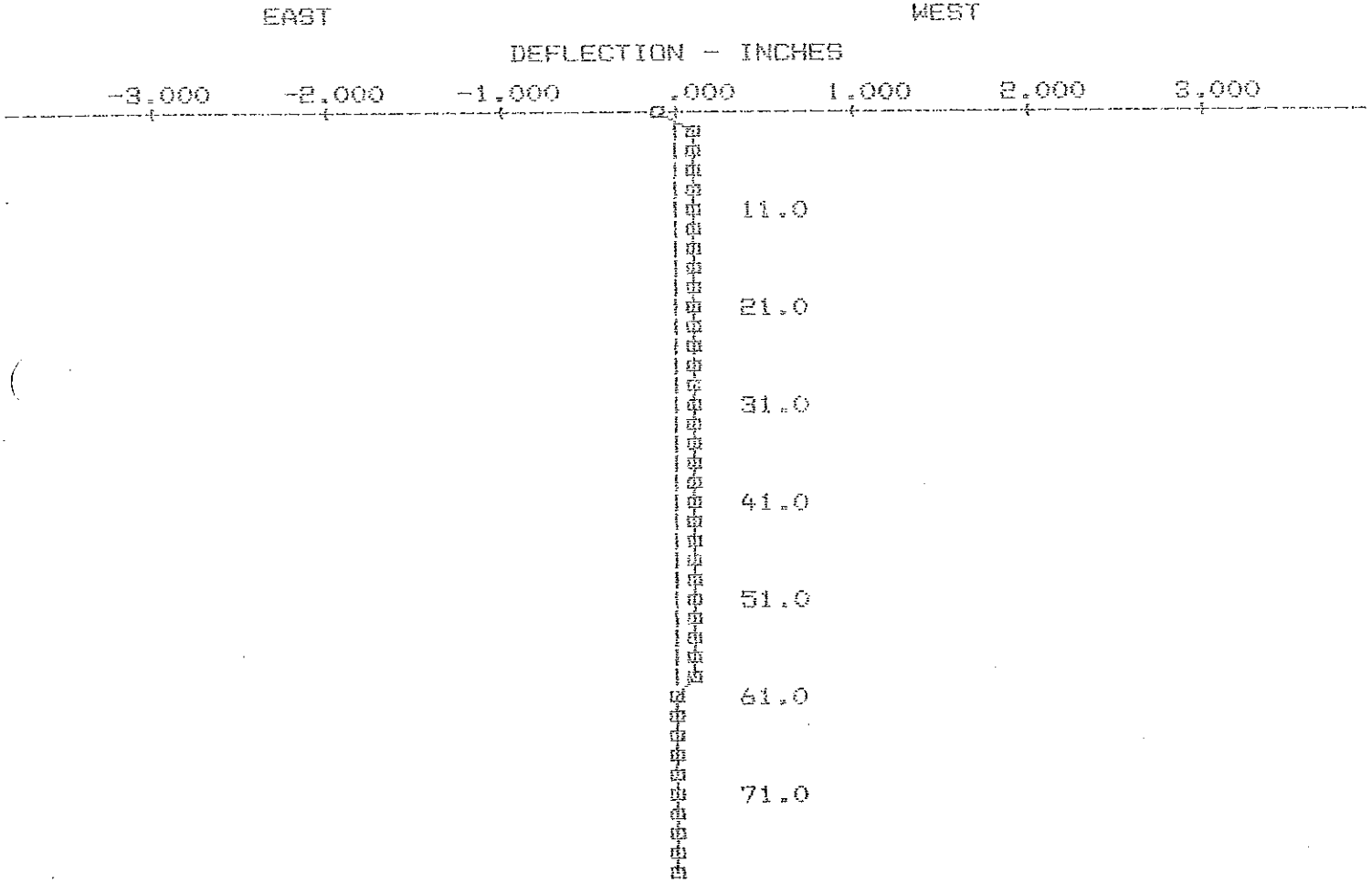
GEO-SLOPE | PC-SLIN

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

HOLE NUMBER: 1

PAST FILE NAME: NG.B1 PAST DATE: 3/14/89

FILE NAME: NG.B1A DATE: 8/2/89



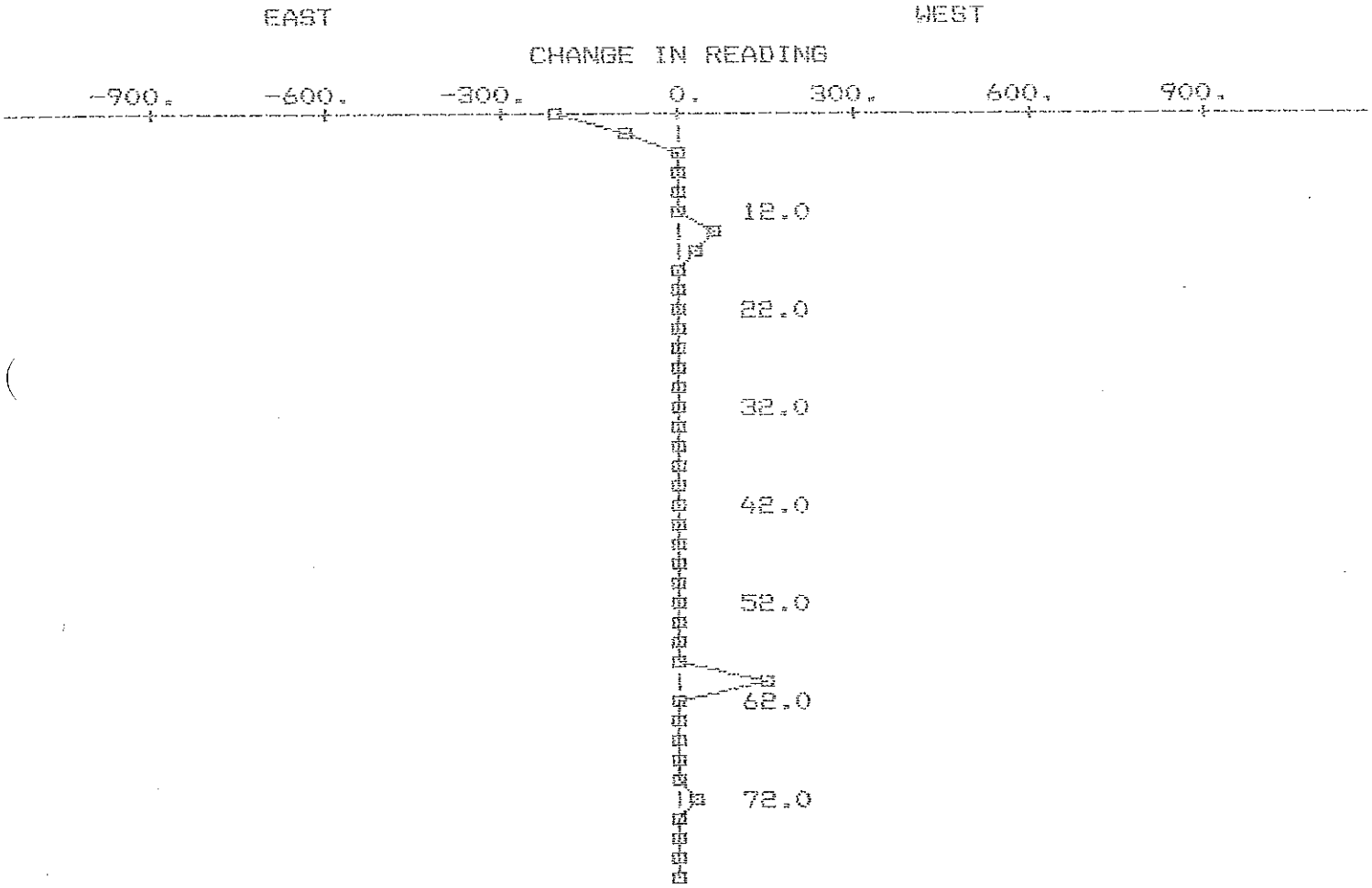
GEO-SLOPE	PC-SLIN	

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

HOLE NUMBER: 1

PAST FILE NAME: NG.B1 PAST DATE: 3/14/89

FILE NAME: NG.B1A DATE: 8/2/89



GEO-SLOPE

PC-SLIN

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

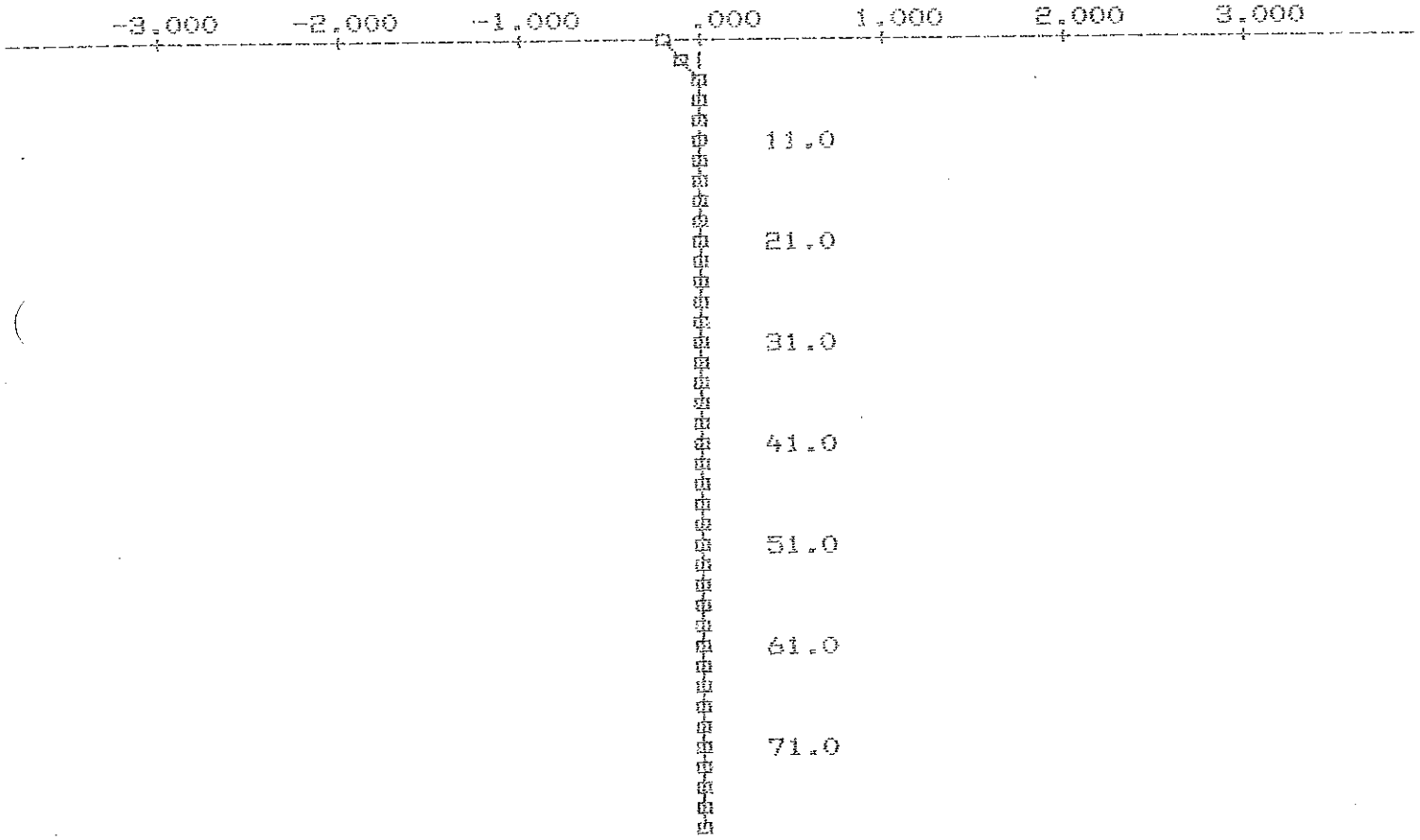
HOLE NUMBER: 1

PAST FILE NAME: NG.B1 PAST DATE: 3/14/89

FILE NAME: NG.B1A DATE: 8/2/89

SOUTH NORTH

DEFLECTION - INCHES



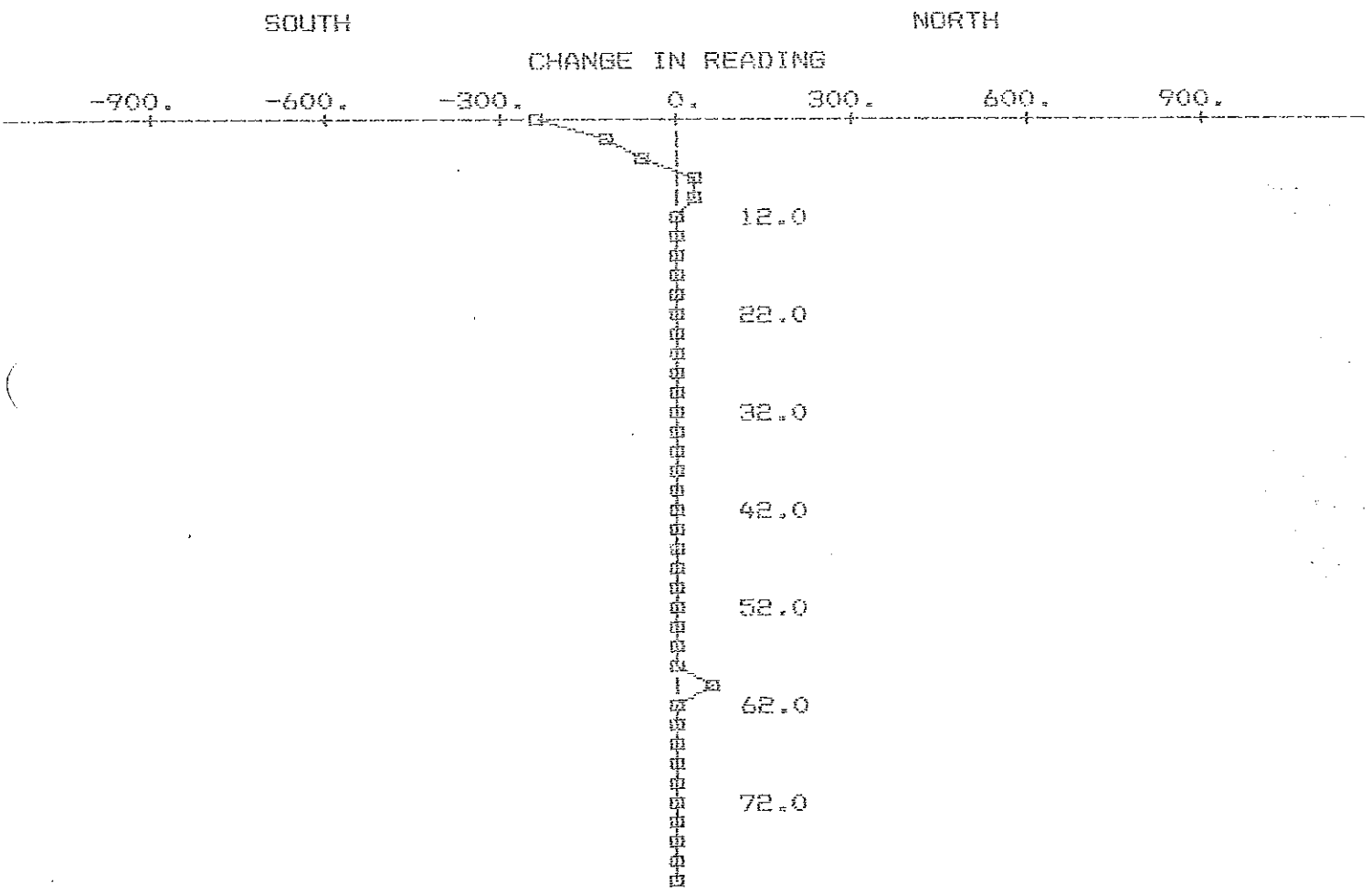
GEO-SLOPE	PC-SLIN	

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

HOLE NUMBER: 1

PAST FILE NAME: NG.B1 PAST DATE: 3/14/89

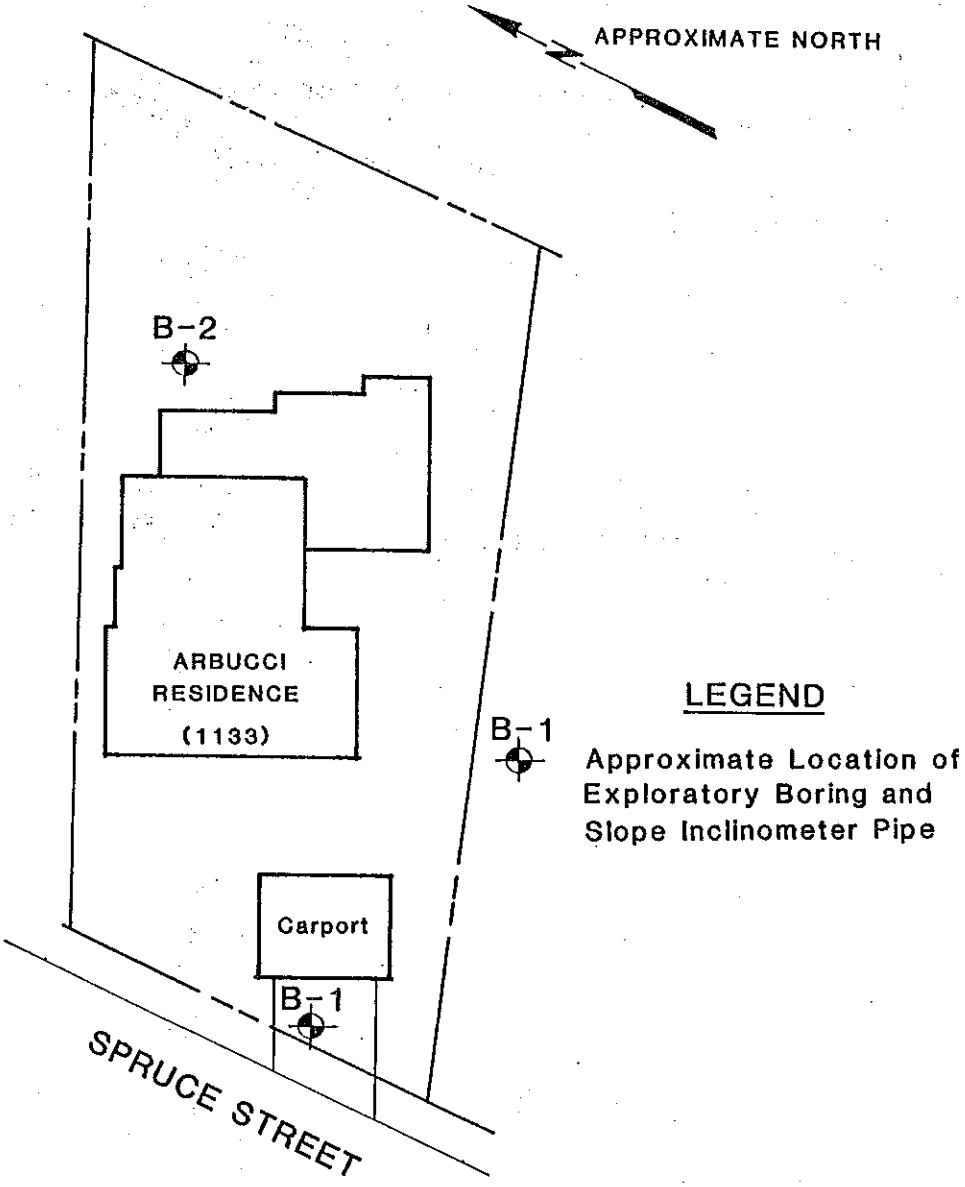
FILE NAME: NG.B1A DATE: 8/2/89



1133 SPRUCE STREET
BORING LOGS

956-1 Arbucci Residence Distress

1133 Spruce Street



LEGEND

Approximate Location of Exploratory Boring and Slope Inclinometer Pipe

BASE: City of Berkeley Zoning map, Bk 3, Pg 363, and Aerial Photo by Pacific Aerial Surveys.

0 20 40 60 80

APPROXIMATE SCALE (FEET)

1133 Spruce

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

SITE PLAN

ARBUCCI RESIDENCE DISTRESS
Berkeley, California

PROJECT NO.	DATE	FIGURE
956-1	Feb. 1988	1

DRILLING Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY B.L.
DEPTH TO GROUNDWATER 19½ Feet	BORING DIAMETER 6 Inches	DATE DRILLED 8/6/87

DESCRIPTION AND CLASSIFICATION

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
Unreinforced Concrete Slab with 1"-2" of gravel below	--	--	--							
CLAY, very sandy, silty with numerous angular rock fragments to ½ inch Liquid Limit = 36% Plasticity Index = 21% Passing No.200 Sieve = 49% - varying between sandy clay and clayey sand from 2 feet - occasional blue grey clay seams Passing No.200 Sieve = 63%	Olive Mottled with Bluish Grey and Yellow Brown	STIFF	CL/SC CL CL	1 2 3 4 5 6	X X				13 15	11 8
CLAY, very sandy, silty	Mottled Dark Bluish Grey	STIFF	CL	7 8 9	X X				19 20	13
CLAY, very sandy, very silty with numerous angular rock fragments to 1 inch - fewer rock fragments from 11 feet	Dark Brown and Dark Reddish Brown to Speckled Brownish Red	STIFF		10 11 12 13 14 15						
SAND and GRAVEL, fine to coarse grained sand with abundant subangular gravels to 2 inches, very clayey, silty - fewer gravels with depth Passing No.200 Sieve = 41%	Mottled Brownish Red and Olive Grey	MEDIUM DENSE	SC/GC SC	16 17 18 19 20	X				17 ▽	14 ATOD

(continued on next sheet)

JAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

ARBUCCI RESIDENCE DISTRESS
Berkeley, California

PROJECT NO.	DATE	SHEET NO.	BORING NO.
956-1	Feb. 1988	1 OF 3	1

RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY B.L.
DEPTH TO GROUNDWATER 19½ Feet	BORING DIAMETER 6 Inches	DATE DRILLED 8/6/87

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
SAND, medium grained, very clayey, silty with numerous angular gravels to 1" - occasional brick red clay layers	Very Mottled Brownish Red and Olive Grey	MEDIUM DENSE	SC	20						
				21						
				22						
- gradual transition				23						
CLAY, sandy, silty with numerous angular rock fragments to 1 inch	Mottled Reddish Brown and Greyish Brown	STIFF	CL	24						
				25						
				26						
				27						
				28						
CLAY, sandy, silty with numerous subrounded to subangular rock fragments to ½ inch	Dark Grey Slightly Mottled to Dark Greyish Brown	STIFF	CL	29						
				30						
				31						
				32						
CLAY, very sandy, silty with numerous subangular rock fragments to 1 inch	Mottled Dark Yellow Brown to Strong Brown and Yellow Brown	STIFF	CL	33						
		VERY STIFF		34						
- increasingly sandy with depth				35						
				36						
- gradual transition			CL/SC	37						
SAND, fine to medium grained, very clayey, silty with abundant subangular and angular rock fragments	Yellow Brown and Strong Brown	MEDIUM DENSE TO DENSE	SC	38						
				39						
				40						

(Continued on next sheet)

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

ARBUCCI RESIDENCE DISTRESS
Berkeley, California

PROJECT NO.	DATE	SHEET NO.	BORING NO.
956-1	Feb. 1988		1 (con't)

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY B.L.
DEPTH TO GROUNDWATER 19½ Feet	BORING DIAMETER 6 Inches	DATE DRILLED 8/6/87

DESCRIPTION AND CLASSIFICATION

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
SAND, very clayey, silty with rock fragments (continued) - bedrock structure apparent at intervals from 38 feet	Yellow Brown and Strong Brown	DENSE	SC	40 41 42 43	X				17	20/3"
SHEARED ROCK, very severely to completely weathered, intensely fractured and contorted, clayey - subangular and angular rock fragments in a sandy and silty clay matrix - highly to severely weathered from 45 feet	Yellow Brown and Strong Brown	SOFT TO MEDIUM HARDNESS	BED-ROCK	44 45 46 47 48 49 50 51						

Bottom of Boring at 51 feet.

NOTES

1. Groundwater was encountered at 19½ feet at the time of drilling, and a 3 inch O.D. slope inclinometer casing was grouted into the hole immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

ARBUCCI RESIDENCE DISTRESS
Berkeley, California

PROJECT NO.	DATE	SHEET NO.	BORING NO.
956-1	Feb. 1988	3 OF 3	1 (con't.)

DRILL RIG Continuous Flight Auger | SURFACE ELEVATION — | LOGGED BY B.L.

DEPTH TO GROUNDWATER Not Encountered | BORING DIAMETER 4 Inches | DATE DRILLED 8/13/87

DESCRIPTION AND CLASSIFICATION

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
SILT, very sandy, clayey with abundant small roots - grass at surface	Brown	FIRM	ML	1						
CLAY, very silty, sandy with numerous to abundant subangular gravels to 2 inches - few gravels from 3 feet, very sandy - strong brown mottling at 4 feet	Mottled Dark Greyish Brown and Dark Yellow Brown	STIFF	CL	2	X				13	7
				3						
				4						
				5	X				18	13
			CL	6						
CLAY, very silty, sandy with abundant subangular and angular rock fragments to 2 inches - fewer rock fragments from 7 feet some strong brown iron staining - larger rock fragments at intervals	Mottled Yellow Brown and Grey Brown	STIFF		7	X				17	16
				8						
				9						
				10	X				16	12
- intermittent clay seams	Dark Yellow Brown to Dark Olive Grey			11						
				12						
- some caliche and iron staining at 14 feet				13						
- siltstone fragments to cobble size at 15 feet				14						
- rock fragments abundant from 16 feet				15	X				25	16
				16						
				17						
	Dark Brown			18						
				19						
				20	X				26	9

(Continued on next sheet)

IN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

ARBUCCI RESIDENCE DISTRESS
Berkeley, California

PROJECT NO.	DATE	SHEET NO.	BORING NO.
956-1	Feb. 1988	1 OF 2	2

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY B.L.
DEPTH TO GROUNDWATER Not Encountered	BORING DIAMETER 4 Inches	DATE DRILLED 8/13/87

DESCRIPTION AND CLASSIFICATION

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
CLAY, silty, sandy with numerous rock fragments (continued)	Dark Brown Slightly Mottled	STIFF	CL	20						
				21						
				22						
	Varying to Olive and Olive Brown			23						
				24						
- transition obscured				25						
CLAY, very silty, sandy with occasional weathered serpentine pieces to 1 inch Liquid Limit = 40% Plasticity Index = 25% Passing No.200 Sieve = 74%	Dark Grey Mottled with Olive	STIFF	CL	26						
				27						
				28	X				21	12
CLAY, very sandy, silty with abundant angular rock fragments, primarily serpentine	Variable, Olive Grey and Red with Olive Brown	VERY STIFF	CL	29						
				30						
				31	X				20	13
Bottom of Boring at 31 feet.										

NOTES

1. No groundwater was encountered at the time of drilling, and a 3 inch O.D. slope inclinometer casing was grouted into the hole immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.

GEO-SLOPE | **PC-SLIN**

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

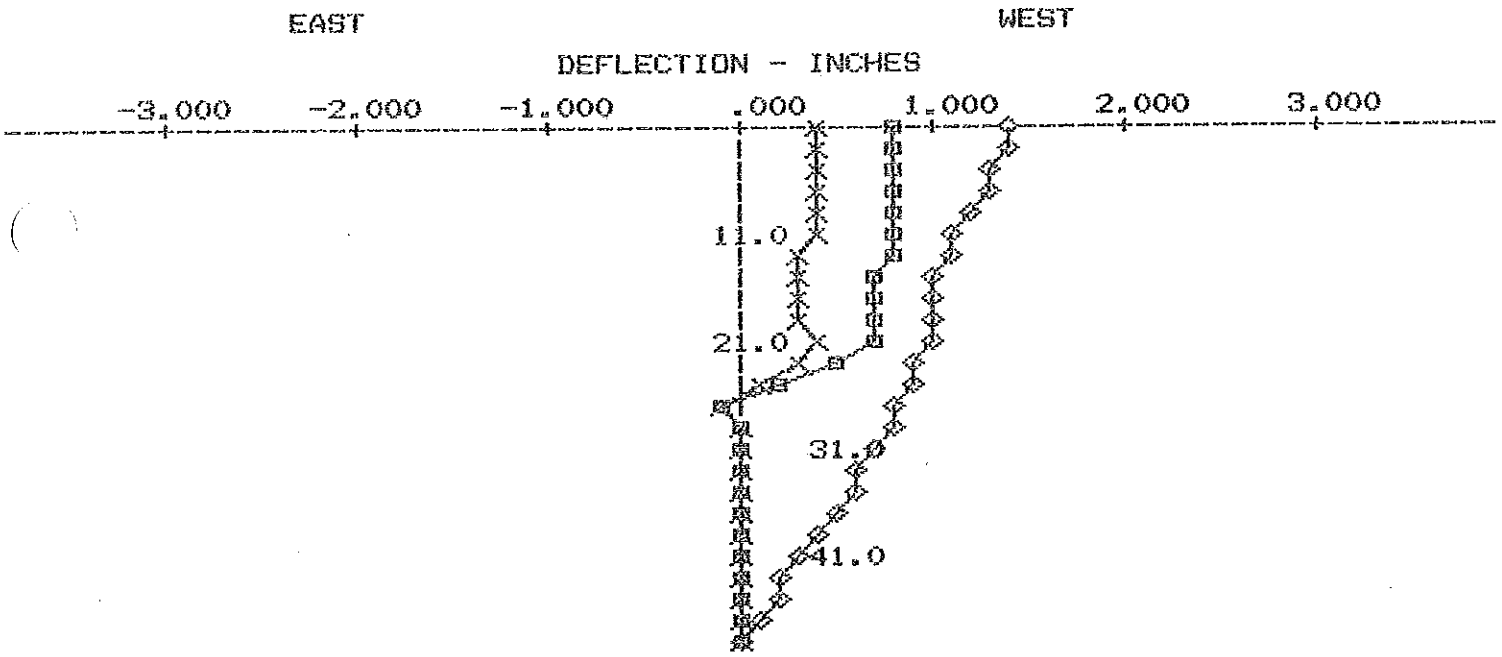
HOLE NUMBER: 1

PAST FILE NAME: ARBUCCI.B1 PAST DATE: 8/10/87

FILE NAME: ARBUCCI.B1C DATE: 7/27/90 □

FILE NAME: ARBUCCI.B1B DATE: 8/2/89 ×

FILE NAME: arbucci.b1a DATE: 12/11/87 ◇



GEO-SLOPE	PC-SLIN

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

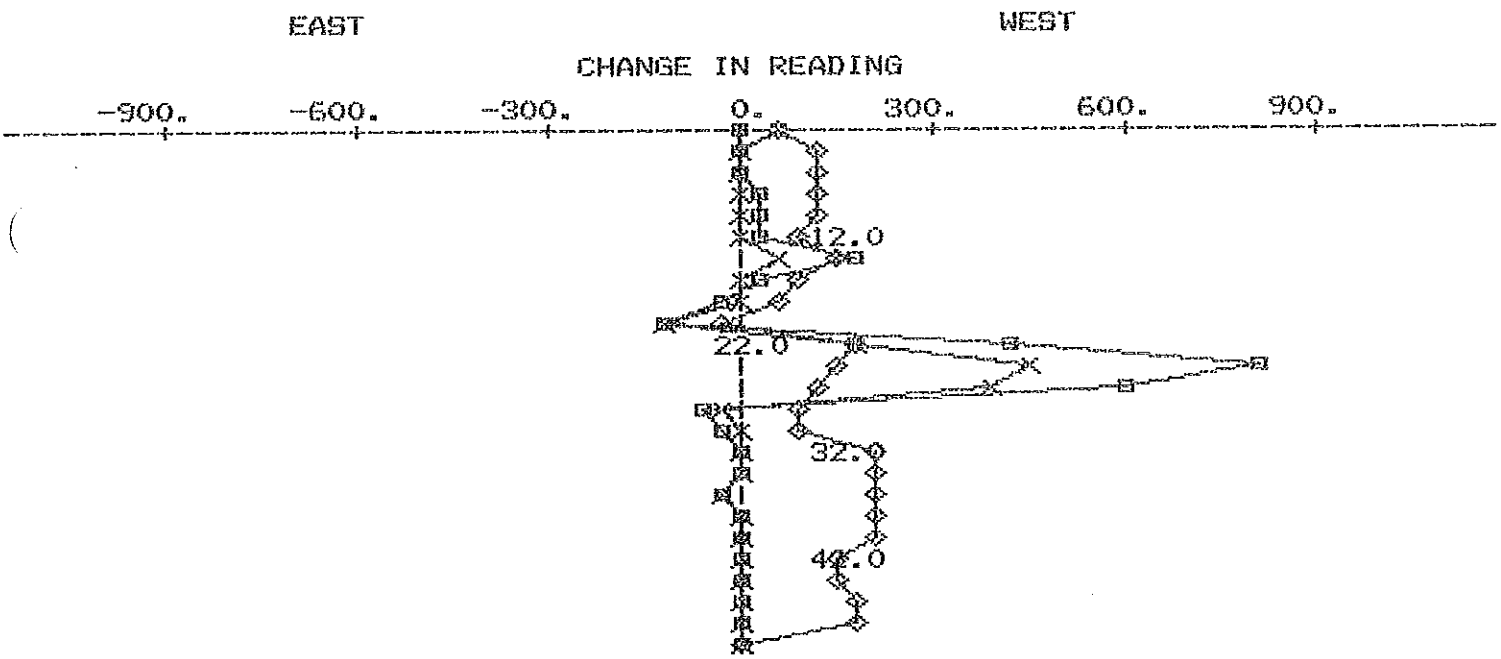
HOLE NUMBER: 1

PAST FILE NAME: ARBUCCI.B1 PAST DATE: 8/10/87

FILE NAME: ARBUCCI.B1C DATE: 7/27/90 □

FILE NAME: ARBUCCI.B1B DATE: 8/2/89 ×

FILE NAME: arbucci.bla DATE: 12/11/87 ◇



GEO-SLOPE | PC-SLIN

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

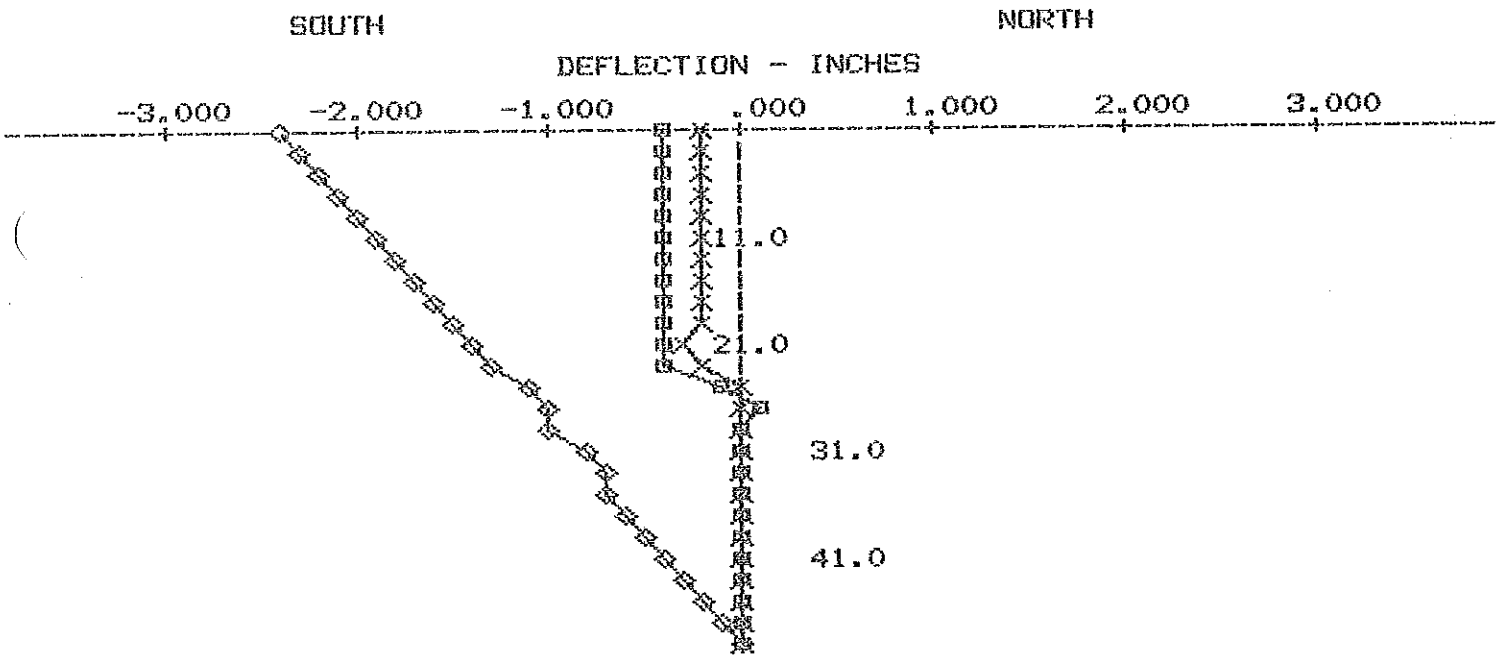
HOLE NUMBER: 1

PAST FILE NAME: ARBUCCI.B1 PAST DATE: 8/10/87

FILE NAME: ARBUCCI.B1C DATE: 7/27/90 □

FILE NAME: ARBUCCI.B1B DATE: 8/2/89 ×

FILE NAME: arbucci.b1a DATE: 12/11/87 ◇



GEO-SLOPE	PC-SLIN

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

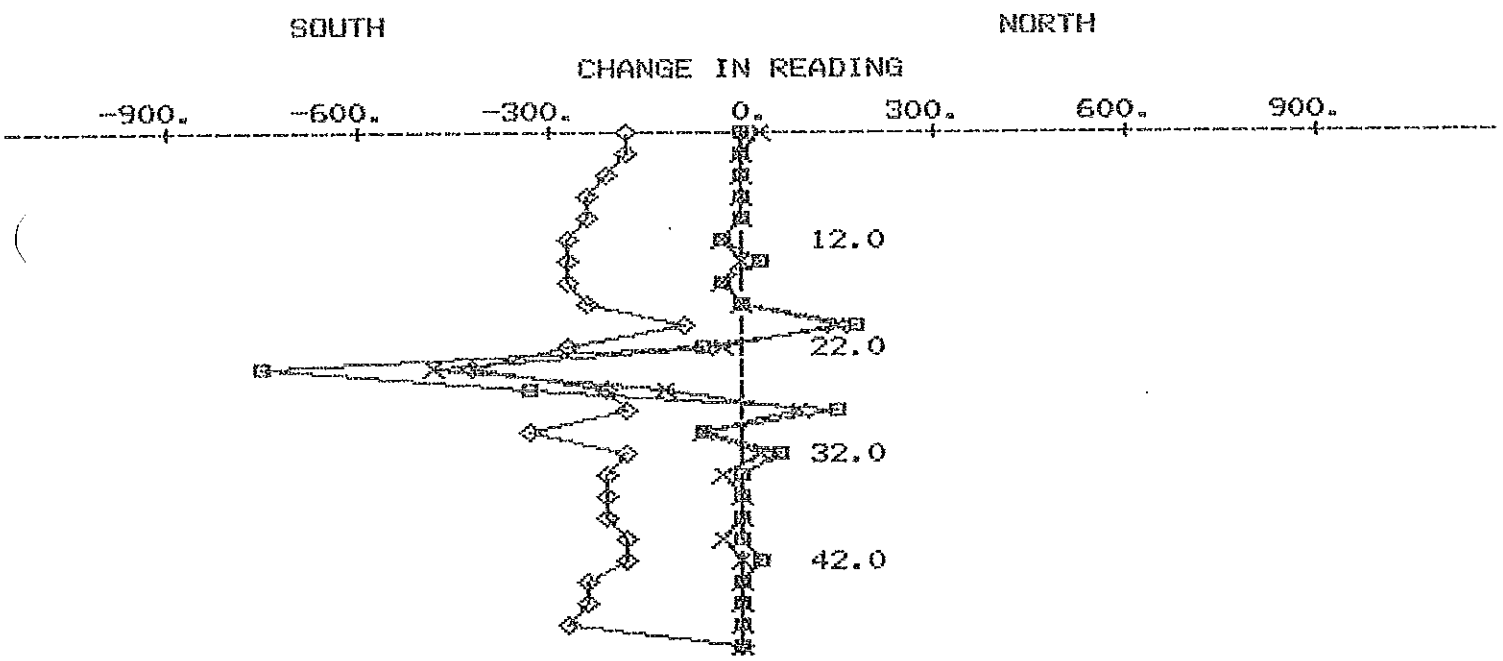
HOLE NUMBER: 1

PAST FILE NAME: ARBUCCI.B1 PAST DATE: 8/10/87

FILE NAME: ARBUCCI.B1C DATE: 7/27/90 □

FILE NAME: ARBUCCI.B1B DATE: 8/2/89 ×

FILE NAME: arbucci.b1a DATE: 12/11/87 ◇



J-SLOPE	PC-SLIN	

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

HOLE NUMBER: 2

PAST FILE NAME: ARBUCCI.B2 PAST DATE: 9/25/87

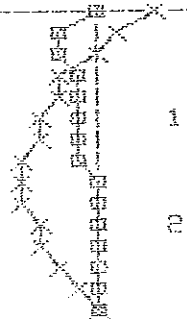
FILE NAME: ARBUCCI.B2A DATE: 12/11/ □

FILE NAME: ARBUCCI.B2B DATE: 8/2/89 ×

EAST WEST

DEFLECTION - INCHES

-3.000 -2.000 -1.000 .000 1.000 2.000 3.000



-SLOPE	PC-SLIN

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

HOLE NUMBER: 2

PAST FILE NAME: ARBUCCI.B2 PAST DATE: 9/25/87

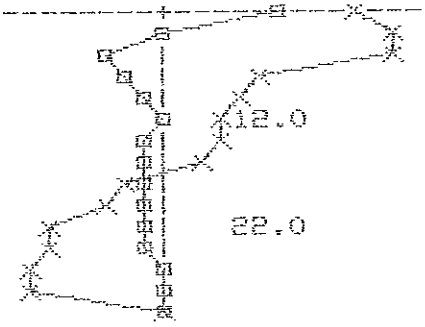
FILE NAME: ARBUCCI.B2A DATE: 12/11/ □

FILE NAME: ARBUCCI.B2B DATE: 8/2/89 ×

EAST WEST

CHANGE IN READING

-900. -600. -300. 0. 300. 600. 900.



.-SLOPE	PC-SLIN

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

HOLE NUMBER: 2

PAST FILE NAME: ARBUCCI.B2 PAST DATE: 9/25/87

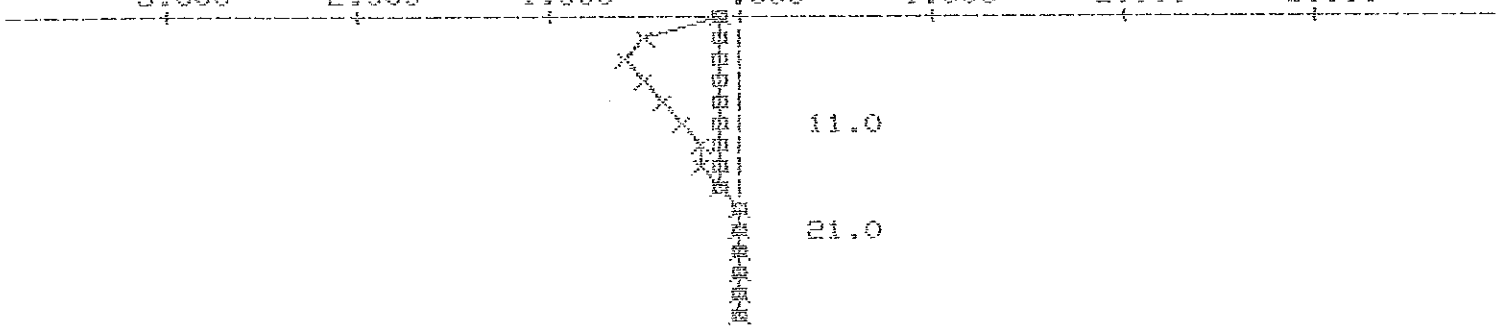
FILE NAME: ARBUCCI.B2A DATE: 12/11/ □

FILE NAME: ARBUCCI.B2B DATE: 8/2/89 ×

SOUTH NORTH

DEFLECTION - INCHES

-3.000 -2.000 -1.000 .000 1.000 2.000 3.000



J-SLOPE	PC-SLIN

SERIAL NO. 86047 ALAN KROPP & ASSOCIATES

HOLE NUMBER: 2

PAST FILE NAME: ARBUCCI.B2 PAST DATE: 9/25/87

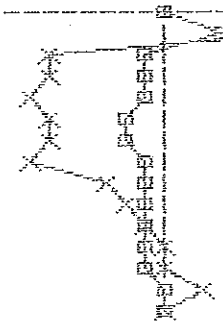
FILE NAME: ARBUCCI.B2A DATE: 12/11/ □

FILE NAME: ARBUCCI.B2B DATE: 8/2/89 ×

SOUTH NORTH

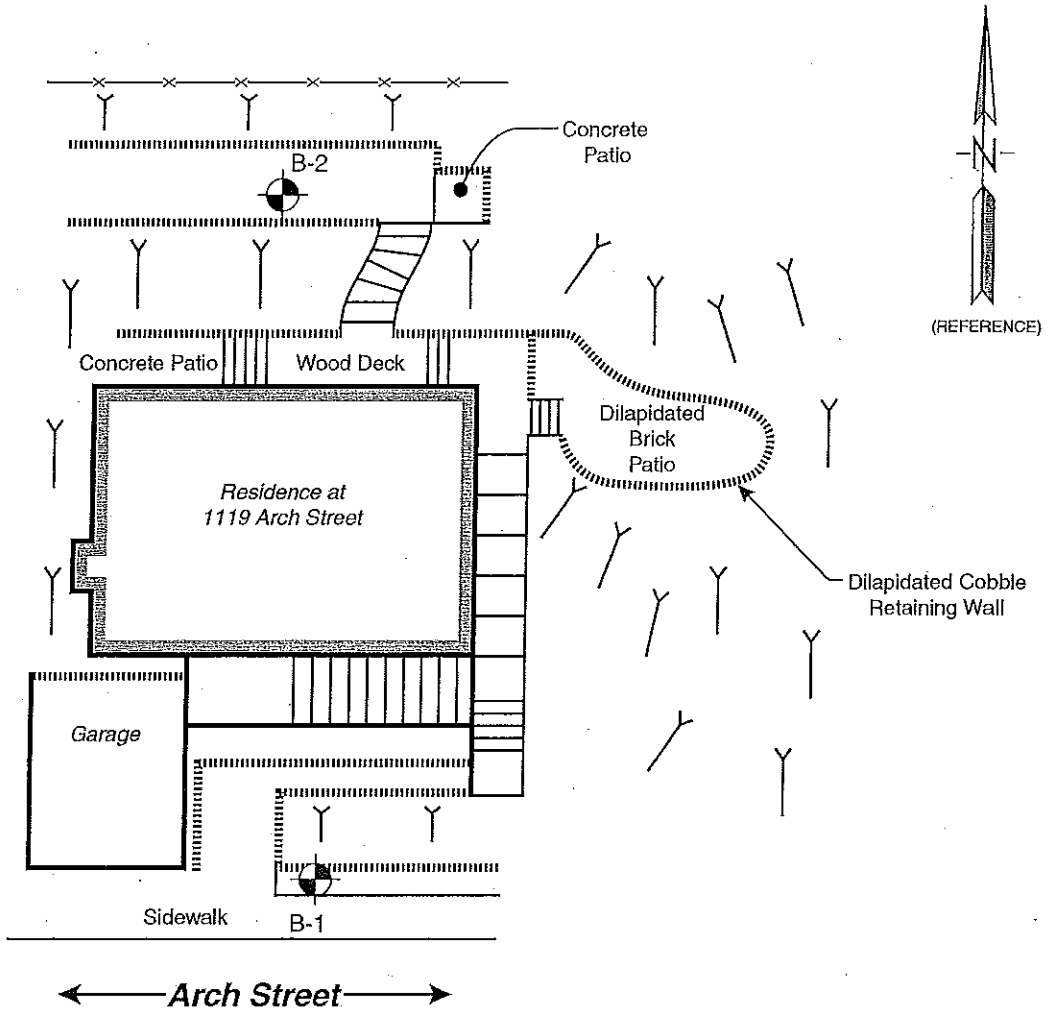
CHANGE IN READING

-900. -600. -300. 0. 300. 600. 900.



1119 ARCH STREET
BORING LOGS

Reuther/Bonomi Res
2249.1 1119 Arch St



LEGEND

- B-2 — Approximate location of exploratory boring
- Approximate location of existing fence
- Approximate location of existing retaining walls
- Slope

NOTE: A slope inclinometer was installed in Boring B-1. ***(Must be protected during construction.)***

Base - Field Sketch

SKETCH: NOT TO SCALE

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

SITE PLAN

REUTHER/BONOMI RESIDENCE
Berkeley, California

PROJECT NO.	DATE	FIGURE
2249-1	April 2003	2

DRILL RIG: Continuous Solid Flight Auger	SURFACE ELEVATION: Not Measured	LOGGED BY: JP
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 4 inches	DATE DRILLED: 03-24-03

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, silty, sandy, with abundant fine to coarse severely weathered bedrock fragments, moist; (FILL) (FILL)	Dark Brown	Firm	CL	1 2					
CLAY, silty, sandy, with some fine to coarse weathered bedrock fragments, moist	Brown	Firm	CL	3 4 5					
- moist to wet (LANDSLIDE DEBRIS)	Brown with Greenish Gray and Black		CL	6 7 8		[8]	17		
CLAY, silty, sandy, with fine subrounded to subangular gravels, dry to moist (POSSIBLE LANDSLIDE DEBRIS)	Brown	Hard	CL	9 10 11 12		[59]	17	112	PP>9.0 ksf
SERPENTINE, severely weathered, fractured, with clay seam	Blueish Gray	Soft Hardness	BED-ROCK	13 14 15 16		[50]			
- harder layer				17 18 19 20					

(continued on next sheet)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

REUTHER/BONOMI RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2249-1	April 2003	1 of 2	1

DRILL RIG: Continuous Solid Flight Auger	SURFACE ELEVATION: Not Measured	LOGGED BY: JP
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 4 inches	DATE DRILLED: 03-24-03

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
SERPENTINE, severely weathered, fractured, with clay seam (continued from previous sheet)	Blueish Greenish Gray	Soft Hardness	BED-ROCK	21		67			
				22					
				23					
				24					
	Light Tan to White to Black			25					
				26		68			
				27					
				28					
				29					
				30		50/2"			

Bottom of boring at 30 feet and 2 inches

NOTES

1. No groundwater was encountered at the time of drilling and a 2.75-inch O.D. slope inclinometer casing was installed in the boring and grouted in place. (See text for discussion.)

2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.

3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler, and are not standard penetration resistance values.

4. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

DRILL RIG: Continuous Solid Flight Auger	SURFACE ELEVATION: Not Measured	LOGGED BY: JP
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 3-1/2 inches	DATE DRILLED: 03-24-03

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, silty, sandy, with fine subangular to subrounded gravels and rootlets	Dark Gray to Brown	Stiff	CH	1					
				2					
	Olive Brown			3					LL = 53 PI = 28 -200 = 67
				4		[19]	22	100	PP=2.4 ksf
				5					
CLAY, silty, sandy, with completely to severely weathered fine bedrock fragments	Reddish Brown to Orangish Gray	Stiff	CL	6					
				7		17			
				8					
				9					
				10					
				11					
-coarse gravels to cobbles, large root in sample	Light Brown to Grayish Brown	Very Stiff		12					
(POSSIBLE LANDSLIDE DEBRIS)				13		[39]			
SERPENTINE, severely weathered, fractured	Gray	Soft Hardness	BED-ROCK	14					
				15					
				16					
				17					
				18					
				19		[30]			

Bottom of boring at 19 feet and 6 inches

(continued on next sheet)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

REUTHER/BONOMI RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2249-1	April 2003	1 of 2	2

DRILL RIG: Continuous Solid Flight Auger	SURFACE ELEVATION: Not Measured	LOGGED BY: JP
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 3-1/2 inches	DATE DRILLED: 03-24-03

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS

NOTES

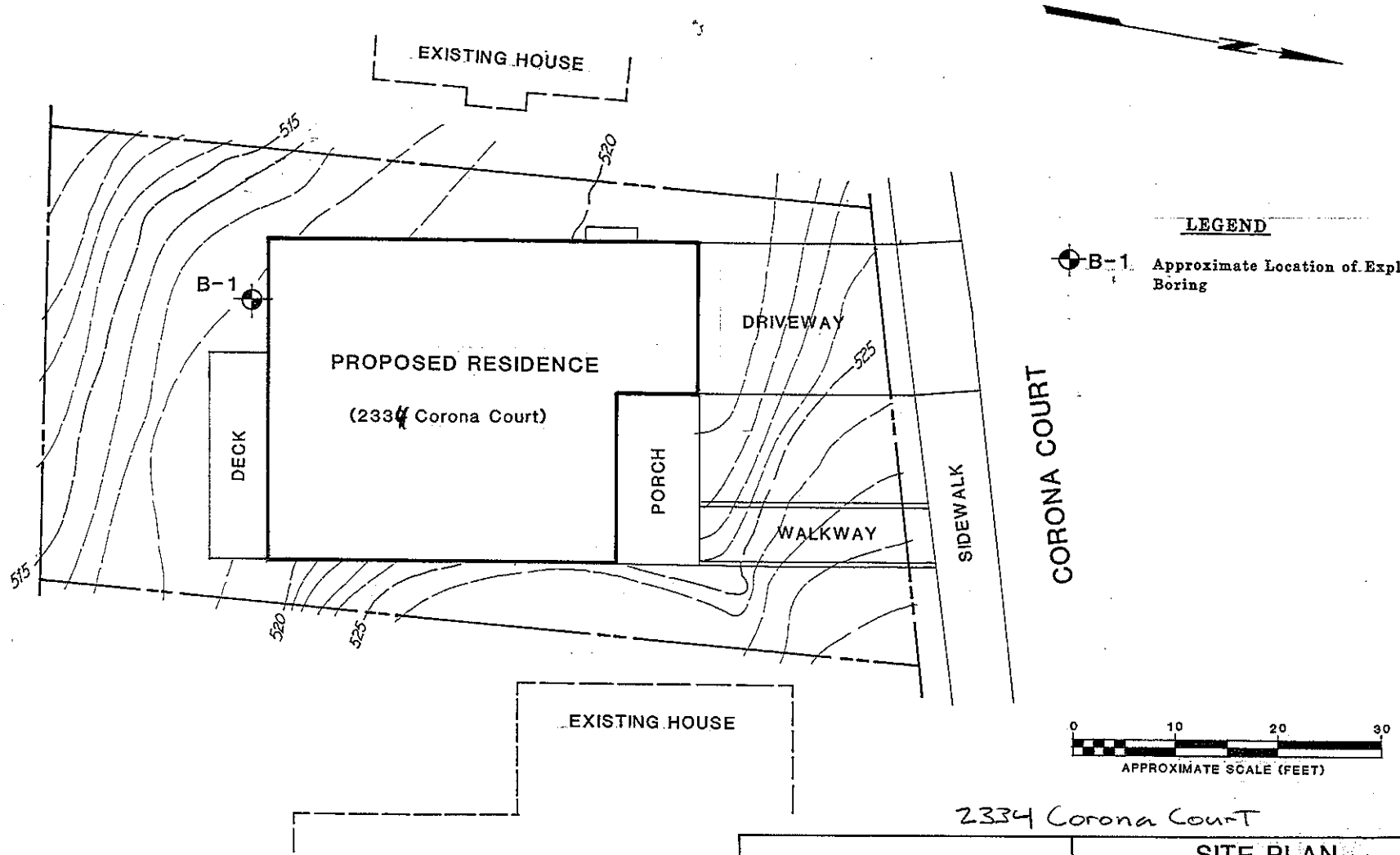
1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See text for discussion.)

2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.

3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler, and are not standard penetration resistance values.

4. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

2334 CORONA COURT
BORING LOGS



2334 Corona Court

BASE: "Elevation Survey of Lot 15, J.W. Brazier's Subdivision of Corona Heights, Berkeley, CA. filed in Map Book 9, Page 15, by David Logan Surveyor, dated October 9, 1990, and "Site Plan", by Andrew Beckerman Architect, undated. Elevations based on City of Berkeley Datum.

ALAN KROPP & ASSOCIATES, INC.
Geotechnical Consultants

SITE PLAN
CORONA COURT RESIDENCE
Berkeley, California

PROJECT NO.	DATE	FIGURE
1261-1	March 1991	1

1261-1 Corona Court Residence 2334 Corona Court

DRILL RIG	Continuous Flight Auger and Rotary Wash	SURFACE ELEVATION	518 Feet	LOGGED BY	JS
DEPTH TO GROUNDWATER	Not Encountered	BORING DIAMETER	8 Inches	DATE DRILLED	3/13/91

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
CLAY, silty, slightly sandy, occasional subrounded sandstone & quartz gravels to ½", SLIDE DEBRIS	Mottled Very Dark Gray	FIRM	CH	1					
- grasses, roots & organics near surface		STIFF		2		18*	23	92	1.5Lu
Liquid Limit = 52%				3					
Plasticity Index = 36%									
Passing No. 200 Sieve = 74%	Very Dark	HARD	CH/	4					
- becoming more sandy, gravelly	Gray Mottled		CL	5		80*	14	101	3.7Lu
- gravels grading larger, occasional cobble-size pieces	With Yellow Brown and White			6					
				7					
				8					
- gravels in sample composed of soft rhyolite fragments intruded with quartz	Variable Mottled Strong Brown	STIFF		9					
				10		12	21		
- cuttings contain sand, but no gravel-size pieces	and Yellow Brown			11					
				12					
				13					
- shear banding of material in approximate downslope direction	Mottled Olive & Reddish Brown	VERY STIFF		14					
				15		23	16		
				16					
				17					
				18					
- quartz intruded serpentine gravels at 20'	Mottled Strong Brown		CH	19					
				20		27	31		

(Continued on next sheet)

ALAN KROPP & ASSOCIATES, INC.
Geotechnical Consultants

EXPLORATORY BORING LOG
CORONA COURT RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
1261-1	March 1991	1

DRILL RIG Rotary Wash	SURFACE ELEVATION 518 Feet	LOGGED BY JS
DEPTH TO GROUNDWATER Not Encountered	BORING DIAMETER 8 Inches	DATE DRILLED 3/14/91

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
CLAY, silty, slightly sandy, occasional hard gravels (Continued)	Mottled Strong Brown	VERY STIFF	CH	21					
				22					
				23					
				24					
				25					
- softer at 26 Feet		STIFF TO VERY STIFF		26					
				27					
				28					
				29					
- gravels to 1" in size		VERY STIFF		30		28	27		
				31					
				32					
				33					
- boulder encountered at 34'		HARD		34					
- frequent boulders after 34'	Mottled Olive to Olive Brown			35					
				36					
				37					
				38					
- gradual transition to bedrock at 40'				39					
				40					
(Continued on next sheet)									

ALAN KROPP & ASSOCIATES, INC.
Geotechnical Consultants

EXPLORATORY BORING LOG
CORONA COURT RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
1261-1	March 1991	1 (con't.)

DRILL RIG Rotary Wash and Continuous Flight Auger	SURFACE ELEVATION 518 Feet	LOGGED BY JS
DEPTH TO GROUNDWATER Not Encountered	BORING DIAMETER 8 Inches	DATE DRILLED 3/14/91

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
SERPENTINIZED SCHIST, severely weathered, severely fractured, occasional clayey zones, occasional quartz pieces - possible bedrock slide debris, rock structure inconsistant	Mottled Dark Olive Gray To Olive Gray	SOFT HARDNESS	BED-ROCK	41					
				42					
				43					
				44					
- auger drilling from 45 feet due to loss of drilling fluid				45					
				46					
				47					
- vertical shear banding evident in rock structure				48		45	8		
				49					
				50					
- variable drilling between samples with hard and soft layers				51					
				52					
				53					
				54					
- zones of serpentinized greenstone encountered in sample				55					
				56		27	9		
- grading to less severe weathing				57					
- abrupt transition at 58 feet, rock structure becoming more consistant		MEDIUM HARDNESS		58					
				59					
				60					

(Continued on next sheet)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG
CORONA COURT RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
1261-1	March 1991	1 (con't.)

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION 518 Ft	LOGGED BY JS
DEPTH TO GROUNDWATER Not Encountered	BORING DIAMETER 8 Inches	DATE DRILLED 3/14/91

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
SERPENTINIZED SCHIST and GREENSTONE moderate to moderately severely weathered (Continued)	Mottled Gray to Olive Gray	MEDIUM HARDNESS	BED-ROCK	61		50/1"	(No Recovery)		
				62					

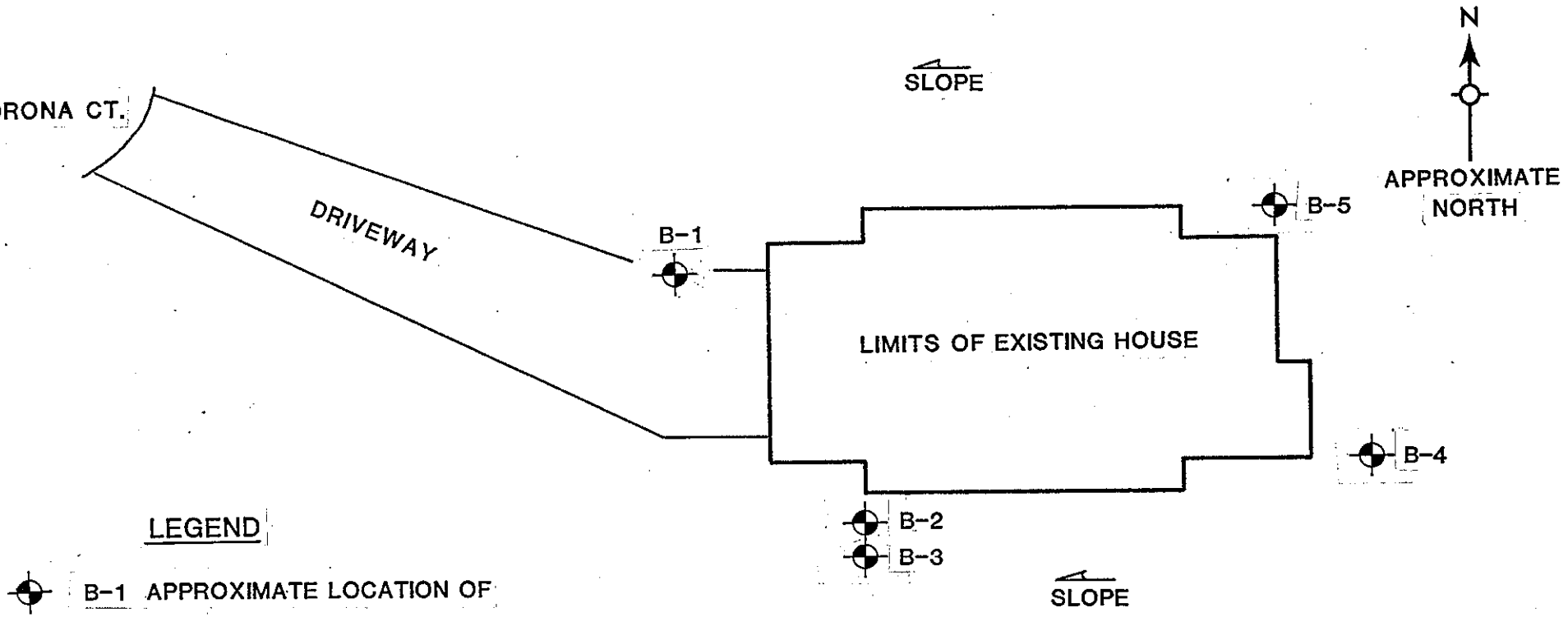
Bottom of Boring at 62 Feet

NOTES

1. No groundwater was encountered at the time of drilling, and an inclinometer casing was installed and grouted into the hole immediately after drilling (see text for discussion).
2. The stratification line represents the approximate boundary between material types, and the transition may be gradual.
3. Penetration resistance values marked with an asterisk (*) were recorded with a 3.0-inch O.D. Modified California sampler, and are not standard penetration resistance values.
4. An explanation of the datum used for the boring elevation is presented on Figure 1.
5. Unconfined compressive strength values of selected samples were determined in laboratory unconfined compression tests. These values are shown on the logs and are followed by the symbol "Lu".

ALAN KROPP & ASSOCIATES, INC. Geotechnical Consultants	EXPLORATORY BORING LOG		
	CORONA COURT RESIDENCE Berkeley, California		
	PROJECT NO.	DATE	BORING NO. 1 (con't.)
	1261-1	March 1991	

2356 CORONA COURT
BORING LOGS



NOTE: THIS IS ONLY A ROUGH SKETCH AND IS DRAWN FROM FIELD MEASUREMENTS MADE BY PACING.
THIS IS NOT DRAWN TO SCALE

574-1 Stothers Residence 2356 Corona Court

2356 Corona

ALAN KROPP & ASSOCIATES *Geotechnical Consultants*	SITE PLAN STOTHERS RESIDENCE Berkeley, California	
	PROJECT NO. 574-1	DATE FEB., 1983
		Figure 1

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION – –	LOGGED BY PKM
DEPTH TO GROUNDWATER See Note 1	BORING DIAMETER 4 Inches	DATE DRILLED 1/6/83

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	SHEAR STRENGTH BY TORVANE (KSF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)
CLAY, silty, sandy and gravelly FILL	Yellow brown	Soft	CL	1					
CLAY, silty and sandy with rock fragments and roots Direct Shear Data: $\phi = 41^{o}$ Apparent Cohesion = 0.15 ksf	Mottled olive with dark yellow brown	Firm	CL	2 3 4 5	X X	13* 13*	18 24	91 81	
CLAY, silty and sandy with rock fragments	Yellow brown	Firm	CL	6 7 8 9	X	18*	20	103	5.0Fp
CLAY, silty and sandy with rock fragments Completely weathered basalt	Mottled yellow brown with gray	Stiff	CL	10 11 12 13 14 15	X	20*	▽ 21	5 hrs after drilling	4.0Ft
MELANGE, very severe weathering with iron staining, in a silty clay matrix, highly fractured (continued on next page)	Variegated yellow brown with gray & green	Soft hardness	BEDROCK	16 17 18 19 20	X	32*	16	111	9.0Fp 8.0Ft

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

STOTHERS RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
574-1	Feb., 1983	1

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION - -	LOGGED BY PKM
DEPTH TO GROUNDWATER See Note 1	BORING DIAMETER 4 Inches	DATE DRILLED 1/6/83

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	SHEAR STRENGTH BY TORVANE (KSF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
MELANGE, very severe weathering with iron staining, in a silty clay matrix (continued)	Variegated yellow brown with gray	Soft hardness	BEDROCK	21					
				22					

Bottom of Boring = 22 Feet

NOTES

1. No groundwater was encountered at the time of drilling but was at a depth of 13 feet 5 hours later.
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.
3. Penetration resistance values marked with an asterisk (*) are not standard penetration resistance values; see page A-1 for discussion.
4. Explanations of the tests used for determining unconfined strengths are found in Appendixes A (for Fp and Ft) and B (for Lu).

ALAN KROPP & ASSOCIATES	EXPLORATORY BORING LOG		
Geotechnical Consultants	STOTHERS RESIDENCE Berkeley, California		
	PROJECT NO.	DATE	BORING NO.
	574-1	Feb., 1983	1

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY PKM
DEPTH TO GROUNDWATER Not Encountered	BORING DIAMETER 4 Inches	DATE DRILLED 1/6/83

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
CLAY, silty and sandy with rock fragments and roots Liquid Limit = 63% Plasticity Index = 38% Passing No. 200 Sieve = 78%	Dark brown	Firm	CH	1 2	X	14*	29	83	
CLAY, silty and sandy with rock fragments	Dark yellow brown	Stiff	CL	3 4 5 6	X	19* 27*	24 23	93 99	5.0Fp 5.0Ft 3.8Lu 5.0Fp 5.0Ft
CLAY, silty and sandy with rock fragments of basalt	Mottled yellow brown with gray and green	Stiff	CL	7 8 9 10	X	22*	23	99	
MELANGE, very severe weathering with iron staining in a silty clay matrix drilling rig met refusal at 11 feet	Variegated yellow brown with gray	Soft hardness:	BED ROCK	11					

Bottom of Boring = 11 Feet

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.
3. Penetration resistance values marked with an asterisk (*) are not standard penetration resistance values; see page A-1 for discussion.
4. Explanations of the tests used for determining unconfined strengths are found in Appendixes A (for Fp and Ft) and B (for Lu).

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

STOTHERS RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
574-1	Feb., 1983	2

DRILL RIG	Continuous Flight Auger	SURFACE ELEVATION	- -	LOGGED BY	PKM
DEPTH TO GROUNDWATER	Not Encountered	BORING DIAMETER	4 Inches	DATE DRILLED	1/6/83

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	SHEAR STRENGTH BY TORVANE (KSF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)
CLAY, silty and sandy with rock fragments and roots	Dark brown	Firm	CH	1 2 3 4					
CLAY, silty and sandy with rock fragments	Dark yellow brown	Stiff	CL	5 6 7 8					
CLAY, silty and sandy with rock fragments	Mottled dark yellow brown, gray & green	Stiff	CL	9 10 11					
MELLANGE, very severe weathering with iron staining, in a silty clay matrix, highly fractured	Variegated brown with gray and green	Soft hardness	BEDROCK	12 13 14 15		29	12		
(drilling rig met refusal at 15')									

Bottom of Boring = 15 Feet

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.
3. Penetration resistance values marked with an asterisk (*) are not standard penetration resistance values; see page A-1 for discussion.

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

STOTHERS RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
574-1	Feb., 1983	3

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION - -	LOGGED BY PKM
DEPTH TO GROUNDWATER Not Encountered	BORING DIAMETER 4 inches	DATE DRILLED 1/6/83

DESCRIPTION AND CLASSIFICATION				DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	SHEAR STRENGTH BY TORVANE (KSF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
CLAY, silty and sandy with rock fragments and roots	Dark brown	Firm	CH	1					
				2		20*	20	92	3.0Ft
MELANGE, very severe weathering with iron staining and some roots near surface, highly fractured	Variegated yellow brown with gray & green	Soft hardness	BEDROCK	3					
				4		26*	19	101	4.0Ft
				5		31*	14	102	
				6					
				7					
				8					
				9		26*	28	89	
				10					
				11					
				12		20/3"	21	94	
(drilling rig met refusal at 13')				13					

Bottom of Boring = 13 Feet

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.
3. Penetration resistance values marked with an asterisk (*) are not standard penetration resistance values; see page A-1 for discussion.
4. Explanations of the tests used for determining unconfined strengths are found in Appendixes A (for Fp and Ft) and B (for Lu).

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

STOTHERS RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
574-1	Feb., 1983	4

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY PKM
DEPTH TO GROUNDWATER Not Encountered	BORING DIAMETER 4 Inches	DATE DRILLED 1/6/83

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT.)	WATER CONTENT (%)	DRY DENSITY PCF	UNCONFINED COMPRESSIVE STRENGTH (KSF)
CLAY, silty and sandy with rock fragments and roots	Dark yellow brown	Soft	CL	1					
				2		6*			
				3					
CLAY, silty and sandy with rock fragments Direct Shear Data: ϕ = 40 Apparent Cohesion = 0.15 Ksf	Mottled yellow brown with gray & green	Stiff	CL	4		17*	23	97	5.0Fp 3.5Ft
				5		28*	23	104	3.0Fp 3.5Ft
MELANGE, very severe weathering with iron staining in a silty clay matrix drilling rig met refusal at 6½ feet	Variegated yellow brown with gray & green	Soft Hardness	BED ROCK	6					

Bottom of Boring = 6½ Feet

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.
3. Penetration resistance values marked with an asterisk (*) are not standard penetration resistance values; see page A-1 for discussion.
4. Explanations of the tests used for determining unconfined strengths are found in Appendixes A (for Fp and Ft) and B (for Lu).

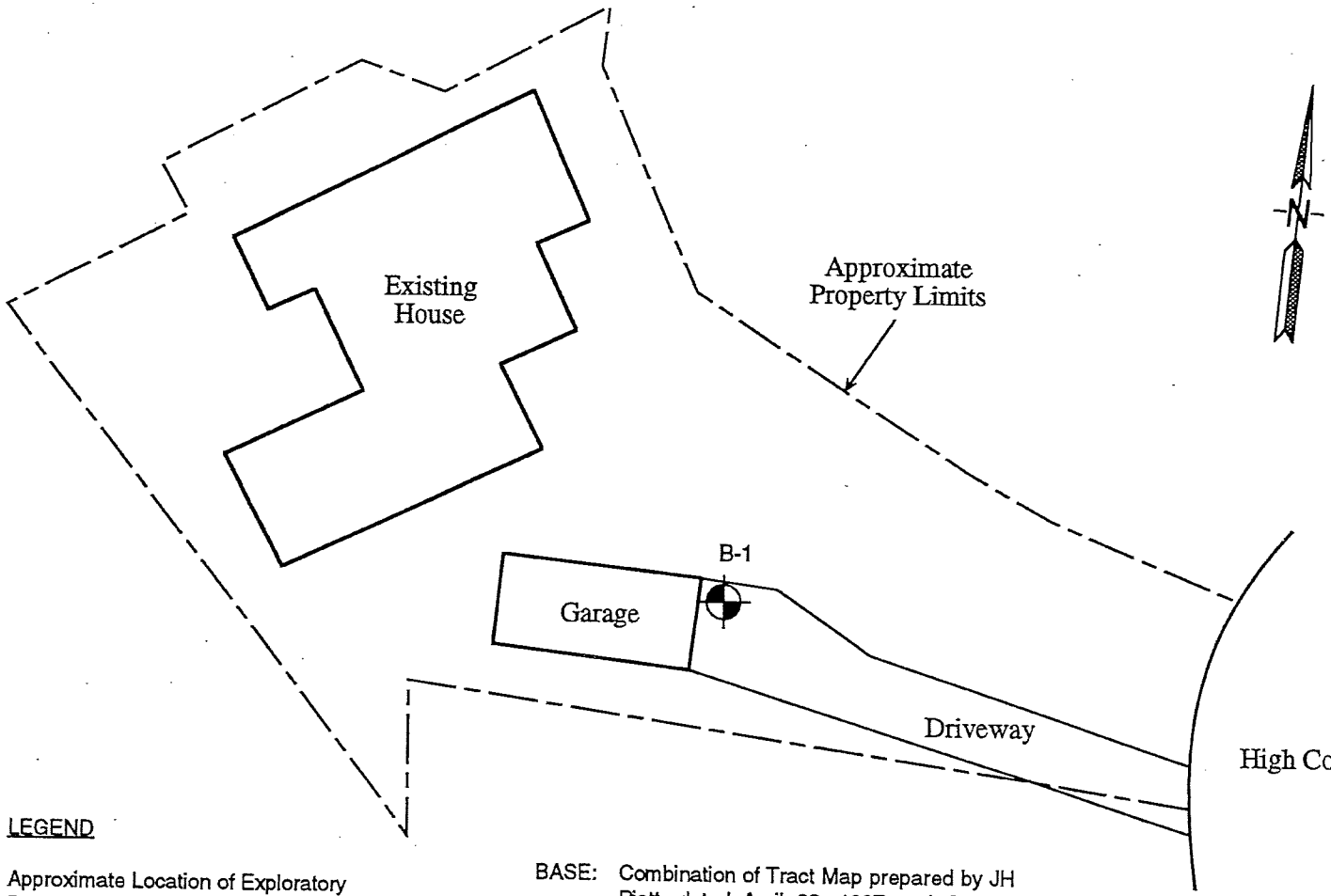
ALAN KROPP & ASSOCIATES
Geotechnical Consultants

EXPLORATORY BORING LOG

STOTHERS RESIDENCE
Berkeley, California

PROJECT NO.	DATE	BORING NO.
574-1	Feb., 1983	5

1109 HIGH COURT
BORING LOGS



LEGEND

B-1 Approximate Location of Exploratory Boring with Inclinometer

BASE: Combination of Tract Map prepared by JH Piatt, dated April 23, 1927 and Garage Plan prepared by Hans G.R. Schickele, AIA, dated January 22, 1951

NOT TO SCALE

1109 High Court

ALAN KROPP & ASSOCIATES *Geotechnical Consultants*	SITE PLAN HIGH COURT RESIDENCE Berkeley, California		
	PROJECT NO. **1691-1A**	DATE **June 1997**	FIGURE **1**

1691-1A High Court Residence 1109 High Court

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ---	LOGGED BY: RK
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 4-1/2 inches	DATE DRILLED: 1-28-97

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
1-1/2" thick asphaltic concrete	---	---	---						
CLAY, silty, sandy; (Landslide Debris) - trace fine roots - trace small gravels	Dark Grayish Brown	Soft to Firm	CL	1 2		[7]	24		LL = 45% PI = 29% -200 = 76%
- numerous small gravels	Yellowish Brown with some Gray			3 4		[15]	27	89	
				5 6 7 8 9		[28]	19	112	
				10 11 12 13 14 15 16 17 18 19		39			
(continued on next sheet)				20					

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

HIGH COURT RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1691-1A	June 1997	1 of 3	1

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ---	LOGGED BY: RK
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 4-1/2 inches	DATE DRILLED: 1-28-97

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, silty, sandy; (Landslide Debris) (continued)	Dark Grayish Brown	Soft to Firm	CL	21–40		27			
(LANDSLIDE DEBRIS ↑)									
SILTSTONE, very severely weathered, fractured	Olive Gray	Soft Hardness	Bed-rock						
(continued on next sheet)									

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

HIGH COURT RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1691-1A	June 1997	2 of 3	1

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ---	LOGGED BY: RK
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 4-1/2 inches	DATE DRILLED: 1-28-97

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (feet)	SAMPLER	BLOWS / FT	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
SILTSTONE, very severely weathered, fractured (continued)	Olive Gray	Soft Hardness	Bed-rock	41 42 43 44		50 / 5-1/2			

Bottom of boring at 44 feet 5-1/2 inches

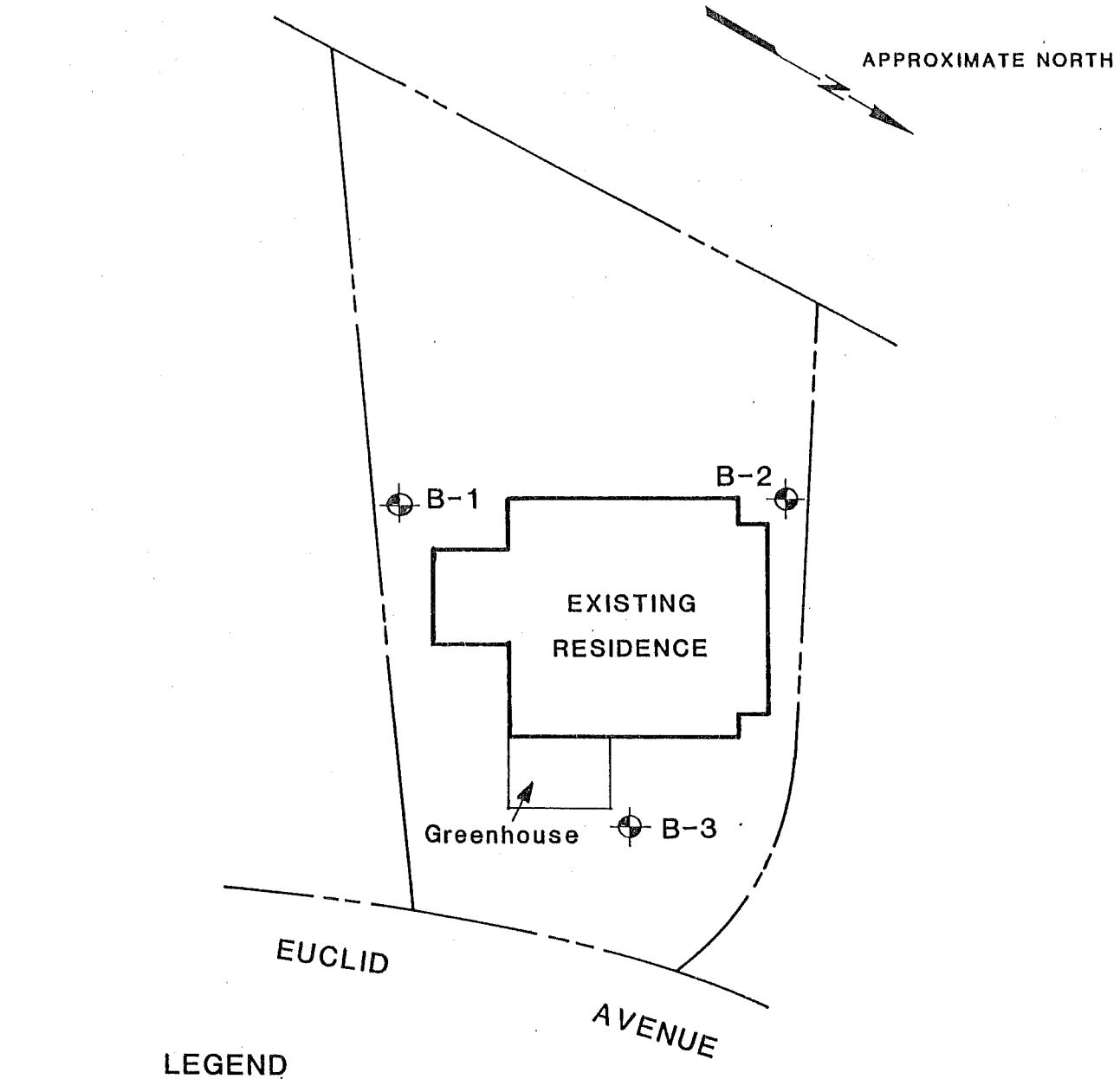
NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.)
2. The stratification line represents the approximate boundary between material types, and the transition may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler, and are not standard penetration resistance values.

ALAN KROPP & ASSOCIATES *Geotechnical Consultants*	EXPLORATORY BORING LOG HIGH COURT RESIDENCE Berkeley, California			
	PROJECT NO.	DATE	SHEET	BORING NO. 1
	1691-1A	June 1997	3 of 3	

1104 EUCLID AVENUE
BORING LOGS

916-1A Euclid Avenue Residence 1104 Euclid Ave



LEGEND

B-1 Approximate Location of Exploratory Boring

BASE: City of Berkeley Zoning Map and field measurements.

0 20 40

APPROXIMATE SCALE (FEET)

ALAN KROPP & ASSOCIATES Geotechnical Consultants	SITE PLAN 1104 EUCLID AVENUE RESIDENCE Berkeley, California

PROJECT NO.	DATE	FIGURE
916-1A	April 1987	1

DRILL RIG	Continuous Flight Auger	SURFACE ELEVATION	--	LOGGED BY	B.L.
DEPTH TO GROUNDWATER	16 Feet	BORING DIAMETER	3½ Inches	DATE DRILLED	3/20/87

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
SAND, very clayey, silty with abundant subangular and angular sheared serpentine fragments; FILL	Mottled Olive Grey and Olive	LOOSE	SC	1	X				16	6
- darker color, very clayey with abundant roots and organics near surface, less clayey from 1 foot			SC/SM	2						
Passing no.200 Sieve = 33%				3						
- intact serpentine fragments are dark bluish black and olive, moderately hard but smooth				4	X				16	6
- becoming clayey from 6' with inclusions of dark Brown silty sandy clay with small gravels (FILL)	Mottled Dark Olive Grey	MEDIUM DENSE	SC	5 6 7	X				22	18
CLAY, silty, sandy with subrounded gravels to ½ inch	Dark Brown	STIFF	CL	8						
			BED-ROCK	9						
SHEARED ROCK, very severely to completely weathered and very severely fractured; clayey moderately hard, angular serpentine, chert, and greywacke fragments in a clay matrix	Mottled Olive, Olive Brown, and Olive Grey	VERY SOFT TO SOFT HARDNESS		10	X				10	15
- moderately to severely weathered and less clayey from 11 feet				11 12 13	X				7	19
SERPENTINE, very severely weathered and very severely fractured clayey, some included moderately hard subangular gravels (serpent.) to ½ inch	Pale Olive and Olive Speckled	VERY SOFT HARDNESS	BED-ROCK	14 15 16					▽	ATOD
Liquid Limit = 34%				17						
Plasticity Index = 14%				18						
Passing no.200 Sieve = 78%				19	X				19	19
- shear zone or fault gouge material				20						

(continued on next sheet)

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

EUCLID AVENUE RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET NO.	BORING NO.
916-1A	April 1987	1 OF 1	1

DRILL RIG	Continuous Flight Auger	SURFACE ELEVATION	--	LOGGED BY	B.L.
DEPTH TO GROUNDWATER	16 Feet	BORING DIAMETER	3½ Inches	DATE DRILLED	3/20/87

DESCRIPTION AND CLASSIFICATION				DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE							
SERPENTINE (continued)	Bluish Olive Grey to Light Bluish Grey	VERY SOFT HARDNESS	BED-ROCK	20						
				21						
				22						
				23						
				24						
- highly to severely weathered from 25 feet				25						
				26						
				27						
				28	X				17	35
				29						
				30						

Bottom of boring at 30 feet.

NOTES

1. Groundwater was encountered at 16 feet at the time of drilling, and the hole was backfilled immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

EUCLID AVENUE RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET NO.	BORING NO.
916-1A	April 1987	1 OF 1	1

DRILL RIG Continuous Flight Auger	SURFACE ELEVATION --	LOGGED BY B.L.
DEPTH TO GROUNDWATER 1 Feet	BORING DIAMETER 3½ Inches	DATE DRILLED 3/20/87

DESCRIPTION AND CLASSIFICATION				DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE							
SILT, clayey, sandy with numerous subangular gravels to 1 inch; FILL - abundant organics (roots and decomposed leaves) near surface	Mottled Greyish Brown and Olive	FIRM	ML SC	1 2	X				15	7
SAND, clayey, silty with abundant subangular to angular serpentine gravels to 2 inches; FILL Passing no.200 Sieve = 34% (FILL)	Mottled Olive Grey	LOOSE MEDIUM DENSE		3 4 5 6 7						
CLAY, very silty, very sandy with numerous subangular to angular gravels to 1 inch	Dark Brown Mottled	STIFF	CL BED-ROCK	8	X				26	18
SERPENTINE and SHEARED ROCK, very severely to completely weathered and very severely fractured, clayey - grading to SERPENTINE from 10 feet	Mottled Olive Brown and Olive Grey to Olive and Dark Bluish Grey	VERY SOFT HARDNESS		9 10 11 12 13 14 15 16 17	X				▽ 10	3/25/87 11
- olive inclusions	Dark Grey			18 19						
(continued on next sheet)				20						

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

EUCLID AVENUE RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET NO.	BORING NO.
916-1A	April 1987	1 OF 1	2

DRILL RIG	Continuous Flight Auger	SURFACE ELEVATION	--	LOGGED BY	B.L.
DEPTH TO GROUNDWATER	13 Feet	BORING DIAMETER	3½ Inches	DATE DRILLED	3/20/87

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
SERPENTINE (continued)	Olive and Dark Bluish Grey	SOFT HARDNESS	BED-ROCK	20						
				21	X				3	50/6"
				22						
				23						
				24						
				25						
				26						
				27						
				28						
				29						
				30						
				31	X				10	45

Bottom of boring at 31½ feet.

NOTES

1. Groundwater was encountered at 13 feet at the time of drilling, and the hole was backfilled immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundaries between material types, and the transitions may be gradual.

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

EUCLID AVENUE RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET NO.	BORING NO.
916-1A	April 1987	1 OF 1	2

DRILL RIG	Continuous Flight Auger	SURFACE ELEVATION	--	LOGGED BY	B.L.
DEPTH TO GROUNDWATER	Not Encountered	BORING DIAMETER	3½ Inches	DATE DRILLED	3/20/87

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	JARS	SACKS	SPLIT SPOON	SHELBY TUBE	MOISTURE CONTENT %	PENETRATION RESISTANCE BLOWS/FT.
SAND, clayey, silty with abundant subangular and angular gravels to 1 inch; FILL - medium grained clean sand at surface below brick patio (FILL)	Mottled Olive Brown and Olive Grey	LOOSE	SC / CH / GC	1	X				23	8
CLAY, very sandy, silty with abundant subrounded to angular gravels to 1 inch Liquid Limit = 58% Plasticity Index = 32% Passing no.200 Sieve = 50% - gradual transition from 2½ feet	Mottled Dark Brown to Dark Olive Brown	STIFF	BED-ROCK	7	X				6	30
SERPENTINE, very severely to completely weathered and very severely fractured and sheared, very clayey - less clayey, lighter coloring, moderately to severely weathered at 6½'	Mottled Olive Brown and Olive Grey to Pale Olive	VERY SOFT HARDNESS TO SOFT HARDNESS	BED-ROCK	13	X				26	12
SERPENTINE, very severely to completely weathered and very severely fractured and sheared, very clayey - shear zone or fault gouge material - olive inclusions	Dark Grey	VERY SOFT HARDNESS		19	X				17	27
Bottom of boring at 19½ feet.				20						

NOTES

1. No groundwater was encountered at the time of drilling, and the boring was backfilled immediately after drilling. (See text for discussion.) See also Note #2 on prev. boring.

ALAN KROPP & ASSOCIATES

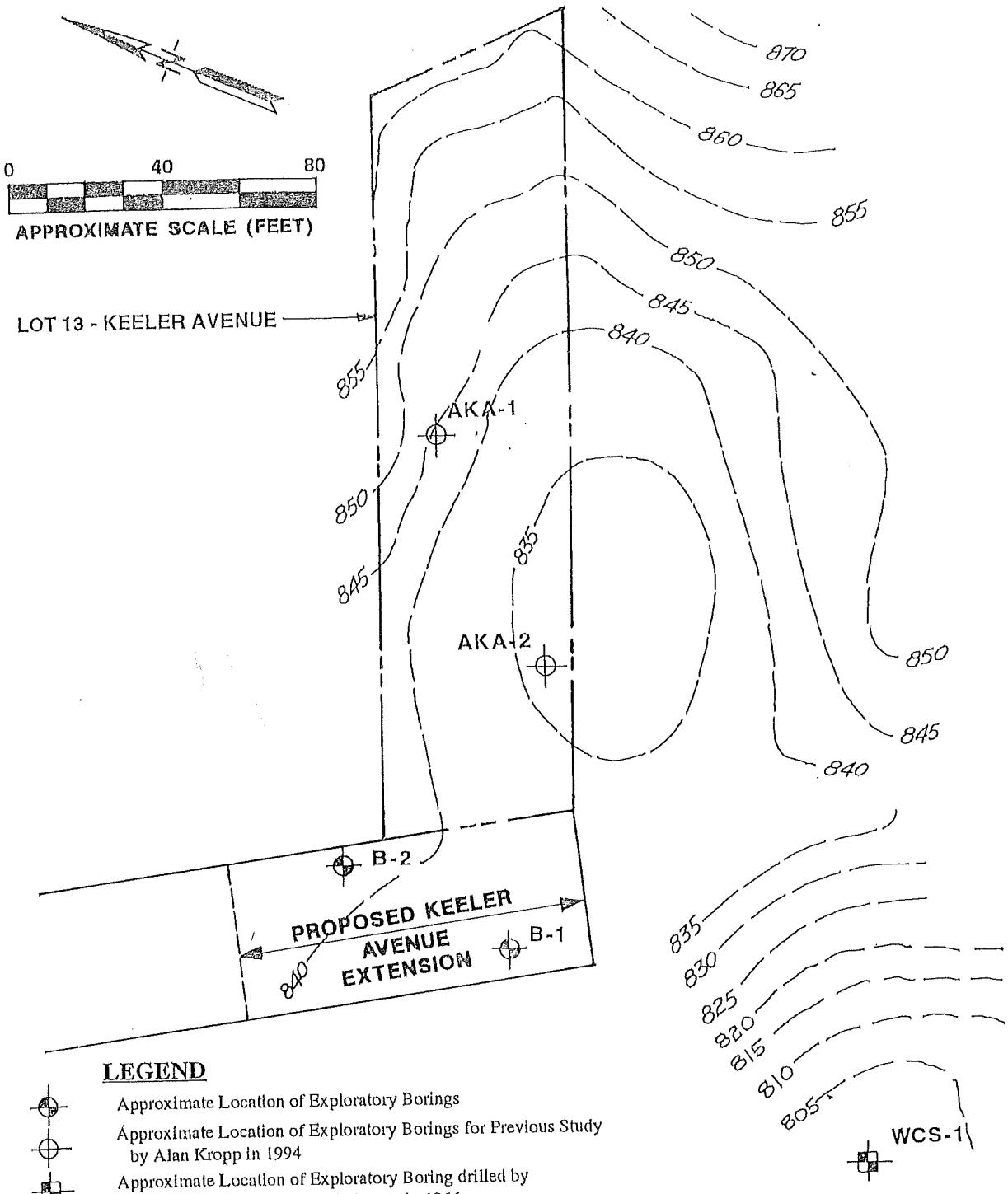
Geotechnical Consultants

EXPLORATORY BORING LOG

EUCLID AVENUE RESIDENCE
Berkeley, California

PROJECT NO.	DATE	SHEET NO.	BORING NO.
916-1A	April 1987	1 OF 1	3

1045 KEELER AVENUE
BORING LOGS



LEGEND

- Approximate Location of Exploratory Borings
- Approximate Location of Exploratory Borings for Previous Study by Alan Kropp in 1994
- Approximate Location of Exploratory Boring drilled by Woodward-Clyde-Sherard & Assoc. in 1966

BASE: "Topography, Portion of North Cragmont, Berkeley, Calif.", prepared by Everett S. Moran Jr., C.E., dated 5-8-78.

ALAN KROPP & ASSOCIATES *Geotechnical Consultants*	SITE PLAN **KEELER AVENUE EXTENSION** Berkeley, California	
	PROJECT NO. 1514-1	DATE June 1994
		FIGURE 1

PRIMARY DIVISIONS			SECONDARY DIVISIONS		
			CRITERIA	GROUP SYMBOL	GROUP NAME
COARSE-GRAINED SOILS MORE THAN 50% RETAINED ON NO.200 SIEVE	GRAVELS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO.4 SIEVE	CLEAN GRAVELS LESS THAN 5% FINES	$Cu \geq 4$ AND $1 \leq Cc \leq 3$ [A]	GW	Well-graded gravel
			$Cu < 4$ AND/OR $1 > Cc > 3$	GP	Poorly-graded gravel
		GRAVELS WITH FINES - MORE THAN 12% FINES	FINES CLASSIFY AS ML OR MH	GM	Silty gravel
			FINES CLASSIFY AS CL OR CH	GC	Clayey gravel
	SANDS 50% OF MORE OF COARSE FRACTION PASSES NO. 4 SIEVE	CLEAN SANDS LESS THAN 5% FINES	$Cu \geq 6$ AND $1 \leq Cc \leq 3$	SW	Well-graded sand
			$Cu < 6$ AND/OR $1 > Cc > 3$	SP	Poorly-graded sand
		SANDS WITH FINES - MORE THAN 12% FINES	FINES CLASSIFY AS ML OR MH	SM	Silty sand
			FINES CLASSIFY AS CL OR CH	SC	Clayey sand
FINE-GRAINED SOILS 50% OR MORE PASSES THE NO.200 SIEVE	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50%	INORGANIC	PI > 7 AND PLOTS ON OR ABOVE 'A' LINE	CL	Lean clay
			PI < 4 OR PLOTS BELOW 'A' LINE	ML	Silt
		ORGANIC	$\frac{\text{LIQUID LIMIT - OVEN DRIED}}{\text{LIQUID LIMIT - NOT DRIED}} < 0.75$	OL	Organic Clay & Organic Silt
	SILTS AND CLAYS LIQUID LIMIT 50% OR MORE	INORGANIC	PI PLOTS ON OR ABOVE 'A' LINE	CH	Fat clay
			PI PLOTS BELOW 'A' LINE	MH	Elastic silt
		ORGANIC	$\frac{\text{LIQUID LIMIT - OVEN DRIED}}{\text{LIQUID LIMIT - NOT DRIED}} < 0.75$	OH	Organic Clay & Organic Silt
	HIGHLY ORGANIC SOILS		PRIMARILY ORGANIC MATTER, DARK IN COLOR, AND ORGANIC ODOR	PT	Peat

SOIL CLASSIFICATION CHART

[A] $C_u = D_{60}/D_{100}$ & $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

U. S. STANDARD SERIES SIEVE				CLEAR SQUARE SIEVE OPENINGS			
200	40	10	4	3/4"	3"	12"	
SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

GRAIN SIZES

SAND AND GRAVELS	BLOWS/FOOT †
VERY LOOSE	0 - 4
LOOSE	4 - 10
MEDIUM DENSE	10 - 30
DENSE	30 - 50
VERY DENSE	OVER 50

RELATIVE DENSITY

SILTS AND CLAYS	STRENGTH§	BLOWS/FOOT †
VERY SOFT	0 - 1/4	0 - 2
SOFT	1/4 - 1/2	2 - 4
FIRM	1/2 - 1	4 - 8
STIFF	1 - 2	8 - 16
VERY STIFF	2 - 4	16 - 32
HARD	OVER 4	OVER 32

CONSISTENCY

† Number of blows of 140-pound hammer falling 30 inches to drive a 2-inch O.D. (1-3/8-inch I. D.) split spoon (ASTM D1586-84).

§ Unconfined compressive strength in tons/sq ft as determined by laboratory testing or approximated by the Standard Penetration Test, (ASTM D 1586-84), pocket penetrometer, torvane, or visual observation.

REFERENCE:
Unified Soil Classification System (ASTM D 2487-90)

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

KEY TO EXPLORATORY BORING LOGS

KEELER AVENUE EXTENSION
Berkeley, California

PROJECT NO.	DATE	FIGURE
1514-1	June 1994	2

TABLE 1

ROCK HARDNESS CRITERIA

Very Hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimen requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately Hard	Can be scratched with knife or pick. Gouges or grooves to 1/4 inch deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by 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 to pieces about 1 inch maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved 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 thin pieces can be broken by finger pressure.
Very Soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1 inch or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

Subsurface Manual for Design and Construction of Foundations of Buildings, 1976, Published by the American Society of Civil Engineers.

TABLE 2

ROCK WEATHERING CRITERIA

Fresh Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.

Very Slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock genrally fresh, joints stained, and discoloration extends into rock up to 1 inch. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significiant portions of rock show discoloration and weather- ing effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. 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 granitoid rocks, 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 grainitoid rocks, 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.

Subsurface Manual for Design and Construction of Foundations of Buildings, 1976, Published by the American Society of Civil Engineers.

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ± 841 feet	LOGGED BY: RK
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 6 inches	DATE DRILLED: 4-18-94

DESCRIPTION AND CLASSIFICATION				DEPTH (feet)	SAMPLER	PENETRATION RESISTANCE (blows/ft)	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	UNCONFINED COMPRESSIVE STRENGTH (ksf)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
CLAY, silty, sandy (slide debris / FILL) - trace fine organics - occasional fine gravels - numerous completely weathered (siltstone / claystone) fragments	Brown	Stiff	CL	1		[27]	16		
SANDSTONE (fine- to medium-grained), very severely weathered, highly fractured, (slide debris?) - some clay in fractures	Olive Gray	Soft Hardness	BR	5		[22]	11		
- bedrock contains piece of quartz and fine gravels -bedding at 45° angle (direction unknown) (inclusion?) - trace root tracks	and Red Brown			8		[33]	9		
				11		20	7		
- numerous fine to medium gravels				16		35	10		
				20					

(continued on next sheet)

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

KEELER AVENUE EXTENSION
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1514-1	June 1994	1 of 2	1

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ± 841 feet	LOGGED BY: RK
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 6 inches	DATE DRILLED: 4-18-94

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	SAMPLER	PENETRATION RESISTANCE (blows/ft)	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	UNCONFINED COMPRESSIVE STRENGTH (ksf)
SANDSTONE (fine- to medium-grained), very severely weathered, highly fractured, (slide debris?)	Olive Gray	Soft Hardness	BR	21					
				22			▽	2 Hours After Drilling	
				23					
- some fine gravels - very clayey - some moisture (wet) in fractures	Light Olive Gray			24					
				25		28	12		
				26					
				27					
				28					
				29			▽	At Time of Drilling	
				30					
				31					
				32					
- some brown clay				33					
		Medium Hardness		34		68	13		

Bottom of Boring at 35 Feet.

NOTES

1. Groundwater was encountered at a depth of 29 feet at the time of drilling, and was at a depth of 22 feet 2 hours after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundary between material types, and the transition may be gradational.
3. Penetration resistance values enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler, and are not standard penetration resistance values.

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

EXPLORATORY BORING LOG

KEELER AVENUE EXTENSION
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1514-1	June 1994	2 of 2	1

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ± 839 feet	LOGGED BY: RK
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 6 Inches	DATE DRILLED: 4-18-94

DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE	DEPTH (feet)	SAMPLER	PENETRATION RESISTANCE (blows/ft)	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	UNCONFINED COMPRESSIVE STRENGTH (ksf)
CLAY, silty, sandy (slide debris / FILL) - numerous fine to 1/8" diameter organics - numerous fine gravels	Dark Brown	Soft	CL	1					
CLAY, silty, sandy (slide debris / FILL) - numerous variable rock fragments - trace fine roots / tracks	Olive Brown	Stiff	CL	2		[17]	18		
- abundance of roots to 1/8" diameter - variable rock fragments	mottled with Olive Gray			3 4 5					
SILTSTONE, very severely weathered, highly fractured, (slide debris) - clay in fractures	Olive Gray	Soft Hardness	BR	6		[28]	21		
				7 8 9		[36]	18		
- occasional weathered sandstone fragments				10 11 12 13 14 15 16		43	9		
- transitioning to SANDSTONE				17 18 19					
(continued on next sheet)				20					

ALAN KROPP & ASSOCIATES *Geotechnical Consultants*	EXPLORATORY BORING LOG KEELER AVENUE EXTENSION Berkeley, California			
	PROJECT NO.	DATE	SHEET	BORING NO. 2
	1514-1	June 1994	1 of 2	

DRILL RIG: Continuous Flight Auger	SURFACE ELEVATION: ± 839 feet	LOGGED BY: RK
DEPTH TO GROUNDWATER: See Notes	BORING DIAMETER: 6 Inches	DATE DRILLED: 4-18-94

DESCRIPTION AND CLASSIFICATION				DEPTH (feet)	SAMPLER	PENETRATION RESISTANCE (blows/ft)	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	UNCONFINED COMPRESSIVE STRENGTH(ksf)
DESCRIPTION AND REMARKS	COLOR	CONSIST.	SOIL TYPE						
SANDSTONE (fine- to medium-grained), very severely weathered, highly fractured, (slide debris?)	Olive Gray	Soft Hardness	BR	21 22 23 24 25 26		74	11		

Bottom of Boring at 26.5 Feet.

