APPENDIX C

Draft Phase 1 Potential Rockfall And Slope Hazard Assessment Hawaiian Memorial Park Cemetery Expansion – January 2018

Prepared by: Geolabs, Inc.

GEOTECHNICAL CONSULTATION SERVICES

PHASE 1 POTENTIAL ROCKFALL AND SLOPE HAZARD ASSESSMENT

HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION

KANEOHE, OAHU, HAWAII

TMK: 4-5-033: 001

W.O. 7604-00 JANUARY 18, 2018

Prepared for

HHF PLANNERS

GEOLABS, INC.
Geotechnical Engineering and Drilling Services

DRAFT REPORT - 01/18/18

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ROBIN M. LIM
LICENSED PROFESSIONAL ENGINEER
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HAWAII, U.S.A.

THIS WORK WAS PREPARED BY
ME OR UNDER MY SUPERVISION.

SIGNATURE

4-30-18
EXPIRATION DATE
OF THE LICENSE

GEOLABS, INC.
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Hawaii • California

GEOLABS, INC.

Geotechnical Engineering and Drilling Services

January 18, 2018
W.O. 7604-00

Mr. Scott Ezer
HHF Planners
733 Bishop Street, Suite 2590
Honolulu, HI 96813

Dear **Mr. Ezer:**

Geolabs, Inc. is pleased to submit our report entitled "Geotechnical Consultation Services, Phase I Potential Rockfall and Slope Hazard Assessment, Hawaiian Memorial Park Cemetery Expansion, TMK: 4-5-033: 001, Kaneohe, Oahu, Hawaii," prepared in support of the Phase I geotechnical assessment.

Our work was performed in general accordance with the scope of services outlined in our fee proposal dated August 29, 2017.

Please note that the soil samples recovered during our field exploration (remaining after testing) will be stored for a period of two months from the date of this report. The samples will be discarded after that date unless arrangements are made for a longer sample storage period. Please contact our office for alternative sample storage requirements, if appropriate.

Detailed discussion and preliminary recommendations are contained in the body of the report. If there is any point that is not clear, please contact our office.

Very truly yours,

GEOLABS, INC.

Robin M. Lim, P.E.
President

RML:SC:mj

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SUMMARY OF FINDINGS AND RECOMMENDATIONS

Source regions for potential falling rock hazards were identified in portions of the upland hillside above the proposed cemetery expansion development area. Based on our computer rockfall simulation, most of the potential falling rock activity should remain on the steeper hillside upslope from the proposed development boundary. However, a section of the central portion of the upslope development boundary appears to be exposed to some potential encroachment of falling rock. As a result, we recommend constructing a segment of rockfall catchment ditch along the boundary to reduce the potential for falling rock encroachment at this portion of the project site.

Our ground surface reconnaissance of the project site interior and the bordering higher elevation slopes contained within the proposed Conservation Easement area indicate that the majority of the existing slopes flatter than about 2H:1V inclination and contained within the development boundary, appear to be composed of mixed silty and clayey alluvial and colluvial soils with appreciable weathered rock fragments ranging from gravel to larger boulders. The deposits are likely the result of erosion and mass wasting processes (old landslide and rockfall activity) from the adjacent high slopes during the early evolution of the area geomorphology.

Additional detailed test boring exploration should be conducted throughout the site to verify the anticipated geological and soil conditions including the presence or absence of soft soil and under consolidated alluvial deposits that could indicate the potential for ground settlement when loaded with fill.

Upon acceptance of this Phase I conceptual rockfall hazard mitigation scheme, a Phase II design-level study would be performed to refine the conceptual rockfall hazard mitigation scheme and develop a basis of design and construction documents package, which would include appropriate construction plans and technical specifications to construct the rockfall hazard mitigation system. Refinement of the Phase I conceptual rockfall mitigation scheme may include some minor adjustments involving the proposed rockfall interception structure. Finally, we envision other minor adjustments may be required to coordinate the rockfall protection design with other planned improvements.

The text of this report should be referred to for detailed discussion pertaining to the existing site conditions and potential natural hazard conditions, including our preliminary engineering and statistical analyses of the potential rockfall processes anticipated at the project site. The preliminary findings and recommendations are subject to the limitations noted at the end of this report.

END OF SUMMARY OF FINDINGS AND RECOMMENDATIONS

SECTION 1. GENERAL

This report presents the results of our Phase I geotechnical assessment of the potential rockfall and slope hazard conditions at the proposed *Hawaiian Memorial Park Cemetery Expansion* project site. The project location and general vicinity are shown on the Project Location Map, Plate 1.

This report summarizes the findings based on our field reconnaissance and literature review pertaining to the existing site conditions and potential natural hazard conditions, including our preliminary engineering and statistical analyses of the potential rockfall processes anticipated at the project site.

1.1 Project Considerations

The proposed *Hawaiian Memorial Park Cemetery Expansion* project is in the Kaneohe area on the Island of Oahu, Hawaii. The proposed cemetery expansion area is adjacent to and northeasterly from the existing Hawaiian Memorial Park Cemetery. The proposed expansion area encompasses existing undeveloped and forested land along the lower elevation slopes of Oneawa Hills, which surround the proposed expansion area toward the north through east. The proposed expansion area is also adjacent to the existing residential community, located westerly of the proposed development area.

We understand the current proposed cemetery expansion plan has been reduced in size from an earlier scope. The current development proposes a Land Use Commission (LUC) boundary encompassing about 51 acres of currently undeveloped land. The proposed park expansion includes the development of about 28 acres for park burial use and about 15 acres for a proposed cultural preservation area. The remaining 8 acres of land within the proposed 51-acre expansion petition will remain as scattered undeveloped buffer areas adjacent to the existing residential community. Finally, the proposed cemetery expansion will include the designation of a Conservation Easement encompassing an additional 156 acres of hillside extending from the proposed cemetery development boundary toward the adjacent ridgeline summit comprising a portion of the Oneawa Hills.

We understand the project may be developed in phases over an extended period of time. In general, we understand that mass grading of the project site may occur in the early stage of the project development. The mass grading would be followed by a phased approach to incrementally develop the site in conformance with the accepted overall site development plan.

Based on the available preliminary grading plan, substantial earth moving and grading may be necessary to develop the site under the current development plan. In general, the current grading plan consists of major cuts at the west side and filling at the east side of the development area. The preliminary grading plan shows cuts generally ranging from about 10 to 75 feet and fills generally ranging between about 10 and 30 feet. A retaining wall structure of up to about 25 feet in height is proposed at the makai side of the development area to contain the fills and provide a development setback away from an existing documented groundwater spring. Based on the available grading plan, there is a large net excess of cut material that may not be accommodated by the fill needs for the project.

We conducted a ground reconnaissance study of the surrounding slopes above and within the proposed development area to obtain preliminary information pertaining to the existing site conditions, the potential for falling rock hazards, and slope instability. In addition, we conducted a limited subsurface exploration consisting of two test borings to evaluate the general regional subsurface conditions at the project site. The test boring exploration was conducted at existing truck accessible locations at the perimeter of the Ocean View Garden adjacent to the proposed expansion area.

Upon acceptance of this conceptual rockfall hazard mitigation scheme, a Phase II design-level study will be performed to refine the conceptual rockfall hazard mitigation scheme and develop a basis of design and construction documents package, which would include appropriate construction plans and technical specifications to construct the rockfall hazard mitigation system. Refinement of the Phase I conceptual rockfall mitigation scheme may include some minor adjustments involving the proposed rockfall interception structure. Finally, we envision other minor adjustments may be required to coordinate the rockfall protection design with other planned improvements.

In addition, a detailed geotechnical engineering exploration would be conducted to investigate the existing subsurface conditions and provide technical recommendations for development of the site from a geotechnical perspective.

Our preliminary potential rockfall hazard analyses and conceptual design of rockfall mitigation improvements are subject to the limitations and restrictions presented herein.

1.2 Purpose and Scope

The purpose of our geotechnical consultation services was to evaluate the existing site conditions for potential rockfall and slope stability hazards and to provide preliminary geotechnical recommendations for grading and potential rockfall hazard mitigation. Our Phase I study generally consisted of the following tasks and work efforts:

1. Research and review of available geological, soil and topographic maps, aerial photographs, and in-house soil/rock data from the project vicinity.
2. Performance of a field reconnaissance to observe the slopes and map the existing conditions of the surface rock exposures. The reconnaissance was conducted by a project geologist and field engineer from our office.
3. Test boring stakeout and coordination of underground utility toning and site access by our field engineer/geologist.
4. Mobilization of a truck-mounted drill rig and two operators to and from the project site.
5. Drilling and sampling of two test borings to depths of about 45 feet each below the existing ground surface at accessible locations within the existing cemetery park.
6. Laboratory testing of selected samples obtained during the field exploration as an aid in classifying the materials and evaluating their engineering properties.
7. Analyses of the field and laboratory data to formulate preliminary geotechnical recommendations for site grading.
8. Analyses of the field reconnaissance data to formulate preliminary geotechnical recommendations and conceptual rockfall hazard mitigation alternatives to reduce the potential for encroachment of falling rock material from the adjacent slopes.

9. Analyses included some preliminary computer modeling of the slopes and probable rockfall path simulation using the Colorado Rockfall Simulation Program (CRSP). Based on the analyses, concept-level rockfall hazard mitigation options were evaluated to provide appropriate preliminary recommendations.

10. Preparation of this report summarizing our work on the project and presenting our findings and preliminary geotechnical recommendations.

11. Attendance of meetings for consultation in support of our findings and preliminary recommendations by our principal engineer.

12. Coordination of our overall work on the project by our project geologist/engineer.

13. Quality assurance of our work and client/design team consultation by our principal engineer.

Detailed descriptions of our field exploration methodology and the Logs of Borings are presented in Appendix A. Laboratory test results conducted on selected samples are presented in Appendix B. Selected photographs of the existing site conditions are presented in Appendix C, and the summary results of the CRSP Analyses are presented in Appendix D.

END OF SUMMARY OF GENERAL

SECTION 2. SITE CHARACTERIZATION

The Island of Oahu was built by the extrusion of basaltic lava from the Waianae and Koolau Shield Volcanoes. The older Waianae Volcano is estimated to be middle to late Pliocene in age (2.7 – 3.4 million years ago) and forms the bulk of the western one-third of the island. The younger Koolau Volcano is estimated to be late Pliocene to early Pleistocene (Ice Age) in age (2.2 – 2.5 million years ago) and forms the majority of the eastern two-thirds of the island. After a long period of volcanic inactivity, during which time erosion incised deep valleys into the Waianae and Koolau Shields, volcanic activity returned with a series of lava flows followed by cinder and tuff cone formations mainly at the southeastern portion of the Island of Oahu.

During the Pleistocene Epoch (Ice Age), sea levels fluctuated in response to the cycles of continental glaciation. As the glaciers grew and advanced, less water was available to fill the oceanic basins such that sea levels fell below the present stands of the sea. When the glaciers melted and receded, an excess of water became available such that the sea levels rose to elevations above the present sea level.

The processes of erosion and deposition were affected by these glacio-eustatic sea level fluctuations. When the sea level was low, the erosional base level was correspondingly lower, and valleys were carved to depths below the present sea level. When the sea level was high, the erosional base level was raised such that sediments filled pre-existing depressions and accumulated at higher elevations.

In the mountainous regions of Hawaii and at the heads of valleys, erosional processes are dominated by detachment of soil and rock materials from the steep valley walls and transportation of the material down slope toward a valley axis primarily by gravity as colluvial earth materials. Once these materials reach a stream in the central portion of a valley, stream flow processes become dominant, and the sediments become transported and deposited as alluvial earth materials.

2.1 <u>Project Area Geology</u>

The Hawaiian Memorial Park Cemetery Expansion project site is on the western flank of the Oneawa Hills, near the southern terminus of the elongated hills which trend generally northeast to southwest and form a geographic boundary between the communities of Kailua and Kaneohe, as indicated on the Project Location Map, Plate 1. The proposed cemetery development is generally on the lower elevation, westerly facing flank, of the Oneawa Hills and generally encompasses a topographic knoll and an adjacent lowland basin area at the foot of the Oneawa Hills hillside. The basin area contains a confluence of intermittent stream channels that emanate from the bordering steeper terrain comprising the uplands of the Oneawa Hills.

It should be noted that the original Kapaa Quarry site is on the opposite side of the Oneawa Hills ridgeline bordering the eastern side of the proposed development property. Previous extensive mining (blasting and excavation) of the hard basalt rock comprising the core of the Oneawa Hills has produced sub-vertical rock cut slope exposures and a deep pit basin at the former quarry site. The basalt rock materials exposed by the quarry cuts provide an excellent overview of the typical hard rock material that is believed to form the core of the Oneawa Hills structure.

Based on our review of available geologic information, the Oneawa Hills, at their core, are composed of massive basaltic caldera-filling lava rock containing some basaltic breccia rock. The caldera filling lavas were intruded by a series of volcanic dikes (narrow elongated columns of very dense fine-grained rock) that fed the caldera filling lava extrusion. The combined basaltic rock materials represent the late stage caldera filling lava materials of the old Koolau Volcano vent, which once spanned between Kaneohe and Waimanalo including the Kailua area. The rock materials comprising the Oneawa Hills belong to the Kailua Member of the Koolau Volcanic Series and generally are highly to completely weathered at the ground surface and also may contain buried zones of deeply decomposed rock, which was hydrothermally altered by hot volcanic fluids and gases following deposition in the caldera environment.

Based on our site reconnaissance and review of available geological information, we believe the ground surface of the steeper slopes above the proposed development boundary may be composed of silty and clayey residual and saprolitic soils representing the weathered soil products derived from the decomposition of the parent basaltic rock described previously. As a result, scattered remnant hard rock outcroppings may be encountered at the ground surface and buried in the subsurface. The rock outcroppings observed in the field lack identifiable bedding surfaces or other notable layering as is typical with basaltic lava flows composed of alternating soft clinker and hard rock layers. Instead, the outcroppings we observed in the field on the higher slopes generally consist of isolated massive blocks of rock protruding from the surrounding soil covered ground surfaces (potential rockfall source) or as relatively flat low relief outcroppings that are generally smooth and nearly flush with the surrounding soil covered ground surfaces (very limited potential rockfall source).

It also should be noted that the dense rock we observed in the field contains limited vesicularity (gas bubble texture), and lava tubes or other volcanic cavities are generally absent. The slightly to moderately weathered basaltic rock observed in the rock outcroppings and boulders has a fine-grained crystalline structure and typically is hard to very hard. Occasionally, fragments of dissimilar basaltic rock are visible as welded inclusions in the basaltic rock mass indicating a breccia origin. We observed many rock outcroppings that expose a closely to severely fractured rock mass containing fine micro-fracture traces that when exposed to long-term surface weathering or mechanical abrasion, produces small angular equi-dimensional shaped hard stones ranging from gravel to small cobbles in size. We observed local accumulations of this rocky talus material surrounding some rock outcroppings and within some of the established drainages on the mountainside.

Based on our reconnaissance, we anticipate the lower elevation slopes within the proposed development boundary may contain areas of stiff residual/saprolitic soils with generally very few hard rock outcroppings at the ground surface. The residual/saprolitic soil areas may be more commonly encountered in the slope inclination transition area just below the steep mountain up-slopes and within the lower height hills and ridges at the north and western portions of the project site.

Based on our reconnaissance, the majority of the existing slopes flatter than about two horizontal to one vertical (2H:1V) inclination and contained within the development boundary, appear to be composed of mixed silty and clayey alluvial and colluvial soils with appreciable weathered rock fragments ranging from gravel to larger boulders. The deposits are likely the result of erosion and mass wasting processes (old landslide and rockfall activity) from the adjacent high slopes during the early evolution of the area geomorphology. Additional test boring exploration should be conducted throughout the site to verify the anticipated geological and soil conditions including the presence or absence of soft soil and under consolidated alluvial deposits that could indicate the potential for ground settlement when loaded with fill.

Selected photographs of the existing site conditions are presented as Photograph Nos. 1 through 55 in Appendix C.

2.2 Existing Site Conditions

The project site is adjacent to the existing Hawaiian Memorial Park Cemetery in Kaneohe on the Island of Oahu. The proposed 51-acre project site is bounded by the existing cemetery toward the west through south, residential subdivisions toward the west through north, and the Oneawa Hills and Kapaa Quarry toward the east. The general project location and vicinity is shown on the Project Location Map, Plate 1.

The project site is along the lower flank slopes of the Oneawa Hills. As a result, the terrain generally rises and steepens toward the east and south within the project site and generally falls toward the north and west within the project site. The proposed development generally is contained within a broad drainage basin structure bounded by the Oneawa Hills slopes and summit ridgeline. Although the eastern side of the development area primarily resides within gently sloping drainage basin terrain, there are some moderate slopes and hilly upland terrain at the western end of the project site. It should be noted that the preliminary grading plan shows substantial earth cuts up to about 75 feet that will reduce the hills at the western portion of the project site. Based on our site reconnaissance and review of available geological information, we believe there is some potential for these deep hillside cuts to encounter hard basalt rock buried at some depth.

Based on the available topographic plan for the project site and vicinity, the existing ground surface elevations within the project site range from about +175 feet MSL (Mean Sea Level) at the northwestern (makai) perimeter of the project site to about +400 feet MSL at the southeastern (mauka) portion of the project site. The upland slopes extending beyond the project site reach summit elevations of about +700 to +940 feet MSL easterly from the project site. An overview of the project site and vicinity showing the topography and features discussed in the following report sections is presented on the Site Plan, Plate 2.

2.3 Site Reconnaissance

Our geologist and field engineer conducted a ground surface reconnaissance of the project site interior and the bordering higher elevation slopes contained within the proposed Conservation Easement area on several site visits conducted in October and November 2017. Navigation and feature location referencing in the field was performed using a handheld GPS unit combined with the project topographic map and other available aerial imagery.

Based on our reconnaissance, the project site is presently undeveloped and densely covered with forest type vegetation. The forest vegetation generally consists of relatively dense shrubbery containing areas of thick ground cover (understory) consisting of fern and vine growth. Amongst the understory are widely scattered medium to large trees including dense groves of Umbrella/Rubber tree and Christmas Berry and scattered large Albizia, Mango, and Koa trees. Also, on the higher elevation slopes, dense groves of Strawberry Guava shrubbery were encountered sporadically.

In addition to the predominantly thick ground cover vegetation, we encountered scattered areas offering good ground exposure, usually beneath the canopy of larger trees or beneath the dense groves of Umbrella, Strawberry Guava, and Christmas Berry trees. The generally thick vegetation density appears to provide some buffer against the unrestrained movement of rocks and boulders on the sloping terrain and also may aid in reducing the energy and slowing the velocity of potential larger falling rock material from the slopes.

2.4 Basin Area Reconnaissance

We define the project basin area as the portion of the proposed development located at the foot of the adjacent steeper slopes where the existing ground surface inclinations stand at about 3H:1V or flatter. The basin area generally encompasses gently rolling and gently sloping terrain where multiple small drainage tributaries merge into fewer established channels.

Based on our site reconnaissance, it appears that the lower basin area within the project site may be underlain primarily by reddish brown and brown silty and clayey alluvial and/or colluvial soils containing some embedded rock fragments derived from erosion of the upland areas. More frequent exposure of rocky colluvial material, consisting of mixed cobbles and boulders and clayey soils, generally were encountered within the tributaries and established drainages emanating from the surrounding slopes. However, we observed the topographic hills at the far northern and far northwestern corners of the development area may be composed of stiff clayey and silty residual soils derived from deep and long-term in-situ weathering and decomposition of rock material.

Based on our site reconnaissance, visible evidence of extensive areas of dark colored, organic rich soft alluvial soil conditions at the ground surface were not encountered except in the vicinity of the documented groundwater spring at the northwestern portion of the project site. The spring area contains multiple swale alignments and localized standing water. Therefore, we anticipate the reddish brown clayey soils may be saturated, and soft soil conditions should be anticipated within and immediately surrounding the groundwater spring discharges.

We observed several isolated very large boulders with dimensions greater than about 6 feet residing in stable, generally flat ground settings within the cemetery development area limits. Visible evidence indicating a recent rockslide and deposition event such as missing vegetation and rock surface abrasion were not observed. It should be noted that a parent rock outcrop that could produce the observed large boulders was not encountered during our upper slope reconnaissance above the proposed cemetery development area, except on the slopes directly above the proposed cultural preservation area. Thus, the origin of these anomalous boulders in the lowland basin is suspect and could be a result of the following:

1. prehistoric large-scale mass wasting (rockfall/rockslide), which occurred during the early evolution of the sloping landscape; or

2. erosional remnant rock embedded in older alluvial and colluvial deposits comprising the basin that was “brought” to the surface by stream incision and erosion over time; or

3. man-induced rockfall caused by the early development (blasting and heavy excavation) of the adjacent rock quarry where earth cuts in rock material reach the top of the adjacent Oneawa Hills summit.

Based on our site reconnaissance conducted within and upslope from the area proposed for cultural preservation, we encountered numerous large boulders and clusters of large boulders greater than 6 feet in dimension residing in stable ground settings at the far northeastern corner of the project site as shown on the Site Plan, Plate 2. We observed that a few of the large boulder deposits were associated with underlying deposits of broken angular gravel and cobbles mixed with soil that may be indicative of an old landslide/rockslide event.

In addition, we observed numerous scattered individual boulders and clusters of boulders ranging in size between about 3 and 8 feet residing in stable ground settings. The concentration and frequency of the boulder deposits suggest that an outcropping of source rock resides upslope from the deposition area. Based on our reconnaissance of the suspected source area extending toward the ridge summit, some large, massive rock outcroppings were observed in steep terrain settings. The widely scattered, massive rock outcroppings located high on the slopes are directly above the observed deposition area; therefore, we believe the sub-valley extending toward the ridge summit above the proposed cultural preservation area may harbor additional large block outcroppings that could pose potentially dangerous large block rockfall activity and encroachment at the upslope cultural preserve boundary.

2.5 Upland Slope Reconnaissance

We define the upland slope area as the steeper hillside terrain generally extending upslope and beyond the cemetery development boundary, except at the far southwestern corner of the development area where some steeper hill slopes reside within the development area boundary (i.e. the proposed large earth cut area). Due to the steepness of these upland slopes and the high density of forest vegetation, our reconnaissance was limited to traversing various foot accessible areas on the mid-slope, including a traverse along the Oneawa Hills ridge summit and traverses made by climbing up the primary “U” shaped ravines (drainage chutes) that extend toward the ridge summit.

