PRELIMINARY ENGINEERING GEOLOGIC AND GEOTECHNICAL INVESTIGATION:

DARK GULCH CROSSING STABILIZATION PROJECT

Pescadero Creek County Park

San Mateo County, CA

March 2019 (revised)

Prepared for:

San Mateo County Resource Conservation District
625 Miramontes Street, Suite 103
Half Moon Bay, CA 94019

SMCRCD- OLDHAULROAD-SRP-688

TIMOTHY C. BEST, CEG #1682
ENGINEERING GEOLOGY AND HYDROLOGY
1002 Columbia Street, Santa Cruz, CA 95060 • Tel (831) 425-5832 • Fax: (831) 425-5830 • e-mail: timbest@coastgeo.com

TIMOTHY C. BEST, CEG
ENGINEERING GEOLOGY AND HYDROLOGY

1002 Columbia Street, Santa Cruz, CA 95060
(831) 425-5832 ● Fax: (831) 425-5830 ● e-mail: timbest@coastgeo.com

March 11, 2019 (revised)

Ms. Sara Polgar
San Mateo County Resource Conservation District
625 Miramontes Street Suite 103
Half Moon Bay, CA 94019

Job: SMRCD-DARKGULCH-775

REFERENCE: PRELIMINARY ENGINEERING GEOLOGIC AND GEOTECHNICAL INVESTIGATION: DARK GULCH CROSSING STABILIZATION PROJECT
Old Haul Road, Pescadero Creek County Park, San Mateo County, CA

Dear Ms. Polar:

This report and accompanying plan sheets presents the findings of our preliminary engineering and geotechnical investigation of the proposed crossing repairs at Dark Gulch located along Old Haul Road in Pescadero Creek County Park.

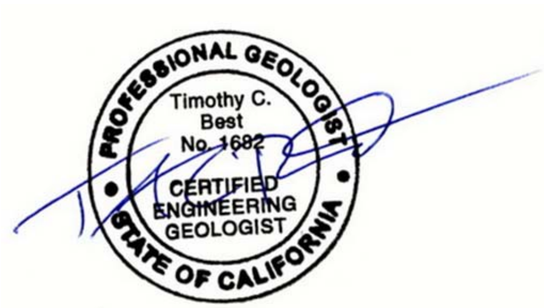
The Dark Gulch crossing is an actively failing crib log crossing located on the Old Haul Road within the Park. The crossing consists of over 37,000 cy of fill that is partially supported by decaying crib logs. The crib logs forming the foundation and internal reinforcement of this crossing are decaying and starting to collapse resulting in large volumes of sediment to be delivered to the stream network and has compromised the safe use of the roadway. If left untreated, erosion and instability is likely to occur at an increasing higher rate as the log decay further and erosion undermines the embankments.

The project proposes to stabilize the crossing by excavating the unstable and actively failing fill material and accompanying embedded logs, installing a large diameter culvert to safely convey streamflow past the road, and reconstructing of the road prism on new engineered fill. Additional improves to road drainage are also proposed along Old Haul Road to reduce fine grained sediment delivery to the stream,

The proposed road improvements are designed to improve habitat conditions and water quality in the Pescadero-Butano Watershed for the benefit of native fish and other species by reducing sediment sources into Pescadero Creek. Stabilizing the crossings will also result in safe road access for continued recreation, administrative and emergency purposes for San Mateo County Parks Department and CalFire.

Please contact us if you have any questions regarding the contents of this report.

Very truly yours,



Timothy C. Best
Certified Engineering Geologist #1682

CONTENTS

INTRODUCTION

This report summarizes the findings of our engineering and geotechnical investigation of the Dark Gulch stream crossing. The project site is located on Old Haul Road in Pescadero Creek County Park in an unincorporated region of San Mateo County, California (Figure 1).

The Dark Gulch crossing is a large 1940's era crib log crossing incorporating over 37,000 cy of fill material up to 70 feet deep. The interlocking crib logs that support the crossing are actively failing resulting in increased sediment loading to Pescadero Creek with associated impacts to water quality, and has compromised safe use of the roadway. If left untreated, erosion and instability is likely to occur at an increasing higher rate as the logs decay further and erosion undermines the embankments with the possibility of significant damage to the downstream channel and structures (e.g. bridge) if the crossing were to catastrophically fail.

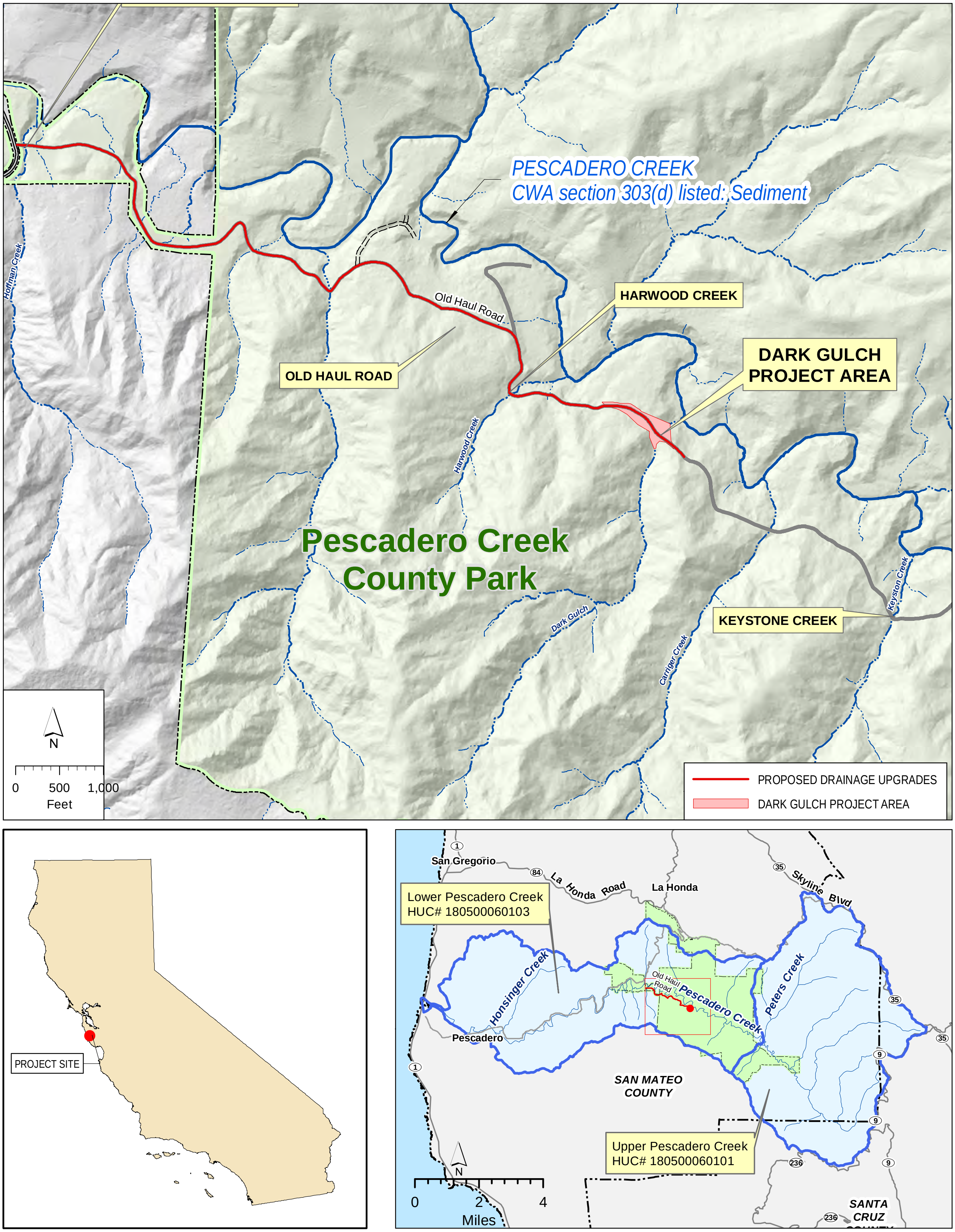
The project proposes to stabilize the failing crossing to reduce sediment loading and other environmental impacts to Pescadero Creek while maintaining safe recreational and restricted emergency and maintenance vehicle access. This work will require the excavation of the unstable and actively failing fill material and accompanying embedded crib logs, installation of large diameter culvert to safely convey streamflow past the road, and reconstruction of the road prism on new engineered fill. Drainage upgrades along Old Haul Road adjacent to the work area will also be improved by installing new or enlarging exiting daring dips and rocking the road surface.

SCOPE OF SERVICES

This investigation was undertaken at the request of the San Mateo County Resource Conservation District (RCD) and San Mateo County Parks (Parks) to evaluate the geologic, geotechnical and hydrologic conditions at the project site, and to develop recommendations and design parameters to reconstruct and stabilize the stream crossing with the overarching goal to reduce road related sediment delivery to Pescadero Creek while maintaining important recreational trail and restricted vehicle access. This investigation was undertaken in association with Geotechnical Engineers Haro Kasunich and Associates, Inc. (HKA).

Work performed during this investigation included:

1. Review of existing background information (data and reports) related to the project;
2. Topographic site survey of Dark Gulch;
3. Geologic and geomorphic field mapping;
4. Drilling of four exploratory borings to evaluate geotechnical properties of soil and to confirm depth of road fill;
5. Laboratory testing of soils strength and compaction;
6. Geotechnical, hydrologic and engineering analysis;
7. Discussions with District Staff, Parks Staff and Geotechnical Engineer;
8. Preparation of this report and the accompanying plan sheets.



TIMOTHY C. BEST, CEG
ENGINEERING GEOLOGY AND HYDROLOGY
1002 Columbia Street, Santa Cruz, CA 95060
(831) 425 5832 (831) 425 5830 (fax)

LOCATION MAP

DARK GULCH STABILIZATION PROJECT
PESCADERO CREEK COUNTY PARK, SAN MATEO COUNTY, CA

FIGURE 1

Job: SMRCD-DARKGULCH-775
Date: Date: 3/11/2019

This report is a revision our earlier March 23, 2015 report to focus on Dark Gulch and to incorporate a more detailed topographic surveying and subsurface exploration to more accurately define the fill limits and soil characteristics. It also addresses the impacts of the 2017 storms which resulted in the partial failure of the Dark Gulch stream crossing.