NOTES

1. No groundwater was encountered at the site and the boring was backfilled immediately after drilling. (See text for discussion.)
2. Stratification lines represent the approximate boundary between material types, and the transition may be gradational.
3. Penetration resistance values enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler, and are not standard penetration resistance values.

ALAN KROPP & ASSOCIATES

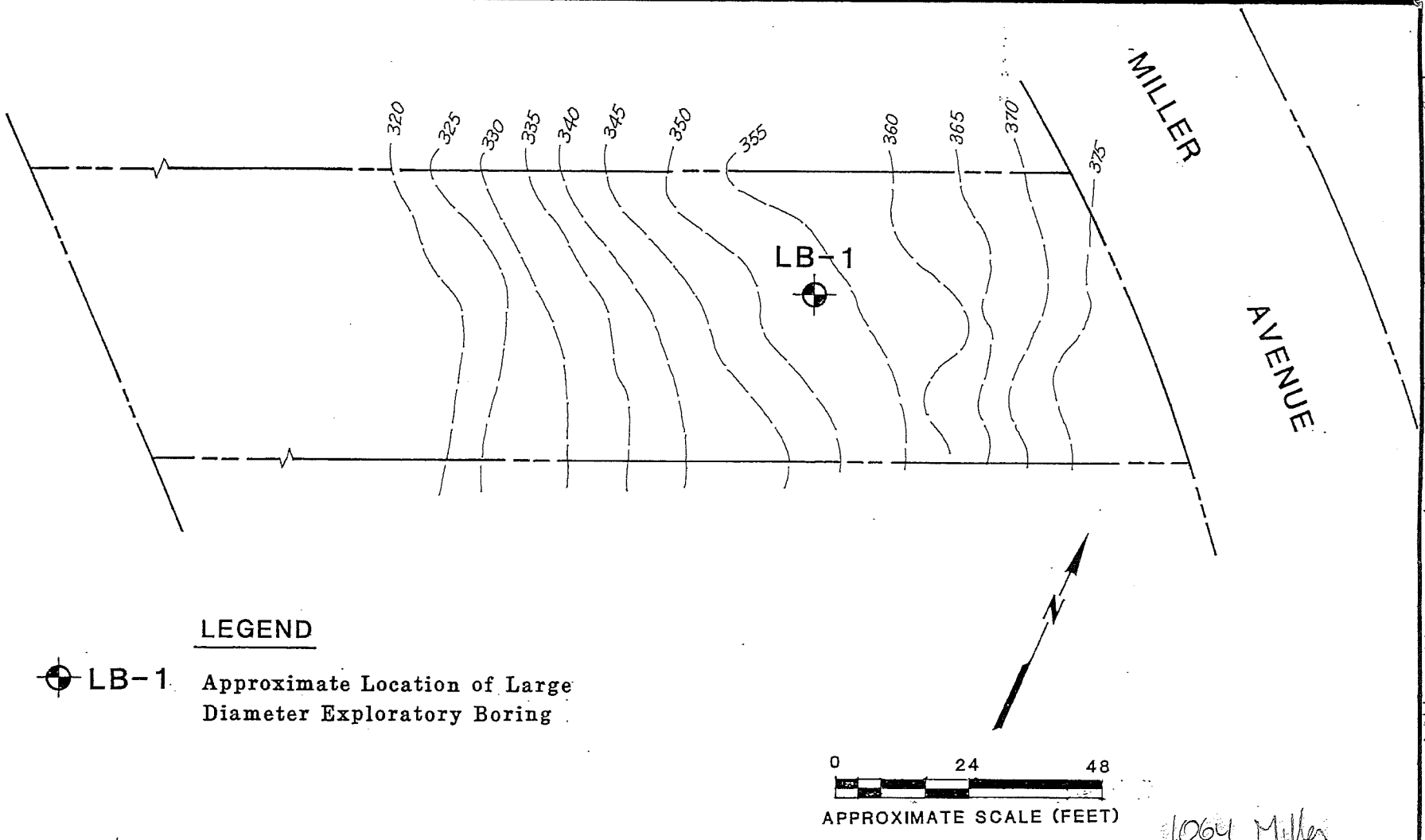
Geotechnical Consultants

EXPLORATORY BORING LOG

KEELER AVENUE EXTENSION
Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
1514-1	June 1994	2 of 2	2

1064 MILLER AVENUE
BORING LOGS



902-1A Fulton Residence 1064 Miller Ave.

LEGEND

LB-1 Approximate Location of Large Diameter Exploratory Boring

1064 Miller

BASE: Map from John E. Koch, Land Surveyor, 9/22/88.

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

SITE PLAN

FULTON RESIDENCE
Berkeley, California

PROJECT NO.	DATE	FIGURE
902-1A	March 1990	1

LOG OF LARGE DIAMETER EXPLORATORY BORING

Depth (Feet)	Description
0-3	TOPSOIL. Silty clay, very dark gray, abundant roots and organic debris.
3-6	SLIDE DEBRIS. Silty clay, highly mottled, olive gray, some angular rock fragments.
6-13	SLIDE DEBRIS. Very clayey sand, mottled yellow brown, no apparent rock structure, few angular chunks of Contra Costa Group rock, slightly moist, Compressive strength > 4 tsf.
13	SLIDE DEBRIS. Silty clay seam about 1 inch thick with angular sandstone chunks. Seam dips at 75° into hillside.
13½-20	SLIDE DEBRIS. Very clayey sand, yellow brown, angular sandstone chunks in the sand matrix, abundant fine roots, persistent blobs of dark brown, silty clay. Compressive strength = 5 tsf.
20-29	SLIDE DEBRIS. Clayey, very pebbly sand with chunks of sandstone to 2 inches, yellow, brown, and gray coloring. Groundwater encountered at 25 feet at the time of drilling.
29-30	SLIDE DEBRIS. Pebbly clay with abundant roots, mottled olive brown and reddish brown, angular sandstone chunks to 1 inch.
30-33	BEDROCK. Interbedded clayey sandstone and gravelly, coarse-grained sandstone; clayey sandstone was impervious, moist, firm; olive gray to olive brown; gravelly sandstone was wet, contained rounded basalt pebbles, subangular to subrounded sandstone and chert pebbles; weakly stratified and with a preferred orientation of platey pebbles; gravelly sandstone contained some clay binder, poorly sorted.

APPENDIX H

LANDSLIDE DISPLACEMENT CALCULATIONS

SECTION 1

LANDSLIDE CALCULATIONS
PSEUDO-STATIC SAFETY FACTOR – FS
SEISMIC YIELD COEFFICIENT – Ky

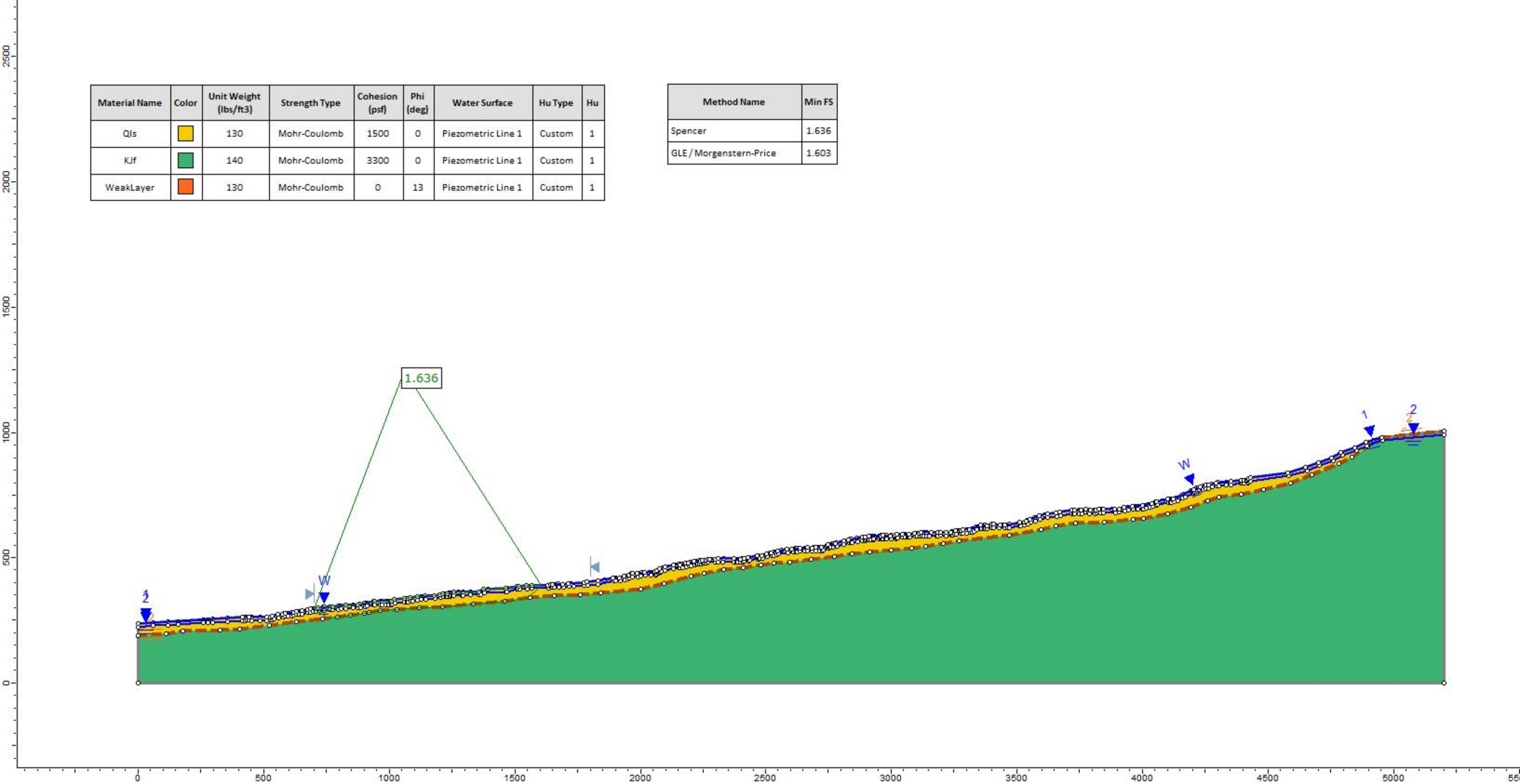
ANALYSIS RUN 1-A

$\phi = 13^{o}$

GW = 0 FEET

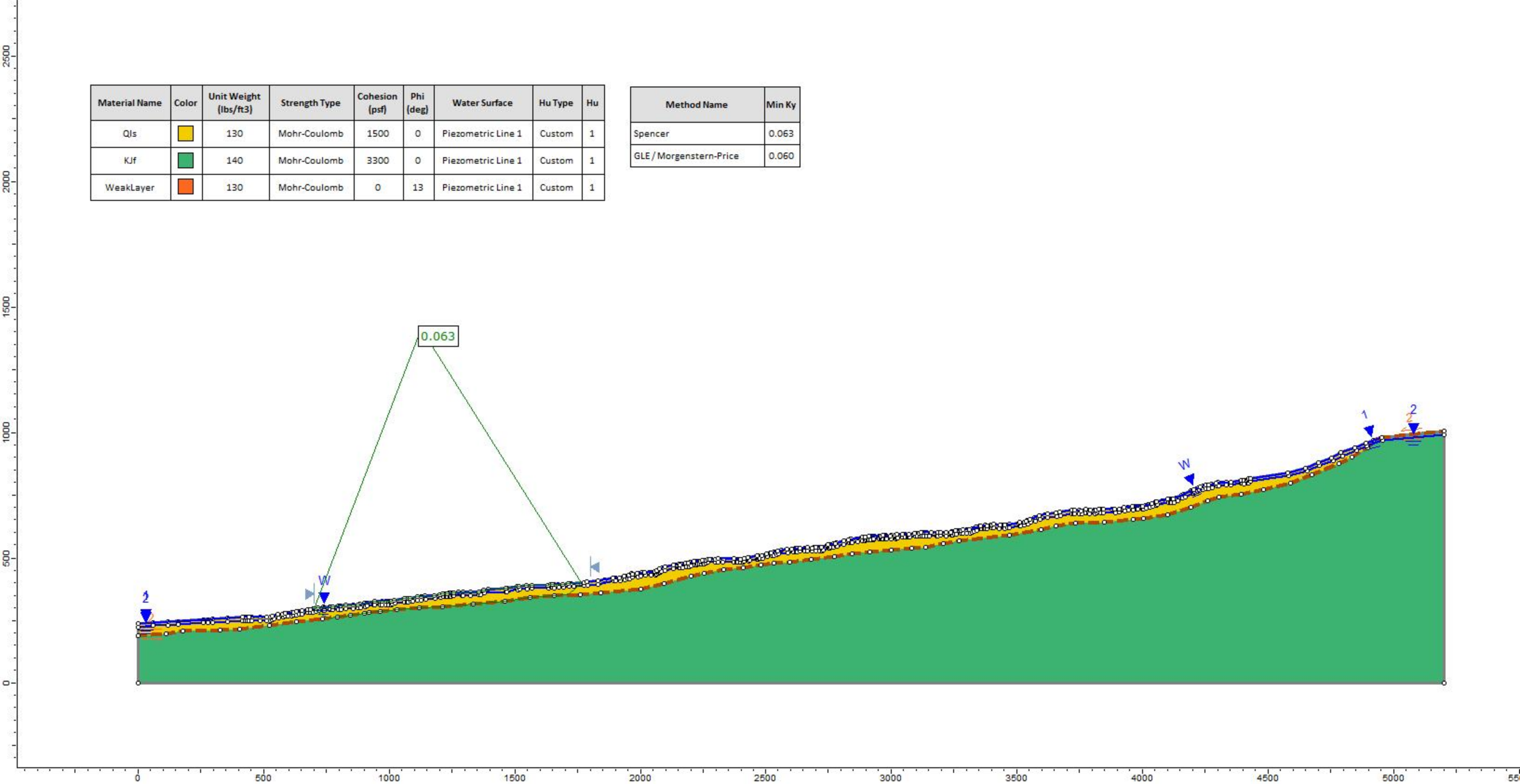
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Qls		130	Mohr-Coulomb	1500	0	Piezometric Line 1	Custom	1
KJf		140	Mohr-Coulomb	3300	0	Piezometric Line 1	Custom	1
WeakLayer		130	Mohr-Coulomb	0	13	Piezometric Line 1	Custom	1

Method Name	Min FS
Spencer	1.636
GLE / Morgenstern-Price	1.603



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Qls		130	Mohr-Coulomb	1500	0	Piezometric Line 1	Custom	1
KJf		140	Mohr-Coulomb	3300	0	Piezometric Line 1	Custom	1
WeakLayer		130	Mohr-Coulomb	0	13	Piezometric Line 1	Custom	1

Method Name	Min Ky
Spencer	0.063
GLE / Morgenstern-Price	0.060



Slide Analysis Information

Slide_xs1_2019-09-06_phi-13

Project Summary

File Name:	Slide_xs1_2019-09-06_phi-13.slmd
Slide Modeler Version:	8.027
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	9/6/2019, 8:16:52 PM

Currently Open Scenarios

Group Name	Scenario Name	Global Minimum	Compute Time
Groundwater at Surface	School_phi=13_FS	Spencer: 1.635610 Gle/morgenstern-price: 1.603010	00h:00m:15.263s
	School_phi=13_Ky	Spencer: 0.062704 Gle/morgenstern-price: 0.060443	00h:01m:28.528s

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

All Open Scenarios

Slices Type:	Vertical
Analysis Methods Used	
	GLE/Morgenstern-Price with interslice force function (Half Sine)
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

All Open Scenarios

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Use negative pore pressure cutoff:	Yes
Maximum negative pore pressure [psf]:	0
Advanced Groundwater Method:	None

Random Numbers

All Open Scenarios

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

All Open Scenarios	
Search Method:	Cuckoo Search
Initial # of Surface Vertices:	8
Maximum Iterations:	500
Number of Nests:	50
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined
Convex Surfaces Only:	Enabled

Seismic Loading

Groundwater at Surface - School_phi=13_FS		Groundwater at Surface - School_phi=13_Ky	
Advanced seismic analysis:	No	Advanced seismic analysis:	Yes
Staged pseudostatic analysis:	No	Locate surface with minimum critical horizontal seismic acceleration (Ky):	Yes
		Target factor of safety:	1
		Using Newmark analysis:	No
		Staged pseudostatic analysis:	No

Materials

Property	Qls	KJf	WeakLayer
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	130	140	130
Cohesion [psf]	1500	3300	0
Friction Angle [°]	0	0	13
Water Surface	Assigned per scenario	Assigned per scenario	Assigned per scenario
Hu Value	1	1	1

Materials In Use

Material	School_phi=13_FS	School_phi=13_Ky
Qls	✓	✓
KJf	✓	✓
WeakLayer	✓	✓

Global Minimums

Groundwater at Surface - School_phi=13_FS

Method: spencer

FS	1.635610
Axis Location:	1058.738, 1248.054
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1603.440, 391.104
Resisting Moment:	7.49286e+08 lb-ft
Driving Moment:	4.58108e+08 lb-ft
Resisting Horizontal Force:	727524 lb
Driving Horizontal Force:	444803 lb
Total Slice Area:	39347.5 ft2
Surface Horizontal Width:	903.44 ft
Surface Average Height:	43.553 ft

Method: gle/morgenstern-price

FS	1.603010
Axis Location:	1057.288, 1245.202
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1600.579, 391.124
Resisting Moment:	7.3966e+08 lb-ft
Driving Moment:	4.6142e+08 lb-ft
Resisting Horizontal Force:	719026 lb
Driving Horizontal Force:	448549 lb
Total Slice Area:	39353.4 ft2
Surface Horizontal Width:	900.579 ft
Surface Average Height:	43.6979 ft

Groundwater at Surface - School_phi=13_Ky

Method: spencer

Ky	0.062704
Axis Location:	1128.201, 1414.088
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1764.053, 401.948
Resisting Moment:	9.89766e+08 lb-ft
Driving Moment:	9.89766e+08 lb-ft
Resisting Horizontal Force:	832346 lb
Driving Horizontal Force:	832346 lb
Total Slice Area:	46659.6 ft2
Surface Horizontal Width:	1064.05 ft
Surface Average Height:	43.8509 ft

Method: gle/morgenstern-price

Ky	0.060443
Axis Location:	1132.710, 1424.702
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1774.347, 402.586
Resisting Moment:	1.00488e+09 lb-ft
Driving Moment:	1.00488e+09 lb-ft
Resisting Horizontal Force:	836727 lb
Driving Horizontal Force:	836727 lb
Total Slice Area:	47290.9 ft2
Surface Horizontal Width:	1074.35 ft
Surface Average Height:	44.0183 ft

Global Minimum Coordinates

Groundwater at Surface - School_phi=13_FS

Method: spencer

X	Y
700	298.122
721.611	280.981
743.222	268.065
757.154	260.866
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1548.33	339.549
1559.62	348.841
1582.28	369.732
1603.44	391.104

Method: gle/morgenstern-price

X	Y
700	298.122
733.512	270.461
749.465	259.931
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1547.51	339.441
1559.01	349.259
1579.79	370.037
1600.58	391.124

Groundwater at Surface - School_phi=13_Ky

Method: spencer

X	Y
700	298.122
727.568	277.567
759.387	261.138
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1561.32	341.251
1656.06	349.411
1710.03	352.384
1734.17	371.023
1764.05	401.948

Method: gle/morgenstern-price

X	Y
700	298.122
727.947	273.539
748.839	259.855
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1561.32	341.251
1656.06	349.411
1719.82	352.923
1729.21	360.825
1752.24	380.186
1774.35	402.586

Slice Data

Groundwater at Surface - School_phi=13_FS

- Global Minimum Query (spencer) - Safety Factor: 1.63561

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	13.3406	11336.6	-38.4211	Qls	1500	0	917.089	1500	1747.78	395.012	1352.76	1020.35	625.338
2	8.27063	19091.9	-38.4211	Qls	1500	0	917.089	1500	3297.41	1120.92	2176.49	2569.98	1449.06
3	21.6112	80520.7	-30.8637	Qls	1500	0	917.089	1500	4542.89	1794.98	2747.91	3994.81	2199.83
4	13.9312	72188.3	-27.3277	Qls	1500	0	917.089	1500	5951.33	2482.44	3468.89	5477.43	2994.99
5	17.803	100441	6.93654	WeakLayer	0	13	401.941	657.419	5572.46	2724.87	2847.59	5621.36	2896.49
6	17.803	99105.7	6.93654	WeakLayer	0	13	396.263	648.132	5498.38	2691.01	2807.37	5546.59	2855.58
7	17.2991	95565.8	7.47508	WeakLayer	0	13	393.75	644.021	5448.87	2659.31	2789.56	5500.54	2841.23
8	17.2991	94651.3	7.47508	WeakLayer	0	13	391.835	640.889	5396.62	2620.63	2775.99	5448.04	2827.41
9	17.2991	92689.6	7.47508	WeakLayer	0	13	384.87	629.497	5284.72	2558.07	2726.65	5335.22	2777.15
10	18.9112	98594.4	6.22811	WeakLayer	0	13	380.567	622.46	5158.51	2462.34	2696.17	5200.04	2737.7
11	18.9112	96767.3	6.22811	WeakLayer	0	13	370.321	605.701	5063.02	2439.44	2623.58	5103.43	2663.99
12	18.9112	99137.2	6.22811	WeakLayer	0	13	379.029	619.944	5187.03	2501.76	2685.27	5228.39	2726.63
13	17.1807	90786.8	12.3472	WeakLayer	0	13	374.01	611.735	5146.63	2496.92	2649.71	5228.5	2731.58
14	21.7549	114696	8.89484	WeakLayer	0	13	372.949	609.999	5181.4	2539.21	2642.19	5239.76	2700.55
15	21.7549	111271	8.89484	WeakLayer	0	13	365.472	597.77	5026.35	2437.12	2589.23	5083.55	2646.43
16	16.7749	81001	4.46366	WeakLayer	0	13	349.897	572.295	4799.56	2320.68	2478.88	4826.88	2506.2
17	16.7749	78436.9	4.46366	WeakLayer	0	13	337.459	551.951	4647.63	2256.87	2390.76	4673.98	2417.11
18	16.7749	77081.1	4.46366	WeakLayer	0	13	338.468	553.602	4567.27	2169.36	2397.91	4593.69	2424.33
19	16.7749	86540.2	4.46366	WeakLayer	0	13	370.327	605.71	5127.79	2504.17	2623.62	5156.7	2652.53
20	18.033	95380.8	4.3189	WeakLayer	0	13	383.998	628.071	5259.26	2538.79	2720.47	5288.26	2749.47
21	18.033	96571.5	4.3189	WeakLayer	0	13	388.008	634.63	5324.91	2576.03	2748.88	5354.22	2778.19
22	18.033	96014.9	4.3189	WeakLayer	0	13	392.175	641.445	5294.21	2515.81	2778.4	5323.83	2808.02
23	18.033	101632	4.3189	WeakLayer	0	13	409.166	669.236	5603.96	2705.19	2898.77	5634.86	2929.67
24	18.033	104643	4.3189	WeakLayer	0	13	420.288	687.427	5769.96	2792.39	2977.57	5801.7	3009.31
25	18.3475	108316	2.28881	WeakLayer	0	13	435.854	712.887	5900.94	2813.09	3087.85	5918.36	3105.27
26	18.3475	110542	2.28881	WeakLayer	0	13	439.978	719.633	6022.05	2904.99	3117.06	6039.64	3134.65
27	18.3475	112768	2.28881	WeakLayer	0	13	449.918	735.89	6143.39	2955.89	3187.5	6161.37	3205.48
28	18.3475	115481	2.28881	WeakLayer	0	13	461.857	755.418	6291.19	3019.13	3272.06	6309.65	3290.52
29	18.3475	120433	2.28881	WeakLayer	0	13	484.739	792.844	6561.04	3126.89	3434.15	6580.42	3453.53
30	20.6691	140326	4.91045	WeakLayer	0	13	490.746	802.669	6740.45	3263.72	3476.73	6782.61	3518.89
31	20.6691	142220	4.91045	WeakLayer	0	13	496.233	811.644	6831.46	3315.84	3515.62	6874.09	3558.25
32	20.6691	144709	4.91045	WeakLayer	0	13	505.405	826.645	6951	3370.44	3580.56	6994.43	3623.99
33	20.6691	141296	4.91045	WeakLayer	0	13	493.228	806.728	6787.06	3292.74	3494.32	6829.44	3536.7
34	20.6691	137771	4.91045	WeakLayer	0	13	481.37	787.333	6617.77	3207.45	3410.32	6659.13	3451.68
35	20.6691	134247	4.91045	WeakLayer	0	13	465.566	761.485	6448.53	3150.16	3298.37	6488.53	3338.37
36	21.0977	132910	5.88883	WeakLayer	0	13	452.375	739.909	6238.91	3034.03	3204.88	6285.57	3251.54
37	21.0977	142641	5.88883	WeakLayer	0	13	488.404	798.838	6695.64	3235.47	3460.17	6746.01	3510.54
38	21.0977	148114	5.88883	WeakLayer	0	13	502.913	822.569	6952.64	3389.7	3562.94	7004.51	3614.81
39	21.0977	144598	5.88883	WeakLayer	0	13	490.921	802.956	6787.62	3309.64	3477.98	6838.26	3528.62
40	21.0977	141083	5.88883	WeakLayer	0	13	479.992	785.079	6622.6	3222.04	3400.56	6672.11	3450.07
41	21.0977	137568	5.88883	WeakLayer	0	13	469.062	767.202	6457.54	3134.43	3323.11	6505.92	3371.49
42	17.3292	112141	7.46563	WeakLayer	0	13	464.192	759.237	6382.83	3094.22	3288.61	6443.66	3349.44
43	17.3292	114757	7.46563	WeakLayer	0	13	470.978	770.337	6531.94	3195.24	3336.7	6593.66	3398.42
44	17.3292	117424	7.46563	WeakLayer	0	13	478.179	782.114	6683.96	3296.27	3387.69	6746.63	3450.36
45	17.3292	117706	7.46563	WeakLayer	0	13	485.084	793.408	6699.7	3263.06	3436.64	6763.26	3500.2
46	17.3292	113554	7.46563	WeakLayer	0	13	468.389	766.102	6463.34	3144.99	3318.35	6524.71	3379.72
47	11.2894	66916.2	39.4566	Qls	1500	0	917.089	1500	4939.38	2845.07	2094.31	5694.2	2849.13
48	22.6617	93920.2	42.6719	Qls	1500	0	917.089	1500	3151.76	1999.34	1152.42	3997.2	1997.86
49	8.34543	18741.3	45.2879	Qls	1500	0	917.089	1500	1290.7	1077.88	212.824	2217.06	1139.18
50	12.8137	10853.4	45.2879	Qls	1500	0	917.089	1500	-10.6322	406.52	-417.152	915.72	509.2

- Global Mi

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Mate
1	13.9609	11853	-36.7086	
2	13.6073	34859.1	-36.7086	
3	31.8184	142878	-27.3095	
4	16.6865	93946.1	6.93654	WeakL
5	16.6865	92873.5	6.93654	WeakL
6	25.9486	143006	7.47508	WeakL
7	25.9486	139900	7.47508	WeakL
8	18.9112	98594.4	6.22811	WeakL
9	18.9112	96767.3	6.22811	WeakL
10	18.9112	99137.2	6.22811	WeakL
11	17.1807	90786.8	12.3472	WeakL
12	21.7549	114696	8.89484	WeakL
13	21.7549	111271	8.89484	WeakL
14	22.3665	107432	4.46366	WeakL
15	22.3665	102958	4.46366	WeakL
16	22.3665	112670	4.46366	WeakL
17	22.5412	119445	4.3189	WeakL
18	22.5412	120109	4.3189	WeakL
19	22.5412	124331	4.3189	WeakL
20	22.5412	130358	4.3189	WeakL
21	22.9344	135742	2.28881	WeakL
22	22.9344	139221	2.28881	WeakL
23	22.9344	142906	2.28881	WeakL
24	22.9344	149670	2.28881	WeakL
25	20.6691	140326	4.91045	WeakL
26	20.6691	142220	4.91045	WeakL
27	20.6691	144709	4.91045	WeakL
28	20.6691	141296	4.91045	WeakL
29	20.6691	137771	4.91045	WeakL
30	20.6691	134247	4.91045	WeakL
31	21.0977	132910	5.88883	WeakL
32	21.0977	142641	5.88883	WeakL
33	21.0977	148114	5.88883	WeakL
34	21.0977	144598	5.88883	WeakL
35	21.0977	141083	5.88883	WeakL
36	21.0977	137568	5.88883	WeakL
37	19.9271	129175	7.46563	WeakL
38	19.9271	132651	7.46563	WeakL
39	19.9271	135907	7.46563	WeakL
40	19.9271	132895	7.46563	WeakL
41	19.9271	128525	7.46563	WeakL
42	23.6839	150707	4.92318	WeakL
43	23.6839	144212	4.92318	WeakL
44	23.6839	137430	4.92318	WeakL
45	23.6839	139920	4.92318	WeakL
46	26.9895	158839	3.15232	WeakL
47	26.9895	158044	3.15232	WeakL
48	24.1363	118083	37.6763	
49	16.2561	44729.7	45.9826	
50	13.6264	11742.7	45.9826	

- Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.60301
- Global Minimum

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	12.9509	11012.4	-39.5367	Qls	1500	0	935.74	1500	1634.06	394.884	1239.17	861.686	466.802
2	20.5612	62938	-39.5367	Qls	1500	0	935.74	1500	3897.38	1478.09	2419.29	3125	1646.91
3	15.953	79991.2	-33.428	Qls	1500	0	935.74	1500	5763.62	2385.78	3377.84	5145.96	2760.18
4	21.6473	123054	6.93654	WeakLayer	0	13	425.401	681.922	5696.27	2742.57	2953.7	5748.03	3005.46
5	21.6473	120598	6.93654	WeakLayer	0	13	416.141	667.078	5578.56	2689.13	2889.43	5629.19	2940.06
6	17.2991	95565.8	7.47508	WeakLayer	0	13	412.175	660.721	5521.21	2659.31	2861.9	5575.29	2915.98
7	17.2991	94651.3	7.47508	WeakLayer	0	13	409.454	656.359	5463.63	2620.63	2843	5517.36	2896.73
8	17.2991	92689.6	7.47508	WeakLayer	0	13	401.575	643.728	5346.36	2558.07	2788.29	5399.05	2840.98
9	18.9112	98594.4	6.22811	WeakLayer	0	13	396.194	635.103	5213.27	2462.34	2750.93	5256.51	2794.17
10	18.9112	96767.3	6.22811	WeakLayer	0	13	385.137	617.378	5113.6	2439.44	2674.16	5155.63	2716.19
11	18.9112	99137.2	6.22811	WeakLayer	0	13	393.408	630.637	5233.35	2501.76	2731.59	5276.28	2774.52
12	17.1807	90786.8	12.3472	WeakLayer	0	13	387.341	620.912	5186.38	2496.92	2689.46	5271.17	2774.25
13	21.7549	114696	8.89484	WeakLayer	0	13	385.239	617.542	5214.09	2539.21	2674.88	5274.38	2735.17
14	21.7549	111271	8.89484	WeakLayer	0	13	376.577	603.656	5051.83	2437.12	2614.71	5110.77	2673.65
15	16.7749	81001	4.46366	WeakLayer	0	13	360.852	578.449	4826.22	2320.68	2505.54	4854.39	2533.71
16	16.7749	78436.9	4.46366	WeakLayer	0	13	347.822	557.562	4671.94	2256.87	2415.07	4699.09	2442.22
17	16.7749	77081.1	4.46366	WeakLayer	0	13	348.527	558.693	4589.33	2169.36	2419.97	4616.53	2447.17
18	16.7749	86540.2	4.46366	WeakLayer	0	13	380.642	610.173	5147.12	2504.17	2642.95	5176.83	2672.66
19	18.033	95380.8	4.3189	WeakLayer	0	13	394.283	632.04	5276.45	2538.79	2737.66	5306.23	2767.44
20	18.033	96571.5	4.3189	WeakLayer	0	13	397.98	637.966	5339.37	2576.03	2763.34	5369.42	2793.39
21	18.033	96014.9	4.3189	WeakLayer	0	13	401.863	644.191	5306.11	2515.81	2790.3	5336.46	2820.65
22	18.033	101632	4.3189	WeakLayer	0	13	418.77	671.292	5612.86	2705.19	2907.67	5644.49	2939.3
23	18.033	104643	4.3189	WeakLayer	0	13	429.703	688.818	5775.99	2792.39	2983.6	5808.44	3016.05
24	18.3475	108316	2.28881	WeakLayer	0	13	446.304	715.429	5911.94	2813.09	3098.85	5929.77	3116.68
25	18.3475	110542	2.28881	WeakLayer	0	13	450.091	721.501	6030.17	2904.99	3125.18	6048.16	3143.17
26	18.3475	112768	2.28881	WeakLayer	0	13	459.801	737.066	6148.46	2955.89	3192.57	6166.83	3210.94
27	18.3475	115481	2.28881	WeakLayer	0	13	471.516	755.845	6293.05	3019.13	3273.92	6311.89	3292.76
28	18.3475	120433	2.28881	WeakLayer	0	13	494.386	792.506	6559.63	3126.89	3432.74	6579.39	3452.5
29	20.6691	140326	4.91045	WeakLayer	0	13	498.488	799.081	6724.93	3263.72	3461.21	6767.76	3504.04
30	20.6691	142220	4.91045	WeakLayer	0	13	503.607	807.287	6812.56	3315.84	3496.72	6855.83	3539.99
31	20.6691	144709	4.91045	WeakLayer	0	13	512.523	821.58	6929.07	3370.44	3558.63	6973.1	3602.66
32	20.6691	141296	4.91045	WeakLayer	0	13	499.701	801.026	6762.38	3292.74	3469.64	6805.31	3512.57
33	20.6691	137771	4.91045	WeakLayer	0	13	487.238	781.048	6590.54	3207.45	3383.09	6632.4	3424.95
34	20.6691	134247	4.91045	WeakLayer	0	13	470.775	754.657	6418.93	3150.16	3268.77	6459.38	3309.22
35	18.0838	114198	5.88883	WeakLayer	0	13	457.751	733.78	6221.56	3043.21	3178.35	6268.77	3225.56
36	18.0838	118533	5.88883	WeakLayer	0	13	482.47	773.404	6458.09	3108.1	3349.99	6507.85	3399.75
37	18.0838	127887	5.88883	WeakLayer	0	13	513.062	822.444	6970.2	3407.81	3562.39	7023.11	3615.3
38	18.0838	125448	5.88883	WeakLayer	0	13	501.685	804.206	6836.86	3353.45	3483.41	6888.61	3535.16
39	18.0838	122865	5.88883	WeakLayer	0	13	492.183	788.975	6695.77	3278.35	3417.42	6746.53	3468.18
40	18.0838	120283	5.88883	WeakLayer	0	13	482.711	773.791	6554.9	3203.26	3351.64	6604.69	3401.43
41	18.0838	117700	5.88883	WeakLayer	0	13	473.267	758.652	6414.25	3128.17	3286.08	6463.06	3334.89
42	17.1654	111069	7.46563	WeakLayer	0	13	469.929	753.301	6356.63	3093.74	3262.89	6418.21	3324.47
43	17.1654	113635	7.46563	WeakLayer	0	13	477.32	765.149	6508.03	3193.81	3314.22	6570.58	3376.77
44	17.1654	116252	7.46563	WeakLayer	0	13	485.21	777.797	6662.89	3293.89	3369	6726.47	3432.58
45	17.1654	116696	7.46563	WeakLayer	0	13	493.286	790.743	6692.06	3266.96	3425.1	6756.7	3489.74
46	17.1654	112651	7.46563	WeakLayer	0	13	477.177	764.919	6463.26	3150.01	3313.25	6525.79	3375.78
47	11.5002	67807.6	40.4871	Qls	1500	0	935.74	1500	5017.18	2830.14	2187.04	5816.01	2985.87
48	20.7837	85070.3	44.9923	Qls	1500	0	935.74	1500	3127.07	1977.42	1149.65	4062.56	2085.14
49	8.03073	17881.8	45.4151	Qls	1500	0	935.74	1500	1279.45	1068.75	210.695	2228.84	1160.09
50	12.753	10798.4	45.4151	Qls	1500	0	935.74	1500	-97.6047	406.384	-503.989	851.791	445.407

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material
1	12.3441	10508	-41.336	
2	15.6033	44263.4	-41.336	
3	20.8914	100137	-33.2256	
4	21.9604	124911	6.93654	WeakL
5	21.9604	122353	6.93654	WeakL
6	25.9486	143006	7.47508	WeakL
7	25.9486	139900	7.47508	WeakL
8	18.9112	98594.4	6.22811	WeakL
9	18.9112	96767.3	6.22811	WeakL
10	18.9112	99137.2	6.22811	WeakL
11	17.1807	90786.8	12.3472	WeakL
12	21.7549	114696	8.89484	WeakL
13	21.7549	111271	8.89484	WeakL
14	22.3665	107432	4.46366	WeakL
15	22.3665	102958	4.46366	WeakL
16	22.3665	112670	4.46366	WeakL
17	22.5412	119445	4.3189	WeakL
18	22.5412	120109	4.3189	WeakL
19	22.5412	124331	4.3189	WeakL
20	22.5412	130358	4.3189	WeakL
21	22.9344	135742	2.28881	WeakL
22	22.9344	139221	2.28881	WeakL
23	22.9344	142906	2.28881	WeakL
24	22.9344	149670	2.28881	WeakL
25	24.8029	168302	4.91045	WeakL
26	24.8029	172483	4.91045	WeakL
27	24.8029	171669	4.91045	WeakL
28	24.8029	166594	4.91045	WeakL
29	24.8029	161519	4.91045	WeakL
30	21.0977	132910	5.88883	WeakL
31	21.0977	142641	5.88883	WeakL
32	21.0977	148114	5.88883	WeakL
33	21.0977	144598	5.88883	WeakL
34	21.0977	141083	5.88883	WeakL
35	21.0977	137568	5.88883	WeakL
36	24.9089	162007	7.46563	WeakL
37	24.9089	167466	7.46563	WeakL
38	24.9089	168459	7.46563	WeakL
39	24.9089	161220	7.46563	WeakL
40	23.6839	150707	4.92318	WeakL
41	23.6839	144212	4.92318	WeakL
42	23.6839	137430	4.92318	WeakL
43	23.6839	139920	4.92318	WeakL
44	21.2547	125399	3.15232	WeakL
45	21.2547	123579	3.15232	WeakL
46	21.2547	126701	3.15232	WeakL
47	9.39524	52061.3	40.0648	
48	23.0206	89773.9	40.0648	
49	8.27194	18385	45.3709	
50	13.8403	11841.8	45.3709	

Interslice Data

Groundwater at Surface - School_phi=13_FS

- **Global Minimum Query (spencer) - Safety Factor: 1.63561**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	713.341	287.541	30728.8	2275.49	4.23506
3	721.611	280.981	59945.3	4438.98	4.23505
4	743.222	268.065	138439	10251.5	4.23506
5	757.154	260.866	194058	14370.1	4.23505
6	774.957	263.032	189144	14006.2	4.23505
7	792.76	265.198	184290	13646.8	4.23506
8	810.059	267.468	178733	13235.3	4.23506
9	827.358	269.738	173262	12830.2	4.23507
10	844.657	272.007	167925	12434.9	4.23504
11	863.568	274.071	164476	12179.5	4.23504
12	882.479	276.135	161030	11924.4	4.23507
13	901.391	278.199	157493	11662.4	4.23504
14	918.571	281.96	144563	10705	4.23507
15	940.326	285.364	135035	9999.43	4.23506
16	962.081	288.769	125873	9320.95	4.23505
17	978.856	290.079	125457	9290.17	4.23506
18	995.631	291.388	125032	9258.68	4.23505
19	1012.41	292.698	124729	9236.24	4.23505
20	1029.18	294.007	124226	9199.01	4.23506
21	1047.21	295.369	123988	9181.4	4.23506
22	1065.25	296.731	123733	9162.51	4.23506
23	1083.28	298.093	123595	9152.29	4.23506
24	1101.31	299.455	123342	9133.52	4.23504
25	1119.35	300.817	123063	9112.86	4.23504
26	1137.69	301.55	126732	9384.59	4.23506
27	1156.04	302.283	130389	9655.35	4.23504
28	1174.39	303.017	134138	9933.02	4.23507
29	1192.74	303.75	137999	10218.9	4.23505
30	1211.08	304.483	142081	10521.2	4.23506
31	1231.75	306.259	140255	10386	4.23507
32	1252.42	308.035	138381	10247.2	4.23506
33	1273.09	309.811	136484	10106.7	4.23505
34	1293.76	311.586	134626	9969.12	4.23505
35	1314.43	313.362	132824	9835.68	4.23505
36	1335.1	315.138	130996	9700.3	4.23504
37	1356.2	317.314	126963	9401.7	4.23506
38	1377.29	319.49	122697	9085.8	4.23506
39	1398.39	321.666	118178	8751.15	4.23506
40	1419.49	323.842	113765	8424.36	4.23505
41	1440.59	326.018	109480	8107.09	4.23507
42	1461.68	328.194	105324	7799.33	4.23507
43	1479.01	330.465	98874	7321.67	4.23505
44	1496.34	332.736	92202.6	6827.65	4.23505
45	1513.67	335.007	85310.7	6317.3	4.23505
46	1531	337.278	78502.7	5813.17	4.23506
47	1548.33	339.549	71942.2	5327.36	4.23505
48	1559.62	348.841	36399.2	2695.38	4.23505
49	1582.28	369.732	-8661.74	-641.406	4.23505
50	1590.63	378.161	-11888.5	-880.353	4.23507
51	1603.44	391.104	0	0	0

Groundwater at Surface - School_phi=13_Ky

- **Global Minimum Query (spencer) - Critical Seismic Coefficient: 0.0627042**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	713.961	287.713	44892	5644.97	7.16707
3	727.568	277.567	106195	13353.6	7.1671
4	759.387	261.138	240201	30204.1	7.16705
5	776.073	263.168	233941	29417.1	7.16709
6	792.76	265.198	227677	28629.4	7.16708
7	818.708	268.603	216873	27270.8	7.16707
8	844.657	272.007	206239	25933.6	7.16706
9	863.568	274.071	201089	25286.1	7.16709
10	882.479	276.135	195936	24638.1	7.16708
11	901.391	278.199	190645	23972.8	7.16708
12	918.571	281.96	176099	22143.7	7.16708
13	940.326	285.364	164439	20677.5	7.16708
14	962.081	288.769	153259	19271.7	7.1671
15	984.448	290.515	150809	18963.6	7.16709
16	1006.81	292.261	148694	18697.6	7.16707
17	1029.18	294.007	145760	18328.7	7.16708
18	1051.72	295.71	143396	18031.3	7.16703
19	1074.26	297.412	140920	17720.1	7.16709
20	1096.8	299.114	138328	17394.1	7.16706
21	1119.35	300.817	135717	17065.8	7.16707
22	1142.28	301.733	138108	17366.5	7.16709
23	1165.21	302.65	140422	17657.4	7.16706
24	1188.15	303.567	142871	17965.3	7.16704
25	1211.08	304.483	145520	18298.5	7.16708
26	1231.75	306.259	141225	17758.4	7.16707
27	1252.42	308.035	136833	17206.2	7.1671
28	1273.09	309.811	132381	16646.3	7.16706
29	1293.76	311.586	128025	16098.6	7.16708
30	1314.43	313.362	123793	15566.5	7.16711
31	1335.1	315.138	119551	15033	7.16707
32	1356.2	317.314	113127	14225.2	7.16706
33	1377.29	319.49	106335	13371.1	7.16704
34	1398.39	321.666	99134.3	12465.7	7.16707
35	1419.49	323.842	92102.8	11581.5	7.16706
36	1440.59	326.018	85277.3	10723.2	7.16705
37	1461.68	328.194	78657.7	9890.85	7.16707
38	1481.61	330.806	68884	8661.85	7.16707
39	1501.54	333.417	58696.7	7380.84	7.16706
40	1521.47	336.028	48339.7	6078.5	7.16707
41	1541.39	338.639	38238.5	4808.32	7.16707
42	1561.32	341.251	28491.6	3582.69	7.16707
43	1585	343.291	23838	2997.52	7.16707
44	1608.69	345.331	19415.6	2441.42	7.16706
45	1632.37	347.371	15201.2	1911.48	7.16706
46	1656.06	349.411	10709	1346.61	7.16708
47	1683.04	350.898	10798.2	1357.83	7.1671
48	1710.03	352.384	11054.2	1390.01	7.16704
49	1734.17	371.023	-26080.7	-3279.52	7.16705
50	1750.43	387.846	-24752.9	-3112.57	7.16708
51	1764.05	401.948	0	0	0

- **Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.60301**
- **Global Minimum Query (gle/morgenstern-price) - Critical Seismic Coefficient: 0.060443**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	712.951	287.433	29588.8	145.428	0.281605
3	733.512	270.461	114977	1459.46	0.727245
4	749.465	259.931	190600	3561.52	1.07049
5	771.112	262.564	184809	4938.27	1.53063
6	792.76	265.198	179127	6198.48	1.98186
7	810.059	267.468	173727	7081.72	2.33428
8	827.358	269.738	168410	7877.36	2.67805
9	844.657	272.007	163223	8588.14	3.0119
10	863.568	274.071	159958	9402.56	3.36406
11	882.479	276.135	156689	10136.4	3.70138
12	901.391	278.199	153330	10782.1	4.02239
13	918.571	281.96	140481	10559.7	4.29873
14	940.326	285.364	131111	10609.3	4.62621
15	962.081	288.769	122104	10525.8	4.92692
16	978.856	290.079	121839	10958.3	5.1394
17	995.631	291.388	121557	11349.8	5.33425
18	1012.41	292.698	121395	11712.1	5.5108
19	1029.18	294.007	121041	12014.5	5.6686
20	1047.21	295.369	120966	12322.6	5.81656
21	1065.25	296.731	120873	12579.8	5.94164
22	1083.28	298.093	120895	12798.9	6.04327
23	1101.31	299.455	120804	12955.4	6.12118
24	1119.35	300.817	120688	13057.8	6.17508
25	1137.69	301.55	124543	13540.7	6.205
26	1156.04	302.283	128380	13968.6	6.20973
27	1174.39	303.017	132309	14348.1	6.18919
28	1192.74	303.75	136347	14676	6.1435
29	1211.08	304.483	140609	14959.4	6.07286
30	1231.75	306.259	138973	14517.6	5.96368
31	1252.42	308.035	137286	14002.4	5.82371
32	1273.09	309.811	135577	13421.4	5.65356
33	1293.76	311.586	133899	12784.8	5.45412
34	1314.43	313.362	132269	12098.7	5.22633
35	1335.1	315.138	130603	11360.5	4.97136
36	1353.18	317.003	127278	10524.4	4.72694
37	1371.27	318.868	123958	9676.69	4.4637
38	1389.35	320.733	120237	8792.78	4.18252
39	1407.43	322.599	116559	7914.62	3.88455
40	1425.52	324.464	112972	7050.11	3.57096
41	1443.6	326.329	109477	6203.06	3.24296
42	1461.68	328.194	106073	5376.91	2.90188
43	1478.85	330.444	99842.7	4476.61	2.56723
44	1496.01	332.693	93398.5	3625.91	2.22322
45	1513.18	334.942	86741.5	2833.68	1.87108
46	1530.35	337.192	80157.5	2115.93	1.51209
47	1547.51	339.441	73811.6	1478.57	1.14758
48	1559.01	349.259	35318.2	555.392	0.900923
49	1579.79	370.037	-10204.7	-80.4479	0.451677
50	1587.83	378.185	-13113.5	-63.4683	0.277305
51	1600.58	391.124	0	0	0

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	712.344	287.264	41704.6	287.956	0.395601
3	727.947	273.539	120887	1888.06	0.894795
4	748.839	259.855	228039	6209.75	1.55984
5	770.799	262.526	220289	8663.47	2.25215
6	792.76	265.198	212672	10902	2.93453
7	818.708	268.603	202523	13181.8	3.72401
8	844.657	272.007	192503	15119	4.49074
9	863.568	274.071	187809	16538.8	5.03259
10	882.479	276.135	183090	17817.5	5.55827
11	901.391	278.199	178222	18939.9	6.06613
12	918.571	281.96	163887	18703.9	6.51081
13	940.326	285.364	152588	18868.8	7.04932
14	962.081	288.769	141741	18807.5	7.55838
15	984.448	290.515	139708	19756.7	8.04907
16	1006.81	292.261	137982	20633.1	8.50469
17	1029.18	294.007	135439	21266	8.92346
18	1051.72	295.71	133466	21871.6	9.30657
19	1074.26	297.412	131364	22334.9	9.64933
20	1096.8	299.114	129134	22654.2	9.95024
21	1119.35	300.817	126880	22848.5	10.2084
22	1142.28	301.733	129694	23864.5	10.4262
23	1165.21	302.65	132420	24776.5	10.5978
24	1188.15	303.567	135273	25615.6	10.7227
25	1211.08	304.483	138323	26387.6	10.8004
26	1235.89	306.614	133521	25545.6	10.8311
27	1260.69	308.745	128642	24554.3	10.8062
28	1285.49	310.876	123612	23414.4	10.7258
29	1310.29	313.007	118821	22215.8	10.5902
30	1335.1	315.138	113954	20914.6	10.4001
31	1356.2	317.314	107722	19374.2	10.1959
32	1377.29	319.49	101136	17748.2	9.9534
33	1398.39	321.666	94151.4	16048.6	9.67339
34	1419.49	323.842	87330.6	14389.8	9.35677
35	1440.59	326.018	80712.5	12790.1	9.0045
36	1461.68	328.194	74298.1	11260.2	8.61784
37	1486.59	331.458	62280	8884.46	8.11867
38	1511.5	334.723	49645.5	6602.7	7.57571
39	1536.41	337.987	37123.6	4552.66	6.99157
40	1561.32	341.251	25270.7	2820.78	6.36914
41	1585	343.291	20918.5	2104.45	5.74476
42	1608.69	345.331	16795.1	1496.43	5.09156
43	1632.37	347.371	12876.4	993.66	4.41272
44	1656.06	349.411	8700.81	564.413	3.71152
45	1677.31	350.582	9090.77	486.937	3.06605
46	1698.56	351.752	9518.66	400.279	2.40799
47	1719.82	352.923	9905.43	300.904	1.73998
48	1729.21	360.825	-12448.6	-313.42	1.44224
49	1752.24	380.186	-34328.1	-424.381	0.708283
50	1760.51	388.565	-29124.1	-225.453	0.443524
51	1774.35	402.586	0	0	0