Based on our site reconnaissance, the upland hill slope surfaces appear to be composed of mainly residual and saprolitic soils derived from the deep weathering and decomposition of the parent basalt rock, which typically forms the core of the Oneawa Hills. As a result, erosional remnant hard rock material (ranging from cobble/boulder corestones to very large blocks in excess of 10 to 15 feet) may be embedded within the residual and saprolitic soils. In addition, we anticipate the near-surface residual and saprolitic soils may grade to hard basaltic rock material at variable depths. The potential presence of the hard and massive rock material embedded in the subsurface is difficult to predict based on surface observation alone, due to the great variability in depth and extent of weathering and rock decomposition associated with the caldera filling lavas of the Kailua Volcanic Series.

Based on our reconnaissance, we observed some widely scattered to scattered hard rock outcroppings at the ground surface, primarily on the steeper mountain slope segments with the Potential Rockfall Source Area Nos. 1 and 2 (PRSA-1 and PRSA-2) shown on the Site Plan (Plate 2). We observed three general types of basalt rock outcropping related to the Kailua Volcanic Series caldera filling lavas and dike rock encountered on the upland slopes.

1. Isolated, scattered to widely scattered, hard rock masses protruding from the surrounding low relief soil covered ground surfaces. The rock character may be sub-angular, generally equi-dimensional to cylindrical in shape, predominantly 3 to 5 feet in larger dimension, slightly to moderately weathered and ranging from massive to severely fractured. These outcroppings are capable of producing falling rock hazards and were the most common type of rock outcropping encountered on the upper slopes above the cemetery development area.

2. Isolated, very widely scattered, hard rock surfaces that have low relief and are generally flush with the surrounding soil covered ground surfaces. These flattened outcroppings have very limited or no potential to produce falling rock hazards and were encountered as isolated outcroppings on steep slope segments and within the scoured floor of some drainages. These outcrops were encountered throughout the upland slopes.

3. Isolated, very widely scattered, massive, high relief hard rock outcroppings that appear anomalous to the surrounding landscape and soil covered slopes. These outcroppings are fewer in number but may produce large and very dangerous falling rock hazards. The outcrops were sporadically encountered on the upper portion of the sub-valley above the proposed cultural preserve area at the far northeastern corner of the project site.

Based on our site reconnaissance, we did not observe overt visible signs of mass slope instability expressed as recent landslide or debris flow scarification deposits within or adjacent to the proposed development area. Some topographic features resembling localized shallow earth slumps were encountered outside of the proposed development area within the soil deposits located adjacent to the steep upland slope area. The old slump scars are re-vegetated and show no visible indication of reactivation or continued creep movement.

Because the project site is within an amphitheater-shaped geomorphic environment, storm water runoff from the steep slopes appears to merge and concentrate within the lower elevation basin area of the proposed development area. Due to the forested upland environment, appreciable forest litter debris including branches, organic matter, soils, and broken rock fragments may be anticipated to shed from the steep upland slopes and drainage chutes during high volume storm runoff. The upslope drainage interception system proposed for the project should consider the interception of storm water potentially laden with entrained debris.

END OF SITE CHARACTERIZATION

SECTION 3. DISCUSSION AND RECOMMENDATIONS

Site reconnaissance, limited subsurface exploration, a review of literature and aerial imagery and a global slope stability analysis was performed to aid in our assessment of the existing geological and geotechnical subsurface conditions at the project site. Our study was conducted with respect to the potential occurrence of natural hazards, such as rockfall, hill slope instability, and debris flow potential. In addition, we performed computer simulation and statistical analysis of potential rockfall activity using the Colorado Rockfall Simulation Program (CRSP) Version 4.

Based on our evaluation of the existing project site conditions with respect to potential natural hazards such as rockfall, slope instability, and debris flow, it is our opinion that the site is suitable for cemetery development and is feasible from a geotechnical point-of-view, provided the preliminary recommendations presented herein are implemented. Once the final grading plans for the project are available and have been reviewed, Geolabs should render an opinion addressing the stability of slopes in the post-development condition.

We explored the subsurface conditions by drilling and sampling two borings, designated as Boring Nos. 1 and 2, extending to depths of about 45 feet below the existing ground surface. The preliminary borings were drilled at accessible locations within the existing Ocean View Garden adjacent to the proposed cemetery expansion area as shown on the Site Plan, Plate 2.

Our field exploration generally encountered stiff to very stiff residual and saprolitic soils consisting of clayey silts with some sand and decomposed gravel extending to about 46.5 feet below the existing ground surface. We did not encounter groundwater in the drilled borings at the time of our field exploration.

Detailed description of the materials encountered in the borings are presented on The Logs of Borings in Appendix A. Results of the laboratory tests performed on selected soil samples retrieved from our field exploration are presented in Appendix B.

Site Photographs are presented in Appendix C, and results of the CRSP analyses are presented in Appendix D.

Detailed discussion of these items and our preliminary geotechnical recommendations for planning and preliminary design are presented in the following sections.

3.1 Potential Rockfall Hazard Conditions

Based on our reconnaissance and observation of the existing geological site conditions, it appears that some mauka portions of the proposed cemetery development area may be exposed to potential falling rock hazards from the adjacent steep mountain slopes. Based on our reconnaissance, Potential Rockfall Source Areas (PRSA) were observed on the upper mountain slopes. The potential rockfall source areas are identified as Potential Rockfall Source Area No. 1 (PRSA-1) and Potential Rockfall Source Area No. 2 (PRSA-2), as shown on the Site Plan (Plate 2).

The greater risk for potential rockfall encroachment involves the sub-valley at the far northeastern portion of the project site where the cultural preservation area is proposed. Based on our reconnaissance, this portion of the project site may have at least a moderate potential for potentially dangerous rockfall activity. The greater risk and hazard is due to the large number and large size of existing boulder deposits encountered on the lower elevation slopes within the proposed cultural preservation area. The existing boulder deposits and their depositional characteristics suggest evidence for significant older rockfall events with deposits that reside within the proposed cultural preservation area.

In addition, there appears to be a more frequent occurrence of widely scattered large-block, high relief, massive rock outcroppings that could represent potential rockfall source material on the higher elevation slopes above the cultural preservation sub-valley. This source is identified as PRSA-1 on the Site Plan (Plate 2). Because the proposed cultural preservation area is intended to remain in a natural condition and will not be developed, we believe rockfall mitigation and protection controls would not be necessary for this preservation portion of the project site. The alignment of the proposed cultural preservation area boundaries with respect to the sub-valley topography aids in the natural containment of rockfall within the boundaries of the preservation area.

Based on our reconnaissance, a generally low to moderate potential for falling rock encroachment was observed at the central portion of the project site encompassing the cemetery development area. The generally lower risk and hazard is due to the reduced number and size of existing rock outcroppings encountered within the PRSA-2 upslope from the central portion of the project site. In addition, the existing rock outcroppings are smaller in size and possess limited relief (height protrusion above the surrounding ground surfaces). Finally, the identified potential rockfall source area appears to have a lower density of rock outcroppings and less extensive reach in terms of outcropping elevation span on the hillside.

Based on our reconnaissance and observation of the existing lower slope boulder deposits and the upper slope potential rockfall source areas, the central portion of the cemetery development appears to be exposed to some potential rockfall encroachment

3.2 Preliminary Rockfall Simulation Analysis

As discussed, a ground-based site reconnaissance was performed to obtain a visual overview of the existing geological site conditions to aid in our evaluation and understanding of the potential rockfall hazards that could affect the project site. Our reconnaissance of the proposed development area and the upland slopes extending beyond the proposed development area included the identification of existing rockfall source and deposition areas and probable falling rock trajectories in support of our computer simulation of potential falling rock conditions. The field information was reviewed and idealized to define the various input data parameters needed to run the CRSP.

The CRSP is a computer program that is a widely accepted engineering tool used to estimate potential rockfall activity by simulating the activity based on input parameters that are assigned on a site-specific basis. The input parameters for this project were assigned based on the available topographic information, our observations and measurements collected in the field. The program output provides a statistical evaluation of potential rockfall activity based on the hill slope profile and other input parameters such as rock size, shape, and numerical coefficients used to characterize the typical ground surface conditions. The CRSP output includes the predicted falling rock velocity, bouncing height, kinetic energy, and natural roll-out distance. The output information is useful to assist in the statistical evaluation of the probable level of risk for a defined location and to support the site-specific design of various rockfall mitigation systems, such as rock catchment ditches and rockfall impact barriers.

Topographic information was obtained from the available project topographic map, which is based on regional Geographic Information System (GIS) topographic information. The available map uses a 5-foot elevation contour interval and covers the slopes within and beyond the proposed project development area.

Five (5) idealized slope model profiles were developed to support our preliminary CRSP analysis for the project (idealized Slope Profiles “A” through “E”). The selected slope profiles extend from the ridgeline summit down through the project development boundary and into the project site interior. The profile locations were selected to ideally represent the existing slope conditions where potential rockfall encroachment is suspected based on site reconnaissance. The CRSP was run using the five selected profiles to evaluate the statistical probability for potential rockfall encroachment at the upslope development boundary of the project site.

Rockfall mitigation efforts typically are recommended at locations where the statistical probability of rockfall encroachment at the upslope development boundary calculated by CRSP is greater than 10 percent of total simulated rockfall passing a given Analysis Point (AP) specified along the slope profile. In this case, the analysis points are set at the upslope development boundary to evaluate the potential passage of falling rock into the project site from the natural hillside above. The CRSP also is used to statistically analyze and interpret locations where rockfall encroachment is not anticipated. By pairing the site reconnaissance observations with the results of the computer rockfall simulation, the simulation model can be adjusted such that the model output best supports what is actually observed in the field.

Our rockfall protection criterion is defined as the probable interception and catchment of 90 percent of probable rockfall hazards assessed by the computer rockfall simulation analysis (CRSP). Similarly, it should be noted that if statistical rockfall encroachment is shown by CRSP to be 10 percent or less for simulated rockfall passing a given model Analysis Point (AP), a hazardous rockfall condition is considered a remote risk and rockfall protections may not be warranted, unless direct field observation or other information supports a higher probability of encroachment.

The 90 percent rock catchment criteria is a target that is commonly used in engineering practice for evaluation criteria that can be quantified by a statistical and probability analysis using model data for natural occurrences such as rockfall activity. Because the analyses are based on statistics and probability, a 100 percent criterion is impractical to achieve.

Our CRSP analysis was performed using cylindrical-shaped basaltic boulders measuring 3 and 5 feet in larger dimension randomly released from the identified source area(s) on the slope. The boulder size and shape used for rockfall simulation was selected based on the typical dimension and shape of boulders observed in the rock deposits encountered on the lower flanking slopes of the project site. For each simulation run, 1,000 source rocks were released to develop a wide statistical distribution of the results. Numerical input coefficients were selected to approximate the typical condition of the existing ground surfaces and vegetation density based on our field observations. Model sensitivity and calibration analysis were conducted by varying the model input parameters to correlate the modeled boulder deposition with actual boulder deposits observed in the field. The following subsections present the results for the various areas assessed from our CRSP analysis.

3.2.1 Cultural Preservation Area

Based on our CRSP analysis, a potential rockfall encroachment condition, representing at least a moderate potential hazard, encompasses the lower elevation basin slopes within a portion of the proposed cultural preservation area and the adjacent steeper mountain up slopes.

Our rockfall simulation conducted for Slope Profile “E” indicates that under the existing natural site condition, approximately 86 percent of simulated rockfall involving boulders of 3 and 5 feet in dimension could pass the upslope boundary of the proposed cultural preservation area (at Elevation +450 feet MSL, Analysis Point No. 1). Evaluation of a second slope analysis point (at Elevation +386 feet MSL, Analysis Point No. 2) indicates that no simulated rockfall passes the lower elevation analysis point.

Thus, the model indicates that the simulated falling rock that passes the Analysis Point No. 1 comes to rest in the zone between the two analysis points on the slope. Because the cultural preservation area will remain undeveloped in a natural site condition, rockfall mitigation should not be required for this portion of the project site. However, it is recommended that rockfall hazard warning signage be posted at appropriate entry locations to the cultural preservation area to alert the public of the potential for falling rock hazards in the mauka portion of the preservation area.

3.2.2 Central Cemetery Expansion Area

Based on our CRSP analysis, a potential rockfall encroachment condition, representing a generally low to moderate potential hazard, encompasses the steep mountain up slopes and the lower elevation basin slopes at the central portion of the cemetery expansion area.

Our rockfall simulation conducted for Slope Profile “A” indicates that under the existing natural site condition, approximately 64 to 66 percent of simulated rockfall involving boulders 3 and 5 feet in dimension could pass the upslope boundary of the cemetery expansion area (at Elevation +316 feet MSL, Analysis Point No. 1).

The simulated rockfall passing the analysis point may be reduced to 10 percent of simulated rocks passing the boundary by constructing a catchment ditch along the upslope boundary of the cemetery expansion area as shown on the Site Plan (Plate 2).

3.2.3 Remaining Cemetery Expansion Area

Based on our CRSP analysis, there is limited potential for rockfall encroachment along the remainder of the upper cemetery expansion boundary. Our rockfall simulation analysis involving the idealized Slope Profiles “B”, “C” and “D” indicate a probability of 10 percent or less for simulated rockfall involving boulders 3 and 5 feet in dimension to pass into cemetery expansion boundary.

Our rockfall simulation conducted for Slope Profiles “B” and “C” indicates that no simulated rockfall passes the analysis point set at the upslope cemetery boundary. Our rockfall simulation conducted for Slope Profile “D” indicates that approximately 8 to 9 percent of simulated rockfall involving boulders 3 and 5 feet in dimension could pass the upslope boundary of the cemetery expansion area (between Elevation +373 and +401 feet MSL, Analysis Point No. 1).

Considering the generally accepted engineering criteria for requiring rockfall mitigation action (greater than 10 percent probability of simulated rockfall passing an analysis point), rockfall mitigation controls should not be required for the remaining length of upslope boundary of the cemetery expansion area.

3.3 Landslide & Debris Flow Hazard

Based on our site reconnaissance, a number of converging drainages emanate from the adjacent upland slopes and pass through the project site. We believe the drainages could be capable of transmitting appreciable storm water runoff conditions. A rapid increase in discharge during storm conditions (flash-flood conditions) should be anticipated in the normally dry drainage channels. A surface drainage interception system consisting of an interceptor ditch network with appropriate debris barriers and discharge outlets is recommended to reduce the potential for storm water runoff encroachment along the upper boundary of the development.

No record or documentation of previous debris flow or landslide activity at the project site is known and we observed no overt visible evidence of significant debris flow deposits or evidence of recent ground scour. However, the potential for transmission of debris laden storm water runoff from the adjacent slopes should be considered due to the large area of steep forested slopes that harbor appreciable forest litter debris on the ground surfaces.

In addition, local areas of exposed soil and gravel/cobble talus were encountered at the ground surface within the steep upland drainage chutes adjacent to the proposed development. These loose alluvial/colluvial deposits have some potential to be scoured and entrained in heavy storm water runoff on the upper mountain slopes. Based on our observations, it appears that the existing natural flatter ground topography at the foot of the steep terrain combined with the existing dense vegetation growth could provide some natural buffer and reduce the risk for debris laden runoff to reach the drainage interception system at the upslope development boundary.

3.4 Recommended Phase I Conceptual Rockfall Mitigation Plan

Based on our assessment of the potential rockfall hazard conditions including a review of possible mitigation alternatives, we recommend constructing approximately 1,000-linear feet of concrete lined rockfall catchment ditch along a portion of the upslope cemetery development boundary as shown on the Site Plan (Plate 2). Based on our CRSP analysis, a 5-foot deep “V” shaped concrete lined catchment ditch was found to be effective at containing the simulated falling rock and reducing the potential for rockfall encroachment to an acceptable level.

We anticipate the proposed ditch could be designed to perform double duty both as a rock catchment and drainage interception structure along the upslope cemetery development boundary. To reduce the potential for introduction of potential large quantities of organic debris including branches and other debris from the adjacent forest area, we recommend installing chain link fencing along and upslope from the catchment ditch to aid in reducing the amount of debris that could accumulate in the ditch and potentially reduce the rock catchment capacity.

If possible, we also recommend creating a vegetation free clear zone on the order of about 10 feet in width upslope from the ditch and encompassing the chain link debris barrier fence. Despite these additional remedial measures, we do anticipate the need for periodic inspection of the rock catchment ditch with possible periodic clearing of accumulated debris to maintain the intended rock catchment capacity. A conceptual schematic of the recommended rock catchment ditch is presented on Plate 4.

Based on our evaluation and analyses, our professional opinion is that the recommended rockfall catchment ditch should significantly reduce the potential for dangerous rockfall activity to affect the cemetery expansion development at Hawaiian Memorial Park Cemetery project site. However, it must be stated that there are no guarantees in the professional engineering design fields with respect to protection from potential rockfall hazards. Construction of a rockfall catchment ditch as described in the conceptual-level context of this report should provide a high level of safety against rockfall hazard based on past applications of similar mitigation methods.

To address the potential rockfall hazard within the mauka portion of the proposed cultural preservation area, we recommend posting rockfall hazard warning signage at appropriate entry locations to the cultural preservation area to alert the public of the potential for falling rock hazards in the mauka portion of the preservation area.

3.5 Other Rockfall Mitigation Alternatives

Another possible alternative could consist of creating a development setback (buffer zone) on the order of about 100 to 200 feet in width starting from the present upslope development boundary and extending makai in the down slope direction. The setback (avoidance mitigation alternative) could allow for natural rockfall energy dissipation and deposition within a designated no development buffer zone. We understand this alternative may not be viable due to the unavailability of additional open space to create such a rockfall buffer zone.

Finally, if a setback or catchment ditch is not a viable alternative, a specialized rockfall impact barrier constructed across the slope and within the development boundary could be used to provide a high level of rockfall protection. A disadvantage of this alternative is that the barrier fence alignment must traverse generally on-contour across the slope and deflections in the barrier alignment must be minimized and consist of very gradual alignment deflections.

Another disadvantage is that a significant number of wire rope ground anchors will be needed along the upslope side of the barrier and along the down slope side of the barrier where alignment deflections must be accommodated. Thus, the footprint of a typical rockfall impact barrier structure including the supporting anchors ground anchors on the slope may range up to about 30 to 40 feet in width across the slope. It also should be noted that the steel rockfall impact barrier will require routine inspection and maintenance and ultimately replacement of the entire system or primary components (nets, support posts, support cables and ground anchors) due to age and environmental corrosion at approximately 20 to 40-year intervals.

3.6 Site Grading

As discussed above, substantial earth moving and grading may be necessary to develop the site under the current development plan. In general, the current grading plan consists of major cuts at the west side of the development area and filling at the east side of the development area. The preliminary grading plan indicates cuts generally ranging from about 10 to 75 feet deep and fills generally ranging from about 10 to 30 feet thick.

The project site is located in a high rainfall environment throughout the year; therefore, the in-situ soils will constantly be in a very moist to wet condition. Due to the relatively high moisture contents anticipated in the subsoils at the site, substantial aeration of the high moisture soils is essential to achieve a 90 percent relative compaction normally required. This field method of reducing the moisture content in the soil may not be feasible at all times due to the high rainfall frequency experienced at the project site.

As a result, the compaction requirements for general fill placement will have to be reduced in order to aid in the earthwork construction using the high moisture tropical soils in this wet environment. Based on our experience with similar high moisture tropical soils, we believe a reduced compaction requirement of 85 percent relative compaction may be used to facilitate placement of fills and to reduce the potential of inducing pumping conditions. The following grading items are addressed in the succeeding subsections:

1. Site Preparation
2. Fills and Backfills
3. Fill Placement and Compaction Requirements – Soil
4. Fill Placement and Compaction Requirements – Rock Fill
5. Boulder Fill Placement
6. Excavations
7. Cut and Fill Slopes
8. Subdrains

A Geolabs representative should monitor site grading operations to observe whether undesirable materials are encountered during the site preparation and excavation, and to confirm whether the exposed soil conditions are similar to those assumed herein.

3.6.1 Site Preparation

At the on-set of earthwork, the area within the contract grading limits should be cleared and grubbed thoroughly. Vegetation, debris, deleterious materials, and other unsuitable materials should be removed and disposed of properly off-site or in a designated area to reduce the potential for contamination of the excavated materials. Due to the relatively large acreage of the site, it is anticipated that the clearing and grubbing work may need to be performed incrementally. Care should be exercised during the clearing and grubbing operations to avoid contaminating previously cleared and/or filled areas with unsuitable materials, such as organic matter and/or soft soils.

Soft and yielding areas encountered during clearing and grubbing below areas designated to receive fill and/or future improvements should be over-excavated to expose firm material, and the resulting excavation should be backfilled with well-compacted fill. The excavated soft soils should not be re-used as fill materials and should be properly disposed of off-site or in landscaped areas, if appropriate. Special attention should be given to the potential presence of soft and/or loose soils along the bottom of gullies where deep fills are planned. Contract documents should include additive and deductive unit prices for over-excavation and compacted fill placement to account for variations in the over-excavation quantities.

After clearing and grubbing, areas to receive fills and finished subgrades in cut areas should be scarified to a depth of 8 inches, moisture-conditioned to at least 2 percent above the optimum moisture content, and compacted to a minimum of 85 percent relative compaction.

Where shrinkage cracks are observed after the subgrade compaction, we recommend preparing the subgrade soil again as recommended above. Saturation and subsequent yielding of the exposed subgrade due to inclement weather and poor drainage may require over-excavating the soft areas and replacing these areas with engineered fill. A Geolabs field representative should evaluate the need for over-excavation due to soft subgrade soil conditions.

3.6.2 Fills and Backfills

Generally, we anticipate the earthwork will involve four main types of materials: wet onsite soils; excavated basalt rock materials; boulder fills; and, imported fill materials. In general, the on-site soils may be re-used as a source of general fill material, provided they are free of vegetation, deleterious materials, and rock fragments greater than 12 inches in maximum dimension. Fill materials within the upper 6 feet of finished grades should contain rock fragments no greater than 6 inches in maximum dimension. It should be noted that the project site is situated in a high rainfall environment throughout the year; therefore, the in-situ soils will constantly be in a very moist to wet condition and drying or aerating the excavated materials may be necessary prior to their use as general fill.