BACKGROUND

The project area is located within the Pescadero Creek watershed, an important anadromous river to the California Central Coast, supporting coho salmon and steelhead trout. Pescadero Creek is listed as impaired by sediment under the Clean Water Act Section 303(d). Ongoing erosion of the stream crossing is resulting in increased sediment loads to Pescadero Creek potentially adversely impacting water quality.

Old Haul Road extends over 5 miles through the Park on the south side of Pescadero Creek. The majority of the road was constructed in the early 1900’s to 1940’s by Santa Cruz Lumber Company as a rail line providing access to their mill in upper Pescadero Creek. The rail line was later converted to a main line truck road for use in subsequent timber operations.

The San Mateo County Parks Department (Department) currently maintains Pescadero Creek County Park for recreational, administrative, and emergency access purposes, and Old Haul Road is used by Department staff at least once per day for vehicle access in support of these functions. The road is also utilized by CalFire for emergency and maintenance vehicle access. Continued erosion of the crossing has compromised safe vehicle access.

OLD HAUL ROAD HISTORY

The road was constructed across locally steep slopes at a wide 20 to 40+ foot width and with a relatively straight and constant grade. At the tributary crossings to Pescadero Creek, the crossings were constructed by infilling the narrow and incised drainages with large volumes of fill to form a level rail road grade with constant gradient. Many of the fill embankments were partially supported by large crib logs stacked like a log cabin. At Dark Gulch these walls were greater than 20 feet in height. Crib logs were also used to form log “box” culverts at the base of the fill to convey stream from one side of the crossing to the other. Log stringers were used to cap the top of the box culvert, in much the same way as a bridge, and the entire structure then backfilled and capped by thick fill. An opening was likely left at the bottom of the structure for the stream to flow through, which has since collapsed. An example of a log bridge on Old Haul Road is shown in Photo 1A, and a large fill embankment shown in Photo 1B.

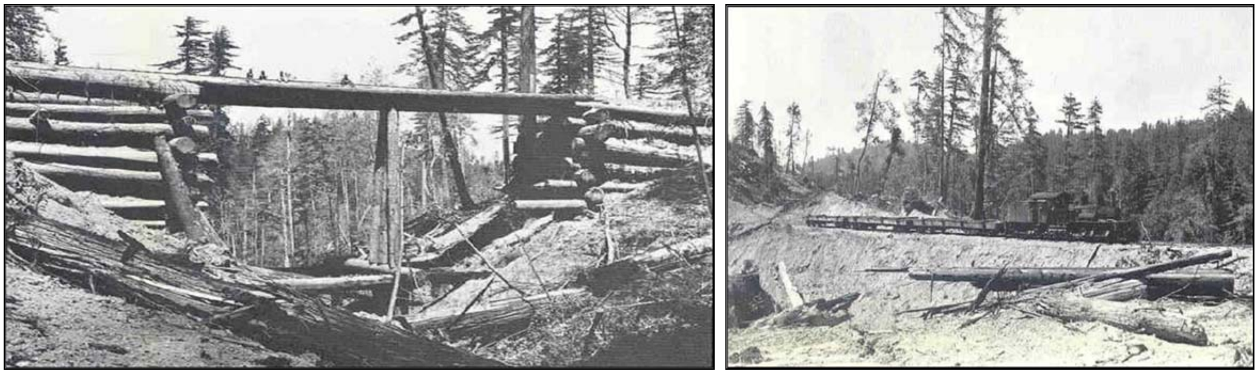


Photo 1: Rail crossings on Old Haul Road circa 1940s. Left Photo (A) shows tressel and possible crib log box culvert. Note the men sitting on top of the crossing. (Santa Cruz Lumber Company photo (1943)). Right Photo (B) is an example of large fill embankment. (Jack Gison photo (1947)). Both photos referenced in Dwight Ennis, http://www.santacruzlumberco.com/index1.htm)

Over the past 70 to 100 years the logs that make up the structural integrity of the crossings have decayed and the box culverts that convey stream flow through the fill embankment have collapsed to varying degrees. As a result the overlying fill has settled and infilled the watercourse and no longer allows safe passage of stream runoff through the crossing. Stream flow is thus forced to percolate through the fill eroding and forming cavities within the fill. Where cavities have collapsed, cone shaped “sinkholes” have developed on the ground surface which presents a safety hazard to users of the road. In 2014-15 our firm reviewed the condition of the Old Haul Road and found active and ongoing erosion occurring at several watercourse crossings with the most significant occurring at Dark Gulch.

Some of the old crossings have completely failed and the road is now rerouted around the failure upstream. During the 2017 storms partial failures occurred at Harwood Creek, Dark Gulch, and Keyston Creek. Both Harwood and Keyson crossings were repaired in 2018. Temporary repairs were made to Dark Gulch to allow for temporary access, however, this work did not correct the underlying cause for crossing failure and the crossing is still at high risk for failure.

PAST STUDIES

Several earlier studies have been undertaken to review erosion and stability concerns along Old Haul Road.

1995 Storms and subsequent inter agency review. In January and March 1995 the area experienced a series of large storms that resulted in widespread erosion and instability in the Pescadero Creek area, including portions of the Old Haul Road. In response, a multi-agency technical review team was convened to review erosion stability concerns at the crib log crossings. The review team found the majority of the drainage structures are at risk for future failure with the potential to release significant quantities of sediment over time.

1998 Storms, PWA Sediment Assessment and subsequent road upgrades: The watershed again experienced significant storms in 1998 as documented by Pacific Watershed Associates (2003) in "Sediment Assessment of Roads and Trails within the Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek Watershed, San Mateo County, California". In response to the PWA assessment, portions of the Old Haul Road were upgraded by installing rolling drain dips, though little work appears to have been done on the larger watercourse crossings.

2014-15 Road Erosion Inventory and interagency meeting: In 2014-15 our firm reviewed the condition of the Old Haul Road and found active and ongoing erosion occurring at several watercourse crossings with the most significant occurring at Dark Gulch (Best, 2015).

2015: We discussed the results of our 2015 assessment in a February 2015 field meetings attended by representatives of San Mateo County Resource Conservation District (RCD), San Mateo County Parks (Parks), California Department of Fish and Wildlife (CDFW), US Fish and Wildlife service (USFWS), and NOAA National Marine Fisheries Service (NMFS). The purpose of these meetings were to discuss the implication and risks of future erosion along the Old Haul Road, identify sites with the greatest need of immediate treatment, and funding sources for implementation. These meetings concluded the Dark Gulch crossing should be repaired as soon as possible.

2015 Dark Gulch Upgrade and Sediment Reduction Project: In March 2015 we prepared a revised report and 35% construction documents to improve Dark Gulch. We identified four treatment alternatives with the preferred alternative being installation of a large diameter culvert and replacement of the crossing fill. In this alternative all unstable fill material would be removed, a large diameter culvert capable of conveying a 100 year flood flow installed, and the crossing embankment reconstructed with engineered fill.

2017 Storms: In the 2017 the watershed again experienced a series of large storms that resulted in widespread erosion and instability throughout the Santa Cruz Mountains. At Dark Gulch the existing sinkholes enlarged significantly from water flowing through the bottom of the fill prism and a large portion of the downstream fill embankment failed as a debris slide. Portions of the remaining fill prism have cracked and shows signs of instability. In addition to the distress at Dark Gulch, a large sink hole developed in Hardwood Creek crossing and the outer fill prism at Keyston Creek failed.

2017 Plan Revision and Geotechnical Investigation: In 2017-18 we were retained by San Mateo County RCD to update our March 2015 report and construction documents for Harwood Creek, Keyston Creek and Dark Gulch. This work included preparation of a surveyed topographic map, subsurface exploratory borings to determine depth and characteristics of fill, and geotechnical and slope stability analysis to provide grading and compaction requirements. A separate report and plan set was prepared for Harwood and Keyston. This current report presents our findings at Dark Gulch.

2018 Harwood Creek and Keyston Creek Upgrades: In early 2018 we prepared construction documents for repairs at Harwood and Keyston Creeks, which incorporated removal of unstable fill material, installation of new culverts, and reconstruction of the fill embankment. The recommended work was successfully completed in fall 2018.

REGIONAL SETTING

REGIONAL GEOGRAPHIC SETTING

LOCATION

The proposed project is located along Old Haul Road in Pescadero Creek County Park in an unincorporated region of San Mateo County, California (Figure 1).

PHYSIOGRAPHY

The project area is located on moderate to steep slopes along the south side of Pescadero Creek (Figure 2). Slope gradients range from less than 10% on the valley bottom and streamside benches to greater than 75% on local steep streamside slopes and other areas. Hillslopes tend to be slightly convex, rounded towards the ridge top and steepening to the valley bottom. Topography is locally benched and irregular consistent with large-scale deep-seated landsliding. Pescadero Creek and its larger tributaries are deeply incised into the landscape with local steep streamside and inner gorge slopes. Shallow landslide processes are intermittently active on these steep slopes. A series of intermittent fluvial terraces are found along Pescadero Creek.

VEGETATION

Vegetation is primarily second growth redwood and Douglas-fir with patches of hardwood and grassland.

CLIMATE

The local climate is characterized as Mediterranean with warm, dry summers and mild, wet winters. The mean annual precipitation is 33.5 to 36 inches (CalTrans, 2013). The area is subject to periodic high intensity rainfall with significant rainfall events having occurred most recently in 1956, 1982, 1984, and 1996.

REGIONAL GEOLOGIC SETTING

The plan area is situated on the western flank of the Coast Range Physiographic Province of Northwest California, a series of coastal mountain chains paralleling the pronounced northwest-southeast structural grain of northwest California. These mountain ranges are controlled by folds and faults that resulted from the collision of the Pacific and North American plates and subsequent strike-slip faulting along the San Andreas Fault zone. The area is geologically active, dominated by the northwest-southeast trending San Andreas Fault Zone (SAFZ) located about 7 miles northeast from the site.