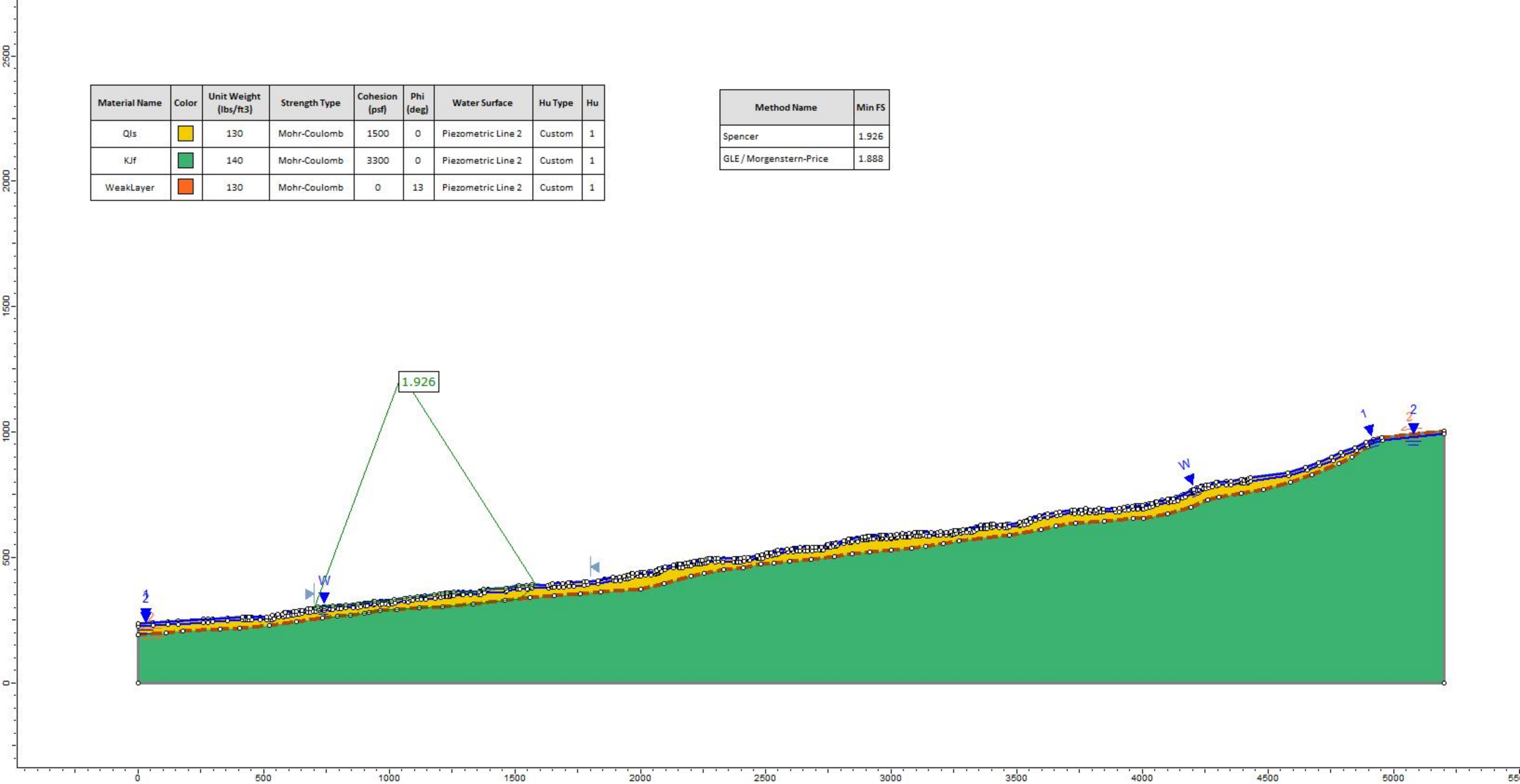
ANALYSIS RUN 1-B

$\phi = 13^{o}$

GW = 13 FEET

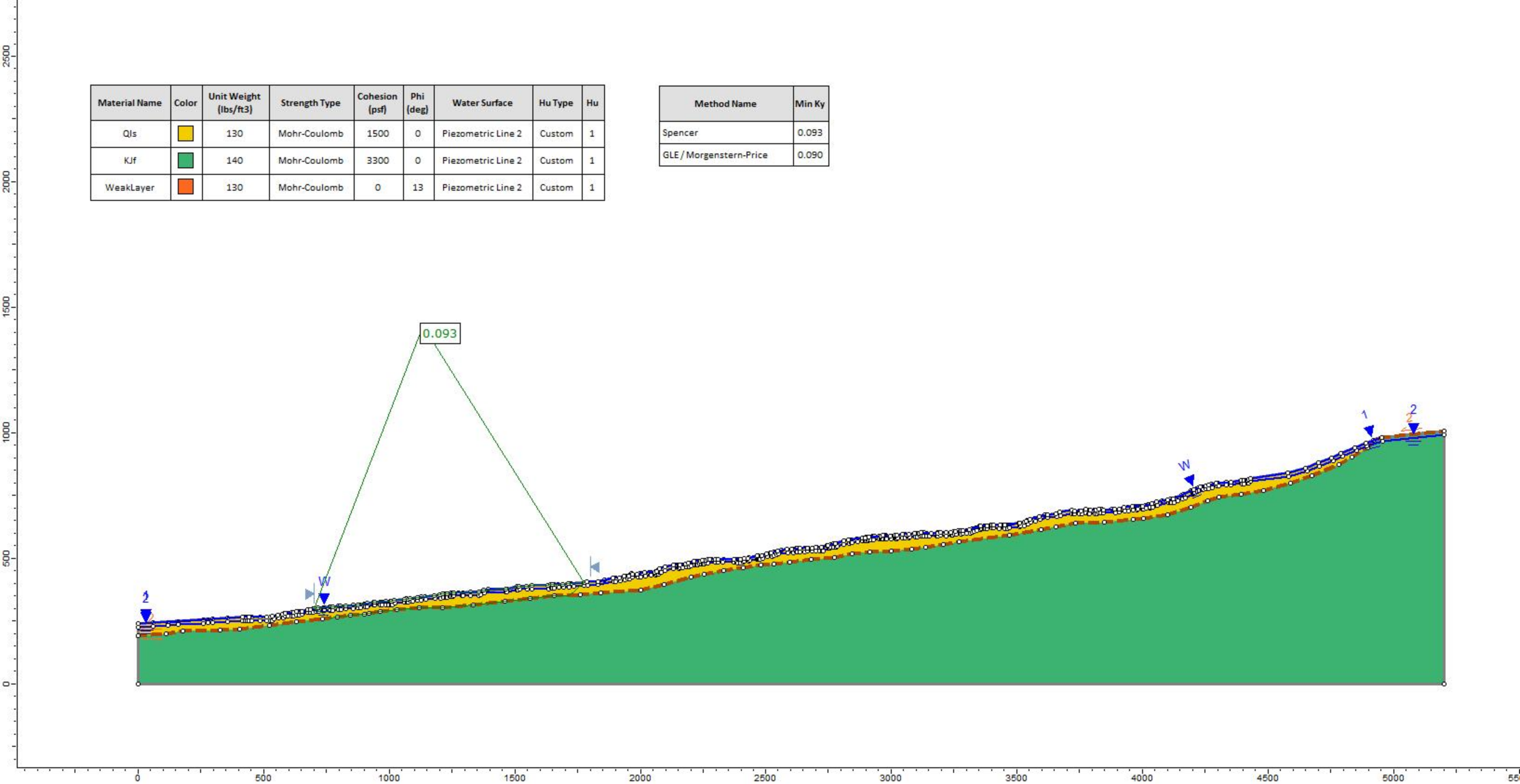
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Qls		130	Mohr-Coulomb	1500	0	Piezometric Line 2	Custom	1
KJf		140	Mohr-Coulomb	3300	0	Piezometric Line 2	Custom	1
WeakLayer		130	Mohr-Coulomb	0	13	Piezometric Line 2	Custom	1

Method Name	Min FS
Spencer	1.926
GLE / Morgenstern-Price	1.888



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Qls		130	Mohr-Coulomb	1500	0	Piezometric Line 2	Custom	1
KJf		140	Mohr-Coulomb	3300	0	Piezometric Line 2	Custom	1
WeakLayer		130	Mohr-Coulomb	0	13	Piezometric Line 2	Custom	1

Method Name	Min Ky
Spencer	0.093
GLE / Morgenstern-Price	0.090



Slide Analysis Information

Slide_xs1_2019-09-06_phi-13

Project Summary

File Name:	Slide_xs1_2019-09-06_phi-13.slmd
Slide Modeler Version:	8.027
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	9/6/2019, 8:16:52 PM

Currently Open Scenarios

Group Name	Scenario Name	Global Minimum	Compute Time
Groundwater at depth 13 ft	School_phi=13_FS	Spencer: 1.926390 Gle/morgenstern-price: 1.887760	00h:00m:17.287s
	School_phi=13_Ky	Spencer: 0.093137 Gle/morgenstern-price: 0.090187	00h:01m:29.129s

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

All Open Scenarios

Slices Type:	Vertical

Analysis Methods Used

	GLE/Morgenstern-Price with interslice force function (Half Sine)
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

All Open Scenarios

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Use negative pore pressure cutoff:	Yes
Maximum negative pore pressure [psf]:	0
Advanced Groundwater Method:	None

Random Numbers

All Open Scenarios

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

All Open Scenarios	
Search Method:	Cuckoo Search
Initial # of Surface Vertices:	8
Maximum Iterations:	500
Number of Nests:	50
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined
Convex Surfaces Only:	Enabled

Seismic Loading

Groundwater at depth 13 ft - School_phi=13_FS		Groundwater at depth 13 ft - School_phi=13_Ky	
Advanced seismic analysis:	No	Advanced seismic analysis:	Yes
Staged pseudostatic analysis:	No	Locate surface with minimum critical horizontal seismic acceleration (Ky):	Yes
		Target factor of safety:	1
		Using Newmark analysis:	No
		Staged pseudostatic analysis:	No

Materials

Property	Qls	KJf	WeakLayer
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	130	140	130
Cohesion [psf]	1500	3300	0
Friction Angle [°]	0	0	13
Water Surface	Assigned per scenario	Assigned per scenario	Assigned per scenario
Hu Value	1	1	1

Materials In Use

Material	School_phi=13_FS	School_phi=13_Ky
Qls	✓	✓
KJf	✓	✓
WeakLayer	✓	✓

Global Minimums

Groundwater at depth 13 ft - School_phi=13_FS

Method: spencer

FS	1.926390
Axis Location:	1049.110, 1229.124
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1584.446, 391.235
Resisting Moment:	8.67567e+08 lb-ft
Driving Moment:	4.50359e+08 lb-ft
Resisting Horizontal Force:	868049 lb
Driving Horizontal Force:	450609 lb
Total Slice Area:	38139 ft2
Surface Horizontal Width:	884.446 ft
Surface Average Height:	43.1219 ft

Method: gle/morgenstern-price

FS	1.887760
Axis Location:	1047.185, 1225.339
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1580.648, 391.261
Resisting Moment:	8.56241e+08 lb-ft
Driving Moment:	4.53576e+08 lb-ft
Resisting Horizontal Force:	858750 lb
Driving Horizontal Force:	454905 lb
Total Slice Area:	38102.1 ft2
Surface Horizontal Width:	880.648 ft
Surface Average Height:	43.266 ft

Groundwater at depth 13 ft - School_phi=13_Ky

Method: spencer

Ky	0.093137
Axis Location:	1132.710, 1424.702
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1774.347, 402.586
Resisting Moment:	1.21283e+09 lb-ft
Driving Moment:	1.21283e+09 lb-ft
Resisting Horizontal Force:	1.02312e+06 lb
Driving Horizontal Force:	1.02312e+06 lb
Total Slice Area:	46861.2 ft2
Surface Horizontal Width:	1074.35 ft
Surface Average Height:	43.6183 ft

Method: gle/morgenstern-price

Ky	0.090187
Axis Location:	1130.181, 1418.750
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1768.575, 402.228
Resisting Moment:	1.19816e+09 lb-ft
Driving Moment:	1.19816e+09 lb-ft
Resisting Horizontal Force:	1.01464e+06 lb
Driving Horizontal Force:	1.01464e+06 lb
Total Slice Area:	46924.3 ft2
Surface Horizontal Width:	1068.57 ft
Surface Average Height:	43.913 ft

Global Minimum Coordinates

Groundwater at depth 13 ft - School_phi=13_FS

Method: spencer

X	Y
700	298.122
729.233	276.826
757.237	262.261
759.436	261.144
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1514.82	335.157
1517.7	336.936
1539.76	351.56
1562.1	368.941
1584.45	391.235

Method: gle/morgenstern-price

X	Y
700	298.122
733.727	270.953
752.415	260.29
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1515.4	335.234
1523.19	341.081
1557.82	368.63
1580.65	391.261

Groundwater at depth 13 ft - School_phi=13_Ky

Method: spencer

X	Y
700	298.122
733.067	278.865
764.401	261.748
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1561.32	341.251
1656.06	349.411
1715.5	352.685
1742.8	371.641
1774.35	402.586

Method: gle/morgenstern-price

X	Y
700	298.122
721.695	279.528
751.97	260.35
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1561.32	341.251
1656.06	349.411
1712.29	352.508
1728.78	364.564
1768.57	402.228

Slice Data

Groundwater at depth 13 ft - School_phi=13_FS

- Global Minimum Query (spencer) - Safety Factor: 1.92639

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	14.1983	12050.8	-36.0735	Qls	1500	0	778.659	1500	1568.24	0	1568.24	1000.98	1000.98
2	15.0345	39332.5	-36.0735	Qls	1500	0	778.659	1500	3443.91	447.071	2996.84	2876.66	2429.58
3	28.0044	124998	-27.4785	Qls	1500	0	778.659	1500	5142.11	1310.91	3831.2	4737.14	3426.23
4	2.19865	12332.3	-26.9457	Qls	1500	0	778.659	1500	6321.18	1889.26	4431.92	5925.36	4036.1
5	16.662	93803.6	6.93654	WeakLayer	0	13	437.674	843.13	5557.66	1905.66	3652	5610.91	3705.25
6	16.662	92736.4	6.93654	WeakLayer	0	13	433.987	836.029	5494.38	1873.14	3621.24	5547.18	3674.04
7	17.2991	95565.8	7.47508	WeakLayer	0	13	431.14	830.544	5445.3	1847.82	3597.48	5501.87	3654.05
8	17.2991	94651.3	7.47508	WeakLayer	0	13	430.208	828.749	5393.02	1803.32	3589.7	5449.47	3646.15
9	17.2991	92689.6	7.47508	WeakLayer	0	13	423.578	815.976	5281.14	1746.76	3534.38	5336.72	3589.96
10	18.9112	98594.4	6.22811	WeakLayer	0	13	420.191	809.451	5156.39	1650.28	3506.11	5202.25	3551.97
11	18.9112	96767.3	6.22811	WeakLayer	0	13	411.89	793.461	5060.85	1624	3436.85	5105.8	3481.8
12	18.9112	99137.2	6.22811	WeakLayer	0	13	420.753	810.534	5184.83	1674.02	3510.81	5230.75	3556.73
13	17.1807	90786.8	12.3472	WeakLayer	0	13	414.204	797.918	5137.28	1681.12	3456.16	5227.95	3546.83
14	21.7549	114696	8.89484	WeakLayer	0	13	415.47	800.358	5175.9	1709.19	3466.71	5240.92	3531.73
15	21.7549	111271	8.89484	WeakLayer	0	13	407.056	784.149	5020.99	1624.49	3396.5	5084.7	3460.21
16	16.7749	81001	4.46366	WeakLayer	0	13	394.368	759.706	4799.48	1508.84	3290.64	4830.27	3321.43
17	16.7749	78436.9	4.46366	WeakLayer	0	13	383.54	738.847	4647.56	1447.26	3200.3	4677.5	3230.24
18	16.7749	77081.1	4.46366	WeakLayer	0	13	385.326	742.288	4567.23	1352.03	3215.2	4597.31	3245.28
19	16.7749	86540.2	4.46366	WeakLayer	0	13	416.567	802.471	5127.69	1651.81	3475.88	5160.21	3508.4
20	18.033	95380.8	4.3189	WeakLayer	0	13	423.43	815.691	5259.34	1726.2	3533.14	5291.31	3565.11
21	18.033	96571.5	4.3189	WeakLayer	0	13	427.074	822.711	5324.98	1761.43	3563.55	5357.24	3595.81
22	18.033	96014.9	4.3189	WeakLayer	0	13	433.58	835.244	5294.33	1676.49	3617.84	5327.07	3650.58
23	18.033	101632	4.3189	WeakLayer	0	13	444.267	855.831	5604.02	1897.02	3707	5637.57	3740.55
24	18.033	104643	4.3189	WeakLayer	0	13	455.01	876.526	5770.02	1973.36	3796.66	5804.38	3831.02
25	18.3475	108316	2.28881	WeakLayer	0	13	468.434	902.386	5903.28	1994.59	3908.69	5922	3927.41
26	18.3475	110542	2.28881	WeakLayer	0	13	471.446	908.189	6024.34	2090.53	3933.81	6043.18	3952.65
27	18.3475	112768	2.28881	WeakLayer	0	13	479.91	924.494	6145.62	2141.18	4004.44	6164.8	4023.62
28	18.3475	115481	2.28881	WeakLayer	0	13	490.502	944.899	6293.43	2200.61	4092.82	6313.03	4112.42
29	18.3475	120433	2.28881	WeakLayer	0	13	510.24	982.921	6563.22	2305.72	4257.5	6583.61	4277.89
30	20.6691	140326	4.91045	WeakLayer	0	13	512.599	987.465	6739.87	2462.68	4277.19	6783.91	4321.23
31	20.6691	142220	4.91045	WeakLayer	0	13	522.335	1006.22	6830.83	2472.4	4358.43	6875.71	4403.31
32	20.6691	144709	4.91045	WeakLayer	0	13	526.591	1014.42	6950.43	2556.49	4393.94	6995.67	4439.18
33	20.6691	141296	4.91045	WeakLayer	0	13	515.315	992.697	6786.44	2486.61	4299.83	6830.71	4344.1
34	20.6691	137771	4.91045	WeakLayer	0	13	505.965	974.686	6617.14	2395.33	4221.81	6660.61	4265.28
35	20.6691	134247	4.91045	WeakLayer	0	13	492.366	948.489	6447.9	2339.52	4108.38	6490.2	4150.68
36	18.0838	114198	5.88883	WeakLayer	0	13	481.571	927.694	6252.36	2234.06	4018.3	6302.03	4067.97
37	18.0838	118533	5.88883	WeakLayer	0	13	513.414	989.036	6489.33	2205.36	4283.97	6542.28	4336.92
38	18.0838	127887	5.88883	WeakLayer	0	13	528.086	1017.3	7002.1	2595.66	4406.44	7056.57	4460.91
39	18.0838	125448	5.88883	WeakLayer	0	13	520.544	1002.77	6868.49	2524.99	4343.5	6922.18	4397.19
40	18.0838	122865	5.88883	WeakLayer	0	13	512.061	986.43	6727.01	2454.33	4272.68	6779.83	4325.5
41	18.0838	120283	5.88883	WeakLayer	0	13	503.577	970.086	6585.59	2383.66	4201.93	6637.53	4253.87
42	18.0838	117700	5.88883	WeakLayer	0	13	495.093	953.743	6444.11	2313	4131.11	6495.18	4182.18
43	17.7111	114641	7.46563	WeakLayer	0	13	493.413	950.506	6381.01	2263.94	4117.07	6445.67	4181.73
44	17.7111	117376	7.46563	WeakLayer	0	13	499.316	961.877	6533.57	2367.2	4166.37	6599	4231.8
45	17.7111	120162	7.46563	WeakLayer	0	13	505.563	973.912	6688.92	2470.45	4218.47	6755.17	4284.72
46	2.8867	19572.8	31.6401	Qls	1500	0	778.659	1500	6066.08	2429.22	3636.86	6545.86	4116.64
47	22.0573	127107	33.5445	Qls	1500	0	778.659	1500	5043.12	1954.47	3088.65	5559.37	3604.9
48	22.3422	85087.7	37.8816	Qls	1500	0	778.659	1500	3074.77	1004.11	2070.66	3680.54	2676.43
49	9.40174	21446.1	44.9376	Qls	1500	0	778.659	1500	1451.08	285.445	1165.64	2228.05	1942.6
50	12.9405	10935.8	44.9376	Qls	1500	0	778.659	1500	120.298	0	120.298	897.263	897.263

G

- Global Mir

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Materi
1	16.611	14065.4	-30.215	
2	16.456	40724.6	-30.215	
3	31.3345	138195	-28.647	
4	28.3582	158373	6.93654	WeakLa
5	25.9486	143006	7.47508	WeakLa
6	25.9486	139900	7.47508	WeakLa
7	18.9112	98594.4	6.22811	WeakLa
8	18.9112	96767.3	6.22811	WeakLa
9	18.9112	99137.2	6.22811	WeakLa
10	17.1807	90786.8	12.3472	WeakLa
11	21.7549	114696	8.89484	WeakLa
12	21.7549	111271	8.89484	WeakLa
13	22.3665	107432	4.46366	WeakLa
14	22.3665	102958	4.46366	WeakLa
15	22.3665	112670	4.46366	WeakLa
16	22.5412	119445	4.3189	WeakLa
17	22.5412	120109	4.3189	WeakLa
18	22.5412	124331	4.3189	WeakLa
19	22.5412	130358	4.3189	WeakLa
20	22.9344	135742	2.28881	WeakLa
21	22.9344	139221	2.28881	WeakLa
22	22.9344	142906	2.28881	WeakLa
23	22.9344	149670	2.28881	WeakLa
24	20.6691	140326	4.91045	WeakLa
25	20.6691	142220	4.91045	WeakLa
26	20.6691	144709	4.91045	WeakLa
27	20.6691	141296	4.91045	WeakLa
28	20.6691	137771	4.91045	WeakLa
29	20.6691	134247	4.91045	WeakLa
30	21.0977	132910	5.88883	WeakLa
31	21.0977	142641	5.88883	WeakLa
32	21.0977	148114	5.88883	WeakLa
33	21.0977	144598	5.88883	WeakLa
34	21.0977	141083	5.88883	WeakLa
35	21.0977	137568	5.88883	WeakLa
36	19.9271	129175	7.46563	WeakLa
37	19.9271	132651	7.46563	WeakLa
38	19.9271	135907	7.46563	WeakLa
39	19.9271	132895	7.46563	WeakLa
40	19.9271	128525	7.46563	WeakLa
41	23.6839	150707	4.92318	WeakLa
42	23.6839	144212	4.92318	WeakLa
43	23.6839	137430	4.92318	WeakLa
44	23.6839	139920	4.92318	WeakLa
45	19.8161	116985	3.15232	WeakLa
46	19.8161	115176	3.15232	WeakLa
47	19.8161	117558	3.15232	WeakLa
48	27.3013	133531	34.7724	
49	17.2161	47177.6	44.4523	
50	14.3266	12262.2	44.4523	

- Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.88776

- Global Minimum

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	13.1882	11209.8	-38.8537	Qls	1500	0	794.593	1500	1501.11	0	1501.11	861.014	861.014
2	20.5385	62190.6	-38.8537	Qls	1500	0	794.593	1500	3732.23	646.633	3085.6	3092.13	2445.5
3	18.6879	92917.6	-29.71	Qls	1500	0	794.593	1500	5554.24	1554.7	3999.54	5100.83	3546.13
4	20.1725	114338	6.93654	WeakLayer	0	13	458.88	866.256	5677.6	1925.42	3752.18	5733.42	3808
5	20.1725	112342	6.93654	WeakLayer	0	13	452.868	854.906	5574.5	1871.51	3702.99	5629.6	3758.09
6	17.2991	95565.8	7.47508	WeakLayer	0	13	448.964	847.536	5518.9	1847.82	3671.08	5577.81	3729.99
7	17.2991	94651.3	7.47508	WeakLayer	0	13	447.358	844.505	5461.28	1803.32	3657.96	5519.97	3716.65
8	17.2991	92689.6	7.47508	WeakLayer	0	13	439.937	830.495	5344.03	1746.76	3597.27	5401.75	3654.99
9	18.9112	98594.4	6.22811	WeakLayer	0	13	435.643	822.389	5212.43	1650.28	3562.15	5259.97	3609.69
10	18.9112	96767.3	6.22811	WeakLayer	0	13	426.674	805.458	5112.82	1624	3488.82	5159.38	3535.38
11	18.9112	99137.2	6.22811	WeakLayer	0	13	435.212	821.575	5232.65	1674.02	3558.63	5280.15	3606.13
12	17.1807	90786.8	12.3472	WeakLayer	0	13	427.622	807.248	5177.7	1681.12	3496.58	5271.3	3590.18
13	21.7549	114696	8.89484	WeakLayer	0	13	428.082	808.116	5209.51	1709.19	3500.32	5276.5	3567.31
14	21.7549	111271	8.89484	WeakLayer	0	13	418.605	790.226	5047.33	1624.49	3422.84	5112.85	3488.36
15	16.7749	81001	4.46366	WeakLayer	0	13	405.922	766.284	4827.98	1508.84	3319.14	4859.66	3350.82
16	16.7749	78436.9	4.46366	WeakLayer	0	13	394.598	744.906	4673.8	1447.26	3226.54	4704.61	3257.35
17	16.7749	77081.1	4.46366	WeakLayer	0	13	396.155	747.845	4591.3	1352.03	3239.27	4622.23	3270.2
18	16.7749	86540.2	4.46366	WeakLayer	0	13	427.694	807.384	5148.97	1651.81	3497.16	5182.36	3530.55
19	18.033	95380.8	4.3189	WeakLayer	0	13	434.405	820.053	5278.23	1726.2	3552.03	5311.04	3584.84
20	18.033	96571.5	4.3189	WeakLayer	0	13	437.766	826.397	5340.95	1761.43	3579.52	5374.01	3612.58
21	18.033	96014.9	4.3189	WeakLayer	0	13	444.075	838.307	5307.59	1676.49	3631.1	5341.13	3664.64
22	18.033	101632	4.3189	WeakLayer	0	13	454.549	858.079	5613.75	1897.02	3716.73	5648.08	3751.06
23	18.033	104643	4.3189	WeakLayer	0	13	465.113	878.022	5776.49	1973.36	3803.13	5811.61	3838.25
24	18.3475	108316	2.28881	WeakLayer	0	13	479.433	905.054	5914.82	1994.59	3920.23	5933.98	3939.39
25	18.3475	110542	2.28881	WeakLayer	0	13	482.074	910.04	6032.35	2090.53	3941.82	6051.61	3961.08
26	18.3475	112768	2.28881	WeakLayer	0	13	490.26	925.494	6149.93	2141.18	4008.75	6169.52	4028.34
27	18.3475	115481	2.28881	WeakLayer	0	13	500.581	944.976	6293.75	2200.61	4093.14	6313.76	4113.15
28	18.3475	120433	2.28881	WeakLayer	0	13	520.21	982.031	6559.35	2305.72	4253.63	6580.15	4274.43
29	17.7163	120469	4.91045	WeakLayer	0	13	521.709	984.862	6731.62	2465.72	4265.9	6776.44	4310.72
30	17.7163	120846	4.91045	WeakLayer	0	13	526.715	994.312	6749.5	2442.64	4306.86	6794.76	4352.12
31	17.7163	124305	4.91045	WeakLayer	0	13	538.829	1017.18	6939.98	2534.12	4405.86	6986.27	4452.15
32	17.7163	122621	4.91045	WeakLayer	0	13	528.451	997.588	6842.58	2521.55	4321.03	6887.98	4366.43
33	17.7163	120032	4.91045	WeakLayer	0	13	518.871	979.504	6694.73	2452.01	4242.72	6739.31	4287.3
34	17.7163	117442	4.91045	WeakLayer	0	13	509.096	961.052	6546.99	2384.2	4162.79	6590.73	4206.53
35	17.7163	114853	4.91045	WeakLayer	0	13	497.405	938.981	6399.42	2332.23	4067.19	6442.16	4109.93
36	18.0838	114198	5.88883	WeakLayer	0	13	486.623	918.627	6213.09	2234.06	3979.03	6263.28	4029.22
37	18.0838	118533	5.88883	WeakLayer	0	13	518.987	979.722	6449.01	2205.36	4243.65	6502.54	4297.18
38	18.0838	127887	5.88883	WeakLayer	0	13	533.887	1007.85	6961.12	2595.66	4365.46	7016.19	4420.53
39	18.0838	125448	5.88883	WeakLayer	0	13	526.173	993.289	6827.4	2524.99	4302.41	6881.67	4356.68
40	18.0838	122865	5.88883	WeakLayer	0	13	517.528	976.969	6686.03	2454.33	4231.7	6739.41	4285.08
41	18.0838	120283	5.88883	WeakLayer	0	13	508.908	960.697	6544.89	2383.66	4161.23	6597.38	4213.72
42	18.0838	117700	5.88883	WeakLayer	0	13	500.311	944.468	6403.96	2313	4090.96	6455.56	4142.56
43	17.907	115924	7.46563	WeakLayer	0	13	499.518	942.971	6348.97	2264.51	4084.46	6414.42	4149.91
44	17.907	118721	7.46563	WeakLayer	0	13	506.124	955.44	6507.38	2368.91	4138.47	6573.71	4204.8
45	17.907	121569	7.46563	WeakLayer	0	13	513.152	968.708	6669.23	2473.31	4195.92	6736.48	4263.17
46	7.78579	50805.1	36.9042	Qls	1500	0	794.593	1500	5803.53	2321.31	3482.22	6400.21	4078.9
47	17.3149	91558.5	38.5033	Qls	1500	0	794.593	1500	4578.71	1726.69	2852.02	5210.83	3484.14
48	17.3149	62126	38.5033	Qls	1500	0	794.593	1500	2931.76	898.044	2033.71	3563.88	2665.84
49	9.75107	21993.4	44.7532	Qls	1500	0	794.593	1500	1465.59	265.841	1199.75	2253.36	1987.52
50	13.0759	11094.7	44.7532	Qls	1500	0	794.593	1500	64.8498	0	64.8498	852.625	852.625

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Materi
1	12.5895	10711.9	-40.5991	
2	9.10582	21906.7	-40.5991	
3	30.2749	131958	-32.3521	
4	20.3948	115420	6.77759	WeakLa
5	20.3948	113509	6.77759	WeakLa
6	25.9486	143006	7.47508	WeakLa
7	25.9486	139900	7.47508	WeakLa
8	18.9112	98594.4	6.22811	WeakLa
9	18.9112	96767.3	6.22811	WeakLa
10	18.9112	99137.2	6.22811	WeakLa
11	17.1807	90786.8	12.3472	WeakLa
12	21.7549	114696	8.89484	WeakLa
13	21.7549	111271	8.89484	WeakLa
14	22.3665	107432	4.46366	WeakLa
15	22.3665	102958	4.46366	WeakLa
16	22.3665	112670	4.46366	WeakLa
17	22.5412	119445	4.3189	WeakLa
18	22.5412	120109	4.3189	WeakLa
19	22.5412	124331	4.3189	WeakLa
20	22.5412	130358	4.3189	WeakLa
21	22.9344	135742	2.28881	WeakLa
22	22.9344	139221	2.28881	WeakLa
23	22.9344	142906	2.28881	WeakLa
24	22.9344	149670	2.28881	WeakLa
25	24.8029	168302	4.91045	WeakLa
26	24.8029	172483	4.91045	WeakLa
27	24.8029	171669	4.91045	WeakLa
28	24.8029	166594	4.91045	WeakLa
29	24.8029	161519	4.91045	WeakLa
30	21.0977	132910	5.88883	WeakLa
31	21.0977	142641	5.88883	WeakLa
32	21.0977	148114	5.88883	WeakLa
33	21.0977	144598	5.88883	WeakLa
34	21.0977	141083	5.88883	WeakLa
35	21.0977	137568	5.88883	WeakLa
36	19.9271	129175	7.46563	WeakLa
37	19.9271	132651	7.46563	WeakLa
38	19.9271	135907	7.46563	WeakLa
39	19.9271	132895	7.46563	WeakLa
40	19.9271	128525	7.46563	WeakLa
41	23.6839	150707	4.92318	WeakLa
42	23.6839	144212	4.92318	WeakLa
43	23.6839	137430	4.92318	WeakLa
44	23.6839	139920	4.92318	WeakLa
45	18.7459	110718	3.15232	WeakLa
46	18.7459	108989	3.15232	WeakLa
47	18.7459	110713	3.15232	WeakLa
48	16.4908	87285.4	36.169	
49	24.8375	78181.8	43.4271	
50	14.9535	12857.1	43.4271	

Interslice Data

Groundwater at depth 13 ft - School_phi=13_FS

- **Global Minimum Query (spencer) - Safety Factor: 1.92639**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	714.198	287.779	27276.7	2161.38	4.5306
3	729.233	276.826	76703.3	6077.9	4.5306
4	757.237	262.261	173403	13740.3	4.5306
5	759.436	261.144	182180	14435.8	4.53061
6	776.098	263.171	178206	14120.9	4.5306
7	792.76	265.198	174300	13811.4	4.53061
8	810.059	267.468	169398	13423	4.53062
9	827.358	269.738	164599	13042.7	4.53061
10	844.657	272.007	159940	12673.5	4.5306
11	863.568	274.071	157244	12459.9	4.53061
12	882.479	276.135	154589	12249.5	4.5306
13	901.391	278.199	151845	12032.1	4.53061
14	918.571	281.96	139641	11065	4.53059
15	940.326	285.364	131057	10384.9	4.53063
16	962.081	288.769	122818	9731.95	4.53058
17	978.856	290.079	123148	9758.14	4.5306
18	995.631	291.388	123496	9785.7	4.53059
19	1012.41	292.698	123979	9823.97	4.53059
20	1029.18	294.007	124252	9845.62	4.5306
21	1047.21	295.369	124725	9883.1	4.5306
22	1065.25	296.731	125175	9918.71	4.53058
23	1083.28	298.093	125783	9966.93	4.5306
24	1101.31	299.455	126162	9996.99	4.53061
25	1119.35	300.817	126510	10024.5	4.53058
26	1137.69	301.55	130775	10362.5	4.5306
27	1156.04	302.283	135007	10697.8	4.53059
28	1174.39	303.017	139306	11038.4	4.53057
29	1192.74	303.75	143690	11385.9	4.53061
30	1211.08	304.483	148239	11746.3	4.53059
31	1231.75	306.259	146865	11637.5	4.53062
32	1252.42	308.035	145532	11531.8	4.53059
33	1273.09	309.811	144073	11416.2	4.53059
34	1293.76	311.586	142673	11305.3	4.53061
35	1314.43	313.362	141381	11202.9	4.5306
36	1335.1	315.138	140108	11102	4.53059
37	1353.18	317.003	137154	10868	4.53062
38	1371.27	318.868	134335	10644.6	4.53061
39	1389.35	320.733	130824	10366.4	4.53061
40	1407.43	322.599	127426	10097.1	4.53059
41	1425.52	324.464	124139	9836.66	4.5306
42	1443.6	326.329	120962	9584.93	4.5306
43	1461.68	328.194	117896	9341.94	4.53058
44	1479.4	330.515	111825	8860.89	4.53059
45	1497.11	332.836	105505	8360.08	4.53058
46	1514.82	335.157	98934.3	7839.46	4.5306
47	1517.7	336.936	90392.3	7162.6	4.5306
48	1539.76	351.56	33816.8	2679.61	4.53059
49	1562.1	368.941	-2230.06	-176.708	4.5306
50	1571.51	378.322	-8522.3	-675.299	4.5306
51	1584.45	391.235	0	0	0

Groundwater at depth 13 ft - School_phi=13_Ky

- **Global Minimum Query (spencer) - Critical Seismic Coefficient: 0.0931375**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	716.611	288.449	44452	7219.02	9.22432
3	733.067	278.865	102965	16721.5	9.2243
4	764.401	261.748	238653	38757.3	9.22432
5	792.76	265.198	228480	37105.2	9.22432
6	818.708	268.603	218073	35415.1	9.22432
7	844.657	272.007	207930	33767.9	9.22432
8	863.568	274.071	203253	33008.3	9.22431
9	882.479	276.135	198643	32259.7	9.22433
10	901.391	278.199	193876	31485.5	9.22431
11	918.571	281.96	179777	29195.9	9.22434
12	940.326	285.364	168710	27398.5	9.2243
13	962.081	288.769	158142	25682.2	9.22428
14	984.448	290.515	156558	25425.1	9.22433
15	1006.81	292.261	155490	25251.6	9.22431
16	1029.18	294.007	153895	24992.6	9.22432
17	1051.72	295.71	152060	24694.6	9.22432
18	1074.26	297.412	150102	24376.5	9.22428
19	1096.8	299.114	147963	24029.3	9.22435
20	1119.35	300.817	145564	23639.7	9.22434
21	1142.28	301.733	148127	24055.9	9.22433
22	1165.21	302.65	150482	24438.3	9.22431
23	1188.15	303.567	152859	24824.3	9.2243
24	1211.08	304.483	155256	25213.6	9.22431
25	1231.75	306.259	150412	24426.9	9.2243
26	1252.42	308.035	145616	23648	9.22429
27	1273.09	309.811	140539	22823.5	9.22429
28	1293.76	311.586	135628	22026	9.22431
29	1314.43	313.362	130980	21271.2	9.22432
30	1335.1	315.138	126425	20531.5	9.22434
31	1356.2	317.314	119795	19454.8	9.22435
32	1377.29	319.49	113073	18363	9.22428
33	1398.39	321.666	105259	17094	9.22427
34	1419.49	323.842	97735.6	15872.3	9.22433
35	1440.59	326.018	90503.9	14697.8	9.22428
36	1461.68	328.194	83563.2	13570.7	9.22433
37	1481.61	330.806	73579	11949.2	9.22428
38	1501.54	333.417	63071.8	10242.9	9.22434
39	1521.47	336.028	52275.2	8489.51	9.22432
40	1541.39	338.639	41754.8	6780.99	9.22432
41	1561.32	341.251	31750.2	5156.24	9.22432
42	1585	343.291	26841.9	4359.12	9.22429
43	1608.69	345.331	22381.9	3634.83	9.22433
44	1632.37	347.371	18356	2981.02	9.22432
45	1656.06	349.411	14111	2291.63	9.22432
46	1675.87	350.502	14394.3	2337.64	9.22433
47	1695.69	351.594	14648.1	2378.86	9.22434
48	1715.5	352.685	14932	2424.96	9.22432
49	1742.8	371.641	-25017.9	-4062.91	9.22431
50	1760.02	388.531	-25016.8	-4062.74	9.22433
51	1774.35	402.586	0	0	0

- **Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.88776**
- **Global Minimum Query (gle/morgenstern-price) - Critical Seismic Coefficient: 0.0901866**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	713.188	287.498	26427.9	144.841	0.314013
3	733.727	270.953	104499	1461.64	0.801351
4	752.415	260.29	178579	3868.58	1.24101
5	772.587	262.744	173902	5189.24	1.7092
6	792.76	265.198	169358	6412.27	2.16831
7	810.059	267.468	164598	7339	2.55298
8	827.358	269.738	159942	8179.84	2.9277
9	844.657	272.007	155423	8937.32	3.29107
10	863.568	274.071	152905	9817.29	3.67364
11	882.479	276.135	150423	10622.1	4.03923
12	901.391	278.199	147854	11341	4.38623
13	918.571	281.96	135730	11120.8	4.68397
14	940.326	285.364	127306	11217.2	5.03545
15	962.081	288.769	119229	11178.9	5.35639
16	978.856	290.079	119717	11700	5.58182
17	995.631	291.388	120216	12184.1	5.78726
18	1012.41	292.698	120850	12642.1	5.97198
19	1029.18	294.007	121282	13037.2	6.13545
20	1047.21	295.369	121928	13432.2	6.28664
21	1065.25	296.731	122550	13772.1	6.41197
22	1083.28	298.093	123330	14075.7	6.51102
23	1101.31	299.455	123882	14297	6.58328
24	1119.35	300.817	124403	14456.7	6.62853
25	1137.69	301.55	128863	15016.4	6.6467
26	1156.04	302.283	133285	15507.9	6.63661
27	1174.39	303.017	137771	15936.7	6.59838
28	1192.74	303.75	142341	16298.6	6.53214
29	1211.08	304.483	147076	16596.3	6.43812
30	1228.8	306.005	146074	16181.8	6.32134
31	1246.52	307.527	145133	15713.9	6.17948
32	1264.23	309.049	144117	15180.4	6.01301
33	1281.95	310.572	143065	14589.1	5.82263
34	1299.66	312.094	142068	13952.4	5.60899
35	1317.38	313.616	141123	13272.8	5.37294
36	1335.1	315.138	140196	12550	5.11534
37	1353.18	317.003	137408	11613.9	4.83123
38	1371.27	318.868	134765	10669.8	4.52686
39	1389.35	320.733	131437	9660.12	4.20346
40	1407.43	322.599	128218	8656.45	3.86238
41	1425.52	324.464	125107	7662.75	3.50496
42	1443.6	326.329	122103	6682.82	3.13273
43	1461.68	328.194	119207	5720.09	2.7472
44	1479.59	330.541	113254	4655.58	2.35396
45	1497.5	332.887	107048	3646.32	1.95088
46	1515.4	335.234	100588	2703.66	1.53966
47	1523.19	341.081	72844	1727.8	1.35875
48	1540.51	354.855	23534.1	391.393	0.952792
49	1557.82	368.63	-3090	-29.2907	0.543101
50	1567.57	378.297	-9509.66	-51.6753	0.311341
51	1580.65	391.261	0	0	0

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	712.589	287.332	41284.4	365.437	0.507152
3	721.695	279.528	82542.1	1258.53	0.873528
4	751.97	260.35	222191	8089.21	2.08502
5	772.365	262.774	215746	10897	2.89146
6	792.76	265.198	209479	13496.5	3.68641
7	818.708	268.603	199934	16354.4	4.67633
8	844.657	272.007	190601	18810.9	5.63641
9	863.568	274.071	186522	20638.4	6.31401
10	882.479	276.135	182486	22311.2	6.97053
11	901.391	278.199	178280	23800.2	7.60397
12	918.571	281.96	164472	23577.2	8.15782
13	940.326	285.364	153895	23899.5	8.82737
14	962.081	288.769	143783	23955.4	9.45905
15	984.448	290.515	142764	25344.4	10.0666
16	1006.81	292.261	142228	26693	10.6295
17	1029.18	294.007	141173	27813.5	11.1455
18	1051.72	295.71	139879	28754.8	11.6164
19	1074.26	297.412	138440	29517.9	12.0363
20	1096.8	299.114	136809	30088.5	12.4036
21	1119.35	300.817	134909	30445.9	12.7173
22	1142.28	301.733	138054	31822.6	12.9804
23	1165.21	302.65	140976	33029.3	13.186
24	1188.15	303.567	143905	34106.7	13.3336
25	1211.08	304.483	146848	35045.2	13.4225
26	1235.89	306.614	141516	33851	13.4525
27	1260.69	308.745	136046	32445	13.4137
28	1285.49	310.876	130476	30857.6	13.306
29	1310.29	313.007	125260	29218	13.13
30	1335.1	315.138	120120	27480.6	12.8862
31	1356.2	317.314	113767	25484.5	12.6262
32	1377.29	319.49	107347	23441.8	12.3185
33	1398.39	321.666	99843.2	21157	11.9641
34	1419.49	323.842	92624.4	18952.4	11.564
35	1440.59	326.018	85692.3	16842.1	11.1193
36	1461.68	328.194	79048.3	14838.3	10.6314
37	1481.61	330.806	69365.8	12396.2	10.1322
38	1501.54	333.417	59184.1	10007.5	9.59742
39	1521.47	336.028	48739.2	7744.37	9.02848
40	1541.39	338.639	38579.9	5715.69	8.42719
41	1561.32	341.251	28942.2	3962.23	7.79542
42	1585	343.291	24456.1	3006.2	7.00777
43	1608.69	345.331	20411.8	2211.57	6.18374
44	1632.37	347.371	16792.7	1565.88	5.32729
45	1656.06	349.411	12979.4	1008.44	4.44269
46	1674.8	350.444	13555.8	882.691	3.72558
47	1693.55	351.476	14059	735.812	2.99598
48	1712.29	352.508	14636.9	576.702	2.25632
49	1728.78	364.564	-18294.3	-510.771	1.59926
50	1753.62	388.074	-28907.7	-303.902	0.602319
51	1768.57	402.228	0	0	0

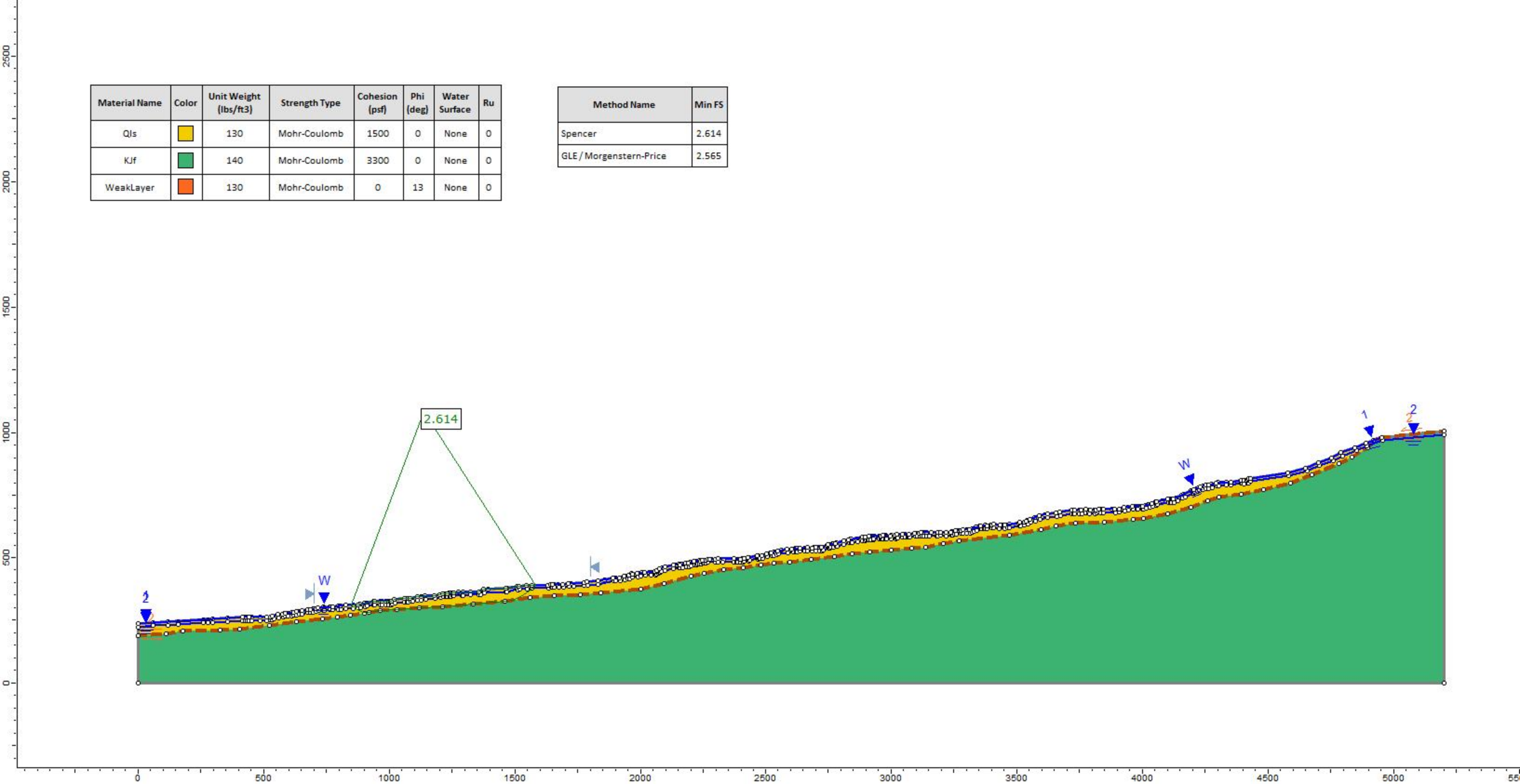
ANALYSIS RUN 1-C

$\phi = 13^{o}$

GW = NO GROUNDWATER

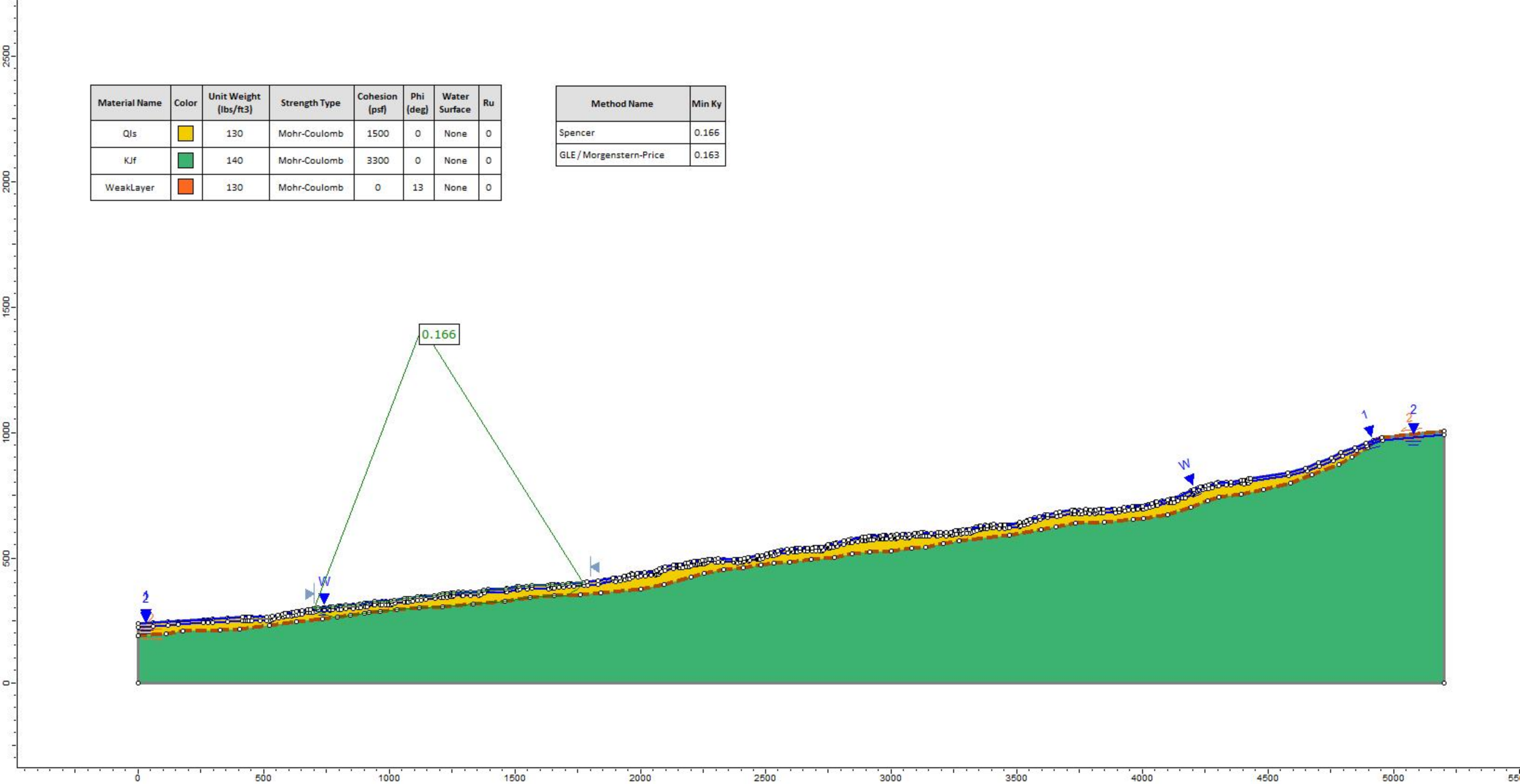
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Ru
Qls		130	Mohr-Coulomb	1500	0	None	0
KJf		140	Mohr-Coulomb	3300	0	None	0
WeakLayer		130	Mohr-Coulomb	0	13	None	0

Method Name	Min FS
Spencer	2.614
GLE / Morgenstern-Price	2.565



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Ru
Qls		130	Mohr-Coulomb	1500	0	None	0
KJf		140	Mohr-Coulomb	3300	0	None	0
WeakLayer		130	Mohr-Coulomb	0	13	None	0

Method Name	Min Ky
Spencer	0.166
GLE / Morgenstern-Price	0.163



Slide Analysis Information

Slide_xs1_2019-09-06_phi-13

Project Summary

File Name:	Slide_xs1_2019-09-06_phi-13.slmd
Slide Modeler Version:	8.027
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	9/6/2019, 8:16:52 PM