In general, excavated rock materials less than 12 inches in size may be used as general fill material. These rock materials may need to be processed and crushed to a relatively well-graded granular material with an average size of about 6 inches and a maximum size of 12 inches. In addition, excavated rock materials and boulders less than 2 feet in size may be used as fill material provided that their usage does not complicate trenching operations and that the placement procedures outlined in the “Boulder Fill Placement” subsection presented herein are followed. It should be noted that the grading contractor must have sufficient heavy equipment to effectively compact the fill materials with larger particle sizes. In addition, fill materials containing rock fragments greater than 12 inches in maximum size should be placed a minimum of 6 feet below finished subgrades.

Imported fill materials should consist of non-expansive, select granular materials such as crushed basalt or coral. Select granular fill should be well-graded from coarse to fine with particles no larger than 3 inches in largest dimension and should contain between 10 and 30 percent particles passing the No. 200 sieve. The material should have a laboratory CBR value of 20 or more and should have a maximum swell of less than 1 percent when tested in accordance with ASTM D1883.

3.6.3 Fill Placement and Compaction Requirements – Soil

As mentioned above, the project site is situated in a high rainfall environment throughout the year; therefore, the in-situ soils will constantly be in a very moist to wet condition. Due to the relatively high moisture contents anticipated in the subsoils at the site, substantial aeration of the high moisture soils is essential to achieve a 90 percent relative compaction normally required. This field method of reducing the moisture content in the soil may not be feasible at all times due to the high rainfall frequency experienced at the project site. As a result, the compaction requirements for general fill placement will have to be reduced in order to aid in the earthwork construction using the high moisture tropical soils in this wet environment. Based on our experience with similar high moisture tropical soils, we believe that a reduced compaction requirement of 85 percent relative compaction may be used to facilitate placement of fills and to reduce the potential of inducing pumping conditions.

General fills and backfills consisting of the on-site soils with high in-situ moisture contents should be moisture-conditioned to about 2 percent above the optimum moisture, placed in level lifts not exceeding 8 inches in loose thickness, and compacted to at least 85 percent relative compaction. The non-expansive select granular fill materials should be placed in level lifts of about 8 inches in loose thickness, moisture-conditioned to above the optimum moisture, and compacted to at least 90 percent relative compaction.

Relative compaction refers to the in-place dry density of soil expressed as a percentage of the maximum dry density as determined by ASTM D1557. Optimum moisture is the water content (percentage by dry weight) corresponding to the maximum dry density. Compaction of fill materials should be accomplished by sheepsfoot rollers, vibratory rollers, or other types of acceptable compaction equipment. Water tamping, jetting, or ponding should not be allowed to compact the fills.

Compaction should be accomplished by sheepsfoot rollers, vibratory rollers, or other types of acceptable compaction equipment. Water tamping, jetting, or ponding should not be allowed to compact the fills. Where compaction is less than required, additional compactive effort should be applied with adjustment of moisture content as necessary, to obtain the specified compaction. It should be noted that excessive vibrations from compaction equipment may soften the on-site soils with high in-situ moisture contents; therefore, vibrations should be carefully controlled during compaction efforts.

3.6.4 Fill Placement and Compaction Requirements – Rock Fill

In general, excavated rock materials and boulders stockpiled on the site less than 12 inches in size may be used as fill material. These rock materials may need to be processed and crushed to a relatively well-graded granular material with an average size of about 6 inches and a maximum size of about 12 inches.

These excavated rock materials should be moisture-conditioned to above the optimum moisture, placed in level lifts not exceeding 12 inches in loose thickness, and compacted to at least 90 percent relative compaction. Compaction equipment (such as a Caterpillar 825 sheepsfoot roller, D-9 bulldozer, or similar heavy compaction equipment) providing suitable energy to achieve the required compaction should be utilized to compact the rock fill.

Conventional compaction testing may not be practicable in rock fills containing a significant amount of cobbles and boulders less than 12 inches in size. Instead, a testing program to determine the number of passes of a compactor needed to achieve the desired level of compaction should be conducted at the start of the grading phase of the project. The number of passes to be made to achieve proper compaction should be determined at the on-set of site grading by the performance of a trial compaction test section. On the basis of this testing program, the number of passes may then be used as the field criterion for adequate compaction.

3.6.5 Boulder Fill Placement

Boulders (i.e., rock fragments larger than 12 inches in maximum size but less than 2 feet in largest dimension) may be used as fill, provided that the following preliminary recommendations are followed:

1. Boulders less than 2 feet in largest dimension may be utilized as fill, provided that the top of the boulder fill layer is placed at least 6 feet below the finished subgrades. Boulders larger than 2 feet in maximum dimension should not be used as fill unless reduced in size.

2. Boulders should not be utilized within 8 feet from slope faces.

3. Boulders may be placed in a lift of about 2 feet in thickness. The maximum lift thickness is determined by the maximum size of the material (i.e., 12-inch lift thickness for 12-inch maximum boulder size).

4. Boulders should be spread and compacted with a Caterpillar D-9 bulldozer (or larger) and sheepsfoot rollers, such as a Caterpillar 825 or equivalent, for a minimum of six to eight passes to facilitate “seating” of the boulders. The boulder fill should be watered heavily by water trucks traversing in front of the current boulder lift face and sprayed with water continuously during placement.

5. A minimum 18-inch thick choking layer should be spread on the top of the boulder fill layer and worked into the voids with a large bulldozer or other heavy compaction equipment to seal off the voids of the boulder fill. The choking layer should consist of well-graded granular fill materials with particle size of 6 inches or less in dimension. The choking layer of well-graded granular fill should be watered heavily during placement and compaction.

6. Care must be exercised to avoid placement of boulders within the depths of the planned utility lines (or future excavations) to reduce the potential for encountering the boulders during utility trench excavation.

7. The lateral extent and elevations of the top of the boulder fill should be surveyed for future reference.

It should be noted that the use of boulders as fills will require that the entire boulder fill mass be compacted and properly “choked-off” at the surface (and each layer of boulder fill) to reduce the potential for migration of fines through the voids between boulders. Therefore, it is imperative that a Geolabs’ representative observe the placement and compaction of the boulder fill mass to confirm whether the intent of our recommendations is implemented in the field.

3.6.6 Excavations

Based on the preliminary grading plan provided and our field exploration, we anticipate excavations for the project may encounter stiff to hard residual and saprolitic soils and the underlying basalt rock formation. In addition, some of the excavations may encounter boulders, clusters of cobbles, and hard basalt rock formation. It is anticipated that most of the materials may be excavated with normal heavy excavation equipment. However, deep excavations, boulder excavations, and excavations into the underlying basalt rock formation may require the use of hoerams.

The above discussions regarding the rippability of the subsurface materials are based on field data from the borings drilled at the site and our experience in the project vicinity. Contractors should be encouraged to examine the site conditions and the subsurface data to make their own reasonable and prudent interpretation.

3.6.7 Cut and Fill Slopes

We envision that cut slopes at the project site generally will expose stiff to hard residual and saprolitic soils encountered in the drilled borings and/or the anticipated basalt rock formation underlying the project site. In general, we believe cut slopes of the on-site soils may be designed with a slope inclination of 2H:1V or flatter and cut slopes into the basalt formation may be cut at an inclination of 1.5H:1V or flatter.

Fill slopes should be designed with a slope inclination of 2H:1V or flatter. Slope benches are recommended at maximum 30-foot vertical height intervals. Fills placed on slopes steeper than 5H:1V should be keyed and benched into the existing slope to provide stability of the new fill embankment against sliding. The filling operations should start at the lowest point and continue up in level horizontal compacted layers in accordance with the above general fill placement recommendations.

At the toe of large fill segments, a keyway should be constructed with the fill materials to a minimum depth of 2 to 4 feet below the toe of the proposed fill slope and extending a minimum of 15 feet into the new fill slope. The floor of the key should be sloped back under the base of the fill at an inclination of about 10H:1V to bond the new fill into the existing slope.

Fill slopes should be constructed by overfilling and cutting back to the design slope ratio to obtain a well-compacted slope face. Surface water should be diverted away from the tops of slopes, and slope planting should be provided as soon as possible to reduce the potential for erosion of the finished slopes.

3.6.8 Subdrains

Considering the climate and topography of the area, seepage conditions may be present in localized areas at the site. The accumulation of water along the base of the fill could adversely affect the performance of the fill. Therefore, we recommend installing subdrains in the base of the fills to drain at the toe. In general, the subdrains should follow the existing drainage paths on the site.

In general, subdrains should consist of 4-inch or larger diameter perforated pipes with perforations facing down. Subdrains should be surrounded and underlain by at least 6 inches of drainage material, such as No. 3B Fine gravel (ASTM C33, No. 67 gradation) or equivalent. A non-woven filter fabric, such as Mirafi 180N or equivalent, should wrap around the drainage material.

3.7 Ground Settlement

Ground settlements are anticipated when new fills are placed over the existing ground to raise the site to the proposed finished elevations. These settlements will affect the construction schedule and the earthwork quantity estimates for the project. Based on the results of our exploration, the anticipated ground settlements are primarily the result of the following two processes:

- Compression of the fill material under its own weight, especially since the fill materials are placed at a lower degree of compaction; and
- Consolidation of the in-situ soils induced by the new fill loads, especially where new fills are placed over soft and/or loose materials along the bottom of gullies.

Based on our engineering analyses, we estimate settlements on the order of about 10 to 15 inches may occur for new fills up to 30 feet in thickness. Significant ground settlements may occur when new fills are placed over soft ground conditions. Therefore, soft and/or loose soils encountered below fill areas should be removed as much as practicable prior to the placement of the new fills. Because of the ground settlements resulting from the compression of the fill materials and potential consolidation of the existing subsoils, it is our opinion that the planned embankments should be over-filled by the appropriate amount and the finish subgrades should be adjusted during construction to account for the anticipated fill ground settlements. It should be noted that some of the estimated ground settlements would occur as the fill loads are applied during the earthwork operations.

As previously indicated, it should be expected that the fill material would settle under its own weight due to the reduced compaction criteria for fill placement. In order to reduce the effects of the anticipated settlements on the planned structures and other improvements constructed on fills, a settlement waiting period should be implemented after placement of the fills and prior to construction of improvements on the fills. The settlement waiting period may be on the order of about 4 to 8 months depending on the fill thickness.

It should be recognized that it is difficult to accurately predict the exact time required for the filled ground to settle, since the settlement rates will be affected by variations in the properties and thickness of the compressible subsoil structure, and the history of the subsoil deposition. Therefore, the actual settlement rates should be monitored with a settlement monitoring program established during fill construction to evaluate the magnitude and rate of the estimated settlements prior to the construction of structures and other improvements on the fills. In addition, provisions should be made for potential delays in the construction schedule if a longer settlement period is required.

To monitor the actual settlement rate, we recommend installing settlement gauges in areas where fills are planned. The actual number and location of the settlement gauges should be evaluated by our office prior to installation at the project site. The gauges should be read optically by a qualified professional surveyor, and the readings should be transmitted for review in a timely manner. Two readings should be taken (minimum 24 hours apart) for each settlement gauge 10 days prior to site filling to establish a baseline. Subsequent readings of the settlement gauges should be taken on a weekly basis for the entire settlement waiting period until the cessation of the settlement process.

END OF SITE CHARACTERIZATION

SECTION 4. LIMITATIONS

The findings and preliminary recommendations submitted herein are based, in part, upon information obtained from visual site observations, limited test borings and computer simulation and statistical analysis of potential rockfall behavior only. Variation in the surface and subsurface conditions between our observations and analysis points may occur, and the nature and extent of these variations may not become evident until additional field exploration or construction is underway. If variations then appear evident, it will be necessary to re-evaluate the findings and preliminary recommendations provided herein.

It should be noted that slopes composed of rock materials (rock slopes) deteriorate with the passage of time due to natural weathering processes, wet-dry and hot-cold cycles, and erosion conditions. Due to the inherent deterioration of rock slopes resulting from natural processes (weathering, wet-dry and hot-cold cycles, and erosion conditions), the potential for rockfall hazard at any site changes with the passage of time. Therefore, the findings and preliminary recommendations contained herein may be used only within two years from the date of issuance of the final report. Land use, site conditions, and/or other factors may change with the passage of time. Therefore, additional work to evaluate the applicability of the findings and preliminary recommendations contained in this report due to changes with the passage of time will be required. Finally, there are no guarantees in the professional engineering and architectural design fields with respect to potential rockfall hazards due in large part to the unpredictable nature of rockfall activity, which is affected by many external variables including natural and man-induced causes.

This report has been prepared for the exclusive use of HHF Planners and their consultants for specific application to the Phase I Potential Rockfall and Slope Hazard Assessment in accordance with generally accepted geotechnical engineering principles and practices. No warranty is expressed or implied. Any party other than the client who wishes to use this report shall notify Geolabs, Inc. in writing of their intended use.

This report has been prepared solely for the purpose of evaluating and assisting the client/owner in the understanding of potential rockfall and slope hazards located within the project study area. Therefore, this report may not contain sufficient data, or the proper information, to serve as the basis for construction cost estimates. A contractor wishing to bid on this project is urged to retain a competent geotechnical engineer to assist in the interpretation of this report and/or in the performance of additional site-specific exploration for bid estimating purposes.

The owner/client should be aware that unanticipated surface and subsurface conditions are commonly encountered. Unforeseen conditions, such as surface rock outcroppings, archeological features, terrain irregularities, perched groundwater, soft deposits, hard layers or loose fills, may occur in localized areas and may require additional exploration or corrections in the field (which may result in construction delays) to attain a properly constructed project. Therefore, a sufficient contingency fund is recommended to accommodate these possible extra costs.

END OF LIMITATIONS

CLOSURE

The following plates and appendices are attached and complete this report:

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Respectfully submitted,

GEOLABS, INC.

DRAFT

By ____________________________
Robin M. Lim, P.E.
President

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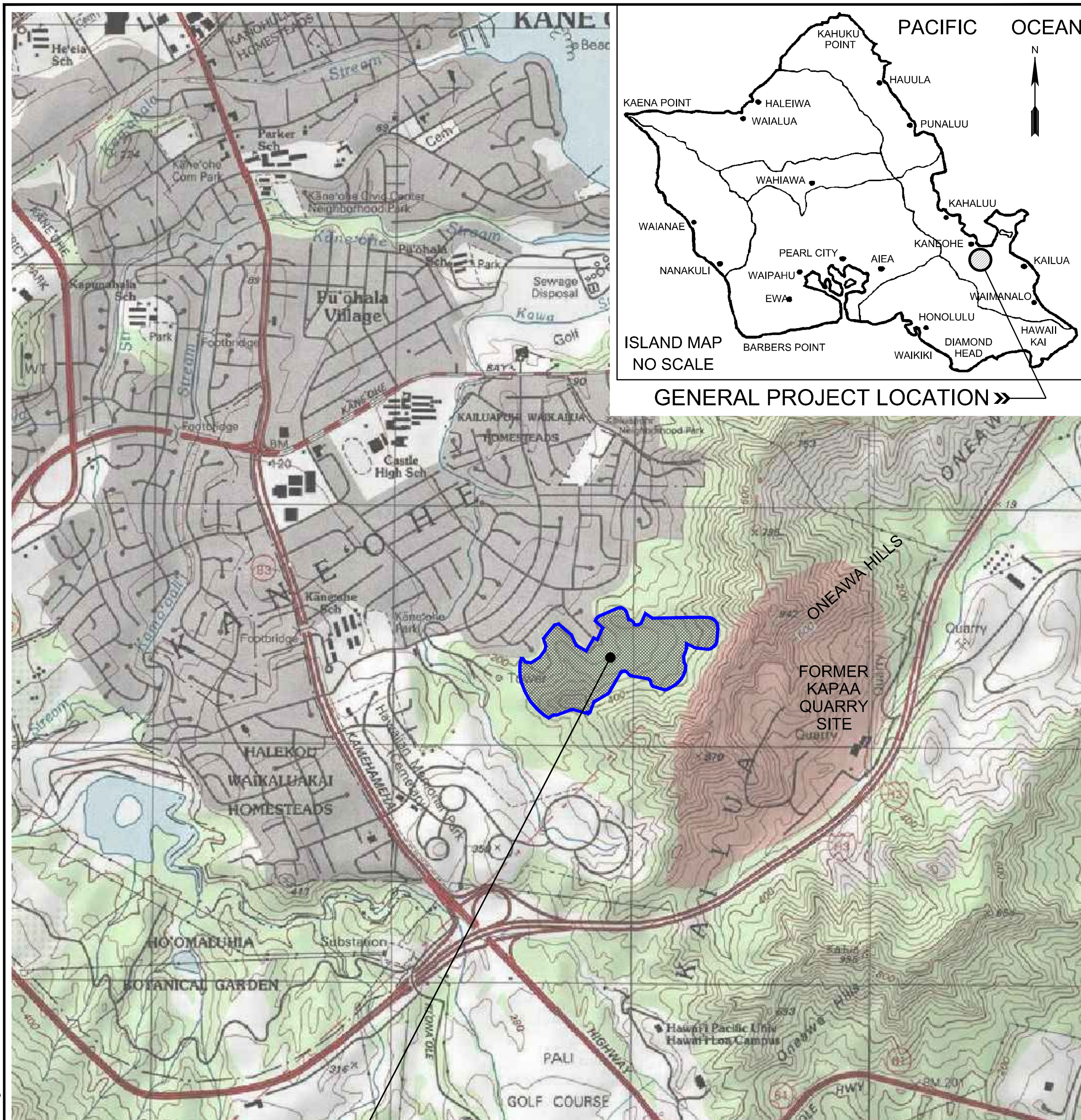
PLATES



PROJECT LOCATION »

PROJECT LOCATION MAP

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

N

2000 1000 0 2000 FT.

GRAPHIC SCALE

REFERENCE: MAP CREATED WITH TOPO!® ©2010 NATIONAL GEOGRAPHIC; ©2007 TELE ATLAS, REL. 1/2007.

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
NOVEMBER 2017	HYC	
SCALE	W.O.	1
1" = 2,000'	7604-00	

CAD User: HENRY File Last Updated: November 30, 2017 11:43:08am Plot Date: December 01, 2017 - 9:26:41am
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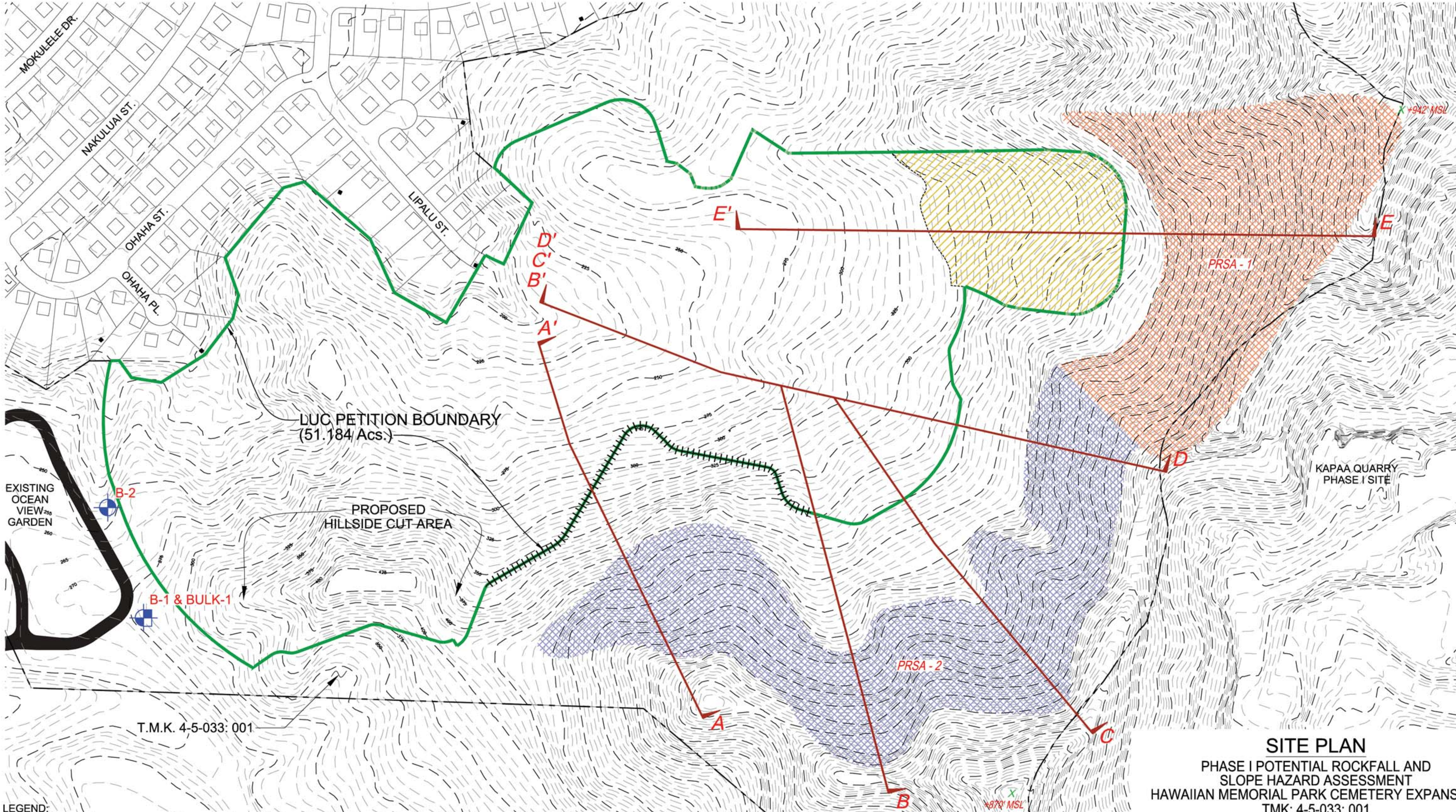
Plotter: DWG To PDF-GEO.pc3 Plotstyle: GEO-No-Dithering-Blue-Boring.ctb



LEGEND:

- APPROXIMATE BORING LOCATION
- APPROXIMATE BULK SAMPLE LOCATION
- IDEALIZED SLOPE PROFILE FOR ROCKFALL SIMULATION
- BOULDER DEPOSITION AREA (BASIN AREA SLOPES CONTAINING SCATTERED LARGE BOULDER BLOCKS AND SOME COBBLE/BOULDER TALUS)
- PRSA-1 APPROXIMATE POTENTIAL ROCKFALL SOURCE AREA WITH GREATER HAZARD POTENTIAL
- PRSA-2 APPROXIMATE POTENTIAL ROCKFALL SOURCE AREA WITH LESSER HAZARD POTENTIAL
- APPROXIMATE LOCATION OF PROPOSED ROCK CATCHMENT DITCH
- x APPROXIMATE SUMMIT LOCATION

REFERENCE: TOPOGRAPHIC BASE MAP TRANSMITTED BY SAM O. HIROTA, INC. ON OCTOBER 17, 2017.