GEOLOGY AND SOILS

Regional mapping by Brabb et al. (1998) shows the project area located immediately south of the Butano Fault which at this location parallels Pescadero Creek and juxtaposes marine clastic sediments rocks of Butano Sandstone (Tb) to the south against Tahana Member of the Purisma Formation (Tpt) to the north (Figure 2). Project site is mapped as underlain by Butano Sandstone (Tb) which is described as a massive to poorly bedded sandstone with local interbeds of mudstone and shale. The Tahana Member of the Purisma Formation (Tpt), located to the north of the project site is described as a medium- to very fine-grained sandstone, siltstone and mudstone. Bedding generally strikes northwest and dips steeply to the northeast.

Overlying bedrock is colluvium, weathered bedrock and non-engineered fill. The depth of these deposits is variable but typically thickest towards the base of hillsides and axes of swales and drainages and thinnest on the steeper side slopes where material has moved by erosion and shallow landsliding. Colluvial sediments generally consist of loose silty sand, clayey sandy silt and lean silty clay.

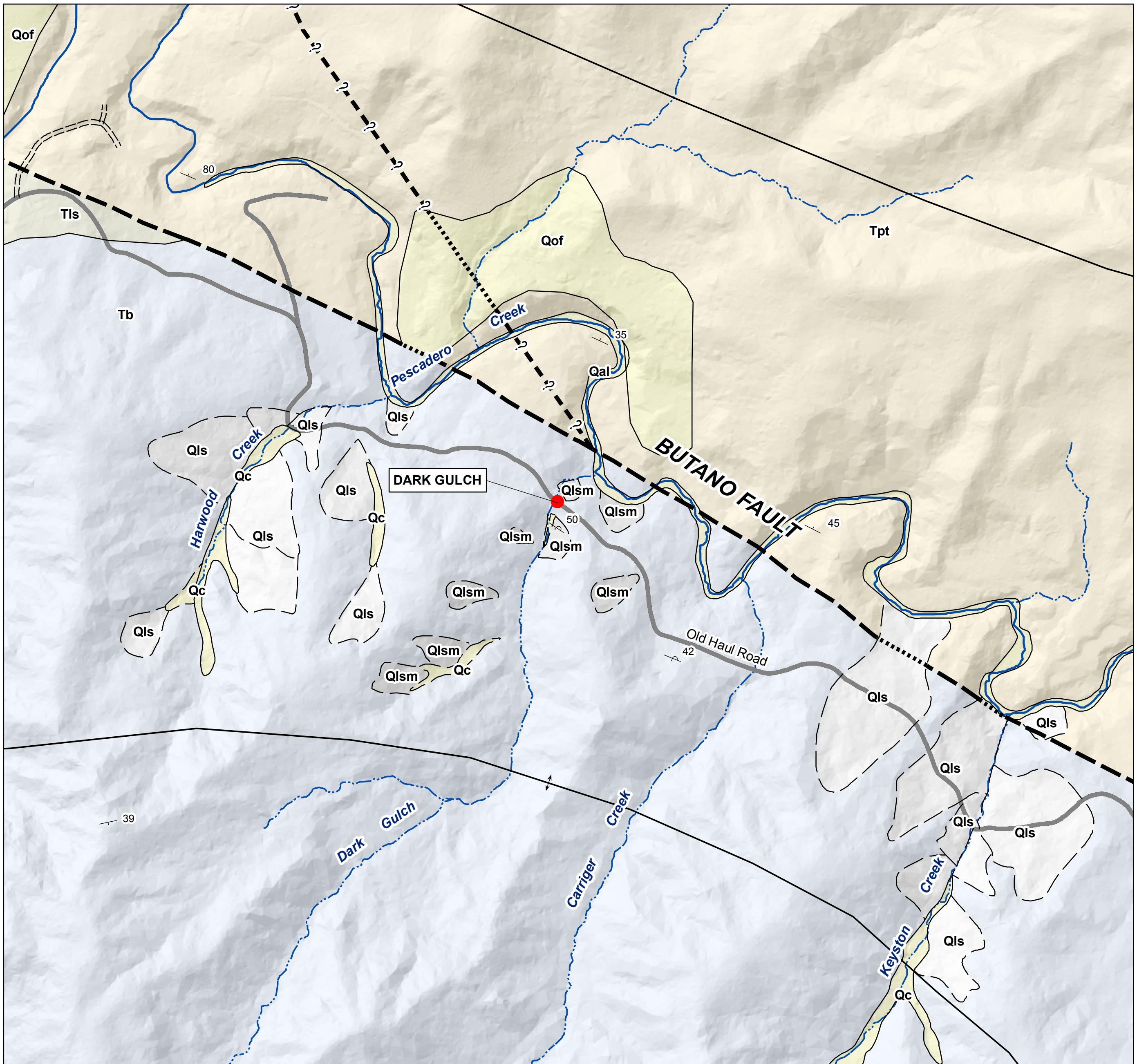
FAULTING AND SEISMICITY

The subject property is located within a highly seismically-active region of California. A broad system of inter-related northwest-southeast trending strike-slip faults represents a segment of the boundary between the Pacific and North American crustal plates. For approximately the past 15 million years (mid-Miocene) the Pacific plate has been slipping northwestward with respect to the North American plate (Atwater, 1970; Graham and Dickinson, 1978). The majority of movement has been taken up by the San Andreas Fault itself; however, there are other faults within this broad system that have also experienced movement at one time or another including Butano, La Honda, and San Gregorio Faults.

The subject site is located approximately 7 miles southwest of the active San Andreas Fault zone. The San Andreas Fault is a right-lateral strike slip fault capable of generating a Maximum Moment Magnitude 7.9 earthquake with a recurrence interval of roughly 210 years (Petersen et al., 1996). This segment of the San Andreas Fault last ruptured in 1906. The San Andreas Fault is the closest fault to the property with a high probability of generating a large magnitude earthquake in the next 50 years.

The Butano Fault transects the project area immediately to the north. Based on Pliocene stratigraphic offsets, geomorphic evidence, and questionable historic seismicity, the Butano fault may be active. Based on its position relative to the San Andreas Fault, the Butano may be capable of a magnitude 6.4 earthquake.

The property is subject to strong ground motions during large magnitude earthquakes. High ground accelerations are likely responsible for incremental movement on many of the deep-seated landslides found in the area.



N

0 500 1,000
Feet

GEOLOGIC UNITS

- Qal: Alluvium
- Qlsm: Deep-seated landsde (approx.)
- Qcl: Colluvium
- Qof: Old Stream Terrace Deposits
- Tpt: Tahana Member of Purisma Formation
- Tsc: Santa Cruz Mudstone
- Tls: Lamber Shale and San Lorenzo Frm
- Tb: Butano Sandstone

SYMBOLS

- contact, approx
- Contact: certain
- Contact: approx. located
- fault, inferred, queried
- Fault - certain
- Fault - approximate
- Fault - concealed
- anticline
- Syncline
- Bedding
- Overturned bedding

Bedrock Geology from Brabb and others, 1998
Quaternary Geology in vicinity of project interpreted from 2014 San Mateo County LiDAR
Landslides in vicinity of project interpreted from 2014 San Mateo County LiDAR and should be considered approximate.

TIMOTHY C. BEST, CEG
ENGINEERING GEOLOGY AND HYDROLOGY
1002 Columbia Street, Santa Cruz, CA 95060
(831) 425 5832 (831) 425 5830 (fax)

GEOLOGIC MAP

DARK GULCH STABILIZATION PROJECT
PESCADERO CREEK COUNTY PARK, SAN MATEO COUNTY, CA

FIGURE 2
Job: SMRCD-DARKGULCH-775
Date: Date: 3/11/2019

REGIONAL LANDSLIDING

The geomorphology of the hillslopes surrounding the project area is locally consistent with infrequent shallow and deep-seated landslide processes. Shallow landslides are classified as debris slides, debris flows and channel bank failures and characterized by rapid, shallow (generally less than 10 feet thick) downslope movement of surficial soil, colluvium, and weathered bedrock. Most natural shallow slides are triggered by elevated porewater pressures resulting from high intensity and/or long duration rainfall or from being undercut by stream bank erosion. Deep-seated landslides, in comparison, tend to be larger and typically have a failure plane that extends well into bedrock. Most slides of this type tend to fail incrementally in response to large storms or earthquakes.

Deep-seated landsliding

Review of LiDAR imagery reveal that portions of the property are underlain by a series of large, relatively slow moving deep-seated translational block slides (Figure 2). These failures are characterized by benched topography and are formed by translational movement of a relatively intact mass with a failure plane that extends below the colluvial layer into the underlying bedrock. The slides typically consist of several smaller secondary blocks that coalesce together to form a larger landslide complex. In general, deep-seated landslides tend to fail incrementally in response to intense ground shaking from earthquakes on nearby faults (such as the 1906 San Francisco earthquake or 1989 Loma Prieta earthquake) and/or from prolonged heavy rainfall.

The majority of the deep-seated landslides in the project area exhibit distinct but subdued topography consistent “dormant-young" morphological age classification of Keaton and DeGraff (1996). Within the immediate project area we did not observed evidence of recent slide activity, such as fresh cracks, scarps, offset road prisms or leaning trees. Lobate toes with a well-defined zone of accumulation are also not apparent indicating the rate of slide movement is relatively slow in comparison to the rate of stream bank erosion. Overall, the rate of deep-seated landsliding appears to be slow and episodic.

Though no evidence of historic activity was observed, overall site morphology suggests that portions of the slides may periodically active and may subject to small scale slope displacements in response to long duration rainfall, undercutting of the hillslope by stream bank erosion, and/or from ground shaking from earthquakes on nearby faults. Future movement on these slides could damage or offset portions of the Old Haul Road prism requiring the road to be repaired. Overall we find this hazard to be relatively low.

Shallow-seated landsliding

Portions of the Dark Gulch drainage can be characterized as debris slide slopes having formed over time by repeated shallow landslide processes. Though slopes are locally steep no shallow landslides of significance were observed in the historic set of digital orthophotographs dating back to 1953. In our field review, we identified several small debris slides along the steep streamside slopes of the Dark Gulch drainage. Most of the recent slides we observed were relatively small events, typically mobilizing less than 100 to 200 cy and traveling only a short distance downslope.