Currently Open Scenarios

Group Name	Scenario Name	Global Minimum	Compute Time
No Groundwater	School_phi=13_FS	Spencer: 2.613980 Gle/morgenstern-price: 2.565150	00h:00m:19.933s
	School_phi=13_Ky	Spencer: 0.166374 Gle/morgenstern-price: 0.163087	00h:01m:30.213s

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

All Open Scenarios

Slices Type:	Vertical
Analysis Methods Used	
	GLE/Morgenstern-Price with interslice force function (Half Sine)
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

All Open Scenarios

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Use negative pore pressure cutoff:	Yes
Maximum negative pore pressure [psf]:	0
Advanced Groundwater Method:	None

Random Numbers

All Open Scenarios

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

All Open Scenarios	
Search Method:	Cuckoo Search
Initial # of Surface Vertices:	8
Maximum Iterations:	500
Number of Nests:	50
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined
Convex Surfaces Only:	Enabled

Seismic Loading

No Groundwater - School_phi=13_FS		No Groundwater - School_phi=13_Ky	
Advanced seismic analysis:	No	Advanced seismic analysis:	Yes
Staged pseudostatic analysis:	No	Locate surface with minimum critical horizontal seismic acceleration (Ky):	Yes
		Target factor of safety:	1
		Using Newmark analysis:	No
		Staged pseudostatic analysis:	No

Materials

Property	Qls	KJf	WeakLayer
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	130	140	130
Cohesion [psf]	1500	3300	0
Friction Angle [°]	0	0	13
Water Surface	Assigned per scenario	Assigned per scenario	Assigned per scenario
Ru Value	0	0	0

Materials In Use

Material	School_phi=13_FS	School_phi=13_Ky
Qls	✓	✓
KJf	✓	✓
WeakLayer	✓	✓

Global Minimums

No Groundwater - School_phi=13_FS

Method: spencer

FS	2.613980
Axis Location:	1137.207, 1084.572
Left Slip Surface Endpoint:	849.337, 312.865
Right Slip Surface Endpoint:	1581.851, 391.253
Resisting Moment:	8.56254e+08 lb-ft
Driving Moment:	3.27568e+08 lb-ft
Resisting Horizontal Force:	1.03739e+06 lb
Driving Horizontal Force:	396862 lb
Total Slice Area:	31506.4 ft2
Surface Horizontal Width:	732.513 ft
Surface Average Height:	43.0114 ft

Method: gle/morgenstern-price

FS	2.565150
Axis Location:	1134.120, 1085.725
Left Slip Surface Endpoint:	845.847, 312.662
Right Slip Surface Endpoint:	1579.606, 391.268
Resisting Moment:	8.56819e+08 lb-ft
Driving Moment:	3.34023e+08 lb-ft
Resisting Horizontal Force:	1.03483e+06 lb
Driving Horizontal Force:	403417 lb
Total Slice Area:	31781.7 ft2
Surface Horizontal Width:	733.76 ft
Surface Average Height:	43.3135 ft

No Groundwater - School_phi=13_Ky

Method: spencer

Ky	0.166374
Axis Location:	1131.781, 1422.515
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1772.226, 402.454
Resisting Moment:	1.70048e+09 lb-ft
Driving Moment:	1.70048e+09 lb-ft
Resisting Horizontal Force:	1.46629e+06 lb
Driving Horizontal Force:	1.46629e+06 lb
Total Slice Area:	46579.3 ft2
Surface Horizontal Width:	1072.23 ft
Surface Average Height:	43.4417 ft

Method: gle/morgenstern-price

Ky	0.163087
Axis Location:	1057.773, 1246.157
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1601.537, 391.118
Resisting Moment:	1.2279e+09 lb-ft
Driving Moment:	1.2279e+09 lb-ft
Resisting Horizontal Force:	1.23477e+06 lb
Driving Horizontal Force:	1.23477e+06 lb
Total Slice Area:	38889 ft2
Surface Horizontal Width:	901.537 ft
Surface Average Height:	43.1363 ft

Global Minimum Coordinates

No Groundwater - School_phi=13_FS

Method: spencer

X	Y
849.337	312.865
867.698	298.427
886.059	287.743
911.396	280.389
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1494.04	332.435
1510.34	339.094
1534.18	351.869
1558.01	368.199
1581.85	391.253

Method: gle/morgenstern-price

X	Y
845.847	312.662
863.657	297.244
881.468	283.392
894.639	277.462
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1499.29	333.122
1500.48	333.695
1518.42	342.318
1549.73	362.738
1564.67	376.737
1579.61	391.268

No Groundwater - School_phi=13_Ky

Method: spencer

X	Y
700	298.122
728.191	280.089
776.798	263.256
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1561.32	341.251
1656.06	349.411
1704.3	352.068
1748.22	377.474
1772.23	402.454

Method: gle/morgenstern-price

X	Y
700	298.122
732.768	270.753
758.738	261.059
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1504.54	333.811
1518.93	338.054
1557.38	354.702
1579.46	371.896
1601.54	391.118

Slice Data

No Groundwater - School_phi=13_FS

- Global Minimum Query (spencer) - Safety Factor: 2.61398

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	0.647084	22.9888	-38.1808	Qls	1500	0	573.838	1500	575.066	0	575.066	123.812	123.812
2	15.2514	13854.4	-38.1808	Qls	1500	0	573.838	1500	1511.28	0	1511.28	1060.03	1060.03
3	2.46204	4630.89	-38.1808	Qls	1500	0	573.838	1500	2554.38	0	2554.38	2103.12	2103.12
4	18.3608	52147.4	-30.1935	Qls	1500	0	573.838	1500	3393.3	0	3393.3	3059.41	3059.41
5	12.6685	52156.3	-16.1862	Qls	1500	0	573.838	1500	4443.92	0	4443.92	4277.36	4277.36
6	12.6685	61952.9	-16.1862	Qls	1500	0	573.838	1500	5237.03	0	5237.03	5070.47	5070.47
7	7.17563	37732.9	12.3472	WeakLayer	0	13	450.654	1178	5102.5	0	5102.5	5201.15	5201.15
8	14.5033	76308.6	8.89484	WeakLayer	0	13	455.723	1191.25	5159.88	0	5159.88	5231.2	5231.2
9	14.5033	76487	8.89484	WeakLayer	0	13	456.79	1194.04	5171.94	0	5171.94	5243.43	5243.43
10	14.5033	73171.5	8.89484	WeakLayer	0	13	436.989	1142.28	4947.75	0	4947.75	5016.14	5016.14
11	16.7749	81001	4.46366	WeakLayer	0	13	423.924	1108.13	4799.85	0	4799.85	4832.95	4832.95
12	16.7749	78436.9	4.46366	WeakLayer	0	13	410.504	1073.05	4647.91	0	4647.91	4679.95	4679.95
13	16.7749	77081.1	4.46366	WeakLayer	0	13	403.412	1054.51	4567.57	0	4567.57	4599.07	4599.07
14	16.7749	86540.2	4.46366	WeakLayer	0	13	452.915	1183.91	5128.09	0	5128.09	5163.45	5163.45
15	15.0275	79386.9	4.3189	WeakLayer	0	13	463.994	1212.87	5253.51	0	5253.51	5288.56	5288.56
16	15.0275	80358.5	4.3189	WeakLayer	0	13	469.675	1227.72	5317.82	0	5317.82	5353.29	5353.29
17	15.0275	79808.2	4.3189	WeakLayer	0	13	466.457	1219.31	5281.4	0	5281.4	5316.62	5316.62
18	15.0275	81927	4.3189	WeakLayer	0	13	478.841	1251.68	5421.61	0	5421.61	5457.78	5457.78
19	15.0275	85376.2	4.3189	WeakLayer	0	13	498.998	1304.37	5649.86	0	5649.86	5687.55	5687.55
20	15.0275	87385.6	4.3189	WeakLayer	0	13	510.742	1335.07	5782.84	0	5782.84	5821.41	5821.41
21	15.2896	90108.4	2.28881	WeakLayer	0	13	520.842	1361.47	5897.16	0	5897.16	5917.98	5917.98
22	15.2896	91654.4	2.28881	WeakLayer	0	13	529.775	1384.82	5998.34	0	5998.34	6019.51	6019.51
23	15.2896	93200.3	2.28881	WeakLayer	0	13	538.711	1408.18	6099.51	0	6099.51	6121.04	6121.04
24	15.2896	94748.7	2.28881	WeakLayer	0	13	547.663	1431.58	6200.85	0	6200.85	6222.74	6222.74
25	15.2896	97029.1	2.28881	WeakLayer	0	13	560.842	1466.03	6350.08	0	6350.08	6372.5	6372.5
26	15.2896	100798	2.28881	WeakLayer	0	13	582.629	1522.98	6596.74	0	6596.74	6620.02	6620.02
27	17.7163	120469	4.91045	WeakLayer	0	13	596.168	1558.37	6750.07	0	6750.07	6801.29	6801.29
28	17.7163	120846	4.91045	WeakLayer	0	13	598.034	1563.25	6771.21	0	6771.21	6822.59	6822.59
29	17.7163	124305	4.91045	WeakLayer	0	13	615.154	1608	6965.01	0	6965.01	7017.86	7017.86
30	17.7163	122621	4.91045	WeakLayer	0	13	606.818	1586.21	6870.64	0	6870.64	6922.77	6922.77
31	17.7163	120032	4.91045	WeakLayer	0	13	594.006	1552.72	6725.55	0	6725.55	6776.58	6776.58
32	17.7163	117442	4.91045	WeakLayer	0	13	581.19	1519.22	6580.45	0	6580.45	6630.39	6630.39
33	17.7163	114853	4.91045	WeakLayer	0	13	568.378	1485.73	6435.36	0	6435.36	6484.19	6484.19
34	15.8233	100111	5.88883	WeakLayer	0	13	553.046	1445.65	6261.78	0	6261.78	6318.82	6318.82
35	15.8233	101422	5.88883	WeakLayer	0	13	560.284	1464.57	6343.78	0	6343.78	6401.57	6401.57
36	15.8233	111376	5.88883	WeakLayer	0	13	615.28	1608.33	6966.46	0	6966.46	7029.92	7029.92
37	15.8233	110756	5.88883	WeakLayer	0	13	611.849	1599.36	6927.61	0	6927.61	6990.71	6990.71
38	15.8233	108778	5.88883	WeakLayer	0	13	600.927	1570.81	6803.95	0	6803.95	6865.93	6865.93
39	15.8233	106801	5.88883	WeakLayer	0	13	590.001	1542.25	6680.23	0	6680.23	6741.09	6741.09
40	15.8233	104824	5.88883	WeakLayer	0	13	579.079	1513.7	6556.58	0	6556.58	6616.31	6616.31
41	15.8233	102846	5.88883	WeakLayer	0	13	568.157	1485.15	6432.86	0	6432.86	6491.46	6491.46
42	16.1794	104621	7.46563	WeakLayer	0	13	562.533	1470.45	6369.22	0	6369.22	6442.93	6442.93
43	16.1794	106895	7.46563	WeakLayer	0	13	574.756	1502.4	6507.59	0	6507.59	6582.91	6582.91
44	16.301	105256	22.2221	Qls	1500	0	573.838	1500	6058.99	0	6058.99	6293.43	6293.43
45	11.9178	70838	28.1896	Qls	1500	0	573.838	1500	5435.08	0	5435.08	5742.63	5742.63
46	11.9178	61800.1	28.1896	Qls	1500	0	573.838	1500	4710.15	0	4710.15	5017.7	5017.7
47	11.9177	50930.3	34.4156	Qls	1500	0	573.838	1500	3710.96	0	3710.96	4104.11	4104.11
48	11.9177	39431.3	34.4156	Qls	1500	0	573.838	1500	2799.81	0	2799.81	3192.96	3192.96
49	10.493	24005	44.0437	Qls	1500	0	573.838	1500	1645.2	0	1645.2	2200.19	2200.19
50	13.3431	11271.9	44.0437	Qls	1500	0	573.838	1500	313.094	0	313.094	868.09	868.09

- Global M

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Bas Mate
1	15.5728	13197.6	-32.6068	
2	12.6185	30113.4	-32.6068	
3	24.3032	87871	-19.101	
4	24.3032	119425	-19.101	
5	15.9619	88829.7	6.93654	Weakl
6	25.9486	143006	7.47508	Weakl
7	25.9486	139900	7.47508	Weakl
8	18.9112	98594.4	6.22811	Weakl
9	18.9112	96767.3	6.22811	Weakl
10	18.9112	99137.2	6.22811	Weakl
11	17.1807	90786.8	12.3472	Weakl
12	21.7549	114696	8.89484	Weakl
13	21.7549	111271	8.89484	Weakl
14	22.3665	107432	4.46366	Weakl
15	22.3665	102958	4.46366	Weakl
16	22.3665	112670	4.46366	Weakl
17	22.5412	119445	4.3189	Weakl
18	22.5412	120109	4.3189	Weakl
19	22.5412	124331	4.3189	Weakl
20	22.5412	130358	4.3189	Weakl
21	22.9344	135742	2.28881	Weakl
22	22.9344	139221	2.28881	Weakl
23	22.9344	142906	2.28881	Weakl
24	22.9344	149670	2.28881	Weakl
25	24.8029	168302	4.91045	Weakl
26	24.8029	172483	4.91045	Weakl
27	24.8029	171669	4.91045	Weakl
28	24.8029	166594	4.91045	Weakl
29	24.8029	161519	4.91045	Weakl
30	21.0977	132910	5.88883	Weakl
31	21.0977	142641	5.88883	Weakl
32	21.0977	148114	5.88883	Weakl
33	21.0977	144598	5.88883	Weakl
34	21.0977	141083	5.88883	Weakl
35	21.0977	137568	5.88883	Weakl
36	19.9271	129175	7.46563	Weakl
37	19.9271	132651	7.46563	Weakl
38	19.9271	135907	7.46563	Weakl
39	19.9271	132895	7.46563	Weakl
40	19.9271	128525	7.46563	Weakl
41	23.6839	150707	4.92318	Weakl
42	23.6839	144212	4.92318	Weakl
43	23.6839	137430	4.92318	Weakl
44	23.6839	139920	4.92318	Weakl
45	24.1215	142137	3.15232	Weakl
46	24.1215	140614	3.15232	Weakl
47	21.9629	115299	30.0448	
48	21.9629	83269.2	30.0448	
49	10.5371	25117.4	46.1437	
50	13.4652	11535.2	46.1437	

- Global Minimum Query (gle/morgenstern-price) - Safety Factor: 2.56515
- Global Minimun

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	0.499677	14.9948	-40.8818	Qls	1500	0	584.761	1500	536.512	0	536.512	30.3011	30.3011
2	14.2366	13026.8	-40.8818	Qls	1500	0	584.761	1500	1435.7	0	1435.7	929.488	929.488
3	3.07443	6009.5	-40.8818	Qls	1500	0	584.761	1500	2500.6	0	2500.6	1994.39	1994.39
4	17.8108	55754.7	-37.8731	Qls	1500	0	584.761	1500	3667.73	0	3667.73	3212.94	3212.94
5	13.1713	62273.7	-24.2367	Qls	1500	0	584.761	1500	5114.77	0	5114.77	4851.52	4851.52
6	6.75123	35765.9	6.22811	WeakLayer	0	13	478.046	1226.26	5311.51	0	5311.51	5363.68	5363.68
7	17.1807	90786.8	12.3472	WeakLayer	0	13	470.132	1205.96	5223.6	0	5223.6	5326.51	5326.51
8	14.5033	76308.6	8.89484	WeakLayer	0	13	470.943	1208.04	5232.6	0	5232.6	5306.31	5306.31
9	14.5033	76487	8.89484	WeakLayer	0	13	471.47	1209.39	5238.45	0	5238.45	5312.24	5312.24
10	14.5033	73171.5	8.89484	WeakLayer	0	13	450.695	1156.1	5007.62	0	5007.62	5078.15	5078.15
11	16.7749	81001	4.46366	WeakLayer	0	13	436.236	1119.01	4846.96	0	4846.96	4881.02	4881.02
12	16.7749	78436.9	4.46366	WeakLayer	0	13	422.443	1083.63	4693.71	0	4693.71	4726.68	4726.68
13	16.7749	77081.1	4.46366	WeakLayer	0	13	415.063	1064.7	4611.7	0	4611.7	4644.1	4644.1
14	16.7749	86540.2	4.46366	WeakLayer	0	13	465.333	1193.65	5170.25	0	5170.25	5206.58	5206.58
15	15.0275	79386.9	4.3189	WeakLayer	0	13	476.448	1222.16	5293.75	0	5293.75	5329.73	5329.73
16	15.0275	80358.5	4.3189	WeakLayer	0	13	482.05	1236.53	5356.02	0	5356.02	5392.43	5392.43
17	15.0275	79808.2	4.3189	WeakLayer	0	13	478.569	1227.6	5317.31	0	5317.31	5353.46	5353.46
18	15.0275	81927	4.3189	WeakLayer	0	13	490.965	1259.4	5455.05	0	5455.05	5492.13	5492.13
19	15.0275	85376.2	4.3189	WeakLayer	0	13	511.268	1311.48	5680.64	0	5680.64	5719.25	5719.25
20	15.0275	87385.6	4.3189	WeakLayer	0	13	522.975	1341.51	5810.73	0	5810.73	5850.23	5850.23
21	15.2896	90108.4	2.28881	WeakLayer	0	13	533.602	1368.77	5928.81	0	5928.81	5950.14	5950.14
22	15.2896	91654.4	2.28881	WeakLayer	0	13	542.506	1391.61	6027.73	0	6027.73	6049.41	6049.41
23	15.2896	93200.3	2.28881	WeakLayer	0	13	551.363	1414.33	6126.14	0	6126.14	6148.18	6148.18
24	15.2896	94748.7	2.28881	WeakLayer	0	13	560.189	1436.97	6224.21	0	6224.21	6246.6	6246.6
25	15.2896	97029.1	2.28881	WeakLayer	0	13	573.288	1470.57	6369.75	0	6369.75	6392.66	6392.66
26	15.2896	100798	2.28881	WeakLayer	0	13	595.127	1526.59	6612.35	0	6612.35	6636.14	6636.14
27	17.7163	120469	4.91045	WeakLayer	0	13	607.387	1558.04	6748.6	0	6748.6	6800.79	6800.79
28	17.7163	120846	4.91045	WeakLayer	0	13	608.764	1561.57	6763.9	0	6763.9	6816.2	6816.2
29	17.7163	124305	4.91045	WeakLayer	0	13	625.683	1604.97	6951.9	0	6951.9	7005.66	7005.66
30	17.7163	122621	4.91045	WeakLayer	0	13	616.662	1581.83	6851.69	0	6851.69	6904.67	6904.67
31	17.7163	120032	4.91045	WeakLayer	0	13	603.084	1547	6700.8	0	6700.8	6752.62	6752.62
32	17.7163	117442	4.91045	WeakLayer	0	13	589.513	1512.19	6550.03	0	6550.03	6600.68	6600.68
33	17.7163	114853	4.91045	WeakLayer	0	13	575.955	1477.41	6399.37	0	6399.37	6448.85	6448.85
34	15.8233	100111	5.88883	WeakLayer	0	13	559.714	1435.75	6218.92	0	6218.92	6276.65	6276.65
35	15.8233	101422	5.88883	WeakLayer	0	13	566.77	1453.85	6297.33	0	6297.33	6355.78	6355.78
36	15.8233	111376	5.88883	WeakLayer	0	13	622.509	1596.83	6916.6	0	6916.6	6980.81	6980.81
37	15.8233	110756	5.88883	WeakLayer	0	13	618.759	1587.21	6874.99	0	6874.99	6938.81	6938.81
38	15.8233	108778	5.88883	WeakLayer	0	13	607.403	1558.08	6748.82	0	6748.82	6811.47	6811.47
39	15.8233	106801	5.88883	WeakLayer	0	13	596.078	1529.03	6622.96	0	6622.96	6684.45	6684.45
40	15.8233	104824	5.88883	WeakLayer	0	13	584.781	1500.05	6497.42	0	6497.42	6557.74	6557.74
41	15.8233	102846	5.88883	WeakLayer	0	13	573.51	1471.14	6372.2	0	6372.2	6431.35	6431.35
42	18.8037	121802	7.46563	WeakLayer	0	13	569.214	1460.12	6324.45	0	6324.45	6399.05	6399.05
43	18.8037	124891	7.46563	WeakLayer	0	13	584.013	1498.08	6488.92	0	6488.92	6565.45	6565.45
44	1.19194	7990.22	25.6733	Qls	1500	0	584.761	1500	6259.41	0	6259.41	6540.5	6540.5
45	17.9386	113939	25.6733	Qls	1500	0	584.761	1500	5934.93	0	5934.93	6216.02	6216.02
46	15.6558	83644.6	33.1096	Qls	1500	0	584.761	1500	4856.15	0	4856.15	5237.5	5237.5
47	15.6558	63606.9	33.1096	Qls	1500	0	584.761	1500	3630.26	0	3630.26	4011.6	4011.6
48	14.9365	39672	43.1455	Qls	1500	0	584.761	1500	2088.35	0	2088.35	2636.43	2636.43
49	1.42525	2538.18	44.2114	Qls	1500	0	584.761	1500	1209.72	0	1209.72	1778.6	1778.6
50	13.5112	11613.8	44.2114	Qls	1500	0	584.761	1500	293.101	0	293.101	861.982	861.982

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Bas Mate
1	12.8363	10917.1	-39.8706	
2	19.9316	60579.8	-39.8706	
3	25.9699	128746	-20.4692	
4	17.011	95829.8	6.93654	WeakL
5	17.011	94684.2	6.93654	WeakL
6	17.2991	95565.8	7.47508	WeakL
7	17.2991	94651.3	7.47508	WeakL
8	17.2991	92689.6	7.47508	WeakL
9	18.9112	98594.4	6.22811	WeakL
10	18.9112	96767.3	6.22811	WeakL
11	18.9112	99137.2	6.22811	WeakL
12	17.1807	90786.8	12.3472	WeakL
13	21.7549	114696	8.89484	WeakL
14	21.7549	111271	8.89484	WeakL
15	16.7749	81001	4.46366	WeakL
16	16.7749	78436.9	4.46366	WeakL
17	16.7749	77081.1	4.46366	WeakL
18	16.7749	86540.2	4.46366	WeakL
19	18.033	95380.8	4.3189	WeakL
20	18.033	96571.5	4.3189	WeakL
21	18.033	96014.9	4.3189	WeakL
22	18.033	101632	4.3189	WeakL
23	18.033	104643	4.3189	WeakL
24	18.3475	108316	2.28881	WeakL
25	18.3475	110542	2.28881	WeakL
26	18.3475	112768	2.28881	WeakL
27	18.3475	115481	2.28881	WeakL
28	18.3475	120433	2.28881	WeakL
29	17.7163	120469	4.91045	WeakL
30	17.7163	120846	4.91045	WeakL
31	17.7163	124305	4.91045	WeakL
32	17.7163	122621	4.91045	WeakL
33	17.7163	120032	4.91045	WeakL
34	17.7163	117442	4.91045	WeakL
35	17.7163	114853	4.91045	WeakL
36	18.0838	114198	5.88883	WeakL
37	18.0838	118533	5.88883	WeakL
38	18.0838	127887	5.88883	WeakL
39	18.0838	125448	5.88883	WeakL
40	18.0838	122865	5.88883	WeakL
41	18.0838	120283	5.88883	WeakL
42	18.0838	117700	5.88883	WeakL
43	21.4298	139055	7.46563	WeakL
44	21.4298	143082	7.46563	WeakL
45	14.3879	96087.2	16.433	
46	19.2226	115839	23.4135	
47	19.2226	96751.2	23.4135	
48	22.0801	79710.8	37.9082	
49	7.23541	15237	41.0411	
50	14.8447	12567.8	41.0411	

Interslice Data

No Groundwater - School_phi=13_FS

- **Global Minimum Query (spencer) - Safety Factor: 2.61398**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	849.337	312.865	0	0	0
2	849.984	312.356	663.946	57.1275	4.91775
3	865.236	300.363	27541.2	2369.71	4.91775
4	867.698	298.427	33899.6	2916.8	4.91775
5	886.059	287.743	80687.8	6942.57	4.91775
6	898.727	284.066	104299	8974.13	4.91775
7	911.396	280.389	130826	11256.6	4.91776
8	918.571	281.96	126046	10845.3	4.91775
9	933.075	284.23	120943	10406.2	4.91774
10	947.578	286.499	115829	9966.17	4.91774
11	962.081	288.769	110936	9545.2	4.91775
12	978.856	290.079	111762	9616.26	4.91775
13	995.631	291.388	112562	9685.07	4.91774
14	1012.41	292.698	113348	9752.69	4.91773
15	1029.18	294.007	114230	9828.61	4.91775
16	1044.21	295.142	115240	9915.55	4.91777
17	1059.24	296.277	116263	10003.6	4.91778
18	1074.26	297.412	117279	10091	4.91777
19	1089.29	298.547	118322	10180.7	4.91775
20	1104.32	299.682	119408	10274.2	4.91778
21	1119.35	300.817	120521	10369.9	4.91775
22	1134.64	301.428	124880	10745	4.91777
23	1149.92	302.039	129315	11126.5	4.91772
24	1165.21	302.65	133824	11514.5	4.91774
25	1180.5	303.261	138408	11909	4.91777
26	1195.79	303.872	143103	12312.9	4.91774
27	1211.08	304.483	147980	12732.5	4.91773
28	1228.8	306.005	148267	12757.3	4.91777
29	1246.52	307.527	148556	12782.1	4.91775
30	1264.23	309.049	148853	12807.7	4.91777
31	1281.95	310.572	149146	12832.9	4.91776
32	1299.66	312.094	149433	12857.6	4.91776
33	1317.38	313.616	149713	12881.7	4.91777
34	1335.1	315.138	149988	12905.3	4.91774
35	1350.92	316.77	148519	12778.9	4.91774
36	1366.74	318.402	147031	12650.9	4.91775
37	1382.57	320.034	145397	12510.3	4.91775
38	1398.39	321.666	143773	12370.5	4.91773
39	1414.21	323.298	142177	12233.2	4.91773
40	1430.04	324.93	140610	12098.4	4.91775
41	1445.86	326.562	139072	11966.1	4.91776
42	1461.68	328.194	137564	11836.3	4.91774
43	1477.86	330.314	133161	11457.5	4.91776
44	1494.04	332.435	128663	11070.5	4.91777
45	1510.34	339.094	97666.3	8403.44	4.91775
46	1522.26	345.482	69788.9	6004.8	4.91775
47	1534.18	351.869	46541.9	4004.58	4.91776
48	1546.1	360.034	23080.7	1985.92	4.91776
49	1558.01	368.199	7059.06	607.378	4.91775
50	1568.51	378.348	-3615.81	-311.113	4.91775
51	1581.85	391.253	0	0	0

No Groundwater - School_phi=13_Ky

- **Global Minimum Query (spencer) - Critical Seismic Coefficient: 0.166374**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	715.573	288.161	44856.2	8971.24	11.3099
3	728.191	280.089	91720.8	18344.2	11.31
4	752.495	271.672	152595	30518.9	11.3099
5	776.798	263.256	219567	43913.3	11.3099
6	792.76	265.198	214126	42825.3	11.31
7	818.708	268.603	204000	40800.1	11.31
8	844.657	272.007	194094	38818.9	11.31
9	863.568	274.071	189305	37861.1	11.31
10	882.479	276.135	184605	36921	11.3099
11	901.391	278.199	179790	35958	11.3099
12	918.571	281.96	165706	33141.2	11.3099
13	940.326	285.364	154721	30944.3	11.31
14	962.081	288.769	144065	28812.9	11.3099
15	984.448	290.515	142286	28457.2	11.3099
16	1006.81	292.261	140581	28116.2	11.3099
17	1029.18	294.007	138715	27743.1	11.31
18	1051.72	295.71	137055	27411	11.3099
19	1074.26	297.412	135385	27077	11.3099
20	1096.8	299.114	133657	26731.3	11.3099
21	1119.35	300.817	131845	26368.9	11.3099
22	1142.28	301.733	135089	27017.8	11.3099
23	1165.21	302.65	138416	27683.3	11.31
24	1188.15	303.567	141832	28366.4	11.3099
25	1211.08	304.483	145409	29081.8	11.3099
26	1235.89	306.614	141247	28249.4	11.3099
27	1260.69	308.745	136981	27396.3	11.31
28	1285.49	310.876	132736	26547.2	11.3099
29	1310.29	313.007	128616	25723.2	11.3099
30	1335.1	315.138	124622	24924.3	11.3099
31	1356.2	317.314	118977	23795.4	11.3099
32	1377.29	319.49	112919	22583.9	11.31
33	1398.39	321.666	106629	21325.8	11.3099
34	1419.49	323.842	100488	20097.7	11.31
35	1440.59	326.018	94496.6	18899.3	11.3099
36	1461.68	328.194	88654.3	17730.9	11.31
37	1481.61	330.806	79529.3	15905.9	11.31
38	1501.54	333.417	70158.8	14031.8	11.31
39	1521.47	336.028	60558.2	12111.6	11.3099
40	1541.39	338.639	51170.4	10234.1	11.31
41	1561.32	341.251	42091.3	8418.26	11.3099
42	1585	343.291	38329.3	7665.87	11.3099
43	1608.69	345.331	34729.5	6945.9	11.3099
44	1632.37	347.371	31298.9	6259.79	11.31
45	1656.06	349.411	27806.2	5561.24	11.3099
46	1680.18	350.74	28900	5780	11.3099
47	1704.3	352.068	29982	5996.41	11.31
48	1726.26	364.771	-7589.6	-1517.92	11.3099
49	1748.22	377.474	-23746.9	-4749.38	11.3099
50	1758.76	388.441	-21525.5	-4305.1	11.3099
51	1772.23	402.454	0	0	0

- **Global Minimum Query (gle/morgenstern-price) - Safety Factor: 2.56515**
- **Global Minimum Query (gle/morgenstern-price) - Critical Seismic Coefficient: 0.163087**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	845.847	312.662	0	0	0
2	846.346	312.229	524.273	0.138065	0.0150886
3	860.583	299.905	26543.5	206.013	0.444683
4	863.657	297.244	34996.6	328.189	0.537289
5	881.468	283.392	96217.1	1799.36	1.07137
6	894.639	277.462	134248	3427.17	1.46237
7	901.391	278.199	133562	3873.07	1.66101
8	918.571	281.96	121994	4600.63	2.15971
9	933.075	284.23	116948	5252.2	2.57146
10	947.578	286.499	111895	5811.44	2.97307
11	962.081	288.769	107066	6291.38	3.36293
12	978.856	290.079	108037	7170.63	3.79727
13	995.631	291.388	108977	8025.09	4.21167
14	1012.41	292.698	109901	8850.16	4.60401
15	1029.18	294.007	110936	9651.68	4.97234
16	1044.21	295.142	112088	10359.3	5.28034
17	1059.24	296.277	113254	11037.4	5.5663
18	1074.26	297.412	114411	11680.3	5.82917
19	1089.29	298.547	115599	12288.3	6.06782
20	1104.32	299.682	116835	12860.3	6.28139
21	1119.35	300.817	118100	13391	6.46897
22	1134.64	301.428	122635	14259.9	6.63252
23	1149.92	302.039	127247	15100.6	6.76773
24	1165.21	302.65	131933	15905.5	6.87425
25	1180.5	303.261	136695	16666.6	6.9515
26	1195.79	303.872	141568	17380.6	6.9993
27	1211.08	304.483	146627	18048.6	7.01735
28	1228.8	306.005	147116	18066.4	7.00108
29	1246.52	307.527	147606	17979.8	6.94495
30	1264.23	309.049	148110	17790.1	6.84922
31	1281.95	310.572	148607	17495.2	6.71441
32	1299.66	312.094	149092	17095.7	6.54128
33	1317.38	313.616	149567	16593.5	6.33071
34	1335.1	315.138	150031	15990.7	6.08377
35	1350.92	316.77	148738	15196.5	5.83364
36	1366.74	318.402	147429	14343	5.55668
37	1382.57	320.034	145991	13425.2	5.25409
38	1398.39	321.666	144562	12462.4	4.92717
39	1414.21	323.298	143159	11461.7	4.57749
40	1430.04	324.93	141782	10428	4.2065
41	1445.86	326.562	140431	9366.57	3.8159
42	1461.68	328.194	139106	8282.67	3.40749
43	1480.49	330.658	134226	6803.22	2.90154
44	1499.29	333.122	129219	5362.49	2.37637
45	1500.48	333.695	126329	5167.8	2.34252
46	1518.42	342.318	85642.7	2730.17	1.82589
47	1534.08	352.528	45218.5	1078.16	1.36586
48	1549.73	362.738	17310.2	271.79	0.899536
49	1564.67	376.737	-3191.26	-25.1045	0.450716
50	1566.1	378.124	-4035.14	-28.7176	0.40776
51	1579.61	391.268	0	0	0

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	712.836	287.401	40479.7	543.025	0.768562
3	732.768	270.753	135364	4626.95	1.9577
4	758.738	261.059	209853	12796.3	3.48943
5	775.749	263.128	204747	16026	4.47554
6	792.76	265.198	199682	19028.1	5.44339
7	810.059	267.468	193601	21733.1	6.40505
8	827.358	269.738	187555	24159.6	7.34005
9	844.657	272.007	181612	26316	8.24491
10	863.568	274.071	177527	28739.2	9.19563
11	882.479	276.135	173493	30910.9	10.1023
12	901.391	278.199	169320	32793.1	10.9611
13	918.571	281.96	155542	32202.9	11.6971
14	940.326	285.364	145078	32335.6	12.5649
15	962.081	288.769	134895	32031.2	13.3577
16	978.856	290.079	134018	33204.1	13.9153
17	995.631	291.388	133155	34250	14.4249
18	1012.41	292.698	132290	35162.6	14.885
19	1029.18	294.007	131276	35900.4	15.2949
20	1047.21	295.369	130389	36597.5	15.6783
21	1065.25	296.731	129465	37127.5	16.0016
22	1083.28	298.093	128522	37495.2	16.2642
23	1101.31	299.455	127493	37681.2	16.4653
24	1119.35	300.817	126406	37694.7	16.6048
25	1137.69	301.55	129436	38790.6	16.6829
26	1156.04	302.283	132498	39742.6	16.6965
27	1174.39	303.017	135588	40538.7	16.6458
28	1192.74	303.75	138718	41171.3	16.5308
29	1211.08	304.483	141948	41647.4	16.3516
30	1228.8	306.005	139224	40232.7	16.1181
31	1246.52	307.527	136474	38684.3	15.8257
32	1264.23	309.049	133631	36996.2	15.4749
33	1281.95	310.572	130810	35213.7	15.0667
34	1299.66	312.094	128032	33354.3	14.6019
35	1317.38	313.616	125300	31430.2	14.0815
36	1335.1	315.138	122614	29453.1	13.5071
37	1353.18	317.003	117924	26935.6	12.8665
38	1371.27	318.868	113064	24389.5	12.173
39	1389.35	320.733	107840	21800.6	11.4287
40	1407.43	322.599	102720	19290.4	10.636
41	1425.52	324.464	97710.3	16873.6	9.79778
42	1443.6	326.329	92812.8	14562.2	8.91693
43	1461.68	328.194	88028.7	12366.7	7.99686
44	1483.11	331.003	78543.4	9450.1	6.86067
45	1504.54	333.811	68821.8	6846.28	5.681
46	1518.93	338.054	49055	4177.97	4.86808
47	1538.15	346.378	15603.3	1025.51	3.76029
48	1557.38	354.702	-7245.84	-333.19	2.63281
49	1579.46	371.896	-28863.2	-665.585	1.32101
50	1586.69	378.195	-25769.2	-399.73	0.888697
51	1601.54	391.118	0	0	0

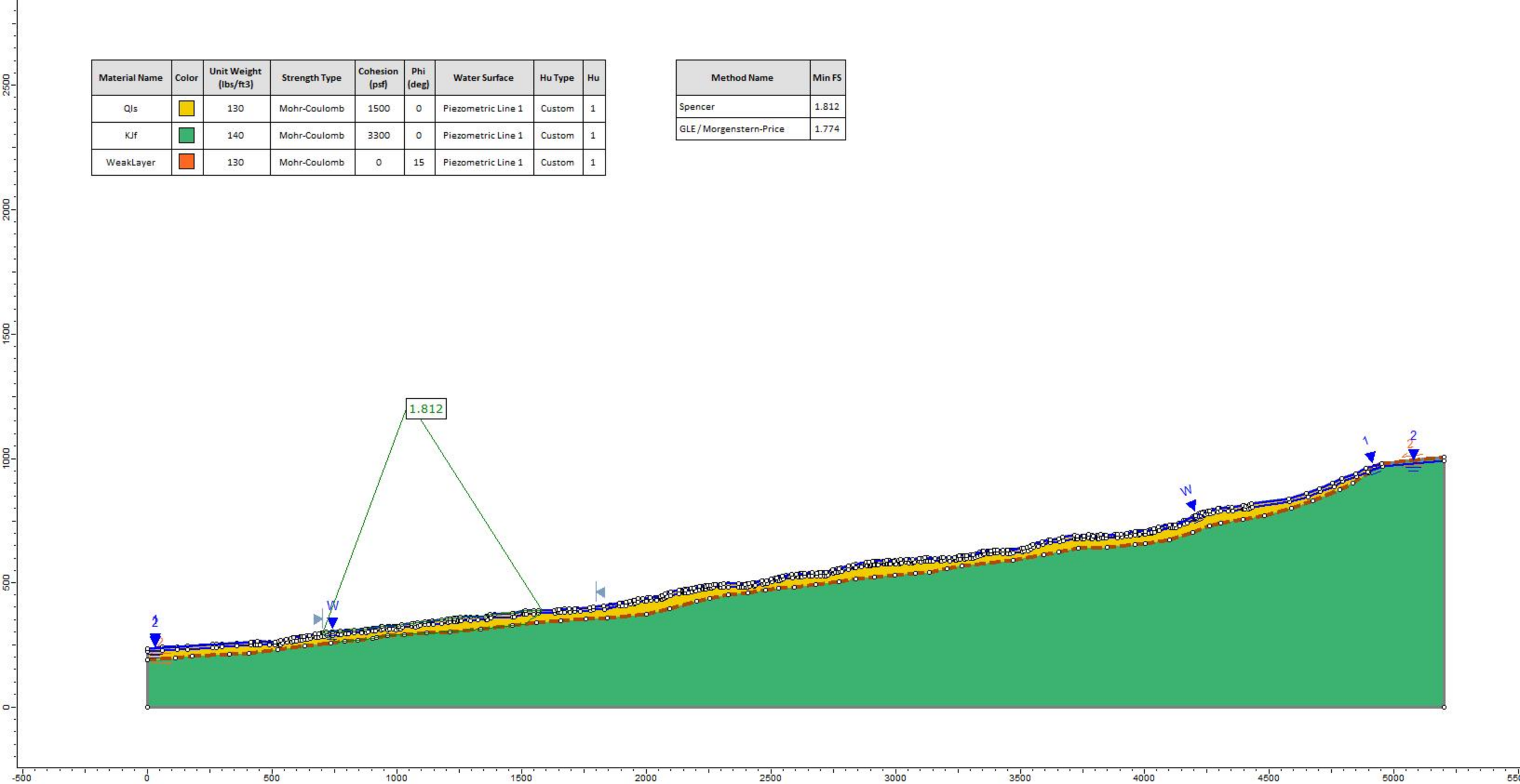
ANALYSIS RUN 2-A

$\phi = 15^{o}$

GW = O FEET

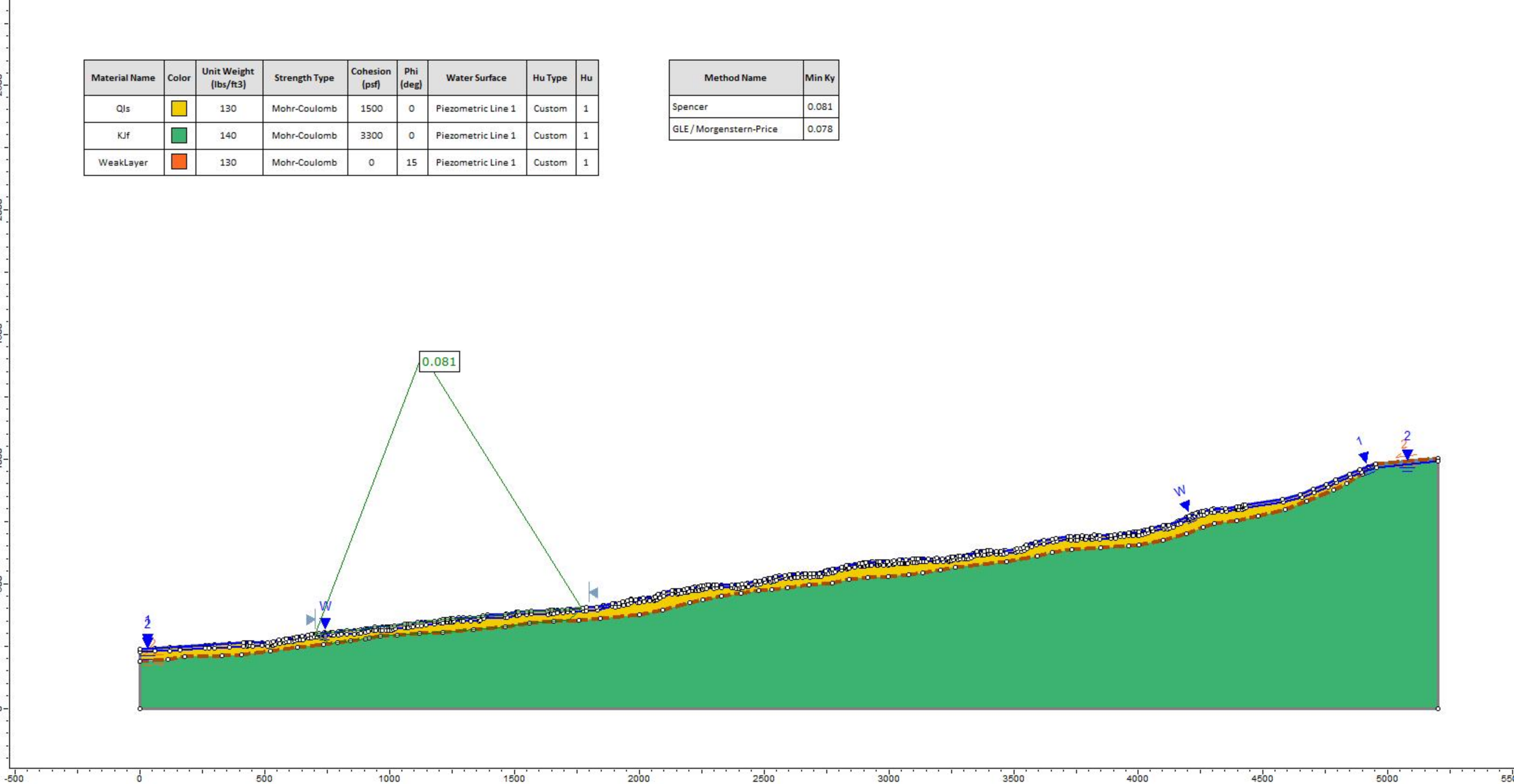
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Qls		130	Mohr-Coulomb	1500	0	Piezometric Line 1	Custom	1
KJf		140	Mohr-Coulomb	3300	0	Piezometric Line 1	Custom	1
WeakLayer		130	Mohr-Coulomb	0	15	Piezometric Line 1	Custom	1

Method Name	Min FS
Spencer	1.812
GLE / Morgenstern-Price	1.774



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Qls		130	Mohr-Coulomb	1500	0	Piezometric Line 1	Custom	1
KJf		140	Mohr-Coulomb	3300	0	Piezometric Line 1	Custom	1
WeakLayer		130	Mohr-Coulomb	0	15	Piezometric Line 1	Custom	1

Method Name	Min Ky
Spencer	0.081
GLE / Morgenstern-Price	0.078



Slide Analysis Information

Slide_xs1_2019-09-06_phi-15

Project Summary

File Name:	Slide_xs1_2019-09-06_phi-15.slmd
Slide Modeler Version:	8.027
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	9/6/2019, 8:16:52 PM

Currently Open Scenarios

Group Name	Scenario Name	Global Minimum	Compute Time
Groundwater at Surface	School_phi=15_FS	Spencer: 1.811700 Gle/morgenstern-price: 1.774380	00h:00m:16.742s
	School_phi=15_Ky	Spencer: 0.080546 Gle/morgenstern-price: 0.078040	00h:01m:24.372s

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

All Open Scenarios

Slices Type:	Vertical
Analysis Methods Used	
	GLE/Morgenstern-Price with interslice force function (Half Sine)
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

All Open Scenarios

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Use negative pore pressure cutoff:	Yes
Maximum negative pore pressure [psf]:	0
Advanced Groundwater Method:	None

Random Numbers

All Open Scenarios

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

All Open Scenarios	
Search Method:	Cuckoo Search
Initial # of Surface Vertices:	8
Maximum Iterations:	500
Number of Nests:	50
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined
Convex Surfaces Only:	Enabled

Seismic Loading

Groundwater at Surface - School_phi=15_FS		Groundwater at Surface - School_phi=15_Ky	
Advanced seismic analysis:	No	Advanced seismic analysis:	Yes
Staged pseudostatic analysis:	No	Locate surface with minimum critical horizontal seismic acceleration (Ky):	Yes
		Target factor of safety:	1
		Using Newmark analysis:	No
		Staged pseudostatic analysis:	No

Materials

Property	Qls	KJf	WeakLayer
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	130	140	130
Cohesion [psf]	1500	3300	0
Friction Angle [°]	0	0	15
Water Surface	Assigned per scenario	Assigned per scenario	Assigned per scenario
Hu Value	1	1	1

Materials In Use

Material	School_phi=15_FS	School_phi=15_Ky
Qls	✓	✓
KJf	✓	✓
WeakLayer	✓	✓

Global Minimums

Groundwater at Surface - School_phi=15_FS

Method: spencer

FS	1.811700
Axis Location:	1048.744, 1228.405
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1583.724, 391.240
Resisting Moment:	8.13822e+08 lb-ft
Driving Moment:	4.49203e+08 lb-ft
Resisting Horizontal Force:	811504 lb
Driving Horizontal Force:	447924 lb
Total Slice Area:	38003.4 ft2
Surface Horizontal Width:	883.724 ft
Surface Average Height:	43.0037 ft

Method: gle/morgenstern-price

FS	1.774380
Axis Location:	1047.439, 1225.837
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1581.147, 391.257
Resisting Moment:	8.03e+08 lb-ft
Driving Moment:	4.52553e+08 lb-ft
Resisting Horizontal Force:	801117 lb
Driving Horizontal Force:	451492 lb
Total Slice Area:	38175 ft2
Surface Horizontal Width:	881.147 ft
Surface Average Height:	43.3242 ft

Groundwater at Surface - School_phi=15_Ky

Method: spencer

Ky	0.080546
Axis Location:	1130.896, 1420.432
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1770.206, 402.329
Resisting Moment:	1.12021e+09 lb-ft
Driving Moment:	1.12021e+09 lb-ft
Resisting Horizontal Force:	943742 lb
Driving Horizontal Force:	943742 lb
Total Slice Area:	46852.3 ft2
Surface Horizontal Width:	1070.21 ft
Surface Average Height:	43.7788 ft

Method: gle/morgenstern-price

Ky	0.078040
Axis Location:	1128.811, 1415.524
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1765.446, 402.034
Resisting Moment:	1.10958e+09 lb-ft
Driving Moment:	1.10958e+09 lb-ft
Resisting Horizontal Force:	939261 lb
Driving Horizontal Force:	939261 lb
Total Slice Area:	46777.1 ft2
Surface Horizontal Width:	1065.45 ft
Surface Average Height:	43.9038 ft

Global Minimum Coordinates

Groundwater at Surface - School_phi=15_FS

Method: spencer

X	Y
700	298.122
731.623	276.006
761.313	261.372
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1513.65	335.004
1535	350.625
1559.36	367.596
1583.72	391.24

Method: gle/morgenstern-price

X	Y
700	298.122
736.042	269.371
752.957	260.356
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1516.47	335.374
1537.71	350.918
1559.43	368.652
1581.15	391.257

Groundwater at Surface - School_phi=15_Ky

Method: spencer

X	Y
700	298.122
734.697	274.05
762.006	261.537
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1561.32	341.251
1656.06	349.411
1713.72	352.587
1740.49	372.273
1770.21	402.329

Method: gle/morgenstern-price

X	Y
700	298.122
718.846	281.31
737.692	268.357
751.873	260.224
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1561.32	341.251
1656.06	349.411
1709.32	352.345
1720.85	361.238
1765.45	402.034