0 125 250 500 750 FT.

GRAPHIC SCALE

SITE PLAN

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
DECEMBER 2017	HYC	
SCALE	W.O.	
1" = 250'	7604-00	2

CAD User: HENRY File Last Updated: December 21, 2017 11:28:52am Plot Date: December 21, 2017 - 11:44:03am
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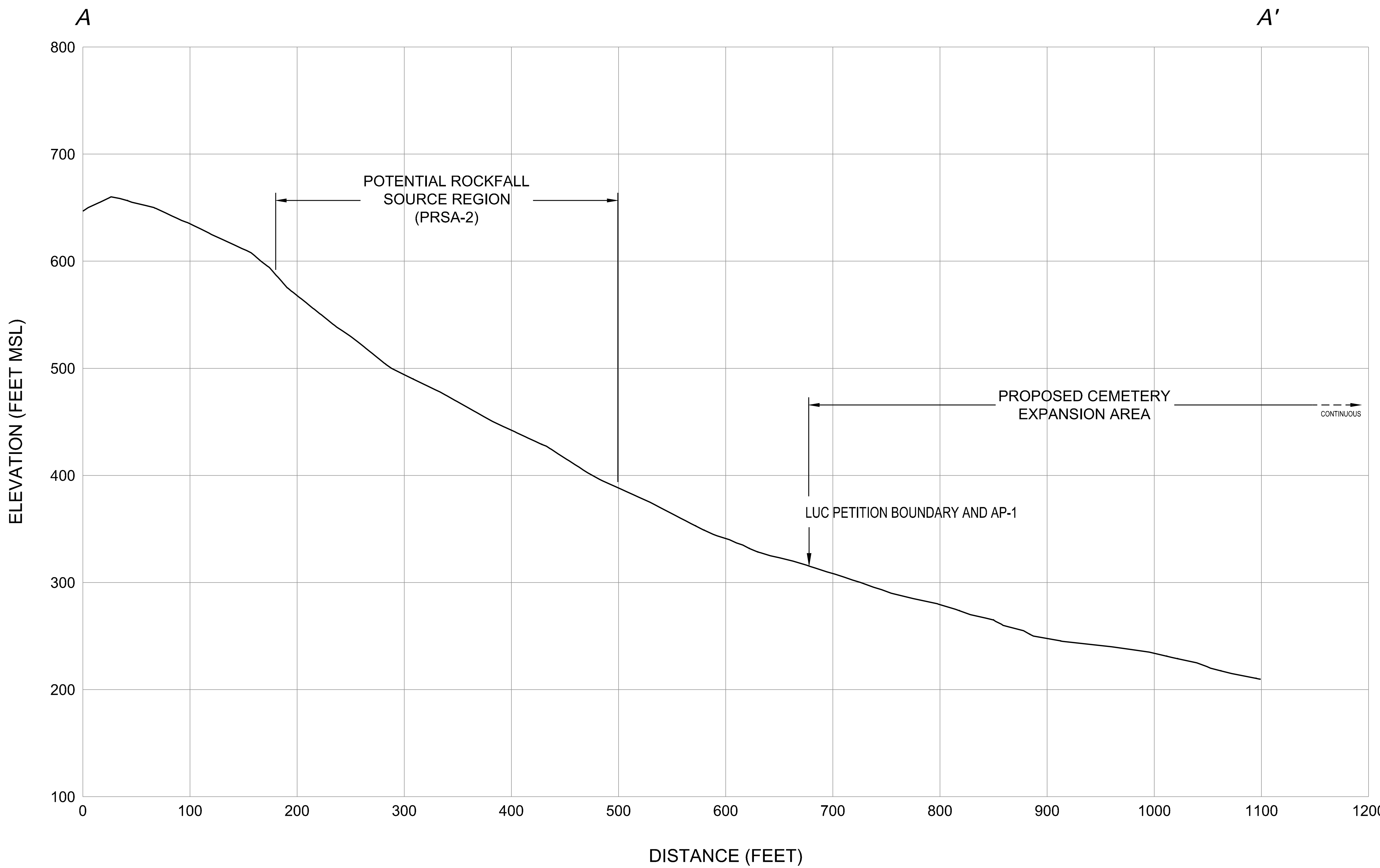


LEGEND:

AP-1 ANALYSIS POINT FOR COMPUTER ROCKFALL SIMULATION

0 50 100 200 300 FT.

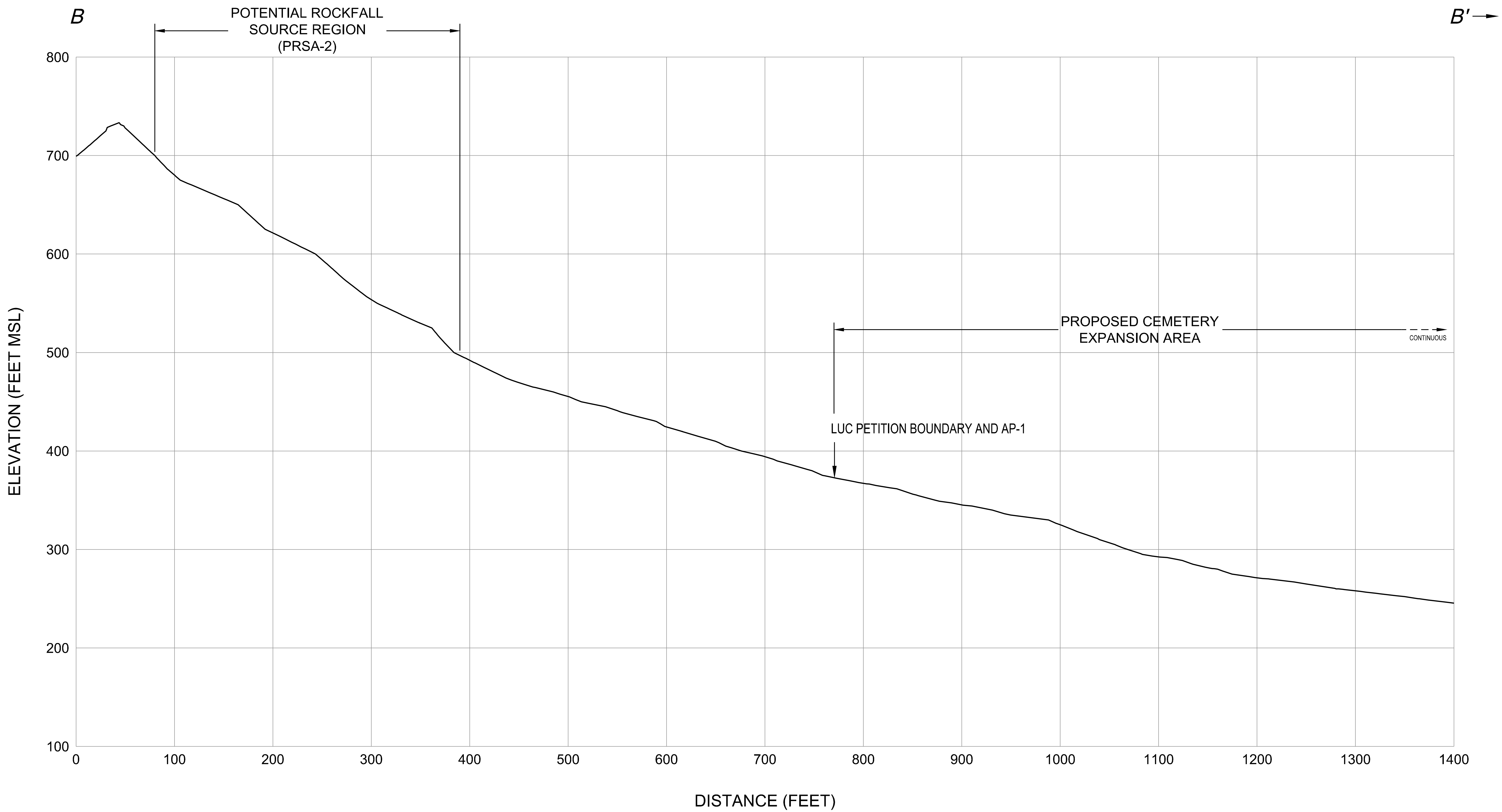
GRAPHIC SCALE

SLOPE PROFILE A-A'

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
DECEMBER 2017	HYC	
SCALE	W.O.	
1" = 100'	7604-00	3.1



LEGEND:

AP-1 ANALYSIS POINT FOR COMPUTER ROCKFALL SIMULATION

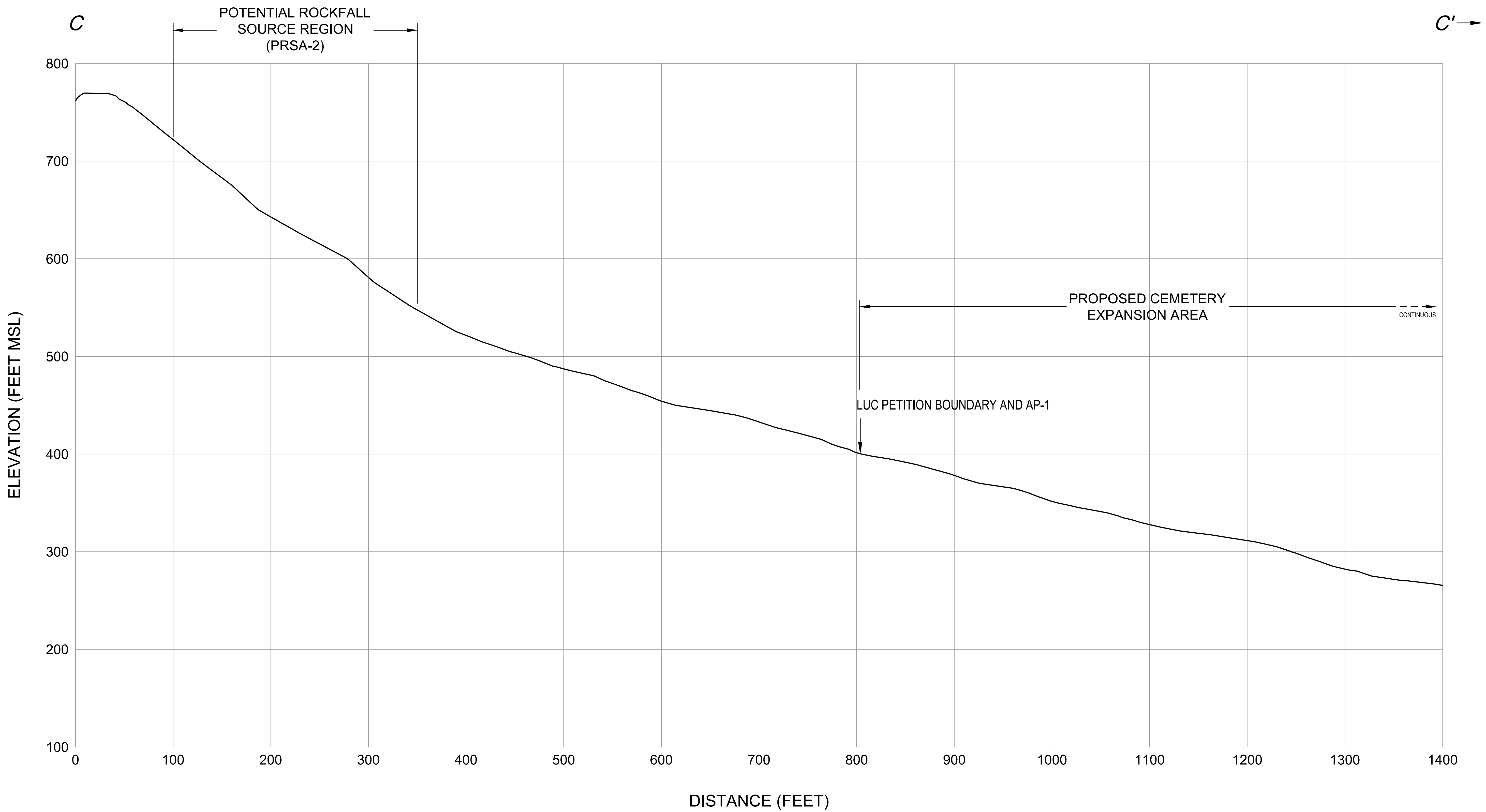
0 50 100 200 300 FT.

GRAPHIC SCALE

SLOPE PROFILE B-B'

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

GEOLABS, INC. *Geotechnical Engineering*		
DATE: DECEMBER 2017	DRAWN BY: HYC	PLATE
SCALE: 1" = 100'	W.O.: 7604-00	3.2



LEGEND:

AP-1 ANALYSIS POINT FOR COMPUTER ROCKFALL SIMULATION

0 50 100 200 300 FT.

GRAPHIC SCALE

SLOPE PROFILE C-C'

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

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DATE	DRAWN BY	PLATE
DECEMBER 2017	HYC	
SCALE	W.O.	
1" = 100'	7604-00	3.3

CAD User: HENRY File Last Updated: January 03, 2018 5:24:31pm Plot Date: January 04, 2018 - 10:26:12am
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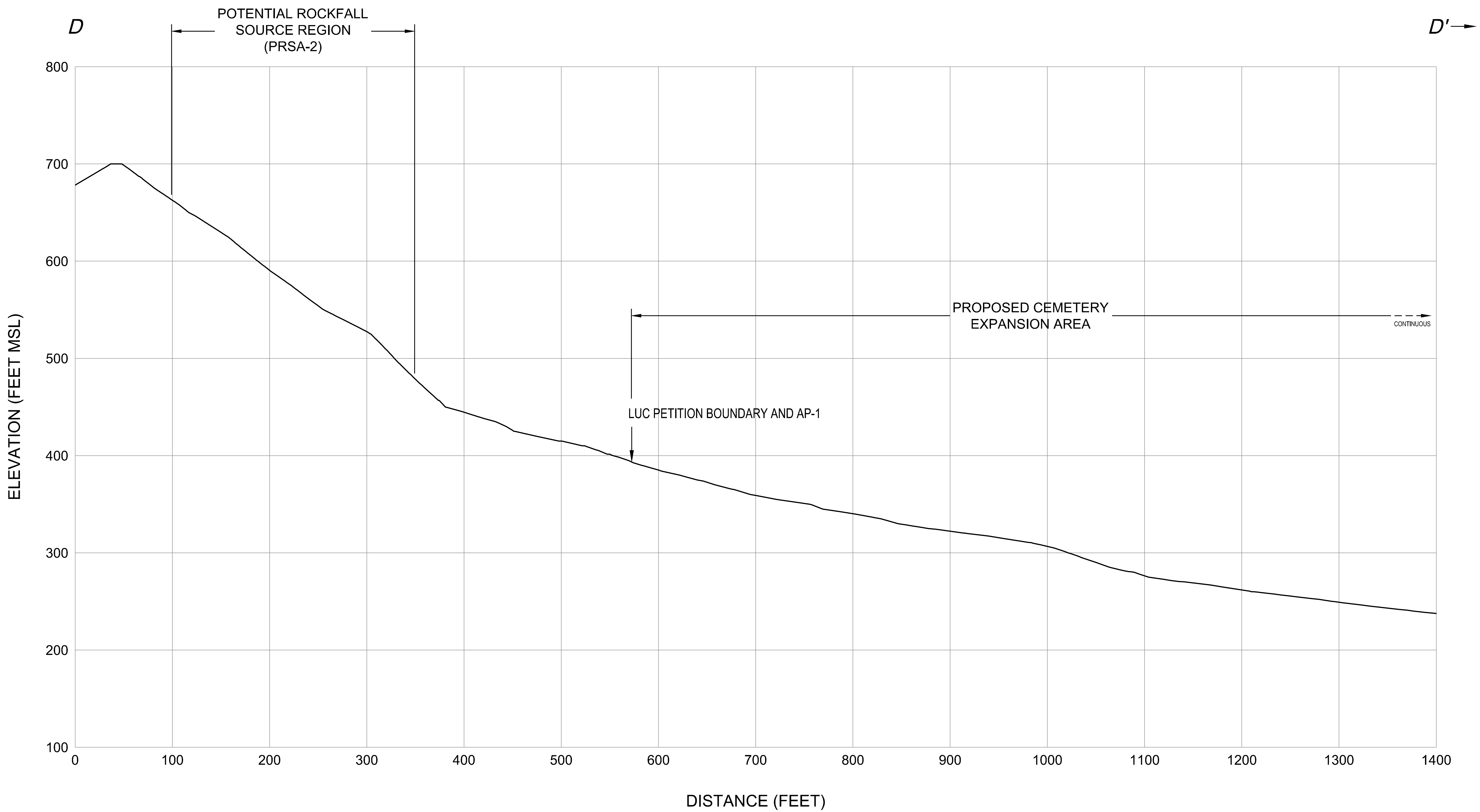

LEGEND:

AP-1 ANALYSIS POINT FOR COMPUTER ROCKFALL SIMULATION

0 50 100 200 300 FT.

GRAPHIC SCALE

SLOPE PROFILE D-D'

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

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DATE	DRAWN BY	PLATE
DECEMBER 2017	HYC	
SCALE	W.O.	
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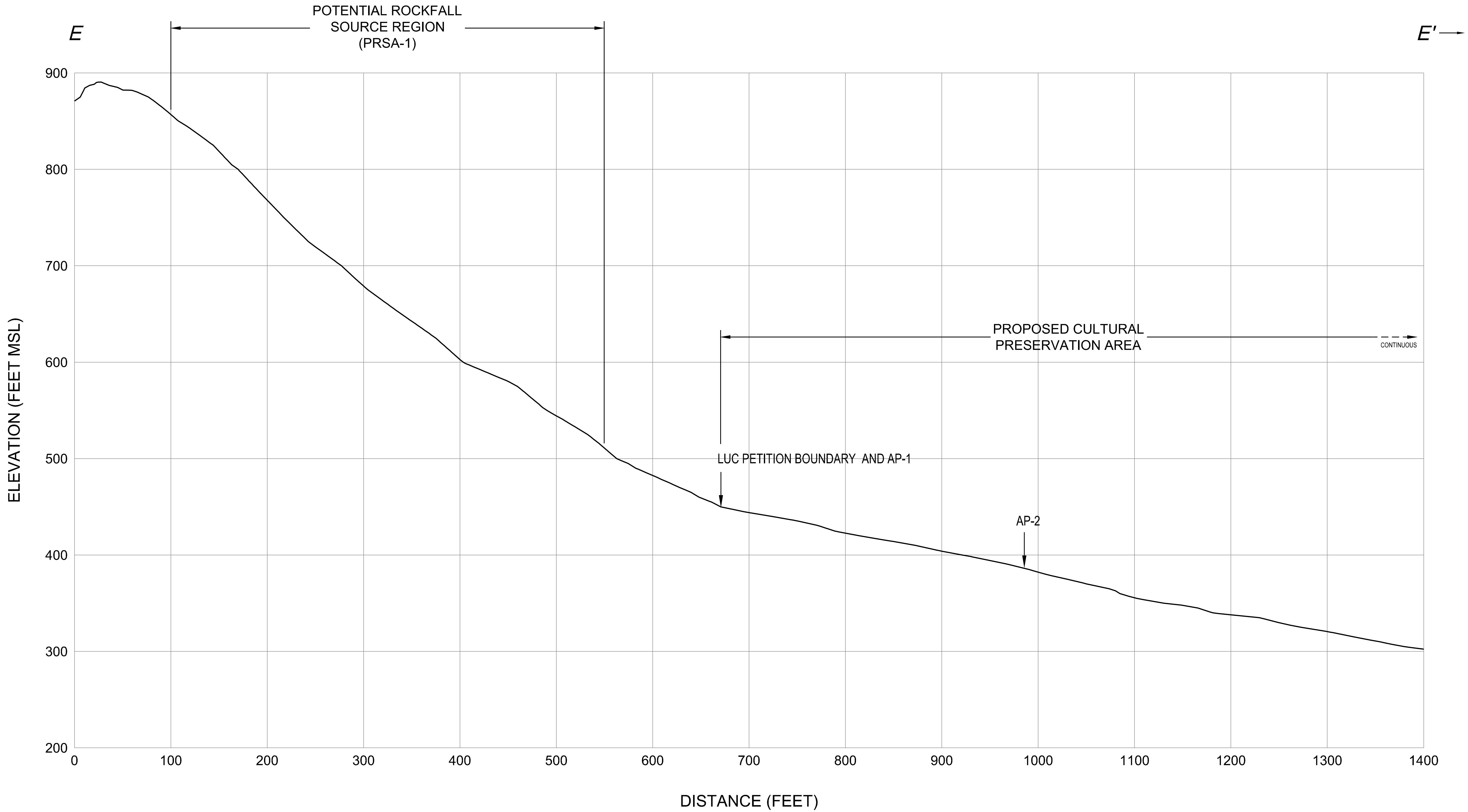

LEGEND:

AP-1 ANALYSIS POINT FOR COMPUTER ROCKFALL SIMULATION

0 50 100 200 300 FT.