DARK GULCH

EXISTING CONDITIONS

Dark Gulch is a narrow steep sided V-shaped valley draining a 183 acre forested watershed. The active stream channel is about 5 to 7 feet wide but has been heavily impacted with logging debris. The native channel grade (prior to construction of the crossing) is approximated at 16%. Side slopes are between 65% to 80+%. The steep sideslopes of the drainage are subject to shallow landslide processes.

Past Crossing Construction: The Dark Gulch crossing was constructed sometime in the mid 1940's by infilling the tributary with over 37,000 cy of fill material placed up to 69 feet thick (Figures 3 and 4). Much of the fill was likely generated by cutting into the steep hillside on the north side of the crossing forming a large (nearly 150 foot wide) landing.

The up and downstream sides of the crossing were partially supported with large (24 inch to 48 inch) diameter redwood crib logs stacked 15 to 25 feet high like a log cabin. The tie back logs to the crib wall extend about 20 feet into the fill embankment. A wood box culvert was likely built at the bottom of the fill conveyed stream flow through the crossing, though evidence of this structure is not visible, either having rotted away or been buried.

A large landing (bench) grained into the steep hillside is found immediately to the west of the crossing. This bench was likely graded to generate the large amount of fill material needed to construct the Dark Gulch crossing.

The Dark Gulch crosisng is visible in the 1948 aerial photographs (Photo 2) which shows bare ground along the Old Haul Road, the downstream crib wall and the large landing located to the west of the crossing. The upstream wall is not apparent in the aerial photographs due to the ground in that area appearing washed out in the photos. The area extending upstream along Pescadero Creek had been tractor harvested and the area downstream not yet reentered.

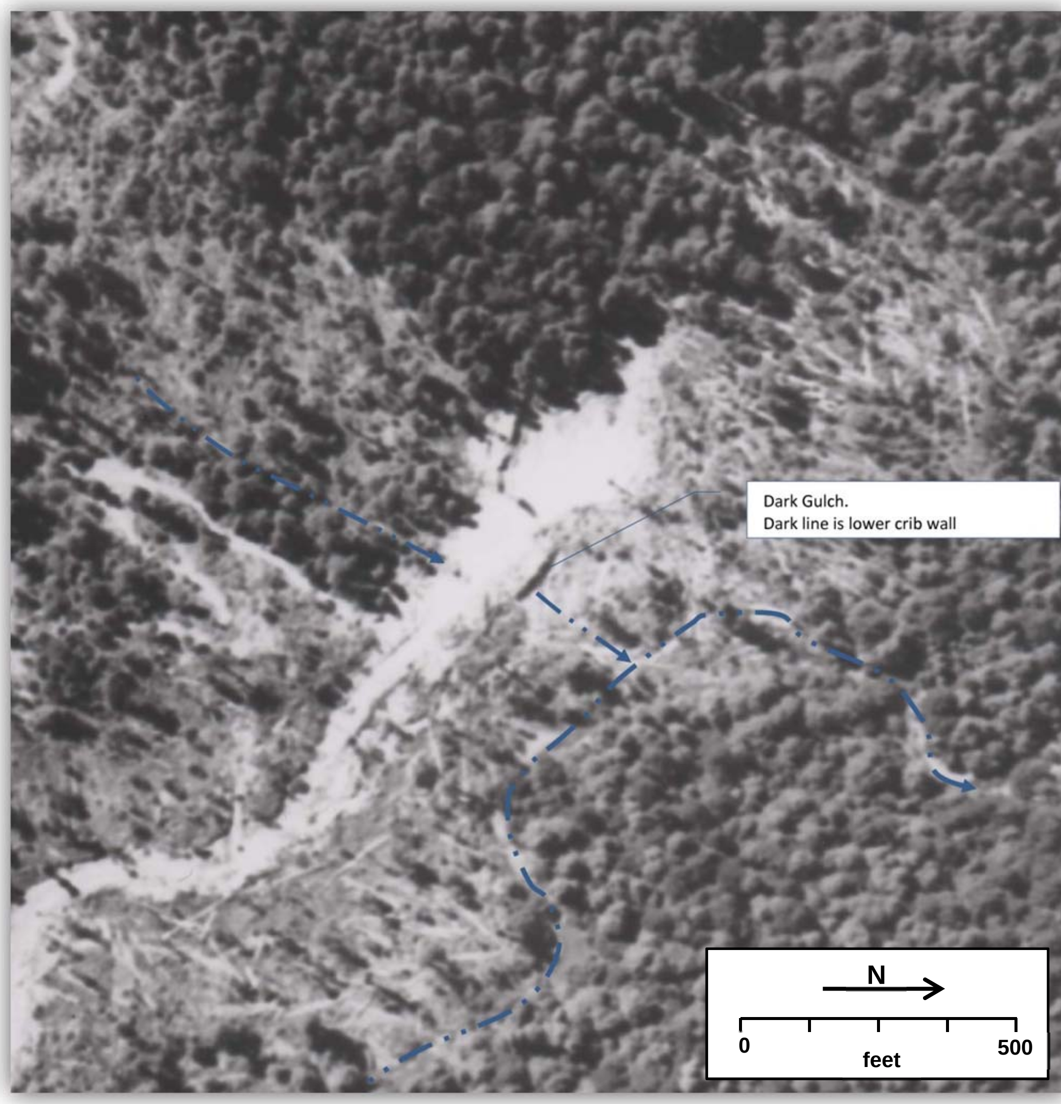
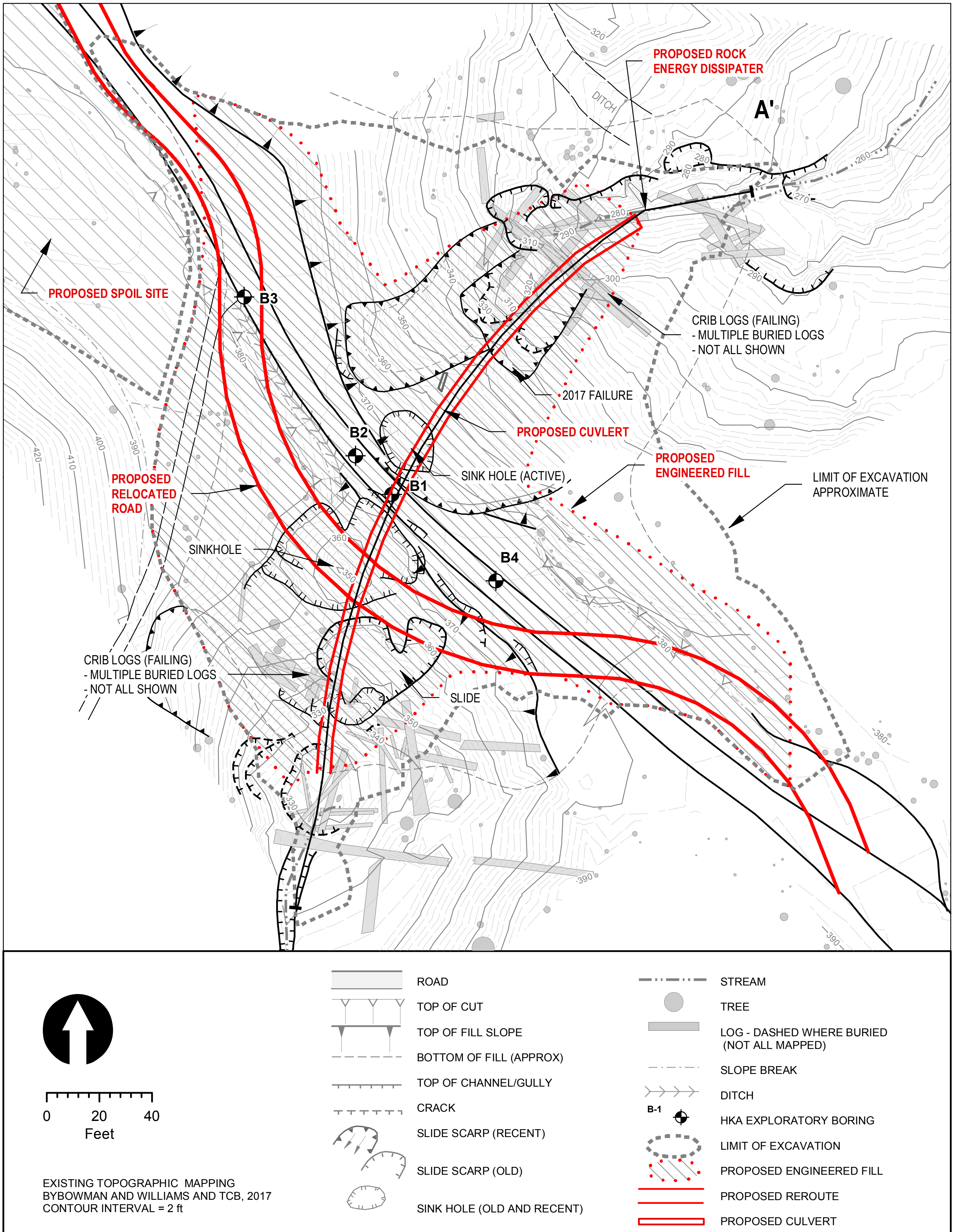


Photo 2: 1948 aerial photograph of Dark Gulch. The rail line appears to have been recently constructed down to this point. The photo clearly shows the shadow formed by the downstream cribwall. The upstream wall is not apparent due to the photo being washed out in that area. To the right of the crossing is a large landing. The spoils from the construction of this landing were likely used to infill Dark Gulch.

2014-15 Observations: In our 2014-15 assessment we found the logs that make up the structural integrity of the crossing were in varying states of decay and portions of some crib logs had failed or collapsed. Overtime the log structure that once upon a time functioned as a box culvert and allowed safe passage of storm runoff through the base of the fill had collapsed and infilled the watercourse. Stream flow was thus forced to percolate through the fill eroding and forming cavities within the fill. Where cavities have collapsed, cone shaped “sinkholes” have developed on the ground surface. These sinkholes essentially drain large volumes of eroding fill directly into the watercourse. There is abundant evidence of slope instability within the fill soils, including evidence that the massive fill that was built has settled approximately 6 feet vertically in the center third of the Old Haul Road where it crosses the creek.