Slice Data

Groundwater at Surface - School_phi=15_FS

- **Global Minimum Query (spencer) - Safety Factor: 1.8117**

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	14.6216	12403.7	-34.9679	Qls	1500	0	827.952	1500	1577.09	395.432	1181.65	998.04	602.608
2	17.0009	45505.2	-34.9679	Qls	1500	0	827.952	1500	3510.24	1290.11	2220.13	2931.2	1641.09
3	14.8453	60331.2	-26.2383	Qls	1500	0	827.952	1500	4716.55	1948.95	2767.6	4308.45	2359.5
4	14.8453	76293.7	-26.2383	Qls	1500	0	827.952	1500	5834.53	2468.92	3365.61	5426.44	2957.52
5	15.7233	88370.7	6.93654	WeakLayer	0	15	422.402	765.265	5549.38	2693.38	2856	5600.77	2907.39
6	15.7233	87498.6	6.93654	WeakLayer	0	15	414.524	750.994	5494.78	2692.03	2802.75	5545.21	2853.18
7	17.2991	95565.8	7.47508	WeakLayer	0	15	412.264	746.899	5446.78	2659.31	2787.47	5500.87	2841.56
8	17.2991	94651.3	7.47508	WeakLayer	0	15	410.262	743.271	5394.56	2620.63	2773.93	5448.39	2827.76
9	17.2991	92689.6	7.47508	WeakLayer	0	15	402.97	730.06	5282.69	2558.07	2724.62	5335.56	2777.49
10	18.9112	98594.4	6.22811	WeakLayer	0	15	398.585	722.116	5157.31	2462.34	2694.97	5200.81	2738.47
11	18.9112	96767.3	6.22811	WeakLayer	0	15	387.851	702.67	5061.84	2439.44	2622.4	5104.17	2664.73
12	18.9112	99137.2	6.22811	WeakLayer	0	15	396.971	719.193	5185.82	2501.76	2684.06	5229.14	2727.38
13	17.1807	90786.8	12.3472	WeakLayer	0	15	391.156	708.658	5141.67	2496.92	2644.75	5227.29	2730.37
14	21.7549	114696	8.89484	WeakLayer	0	15	390.355	707.206	5178.53	2539.21	2639.32	5239.63	2700.42
15	21.7549	111271	8.89484	WeakLayer	0	15	382.533	693.035	5023.58	2437.12	2586.46	5083.45	2646.33
16	16.7749	81001	4.46366	WeakLayer	0	15	366.611	664.189	4799.47	2320.68	2478.79	4828.08	2507.4
17	16.7749	78436.9	4.46366	WeakLayer	0	15	353.578	640.577	4647.54	2256.87	2390.67	4675.14	2418.27
18	16.7749	77081.1	4.46366	WeakLayer	0	15	354.639	642.499	4567.2	2169.36	2397.84	4594.88	2425.52
19	16.7749	86540.2	4.46366	WeakLayer	0	15	388.015	702.966	5127.68	2504.17	2623.51	5157.97	2653.8
20	18.033	95380.8	4.3189	WeakLayer	0	15	402.355	728.947	5259.25	2538.79	2720.46	5289.64	2750.85
21	18.033	96571.5	4.3189	WeakLayer	0	15	406.556	736.558	5324.9	2576.03	2748.87	5355.61	2779.58
22	18.033	96014.9	4.3189	WeakLayer	0	15	410.926	744.474	5294.22	2515.81	2778.41	5325.26	2809.45
23	18.033	101632	4.3189	WeakLayer	0	15	428.726	776.723	5603.96	2705.19	2898.77	5636.34	2931.15
24	18.033	104643	4.3189	WeakLayer	0	15	440.379	797.835	5769.96	2792.39	2977.57	5803.22	3010.83
25	18.3475	108316	2.28881	WeakLayer	0	15	456.911	827.786	5902.41	2813.09	3089.32	5920.67	3107.58
26	18.3475	110542	2.28881	WeakLayer	0	15	461.234	835.617	6023.52	2904.99	3118.53	6041.96	3136.97
27	18.3475	112768	2.28881	WeakLayer	0	15	471.653	854.494	6144.92	2955.89	3189.03	6163.77	3207.88
28	18.3475	115481	2.28881	WeakLayer	0	15	484.17	877.17	6292.77	3019.13	3273.64	6312.13	3293
29	18.3475	120433	2.28881	WeakLayer	0	15	508.158	920.629	6562.73	3126.89	3435.84	6583.04	3456.15
30	17.7163	120469	4.91045	WeakLayer	0	15	514.935	932.908	6750.63	3268.94	3481.69	6794.87	3525.93
31	17.7163	120846	4.91045	WeakLayer	0	15	518.456	939.287	6771.72	3266.24	3505.48	6816.26	3550.02
32	17.7163	124305	4.91045	WeakLayer	0	15	529.124	958.614	6965.57	3387.99	3577.58	7011.03	3623.04
33	17.7163	122621	4.91045	WeakLayer	0	15	522.253	946.165	6871.2	3340.07	3531.13	6916.07	3576
34	17.7163	120032	4.91045	WeakLayer	0	15	513.693	930.658	6726.11	3252.82	3473.29	6770.24	3517.42
35	17.7163	117442	4.91045	WeakLayer	0	15	500.585	906.909	6581.02	3196.38	3384.64	6624.02	3427.64
36	17.7163	114853	4.91045	WeakLayer	0	15	487.059	882.404	6435.92	3142.75	3293.17	6477.77	3335.02
37	18.0838	114198	5.88883	WeakLayer	0	15	474.695	860.005	6252.8	3043.21	3209.59	6301.76	3258.55
38	18.0838	118533	5.88883	WeakLayer	0	15	500.173	906.164	6489.93	3108.1	3381.83	6541.52	3433.42
39	18.0838	127887	5.88883	WeakLayer	0	15	531.626	963.146	7002.32	3407.81	3594.51	7057.15	3649.34
40	18.0838	125448	5.88883	WeakLayer	0	15	519.921	941.94	6868.82	3353.45	3515.37	6922.45	3569
41	18.0838	122865	5.88883	WeakLayer	0	15	510.109	924.164	6727.4	3278.35	3449.05	6780.01	3501.66
42	18.0838	120283	5.88883	WeakLayer	0	15	500.297	906.388	6585.92	3203.26	3382.66	6637.52	3434.26
43	18.0838	117700	5.88883	WeakLayer	0	15	490.485	888.612	6444.5	3128.17	3316.33	6495.09	3366.92
44	17.3209	112087	7.46563	WeakLayer	0	15	486.021	880.525	6380.33	3094.19	3286.14	6444.02	3349.83
45	17.3209	114700	7.46563	WeakLayer	0	15	493.12	893.385	6529.34	3195.17	3334.17	6593.96	3398.79
46	17.3209	117365	7.46563	WeakLayer	0	15	500.651	907.03	6681.21	3296.15	3385.06	6746.81	3450.66
47	21.3545	126667	36.1871	Qls	1500	0	827.952	1500	5100.79	2849.42	2251.37	5706.47	2857.05
48	24.3613	95533.8	34.8619	Qls	1500	0	827.952	1500	3234.26	1864.53	1369.73	3811.03	1946.5
49	11.0614	25959.5	44.1437	Qls	1500	0	827.952	1500	1494.98	1129.9	365.08	2298.55	1168.65
50	13.2999	11238	44.1437	Qls	1500	0	827.952	1500	98.2209	405.537	-307.316	901.789	496.252

- **Global Mi**

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Mate
1	14.7058	12473.9	-34.7522	
2	19.9911	56308.1	-34.7522	
3	27.3096	129278	-24.6174	
4	30.7532	171774	6.78877	WeakL
5	25.9486	143006	7.47508	WeakL
6	25.9486	139900	7.47508	WeakL
7	18.9112	98594.4	6.22811	WeakL
8	18.9112	96767.3	6.22811	WeakL
9	18.9112	99137.2	6.22811	WeakL
10	17.1807	90786.8	12.3472	WeakL
11	21.7549	114696	8.89484	WeakL
12	21.7549	111271	8.89484	WeakL
13	22.3665	107432	4.46366	WeakL
14	22.3665	102958	4.46366	WeakL
15	22.3665	112670	4.46366	WeakL
16	22.5412	119445	4.3189	WeakL
17	22.5412	120109	4.3189	WeakL
18	22.5412	124331	4.3189	WeakL
19	22.5412	130358	4.3189	WeakL
20	22.9344	135742	2.28881	WeakL
21	22.9344	139221	2.28881	WeakL
22	22.9344	142906	2.28881	WeakL
23	22.9344	149670	2.28881	WeakL
24	20.6691	140326	4.91045	WeakL
25	20.6691	142220	4.91045	WeakL
26	20.6691	144709	4.91045	WeakL
27	20.6691	141296	4.91045	WeakL
28	20.6691	137771	4.91045	WeakL
29	20.6691	134247	4.91045	WeakL
30	21.0977	132910	5.88883	WeakL
31	21.0977	142641	5.88883	WeakL
32	21.0977	148114	5.88883	WeakL
33	21.0977	144598	5.88883	WeakL
34	21.0977	141083	5.88883	WeakL
35	21.0977	137568	5.88883	WeakL
36	19.9271	129175	7.46563	WeakL
37	19.9271	132651	7.46563	WeakL
38	19.9271	135907	7.46563	WeakL
39	19.9271	132895	7.46563	WeakL
40	19.9271	128525	7.46563	WeakL
41	23.6839	150707	4.92318	WeakL
42	23.6839	144212	4.92318	WeakL
43	23.6839	137430	4.92318	WeakL
44	23.6839	139920	4.92318	WeakL
45	19.2225	113510	3.15232	WeakL
46	19.2225	111738	3.15232	WeakL
47	19.2225	113765	3.15232	WeakL
48	26.7684	129553	36.3314	
49	15.8108	42565.3	45.3268	
50	13.9045	11932.5	45.3268	

- **Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.77438**
- **Global Minimum**

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	13.2843	11289.8	-38.5802	Qls	1500	0	845.366	1500	1535.47	394.994	1140.48	861.104	466.11
2	22.7579	71478.9	-38.5802	Qls	1500	0	845.366	1500	3884.04	1515.58	2368.46	3209.67	1694.09
3	16.9152	85972.9	-28.0555	Qls	1500	0	845.366	1500	5662.92	2424.23	3238.69	5212.38	2788.15
4	19.9011	112740	6.93654	WeakLayer	0	15	443.672	787.243	5676.11	2738.06	2938.05	5730.09	2992.03
5	19.9011	110825	6.93654	WeakLayer	0	15	435.788	773.254	5575.8	2689.98	2885.82	5628.82	2938.84
6	17.2991	95565.8	7.47508	WeakLayer	0	15	432.075	766.666	5520.55	2659.31	2861.24	5577.24	2917.93
7	17.2991	94651.3	7.47508	WeakLayer	0	15	429.209	761.58	5462.88	2620.63	2842.25	5519.2	2898.57
8	17.2991	92689.6	7.47508	WeakLayer	0	15	420.937	746.903	5345.54	2558.07	2787.47	5400.78	2842.71
9	18.9112	98594.4	6.22811	WeakLayer	0	15	415.417	737.107	5213.26	2462.34	2750.92	5258.59	2796.25
10	18.9112	96767.3	6.22811	WeakLayer	0	15	403.817	716.524	5113.55	2439.44	2674.11	5157.62	2718.18
11	18.9112	99137.2	6.22811	WeakLayer	0	15	412.471	731.88	5233.17	2501.76	2731.41	5278.18	2776.42
12	17.1807	90786.8	12.3472	WeakLayer	0	15	405.383	719.304	5181.4	2496.92	2684.48	5270.14	2773.22
13	21.7549	114696	8.89484	WeakLayer	0	15	403.528	716.012	5211.41	2539.21	2672.2	5274.57	2735.36
14	21.7549	111271	8.89484	WeakLayer	0	15	394.426	699.861	5049.01	2437.12	2611.89	5110.74	2673.62
15	16.7749	81001	4.46366	WeakLayer	0	15	378.453	671.52	4826.82	2320.68	2506.14	4856.37	2535.69
16	16.7749	78436.9	4.46366	WeakLayer	0	15	364.779	647.256	4672.46	2256.87	2415.59	4700.94	2444.07
17	16.7749	77081.1	4.46366	WeakLayer	0	15	365.511	648.556	4589.8	2169.36	2420.44	4618.33	2448.97
18	16.7749	86540.2	4.46366	WeakLayer	0	15	399.164	708.268	5147.46	2504.17	2643.29	5178.62	2674.45
19	18.033	95380.8	4.3189	WeakLayer	0	15	413.472	733.657	5276.83	2538.79	2738.04	5308.06	2769.27
20	18.033	96571.5	4.3189	WeakLayer	0	15	417.325	740.494	5339.59	2576.03	2763.56	5371.11	2795.08
21	18.033	96014.9	4.3189	WeakLayer	0	15	421.376	747.682	5306.19	2515.81	2790.38	5338.02	2822.21
22	18.033	101632	4.3189	WeakLayer	0	15	439.071	779.078	5612.75	2705.19	2907.56	5645.91	2940.72
23	18.033	104643	4.3189	WeakLayer	0	15	450.502	799.361	5775.66	2792.39	2983.27	5809.68	3017.29
24	18.3475	108316	2.28881	WeakLayer	0	15	468.166	830.705	5913.3	2813.09	3100.21	5932.01	3118.92
25	18.3475	110542	2.28881	WeakLayer	0	15	472.08	837.649	6031.15	2904.99	3126.16	6050.02	3145.03
26	18.3475	112768	2.28881	WeakLayer	0	15	482.202	855.61	6149.05	2955.89	3193.16	6168.33	3212.44
27	18.3475	115481	2.28881	WeakLayer	0	15	494.421	877.291	6293.21	3019.13	3274.08	6312.97	3293.84
28	18.3475	120433	2.28881	WeakLayer	0	15	518.337	919.727	6559.35	3126.89	3432.46	6580.07	3453.18
29	17.7163	120469	4.91045	WeakLayer	0	15	523.066	928.117	6732.75	3268.94	3463.81	6777.68	3508.74
30	17.7163	120846	4.91045	WeakLayer	0	15	526.188	933.657	6750.68	3266.24	3484.44	6795.89	3529.65
31	17.7163	124305	4.91045	WeakLayer	0	15	536.598	952.129	6941.39	3387.99	3553.4	6987.49	3599.5
32	17.7163	122621	4.91045	WeakLayer	0	15	529.157	938.925	6844.21	3340.07	3504.14	6889.67	3549.6
33	17.7163	120032	4.91045	WeakLayer	0	15	520.024	922.72	6696.47	3252.82	3443.65	6741.15	3488.33
34	17.7163	117442	4.91045	WeakLayer	0	15	506.257	898.293	6548.85	3196.38	3352.47	6592.34	3395.96
35	17.7163	114853	4.91045	WeakLayer	0	15	492.095	873.163	6401.45	3142.75	3258.7	6443.73	3300.98
36	15.8233	100111	5.88883	WeakLayer	0	15	479.804	851.355	6227.4	3050.1	3177.3	6276.89	3226.79
37	15.8233	101422	5.88883	WeakLayer	0	15	497.696	883.102	6308.33	3012.57	3295.76	6359.66	3347.09
38	15.8233	111376	5.88883	WeakLayer	0	15	530.005	940.43	6931.13	3421.39	3509.74	6985.79	3564.4
39	15.8233	110756	5.88883	WeakLayer	0	15	529.855	940.164	6892.09	3383.36	3508.73	6946.74	3563.38
40	15.8233	108778	5.88883	WeakLayer	0	15	520.659	923.847	6768.43	3320.59	3447.84	6822.13	3501.54
41	15.8233	106801	5.88883	WeakLayer	0	15	511.933	908.363	6644.97	3254.89	3390.08	6697.77	3442.88
42	15.8233	104824	5.88883	WeakLayer	0	15	503.231	892.923	6521.63	3189.18	3332.45	6573.53	3384.35
43	15.8233	102846	5.88883	WeakLayer	0	15	494.552	877.524	6398.41	3123.48	3274.93	6449.42	3325.94
44	18.2635	118260	7.46563	WeakLayer	0	15	491.91	872.836	6354.42	3096.94	3257.48	6418.88	3321.94
45	18.2635	121171	7.46563	WeakLayer	0	15	500.237	887.611	6516.04	3203.41	3312.63	6581.59	3378.18
46	18.2635	124134	7.46563	WeakLayer	0	15	509.073	903.289	6681.03	3309.89	3371.14	6747.74	3437.85
47	21.2334	125302	36.2053	Qls	1500	0	845.366	1500	5192.73	2832.51	2360.22	5811.57	2979.06
48	21.7198	83468.5	39.2322	Qls	1500	0	845.366	1500	3124.96	1832.6	1292.36	3815.21	1982.61
49	9.31374	21144.9	46.1445	Qls	1500	0	845.366	1500	1389.69	1090.57	299.117	2269.52	1178.95
50	12.406	10480.5	46.1445	Qls	1500	0	845.366	1500	-30.4716	405.455	-435.927	849.36	443.905

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material
1	12.2127	10398.8	-41.7358	
2	6.63342	15007.4	-41.7358	
3	18.8461	68804.2	-34.5013	
4	14.1807	73164.3	-29.8357	
5	20.4434	115935	6.93654	WeakL
6	20.4434	113857	6.93654	WeakL
7	25.9486	143006	7.47508	WeakL
8	25.9486	139900	7.47508	WeakL
9	18.9112	98594.4	6.22811	WeakL
10	18.9112	96767.3	6.22811	WeakL
11	18.9112	99137.2	6.22811	WeakL
12	17.1807	90786.8	12.3472	WeakL
13	21.7549	114696	8.89484	WeakL
14	21.7549	111271	8.89484	WeakL
15	22.3665	107432	4.46366	WeakL
16	22.3665	102958	4.46366	WeakL
17	22.3665	112670	4.46366	WeakL
18	22.5412	119445	4.3189	WeakL
19	22.5412	120109	4.3189	WeakL
20	22.5412	124331	4.3189	WeakL
21	22.5412	130358	4.3189	WeakL
22	22.9344	135742	2.28881	WeakL
23	22.9344	139221	2.28881	WeakL
24	22.9344	142906	2.28881	WeakL
25	22.9344	149670	2.28881	WeakL
26	24.8029	168302	4.91045	WeakL
27	24.8029	172483	4.91045	WeakL
28	24.8029	171669	4.91045	WeakL
29	24.8029	166594	4.91045	WeakL
30	24.8029	161519	4.91045	WeakL
31	21.0977	132910	5.88883	WeakL
32	21.0977	142641	5.88883	WeakL
33	21.0977	148114	5.88883	WeakL
34	21.0977	144598	5.88883	WeakL
35	21.0977	141083	5.88883	WeakL
36	21.0977	137568	5.88883	WeakL
37	19.9271	129175	7.46563	WeakL
38	19.9271	132651	7.46563	WeakL
39	19.9271	135907	7.46563	WeakL
40	19.9271	132895	7.46563	WeakL
41	19.9271	128525	7.46563	WeakL
42	23.6839	150707	4.92318	WeakL
43	23.6839	144212	4.92318	WeakL
44	23.6839	137430	4.92318	WeakL
45	23.6839	139920	4.92318	WeakL
46	26.6347	156775	3.15232	WeakL
47	26.6347	155867	3.15232	WeakL
48	11.5274	63063.2	37.648	
49	29.0436	96839.9	42.454	
50	15.5502	13405.5	42.454	

Interslice Data

Groundwater at Surface - School_phi=15_FS

- **Global Minimum Query (spencer) - Safety Factor: 1.8117**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	714.622	287.896	28233.2	2189.24	4.43392
3	731.623	276.006	84045.8	6517.01	4.43391
4	746.468	268.689	130849	10146.2	4.43392
5	761.313	261.372	185832	14409.6	4.4339
6	777.036	263.285	181858	14101.5	4.43392
7	792.76	265.198	177865	13791.8	4.43389
8	810.059	267.468	172633	13386.2	4.43392
9	827.358	269.738	167486	12987.1	4.43392
10	844.657	272.007	162466	12597.8	4.43391
11	863.568	274.071	159360	12357	4.43392
12	882.479	276.135	156248	12115.7	4.43393
13	901.391	278.199	153053	11867.9	4.43391
14	918.571	281.96	140436	10889.6	4.43392
15	940.326	285.364	131297	10180.9	4.4339
16	962.081	288.769	122515	9499.98	4.43392
17	978.856	290.079	122380	9489.5	4.43391
18	995.631	291.388	122225	9477.5	4.43392
19	1012.41	292.698	122194	9475.04	4.4339
20	1029.18	294.007	121988	9459.08	4.4339
21	1047.21	295.369	122081	9466.31	4.43391
22	1065.25	296.731	122161	9472.47	4.43389
23	1083.28	298.093	122361	9487.99	4.4339
24	1101.31	299.455	122460	9495.68	4.4339
25	1119.35	300.817	122543	9502.15	4.43392
26	1137.69	301.55	126598	9816.56	4.43391
27	1156.04	302.283	130643	10130.2	4.4339
28	1174.39	303.017	134791	10451.8	4.43389
29	1192.74	303.75	139059	10782.8	4.43391
30	1211.08	304.483	143570	11132.6	4.43392
31	1228.8	306.005	142418	11043.3	4.43393
32	1246.52	307.527	141296	10956.3	4.43393
33	1264.23	309.049	140068	10861	4.43389
34	1281.95	310.572	138862	10767.5	4.4339
35	1299.66	312.094	137725	10679.4	4.43393
36	1317.38	313.616	136577	10590.3	4.43389
37	1335.1	315.138	135410	10499.8	4.43389
38	1353.18	317.003	132331	10261.1	4.43391
39	1371.27	318.868	129271	10023.8	4.4339
40	1389.35	320.733	125824	9756.55	4.43391
41	1407.43	322.599	122414	9492.16	4.43393
42	1425.52	324.464	119091	9234.47	4.43392
43	1443.6	326.329	115854	8983.47	4.43392
44	1461.68	328.194	112704	8739.17	4.43389
45	1479	330.464	106640	8268.99	4.43391
46	1496.33	332.734	100361	7782.13	4.43392
47	1513.65	335.004	93868.1	7278.64	4.43391
48	1535	350.625	31865.4	2470.88	4.43391
49	1559.36	367.596	-2852.06	-221.152	4.43391
50	1570.42	378.332	-9743.27	-755.504	4.43391
51	1583.72	391.24	0	0	0

Groundwater at Surface - School_phi=15_Ky

- **Global Minimum Query (spencer) - Critical Seismic Coefficient: 0.0805455**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	714.706	287.92	45019.8	6766.1	8.54711
3	734.697	274.05	133161	20012.9	8.54707
4	762.006	261.537	238824	35893.3	8.54712
5	792.76	265.198	227815	34238.7	8.54711
6	818.708	268.603	217001	32613.4	8.5471
7	844.657	272.007	206346	31012	8.54709
8	863.568	274.071	201232	30243.5	8.54711
9	882.479	276.135	196098	29471.8	8.54708
10	901.391	278.199	190824	28679.3	8.54712
11	918.571	281.96	176238	26487.2	8.54714
12	940.326	285.364	164526	24726.9	8.54711
13	962.081	288.769	153316	23042.2	8.54714
14	984.448	290.515	150913	22680.9	8.54708
15	1006.81	292.261	148880	22375.4	8.5471
16	1029.18	294.007	145935	21932.7	8.54706
17	1051.72	295.71	143634	21586.9	8.54707
18	1074.26	297.412	141207	21222.2	8.54709
19	1096.8	299.114	138659	20839.3	8.54711
20	1119.35	300.817	136113	20456.7	8.54713
21	1142.28	301.733	138676	20841.9	8.54713
22	1165.21	302.65	141142	21212.5	8.54712
23	1188.15	303.567	143760	21606	8.54714
24	1211.08	304.483	146602	22033	8.54709
25	1231.75	306.259	142356	21394.9	8.5471
26	1252.42	308.035	138008	20741.4	8.54709
27	1273.09	309.811	133603	20079.3	8.54706
28	1293.76	311.586	129291	19431.4	8.54713
29	1314.43	313.362	125105	18802.3	8.54714
30	1335.1	315.138	120888	18168.4	8.54708
31	1356.2	317.314	114475	17204.6	8.54709
32	1377.29	319.49	107711	16188	8.54707
33	1398.39	321.666	100516	15106.7	8.5471
34	1419.49	323.842	93489.1	14050.6	8.54709
35	1440.59	326.018	86674	13026.4	8.54712
36	1461.68	328.194	80070.5	12033.9	8.54709
37	1481.61	330.806	70281.7	10562.8	8.54715
38	1501.54	333.417	60054.4	9025.67	8.5471
39	1521.47	336.028	49669.4	7464.9	8.54711
40	1541.39	338.639	39545.3	5943.32	8.5471
41	1561.32	341.251	29779.6	4475.63	8.54712
42	1585	343.291	25177.4	3783.95	8.5471
43	1608.69	345.331	20809.3	3127.46	8.5471
44	1632.37	347.371	16646.6	2501.85	8.54712
45	1656.06	349.411	12173.6	1829.59	8.54711
46	1675.28	350.47	12423.3	1867.12	8.54712
47	1694.5	351.528	12615	1895.94	8.54716
48	1713.72	352.587	12862.1	1933.06	8.54708
49	1740.49	372.273	-26616.3	-4000.2	8.54709
50	1756.3	388.265	-25316.2	-3804.81	8.5471
51	1770.21	402.329	0	0	0

- **Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.77438**
- **Global Minimum Query (gle/morgenstern-price) - Critical Seismic Coefficient: 0.0780403**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	713.284	287.525	27503.2	148.544	0.30945
3	736.042	269.371	117257	1714.14	0.837528
4	752.957	260.356	182609	3909.83	1.22657
5	772.859	262.777	177697	5206.64	1.67832
6	792.76	265.198	172871	6403.64	2.12143
7	810.059	267.468	167815	7320.58	2.49783
8	827.358	269.738	162841	8148.07	2.86452
9	844.657	272.007	157991	8888.65	3.22009
10	863.568	274.071	155089	9742.46	3.59451
11	882.479	276.135	152173	10513.8	3.95235
12	901.391	278.199	149174	11195.5	4.292
13	918.571	281.96	136653	10955.2	4.58349
14	940.326	285.364	127689	11008.8	4.92761
15	962.081	288.769	119080	10925	5.24193
16	978.856	290.079	119109	11390.7	5.46273
17	995.631	291.388	119110	11813.2	5.66401
18	1012.41	292.698	119232	12205.8	5.84502
19	1029.18	294.007	119188	12538.1	6.0052
20	1047.21	295.369	119458	12879.3	6.15354
21	1065.25	296.731	119713	13166.7	6.27648
22	1083.28	298.093	120086	13414	6.3737
23	1101.31	299.455	120361	13595.9	6.44478
24	1119.35	300.817	120620	13720.3	6.4894
25	1137.69	301.55	124874	14244.3	6.50757
26	1156.04	302.283	129114	14706.3	6.49808
27	1174.39	303.017	133453	15113.2	6.46107
28	1192.74	303.75	137910	15460.9	6.39664
29	1211.08	304.483	142612	15757.1	6.305
30	1228.8	306.005	141632	15363.9	6.1911
31	1246.52	307.527	140680	14916.8	6.05266
32	1264.23	309.049	139622	14404.3	5.89016
33	1281.95	310.572	138581	13842.5	5.70421
34	1299.66	312.094	137602	13238.8	5.49556
35	1317.38	313.616	136604	12588.1	5.26495
36	1335.1	315.138	135580	11893.3	5.01325
37	1350.92	316.77	133009	11102.4	4.77148
38	1366.74	318.402	130590	10310.5	4.51432
39	1382.57	320.034	127665	9470.88	4.24274
40	1398.39	321.666	124802	8633.91	3.95747
41	1414.21	323.298	121995	7802.37	3.65945
42	1430.04	324.93	119251	6979.62	3.34963
43	1445.86	326.562	116571	6168.31	3.02896
44	1461.68	328.194	113955	5370.92	2.69846
45	1479.95	330.588	107732	4338.64	2.3062
46	1498.21	332.981	101275	3366.59	1.90393
47	1516.47	335.374	94583.5	2465.9	1.49343
48	1537.71	350.918	31822.3	559.978	1.00813
49	1559.43	368.652	-5233.99	-46.1896	0.505618
50	1568.74	378.346	-10830.4	-54.6294	0.289002
51	1581.15	391.257	0	0	0

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	712.213	287.228	41776.5	300.814	0.412554
3	718.846	281.31	72384.6	804.068	0.636431
4	737.692	268.357	157934	3503.32	1.27074
5	751.873	260.224	224445	6839.2	1.74535
6	772.316	262.711	217471	9204.26	2.42354
7	792.76	265.198	210602	11377.4	3.0923
8	818.708	268.603	200749	13768.3	3.92347
9	844.657	272.007	190996	15803.8	4.73011
10	863.568	274.071	186527	17302.9	5.29979
11	882.479	276.135	182008	18654.8	5.85206
12	901.391	278.199	177336	19845.1	6.38522
13	918.571	281.96	163118	19599.8	6.85165
14	940.326	285.364	151959	19778.9	7.4159
15	962.081	288.769	141261	19723.5	7.94851
16	984.448	290.515	139429	20741.3	8.46121
17	1006.81	292.261	137933	21689.4	8.93635
18	1029.18	294.007	135529	22368.8	9.37207
19	1051.72	295.71	133774	23034.1	9.76977
20	1074.26	297.412	131872	23547.5	10.1242
21	1096.8	299.114	129837	23909.8	10.4343
22	1119.35	300.817	127802	24145.4	10.6987
23	1142.28	301.733	130934	25261	10.9199
24	1165.21	302.65	133958	26262.6	11.0922
25	1188.15	303.567	137126	27188.7	11.2149
26	1211.08	304.483	140518	28046.3	11.2875
27	1235.89	306.614	135955	27189.8	11.3094
28	1260.69	308.745	131328	26176.4	11.2725
29	1285.49	310.876	126518	24997.9	11.1768
30	1310.29	313.007	121955	23755.8	11.0227
31	1335.1	315.138	117271	22393.7	10.8109
32	1356.2	317.314	111175	20777.7	10.586
33	1377.29	319.49	104755	19076	10.3205
34	1398.39	321.666	97917.7	17293.1	10.0156
35	1419.49	323.842	91241.2	15550.4	9.67209
36	1440.59	326.018	84770.4	13868.1	9.29106
37	1461.68	328.194	78507	12257	8.87374
38	1481.61	330.806	69058.4	10256.3	8.44761
39	1501.54	333.417	59197.4	8310.98	7.99177
40	1521.47	336.028	49208.1	6485.01	7.5076
41	1541.39	338.639	39490	4846.43	6.99667
42	1561.32	341.251	30136.9	3412.71	6.46067
43	1585	343.291	26003.7	2638.36	5.79346
44	1608.69	345.331	22097.6	1970.83	5.09658
45	1632.37	347.371	18389.2	1406.39	4.37342
46	1656.06	349.411	14398.5	912.829	3.62755
47	1682.69	350.878	15076.7	728.508	2.76639
48	1709.32	352.345	15935.4	524.993	1.88693
49	1720.85	361.238	-9361.16	-245.472	1.50209
50	1749.9	387.808	-25265.3	-231.61	0.525222
51	1765.45	402.034	0	0	0

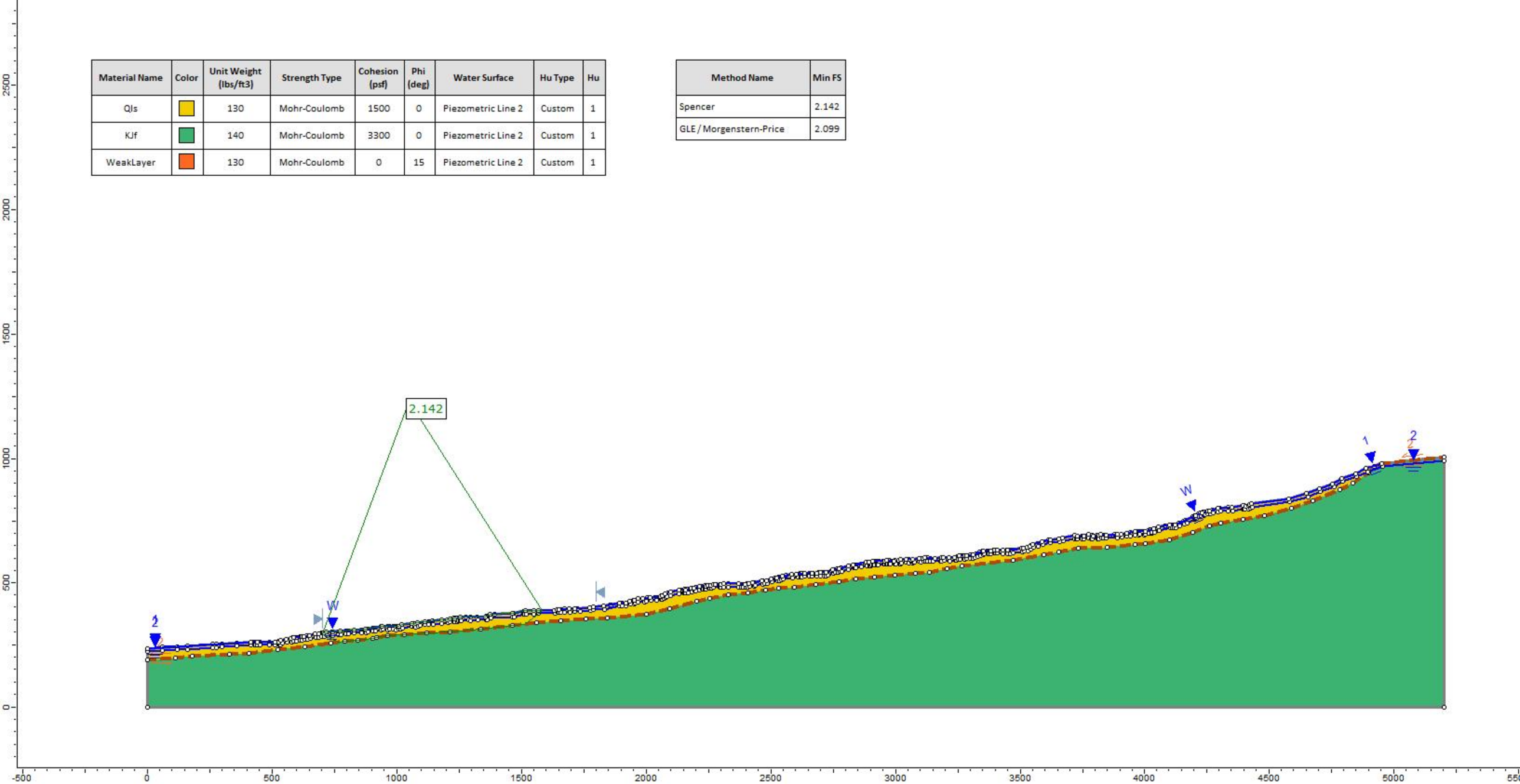
ANALYSIS RUN 2-B

$\phi = 15^{o}$

GW = 13 FEET

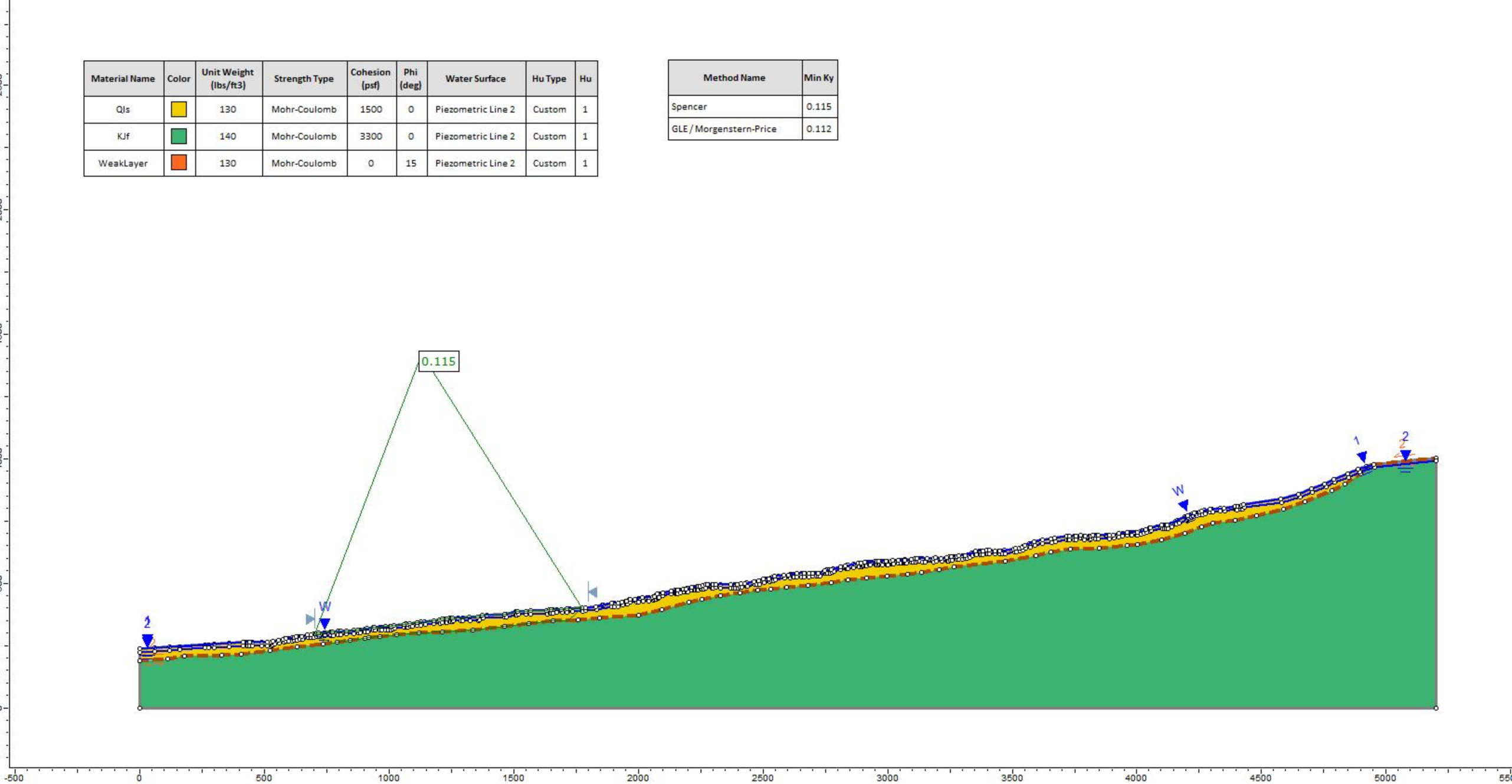
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Qls		130	Mohr-Coulomb	1500	0	Piezometric Line 2	Custom	1
KJf		140	Mohr-Coulomb	3300	0	Piezometric Line 2	Custom	1
WeakLayer		130	Mohr-Coulomb	0	15	Piezometric Line 2	Custom	1

Method Name	Min FS
Spencer	2.142
GLE / Morgenstern-Price	2.099



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Qls		130	Mohr-Coulomb	1500	0	Piezometric Line 2	Custom	1
KJf		140	Mohr-Coulomb	3300	0	Piezometric Line 2	Custom	1
WeakLayer		130	Mohr-Coulomb	0	15	Piezometric Line 2	Custom	1

Method Name	Min Ky
Spencer	0.115
GLE / Morgenstern-Price	0.112



Slide Analysis Information

Slide_xs1_2019-09-06_phi-15

Project Summary

File Name:	Slide_xs1_2019-09-06_phi-15.slmd
Slide Modeler Version:	8.027
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	9/6/2019, 8:16:52 PM

Currently Open Scenarios

Group Name	Scenario Name	Global Minimum	Compute Time
Groundwater at depth 13 ft	School_phi=15_FS	Spencer: 2.141510 Gle/morgenstern-price: 2.098790	00h:00m:16.146s
	School_phi=15_Ky	Spencer: 0.115157 Gle/morgenstern-price: 0.112172	00h:01m:23.866s

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

All Open Scenarios

Slices Type:	Vertical
Analysis Methods Used	
	GLE/Morgenstern-Price with interslice force function (Half Sine)
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

All Open Scenarios

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Use negative pore pressure cutoff:	Yes
Maximum negative pore pressure [psf]:	0
Advanced Groundwater Method:	None

Random Numbers

All Open Scenarios

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

All Open Scenarios	
Search Method:	Cuckoo Search
Initial # of Surface Vertices:	8
Maximum Iterations:	500
Number of Nests:	50
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined
Convex Surfaces Only:	Enabled

Seismic Loading

Groundwater at depth 13 ft - School_phi=15_FS		Groundwater at depth 13 ft - School_phi=15_Ky	
Advanced seismic analysis:	No	Advanced seismic analysis:	Yes
Staged pseudostatic analysis:	No	Locate surface with minimum critical horizontal seismic acceleration (Ky):	Yes
		Target factor of safety:	1
		Using Newmark analysis:	No
		Staged pseudostatic analysis:	No

Materials

Property	Qls	KJf	WeakLayer
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	130	140	130
Cohesion [psf]	1500	3300	0
Friction Angle [°]	0	0	15
Water Surface	Assigned per scenario	Assigned per scenario	Assigned per scenario
Hu Value	1	1	1

Materials In Use

Material	School_phi=15_FS	School_phi=15_Ky
Qls	✓	✓
KJf	✓	✓
WeakLayer	✓	✓

Global Minimums

Groundwater at depth 13 ft - School_phi=15_FS

Method: spencer

FS	2.141510
Axis Location:	1048.910, 1228.731
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1584.051, 391.238
Resisting Moment:	9.72753e+08 lb-ft
Driving Moment:	4.54237e+08 lb-ft
Resisting Horizontal Force:	981472 lb
Driving Horizontal Force:	458308 lb
Total Slice Area:	37876.6 ft2
Surface Horizontal Width:	884.051 ft
Surface Average Height:	42.8444 ft

Method: gle/morgenstern-price

FS	2.098790
Axis Location:	1047.066, 1225.105
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1580.412, 391.263
Resisting Moment:	9.6057e+08 lb-ft
Driving Moment:	4.57679e+08 lb-ft
Resisting Horizontal Force:	970876 lb
Driving Horizontal Force:	462589 lb
Total Slice Area:	38053.2 ft2
Surface Horizontal Width:	880.412 ft
Surface Average Height:	43.222 ft

Groundwater at depth 13 ft - School_phi=15_Ky

Method: spencer

Ky	0.115157
Axis Location:	1132.351, 1423.855
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1773.526, 402.535
Resisting Moment:	1.36086e+09 lb-ft
Driving Moment:	1.36086e+09 lb-ft
Resisting Horizontal Force:	1.15561e+06 lb
Driving Horizontal Force:	1.15561e+06 lb
Total Slice Area:	46885 ft2
Surface Horizontal Width:	1073.53 ft
Surface Average Height:	43.6738 ft

Method: gle/morgenstern-price

Ky	0.112172
Axis Location:	1064.391, 1259.168
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1614.593, 391.028
Resisting Moment:	1.00899e+09 lb-ft
Driving Moment:	1.00899e+09 lb-ft
Resisting Horizontal Force:	992686 lb
Driving Horizontal Force:	992686 lb
Total Slice Area:	39865.4 ft2
Surface Horizontal Width:	914.593 ft
Surface Average Height:	43.5881 ft

Global Minimum Coordinates

Groundwater at depth 13 ft - School_phi=15_FS

Method: spencer

X	Y
700	298.122
724.193	281.821
748.386	269.4
766.644	262.021
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1509.76	334.494
1528.76	346.929
1557.07	366.115
1584.05	391.238

Method: gle/morgenstern-price

X	Y
700	298.122
721.911	279.061
754.234	262.049
757.186	260.87
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1512.51	334.855
1527.47	344.778
1553.94	364.888
1580.41	391.263

Groundwater at depth 13 ft - School_phi=15_Ky

Method: spencer

X	Y
700	298.122
725.967	279.601
765.606	264.266
770.486	262.488
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1561.32	341.251
1656.06	349.411
1714.76	352.644
1740.83	369.862
1773.53	402.535

Method: gle/morgenstern-price

X	Y
700	298.122
726.384	276.235
752.769	262.027
756.089	260.737
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1211.08	304.483
1335.1	315.138
1461.68	328.194
1555.4	340.475
1574.17	353.74
1594.38	372.384
1614.59	391.028

Slice Data

Groundwater at depth 13 ft - School_phi=15_FS

- Global Minimum Query (spencer) - Safety Factor: 2.14151

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	15.0146	12731.5	-33.9722	Qls	1500	0	700.44	1500	1458.11	0	1458.11	986.148	986.148
2	9.17842	20745.3	-33.9722	Qls	1500	0	700.44	1500	2953.11	272.414	2680.69	2481.15	2208.73
3	24.1928	87501	-27.1766	Qls	1500	0	700.44	1500	4211.54	928.047	3283.49	3851.92	2923.87
4	18.258	92772	-22.0073	Qls	1500	0	700.44	1500	5607.92	1634.33	3973.59	5324.82	3690.49
5	26.1159	145714	6.93654	WeakLayer	0	15	455.158	974.725	5506.47	1868.77	3637.7	5561.85	3693.08
6	17.2991	95565.8	7.47508	WeakLayer	0	15	449.907	963.481	5443.58	1847.82	3595.76	5502.62	3654.8
7	17.2991	94651.3	7.47508	WeakLayer	0	15	448.937	961.403	5391.33	1803.32	3588.01	5450.23	3646.91
8	17.2991	92689.6	7.47508	WeakLayer	0	15	442.019	946.589	5279.48	1746.76	3532.72	5337.48	3590.72
9	18.9112	98594.4	6.22811	WeakLayer	0	15	438.579	939.221	5155.5	1650.28	3505.22	5203.36	3553.08
10	18.9112	96767.3	6.22811	WeakLayer	0	15	429.914	920.666	5059.97	1624	3435.97	5106.89	3482.89
11	18.9112	99137.2	6.22811	WeakLayer	0	15	439.165	940.476	5183.92	1674.02	3509.9	5231.85	3557.83
12	17.1807	90786.8	12.3472	WeakLayer	0	15	431.892	924.9	5132.89	1681.12	3451.77	5227.43	3546.31
13	21.7549	114696	8.89484	WeakLayer	0	15	433.457	928.253	5173.49	1709.19	3464.3	5241.33	3532.14
14	21.7549	111271	8.89484	WeakLayer	0	15	424.681	909.459	5018.63	1624.49	3394.14	5085.1	3460.61
15	16.7749	81001	4.46366	WeakLayer	0	15	411.747	881.761	4799.61	1508.84	3290.77	4831.76	3322.92
16	16.7749	78436.9	4.46366	WeakLayer	0	15	400.442	857.551	4647.68	1447.26	3200.42	4678.94	3231.68
17	16.7749	77081.1	4.46366	WeakLayer	0	15	402.311	861.552	4567.38	1352.03	3215.35	4598.79	3246.76
18	16.7749	86540.2	4.46366	WeakLayer	0	15	434.923	931.392	5127.81	1651.81	3476	5161.76	3509.95
19	18.033	95380.8	4.3189	WeakLayer	0	15	442.097	946.756	5259.54	1726.2	3533.34	5292.92	3566.72
20	18.033	96571.5	4.3189	WeakLayer	0	15	445.902	954.904	5325.18	1761.43	3563.75	5358.85	3597.42
21	18.033	96014.9	4.3189	WeakLayer	0	15	452.698	969.457	5294.55	1676.49	3618.06	5328.74	3652.25
22	18.033	101632	4.3189	WeakLayer	0	15	463.851	993.341	5604.24	1897.02	3707.22	5639.27	3742.25
23	18.033	104643	4.3189	WeakLayer	0	15	475.067	1017.36	5770.18	1973.36	3796.82	5806.06	3832.7
24	18.3475	108316	2.28881	WeakLayer	0	15	489.253	1047.74	5904.8	1994.59	3910.21	5924.36	3929.77
25	18.3475	110542	2.28881	WeakLayer	0	15	492.396	1054.47	6025.87	2090.53	3935.34	6045.55	3955.02
26	18.3475	112768	2.28881	WeakLayer	0	15	501.235	1073.4	6147.2	2141.18	4006.02	6167.24	4026.06
27	18.3475	115481	2.28881	WeakLayer	0	15	512.297	1097.09	6295.01	2200.61	4094.4	6315.48	4114.87
28	18.3475	120433	2.28881	WeakLayer	0	15	532.914	1141.24	6564.91	2305.72	4259.19	6586.21	4280.49
29	17.7163	120469	4.91045	WeakLayer	0	15	536.084	1148.03	6750.24	2465.72	4284.52	6796.29	4330.57
30	17.7163	120846	4.91045	WeakLayer	0	15	541.613	1159.87	6771.32	2442.64	4328.68	6817.86	4375.22
31	17.7163	124305	4.91045	WeakLayer	0	15	554.422	1187.3	6965.18	2534.12	4431.06	7012.81	4478.69
32	17.7163	122621	4.91045	WeakLayer	0	15	544.186	1165.38	6870.81	2521.55	4349.26	6917.56	4396.01
33	17.7163	120032	4.91045	WeakLayer	0	15	534.735	1145.14	6725.72	2452.01	4273.71	6771.66	4319.65
34	17.7163	117442	4.91045	WeakLayer	0	15	525.064	1124.43	6580.62	2384.2	4196.42	6625.73	4241.53
35	17.7163	114853	4.91045	WeakLayer	0	15	513.413	1099.48	6435.53	2332.23	4103.3	6479.64	4147.41
36	18.0838	114198	5.88883	WeakLayer	0	15	502.659	1076.45	6251.43	2234.06	4017.37	6303.27	4069.21
37	18.0838	118533	5.88883	WeakLayer	0	15	535.907	1147.65	6488.45	2205.36	4283.09	6543.72	4338.36
38	18.0838	127887	5.88883	WeakLayer	0	15	551.209	1180.42	7001.05	2595.66	4405.39	7057.91	4462.25
39	18.0838	125448	5.88883	WeakLayer	0	15	543.336	1163.56	6867.44	2524.99	4342.45	6923.49	4398.5
40	18.0838	122865	5.88883	WeakLayer	0	15	534.483	1144.6	6726.02	2454.33	4271.69	6781.15	4326.82
41	18.0838	120283	5.88883	WeakLayer	0	15	525.629	1125.64	6584.6	2383.66	4200.94	6638.82	4255.16
42	18.0838	117700	5.88883	WeakLayer	0	15	516.776	1106.68	6443.18	2313	4130.18	6496.48	4183.48
43	16.0252	103613	7.46563	WeakLayer	0	15	514.614	1102.05	6371.92	2259.03	4112.89	6439.36	4180.33
44	16.0252	105843	7.46563	WeakLayer	0	15	520.11	1113.82	6509.28	2352.45	4156.83	6577.43	4224.98
45	16.0252	108124	7.46563	WeakLayer	0	15	526.007	1126.45	6649.85	2445.88	4203.97	6718.78	4272.9
46	18.9997	117167	33.204	Qls	1500	0	700.44	1500	5471.8	2161.87	3309.93	5930.23	3768.36
47	14.1541	68090.5	34.1273	Qls	1500	0	700.44	1500	4161.83	1497.79	2664.04	4636.55	3138.76
48	14.1541	51632.6	34.1273	Qls	1500	0	700.44	1500	3060.36	930.565	2129.8	3535.08	2604.52
49	13.1239	31834.6	42.9543	Qls	1500	0	700.44	1500	1701.04	350.008	1351.03	2353.16	2003.15
50	13.86	11711	42.9543	Qls	1500	0	700.44	1500	232.569	0	232.569	884.696	884.696

G

- Global Mi

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Materi
1	14.4166	12232.8	-35.4991	
2	11.5504	27929.3	-35.4991	
3	19.8193	71211.1	-21.1503	
4	19.8193	94248.6	-21.1503	
5	4.88037	26707.9	-20.0128	
6	22.2738	124110	6.93654	WeakLa
7	25.9486	143006	7.47508	WeakLa
8	25.9486	139900	7.47508	WeakLa
9	18.9112	98594.4	6.22811	WeakLa
10	18.9112	96767.3	6.22811	WeakLa
11	18.9112	99137.2	6.22811	WeakLa
12	17.1807	90786.8	12.3472	WeakLa
13	21.7549	114696	8.89484	WeakLa
14	21.7549	111271	8.89484	WeakLa
15	22.3665	107432	4.46366	WeakLa
16	22.3665	102958	4.46366	WeakLa
17	22.3665	112670	4.46366	WeakLa
18	22.5412	119445	4.3189	WeakLa
19	22.5412	120109	4.3189	WeakLa
20	22.5412	124331	4.3189	WeakLa
21	22.5412	130358	4.3189	WeakLa
22	22.9344	135742	2.28881	WeakLa
23	22.9344	139221	2.28881	WeakLa
24	22.9344	142906	2.28881	WeakLa
25	22.9344	149670	2.28881	WeakLa
26	24.8029	168302	4.91045	WeakLa
27	24.8029	172483	4.91045	WeakLa
28	24.8029	171669	4.91045	WeakLa
29	24.8029	166594	4.91045	WeakLa
30	24.8029	161519	4.91045	WeakLa
31	21.0977	132910	5.88883	WeakLa
32	21.0977	142641	5.88883	WeakLa
33	21.0977	148114	5.88883	WeakLa
34	21.0977	144598	5.88883	WeakLa
35	21.0977	141083	5.88883	WeakLa
36	21.0977	137568	5.88883	WeakLa
37	24.9089	162007	7.46563	WeakLa
38	24.9089	167466	7.46563	WeakLa
39	24.9089	168459	7.46563	WeakLa
40	24.9089	161220	7.46563	WeakLa
41	23.6839	150707	4.92318	WeakLa
42	23.6839	144212	4.92318	WeakLa
43	23.6839	137430	4.92318	WeakLa
44	23.6839	139920	4.92318	WeakLa
45	19.569	115538	3.15232	WeakLa
46	19.569	113742	3.15232	WeakLa
47	19.569	115980	3.15232	WeakLa
48	26.0697	130306	33.442	
49	18.6422	53099.4	44.9814	
50	14.0526	12032.3	44.9814	