GRAPHIC SCALE

SLOPE PROFILE E-E'

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
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GEOLABS, INC.
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DATE	DRAWN BY	PLATE
DECEMBER 2017	HYC	
SCALE	W.O.	
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CAD User: HENRY File Last Updated: December 11, 2017 2:21:16pm Plot Date: December 11, 2017 - 2:23:07pm
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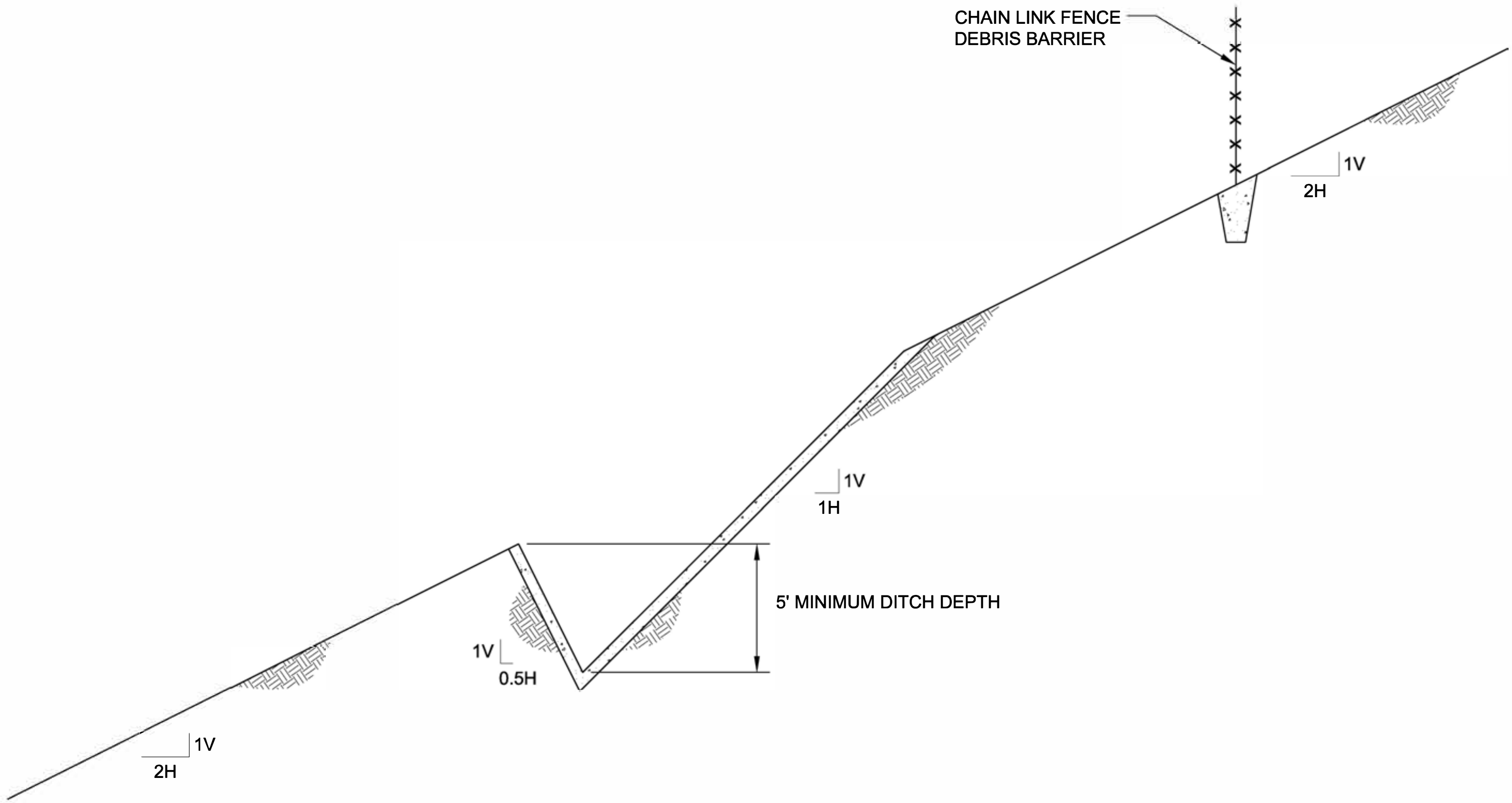

CONCEPTUAL CONCRETE LINED ROCK CATCHMENT DITCH

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
DECEMBER 2017	HYC	
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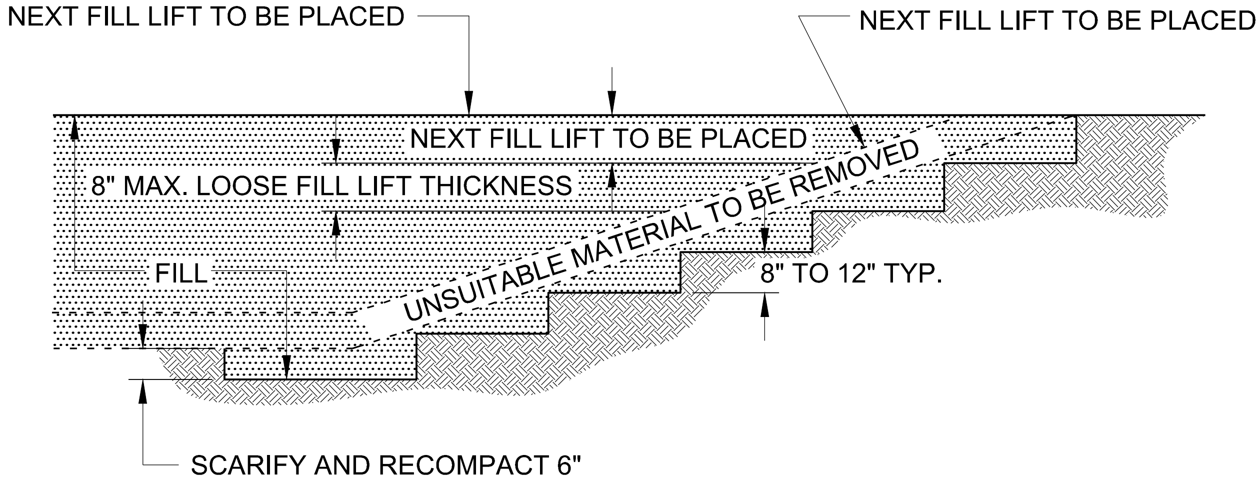
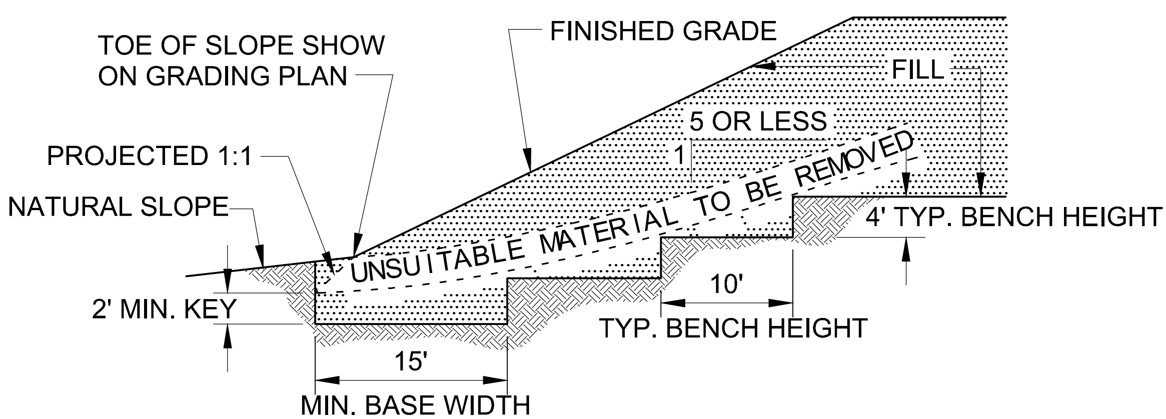


LEVEL FILL ON SLOPING GROUND



FILL SLOPE ON SLOPING GROUND

SKETCH OF KEYING AND BENCING

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

NOTE:
WHERE NATURAL SLOPE IS FLATTER THAN 5: 1 (H: V), BENCHING IS NOT NECESSARY. FILL SHOULD NOT BE PLACED ON COMPRESSIBLE OR UNSUITABLE MATERIAL.

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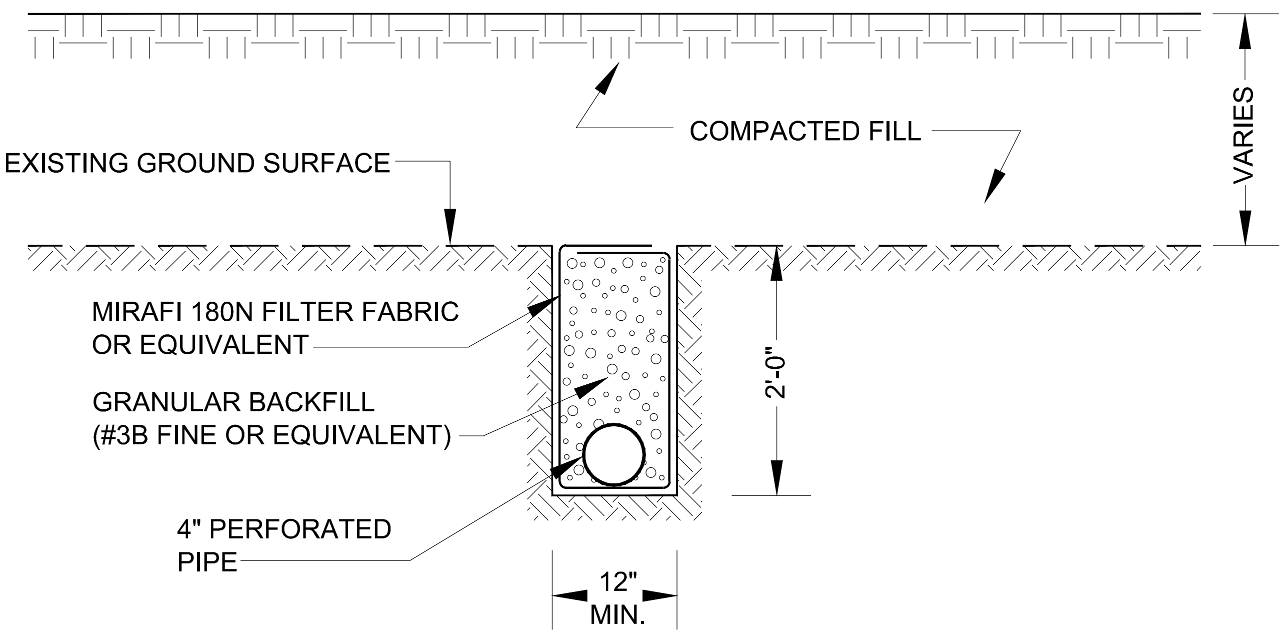
DATE	DRAWN BY	PLATE
DECEMBER 2017	HYC	
SCALE	W.O.	
NOT TO SCALE	7604-00	5

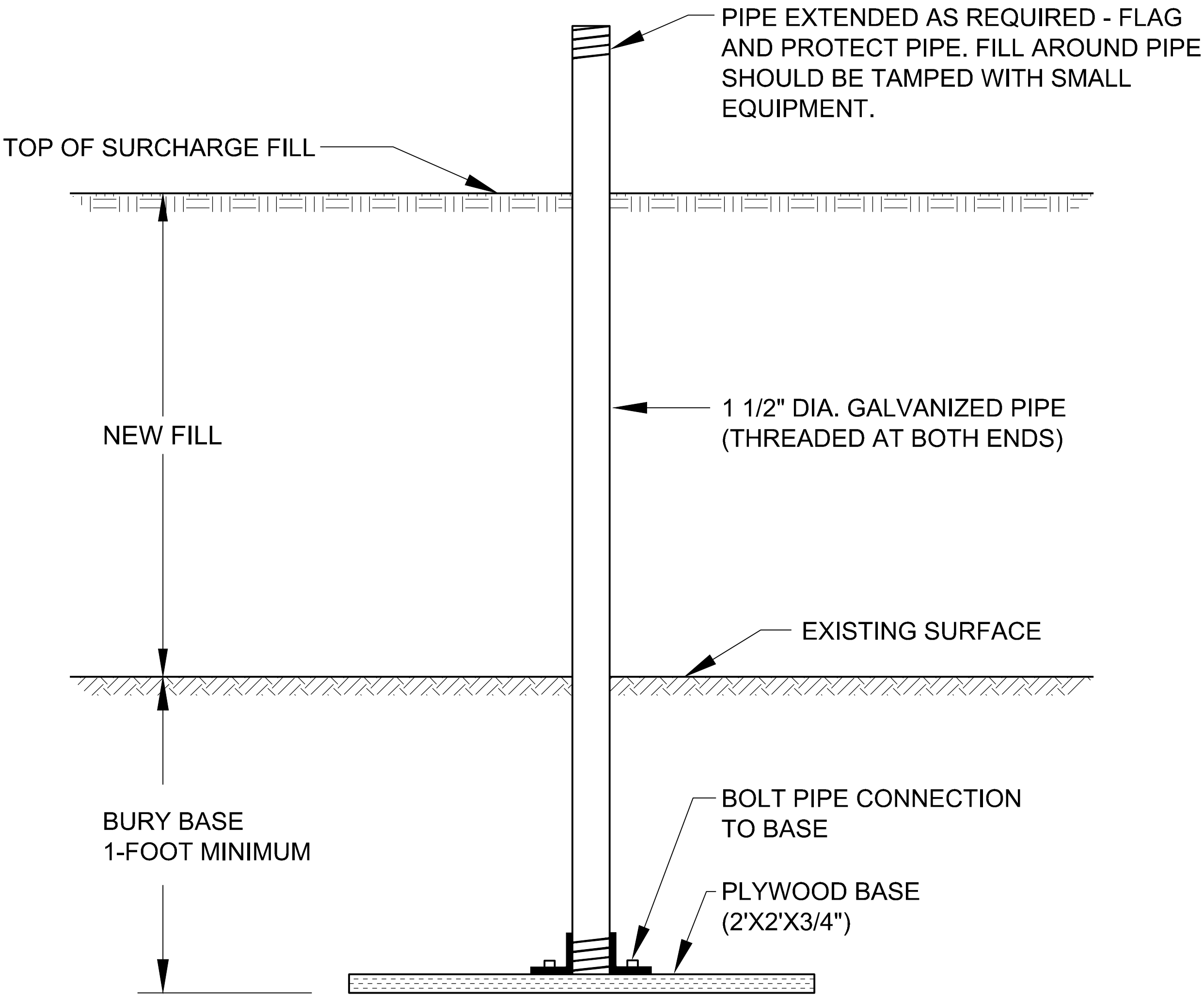


TYPICAL SUBDRAIN DETAIL

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
DECEMBER 2017	HYC	
SCALE	W.O.	
NOT TO SCALE	7604-00	6



TYPICAL SETTLEMENT GAUGE

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

GEOLABS, INC.
Geotechnical Engineering

DATE	DRAWN BY	PLATE
DECEMBER 2017	HYC	
SCALE	W.O.	7
NOT TO SCALE	7604-00	

APPENDIX A

GEOLABS, INC.

Geotechnical Engineering

Soil Log Legend

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

MAJOR DIVISIONS			USCS	TYPICAL DESCRIPTIONS
COARSE-GRAINED SOILS MORE THAN 50% OF MATERIAL RETAINED ON NO. 200 SIEVE	GRAVELS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS LESS THAN 5% FINES	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
			GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES MORE THAN 12% FINES	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SANDS 50% OR MORE OF COARSE FRACTION PASSING THROUGH NO. 4 SIEVE	CLEAN SANDS LESS THAN 5% FINES	SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
			SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		SANDS WITH FINES MORE THAN 12% FINES	SM	SILTY SANDS, SAND-SILT MIXTURES
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE-GRAINED SOILS 50% OR MORE OF MATERIAL PASSING THROUGH NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT 50 OR MORE	MH	INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY
			OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

LEGEND

- (2-INCH) O.D. STANDARD PENETRATION TEST
- (3-INCH) O.D. MODIFIED CALIFORNIA SAMPLE
- S SHELBY TUBE SAMPLE
- G GRAB SAMPLE
- CORE SAMPLE
- ∇ WATER LEVEL OBSERVED IN BORING AT TIME OF DRILLING
- ▼ WATER LEVEL OBSERVED IN BORING AFTER DRILLING
- WATER LEVEL OBSERVED IN BORING OVERNIGHT

LL	LIQUID LIMIT (NP=NON-PLASTIC)
PI	PLASTICITY INDEX (NP=NON-PLASTIC)
TV	TORVANE SHEAR (tsf)
UC	UNCONFINED COMPRESSION OR UNIAXIAL COMPRESSIVE STRENGTH
TXUU	UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION (ksf)
TXCU	CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION (ksf)

Plate

A-0.1

GEOLABS, INC.

Geotechnical Engineering

Soil Classification Log Key
(with deviations from ASTM D2488)

GEOLABS, INC. CLASSIFICATION*

GRANULAR SOIL (- #200 <50%)	COHESIVE SOIL (- #200 ≥ 50%)
• **PRIMARY** constituents are composed of the largest percent of the soil mass. Primary constituents are capitalized and bold (i.e., **GRAVEL, SAND**)	• **PRIMARY** constituents are based on plasticity. Primary constituents are capitalized and bold (i.e., **CLAY, SILT**)
• **SECONDARY** constituents are composed of a percentage less than the primary constituent. If the soil mass consists of 12 percent or more fines content, a cohesive constituent is used (**SILTY** or **CLAYEY**); otherwise, a granular constituent is used (**GRAVELLY** or **SANDY**) provided that the secondary constituent consists of 20 percent or more of the soil mass. Secondary constituents are capitalized and bold (i.e., **SANDY** GRAVEL, **CLAYEY** SAND) and precede the primary constituent.	• **SECONDARY** constituents are composed of a percentage less than the primary constituent, but more than 20 percent of the soil mass. Secondary constituents are capitalized and bold (i.e., **SANDY** CLAY, **SILTY** CLAY, **CLAYEY** SILT) and precede the primary constituent.
• **accessory descriptions** compose of the following: with some: >12% with a little: 5 - 12% with traces of: <5% accessory descriptions are lower cased and follow the Primary and Secondary Constituents (i.e., SILTY GRAVEL **with a little sand**)	• **accessory descriptions** compose of the following: with some: >12% with a little: 5 - 12% with traces of: <5% accessory descriptions are lower cased and follow the Primary and Secondary Constituents (i.e., SILTY CLAY **with some sand**)

EXAMPLE: Soil Containing 60% Gravel, 25% Sand, 15% Fines. Described as: **SILTY GRAVEL** with some sand

RELATIVE DENSITY / CONSISTENCY

Granular Soils			Cohesive Soils			
N-Value (Blows/Foot)		Relative Density	N-Value (Blows/Foot)		PP Readings (tsf)	Consistency
SPT	MCS		SPT	MCS		
0 - 4	0 - 7	Very Loose	0 - 2	0 - 4		Very Soft
4 - 10	7 - 18	Loose	2 - 4	4 - 7	< 0.5	Soft
10 - 30	18 - 55	Medium Dense	4 - 8	7 - 15	0.5 - 1.0	Medium Stiff
30 - 50	55 - 91	Dense	8 - 15	15 - 27	1.0 - 2.0	Stiff
> 50	> 91	Very Dense	15 - 30	27 - 55	2.0 - 4.0	Very Stiff
			> 30	> 55	> 4.0	Hard

MOISTURE CONTENT DEFINITIONS

Dry: Absence of moisture, dry to the touch

Moist: Damp but no visible water

Wet: Visible free water, usually soil is below water table

ABBREVIATIONS

WOH: Weight of Hammer

WOR: Weight of Drill Rods

SPT: Standard Penetration Test Split-Spoon Sampler

MCS: Modified California Sampler

PP: Pocket Penetrometer

GRAIN SIZE DEFINITION

Description	Sieve Number and / or Size
Boulders	> 12 inches (305-mm)
Cobbles	3 to 12 inches (75-mm to 305-mm)
Gravel	3-inch to #4 (75-mm to 4.75-mm)
Coarse Gravel	3-inch to 3/4-inch (75-mm to 19-mm)
Fine Gravel	3/4-inch to #4 (19-mm to 4.75-mm)
Sand	#4 to #200 (4.75-mm to 0.075-mm)
Coarse Sand	#4 to #10 (4.75-mm to 2-mm)
Medium Sand	#10 to #40 (2-mm to 0.425-mm)
Fine Sand	#40 to #200 (0.425-mm to 0.075-mm)

**Soil descriptions are based on ASTM D2488-09a, Visual-Manual Procedure, with the above modifications by Geolabs, Inc. to the Unified Soil Classification System (USCS).*

Plate

A-0.2

GEOLABS, INC. Geotechnical Engineering	PHASE I POTENTIAL ROCKFALL AND SLOPE HAZARD ASSESSMENT HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION TMK: 4-5-033: 001 KANEOHE, OAHU, HAWAII	Log of Boring 1

Approximate Ground Surface Elevation (feet): 269 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	USCS	Description
							0	MH	Orangish brown **CLAYEY SILT** with a little gravel (basaltic), very stiff, moist (fill)
	50	62			12	4.0		MH	Mottled orangish brown **CLAYEY SILT** with some sand, very stiff, moist (residual soil)
	54				5				Mottled orangish brown with some dark gray **CLAYEY SILT** with some sand and traces of decomposed gravel, stiff to very stiff, moist (saprolite)
Direct Shear	56	62			9	4.0	5		
LL=72 PI=22	62				6		10		
TXCU					7	4.0	15		grades with yellowish brown mottling locally
	49				17		20		grades more clayey locally
	53	70			24	4.0	25		
LL=79 PI=30	59				11		30		
							35		

Date Started:	October 12, 2017	Water Level: ▼	Not Encountered
Date Completed:	October 12, 2017		
Logged By:	S. Latronic	Drill Rig:	CME-45C TRUCK *(Energy Transfer Ratio = 78%)*
Total Depth:	46.5 feet	Drilling Method:	4" Solid Stem Auger
Work Order:	7604-00	Driving Energy:	140 lb. wt., 30 in. drop

Plate

A - 1.1

GEOLABS, INC. Geotechnical Engineering	PHASE I POTENTIAL ROCKFALL AND SLOPE HAZARD ASSESSMENT HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION TMK: 4-5-033: 001 KANEOHE, OAHU, HAWAII	Log of Boring 1

(Continued from previous plate)

Other Tests (Laboratory)	Moisture Content (%) (Laboratory)	Dry Density (pcf) (Laboratory)	Core Recovery (%) (Field)	RQD (%) (Field)	Penetration Resistance (blows/foot) (Field)	Pocket Pen. (tsf) (Field)	Depth (feet)	Sample	Graphic	USCS	Description
Direct Shear	55	69			18	2.3				MH	
	51				10		40				
											grades with highly weathered basalt corestones locally
LL=66 PI=33	48				15		45				
											grades to very moist
											Boring terminated at 46.5 feet
											* Elevations based on available Grading Plan for Ocean View Gardens.
							50				
							55				
							60				
							65				
							70				

Date Started:	October 12, 2017	Water Level:	Not Encountered	Plate
Date Completed:	October 12, 2017			
Logged By:	S. Latronic	Drill Rig:	CME-45C TRUCK *(Energy Transfer Ratio = 78%)*	A - 1.2
Total Depth:	46.5 feet	Drilling Method:	4" Solid Stem Auger	
Work Order:	7604-00	Driving Energy:	140 lb. wt., 30 in. drop	

GEOLABS, INC.