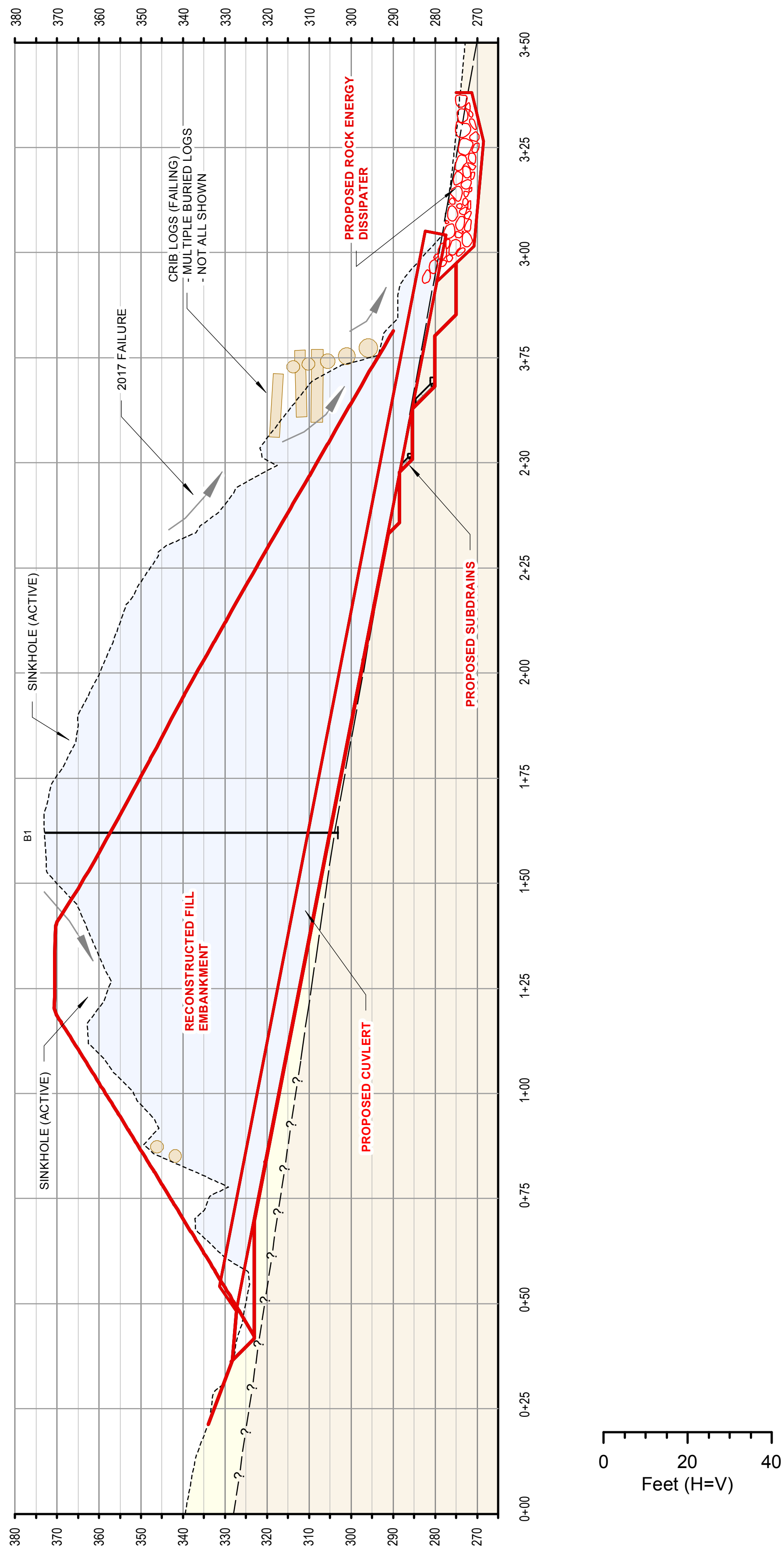


TIMOTHY C. BEST, CEG
ENGINEERING GEOLOGY AND HYDROLOGY
1002 Columbia Street, Santa Cruz, CA 95060
(831) 425 5832 (831) 425 5830 (fax)

SITE MAP

DARK GULCH STABILIZATION PROJECT
PESCADERO CREEK COUNTY PARK, SAN MATEO COUNTY, CA

FIGURE 3
Job: SMRCD-DARKGULCH-775
Date: 3/11/2019



TIMOTHY C. BEST, CEG
ENGINEERING GEOLOGY AND HYDROLOGY
1002 Columbia Street, Santa Cruz, CA 95060
(831) 425 5832 (831) 425 5830 (fax)

SECTION

DARK GULCH STABILIZATION PROJECT
PESCADERO CREEK COUNTY PARK, SAN MATEO COUNTY, CA

FIGURE 4

Job: SMRCD-DARKGULCH-775
Date: 3/11/2019

On the upstream side of the crossing is a 40 foot diameter sinkhole and a small debris flow. In 1996 Tom Spittler (CGS Engineering Geologist) noted erosion at this site and commented that an attempt appeared to have been made to repair it with end dumped rock. That attempt was only partially successful and only temporarily beneficial. Enlargement of this sinkhole has continued to occurred.

On the downstream side of the crossing we observed a smaller 15 foot diameter actively eroding sinkhole and a couple of larger debris flow scars. The sinkhole was not reported by Spittler (1996) and likely postdates his site visit. The sinkhole appears to have been regraded (date unknown) and partially backfilled with end dumped rock. Downslope of the sinkhole is the outlet of an 18 diameter plastic pipe that is aligned to drain the sinkhole. We saw no evidence of flow coming from the pipe and we suspect it is not functional. During our 2014-2015 and 2017 field reviews we documented additional failure and enlargement of the sinkhole, indicating ongoing collapse of the cavity below. The sinkhole has enlarged significantly both in size and depth.

We also observed evidence of old scarps, tension cracks, on old slope failures on both the upstream and downstream fill embankments. Large trees are involved in the mass movement and are translating and slumping downslope toward the stream channel.

2017 Storms: Significant erosion and instability of the fill embankment was observed following the 2017 storms. We estimate that over 500 cy of fill material eroded or failed this past winter.

On the upstream side of the crossing this included deepening and expansion of the large sinkhole, cracking and incipient instability of the fill embankment, and erosion and small slope failures along the toe of the fill.

Photo 3 Photo shows cracking of road prism around upstream sinkhole. The sinkhole has been covered with plastic tarp.

On the downstream side of the crossing the 2017 erosion and instability included the failure of a 40'L x 40'W x 4'+ D portion of the fill embankment as a debris slide behind the crib logs with this portion of the slope now no longer supported by the logs. In addition, significant expansion and deepening in the smaller sinkhole, erosion where stream flow emerges from the toe of the fill embankment, and local incipient cracking the fill face.

Photo 4 Photo showing upper 2017 slide scar

Photo 5 Photo showing lower portion of the 2017 slide scar. The cribwall that had supported the fill embankment is to the left of the photos. The exposed logs are the tie back logs that extended back into the fill prism and proving the structural integrity to the cribwall. With these logs now exposed the structural integrity if the wall has been compromised.

2018 Storms: Addition cracking of the upstream fill embankment was observed following the November – December 2018 storms

SITE GEOLOGY

Subsurface Conditions

Subsurface conditions were evaluated through field observations of soils exposed in the recent failures and from four exploratory borings drilled along the road bed. The soil profile consists up to 69 feet of fill overlying Butano Sandstone bedrock. Please refer to HKA geotechnical report in Appendix 1 for boring logs.

The fill consisted primarily of loose to medium dense silty sand to sandy silt with generally little organic material of significance to a depth of 69 feet, which correlates well to what would be predicted from interpretation of site topography. The lateral limits of fill are depicted on Figure 3

Preliminary geotechnical results find that with the exception of near surface soils, the majority of existing fill material is suitable for engineered fill in the reconstruction of the crossing. Further, it should be relatively straight forward to separate suitable from unsuitable fill when the crossing is reconstructed.

The bottom of Boring B-1 encountered an old redwood log or root on top of sandstone bedrock. No clayey organic rich soils were encountered. This suggests that a stable footing to the fill embankment exists, which is positive for crossing reconstruction.

Photo 6 Photo of the core sample taken near the end of Boring B1. The photo shows the log at the base of the fill (to the right) on top of sandstone bedrock (to the left)

HYDROLOGIC ANALYSIS

Historic streamflow records are not available for the project site; therefore indirect methods were required to estimate the 50 and 100-year peak discharge. 100-year peak flood discharge was estimated using USGS Magnitude and Frequency Method developed for rural ungauged stream in California. The method is outlined in Gotvald et al. (2012) and can be calculated using USGS Stream Stats Version 3 beta. The equations for 50 and 100 year event is as follows:

$$Q_{50} = 36.3A^{0.870} P^{0.589}$$
$$Q_{100} = 48.5A^{0.866} P^{0.566}$$

where:

$Q_{50/100}$ Peak discharge in cfs
A Drainage area in square miles = 0.3 mi^2
P Mean annual precipitation in inches = 34.7 inches

Contributing drainage areas were calculated from LiDAR derived topographic maps. The mean annual rainfall was taken from CalTrans (2013)(PRECIP: Mean annual rainfall in GIS database). Peak flows can be calculated manual or by using USGS Stream Stats Version 3 beta computer model.

Minimum culvert sizing is based on nomographs presented in Normann et al. (2001) and assume inlet control, mitered inlet, and a HW/D ratio of 0. 9.

Our preliminary results of peak discharge and culvert sizing for 50 and 100 year recurrence interval events are summarized in Table 1 below. Based on our field observations of stream channel characteristics, we are of the opinion that the values presented in the table above are likely an overestimate.