- Global Minimum Query (gle/morgenstern-price) - Safety Factor: 2.09879

- Global Minimum

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	12.4483	10594.6	-41.0215	Qls	1500	0	714.698	1500	1483.76	0	1483.76	862.018	862.018
2	9.46246	23071.6	-41.0215	Qls	1500	0	714.698	1500	3103.58	338.752	2764.83	2481.83	2143.08
3	16.1618	59290	-27.758	Qls	1500	0	714.698	1500	4117.42	950.722	3166.69	3741.27	2790.54
4	16.1618	79343.8	-27.758	Qls	1500	0	714.698	1500	5414.31	1530.41	3883.9	5038.16	3507.75
5	2.95142	16583.1	-21.7757	Qls	1500	0	714.698	1500	6051.22	1888.94	4162.28	5765.72	3876.78
6	17.7869	100347	6.93654	WeakLayer	0	15	476.651	1000.39	5649.39	1915.85	3733.54	5707.38	3791.53
7	17.7869	99015.6	6.93654	WeakLayer	0	15	472.15	990.944	5570.87	1872.62	3698.25	5628.31	3755.69
8	17.2991	95565.8	7.47508	WeakLayer	0	15	468.516	983.317	5517.61	1847.82	3669.79	5579.08	3731.26
9	17.2991	94651.3	7.47508	WeakLayer	0	15	466.85	979.82	5460.06	1803.32	3656.74	5521.32	3718
10	17.2991	92689.6	7.47508	WeakLayer	0	15	459.115	963.586	5342.91	1746.76	3596.15	5403.15	3656.39
11	18.9112	98594.4	6.22811	WeakLayer	0	15	454.747	954.418	5212.21	1650.28	3561.93	5261.84	3611.56
12	18.9112	96767.3	6.22811	WeakLayer	0	15	445.402	934.806	5112.74	1624	3488.74	5161.35	3537.35
13	18.9112	99137.2	6.22811	WeakLayer	0	15	454.324	953.531	5232.65	1674.02	3558.63	5282.23	3608.21
14	17.1807	90786.8	12.3472	WeakLayer	0	15	445.856	935.759	5173.42	1681.12	3492.3	5271.02	3589.9
15	21.7549	114696	8.89484	WeakLayer	0	15	446.626	937.375	5207.51	1709.19	3498.32	5277.41	3568.22
16	21.7549	111271	8.89484	WeakLayer	0	15	436.735	916.615	5045.34	1624.49	3420.85	5113.69	3489.2
17	16.7749	81001	4.46366	WeakLayer	0	15	423.923	889.726	4829.34	1508.84	3320.5	4862.43	3353.59
18	16.7749	78436.9	4.46366	WeakLayer	0	15	412.11	864.932	4675.23	1447.26	3227.97	4707.4	3260.14
19	16.7749	77081.1	4.46366	WeakLayer	0	15	413.747	868.369	4592.83	1352.03	3240.8	4625.12	3273.09
20	16.7749	86540.2	4.46366	WeakLayer	0	15	446.673	937.472	5150.5	1651.81	3498.69	5185.37	3533.56
21	18.033	95380.8	4.3189	WeakLayer	0	15	453.694	952.209	5279.89	1726.2	3553.69	5314.15	3587.95
22	18.033	96571.5	4.3189	WeakLayer	0	15	457.2	959.566	5342.58	1761.43	3581.15	5377.11	3615.68
23	18.033	96014.9	4.3189	WeakLayer	0	15	463.787	973.392	5309.24	1676.49	3632.75	5344.26	3667.77
24	18.033	101632	4.3189	WeakLayer	0	15	474.703	996.302	5615.24	1897.02	3718.22	5651.09	3754.07
25	18.033	104643	4.3189	WeakLayer	0	15	485.718	1019.42	5777.87	1973.36	3804.51	5814.55	3841.19
26	18.3475	108316	2.28881	WeakLayer	0	15	500.912	1051.31	5918.14	1994.59	3923.55	5938.17	3943.58
27	18.3475	110542	2.28881	WeakLayer	0	15	503.647	1057.05	6035.51	2090.53	3944.98	6055.64	3965.11
28	18.3475	112768	2.28881	WeakLayer	0	15	512.167	1074.93	6152.87	2141.18	4011.69	6173.34	4032.16
29	18.3475	115481	2.28881	WeakLayer	0	15	522.911	1097.48	6296.42	2200.61	4095.81	6317.32	4116.71
30	18.3475	120433	2.28881	WeakLayer	0	15	543.37	1140.42	6561.8	2305.72	4256.08	6583.52	4277.8
31	20.6691	140326	4.91045	WeakLayer	0	15	543.508	1140.71	6719.87	2462.68	4257.19	6766.56	4303.88
32	20.6691	142220	4.91045	WeakLayer	0	15	553.338	1161.34	6806.59	2472.4	4334.19	6854.12	4381.72
33	20.6691	144709	4.91045	WeakLayer	0	15	557.321	1169.7	6921.89	2556.49	4365.4	6969.77	4413.28
34	20.6691	141296	4.91045	WeakLayer	0	15	544.823	1143.47	6754.09	2486.61	4267.48	6800.9	4314.29
35	20.6691	137771	4.91045	WeakLayer	0	15	534.413	1121.62	6581.23	2395.33	4185.9	6627.15	4231.82
36	20.6691	134247	4.91045	WeakLayer	0	15	519.485	1090.29	6408.52	2339.52	4069	6453.15	4113.63
37	18.0838	114198	5.88883	WeakLayer	0	15	507.43	1064.99	6208.63	2234.06	3974.57	6260.97	4026.91
38	18.0838	118533	5.88883	WeakLayer	0	15	541.164	1135.79	6444.17	2205.36	4238.81	6499.99	4294.63
39	18.0838	127887	5.88883	WeakLayer	0	15	556.645	1168.28	6955.73	2595.66	4360.07	7013.14	4417.48
40	18.0838	125448	5.88883	WeakLayer	0	15	548.549	1151.29	6821.68	2524.99	4296.69	6878.26	4353.27
41	18.0838	122865	5.88883	WeakLayer	0	15	539.478	1132.25	6679.93	2454.33	4225.6	6735.57	4281.24
42	18.0838	120283	5.88883	WeakLayer	0	15	530.434	1113.27	6538.45	2383.66	4154.79	6593.16	4209.5
43	18.0838	117700	5.88883	WeakLayer	0	15	521.419	1094.35	6397.14	2313	4084.14	6450.92	4137.92
44	16.9423	109610	7.46563	WeakLayer	0	15	520.257	1091.91	6336.74	2261.7	4075.04	6404.91	4143.21
45	16.9423	112108	7.46563	WeakLayer	0	15	526.703	1105.44	6486.03	2360.47	4125.56	6555.05	4194.58
46	16.9423	114657	7.46563	WeakLayer	0	15	533.612	1119.94	6638.89	2459.25	4179.64	6708.82	4249.57
47	14.9547	94226.5	33.5657	Qls	1500	0	714.698	1500	5708.81	2218.76	3490.05	6183.04	3964.28
48	26.4733	117322	37.2214	Qls	1500	0	714.698	1500	3835.62	1310.71	2524.91	4378.53	3067.82
49	13.4365	33176.8	44.8931	Qls	1500	0	714.698	1500	1748.69	368.37	1380.32	2460.73	2092.36
50	13.037	11082.3	44.8931	Qls	1500	0	714.698	1500	141.514	0	141.514	853.548	853.548

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Materi
1	12.9023	10972	-39.678	
2	13.4821	35718.4	-39.678	
3	26.3843	118376	-28.3014	
4	3.32001	18652.1	-21.2466	
5	18.3355	103551	6.93654	WeakLa
6	18.3355	102079	6.93654	WeakLa
7	17.2991	95565.8	7.47508	WeakLa
8	17.2991	94651.3	7.47508	WeakLa
9	17.2991	92689.6	7.47508	WeakLa
10	18.9112	98594.4	6.22811	WeakLa
11	18.9112	96767.3	6.22811	WeakLa
12	18.9112	99137.2	6.22811	WeakLa
13	17.1807	90786.8	12.3472	WeakLa
14	21.7549	114696	8.89484	WeakLa
15	21.7549	111271	8.89484	WeakLa
16	16.7749	81001	4.46366	WeakLa
17	16.7749	78436.9	4.46366	WeakLa
18	16.7749	77081.1	4.46366	WeakLa
19	16.7749	86540.2	4.46366	WeakLa
20	18.033	95380.8	4.3189	WeakLa
21	18.033	96571.5	4.3189	WeakLa
22	18.033	96014.9	4.3189	WeakLa
23	18.033	101632	4.3189	WeakLa
24	18.033	104643	4.3189	WeakLa
25	18.3475	108316	2.28881	WeakLa
26	18.3475	110542	2.28881	WeakLa
27	18.3475	112768	2.28881	WeakLa
28	18.3475	115481	2.28881	WeakLa
29	18.3475	120433	2.28881	WeakLa
30	20.6691	140326	4.91045	WeakLa
31	20.6691	142220	4.91045	WeakLa
32	20.6691	144709	4.91045	WeakLa
33	20.6691	141296	4.91045	WeakLa
34	20.6691	137771	4.91045	WeakLa
35	20.6691	134247	4.91045	WeakLa
36	21.0977	132910	5.88883	WeakLa
37	21.0977	142641	5.88883	WeakLa
38	21.0977	148114	5.88883	WeakLa
39	21.0977	144598	5.88883	WeakLa
40	21.0977	141083	5.88883	WeakLa
41	21.0977	137568	5.88883	WeakLa
42	18.7425	121400	7.46563	WeakLa
43	18.7425	124469	7.46563	WeakLa
44	18.7425	127570	7.46563	WeakLa
45	18.7425	126098	7.46563	WeakLa
46	18.7425	121545	7.46563	WeakLa
47	18.7733	106882	35.2464	
48	20.2117	74026.8	42.6892	
49	6.17239	12770	42.6892	
50	14.0393	11905.6	42.6892	

Interslice Data

Groundwater at depth 13 ft - School_phi=15_FS

- **Global Minimum Query (spencer) - Safety Factor: 2.14151**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	715.015	288.006	25268.3	2075.07	4.69468
3	724.193	281.821	49960.6	4102.84	4.69468
4	748.386	269.4	119217	9790.3	4.69469
5	766.644	262.021	173389	14239	4.69469
6	792.76	265.198	167780	13778.4	4.6947
7	810.059	267.468	163207	13402.8	4.69468
8	827.358	269.738	158736	13035.7	4.6947
9	844.657	272.007	154399	12679.5	4.69469
10	863.568	274.071	152053	12486.9	4.69471
11	882.479	276.135	149741	12296.9	4.69466
12	901.391	278.199	147347	12100.4	4.6947
13	918.571	281.96	135464	11124.5	4.69468
14	940.326	285.364	127279	10452.4	4.69471
15	962.081	288.769	119431	9807.86	4.69468
16	978.856	290.079	120053	9858.93	4.69468
17	995.631	291.388	120684	9910.76	4.69468
18	1012.41	292.698	121452	9973.81	4.69468
19	1029.18	294.007	122033	10021.5	4.69467
20	1047.21	295.369	122842	10088	4.69469
21	1065.25	296.731	123631	10152.7	4.69465
22	1083.28	298.093	124584	10231	4.69467
23	1101.31	299.455	125316	10291.1	4.69466
24	1119.35	300.817	126024	10349.3	4.69469
25	1137.69	301.55	130671	10730.9	4.69468
26	1156.04	302.283	135286	11109.9	4.69469
27	1174.39	303.017	139975	11494.9	4.69466
28	1192.74	303.75	144758	11887.7	4.69466
29	1211.08	304.483	149721	12295.4	4.69471
30	1228.8	306.005	148944	12231.5	4.69468
31	1246.52	307.527	148233	12173.1	4.69467
32	1264.23	309.049	147454	12109.2	4.6947
33	1281.95	310.572	146637	12042.1	4.6947
34	1299.66	312.094	145874	11979.4	4.69468
35	1317.38	313.616	145160	11920.7	4.69466
36	1335.1	315.138	144460	11863.3	4.69469
37	1353.18	317.003	141890	11652.2	4.69467
38	1371.27	318.868	139479	11454.2	4.69467
39	1389.35	320.733	136388	11200.4	4.69469
40	1407.43	322.599	133404	10955.4	4.69471
41	1425.52	324.464	130524	10718.9	4.69471
42	1443.6	326.329	127748	10490.9	4.6947
43	1461.68	328.194	125075	10271.4	4.69471
44	1477.71	330.294	119941	9849.75	4.69469
45	1493.73	332.394	114607	9411.67	4.69467
46	1509.76	334.494	109071	8957.12	4.6947
47	1528.76	346.929	54338.4	4462.35	4.69468
48	1542.91	356.522	24328.6	1997.9	4.69468
49	1557.07	366.115	4884.99	401.163	4.69468
50	1570.19	378.334	-6706.87	-550.778	4.69468
51	1584.05	391.238	0	0	0

Groundwater at depth 13 ft - School_phi=15_Ky

- **Global Minimum Query (spencer) - Critical Seismic Coefficient: 0.115157**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	714.417	287.84	46108.6	8644.31	10.6184
3	725.967	279.601	95566.8	17916.6	10.6184
4	745.786	271.933	153281	28736.7	10.6184
5	765.606	264.266	217744	40822.1	10.6184
6	770.486	262.488	233783	43829	10.6184
7	792.76	265.198	225893	42349.7	10.6184
8	818.708	268.603	215635	40426.7	10.6184
9	844.657	272.007	205644	38553.6	10.6184
10	863.568	274.071	201153	37711.5	10.6184
11	882.479	276.135	196722	36880.9	10.6184
12	901.391	278.199	192131	36020.1	10.6184
13	918.571	281.96	178100	33389.6	10.6184
14	940.326	285.364	167143	31335.6	10.6184
15	962.081	288.769	156711	29379.8	10.6184
16	984.448	290.515	155406	29135.1	10.6184
17	1006.81	292.261	154680	28999	10.6184
18	1029.18	294.007	153388	28756.8	10.6184
19	1051.72	295.71	151802	28459.4	10.6184
20	1074.26	297.412	150075	28135.6	10.6184
21	1096.8	299.114	148157	27776.1	10.6184
22	1119.35	300.817	145963	27364.7	10.6184
23	1142.28	301.733	148846	27905.3	10.6184
24	1165.21	302.65	151482	28399.4	10.6184
25	1188.15	303.567	154140	28897.7	10.6184
26	1211.08	304.483	156816	29399.5	10.6184
27	1235.89	306.614	151104	28328.5	10.6184
28	1260.69	308.745	145273	27235.5	10.6184
29	1285.49	310.876	139352	26125.3	10.6184
30	1310.29	313.007	133850	25093.8	10.6184
31	1335.1	315.138	128440	24079.5	10.6184
32	1356.2	317.314	121882	22850.1	10.6184
33	1377.29	319.49	115304	21616.8	10.6184
34	1398.39	321.666	107499	20153.6	10.6184
35	1419.49	323.842	100003	18748.3	10.6184
36	1440.59	326.018	92816	17400.9	10.6184
37	1461.68	328.194	85937.4	16111.3	10.6184
38	1486.59	331.458	73412.1	13763.1	10.6184
39	1511.5	334.723	60005.9	11249.7	10.6184
40	1536.41	337.987	46548.6	8726.81	10.6184
41	1561.32	341.251	34066.9	6386.78	10.6184
42	1585	343.291	29282.7	5489.83	10.6184
43	1608.69	345.331	24981.5	4683.47	10.6184
44	1632.37	347.371	21144.9	3964.2	10.6184
45	1656.06	349.411	17067.9	3199.84	10.6184
46	1675.62	350.489	17572	3294.36	10.6184
47	1695.19	351.567	18028	3379.84	10.6184
48	1714.76	352.644	18536.2	3475.12	10.6184
49	1740.83	369.862	-21419.3	-4015.64	10.6184
50	1759.47	388.492	-24189.7	-4535.02	10.6184
51	1773.53	402.535	0	0	0

- **Global Minimum Query (gle/morgenstern-price) - Safety Factor: 2.09879**
- **Global Minimum Query (gle/morgenstern-price) - Critical Seismic Coefficient: 0.112172**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	712.448	287.293	24965.2	135.948	0.312001
3	721.911	279.061	57276.3	548.605	0.548775
4	738.073	270.555	103850	1724.86	0.951547
5	754.234	262.049	161456	3807.89	1.35105
6	757.186	260.87	170700	4242.02	1.42355
7	774.973	263.034	166953	5412.21	1.85674
8	792.76	265.198	163296	6507.97	2.28225
9	810.059	267.468	158877	7456.49	2.68706
10	827.358	269.738	154560	8320.32	3.08139
11	844.657	272.007	150375	9101.77	3.46372
12	863.568	274.071	148219	10016.7	3.86619
13	882.479	276.135	146090	10858.5	4.25083
14	901.391	278.199	143883	11616.4	4.61577
15	918.571	281.96	132087	11391	4.92891
16	940.326	285.364	124073	11506.6	5.29849
17	962.081	288.769	116397	11486.5	5.63592
18	978.856	290.079	117184	12053.8	5.87291
19	995.631	291.388	117975	12584.7	6.08886
20	1012.41	292.698	118902	13091.1	6.28295
21	1029.18	294.007	119650	13536.5	6.45466
22	1047.21	295.369	120641	13987.5	6.61353
23	1065.25	296.731	121610	14383	6.74512
24	1083.28	298.093	122743	14742.8	6.84905
25	1101.31	299.455	123656	15018.5	6.92488
26	1119.35	300.817	124547	15231.2	6.97224
27	1137.69	301.55	129397	15867.7	6.99116
28	1156.04	302.283	134212	16432.5	6.98038
29	1174.39	303.017	139097	16931.1	6.93999
30	1192.74	303.75	144074	17358.7	6.87014
31	1211.08	304.483	149232	17718.5	6.7711
32	1231.75	306.259	148533	17251.8	6.6251
33	1252.42	308.035	147884	16700.8	6.44321
34	1273.09	309.811	147112	16050.3	6.22649
35	1293.76	311.586	146379	15323	5.97598
36	1314.43	313.362	145739	14528.4	5.69288
37	1335.1	315.138	145096	13661.4	5.37878
38	1353.18	317.003	142692	12684.1	5.07975
39	1371.27	318.868	140459	11694.5	4.75942
40	1389.35	320.733	137552	10629.9	4.41899
41	1407.43	322.599	134748	9564.23	4.05997
42	1425.52	324.464	132044	8501.33	3.68376
43	1443.6	326.329	129441	7445.21	3.29192
44	1461.68	328.194	126939	6399.52	2.88607
45	1478.63	330.414	121684	5301.54	2.49469
46	1495.57	332.635	116208	4248.85	2.09394
47	1512.51	334.855	110510	3251.55	1.68533
48	1527.47	344.778	64549.8	1486.68	1.31938
49	1553.94	364.888	6336.64	73.2984	0.662733
50	1567.38	378.274	-7468.86	-42.5937	0.326745
51	1580.41	391.263	0	0	0

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	712.902	287.419	40996.4	363.264	0.507677
3	726.384	276.235	102134	1848.73	1.037
4	752.769	262.027	206839	7457.28	2.06482
5	756.089	260.737	218098	8351.97	2.19305
6	774.424	262.967	212291	10736.3	2.89518
7	792.76	265.198	206647	12946.9	3.58502
8	810.059	267.468	200447	14797.3	4.222
9	827.358	269.738	194407	16472.1	4.8431
10	844.657	272.007	188563	17977.4	5.44606
11	863.568	274.071	184829	19693.6	6.08194
12	882.479	276.135	181122	21248	6.69097
13	901.391	278.199	177239	22612.2	7.27053
14	918.571	281.96	163658	22329.9	7.7696
15	940.326	285.364	153371	22542.4	8.36144
16	962.081	288.769	143559	22495	8.90556
17	978.856	290.079	143081	23406.9	9.29083
18	995.631	291.388	142671	24246.5	9.64509
19	1012.41	292.698	142579	25056.4	9.96721
20	1029.18	294.007	141826	25662.5	10.2563
21	1047.21	295.369	141069	26220.6	10.5294
22	1065.25	296.731	140214	26652.6	10.7627
23	1083.28	298.093	139715	27044.8	10.9553
24	1101.31	299.455	138555	27200.3	11.1067
25	1119.35	300.817	137239	27215	11.2164
26	1137.69	301.55	140050	27946.5	11.285
27	1156.04	302.283	142614	28522.5	11.3098
28	1174.39	303.017	145161	28982.1	11.2909
29	1192.74	303.75	147703	29322	11.2284
30	1211.08	304.483	150275	29543.4	11.1223
31	1231.75	306.259	145961	28242.6	10.9511
32	1252.42	308.035	141704	26841.3	10.7258
33	1273.09	309.811	137128	25284.5	10.4472
34	1293.76	311.586	132697	23676.7	10.1166
35	1314.43	313.362	128527	22051.2	9.73537
36	1335.1	315.138	124421	20385.7	9.30492
37	1356.2	317.314	118248	18341.4	8.81687
38	1377.29	319.49	112096	16316.8	8.28186
39	1398.39	321.666	104751	14167.3	7.70237
40	1419.49	323.842	97711	12138.1	7.08126
41	1440.59	326.018	90978.1	10239.5	6.42156
42	1461.68	328.194	84553.2	8479.29	5.72667
43	1480.43	330.65	75675.2	6730.79	5.08269
44	1499.17	333.106	66339	5123.65	4.41644
45	1517.91	335.562	56549.3	3687.31	3.7307
46	1536.65	338.019	47095.3	2491.63	3.02847
47	1555.4	340.475	38206.5	1543.08	2.3128
48	1574.17	353.74	-5694.32	-157.627	1.58562
49	1594.38	372.384	-25776.3	-357.623	0.794876
50	1600.55	378.078	-21925.4	-211.385	0.552377
51	1614.59	391.028	0	0	0

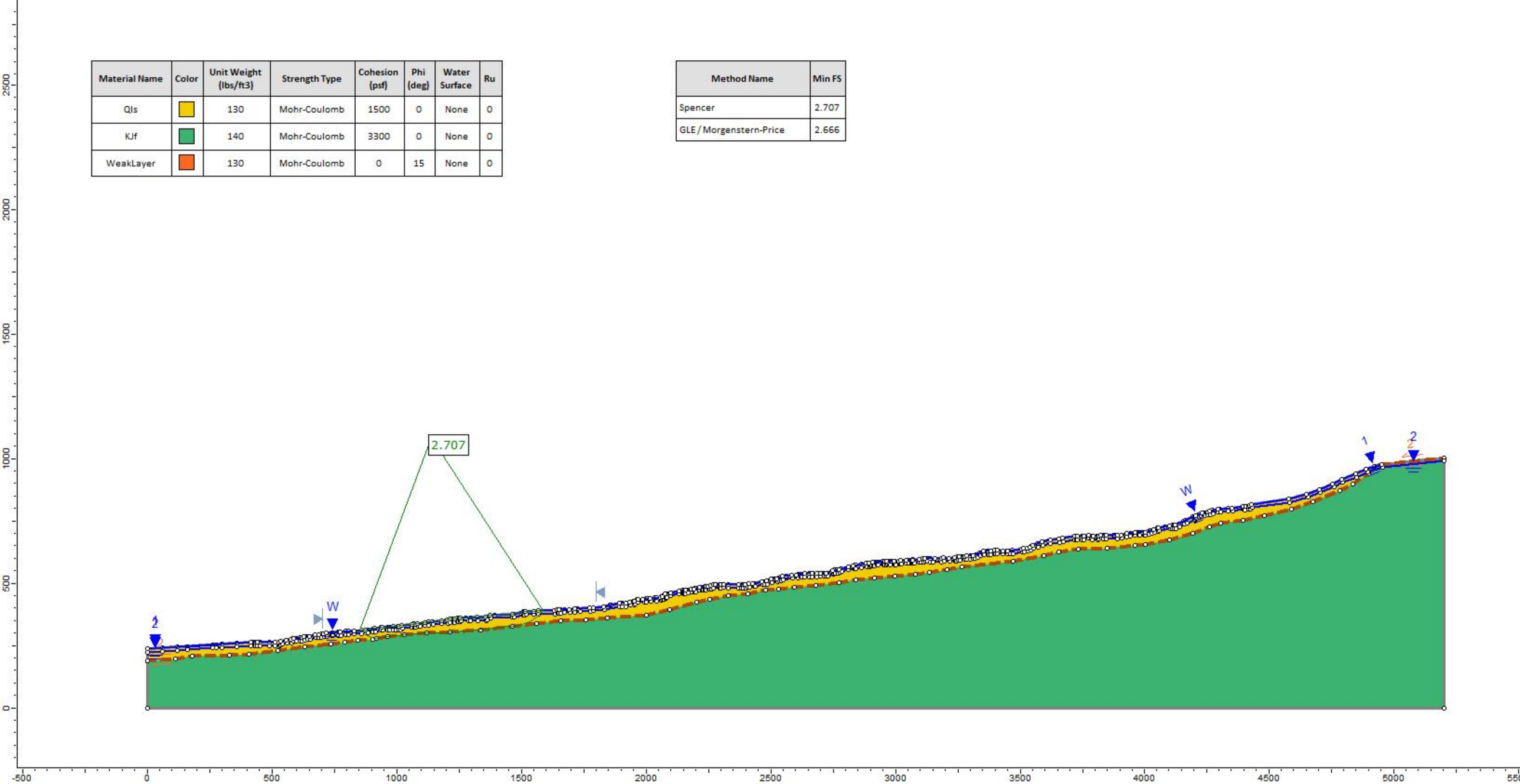
ANALYSIS RUN 2-C

$\phi = 15^{o}$

GW = NO GROUNDWATER

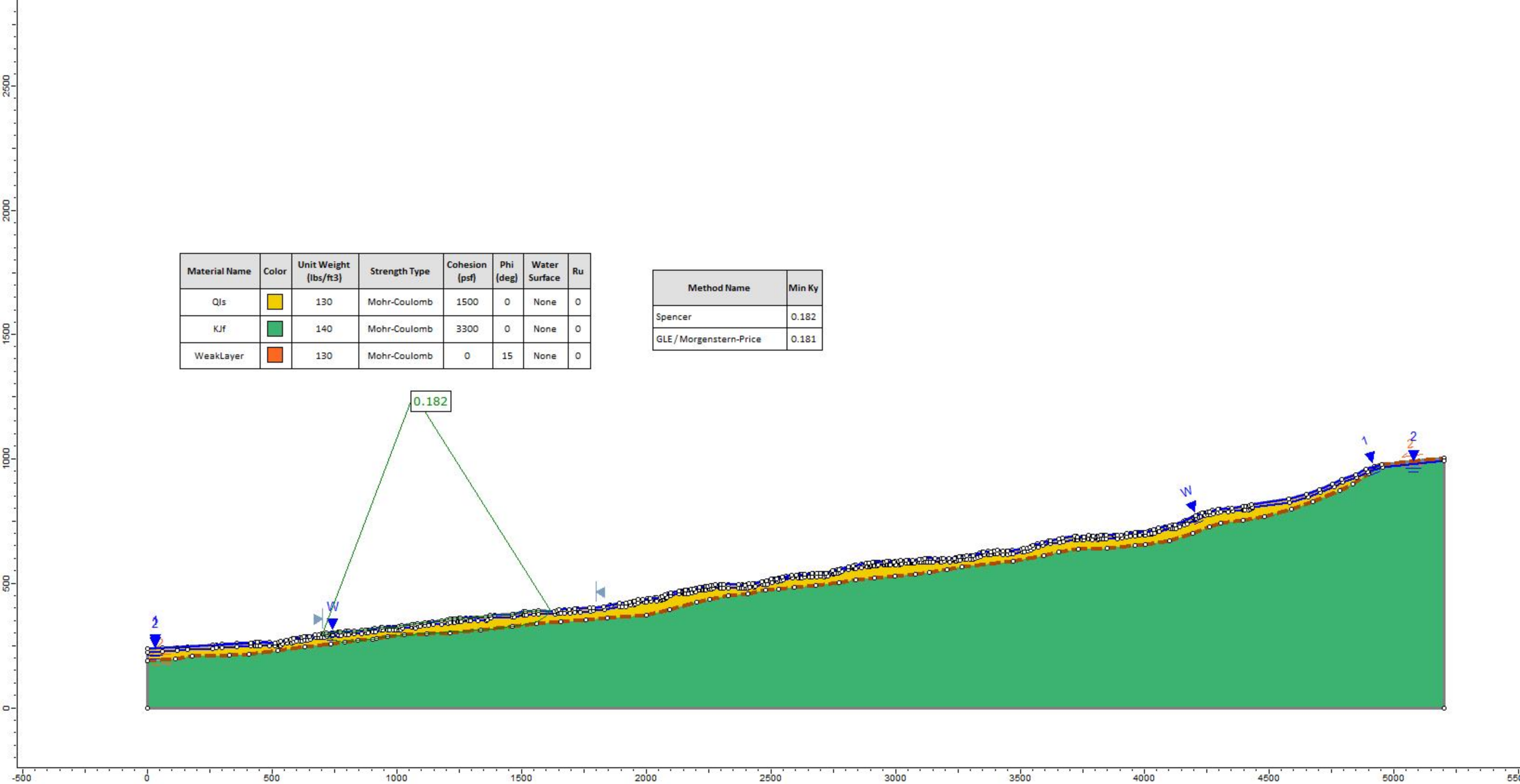
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Ru
Qls		130	Mohr-Coulomb	1500	0	None	0
KJf		140	Mohr-Coulomb	3300	0	None	0
WeakLayer		130	Mohr-Coulomb	0	15	None	0

Method Name	Min FS
Spencer	2.707
GLE / Morgenstern-Price	2.666



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Ru
Qls		130	Mohr-Coulomb	1500	0	None	0
KJf		140	Mohr-Coulomb	3300	0	None	0
WeakLayer		130	Mohr-Coulomb	0	15	None	0

Method Name	Min Ky
Spencer	0.182
GLE / Morgenstern-Price	0.181



Slide Analysis Information

Slide_xs1_2019-09-06_phi-15

Project Summary

File Name:	Slide_xs1_2019-09-06_phi-15.slmd
Slide Modeler Version:	8.027
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	9/6/2019, 8:16:52 PM

Currently Open Scenarios

Group Name	Scenario Name	Global Minimum	Compute Time
No Groundwater	School_phi=15_FS	Spencer: 2.707180 Gle/morgenstern-price: 2.665890	00h:00m:28.895s
	School_phi=15_Ky	Spencer: 0.182155 Gle/morgenstern-price: 0.180909	00h:01m:46.826s

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

All Open Scenarios

Slices Type:	Vertical
Analysis Methods Used	
	GLE/Morgenstern-Price with interslice force function (Half Sine)
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

All Open Scenarios

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Use negative pore pressure cutoff:	Yes
Maximum negative pore pressure [psf]:	0
Advanced Groundwater Method:	None

Random Numbers

All Open Scenarios

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

All Open Scenarios	
Search Method:	Cuckoo Search
Initial # of Surface Vertices:	8
Maximum Iterations:	500
Number of Nests:	50
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined
Convex Surfaces Only:	Enabled

Seismic Loading

No Groundwater - School_phi=15_FS		No Groundwater - School_phi=15_Ky	
Advanced seismic analysis:	No	Advanced seismic analysis:	Yes
Staged pseudostatic analysis:	No	Locate surface with minimum critical horizontal seismic acceleration (Ky):	Yes
		Target factor of safety:	1
		Using Newmark analysis:	No
		Staged pseudostatic analysis:	No

Materials

Property	Qls	KJf	WeakLayer
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	130	140	130
Cohesion [psf]	1500	3300	0
Friction Angle [°]	0	0	15
Water Surface	Assigned per scenario	Assigned per scenario	Assigned per scenario
Ru Value	0	0	0

Materials In Use

Material	School_phi=15_FS	School_phi=15_Ky
Qls	✓	✓
KJf	✓	✓
WeakLayer	✓	✓

Global Minimums

No Groundwater - School_phi=15_FS

Method: spencer

FS	2.707180
Axis Location:	1138.349, 1087.862
Left Slip Surface Endpoint:	848.833, 312.836
Right Slip Surface Endpoint:	1584.660, 391.233
Resisting Moment:	8.90862e+08 lb-ft
Driving Moment:	3.29074e+08 lb-ft
Resisting Horizontal Force:	1.07785e+06 lb
Driving Horizontal Force:	398147 lb
Total Slice Area:	31553.5 ft2
Surface Horizontal Width:	735.827 ft
Surface Average Height:	42.8817 ft

Method: gle/morgenstern-price

FS	2.665890
Axis Location:	1138.349, 1087.862
Left Slip Surface Endpoint:	848.833, 312.836
Right Slip Surface Endpoint:	1584.660, 391.233
Resisting Moment:	8.92798e+08 lb-ft
Driving Moment:	3.34897e+08 lb-ft
Resisting Horizontal Force:	1.08026e+06 lb
Driving Horizontal Force:	405217 lb
Total Slice Area:	31553.5 ft2
Surface Horizontal Width:	735.827 ft
Surface Average Height:	42.8817 ft

No Groundwater - School_phi=15_Ky

Method: spencer

Ky	0.182155
Axis Location:	1065.934, 1262.203
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1617.638, 391.007
Resisting Moment:	1.33815e+09 lb-ft
Driving Moment:	1.33815e+09 lb-ft
Resisting Horizontal Force:	1.33273e+06 lb
Driving Horizontal Force:	1.33273e+06 lb
Total Slice Area:	39149.7 ft2
Surface Horizontal Width:	917.638 ft
Surface Average Height:	42.6636 ft

Method: gle/morgenstern-price

Ky	0.180909
Axis Location:	1065.934, 1262.203
Left Slip Surface Endpoint:	700.000, 298.122
Right Slip Surface Endpoint:	1617.638, 391.007
Resisting Moment:	1.35014e+09 lb-ft
Driving Moment:	1.35014e+09 lb-ft
Resisting Horizontal Force:	1.34338e+06 lb
Driving Horizontal Force:	1.34338e+06 lb
Total Slice Area:	39149.7 ft2
Surface Horizontal Width:	917.638 ft
Surface Average Height:	42.6636 ft

Global Minimum Coordinates

No Groundwater - School_phi=15_FS

Method: spencer

X	Y
848.833	312.836
873.967	294.703
899.102	282.112
912.16	280.556
918.571	281.96
962.081	288.769
1029.18	294.007
1093.43	298.859
1112.07	300.668
1138.56	302.539
1165.05	303.551
1191.55	303.703
1216.05	304.979
1240.56	307.017
1265.37	309.451
1290.18	311.815
1313	314.263
1335.82	316.232
1362.05	317.918
1388.29	320.636
1419.73	323.952
1449.57	327.204
1469.45	329.426
1489.33	331.84
1510.86	338.526
1532.39	349
1558.52	364.577
1584.66	391.233

Method: gle/morgenstern-price

X	Y
848.833	312.836
873.967	294.703
899.102	282.112
912.16	280.556
918.571	281.96
962.081	288.769
1029.18	294.007
1093.43	298.859
1112.07	300.668
1138.56	302.539
1165.05	303.551
1191.55	303.703
1216.05	304.979
1240.56	307.017
1265.37	309.451
1290.18	311.815
1313	314.263
1335.82	316.232
1362.05	317.918
1388.29	320.636
1419.73	323.952
1449.57	327.204
1469.45	329.426
1489.33	331.84
1510.86	338.526
1532.39	349
1558.52	364.577
1584.66	391.233

No Groundwater - School_phi=15_Ky

Method: spencer

X	Y
700	298.122
722.211	285.224
744.423	273.909
783.881	264.118
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1157.3	302.334
1170.63	303.387
1208.28	305.589
1245.92	308.29
1283.56	311.299
1310.03	313.327
1336.5	315.328
1374.52	319.237
1412.53	323.133
1450.63	327.444
1489.33	331.847
1523.45	337.979
1562.31	346.73
1596.5	371.811
1617.64	391.007

Method: gle/morgenstern-price

X	Y
700	298.122
722.211	285.224
744.423	273.909
783.881	264.118
792.76	265.198
844.657	272.007
901.391	278.199
918.571	281.96
962.081	288.769
1029.18	294.007
1119.35	300.817
1157.3	302.334
1170.63	303.387
1208.28	305.589
1245.92	308.29
1283.56	311.299
1310.03	313.327
1336.5	315.328
1374.52	319.237
1412.53	323.133
1450.63	327.444
1489.33	331.847
1523.45	337.979
1562.31	346.73
1596.5	371.811
1617.64	391.007

Slice Data

No Groundwater - School_phi=15_FS

- Global Minimum Query (spencer) - Safety Factor: 2.70718

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	0.68707	23.9253	-35.8084	Qls	1500	0	554.082	1500	514.725	0	514.725	114.984	114.984
2	16.4953	14939.1	-35.8084	Qls	1500	0	554.082	1500	1443.61	0	1443.61	1043.87	1043.87
3	7.95204	17054.8	-35.8084	Qls	1500	0	554.082	1500	2765.24	0	2765.24	2365.5	2365.5
4	12.5672	38952	-26.6071	Qls	1500	0	554.082	1500	3580.39	0	3580.39	3302.84	3302.84
5	12.5672	52917.1	-26.6071	Qls	1500	0	554.082	1500	4742.03	0	4742.03	4464.48	4464.48
6	13.0587	65550.6	-6.7955	Qls	1500	0	554.082	1500	5187.25	0	5187.25	5121.22	5121.22
7	6.41106	33699.7	12.3472	WeakLayer	0	15	504.115	1364.73	5093.24	0	5093.24	5203.59	5203.59
8	21.7549	114696	8.89484	WeakLayer	0	15	511.359	1384.34	5166.45	0	5166.45	5246.48	5246.48
9	21.7549	111271	8.89484	WeakLayer	0	15	496.084	1342.99	5012.09	0	5012.09	5089.73	5089.73
10	16.7749	81001	4.46366	WeakLayer	0	15	475.122	1286.24	4800.32	0	4800.32	4837.41	4837.41
11	16.7749	78436.9	4.46366	WeakLayer	0	15	460.08	1245.52	4648.36	0	4648.36	4684.28	4684.28
12	16.7749	77081.1	4.46366	WeakLayer	0	15	452.131	1224	4568.01	0	4568.01	4603.31	4603.31
13	16.7749	86540.2	4.46366	WeakLayer	0	15	507.613	1374.2	5128.58	0	5128.58	5168.21	5168.21
14	21.4166	113433	4.3189	WeakLayer	0	15	521.395	1411.51	5267.82	0	5267.82	5307.2	5307.2
15	21.4166	114326	4.3189	WeakLayer	0	15	525.499	1422.62	5309.26	0	5309.26	5348.95	5348.95
16	21.4166	117014	4.3189	WeakLayer	0	15	537.855	1456.07	5434.14	0	5434.14	5474.76	5474.76
17	18.6379	106516	5.54151	Qls	1500	0	554.082	1500	5661.67	0	5661.67	5715.43	5715.43
18	13.2463	76744.9	4.04124	Qls	1500	0	554.082	1500	5767.24	0	5767.24	5806.39	5806.39
19	13.2463	77205.4	4.04124	Qls	1500	0	554.082	1500	5801.79	0	5801.79	5840.94	5840.94
20	26.4925	157273	2.1873	Qls	1500	0	554.082	1500	5943.65	0	5943.65	5964.81	5964.81
21	13.2462	80807.6	0.32876	Qls	1500	0	554.082	1500	6142.18	0	6142.18	6145.36	6145.36
22	13.2462	83151.4	0.32876	Qls	1500	0	554.082	1500	6319.04	0	6319.04	6322.22	6322.22
23	12.2524	79095.1	2.98027	Qls	1500	0	554.082	1500	6445.56	0	6445.56	6474.41	6474.41
24	12.2524	82570.6	2.98027	Qls	1500	0	554.082	1500	6727.95	0	6727.95	6756.8	6756.8
25	12.2524	83019.4	4.75498	Qls	1500	0	554.082	1500	6729.19	0	6729.19	6775.28	6775.28
26	12.2524	83025.8	4.75498	Qls	1500	0	554.082	1500	6729.71	0	6729.71	6775.8	6775.8
27	12.4052	86024.9	5.60145	Qls	1500	0	554.082	1500	6869.89	0	6869.89	6924.23	6924.23
28	12.4052	86841	5.60145	Qls	1500	0	554.082	1500	6935.13	0	6935.13	6989.47	6989.47
29	12.4052	85432.6	5.44255	Qls	1500	0	554.082	1500	6825.74	0	6825.74	6878.53	6878.53
30	12.4052	83975.8	5.44255	Qls	1500	0	554.082	1500	6709.26	0	6709.26	6762.05	6762.05
31	11.4113	75859.8	6.12252	Qls	1500	0	554.082	1500	6575.26	0	6575.26	6634.7	6634.7
32	11.4113	74424.1	6.12252	Qls	1500	0	554.082	1500	6450.6	0	6450.6	6510.04	6510.04
33	11.4113	73165.9	4.93096	Qls	1500	0	554.082	1500	6364.36	0	6364.36	6412.16	6412.16
34	11.4113	72085.6	4.93096	Qls	1500	0	554.082	1500	6270.38	0	6270.38	6318.19	6318.19
35	13.1163	81767.7	3.67893	Qls	1500	0	554.082	1500	6211.81	0	6211.81	6247.44	6247.44
36	13.1163	82158.4	3.67893	Qls	1500	0	554.082	1500	6241.44	0	6241.44	6277.06	6277.06
37	13.1164	90148.4	5.91364	Qls	1500	0	554.082	1500	6802.54	0	6802.54	6859.93	6859.93
38	13.1164	92699.9	5.91364	Qls	1500	0	554.082	1500	6995.35	0	6995.35	7052.74	7052.74
39	15.724	109296	6.02075	Qls	1500	0	554.082	1500	6877.57	0	6877.57	6936.01	6936.01
40	15.724	107268	6.02075	Qls	1500	0	554.082	1500	6749.82	0	6749.82	6808.26	6808.26
41	14.9193	99853.6	6.2183	Qls	1500	0	554.082	1500	6618.07	0	6618.07	6678.44	6678.44
42	14.9193	97927.5	6.2183	Qls	1500	0	554.082	1500	6490.18	0	6490.18	6550.55	6550.55
43	19.8783	127723	6.37851	Qls	1500	0	554.082	1500	6349.76	0	6349.76	6411.7	6411.7
44	19.8783	129869	6.92479	Qls	1500	0	554.082	1500	6446.08	0	6446.08	6513.38	6513.38
45	21.5275	139461	17.2531	Qls	1500	0	554.082	1500	6187.74	0	6187.74	6359.82	6359.82
46	21.5276	124593	25.946	Qls	1500	0	554.082	1500	5340.91	0	5340.91	5610.5	5610.5
47	13.0686	60997.1	30.7938	Qls	1500	0	554.082	1500	4169.96	0	4169.96	4500.17	4500.17
48	13.0686	49068.6	30.7938	Qls	1500	0	554.082	1500	3302	0	3302	3632.22	3632.22
49	13.4738	34269.2	45.5621	Qls	1500	0	554.082	1500	1861.86	0	1861.86	2426.92	2426.92
50	12.6641	10702.8	45.5621	Qls	1500	0	554.082	1500	301.431	0	301.431	866.492	866.492

- Global Mi

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Materi
1	16.6433	14092.4	-30.1435	
2	5.56821	11220.3	-30.1435	
3	22.2115	68360.3	-26.9958	
4	19.729	84965	-13.9361	
5	19.729	101073	-13.9361	
6	8.87873	49354.3	6.93654	WeakLa
7	17.2991	95565.8	7.47508	WeakLa
8	17.2991	94651.3	7.47508	WeakLa
9	17.2991	92689.6	7.47508	WeakLa
10	18.9112	98594.4	6.22811	WeakLa
11	18.9112	96767.3	6.22811	WeakLa
12	18.9112	99137.2	6.22811	WeakLa
13	17.1807	90786.8	12.3472	WeakLa
14	21.7549	114696	8.89484	WeakLa
15	21.7549	111271	8.89484	WeakLa
16	22.3665	107432	4.46366	WeakLa
17	22.3665	102958	4.46366	WeakLa
18	22.3665	112670	4.46366	WeakLa
19	18.033	95380.8	4.3189	WeakLa
20	18.033	96571.5	4.3189	WeakLa
21	18.033	96014.9	4.3189	WeakLa
22	18.033	101632	4.3189	WeakLa
23	18.033	104643	4.3189	WeakLa
24	18.9767	112070	2.28881	WeakLa
25	18.9767	114451	2.28881	WeakLa
26	13.335	81398.2	4.51851	
27	18.8209	116097	3.34707	
28	18.8209	119783	3.34707	
29	18.8209	125093	4.1048	
30	18.8209	125844	4.1048	
31	18.8209	130142	4.57007	
32	18.8209	128523	4.57007	
33	26.4691	176423	4.38033	
34	26.4691	171537	4.32341	
35	19.0087	119563	5.87144	
36	19.0087	127065	5.87144	
37	19.0087	133954	5.85126	
38	19.0087	131132	5.85126	
39	19.0471	128314	6.45565	
40	19.0471	124976	6.45565	
41	19.3521	123918	6.48997	
42	19.3521	126280	6.48997	
43	17.0604	113534	10.1885	
44	17.0604	113739	10.1885	
45	19.4288	122513	12.6923	
46	19.4288	113981	12.6923	
47	17.0968	84986.2	36.2603	
48	17.0968	57052.8	36.2603	
49	6.87313	14471.1	42.2473	
50	14.2615	12098.2	42.2473	

- Global Minimum Query (gle/morgenstern-price) - Safety Factor: 2.66589

- Global Minimum

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	0.68707	23.9253	-35.8084	Qls	1500	0	562.664	1500	441.078	0	441.078	35.1465	35.1465
2	16.4953	14939.1	-35.8084	Qls	1500	0	562.664	1500	1325.5	0	1325.5	919.569	919.569
3	7.95204	17054.8	-35.8084	Qls	1500	0	562.664	1500	2595.79	0	2595.79	2189.86	2189.86
4	12.5672	38952	-26.6071	Qls	1500	0	562.664	1500	3449.41	0	3449.41	3167.56	3167.56
5	12.5672	52917.1	-26.6071	Qls	1500	0	562.664	1500	4604.94	0	4604.94	4323.09	4323.09
6	13.0587	65550.6	-6.7955	Qls	1500	0	562.664	1500	5180.76	0	5180.76	5113.71	5113.71
7	6.41106	33699.7	12.3472	WeakLayer	0	15	520.955	1388.81	5183.12	0	5183.12	5297.16	5297.16
8	21.7549	114696	8.89484	WeakLayer	0	15	526.241	1402.9	5235.66	0	5235.66	5318.02	5318.02
9	21.7549	111271	8.89484	WeakLayer	0	15	509.89	1359.31	5072.99	0	5072.99	5152.79	5152.79
10	16.7749	81001	4.46366	WeakLayer	0	15	487.154	1298.7	4846.82	0	4846.82	4884.85	4884.85
11	16.7749	78436.9	4.46366	WeakLayer	0	15	471.831	1257.85	4694.35	0	4694.35	4731.19	4731.19
12	16.7749	77081.1	4.46366	WeakLayer	0	15	463.658	1236.06	4613.05	0	4613.05	4649.25	4649.25
13	16.7749	86540.2	4.46366	WeakLayer	0	15	519.864	1385.9	5172.25	0	5172.25	5212.84	5212.84
14	21.4166	113433	4.3189	WeakLayer	0	15	533.694	1422.77	5309.87	0	5309.87	5350.17	5350.17
15	21.4166	114326	4.3189	WeakLayer	0	15	537.622	1433.24	5348.93	0	5348.93	5389.53	5389.53
16	21.4166	117014	4.3189	WeakLayer	0	15	549.876	1465.91	5470.87	0	5470.87	5512.4	5512.4
17	18.6379	106516	5.54151	Qls	1500	0	562.664	1500	5691.84	0	5691.84	5746.43	5746.43
18	13.2463	76744.9	4.04124	Qls	1500	0	562.664	1500	5797.55	0	5797.55	5837.3	5837.3
19	13.2463	77205.4	4.04124	Qls	1500	0	562.664	1500	5829.4	0	5829.4	5869.15	5869.15
20	26.4925	157273	2.1873	Qls	1500	0	562.664	1500	5973.11	0	5973.11	5994.6	5994.6
21	13.2462	80807.6	0.32876	Qls	1500	0	562.664	1500	6174.33	0	6174.33	6177.56	6177.56
22	13.2462	83151.4	0.32876	Qls	1500	0	562.664	1500	6348.14	0	6348.14	6351.37	6351.37
23	12.2524	79095.1	2.98027	Qls	1500	0	562.664	1500	6460.11	0	6460.11	6489.41	6489.41
24	12.2524	82570.6	2.98027	Qls	1500	0	562.664	1500	6737.97	0	6737.97	6767.26	6767.26
25	12.2524	83019.4	4.75498	Qls	1500	0	562.664	1500	6727.34	0	6727.34	6774.15	6774.15
26	12.2524	83025.8	4.75498	Qls	1500	0	562.664	1500	6723.64	0	6723.64	6770.44	6770.44
27	12.4052	86024.9	5.60145	Qls	1500	0	562.664	1500	6855.63	0	6855.63	6910.82	6910.82
28	12.4052	86841	5.60145	Qls	1500	0	562.664	1500	6916.69	0	6916.69	6971.87	6971.87
29	12.4052	85432.6	5.44255	Qls	1500	0	562.664	1500	6804.43	0	6804.43	6858.04	6858.04
30	12.4052	83975.8	5.44255	Qls	1500	0	562.664	1500	6684.52	0	6684.52	6738.13	6738.13
31	11.4113	75859.8	6.12252	Qls	1500	0	562.664	1500	6545.16	0	6545.16	6605.51	6605.51
32	11.4113	74424.1	6.12252	Qls	1500	0	562.664	1500	6417.88	0	6417.88	6478.24	6478.24
33	11.4113	73165.9	4.93096	Qls	1500	0	562.664	1500	6332.14	0	6332.14	6380.68	6380.68
34	11.4113	72085.6	4.93096	Qls	1500	0	562.664	1500	6234.87	0	6234.87	6283.42	6283.42
35	13.1163	81767.7	3.67893	Qls	1500	0	562.664	1500	6175.05	0	6175.05	6211.23	6211.23
36	13.1163	82158.4	3.67893	Qls	1500	0	562.664	1500	6199.74	0	6199.74	6235.92	6235.92
37	13.1164	90148.4	5.91364	Qls	1500	0	562.664	1500	6753.19	0	6753.19	6811.47	6811.47
38	13.1164	92699.9	5.91364	Qls	1500	0	562.664	1500	6943.65	0	6943.65	7001.93	7001.93
39	15.724	109296	6.02075	Qls	1500	0	562.664	1500	6823.94	0	6823.94	6883.29	6883.29
40	15.724	107268	6.02075	Qls	1500	0	562.664	1500	6694.35	0	6694.35	6753.69	6753.69
41	14.9193	99853.6	6.2183	Qls	1500	0	562.664	1500	6561.25	0	6561.25	6622.55	6622.55
42	14.9193	97927.5	6.2183	Qls	1500	0	562.664	1500	6432.15	0	6432.15	6493.46	6493.46
43	19.8783	127723	6.37851	Qls	1500	0	562.664	1500	6291.02	0	6291.02	6353.92	6353.92
44	19.8783	129869	6.92479	Qls	1500	0	562.664	1500	6389.7	0	6389.7	6458.04	6458.04
45	21.5275	139461	17.2531	Qls	1500	0	562.664	1500	6186.89	0	6186.89	6361.64	6361.64
46	21.5276	124593	25.946	Qls	1500	0	562.664	1500	5405.44	0	5405.44	5679.21	5679.21
47	13.0686	60997.1	30.7938	Qls	1500	0	562.664	1500	4261.2	0	4261.2	4596.54	4596.54
48	13.0686	49068.6	30.7938	Qls	1500	0	562.664	1500	3381.95	0	3381.95	3717.28	3717.28
49	13.4738	34269.2	45.5621	Qls	1500	0	562.664	1500	1952.26	0	1952.26	2526.08	2526.08
50	12.6641	10702.8	45.5621	Qls	1500	0	562.664	1500	273.448	0	273.448	847.261	847.261