Geotechnical Engineering

PHASE I POTENTIAL ROCKFALL AND SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

Log of Boring 2

Approximate Ground Surface Elevation (feet): 263 *

Laboratory			Field						
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	USCS	Description
								MH	Brown **CLAYEY SILT** with some sand and traces of gravel (basaltic), very stiff to hard, moist (fill)
	34	82			40	4.5			
LL=66 PI=29	34				30				
	32	86			34	4.5	5		
	37				40				
								MH	Mottled orangish brown **CLAYEY SILT**, very stiff to hard, moist (residual soil)
								MH	Mottled grayish brown with some orange **CLAYEY SILT** with some sand and a little decomposed gravel, hard, moist (saprolite)
LL=65 PI=8	35	77			68	4.5	10		
								MH	Mottled orangish brown **CLAYEY SILT** with some sand, stiff to very stiff, moist (saprolite)
	55				6		15		
Direct Shear	54	50			16	3.5	20		
									grades more sandy locally
LL=81 PI=21	65				5		25		
Direct Shear	71	57			13	2.3	30		
									grades more clayey
							35		

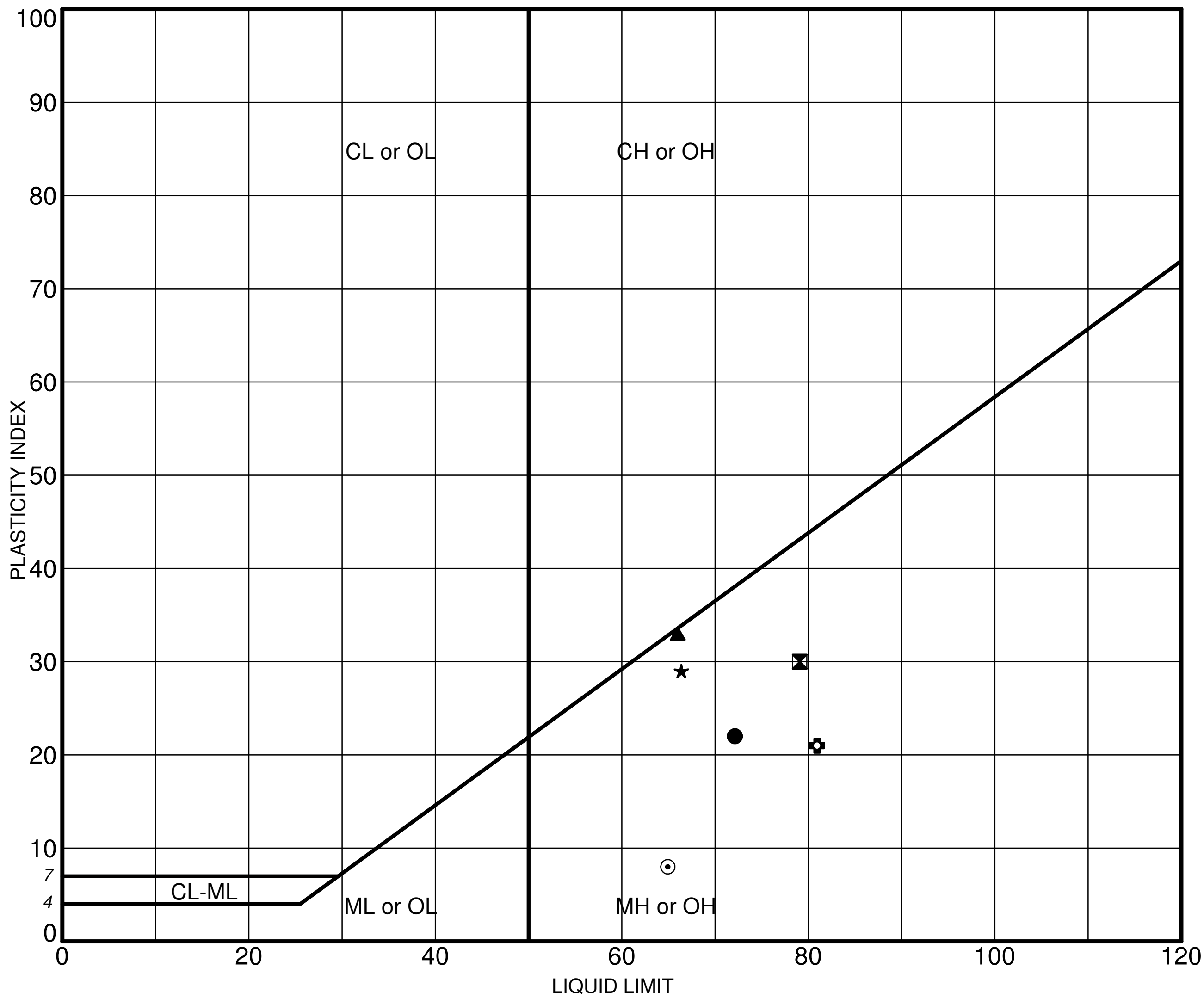
Date Started:	October 12, 2017	Water Level:	Not Encountered
Date Completed:	October 12, 2017		
Logged By:	S. Latronic	Drill Rig:	CME-45C TRUCK *(Energy Transfer Ratio = 78%)*
Total Depth:	46.5 feet	Drilling Method:	4" Solid Stem Auger
Work Order:	7604-00	Driving Energy:	140 lb. wt., 30 in. drop

GEOLABS, INC. Geotechnical Engineering	PHASE I POTENTIAL ROCKFALL AND SLOPE HAZARD ASSESSMENT HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION TMK: 4-5-033: 001 KANEOHE, OAHU, HAWAII	Log of Boring 2

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Field: Core Recovery (%)	Field: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
											(Continued from previous plate)
	50				17					MH	Mottled yellowish brown and gray **CLAYEY SILT** with a little gravel (basaltic) and remnant rock structure, very stiff, moist (saprolite)
	44	77			26	3.5	40				
											grades with highly weathered basalt corestones locally
	23				19		45				grades more silty
											Boring terminated at 46.5 feet
							50				
							55				
							60				
							65				
							70				

Date Started:	October 12, 2017	Water Level:	Not Encountered	Plate
Date Completed:	October 12, 2017			
Logged By:	S. Latronic	Drill Rig:	CME-45C TRUCK *(Energy Transfer Ratio = 78%)*	A - 2.2
Total Depth:	46.5 feet	Drilling Method:	4" Solid Stem Auger	
Work Order:	7604-00	Driving Energy:	140 lb. wt., 30 in. drop	

APPENDIX B



	Sample	Depth (ft)	LL	PL	PI	Description
●	B-1	10.0-12.0	72	50	22	Orangish brown clayey silt (MH) with some sand
⧗	B-1	30.0-31.5	79	49	30	Orangish brown clayey silt (MH) with some sand
▲	B-1	45.0-46.5	66	33	33	Orangish brown clayey silt (MH)
★	B-2	2.5-4.5	66	37	29	Brown clayey silt (MH) with some sand
⊙	B-2	10.0-11.5	65	57	8	Orangish brown clayey silt (MH) with some sand
✿	B-2	25.0-27.0	81	60	21	Orangish brown clayey silt (MH) with some sand

NP = NON-PLASTIC

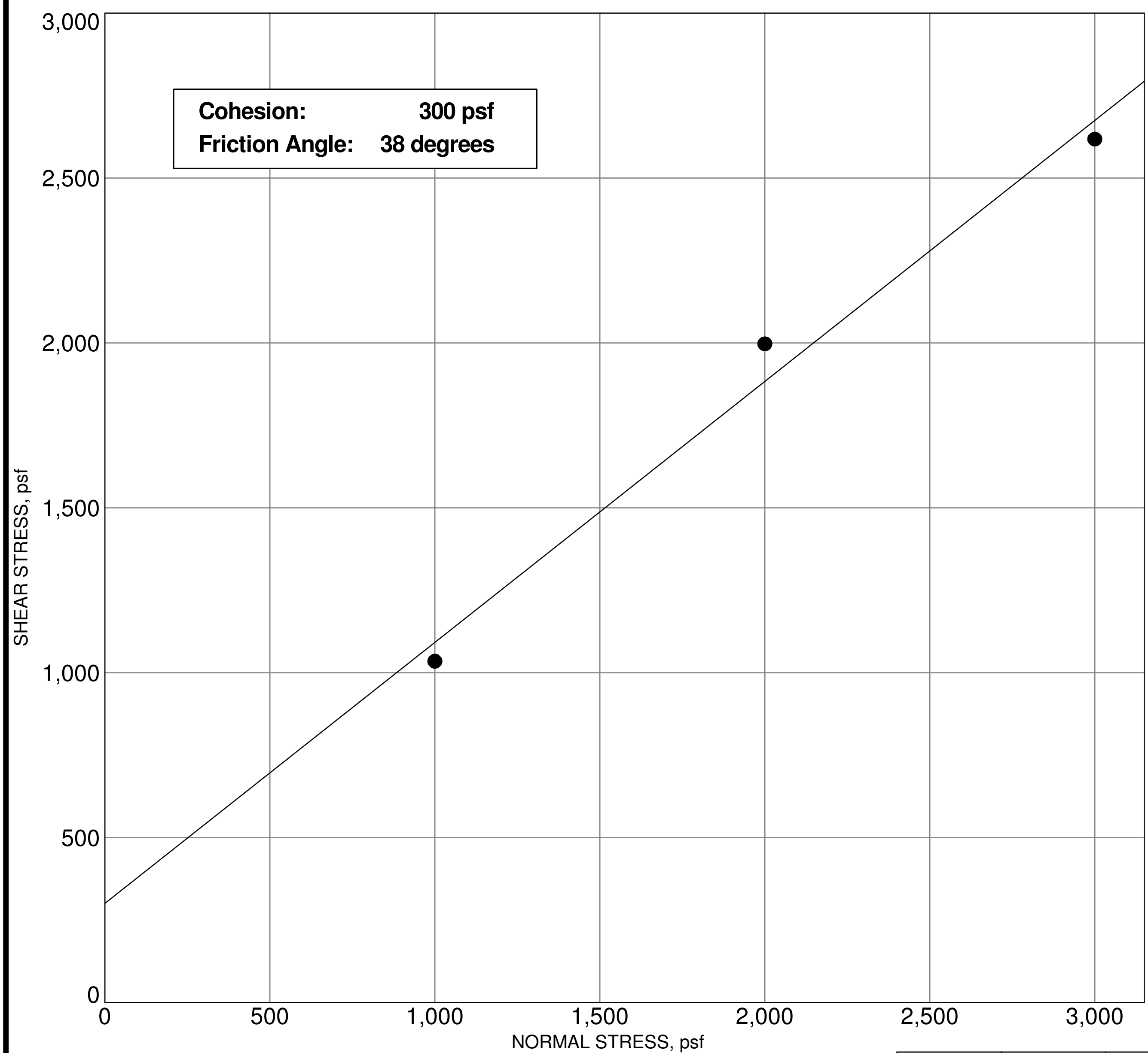
GEOLABS, INC.
GEOTECHNICAL ENGINEERING

W.O. 7604-00

ATTERBERG LIMITS TEST RESULTS - ASTM D4318

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

Plate
B - 1



		Sample #1	Sample #2	Sample #3
INITIAL	Moisture Content, %	58.9	59.8	61.1
	Dry Density, pcf	53.8	57.9	61.3
	Height, inches	1.00	1.00	1.00
FINAL	Moisture Content, %	81.3	70.0	65.3
	Dry Density, pcf	53.2	59.9	63.0
	Height, inches	1.010	0.966	0.973
	Diameter, inches	2.42	2.42	2.42
	Deformation Rate, inch/minute	0.0025	0.0021	0.0020
	Normal Stress, psf	**1000**	**2000**	**3000**
	Peak Shear Stress, psf	**1035**	**1997**	**2618**
	Shear Displacement, inches	0.43	0.41	0.41

Sample: B-1
Depth: 5.0 - 6.5 feet
Description: Mottled orangish brown with some dark gray clayey silt with some sand

G_DIRECT_SHEAR 7604-00.GPJ GEOLABS.GDT 11/30/17

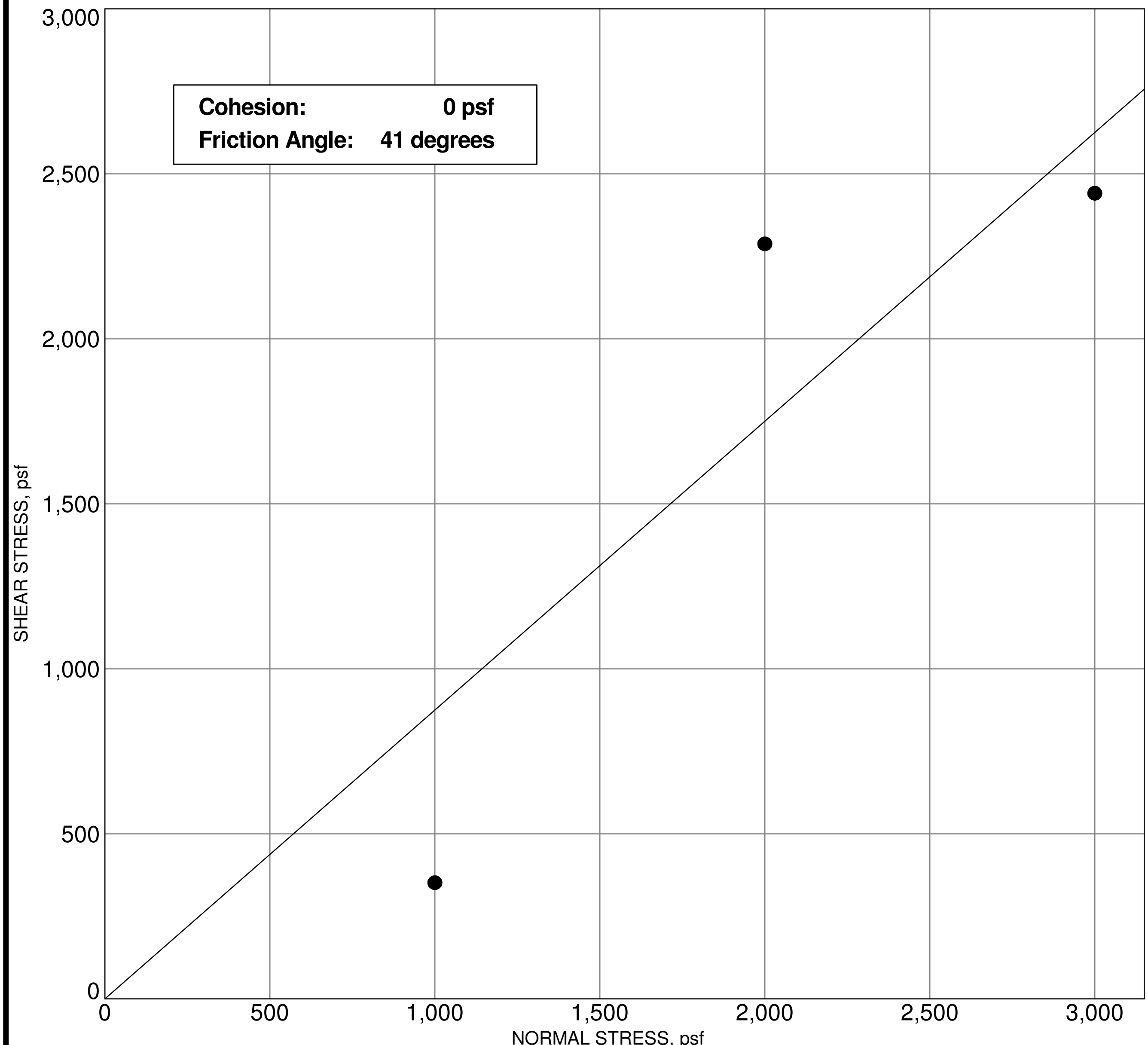
GEOLABS, INC.
GEOTECHNICAL ENGINEERING

W.O. 7604-00

DIRECT SHEAR TEST - ASTM D3080

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

Plate
B - 2



		Sample #1	Sample #2	Sample #3
INITIAL	Moisture Content, %	55.7	56.7	57.1
	Dry Density, pcf	66.3	67.6	67.1
	Height, inches	1.00	1.00	1.00
FINAL	Moisture Content, %	64.8	59.3	56.3
	Dry Density, pcf	67.3	69.6	69.5
	Height, inches	0.985	0.971	0.965
	Diameter, inches	2.42	2.42	2.42
	Deformation Rate, inch/minute	0.0025	0.0012	0.0020
	Normal Stress, psf	**1000**	**2000**	**3000**
	Peak Shear Stress, psf	**352**	**2288**	**2441**
	Shear Displacement, inches	0.43	0.37	0.42

Sample: B-1
Depth: 35.0 - 36.5 feet
Description: Mottled orangish brown clayey silt with some sand

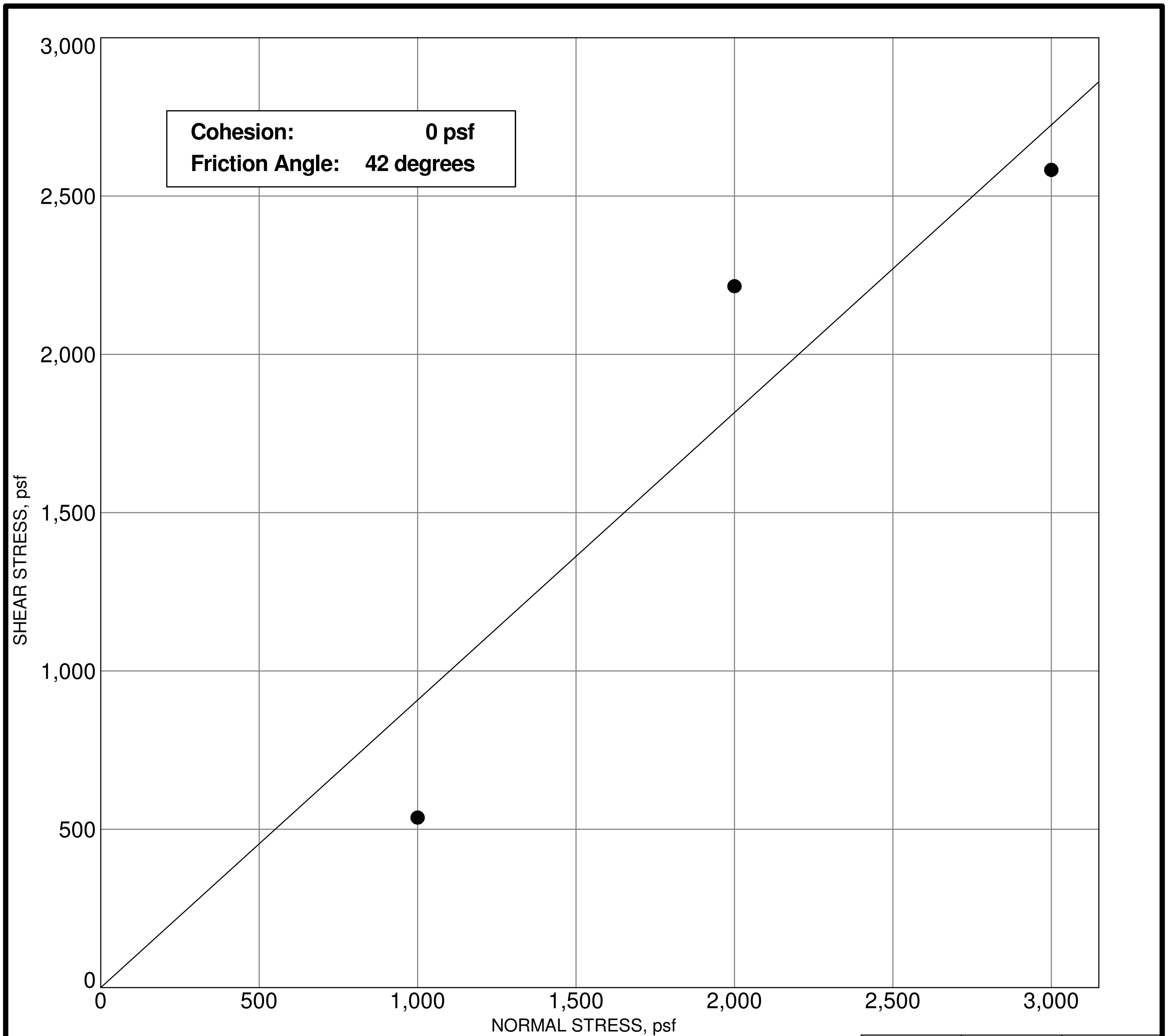
G_DIRECT_SHEAR 7604-00.GPJ GEOLABS.GDT 11/30/17

GEOLABS, INC.
GEOTECHNICAL ENGINEERING
W.O. 7604-00

DIRECT SHEAR TEST - ASTM D3080

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

Plate
B - 3



		Sample #1	Sample #2	Sample #3
INITIAL	Moisture Content, %	55.3	61.8	59.2
	Dry Density, pcf	62.2	61.5	62.0
	Height, inches	1.00	1.00	1.00
FINAL	Moisture Content, %	72.1	68.7	67.8
	Dry Density, pcf	69.2	62.3	63.7
	Height, inches	0.898	0.988	0.973
	Diameter, inches	2.42	2.42	2.42
	Deformation Rate, inch/minute	0.0025	0.0020	0.0020
	Normal Stress, psf	**1000**	**2000**	**3000**
	Peak Shear Stress, psf	**537**	**2215**	**2582**
	Shear Displacement, inches	0.43	0.40	0.42

Sample: B-2
Depth: 20.0 - 21.5 feet
Description: Mottled orangish brown clayey silt with some sand