TABLE 1: DARK GULCH
PEAK DISCHARGE AND CULVERT SIZING RESULTS

Recurrence Interval	Stream Flow (cfs) Q	Minimum Culvert Diameter (in)
Q_{50}	103	60
Q_{100}	123	66

FUTURE EROSION AND SEDIMENT YIELD

There is a high potential for continued slow progressive failure of the crossing as the logs within the crossing degrade and the cavities within the crossing collapse. This potential has increased as a result of the 2017 storms which removed more internal support to the crossing, particularly on the downstream side. There is a high potential for additional failures of the downstream embankment face.

This erosion will result in ongoing collapse of the existing sinkholes and the formation of new ones. Debris flow landslides are also likely to initiate within the oversteepened upstream and downstream fill embankment faces. Progressive failure is resulting in sediment discharge to the stream, the rate of which will likely increase over time. A secondary side effect of sinkhole formation, tension cracks, fissures, and overturning trees rooted in the fill are creating chronic erosion because of the barren soils that are being continuously produced and impacted by seasonal rainfall.

In a worst case scenario, the soil pipes that drain the crossing fill could plug and no longer drain. If this were to happen during a large storm event then water could fill the watercourse up to the elevation of Old Haul Road, essentially turning the fill prism into a weak and unstable dam approximately 65 feet high; then resulting in catastrophic failure of the fill embankment, and sudden release of a very large and erosive torrent of sediment laden flood waters traveling at high velocity. Such a failure could result in significant damage to the downstream channel, streamside habitat and other structures (e.g. bridges).

If left untreated, the future volume of erosion and sediment delivery to Pescadero Creek is estimated at over 30,000 cubic yards. During the 2017 winter we estimate that over 500 cy of fill material eroded out rendering the crossing more unstable than it was before.

CROSSING SAFETY

The collapse of cavities and the formation of sinkholes have been observed in several places and at several times at Dark Gulch, and the historical site conditions (decaying logs, unstable fill, and previous sinkholes) in the road prism may present significant hazards to users of the road. This is because it is generally not possible to predict when or where such features may develop. The concern is that a hidden underground cavity will progressively form, and then suddenly collapse under the weight of a vehicle or horse passing by. The continued degradation of the crossing fill and the formation of sinkholes if undiscovered present a significant hazard to users.

DARK GULCH TREATMENT ALTERNATIVES

In order to reduce the risks associated with the continued decay of embedded logs which otherwise would continue to threaten the stability of untreated portions of the fill prism; with the associated resultant sediment delivery and risks to users of Old Haul Road, all of the crib logs and deleterious materials (root balls, organic soils, etc.) will need to be removed. Because the Park requires permanent truck access past Dark Gulch for visitor use, Park management, and fire suppression the existing crossing will need to be reconstructed.

Several treatment alternatives were considered and are outlined in the table below. In our February 2015 field meeting with representatives from CDFW, NOAA and USFWS it was concluded that replacing the culvert and reconstructing the crossing embankment with engineered fill (Alternative 4) was the most viable and preferred alternative.

DARK GULCH TREATMENT ALTERNATIVES

ALTERNATIVE	DESCRIPTION
ALTERNATIVE 1 **Abandon Road and Reroute**	In this alternative the entire crossing fill is removed (est 35,000 cy), the natural stream channel restored, and the road relocated to a more stable location. Preliminary review found no feasible reroutes and therefore this is not a viable alternative.
ALTERNATIVE 2 **Partial Crossing Removal**	In this alternative the upper 8+ feet of fill material is removed and replaced with engineered fill separated from the log structure below with geotechnical fabric. This will temporarily stabilize the upper portion of the road prism but would have little sediment savings. This would only be a short term solution since it is expected the crossing will continue to decay, and the cumulative risk increases over time. This is not a viable long term solution and not recommended.
ALTERNATIVE 3 **Bridge or Bottomless Arch**	In this alternative the entire crossing fill is removed (est 35,000 cy) and either a long span bridge or bottomless arch installed. The advantage of this alternative is it allows for a native channel bed. However, installing either a bridge or bottomless culvert will be challenging from a geotechnical and logistical standpoint due to the steep and unstable terrain that characterizes the site. As a result the costs for both a bridge and bottomless arch would be very expensive and based on discussions with Park representatives cost prohibitive.
ALTERNATIVE 3 **Boring new culvert**	In this alternative a new culvert would be installed by boring through the fill material. We found that this was not a viable alternative in part because 1) the work would not stabilize the exiting fill around the pipe that has already been compromised and at risk for slope failure and 2) there is significant uncertainty if it would be economically feasible to drill through the fill material with the anticipated embedded large diameter logs.
ALTERNATIVE 4 **Culvert (Preferred Alternative)**	In this alternative all unstable fill material and associated crib logs will be removed (~ 35,000 cy), a large (5 to 6+ foot) diameter culvert installed, and the crossing embankment reconstructed with 22,700 cy of engineered fill. The crossing would be relocated upstream a short distance and the road bed lowered to reduce the crossing footprint and amount of engineered fill required. Crib logs removed from the crossing will be stockpiled onsite for future park use and/or used to augment rock at energy dissipater. On site soils will be used for engineer fill. A rock energy dissipater will be installed at the culvert outfall stacked rock headwall at culver inlet. Excess spoils will be compacted in a stable configuration on the flat cut bench located just north of the crossing.

ROAD DRAINAGE ON OLD HAUL ROAD

DESCRIPTION

This segment of the Old Haul Road extends 3.5 miles between Wurr Road and Rhododendron Creek. The first 0.6 miles of the road contours across the hillside mostly on a gently sloping fluvial terrace. The next 2.9 miles of the Old Haul Road follows the old railroad grade. The road bed is relatively wide at up to 40 feet though the majority is not being used.

Historically the road was poorly drained the 1995 review team noted that a chief source of sediment into the tributaries of Pescadero Creek in Pescadero Creek County Park was from inadequate road drainage. In mid to late 2000 road drainage was reportedly upgraded by installing rolling dips, replacing ditch relief culverts, reshaping the road, and rocking the road tread.

Presently the road appears worn slightly rutted along the wheel tracks from use. Many of the drainage dips have infilled and/or broken down with use and some are no longer effective. Though the road has received some maintenance over the years, a much larger effort is needed to install more permanent drainage structures. The road will benefit from standard maintenance to regrade the road to remove wheel ruts, clean ditch relief culverts and install a few additional drainage dips where existing dips are undersized or are absent. If left untreated is it estimated that about 25% of the road prism would end up being hydrologically connected to watercourses.

FUTURE EROSION AND SEDIMENT YIELD

Future sediment delivery volumes from erosion of the road tread and adjacent cut is estimated at 466 cy over a 20 year time frame. This estimate is based on the methodology outlined in California Salmonid Stream Habitat Restoration Manual Part X (Weaver et al., 2006):

Q_s = [(A x E/27] x T x D, where

Q_s = sediment delivery (cy) from surface erosion;
A = exposed area (ft^2);
E = erosion or lowering rate (ft/yr);
T = time (years);
D = delivery ratio.

The following assumptions and measurements were used to calculate erosion volumes:

Road length	18,500 ft
Road width (exposed)	12 feet
Road tread exposed area (A) (18,500 x 12)	222,000 ft^2
Erosion rate of rocked road surface (E) (modified from CDFG, 2006)	0.01 ft/yr
Cutbank height	8 feet
Percentage of cutbank unvegetated and exposed to erosion	10%
Road cut exposed area (A) (18,500 x 8 x 10%)	14,800 ft^2
Erosion rate of cutbank (E)	0.02 ft/yr
Time (T)	20 years
Sediment delivery ration (D)	25%

Qs = [(222,000ft^2 x 0.1 ft/yr)+(14,800ft^2 x 0.02 ft/r)]*20 yr x 25% /27

Qs = 466 cy

ROAD DRAINAGE TREATMENT

Sediment delivery from road surface erosion can be mitigated installing new and reconstructing old rolling dips. Rolling dips should be installed at roughly 150 foot spacings and conform to standard specifications. Rolling dips may be constructed using import engineer fill obtained from the excavation of Dark Gulch. Rolling dips shall be installed within 100 feet of either side of watercourses to hydrologically disconnect the road from the stream. Portions of the road tread may need to be reshaped to drain.

CONCLUSION

There is a high potential for the continued failure of the Dark Gulch crossing. If left untreated, the future volume of erosion and sediment delivery to Pescadero Creek is estimated at over 30,000 cubic yards. Future instability will also prevent safe passage past the crossing. In a worst case scenario could catastrophically failure resulting in significant damage to the downstream channel, streamside habitat, and other structures (e.g. bridges).

Based on the results of our assessment and HKA's preliminary geotechnical investigation the preferred design alternative at Dark Gulch is to remove all of the unstable fill material and replace with engineered fill incorporating a large diameter culvert to convey stream flow. Drainage along Old Haul Road will also need to be improved by installing or enlarge drainage dips and rocking the road tread as needed.

It is our opinion that the proposed project is geologically and geotechnically feasible, provided the recommendations presented in this report and in the accompanying geotechnical report are incorporated into the project design and construction.

The most significant constraints on the design of the crossings are:

- The presence of relatively thick undifferentiated colluvium and fill incorporating interlocking crib logs. This material will need to be removed and clean fill suitable for engineered fill separated from deterious fill material. Based on our recent experience on the 2018 Harwood and Keyston Creek crossing repairs, we find that the extent and depth of excavation will likely need to be modified based on site conditions encountered, logistic limitations, and site safety, all of which cannot be determined with certainty beforehand. Any changes will need to be made as construction proceeds and under the direction of the project engineering geologist and geotechnical engineer.
- Location of the site in steep terrain makes the site difficult to access. Due to equipment logistical constraints modifications to grading may need to be made at the time of construction.
- Dewatering of the site will be required if water flowing water is flowing at the time of construction
- The crossing site is located on and adjacent to deep-seated landslides. Based on qualitative field observations these slides appear to be dormant with low level of activity. A detailed

slope stability analysis was not undertaken and is outside the project scope. The proposed improvements will not mitigate natural deep-seated instability. The proposed work is unlikely to exacerbate deep-seated slide stability over existing conditions since the mass balance and hydrology of the slide will not be altered.