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Materi
1	16.6433	14092.4	-30.1435	
2	5.56821	11220.3	-30.1435	
3	22.2115	68360.3	-26.9958	
4	19.729	84965	-13.9361	
5	19.729	101073	-13.9361	
6	8.87873	49354.3	6.93654	WeakLa
7	17.2991	95565.8	7.47508	WeakLa
8	17.2991	94651.3	7.47508	WeakLa
9	17.2991	92689.6	7.47508	WeakLa
10	18.9112	98594.4	6.22811	WeakLa
11	18.9112	96767.3	6.22811	WeakLa
12	18.9112	99137.2	6.22811	WeakLa
13	17.1807	90786.8	12.3472	WeakLa
14	21.7549	114696	8.89484	WeakLa
15	21.7549	111271	8.89484	WeakLa
16	22.3665	107432	4.46366	WeakLa
17	22.3665	102958	4.46366	WeakLa
18	22.3665	112670	4.46366	WeakLa
19	18.033	95380.8	4.3189	WeakLa
20	18.033	96571.5	4.3189	WeakLa
21	18.033	96014.9	4.3189	WeakLa
22	18.033	101632	4.3189	WeakLa
23	18.033	104643	4.3189	WeakLa
24	18.9767	112070	2.28881	WeakLa
25	18.9767	114451	2.28881	WeakLa
26	13.335	81398.2	4.51851	
27	18.8209	116097	3.34707	
28	18.8209	119783	3.34707	
29	18.8209	125093	4.1048	
30	18.8209	125844	4.1048	
31	18.8209	130142	4.57007	
32	18.8209	128523	4.57007	
33	26.4691	176423	4.38033	
34	26.4691	171537	4.32341	
35	19.0087	119563	5.87144	
36	19.0087	127065	5.87144	
37	19.0087	133954	5.85126	
38	19.0087	131132	5.85126	
39	19.0471	128314	6.45565	
40	19.0471	124976	6.45565	
41	19.3521	123918	6.48997	
42	19.3521	126280	6.48997	
43	17.0604	113534	10.1885	
44	17.0604	113739	10.1885	
45	19.4288	122513	12.6923	
46	19.4288	113981	12.6923	
47	17.0968	84986.2	36.2603	
48	17.0968	57052.8	36.2603	
49	6.87313	14471.1	42.2473	
50	14.2615	12098.2	42.2473	

Interslice Data

No Groundwater - School_phi=15_FS

- **Global Minimum Query (spencer) - Safety Factor: 2.70718**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	848.833	312.836	0	0	0
2	849.52	312.34	635.835	55.0767	4.95066
3	866.015	300.44	26955.2	2334.89	4.95067
4	873.967	294.703	47225.4	4090.72	4.95067
5	886.534	288.408	76727.8	6646.24	4.95066
6	899.102	282.112	113543	9835.19	4.95065
7	912.16	280.556	128850	11161.2	4.9507
8	918.571	281.96	124935	10822	4.95066
9	940.326	285.364	118469	10261.9	4.95066
10	962.081	288.769	112196	9718.56	4.95068
11	978.856	290.079	113880	9864.44	4.95068
12	995.631	291.388	115511	10005.7	4.95067
13	1012.41	292.698	117114	10144.5	4.95065
14	1029.18	294.007	118913	10300.4	4.95068
15	1050.6	295.625	121559	10529.6	4.95068
16	1072.01	297.242	124226	10760.6	4.95067
17	1093.43	298.859	126956	10997.1	4.95068
18	1112.07	300.668	127045	11004.8	4.95068
19	1125.31	301.604	128987	11173	4.95067
20	1138.56	302.539	130897	11338.5	4.95069
21	1165.05	303.551	139562	12089	4.95066
22	1178.3	303.627	146435	12684.3	4.95064
23	1191.55	303.703	153294	13278.5	4.95067
24	1203.8	304.341	155971	13510.4	4.95067
25	1216.05	304.979	158469	13726.7	4.95064
26	1228.3	305.998	158399	13720.7	4.95067
27	1240.56	307.017	158329	13714.7	4.95069
28	1252.96	308.234	156845	13586	4.95063
29	1265.37	309.451	155280	13450.5	4.95066
30	1277.77	310.633	154086	13347.1	4.95067
31	1290.18	311.815	153030	13255.6	4.95066
32	1301.59	313.039	151304	13106.1	4.95066
33	1313	314.263	149731	12969.9	4.95068
34	1324.41	315.247	149788	12974.8	4.95067
35	1335.82	316.232	149938	12987.8	4.95067
36	1348.94	317.075	151967	13163.5	4.95065
37	1362.05	317.918	153971	13337.1	4.95065
38	1375.17	319.277	151996	13166.1	4.95068
39	1388.29	320.636	149760	12972.3	4.95064
40	1404.01	322.294	147066	12739	4.95066
41	1419.73	323.952	144585	12524.1	4.95066
42	1434.65	325.578	142093	12308.2	4.95065
43	1449.57	327.204	139809	12110.4	4.95066
44	1469.45	329.426	136713	11842.2	4.95065
45	1489.33	331.84	132165	11448.3	4.95068
46	1510.86	338.526	102723	8898	4.95068
47	1532.39	349	58707.6	5085.31	4.95066
48	1545.45	356.789	33470.8	2899.27	4.95065
49	1558.52	364.577	14994	1298.8	4.95068
50	1572	378.318	-3123.81	-270.587	4.95065
51	1584.66	391.233	0	0	0

No Groundwater - School_phi=15_Ky

- **Global Minimum Query (spencer) - Critical Seismic Coefficient: 0.182155**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	716.643	288.458	44088.4	8817.69	11.3099
3	722.211	285.224	61767.5	12353.5	11.3099
4	744.423	273.909	133367	26673.4	11.3099
5	764.152	269.013	172343	34468.7	11.31
6	783.881	264.118	212438	42487.7	11.31
7	792.76	265.198	210392	42078.4	11.3099
8	810.059	267.468	205497	41099.4	11.3099
9	827.358	269.738	200649	40129.9	11.31
10	844.657	272.007	195902	39180.4	11.3099
11	863.568	274.071	193089	38617.8	11.3099
12	882.479	276.135	190328	38065.5	11.3099
13	901.391	278.199	187499	37499.8	11.3099
14	918.571	281.96	175070	35014	11.3099
15	940.326	285.364	166280	33255.9	11.3099
16	962.081	288.769	157752	31550.4	11.3099
17	984.448	290.515	158203	31640.5	11.3099
18	1006.81	292.261	158635	31726.9	11.3099
19	1029.18	294.007	159107	31821.5	11.31
20	1047.21	295.369	159767	31953.4	11.3099
21	1065.25	296.731	160435	32087	11.3099
22	1083.28	298.093	161099	32219.8	11.3099
23	1101.31	299.455	161802	32360.4	11.3099
24	1119.35	300.817	162525	32505.1	11.31
25	1138.32	301.575	167644	33528.8	11.3099
26	1157.3	302.334	172871	34574.2	11.3099
27	1170.63	303.387	171772	34354.5	11.31
28	1189.46	304.488	172181	34436.1	11.3099
29	1208.28	305.589	171712	34342.4	11.3099
30	1227.1	306.94	168396	33679.2	11.3099
31	1245.92	308.29	164891	32978.3	11.31
32	1264.74	309.795	159307	31861.4	11.3099
33	1283.56	311.299	154140	30828	11.3099
34	1310.03	313.327	148544	29708.8	11.3099
35	1336.5	315.328	144355	28871	11.3099
36	1355.51	317.282	139224	27844.9	11.31
37	1374.52	319.237	131998	26399.7	11.31
38	1393.52	321.185	122893	24578.6	11.3099
39	1412.53	323.133	114575	22914.9	11.3099
40	1431.58	325.288	105840	21168.1	11.31
41	1450.63	327.444	98069.8	19614	11.31
42	1469.98	329.645	90989.6	18197.9	11.3099
43	1489.33	331.847	83226.3	16645.3	11.31
44	1506.39	334.913	69088	13817.6	11.3099
45	1523.45	337.979	54878.2	10975.6	11.3099
46	1542.88	342.355	36446.3	7289.26	11.3099
47	1562.31	346.73	21340.5	4268.1	11.3099
48	1579.41	359.271	-12183.7	-2436.74	11.3099
49	1596.5	371.811	-23332.2	-4666.44	11.3099
50	1603.38	378.054	-20721.7	-4144.33	11.3099
51	1617.64	391.007	0	0	0

- **Global Minimum Query (gle/morgenstern-price) - Safety Factor: 2.66589**
- **Global Minimum Query (gle/morgenstern-price) - Critical Seismic Coefficient: 0.180909**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	848.833	312.836	0	0	0
2	849.52	312.34	605.235	0.216807	0.0205245
3	866.015	300.44	25660.9	229.675	0.512806
4	873.967	294.703	45027.3	588.923	0.749343
5	886.534	288.408	73813	1444.66	1.12124
6	899.102	282.112	109873	2857.59	1.48982
7	912.16	280.556	125283	4086.28	1.86812
8	918.571	281.96	121349	4347.32	2.05174
9	940.326	285.364	114971	5345.98	2.66225
10	962.081	288.769	108792	6176.22	3.24925
11	978.856	290.079	110617	7119.56	3.68261
12	995.631	291.388	112385	8049.4	4.09672
13	1012.41	292.698	114122	8960.58	4.48951
14	1029.18	294.007	116070	9866.98	4.85897
15	1050.6	295.625	118912	11018.2	5.29382
16	1072.01	297.242	121775	12120.8	5.68418
17	1093.43	298.859	124703	13166	6.0269
18	1112.07	300.668	124898	13754.1	6.28424
19	1125.31	301.604	126925	14333.7	6.44314
20	1138.56	302.539	128923	14874.6	6.58145
21	1165.05	303.551	137786	16417.8	6.795
22	1178.3	303.627	144770	17441.2	6.86961
23	1191.55	303.703	151741	18422.9	6.92241
24	1203.8	304.341	154514	18839.9	6.95176
25	1216.05	304.979	157110	19185.7	6.96228
26	1228.3	305.998	157148	19167.1	6.95393
27	1240.56	307.017	157190	19096.4	6.9267
28	1252.96	308.234	155829	18802.3	6.88004
29	1265.37	309.451	154394	18449.3	6.81424
30	1277.77	310.633	153332	18092.4	6.7295
31	1290.18	311.815	152411	17704.8	6.62606
32	1301.59	313.039	150820	17222.6	6.51456
33	1313	314.263	149386	16723.6	6.3876
34	1324.41	315.247	149572	16369.4	6.24569
35	1335.82	316.232	149855	15985.4	6.08886
36	1348.94	317.075	152028	15686	5.89084
37	1362.05	317.918	154179	15319.4	5.67435
38	1375.17	319.277	152385	14511.8	5.43994
39	1388.29	320.636	150331	13650.6	5.18844
40	1404.01	322.294	147862	12586.2	4.86536
41	1419.73	323.952	145607	11511.2	4.52021
42	1434.65	325.578	143336	10459.4	4.17354
43	1449.57	327.204	141275	9407.58	3.80973
44	1469.45	329.426	138481	7986.69	3.30079
45	1489.33	331.84	134239	6489.35	2.76762
46	1510.86	338.526	104988	3973.3	2.16734
47	1532.39	349	60481.4	1634.76	1.54828
48	1545.45	356.789	34646.2	704.908	1.16557
49	1558.52	364.577	15659.1	212.953	0.779135
50	1572	378.318	-3585.18	-23.6604	0.378118
51	1584.66	391.233	0	0	0

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	700	298.122	0	0	0
2	716.643	288.458	39409.4	673.292	0.978778
3	722.211	285.224	55406.4	1262.75	1.30558
4	744.423	273.909	122010	5545.32	2.60229
5	764.152	269.013	160363	10481.3	3.73952
6	783.881	264.118	200194	17010.9	4.85687
7	792.76	265.198	198482	18593.2	5.35168
8	810.059	267.468	194192	21435.4	6.29895
9	827.358	269.738	189919	24062.8	7.22092
10	844.657	272.007	185714	26477.9	8.11418
11	863.568	274.071	183517	29243.9	9.0541
12	882.479	276.135	181340	31818.5	9.952
13	901.391	278.199	179065	34172.7	10.8044
14	918.571	281.96	166842	34055.3	11.5366
15	940.326	285.364	158445	34843.8	12.4026
16	962.081	288.769	150259	35233.4	13.1966
17	984.448	290.515	151230	37522	13.9344
18	1006.81	292.261	152139	39599.6	14.5895
19	1029.18	294.007	153058	41468.8	15.1595
20	1047.21	295.369	154059	42885	15.5555
21	1065.25	296.731	155041	44145.9	15.8936
22	1083.28	298.093	155986	45239.7	16.1734
23	1101.31	299.455	156945	46174	16.3941
24	1119.35	300.817	157895	46936.7	16.5554
25	1138.32	301.575	163338	48880.7	16.6604
26	1157.3	302.334	168848	50653.8	16.6991
27	1170.63	303.387	167846	50312.6	16.6863
28	1189.46	304.488	168387	50238.5	16.6125
29	1208.28	305.589	168073	49700.8	16.4735
30	1227.1	306.94	164956	48140.8	16.2694
31	1245.92	308.29	161664	46359.1	16.0009
32	1264.74	309.795	156332	43849.7	15.6683
33	1283.56	311.299	151421	41346.5	15.2727
34	1310.03	313.327	146177	38107.1	14.6113
35	1336.5	315.328	142340	35042.2	13.8304
36	1355.51	317.282	137517	32250	13.1983
37	1374.52	319.237	130615	28977.3	12.5086
38	1393.52	321.185	121836	25372.5	11.7638
39	1412.53	323.133	113827	22056	10.9662
40	1431.58	325.288	105399	18806.5	10.1169
41	1450.63	327.444	97914.3	15895.1	9.22078
42	1469.98	329.645	91105.7	13235.7	8.26602
43	1489.33	331.847	83591.1	10664.8	7.27069
44	1506.39	334.913	69584.9	7759.78	6.36307
45	1523.45	337.979	55430.1	5269.61	5.43065
46	1542.88	342.355	36849.2	2798.52	4.343
47	1562.31	346.73	21532.9	1216.32	3.23301
48	1579.41	359.271	-15414.9	-603.561	2.24224
49	1596.5	371.811	-28149.1	-610.492	1.24242
50	1603.38	378.054	-25320.3	-370.734	0.838852
51	1617.64	391.007	0	0	0

SECTION 2

LANDSLIDE ANALYSIS CALCULATIONS
SEISMIC DEFORMATIONS

Bray & Macedo (2019) Seismic Slope Displacement Spreadsheet_V7 (k_y = 0.12 at 84% hazard case)

Procedure for Estimating Shear-Induced Seismic Slope Displacement for Shallow Crustal Earthquakes

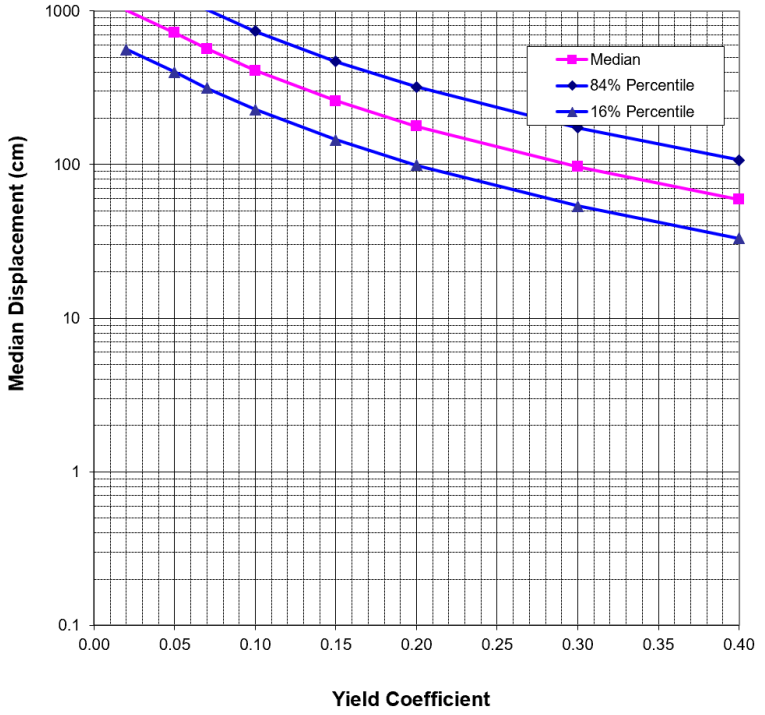
by Jonathan D. Bray and Jorge Macedo, UC Berkeley and Georgia Tech

Procedure for Estimating Shear-Induced Seismic Slope Displacement for Shallow Crustal Earthquakes, ASCE JGGE, 2019.

SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters			
Case	PulsesD100 (EQ4&5)		* Select Ordinary or Pulse or Combined Equations
Yield Coefficient (k_y) [a]	0.12		(a) Based on pseudostatic analysis
Initial Fundamental Period (T_s) [b]	0.26	seconds	(b) 1D: T_s=4H/V_s 2D: T_s=2.6H/V_s
Degraded Period (1.3T_s)	0.34	seconds	(c) Input the Spectral Acceleration (g) at
Moment Magnitude (M_w)	7.2		the base of the sliding mass assuming
Spectral Acceleration (S_a(1.3T_s)) [c]	1.9	g	there is no material above it.
Peak Ground Velocity (PGV) [d]	143.0	cm/s	(d) PGV (cm/s) is required for near-fault pulse
Percentile (if Pulse ground Motion) [e]	100		motions only; it is estimated at the base of
			sliding mass assuming no material above it.
Additional Input Parameters			(e) If Pulse motion the percentile is given
Probability of Exceedance #1 (P1)	84	%	as either D100 or D50. D100 should be
Probability of Exceedance #2 (P2)	50	%	used for fault-normal direction
Probability of Exceedance #3 (P3)	16	%	
Displacement Threshold (d_threshold)	30	cm	
Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	337.3	cm	eq. (3) or (5) or (7) or (9)
Standard Deviation of Non-Zero Seismic D	0.59		
Results			
Probability of Negligible Displ. (P(D=0))	**0.00**		eq. (2) or (4) or (6) or (8)
D1	**187.6**	**cm**	calc. using eq. (11)
D2	**337.3**	**cm**	calc. using eq. (11)
D3	**606.4**	**cm**	calc. using eq. (11)
P(D>d_threshold)	**1.00**		eq. (11)

Dependence on k_y					
k_y	P(D="0")	D (cm)	Dmedian (cm)	D-84% (cm)	D-16% (cm)
0.020	0.000	1008.3	1008.3	1813.1	560.8
0.05	0.000	719.8	719.8	1294.3	400.3
0.07	0.000	565.7	565.7	1017.1	314.6
0.1	0.000	409.1	409.1	735.5	227.5
0.15	0.000	259.7	259.7	466.9	144.4
0.2	0.000	178.0	178.0	320.0	99.0
0.3	0.000	96.6	96.6	173.8	53.7
0.4	0.000	59.3	59.28	106.59	32.97



Notes

1. Values highlighted in blue are input parameters, and results are presented in the table with the yellow heading.
2. Probability of Exceedance is the desired probability of exceeding a particular displacement value.
3. Displacements D1, D2, and D3 correspond to P1, P2, and P3, respectively.
   (e.g., the probability of exceeding displacement D1 is P1 and it is referred to as the (100% - P1) percentile value.
4. The 16%, 50%, and 84% percentile displacement values at selected k_y values are shown to the right.
5. Calculated seismic displacements are due to deviatoric deformation only (add in volumetrically induced movement).
6. k_y may range between 0.01 and 0.8, T_s between 0 and 2 s, S_a between 0.002 and 4.5 g, M_w between 5.5 and 8.2
7. Rigid slope is assumed for T_s < 0.05 s, i.e. T_s = 0.0. If Ts is just less than 0.05 s, set T_s = 0.050 s
8. When a value for D is not calculated, D is < 0.5 cm
9. k_y should be estimated with a slope stability program; the simplified equations shown below provide approximate values.
10. Examples of how T_s is estimated are shown below.
11. V_s = weighted avg. shear wave velocity for the sliding mass, e.g., for 2 layers, V_s = [(h1)(V_s1) + (h2)(V_s2)]/(h1 + h2)

Bray & Macedo (2019) Seismic Slope Displacement Spreadsheet_V7 (k_y = 0.12 at 50% hazard case)

Procedure for Estimating Shear-Induced Seismic Slope Displacement for Shallow Crustal Earthquakes

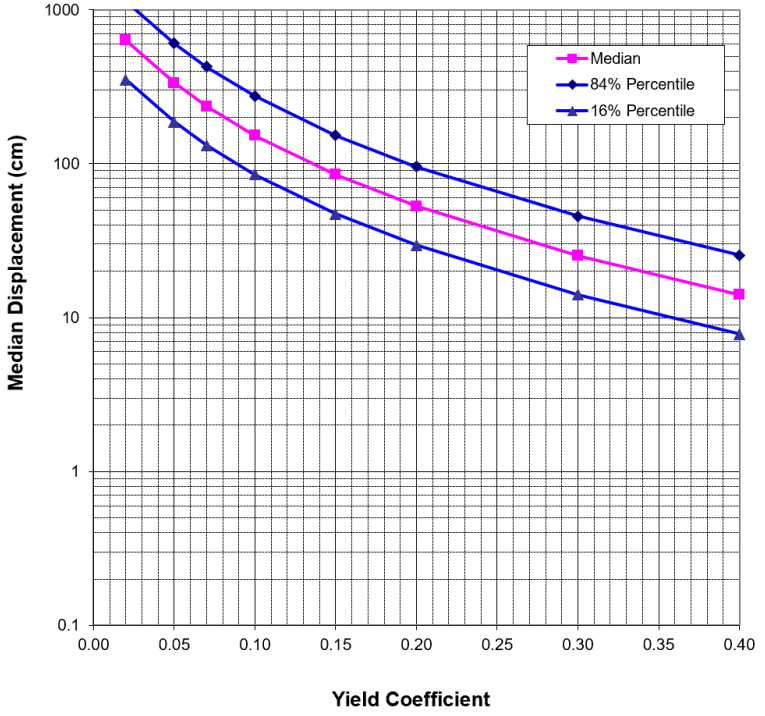
by Jonathan D. Bray and Jorge Macedo, UC Berkeley and Georgia Tech

Procedure for Estimating Shear-Induced Seismic Slope Displacement for Shallow Crustal Earthquakes, ASCE JGGE, 2019.

SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters			
Case	PulsesD100 (EQ4&5)		* Select Ordinary or Pulse or Combined Equations
Yield Coefficient (k_y) [a]	0.12		(a) Based on pseudostatic analysis
Initial Fundamental Period (T_s) [b]	0.26	seconds	(b) 1D: T_s=4H/V_s 2D: T_s=2.6H/V_s
Degraded Period (1.3T_s)	0.34	seconds	(c) Input the Spectral Acceleration (g) at
Moment Magnitude (M_w)	7.2		the base of the sliding mass assuming
Spectral Acceleration (S_a(1.3T_s)) [c]	1.0	g	there is no material above it.
Peak Ground Velocity (PGV) [d]	96.0	cm/s	(d) PGV (cm/s) is required for near-fault pulse
Percentile (if Pulse ground Motion) [e]	100		motions only; it is estimated at the base of
			sliding mass assuming no material above it.
Additional Input Parameters			(e) If Pulse motion the percentile is given
Probability of Exceedance #1 (P1)	84	%	as either D100 or D50. D100 should be
Probability of Exceedance #2 (P2)	50	%	used for fault-normal direction
Probability of Exceedance #3 (P3)	16	%	
Displacement Threshold (d_threshold)	30	cm	
Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	118.6	cm	eq. (3) or (5) or (7) or (9)
Standard Deviation of Non-Zero Seismic D	0.59		
Results			
Probability of Negligible Displ. (P(D=0))	**0.00**		eq. (2) or (4) or (6) or (8)
D1	**65.9**	**cm**	calc. using eq. (11)
D2	**118.6**	**cm**	calc. using eq. (11)
D3	**213.2**	**cm**	calc. using eq. (11)
P(D>d_threshold)	**0.99**		eq. (11)

Dependence on k_y					
k_y	P(D="0")	D (cm)	Dmedian (cm)	D-84% (cm)	D-16% (cm)
0.020	0.000	632.5	632.5	1137.2	351.7
0.05	0.000	335.8	335.8	603.8	186.8
0.07	0.000	236.7	236.7	425.6	131.6
0.1	0.000	152.5	152.5	274.3	84.8
0.15	0.000	84.9	84.9	152.7	47.2
0.2	0.000	53.0	53.0	95.4	29.5
0.3	0.000	25.3	25.3	45.4	14.0
0.4	0.003	14.1	14.10	25.37	7.81



Notes

1. Values highlighted in blue are input parameters, and results are presented in the table with the yellow heading.
2. Probability of Exceedance is the desired probability of exceeding a particular displacement value.
3. Displacements D1, D2, and D3 correspond to P1, P2, and P3, respectively.
   (e.g., the probability of exceeding displacement D1 is P1 and it is referred to as the (100% - P1) percentile value.
4. The 16%, 50%, and 84% percentile displacement values at selected k_y values are shown to the right.
5. Calculated seismic displacements are due to deviatoric deformation only (add in volumetrically induced movement).
6. k_y may range between 0.01 and 0.8, T_s between 0 and 2 s, S_a between 0.002 and 4.5 g, M_w between 5.5 and 8.2
7. Rigid slope is assumed for T_s < 0.05 s, i.e. T_s = 0.0. If Ts is just less than 0.05 s, set T_s = 0.050 s
8. When a value for D is not calculated, D is < 0.5 cm
9. k_y should be estimated with a slope stability program; the simplified equations shown below provide approximate values.
10. Examples of how T_s is estimated are shown below.
11. V_s = weighted avg. shear wave velocity for the sliding mass, e.g., for 2 layers, V_s = [(h1)(V_s1) + (h2)(V_s2)]/(h1 + h2)

Bray & Macedo (2019) Seismic Slope Displacement Spreadsheet_V7 (k_y = 0.09 at 84% hazard case)

Procedure for Estimating Shear-Induced Seismic Slope Displacement for Shallow Crustal Earthquakes

by Jonathan D. Bray and Jorge Macedo, UC Berkeley and Georgia Tech

Procedure for Estimating Shear-Induced Seismic Slope Displacement for Shallow Crustal Earthquakes, ASCE JGGE, 2019.

SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters

Case	PulsesD100 (EQ4&5)		* Select Ordinary or Pulse or Combined Equations
Yield Coefficient (k_y) [(a)]	0.09		(a) Based on pseudostatic analysis
Initial Fundamental Period (T_s) [(b)]	0.26	seconds	(b) 1D: T_s=4H/V_s 2D: T_s=2.6H/V_s
Degraded Period (1.3T_s)	0.34	seconds	(c) Input the Spectral Acceleration (g) at
Moment Magnitude (M_w)	7.2		the base of the sliding mass assuming
Spectral Acceleration (S_a(1.3T_s)) [(c)]	1.9	g	there is no material above it.
Peak Ground Velocity (PGV) [(d)]	143.0	cm/s	(d) PGV (cm/s) is required for near-fault pulse
Percentile (if Pulse ground Motion) [(e)]	100		motions only; it is estimated at the base of
			sliding mass assuming no material above it.
Additional Input Parameters			(e) If Pulse motion the percentile is given
Probability of Exceedance #1 (P1)	84	%	as either D100 or D50. D100 should be
Probability of Exceedance #2 (P2)	50	%	used for fault-normal direction
Probability of Exceedance #3 (P3)	16	%	
Displacement Threshold (d_threshold)	30	cm	

Intermediate Calculated Parameters

Non-Zero Seismic Displacement Est (D)	453.5	cm	eq. (3) or (5) or (7) or (9)
Standard Deviation of Non-Zero Seismic D	0.59		

Results

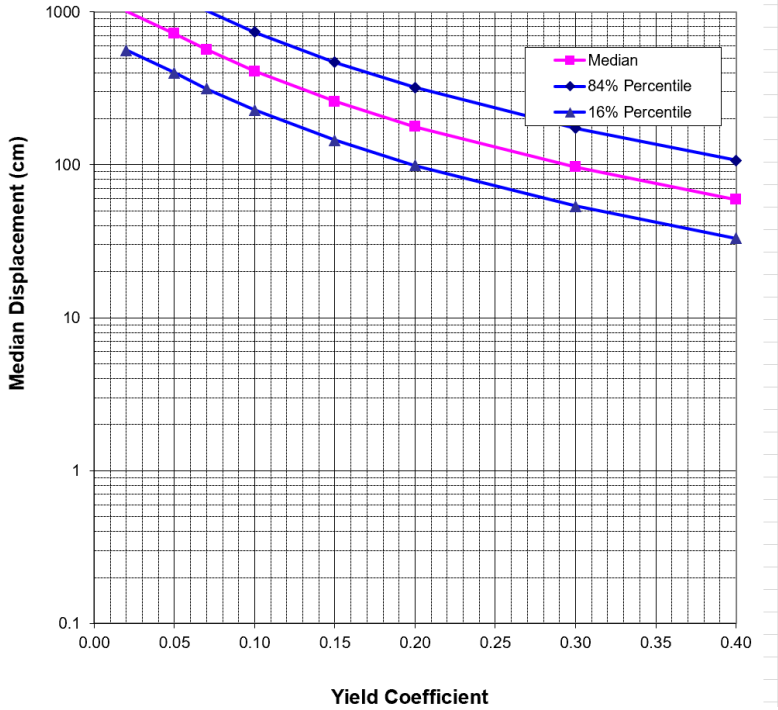
Probability of Negligible Displ. (P(D=0))	**0.00**		eq. (2) or (4) or (6) or (8)
D1	**252.2**	**cm**	calc. using eq. (11)
D2	**453.5**	**cm**	calc. using eq. (11)
D3	**815.4**	**cm**	calc. using eq. (11)
P(D>d_threshold)	**1.00**		eq. (11)

Notes

1. Values highlighted in blue are input parameters, and results are presented in the table with the yellow heading.
2. Probability of Exceedance is the desired probability of exceeding a particular displacement value.
3. Displacements D1, D2, and D3 correspond to P1, P2, and P3, respectively.
   (e.g., the probability of exceeding displacement D1 is P1 and it is referred to as the (100% - P1) percentile value.
4. The 16%, 50%, and 84% percentile displacement values at selected k_y values are shown to the right.
5. Calculated seismic displacements are due to deviatoric deformation only (add in volumetrically induced movement).
6. k_y may range between 0.01 and 0.8, T_s between 0 and 2 s, S_a between 0.002 and 4.5 g, M_w between 5.5 and 8.2
7. Rigid slope is assumed for T_s < 0.05 s, i.e. T_s = 0.0. If Ts is just less than 0.05 s, set T_s = 0.050 s
8. When a value for D is not calculated, D is < 0.5 cm
9. k_y should be estimated with a slope stability program; the simplified equations shown below provide approximate values.
10. Examples of how T_s is estimated are shown below.
11. V_s = weighted avg. shear wave velocity for the sliding mass, e.g., for 2 layers, V_s = [(h1)(V_s1) + (h2)(V_s2)]/(h1 + h2)

Dependence on k_y

k_y	P(D="0")	D (cm)	Dmedian (cm)	D-84% (cm)	D-16% (cm)
0.020	0.000	1008.3	1008.3	1813.1	560.8
0.05	0.000	719.8	719.8	1294.3	400.3
0.07	0.000	565.7	565.7	1017.1	314.6
0.1	0.000	409.1	409.1	735.5	227.5
0.15	0.000	259.7	259.7	466.9	144.4
0.2	0.000	178.0	178.0	320.0	99.0
0.3	0.000	96.6	96.6	173.8	53.7
0.4	0.000	59.3	59.28	106.59	32.97



Bray & Macedo (2019) Seismic Slope Displacement Spreadsheet_V7 (k_y = 0.09 at 50% hazard case)

Procedure for Estimating Shear-Induced Seismic Slope Displacement for Shallow Crustal Earthquakes

by Jonathan D. Bray and Jorge Macedo, UC Berkeley and Georgia Tech

Procedure for Estimating Shear-Induced Seismic Slope Displacement for Shallow Crustal Earthquakes, ASCE JGGE, 2019.

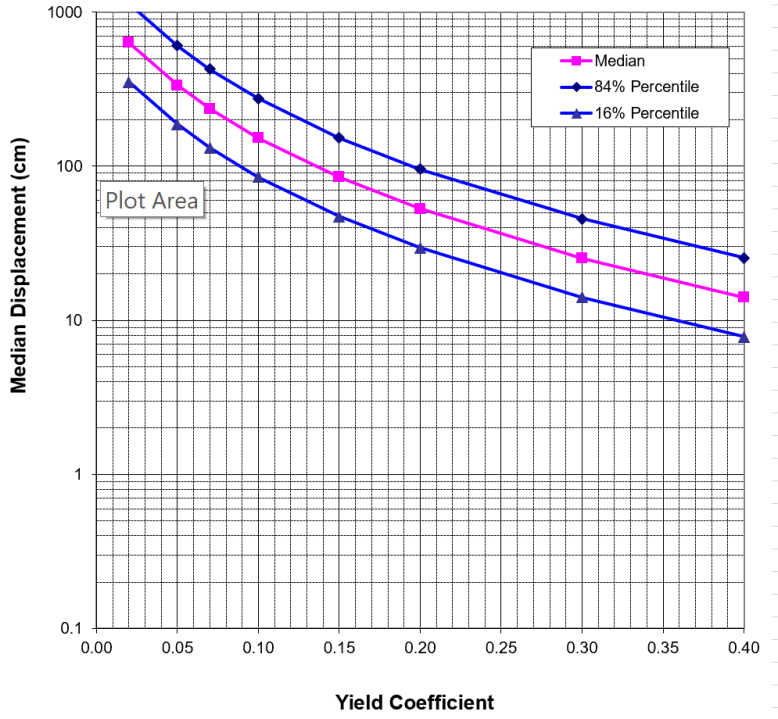
SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters

Case	PulsesD100 (EQ4&5)		* Select Ordinary or Pulse or Combined Equations
Yield Coefficient (k_y) [(a)]	0.09		(a) Based on pseudostatic analysis
Initial Fundamental Period (T_s) [(b)]	0.26	seconds	(b) 1D: T_s=4H/V_s 2D: T_s=2.6H/V_s
Degraded Period (1.3T_s)	0.34	seconds	(c) Input the Spectral Acceleration (g) at
Moment Magnitude (M_w)	7.2		the base of the sliding mass assuming
Spectral Acceleration (S_a(1.3T_s)) [(c)]	1.0	g	there is no material above it.
Peak Ground Velocity (PGV) [(d)]	96.0	cm/s	(d) PGV (cm/s) is required for near-fault pulse
Percentile (if Pulse ground Motion) [(e)]	100		motions only; it is estimated at the base of
			sliding mass assuming no material above it.
Additional Input Parameters			(e) If Pulse motion the percentile is given
Probability of Exceedance #1 (P1)	84	%	as either D100 or D50. D100 should be
Probability of Exceedance #2 (P2)	50	%	used for fault-normal direction
Probability of Exceedance #3 (P3)	16	%	
Displacement Threshold (d_threshold)	30	cm	
Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	175.0	cm	eq. (3) or (5) or (7) or (9)
Standard Deviation of Non-Zero Seismic D	0.59		
Results			
Probability of Negligible Displ. (P(D=0))	**0.00**		eq. (2) or (4) or (6) or (8)
D1	**97.3**	**cm**	calc. using eq. (11)
D2	**175.0**	**cm**	calc. using eq. (11)
D3	**314.6**	**cm**	calc. using eq. (11)
P(D>d_threshold)	**1.00**		eq. (11)

Dependence on k_y

k_y	P(D="0")	D (cm)	Dmedian (cm)	D-84% (cm)	D-16% (cm)
0.020	0.000	632.5	632.5	1137.2	351.7
0.05	0.000	335.8	335.8	603.8	186.8
0.07	0.000	236.7	236.7	425.6	131.6
0.1	0.000	152.5	152.5	274.3	84.8
0.15	0.000	84.9	84.9	152.7	47.2
0.2	0.000	53.0	53.0	95.4	29.5
0.3	0.000	25.3	25.3	45.4	14.0
0.4	0.003	14.1	14.10	25.37	7.81



Notes

1. Values highlighted in blue are input parameters, and results are presented in the table with the yellow heading.
2. Probability of Exceedance is the desired probability of exceeding a particular displacement value.
3. Displacements D1, D2, and D3 correspond to P1, P2, and P3, respectively.
   (e.g., the probability of exceeding displacement D1 is P1 and it is referred to as the (100% - P1) percentile value.
4. The 16%, 50%, and 84% percentile displacement values at selected k_y values are shown to the right.
5. Calculated seismic displacements are due to deviatoric deformation only (add in volumetrically induced movement).
6. k_y may range between 0.01 and 0.8, T_s between 0 and 2 s, S_a between 0.002 and 4.5 g, M_w between 5.5 and 8.2
7. Rigid slope is assumed for T_s < 0.05 s, i.e. T_s = 0.0. If Ts is just less than 0.05 s, set T_s = 0.050 s
8. When a value for D is not calculated, D is < 0.5 cm
9. k_y should be estimated with a slope stability program; the simplified equations shown below provide approximate values.
10. Examples of how T_s is estimated are shown below.
11. V_s = weighted avg. shear wave velocity for the sliding mass, e.g., for 2 layers, V_s = [(h1)(V_s1) + (h2)(V_s2)]/(h1 + h2)

APPENDIX I

REFERENCE MATERIALS

REFERENCES

A. Published Materials

Aagaard, B.T., et al., 2016, "Earthquake Outlook for the San Francisco Bay Region 2014-2043," U.S. Geological Survey, Fact Sheet 2016-3020.

Bishop, C.C., Knox, R.D., Chapman, R.H., Rodgers, D.A., and Chase, G.B., 1973, "Geological and Geophysical Investigations For Tri-Cities Seismic Safety and Environmental Resources Study," California Division of Mines and Geology Preliminary Report 19.

Bozorgnia, Y., et al., 2014, "NGA-West2 research project." *Earthquake Spectra* 30 (3): 973–987.

Bray, J.D. and Travasarou, T., 2007, "Simplified Procedure for Estimating Earthquake-Induced Deviatoric Slope Displacements," *J. of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 133, No. 4, April 2007, pp. 381-392.

Bray, J.D., 2009, "Designing Buildings to Accommodate Earthquake Surface Fault Rupture," Proc., ATC & SEI 2009 Conference on Improving the Seismic Performance of Existing and Other Structures, Dec., 1269-1280.

Bray, J.D., Rodriguez-Marek, A., and Gillie, J. L., 2009, "Design Ground Motions Near Active Faults," *Bulletin of the New Zealand Society for Earthquake Engineering,* 42 (1), March, 8 pp.

Bray, J.D., 2012, "Building Near Faults," Seismological Society of America, William B. Joyner Memorial Lecture.

Bray, J.D. and Macedo, J., 2019, "Procedure for Estimating Shear-Induced Seismic Slope Displacement for Shallow Crustal Earthquakes," *J. of Geotechnical and Geoenvironmental Engineering*, ASCE, in press.

Bray, J.D. and Macedo, J., 2019, "Shear-induced seismic slope displacement estimates for shallow crustal earthquakes," Earthquake Geotechnical Engineering for Protection and Development of Environment and Constructions, Silvestri & Moraci (Eds), Associazione Geotecnica Italiana, Rome, Italy, 1537-1544.

California Division of Mines and Geology, 1982, "Alquist-Priolo Earthquake Fault Zone Map, Richmond Quadrangle," dated July 1, 1982.

California Geological Survey, 2008, Special Publication 117A, "Guidelines for Evaluating and Mitigating Seismic Hazards in California," Revised and Re-adopted September 11, 2008.

California Geological Survey, 2003, "Seismic Hazard Zone Report for the Richmond 7.5-Minute Quadrangle, Alameda County, California."

California Geological Survey, 2013, "Note 48, Checklist for the Review of Engineering Geology and Seismology Reports for California Public Schools, Hospitals and Essential Services Buildings."

Cohen-Waeber, J.F., 2018, "Spatiotemporal Patterns of Seasonality in Landslide Deformation from InSAR and GPS," Graduate Dissertation, University of California, Berkeley.

Dibblee, Thomas W., Jr., 1980, “Preliminary Geologic Map of the Richmond Quadrangle, Alameda and Contra Costa Counties, California,” U.S. Geological Survey, Open File Report OFR 80-1100.

Dibblee, Thomas W., Jr., 2005, “Geologic Map of the Richmond Quadrangle, Contra Costa County, California,” Dibblee Geology Center Map, DF-147.

Goter, Susan K., “Seismicity of California, 1808-1987,” U.S. Geological Survey Open File Report 88-286, 1:1,000,000.

Graymer, R.W., 2000, “Geologic Map and Map Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, California,” U.S. Geological Survey Miscellaneous Field Studies MF-2342.

Hayden, C., Bray, J.D., and Abrahamson, N.A., 2014, “Selection of Near-Fault Pulse Motions,” *J. of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 140(7), Paper 04014030.

Herd, D., 1978, “Map of Quaternary Faulting along the Northern Hayward Fault Zone,” United States Geological Survey, Open File Report OF 78-308.

Hilley, G.E., Bürgmann, R., Ferretti, A., Novali, F., & Rocca, F., 2004, “Dynamics of Slow-Moving Landslides from Permanent Scatterer Analysis,” Science, 304(5679), 1952-1955.

Hoexter, D.F., Levine, C.R., Hecht, B., and Collier, G., 1982, “Deformation along the Hayward fault zone, North Berkeley: Fault creep and landsliding,” in Hart, E.W., Hirschfeld, S.E., and Schulz, S.S., eds., Proceedings, Conference on Earthquake Hazards in the Eastern San Francisco Bay Area: California Division of Mines and Geology Special Publication 62, p. 1–10.

Hoge, P., 2004, “When property lines run through the front door / The slowly shifting ground in the Berkeley hills area means the land that's yours today may be your neighbor's tomorrow,” article, San Francisco Chronicle.

International Conference of Building Officials (ICOB), 1998, "Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada," California Division of Mines and Geology.

Jennings, Charles W., 1994, “Fault Activity Map of California and Adjacent Areas, with Locations and Ages of Recent Volcanic Eruptions,” California Division of Mines and Geology Geologic Data Map No. 6, 1:750,000.

Keefer, D.K., and Johnson, A.M., 1983, “Earth Flows: Morphology, Mobilization, and Movement,” U.S. Geological Survey Professional Paper 1264.

Lawson, Andrew C., 1908, “The California Earthquake of April 18, 1906,” Report of the State Earthquake Investigation Commission, published by the Carnegie Institute of Washington, Pub. No. 87, 2 volumes and atlas.

Lei, L., & Bürgmann, R., 2010, “Application of PSI to Investigate the Berkeley Hills Landslides,” AGU Fall Meeting.

Lienkaemper, James J., 1992, “Map of Recently Active Traces of the Hayward Fault, Alameda and Contra Costa Counties, California,” U.S. Geological Survey Miscellaneous Field Studies Map MF-2196, 1:24,000.

Lienkaemper, James J., and Glenn Borchardt, 1992, “Hayward Fault: Large Earthquakes Versus Surface Creep,” in Borchardt, Glenn, et al., editors, Proceedings of the Second Conference on Earthquake Hazards in the Eastern San Francisco Bay Area: California Division of Mines and Geology Special Publication 113, p. 101-110.

Macedo, J., Bray, J.D., Abrahamson, N., and Travasarou, T., 2018, “Performance-based probabilistic seismic slope displacement procedure,” *Earthquake Spectra J.*, Earthquake Engineering Research Institute.

McNutt, Stephen R., and Tousson R. Toppozada, 1990, “Seismological Aspects of the 17 October 1989 Earthquake,” in McNutt, Stephen R., and Robert H. Sydnor, editors, The Loma Prieta (Santa Cruz Mountains), California, Earthquake of 17 October 1989, California Department of Conservation, Division of Mines and Geology Special Publication 104, p. 11-27.

Murphy, Janice M., and Steven G. Wesnousky, 1994, “A Postearthquake Reevaluation of Seismic Hazard in the San Francisco Bay Region,” in Borcherdt, Roger D., editor, The Loma Prieta, California, Earthquake of October 17, 1989 - Strong Ground Motion: U.S. Geological Survey Professional Paper 1551-A, p. A255 - A272.

Nilsen, Tor H., 1975, “Preliminary Photointerpretation Map of Landslide and Other Surficial Deposits of the Richmond 7-1/2' Quadrangle, Contra Costa and Alameda Counties, California,” U.S. Geological Survey Open File Map 75-277-47, 1:24,000.

Oettle, N, and Bray, J.D., 2013a, “Fault Rupture Propagation through Previously Ruptured Soil,” J. of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 139(10), 1637-1647.

Oettle, N, and Bray, J.D., 2013b, “Geotechnical Mitigation Strategies for Earthquake Surface Fault Rupture,” J. of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 139(11), 1864-1874.

Oettle, N., Bray, J.D., and Dreger, D., 2015, “Dynamic Effects of Surface Fault Rupture Interaction with Structures,” *Soil Dynamics and Earthquake Engineering* J., V. 72, 37-47.

Perkins, Jeanne B., and John Boatwright, 1995, “On Shaky Ground,” Association of Bay Area Governments Publication Number P95001EQK, 56 p., twelve maps at 1:1,000,000.

Quigley, K.C., Bürgmann, R., Giannico, C., & Novali, F., 2010, “Seasonal Acceleration and Structure of Slow Moving Landslides in the Berkeley Hills,” Proceedings of the Third Conference on Earthquake Hazards (2008), Eastern San Francisco Bay Area, Edited By K. Knudsen. California Geological Survey Vol Special Report 219. pp 169-178.

Ritter, J.R., and Dupre, W.R., 1972, “Maps Showing Areas of Potential Inundation by Tsunamis in the San Francisco Bay Region, California,” U.S. Geological Survey Map MF-480.

Schwartz, David P., 1994, "New Knowledge of Northern California Earthquake Potential": in Proceedings of ATC-35 Seminar on New Developments in Earthquake Ground Motion Estimation and Implications for Engineering Design Practice, San Francisco, California, January 27, 1994, presented by the Applied Technology Council, p. 4-1 - 4-9.

Seed, R.B., Dickenson, S.E., Riemer, M.F., Bray, J.D., Sitar, N., Mitchell, J.K., Idriss, I.M., Kayen, R.E., Kropp, A., Harder, L.F., Jr., and Power, M.S., 1990, "Preliminary Report on the Principal Geotechnical Aspects of the October 17, 1989, Loma Prieta Earthquake," Earthquake Engineering Research Center, Report EERC 90-05.

Steinbrugge, Karl V., John H. Bennett, Henry J. Lagorio, James F. Davis, Glenn Borchardt, and Tousson R. Toppozada, 1987, "Earthquake Planning Scenario for a Magnitude 7.5 Earthquake on the Hayward Fault in the San Francisco Bay Area": California Department of Conservation, Division of Mines and Geology Special Publication 78, 245 p., numerous maps at various scales.

Tocher, Don, 1959, "Seismic History of the San Francisco Region," California Division of Mines and Geology, Special Report 57.

Toppozada, Tousson R., and David L. Parke, 1982, "Area Damaged by the 1868 Hayward Earthquake and Recurrence of Damaging Earthquakes near Hayward": in Hart, Earl W., Sue E. Hirschfeld, and Sandra S. Schulz, editors, Proceedings, Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, California Department of Conservation, Division of Mines and Geology Special Publication 62, p. 321-328.

United States Department of Agriculture, 1977, "Soil Survey of Contra Costa County, California."

Wagner, D.L., and Bortugno, E.J., 1982, "Geologic Map of the Santa Rosa Quadrangle, California," California Division of Mines and Geology Regional Geologic Map Series Map No. 2A (Geology), 1:250,000.

Wagner, D.L., Bortugno, E.J., and McJunkin, R.D., 1990, "Geologic Map of the San Francisco-San Jose Quadrangle, California," California Division of Mines and Geology Regional Geologic Map Series Map No. 5A (Geology), 1:250,000.

Working Group on California Earthquake Probabilities (WGCEP), 2003, "Earthquake Probabilities in the San Francisco Bay Region: 2002 – 2031," U.S. Geological Survey Open File Report 03-214.

Youd, T.L. and Hoose, S.N., 1978, "Historic Ground Failures in Northern California Triggered by Earthquakes," U.S. Geological Survey, Professional Paper 993.

B. Consultant Reports

Alan Kropp and Associates, "Geotechnical Report, 1160 Amador Street Residence," dated September 1981.

Alan Kropp and Associates, "Geotechnical Report, Poitier Residence, 1130 Shattuck Avenue," dated April 2000.

Alan Kropp and Associates, "Geotechnical Report, Pollard Residence, 1141 Shattuck Avenue," dated November 2018.

Alan Kropp and Associates, "Geotechnical Report, Ng Residence, 1122 Spruce Street," dated March 1989.

Alan Kropp and Associates, "Geotechnical Report, Arbucci Residence, 1133 Spruce Street," dated February 1988.

Alan Kropp and Associates, "Geotechnical Report, Reuther/Bonomi Residence, 1119 Arch Street," dated April 2003.

Alan Kropp and Associates, "Geotechnical Report, Corona Court Residence, 2334 Corona Court," dated March 1991.

Alan Kropp and Associates, "Geotechnical Report, Strothers Residence, 2356 Corona Court," dated February 1983.

Alan Kropp and Associates, "Geotechnical Report, High Court Residence, 21109 High Court," dated June 1997.

Alan Kropp and Associates, "Geotechnical Report, Euclid Avenue Residence, 1104 Euclid Avenue," dated April 1987.

Alan Kropp and Associates, "Geotechnical Report, Keeler Avenue Extension," dated June 1994.

Alan Kropp and Associates, "Geotechnical Report, Fulton Residence, 1064 Miller Avenue," dated March 1990.

Alan Kropp and Associates with William Lettis and Associates, 2002, "Blakemont Area Geologic Study, El Cerrito and Kensington California," Engineering Consulting Report. Alan Kropp and Associates. Berkeley CA.

Alan Kropp and Associates with William Lettis and Associates, 2006, "Initial Landslide Characterization Study, East Canyon-Building 85 and 85A, Lawrence Berkeley National Laboratory," Engineering Consulting Report. Alan Kropp and Associates. Berkeley CA.

EBMUD, 1985, "Pipe Leak Map."

HJW, 2005, "Arch Street, Berkeley Site," topographic map.

Sandis, 2018, "Topographic Survey 1130 Oxford Elementary School," dated July 10, 2018.

Woodward-Clyde Consultants, “Phase II Geologic Study, Oxford Elementary School, Berkeley, California,” dated January 25, 1977.

C. Aerial Photographs

Type	Date	Scale	Photo No.	Source
Black and White, Stereo Pair	1930	1:9,600	GY-30-31,32	AKA Library
Black and White Photo	1935	Oblique	The Circle, Berkeley	AKA Library
Black and White, Stereo Pair	08/02/39	1:20,000	BUT-BUU-289-97,98	AKA Library
Black and White, Stereo Pair	09/06/46	1:24,000	GS-CP-5-12,13	AKA Library
Black and White Photo	03/24/47	1:20,000	AV11-02-10	AKA Library
Black and White Stereo Pair	09/06/49	1:7,200	AV28-14-24,25	AKA Library
Black and White Photo	08/14/53	1:9,600	AV119-10-24	AKA Library
Black and White Stereo Pair	05/03/57	1:12,000	AV253-8-16,17	AKA Library
Black and White, Stereo Pair	07/08/59	1:9,600	AV337-10-21,22	AKA Library
Black and White, Stereo Pair	05/02/69	1:12,000	AV902-8-13,14	AKA Library
Black and White, Stereo Pair	06/21/83	1:12,000	AV2300-9-16,17	AKA Library