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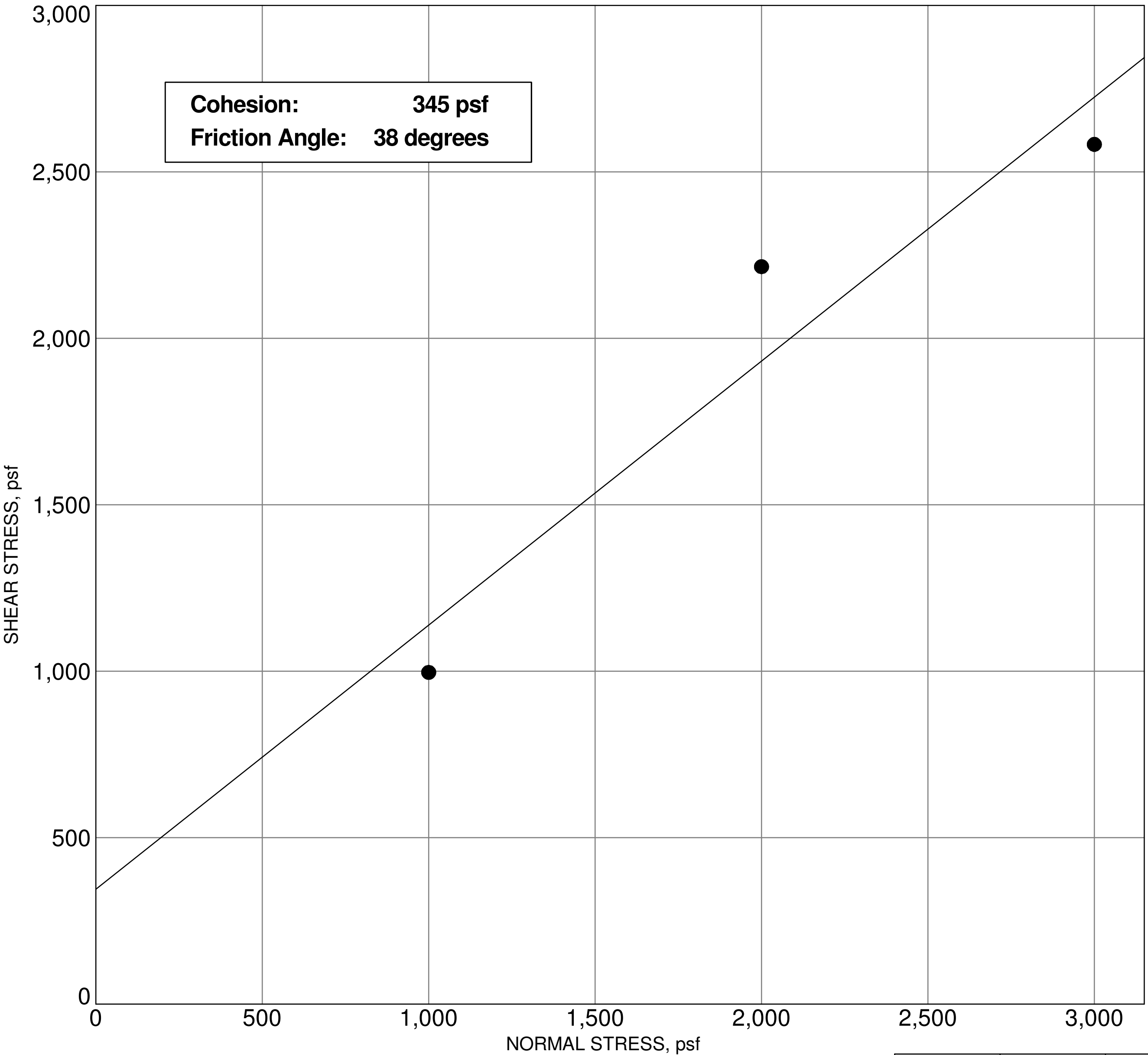
DIRECT SHEAR TEST - ASTM D3080

PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

Plate
B - 4



		Sample #1	Sample #2	Sample #3
INITIAL	Moisture Content, %	64.6	73.6	73.6
INITIAL	Dry Density, pcf	54.5	51.6	54.3
INITIAL	Height, inches	1.00	1.00	1.00
FINAL	Moisture Content, %	74.2	78.1	77.2
FINAL	Dry Density, pcf	54.4	53.4	55.9
FINAL	Height, inches	1.002	0.967	0.973
	Diameter, inches	2.42	2.42	2.42
	Deformation Rate, inch/minute	0.0025	0.0021	0.0021
	Normal Stress, psf	**1000**	**2000**	**3000**
	Peak Shear Stress, psf	**996**	**2215**	**2582**
	Shear Displacement, inches	0.42	0.39	0.43

Sample: B-2
Depth: 30.0 - 31.5 feet
Description: Mottled orangish brown clayey silt with some sand

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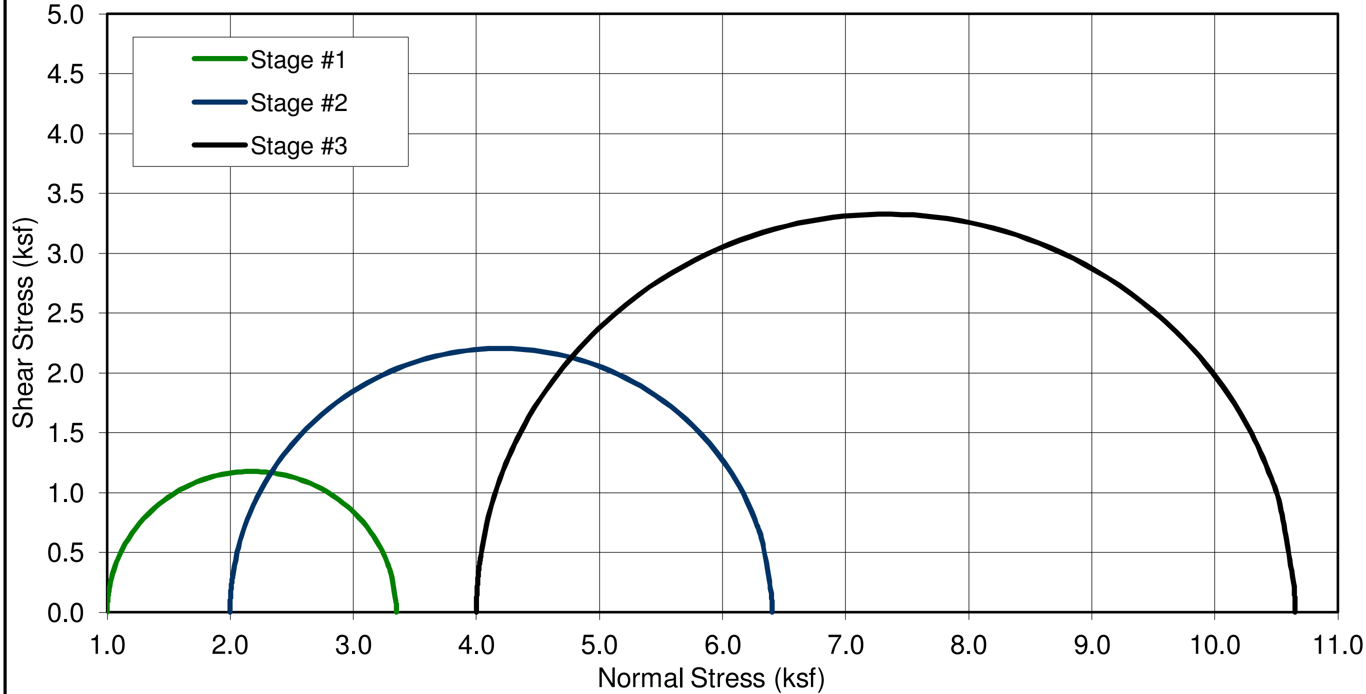
GEOTECHNICAL ENGINEERING
W.O. 7604-00

DIRECT SHEAR TEST - ASTM D3080

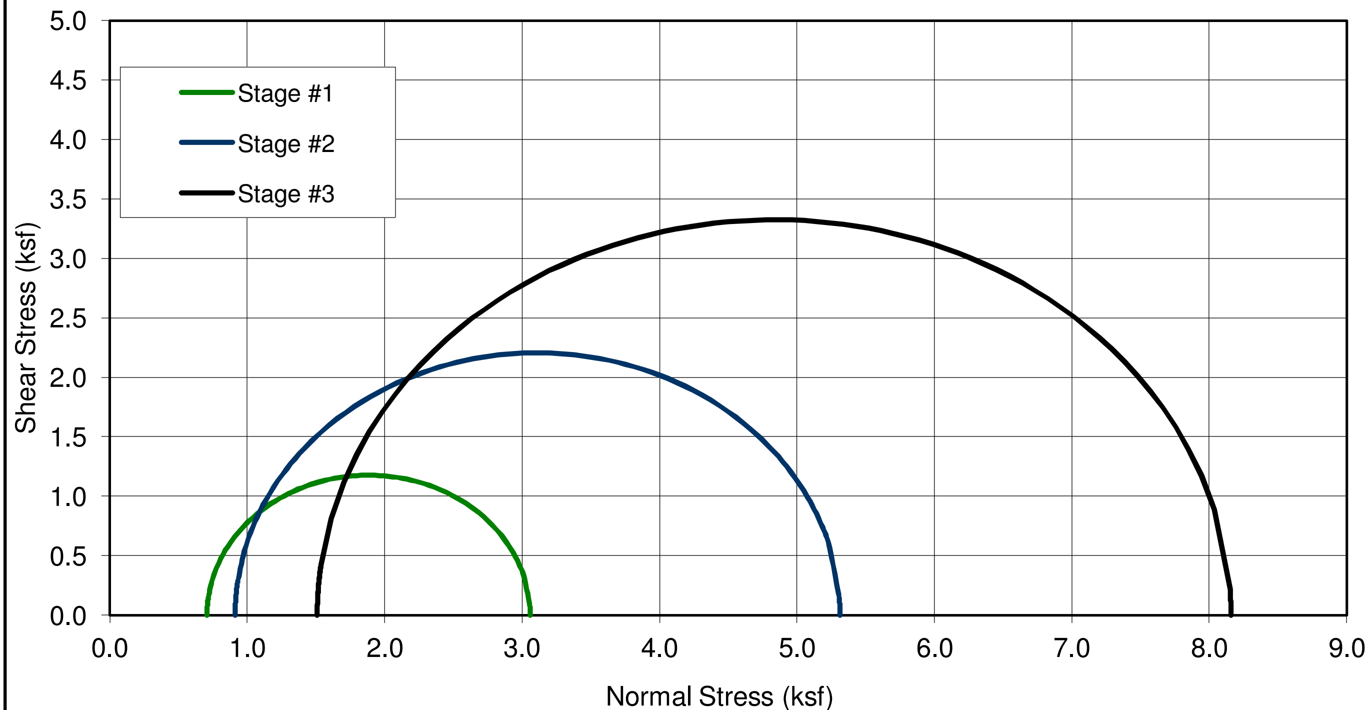
PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

Plate
B - 5

TOTAL STRESS MOHR CIRCLE



EFFECTIVE STRESS MOHR CIRCLE

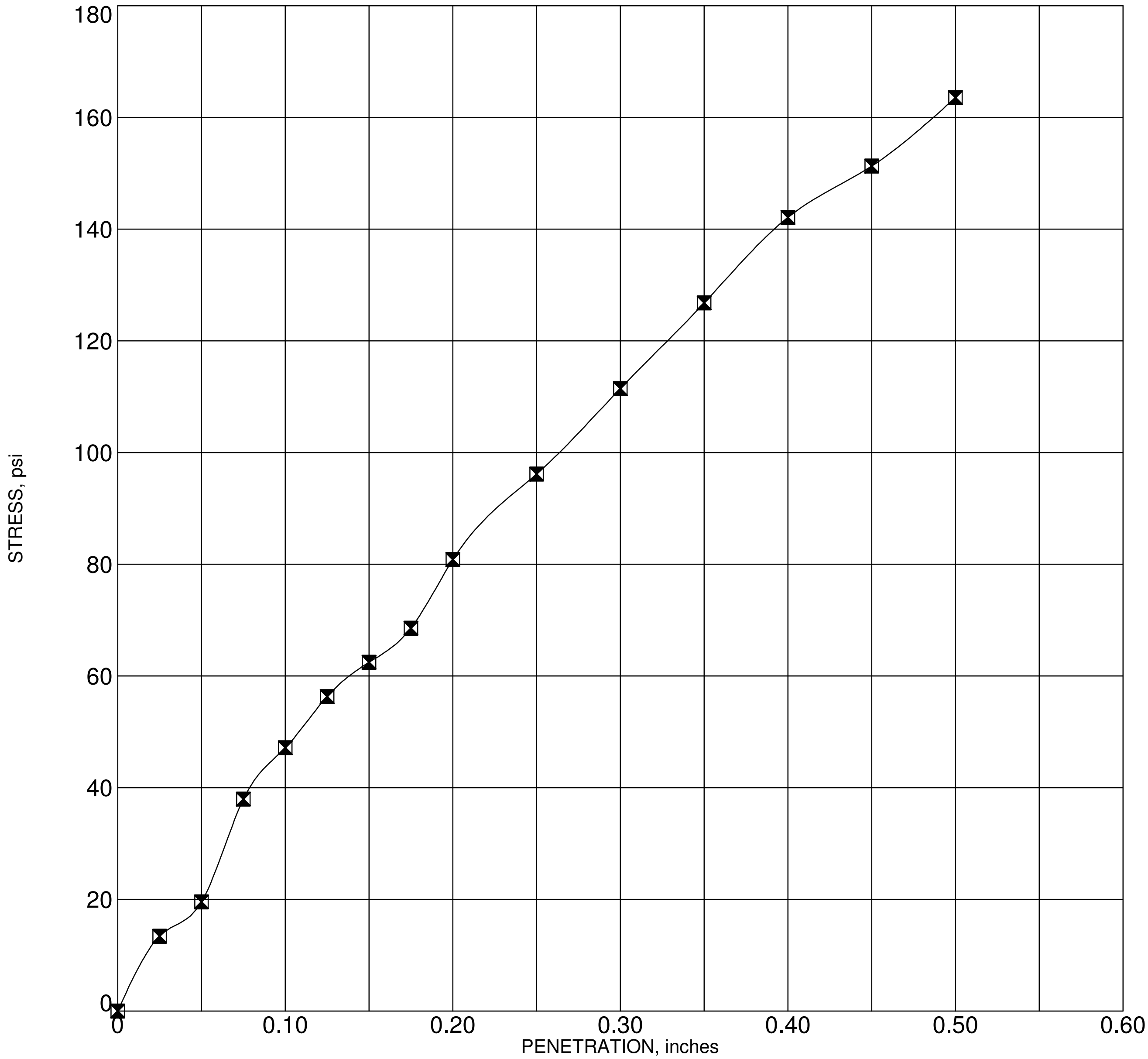


Sample: B-1

Depth: 15.0 - 16.5 feet

Descrition: Mottled orangish brown clayey silt with some sand

GEOLABS, INC. GEOTECHNICAL ENGINEERING	CU TRIAXIAL COMPRESSION TEST - ASTM D 4767	
W.O. 7604-00	PHASE I POTENTIAL ROCKFALL AND SLOPE HAZARD ASSESSMENT HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION TMK: 4-5-033: 001 KANEOHE, OAHU, HAWAII	Plate B - 6



Corr. CBR @ 0.1"	5.6
Corr. CBR @ 0.2"	5.9
Swell (%)	0.31

Sample: Bulk-1
Depth: 0.0 - 2.0 feet
Description: Orangish brown clayey silt with some sand

Molding Dry Density (pcf)	71.9	Hammer Wt. (lbs)	10
Molding Moisture (%)	48.9	Hammer Drop (inches)	18
Days Soaked	5	No. of Blows	56
Aggregate	3/4 inch minus	No. of Layers	5

GEOLABS, INC.
GEOTECHNICAL ENGINEERING
W.O. 7604-00

CALIFORNIA BEARING RATIO - ASTM D1883
PHASE I POTENTIAL ROCKFALL AND
SLOPE HAZARD ASSESSMENT
HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
TMK: 4-5-033: 001
KANEOHE, OAHU, HAWAII

Plate
B - 7

APPENDIX C

Photograph No. 1: (2356) View toward the north of the steep rock quarry cuts that reach the ridge summit of the Oneawa Hills. The approximate location is on the Kailua side of the ridgeline between our Slope Profile lines "D" and "E" shown on the Site Plan, Plate 2.

Photograph No. 3: (2359) Existing massive block type rock outcropping near the ridgeline summit at the northern end of the PRSA-1 area and northerly of the Slope Profile "E" shown on the Site Plan, Plate 2.

Photograph No. 2: (2364) View of the Kappa Quarry Phase II area showing the typical basalt rock that comprises the core of the Oneawa Hills. Note the reddish soil overburden which grades to hard rock at depth. The subsurface conditions are anticipated to be similar at the HMP project site.

Photograph No. 4: (2360) Typical highly to extremely weathered, severely fractured and friable basalt rock outcropping observed sporadically along the Oneawa Hills ridgeline summit, upslope from the PRSA-2 area shown on the Site Plan, Plate 2. Very limited rockfall potential is anticipated from this material.

Photograph No. 5: (2366) Existing massive block type rock outcropping near the ridgeline summit at the southern portion of the PRSA-1 area and just northerly of Slope Profile "D" shown on the Site Plan, Plate 2.

Photograph No. 7: (2371) Other typical low relief, ridgeline summit rock outcropping within the central portion of the PRSA-1 area shown on the Site Plan, Plate 2.

Photograph No. 6: (2368) Another view of the rock outcrop (in Photograph No.5) showing that it is a multi-block outcropping with the major blocks nested together on the sloping terrain just below the ridgeline summit.

Photograph No. 8: (2411) Generally flat and massive rock outcropping comprising the ground surface at the lower elevation northern portion of the PRSA-1 area shown on the Site Plan, Plate 2. (Wpt. OC7).

Photograph No. 9: (2576) Fractured and highly weathered rock outcropping on a side slope of a shallow ravine at the northern boundary of the PRSA-1 area shown on the Site Plan, Plate 2. (Wpt. OC8-1).

Photograph No. 11: (2583) Accumulation of small boulder talus within a gently sloped ravine on the flatter slopes below the PRSA-1 area shown on the Site Plan, Plate 2. (Wpt. TalusRavine).

Photograph No. 10: (2581) Isolated large block rock outcropping on gentle terrain at the lower elevation, northern half of the PRSA-1 area shown on the Site Plan, Plate 2. (Wpt. OC9).

Photograph No. 12: (2582) Scattered cobble and boulder talus just below the break in slope and lower boundary of the PRSA-1 area shown on the Site Plan, Plate 2. (Wpt. TalusBoulders).

Photograph No. 13: (2571) Nested cluster of large boulders within the deposition zone below the PRSA-1 area and within the proposed Cultural Preservation Area. (Wpt. BoulderBloks).

Photograph No. 15: (2416) Talus cluster of large boulders within the deposition zone below the PRSA-1 area and within the proposed Cultural Preservation Area.

Photograph No. 14: (2574) Isolated large boulder within the deposition zone below the PRSA-1 area and within the proposed Cultural Preservation Area. (Wpt. LargeBlok).

Photograph No. 16: (2417) Close view of boulder in previous photograph showing in-situ colluvial talus beneath the boulder indicating an older age and possible large mass rockslide origin.

Photograph No. 17: (2413) Talus boulders and adjacent flat, low relief rock outcropping within the deposition zone below the PRSA-1 area and within the proposed Cultural Preservation Area.

Photograph No. 19: (2407) Scattered boulder deposits on gentle sloping terrain within the deposition zone below the PRSA-1 area and within the proposed Cultural Preservation Area. (Wpt. Boulder1-1).

Photograph No. 18: (2410) Cobble and boulder talus accumulations near the break in slope just below the PRSA-1 area and above the proposed Cultural Preservation Area.

Photograph No. 20: (2409) Example of piles of boulders within the deposition zone below the PRSA-1 area and within the proposed Cultural Preservation Area. (Wpt. Boulder1-2).

Photograph No. 21: (2349) Area of scattered low relief rock outcroppings with limited rockfall potential at the western side of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OC1A).

Photograph No. 23: (2374) Other widely scattered low relief rock outcroppings with limited rockfall potential at the western side of the PRSA-2 area shown on the Site Plan, Plate 2.

Photograph No. 22: (2350) Generally isolated to widely scattered rock outcroppings with limited rockfall potential at the western side of the PRSA-2 area shown on the Site Plan, Plate 2.

Photograph No. 24: (2375) Isolated outcropping within the PRSA-2 area showing the strong microfracturing in the rock. This type of rock material is likely to shatter into angular small pieces during a rockfall event due to the presence of the fracturing.

Photograph No. 25: (2376) Flat low relief rock outcropping with very limited rockfall potential at the western side of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OC1A).

Photograph No. 27: (2388) Isolated protruding spherical rock outcropping within an area of scattered outcroppings at the upper elevation western portion of the PRSA-2 area. (Wpt. OC1-1).

Photograph No. 26: (2351) Other low relief rock outcropping at the western side of the PRSA-2 area. Note the strong microfracturing in the elongated outcropping that resembles a volcanic dike trend.

Photograph No. 28: (2391) Isolated larger rock outcropping at the mid slope region within the western side of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OC5).

Photograph No. 29: (2396) Widely scattered to isolated rock outcroppings at the mid slope region within the western side of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OC6).

Photograph No. 31: (2399) Opposing view of the outcropping in Photograph No. 30 showing the precarious setting on the sloping terrain.

Photograph No. 30: (2397) Isolated larger rock outcropping at the mid slope region within the western side of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OC6-1).

Photograph No. 32: (2606) A portion of an existing large, highly weathered and elongated rock outcropping on the southern side slope of a primary ravine at about the mid slope elevation within the central portion of the PRSA-2 area and along Slope Profile “C” shown on the Site Plan, Plate 2. (Wpt. OCA14).

Photograph No. 33: (2607) Another portion of the elongated outcrop described in Photograph No. 32. (Wpt. OCA14).

Photograph No. 35: (2603) Fractured rock outcropping on the ravine side slope along Slope Profile "C" and within the central portion of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OCA13).

Photograph No. 34: (2605) Typical ground surface in the primary ravine below existing rock outcroppings where some cobble talus accumulations were observed. (Wpt. OCA13).

Photograph No. 36: (2604) Typical gentle slope and dense vegetation conditions within the ravine and down slope from the side slope outcroppings noted previously.

Photograph No. 37: (2599) Large, embedded, rounded rock outcropping observed on the ravine side slope along Slope Profile "C" and within the central portion of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OCA13).

Photograph No. 39: (2596) Typical talus debris accumulations within the mid elevation portion of the ravine at the central portion of the PRSA-2 area shown on the Site Plan, Plate 2.

Photograph No. 38: (2597) Flat low relief rock outcropping within the lower portion of the ravine (along Slope Profile "C") within the PRSA-2 area shown on the Site Plan, Plate 2.

Photograph No. 40: (2592) Portion of an elongated rock outcropping spanning about 60 feet in length along the northern side slope of the ravine at the central portion of the PRSA-2 area shown on the Site Plan, Plate 2. The outcropping is near the lower elevation boundary of the PRSA-2 area. (Wpt. Ledge).

Photograph No. 41: (2594) Another portion of the outcrop from Photograph No. 40 showing the relatively flat ground fronting the elongated rock ledge outcropping. (Wpt. Ledge).