- The project site is in a seismically active area in close proximity to the San Andreas Fault Zone, a major potential source of severe seismic shaking. High ground accelerations would be expected during a large earthquake on this fault or other nearby faults.

PRELIMINARY RECOMMENDATIONS

We recommend that the following provisions and those presented in the Geotechnical Report (Appendix 1) be incorporated in the specifications for the project and made part of the plans. Additional recommendations not specified here may be included in the plan set. Any discrepancies between this report, the geotechnical report or the finished plans shall be brought to our attention of before construction so that these discrepancies can be resolved.

Site Grading

- Over-excavate of over 37,400 cy of unstable fill material, crib logs and deleterious materials (root balls, organic soils, etc.) to native grade and replace as engineered fill. The depth and lateral extent of excavation shall be sufficient to ensure a stable stream crossing. Final depth of excavation will have to be confirmed by the Project Engineering Geologist and/or Geotechnical Engineer at the time of construction.
    - Crib logs will be either used for channel restoration on the downstream side of the new crossing or stockpiled in a stable location.
    - The CONTRACTOR shall inform GEOTECHNICAL ENGINEER prior to any grading resulting in any cuts (temporary or permanent) greater than 4 feet and inclined steeper than 1:1 so that the engineer has the opportunity to evaluate cut stability.
    - The majority of excavated fill may be stockpiled on a large flat graded bench immediately to the west of the crossing or along the road bed. Excavated material to be used for engineered shall will be separated from deterious soils that will be permanently stockpiled.
    - Spoils not used for engineered fill shall be placed on the large landing located west of the crossing as shown on plans and as approved by the engineering geologist.
- Engineered fill shall be keyed into firm native soils placed in accordance with recommendations outlined in the geotechnical report (Appendix 1).Engineered fill shall include under drains to collect subsurface seepage and to discharge in a stable manner downhill of the repair.
-

Culvert:

- Install a 60” to 72” inch diameter x 260 foot long culvert at native channel grade (19%). Final culvert diameter to be determined.
    - During meetings with the RCD and Parks we discussed the possibility of embedding the bottom of the culvert below the streambed to allow for the culvert to partially infill with sediment and create a native channel bottom, however on further analysis this is found not to be feasible due to the steep 16% channel grade.
    - The culvert type may be round CMP, approved plastic, or reinforced concrete. A concrete box culvert may also be used but this will likely be more expensive. If a CMP is installed then consideration should be given to using a heaver gauge metal to improve pipe life expectancy.
- A large trash rack should be installed upstream to reduce the potential for the culvert to plug with debris during large storm events. The large logs that are currently found upstream of the

crossing are too large to be mobilized during peak storm events. Many of these will need to be removed for construction and will be used elsewhere on the project for erosion control protection

- Install rocked headwall at culvert inlet using mixed ½ to 1 ton rock. Place 2 layers thick. Extend rock to top of pipe. Miter culvert at 45 degrees
- Install a rock energy dissipater at culvert outfall using mixed ½ to 2 ton rock. The rock energy dissipater may incorporate large wood debris at the approval of the engineering geologist or geotechnical engineer at the time of construction. Length of energy dissipator to be determined.

Erosion Control

- Following grading exposed bare slopes and soil should be planted or covered as soon as possible with erosion resistant vegetation.

Plan Review, Construction Observation and Testing

- The project engineering geologist and geotechnical engineer shall be provided an opportunity to review project plans with the CONTRACTOR during the pre-construction meeting to evaluate if recommendations have been properly interpreted.
- The CONTRACTOR shall notify the engineering geologist and geotechnical engineer a minimum of 7 days prior to commencement of work and a minimum of 4 working days prior to any inspections.
- In addition, the CONTRACTOR shall notify the geotechnical engineer at least four (4) working days prior to any grading or foundation excavating so the work in the field can be coordinated with the grading contractor and arrangements for testing and observation can be made. The recommendations of this report are based on the assumption that the geotechnical engineer will perform the required testing and observation during grading and construction. It is the owner's responsibility to make the necessary arrangements for these required services.
- Regulatory Agencies may require a final grading compliance letter. We can only offer this letter if we are called to the site to observe and test, as necessary, any grading and excavation operations from the start of construction. We cannot prepare a letter if we are not afforded the opportunity of observation from the beginning of the grading operation. The CONTRACTOR must be made aware of this and earthwork testing and observation must be scheduled accordingly.

REFERENCES

Atwater, T., 1970, Implications of Plate Tectonics for the Cenozoic Tectonic Evolution of Western North America: Geological Society of America Bulletin, v. 81, no. 12, p. 3513-3536.

Best, T. C., 2015, Road Erosion Assessment: Old Haul Road, Pescadero Creek, County Park, CA.

Brabb, E. E., Graymer, R. W., and Jones, D. L., 1998, Geology of onshore part of San Mateo County: A digital data base: USGS Open File Report 98-137.

CalTrans, 2013, PRECIP: Mean annual rainfall in GIS database. Online_Linkage: http://www.dot.ca.gov/hq/tsip/gis/datalibrary/gisdatalibrary.html

Gotvald, A. J., Barth, N. A., Veilleux, A. G., and Parrett, C., 2012, Methods for Determining Magnitude and Frequency of Floods in California, Based on Data through Water Year 2006, *in* U.S. Geological Survey Scientific Investigations Report 2012–5113, a. o. o. a. h. p. u. g. s., ed., p. 38.

Graham, S. A., and Dickinson, W. R., Apparent offset of on-land geologic features across the San Gregorio-Hosgri fault trend, *in* Proceedings San Gregorio-Hosgri fault zone, California1978, California Division of Mines and Geology Special Report 137, p 13-23.

Keaton, J. R., and DeGraff, J. V., 1996, Surface Observations and Geologic Mapping, *in* Turner, A. K., and Schuster, R., eds., Landslides: Investigation and Mitigation: Transportation Research Board, Special Report 247: Washington D.C., National Academy Press, p. 178-230.

Normann, J. M., Houghtalen, R. J., and Johnston, W. J., 2001, Hydraulic design of highway culverts, Federal Highway Administration, U.S. Department of Transportation. Report No. FHWA-NHI-01-020, p. 280.

Petersen, M. D., Bryant, W. A., Cramer, C. H., Cao, T., Reichle, M. S., Frankel, A. D., Lienkaemper, J. J., McCrory, P. A., and Schwartz, D. P., 1996, Probabilistic Seismic Hazard Assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open File Report 96-08; U.S. Geological Survey, Open File Report 96-706.

Weaver, W. E., Hagans, D. K., and Weppner, E., 2006, California Salmonid Stream Habitat Restoration Manual: Part X Upslope Erosion Inventory and Sediment Control Guidance, California Department of Fish and Game, http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp, p. 207.

INVESTIGATIVE LIMITATIONS

1) The purpose of this investigation was to evaluate the geologic, geotechnical and hydrologic conditions at the project site, and develop recommendations and design parameters to reconstruct and stabilize the two stream crossings with the overarching goal to reduce road related sediment delivery to Pescadero Creek while maintaining important recreational trail and restricted vehicle access. The conclusions and recommendations contained herein are professional opinions derived in accordance with current standards of professional practice working in similar remote forested environments. No other warranty expressed or implied is made.

2) Our observations were limited to surface expressions and limited natural and artificial exposures of subsurface materials at and adjacent to the project site. The recommendations of this report are based upon the assumption that the soil conditions do not deviate from those disclosed in the borings. If any variations or undesirable conditions are encountered during construction, or if the proposed construction will differ from that planned at the time, our firm should be notified so that supplemental recommendations can be given.

3) This written report comprises all of our professional opinions, conclusions and recommendations. This report supersedes any previous oral or written communications concerning our opinions, conclusions and recommendations.

4) The conclusions and recommendations noted in this report are based on probability and in no way imply the site will not possibly be subjected to ground failure or seismic shaking so intense that structures or roads will be severely damaged or destroyed.

5) This report is issued with the understanding that it is the duty and responsibility of the client, or his or her representative or agent, to ensure that the recommendations contained herein are called to the attention of the Architects and Engineers for the project and incorporated into the plans, and that the necessary steps are taken to ensure that the Contractors and Subcontractors carry out such recommendations in the field.

6) The findings of this report are valid as of the present date. However, changes in the conditions of a property or landform can occur with the passage of time, whether they be due to natural processes or to the works of man, on this or adjacent properties. In addition, changes in applicable or appropriate standards occur whether they result from legislation or the broadening of knowledge. Accordingly, the findings of this report may be invalidated, wholly or partially, by changes outside our control.

APPENDIX 1: GEOTECHNICAL REPORT

HARO, KASUNICH AND ASSOCIATES, INC.

CONSULTING GEOTECHNICAL & COASTAL ENGINEERS

Project No. SM11180
8 March 2019

TIMOTHY C. BEST
1002 Columbia Street
Santa Cruz, CA 950560

Subject: Geotechnical Investigation

Reference: Grading and Stream Crossing Improvements
Dark Gulch
Old Haul Road
Pescadero, California

Dear Mr. Best:

As requested, Haro, Kasunich and Associates (HKA) has performed a geotechnical investigation for the referenced site. This letter summarizes our field exploration, laboratory testing, engineering analysis, and general recommendations for site grading and drainage. HKA has completed a soil investigation and letter report for both the Harwood and Keystone stream crossings under a separate cover dated 6 June 2018. The Harwood and Keystone crossings were repaired in fall 2018. HKA performed construction observation and testing for the Harwood and Keystone reconstruction projects as summarized in the Final Inspection letter dated 20 December 2018.

Site and Project Description

The Dark Gulch project site is the largest of three project sites that were adversely impacted during the 2016-17 winter rains. The two other project sites are Harwood and Keystone Gulch. All three sites are stream crossings that have been degrading due to subsurface erosion stemming from collapse of old crib logs, cavities within fill embankments, and damaged culverts.

The crossing at Dark Gulch Creek consists of a 35,000 cubic yard, 69 foot thick undocumented fill embankment. The up and downstream sides of the crossing are partially supported with large (24 inch to 48 inch) diameter redwood crib logs stacked 15 to 25 feet high like a log cabin. The tie back logs to the crib wall extend over 20 feet into the fill embankment. A wood box culvert likely built at the bottom of the fill conveyed stream flow through the crossing, though evidence of this structure is no longer visible. The crossing is actively failing resulting in failures on both sides of the fill embankment and the formation of cone shaped “sinkholes” on the ground surface.