Photograph No. 43: (2587) Fractured and highly weathered rock outcropping at the eastern portion of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OC11).

Photograph No. 42: (2588) Another flat, low relief rock outcropping within the ravine at the eastern portion of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OC12).

Photograph No. 44: (2586) Isolated, fractured and highly weathered rock outcropping at the eastern portion of the PRSA-2 area shown on the Site Plan, Plate 2. (Wpt. OC10).

Photograph No. 45: (2381) Existing concrete well housing containing an active groundwater spring with seepage in the lower basin area of the project site.

Photograph No. 47: (2382) Other observed groundwater seepage condition in the vicinity of the groundwater spring well head.

Photograph No. 46: (2383) Stagnant water within a swale located downstream from the groundwater spring well head.

Photograph No. 48: (2380) Another gentle swale feature that appears to transmit periodic drainage in the vicinity of the groundwater spring well head.

Photograph No. 49: (2384) Existing rock pile in the vicinity of the groundwater spring well head in the lower basin area of the project site. The rock pile appears to be anomalous and man-made.

Photograph No. 51: (2612) Existing scoured shallow subsurface exposure showing conditions that appear to represent older alluvial/colluvial soil deposits containing appreciable rock fragments consisting of gravel, cobbles, and boulders. The location is within the lower central basin area. (Wpt. 0161)

Photograph No. 50: (2609) Large, rounded boulders embedded and partly embedded in the soils of the lower basin area. (Wpt. Boulders15)

Photograph No. 52: (2613) Existing primary drainage channel at the central basin portion of the site and just upstream from the existing concrete culvert drainage structure at Lipalu Street.

Photograph No. 53: (2614) Another view of the primary basin drainage channel showing various cobbles and boulders within the channel. The deposits are believed to represent rocks scoured from the alluvial and colluvial deposits that comprise portions of the lower basin area.

Photograph No. 55: (2616) Existing concrete drainage culvert at the end of Lipalu Street.

Photograph No. 54: (2615) Opposing bank of the primary basin channel showing reddish soils with a few embedded rounded cobbles on the channel side slope.

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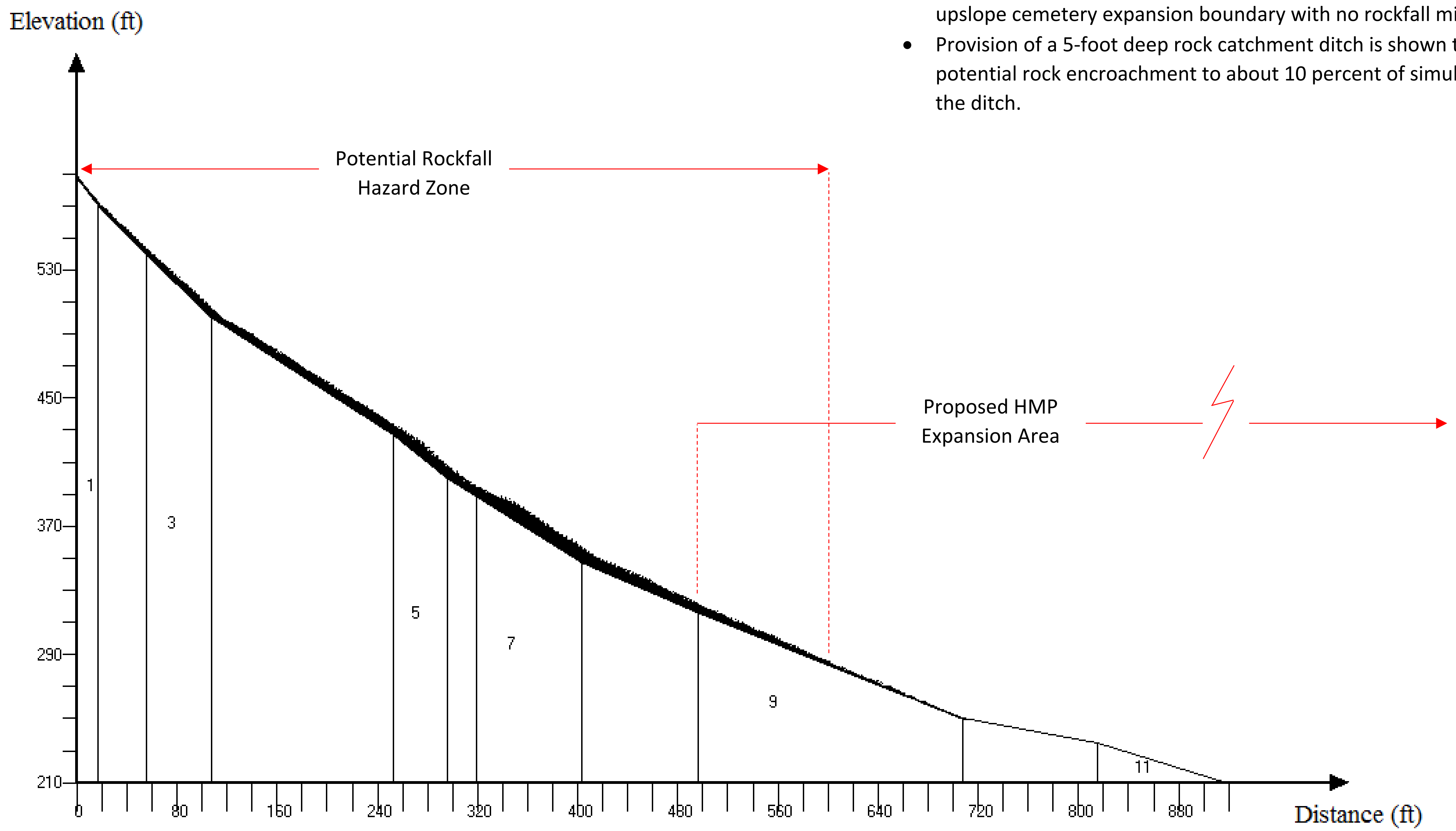
APPENDIX D

HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
KANEOHE, OAHU, HAWAII

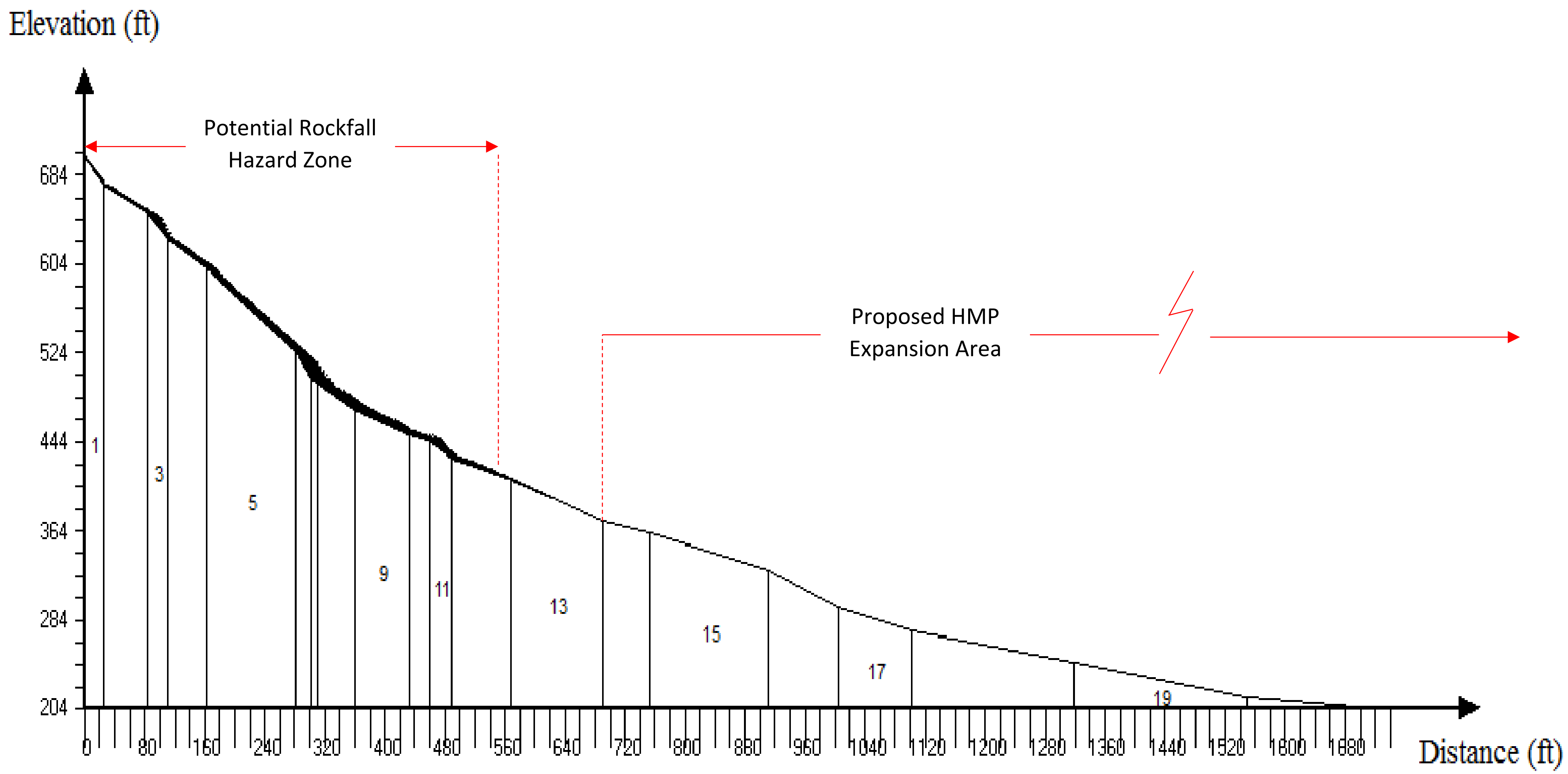
Notes:
- Approximately 64 to 66 percent of simulated falling rock is shown to pass the upslope cemetery expansion boundary with no rockfall mitigation in place.
- Provision of a 5-foot deep rock catchment ditch is shown to reduce the potential rock encroachment to about 10 percent of simulated rockfall passing the ditch.



POTENTIAL ROCKFALL SIMULATION – SLOPE PROFILE "A"
NOT TO SCALE
Image Vertical Exaggeration: 1.28

HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
KANEOHE, OAHU, HAWAII

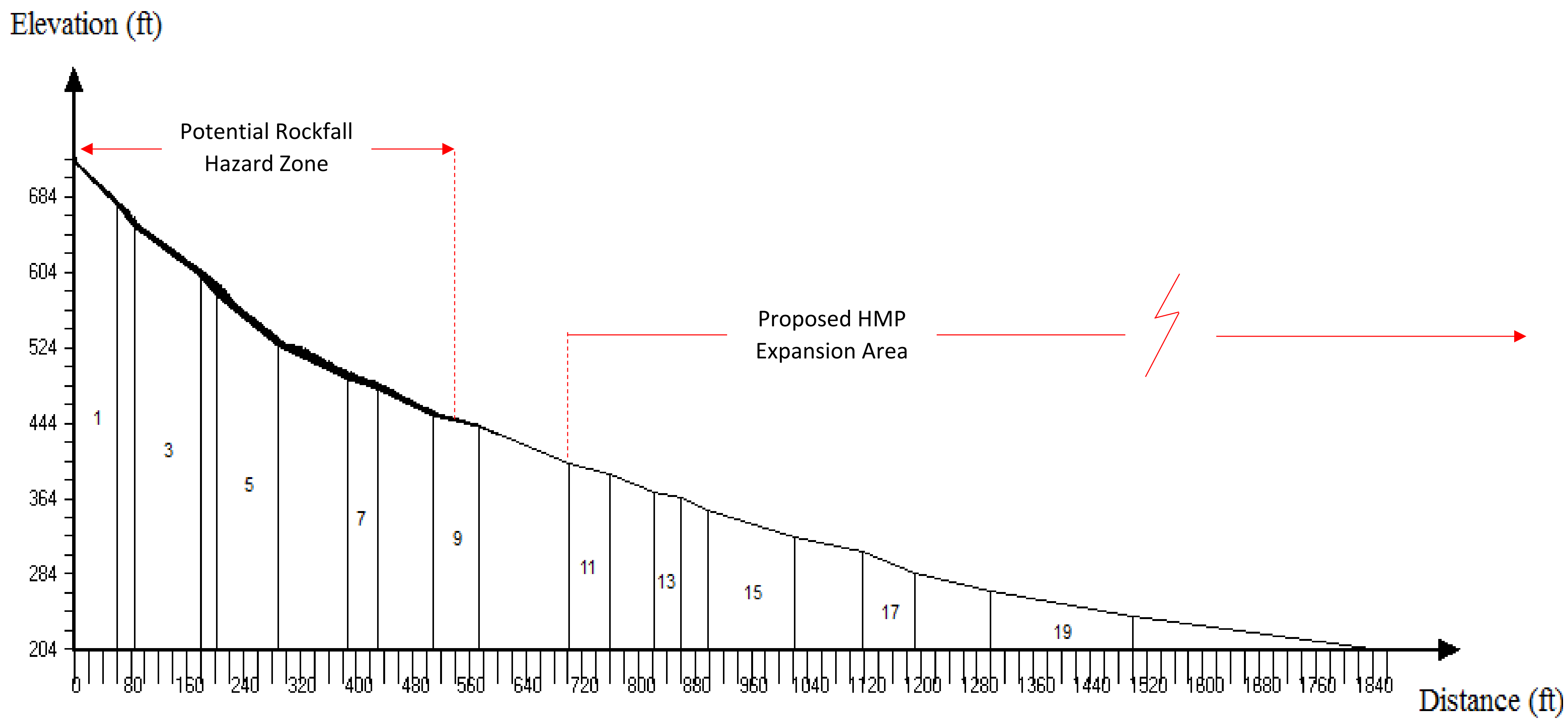
Note:
- No simulated rockfall is shown to pass the upslope cemetery expansion boundary with no rockfall mitigation in place.



POTENTIAL ROCKFALL SIMULATION – SLOPE PROFILE "B"
NOT TO SCALE
Image Vertical Exaggeration: 1.48

HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
KANEOHE, OAHU, HAWAII

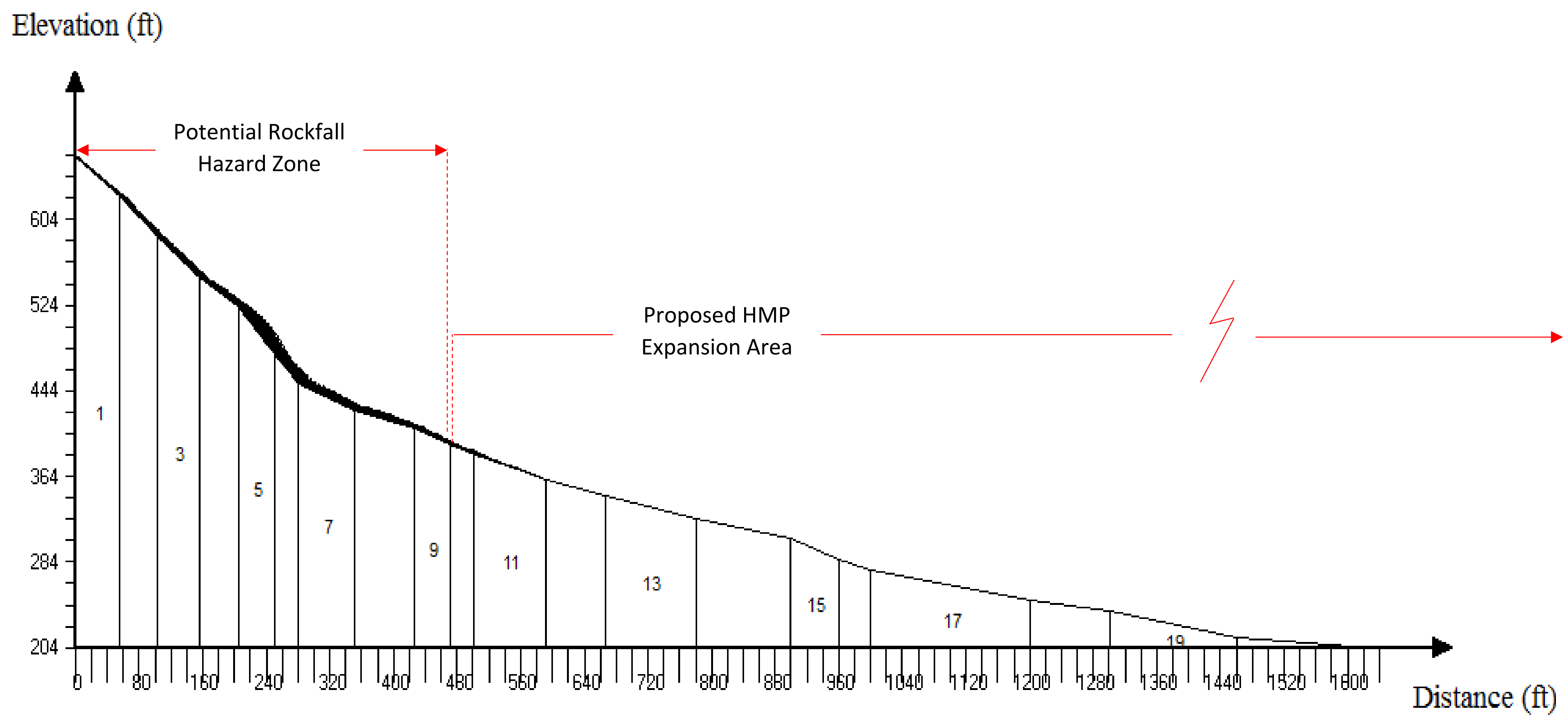
Note:
- No simulated rockfall is shown to pass the upslope cemetery expansion boundary with no rockfall mitigation in place.



POTENTIAL ROCKFALL SIMULATION – SLOPE PROFILE "C"
NOT TO SCALE
Image Vertical Exaggeration: 1.29

HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
KANEOHE, OAHU, HAWAII

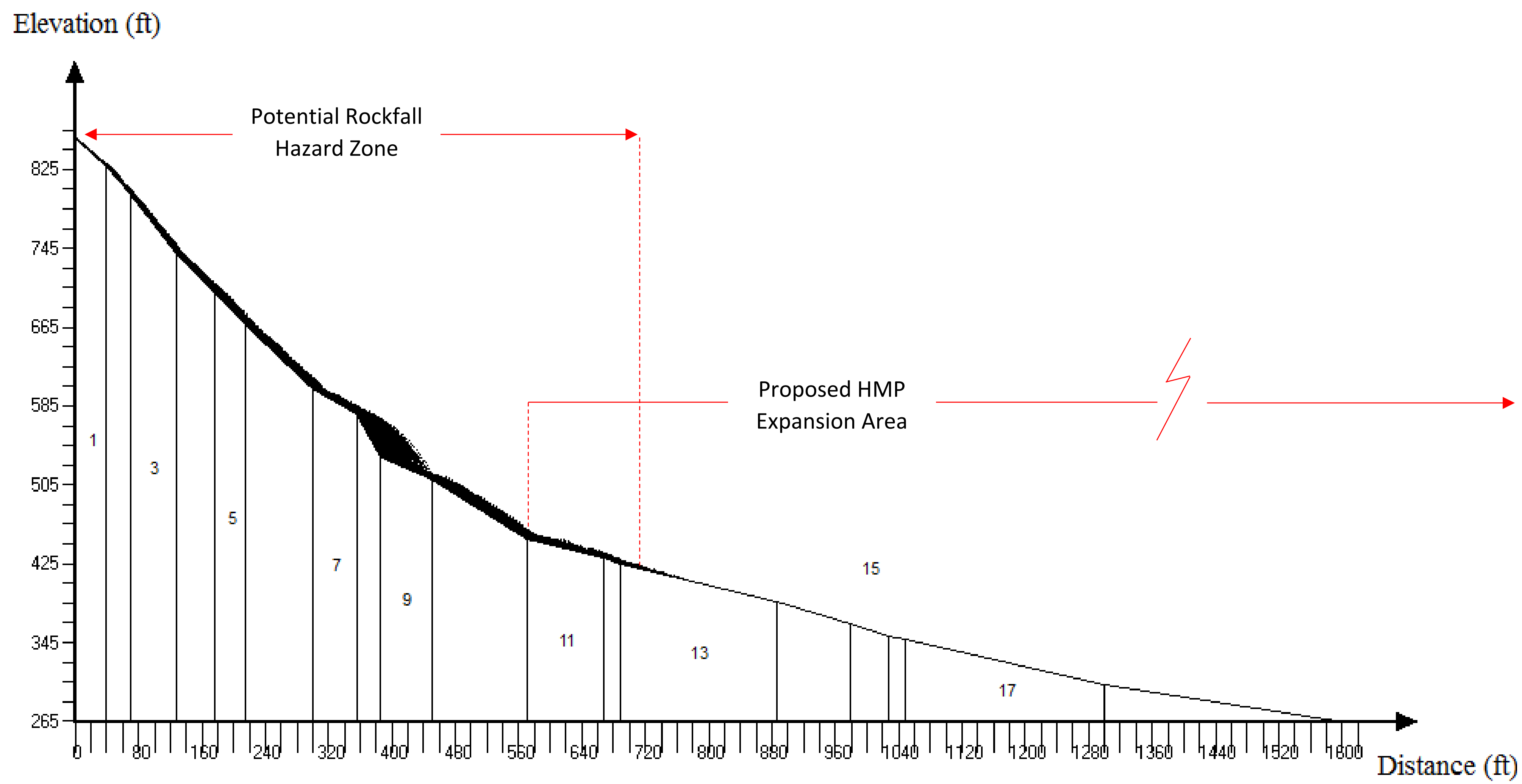
Note:
- Less than 10 percent of simulated falling rocks is shown to pass the upslope cemetery expansion boundary with no rock fall mitigation in place.



POTENTIAL ROCKFALL SIMULATION – SLOPE PROFILE "D"
NOT TO SCALE
Image Vertical Exaggeration: 1.42

HAWAIIAN MEMORIAL PARK CEMETERY EXPANSION
KANEOHE, OAHU, HAWAII

Note:
- Approximately 86 percent of simulated falling rock is shown to pass the upslope cemetery expansion boundary with no rockfall mitigation in place.



POTENTIAL ROCKFALL SIMULATION – SLOPE PROFILE "E"
NOT TO SCALE
Image Vertical Exaggeration: 1.27