Field Exploration

Subsurface conditions were explored on 3 June 2017. A total of four exploratory borings were drilled at the existing road elevation along the length of the stream crossing.

Borings were drilled between 16.5 and 71 feet. The Borings were advanced with 6 inch diameter, solid stem continuous flight auger equipment. Refer to our Boring Site Plan for approximate boring locations and Logs of Test Borings in attached to this report.

Representative soil samples were obtained from the exploratory borings at selected depths, or at major strata changes. These samples were recovered using a 3.0-inch O.D. Modified California Sampler (L), or by Standard Penetration Test, i.e. Terzaghi Sampler (T). The soils encountered in the borings were continuously logged in the field and described in accordance with the Unified Soil Classification System (ASTM D2488, Visual-Manual Proceeding). The Logs of Test Borings are included as an attachment to this letter report. The logs depict subsurface conditions at the approximate locations shown on the Boring Site Plan.

Subsurface conditions at other locations may differ from those encountered at the explored locations. Stratification lines shown on the logs represent the approximate boundaries between soil types. The actual transitions may be gradual.

The penetration blow counts noted on the boring logs were obtained by driving a sampler into the soil with a 140-pound hammer dropping through a 30-inch fall. The samplers were driven up to 18 inches into the soil and the number of blows counted for each 6-inch penetration interval. The numbers indicated on the logs are the total number of blows that were recorded for the second and third 6-inch intervals (i.e. blows per foot), or the blows that were required to drive the penetration depth shown if high resistance was encountered.

Laboratory Testing

Soil samples obtained from the borings at selected depths were taken to our laboratory for further examination and laboratory testing. The laboratory testing program was directed toward determining pertinent engineering properties of soil underlying the project site.
In-situ moisture percentages and dry unit weights were recorded for select samples. The strength parameters of the underlying earth materials were determined from field penetration resistance of the in-situ soil and laboratory direct shear tests. Bulk samples of undocumented fill material from historic grading was taken to our laboratory and compacted per laboratory test method, ASTM D1557. Direct shear testing was performed by our laboratory on this fill soil compacted to 75% and 85% relative compaction in brass liners.

The results of the laboratory testing can be found attached to this report and also appear on the "Logs of Test Boring" opposite the sample tested.

Subsurface Conditions

Soils encountered in our exploratory borings consisted of an undifferentiated road fill and colluvium followed by a weathered to competent sandstone bedrock. The undifferentiated road fill and colluvium was composed of loose to medium dense clayey Silt and Silty Sand.

The bedrock contacts were at depths of 67.5 feet, 11 feet, and 38 feet in borings B-1, B-3, and B-4 respectively. Bedrock was not encountered in B-2 drilled to a total depth of 33 feet, however there was an increase in density from loose (SPT = 8) to medium dense (SPT = 28) observed at 30 feet. The fill colluvium contact was difficult to determine due to the fact that the fill material is composed entirely of colluvium material from the historic inboard cut during construction of the stream crossing.

Groundwater was not observed in any of the exploratory borings at the Dark Gulch crossing. Contrasts in permeability between granular soil, clayey soil and bedrock strata allow perched groundwater conditions to develop. Localized perched groundwater conditions should be expected across the site at varying elevations.

Geotechnical Related Seismicity

The improvements should be designed in conformance with the most current California Building Code (2016 CBC). For seismic design, the soil properties at the site are classified as **Site Class "D"** based on definitions presented in Table 1613.5.2 in the 2013 CBC. The longitude and latitude were determined using a satellite image generated by Google Earth. These coordinates were taken from the approximate middle of the area of the proposed improvements:

Longitude = -122.2519, Latitude = 37.2613

The coordinates listed above were used as inputs in the Java Ground Motion Parameter Calculator created by the USGS to determine the ground motion associated with the maximum considered earthquake (MCE) SM and the reduced ground motion for design SD. The results are as follows:

<u>Site Class D</u>
SM_s= 1.500 g
SM_1= 0.979 g
SD_s= 1.000 g
SD_1= 0.653 g

A maximum considered earthquake geometric mean (MCE_G) peak ground acceleration (PGA) was estimated using the Figure 22-7 of the ASCE Standard 7-10. The mapped PGA was 0.578 g and the site coefficient F_{PGA} for Site Class D is 1.0. The MCE_G peak ground acceleration adjusted for Site Class effects is PGA_M = FPGA * PGA
PGA_M = 1.0 * 0.578g = 0.578 g

Limit Slope Stability Analysis of Temporary Cut Slopes In Undocumented Fill

Limit stability analysis was performed statically in the undocumented fill material of the Dark Gulch stream crossing site. In Limit Analysis the critical slope height, H_c is determined using the equation;

$$H_c = N_s C/\gamma_t$$

Where;

$H_c =$ Critical Slope height at a factor of safety of 1.0
N_s = Stability factor
C = Cohesion of soil (psf)
γ_t = Unit weight of soil (pcf)

N_s is a function of the soils internal friction angle, Ø in degrees, the angle of critical slope, β in degrees, and the angle of the surcharge slope, α in degrees. Solutions of N_s are tabulated based on varying values of Ø, α, and β (Refer to Table 10.2 pg. 368 of the Foundation Handbook included as an attachment to this report).

Using the average soil parameters of the fill material outlined in Table 1 below and interpolation of Table 10.2, the critical slope height of a 1:1 (H:V, $\beta = 45^o$) cut slope with surcharge slope angle, $\alpha = 30^o$ was calculated to be H_C = 82 feet, assuming a static factor of safety of 1.

Table 1: Geotechnical Design Values

Soil Stratum	γ_t (lbs/ft^3)	Ø °(degrees)	Cohesion, C (lbs/ft^2)
Undocumented Fill	108	31	250

Maximum temporary cut slopes in the undocumented fill material are anticipated to be 60 feet high. The following slope heights, H_s, and associated factors of safety are tabulated in Table 2 below, based on the determined critical slope height, $H_c =$ 82 feet.

Table 2: Static Factors of Safety of Cut Slopes in Undocumented Fill, H_c = 82 ft.

H_s (ft.)	FS = H_c/Hs
60	1.37
50	1.64
40	2.1

Limitations of Analysis

It must be cautioned that slope stability analysis is an inexact science; and that the mathematical models of the slopes and soils contain many simplifying assumptions, not the least of which is homogeneity. Density, moisture content and shear strength may vary within a soil type. There may be localized areas of low strength or perched ground water within a soil. Slope stability analyses and the generated factors of safety should be used as indicating trend lines. A slope with a safety factor less than one will not necessarily fail, but the probability of slope movement will be greater than a slope with a higher safety factor. Conversely, a slope with a safety factor greater than one may fail, but the probability of stability is higher than a slope with a lower safety factor.

Plan Review Notice

Haro, Kasunich & Associates should be provided an opportunity to review the project plans during the design phase prior to cost estimating and county submittal. Allow at least one week for this task. The review provides an opportunity to check if our recommendations have been interpreted properly, which could reduce possible confusion and costly changes and time delays during construction. Once the plans meet our recommendations sufficiently we can provide the county-required plan review letter. Please contact our office at (reference Project Number SM11180):

Haro, Kasunich & Associates
116 East Lake Avenue
Watsonville, California 95076
(831) 722-4175 ext. 109
akasunich@harokasunich.com

Construction Observation Notice

Haro, Kasunich and Associates must provide observation and testing services for earthwork performed at the project site. The observation and testing of earthwork allows for evaluation of contractors' compliance with our geotechnical recommendations. It also allows us the opportunity to confirm that actual soil conditions encountered during construction are essentially the same as those anticipated based on the subsurface exploration. Unusual or unforeseen soil conditions may require supplemental evaluation by the geotechnical engineer.

The County usually requires a final grading and/or foundation compliance letter. We can prepare this letter only if we are called to the site to observe and test, as necessary, any grading and excavation operations **from the start of construction**. We cannot prepare a letter if we are not afforded the opportunity of observation from the **beginning of the grading operation**. The contractor must be made aware of this and earthwork testing and observation must be scheduled accordingly. Refer to contact information above.

Site Grading

1. The proposed project will require significant grading. We offer the following recommendations. The geotechnical engineer should be notified **at least four (4) working days prior to any grading or foundation excavating** so the work in the field can be coordinated with the grading contractor and arrangements for testing and observation can be made. The recommendations of this report are based on the assumption that the geotechnical engineer will perform the required testing and observation during grading and construction. It is the owner's responsibility to make the necessary arrangements for these required services.

2. Compaction during inclement weather or wet conditions may hamper compaction efforts and over-excavation may be necessary.

3. Where referenced in this report, Percent Relative Compaction and Optimum moisture Content shall be based on ASTM Test Designation D1557.

4. Areas to be graded or designated to receive engineered fill, should be cleared of all obstructions, tree roots, crib walls, logs, and organic topsoil.

5. In areas to be graded or designated to receive engineered fill, all loose soil, old logs and other unsuitable material must be subexcavated to its full depth. Existing depressions or voids created during site clearing should be backfilled with engineered fill.

6. Cleared and subexcavated areas should then be stripped of organic-laden topsoil. Strippings should be stockpiled in a suitable location on site.

7. Exposed base should be scarified at least 6 inches; moisture conditioned and compacted to 80 percent relative compaction. Engineered fill should be placed in thin lifts not exceeding 8 inches in loose thickness; moisture conditioned, and compacted to a minimum of 85 percent relative compaction, up to desired grade.

8. The upper 6 inches of subgrade and aggregate base sections below pavements should be moisture conditioned and compacted to at least 90 percent relative compaction.

9. Native, none–organic material may be used in engineered fill. Imported material should consist of a predominantly granular soil conforming to the quality and gradation requirements as follows: The soil should be relatively free of organic material and contain no rocks or clods greater than 6 inches in diameter, with no more than 15 percent larger than 4 inches. The material should be predominately granular with a plasticity index less than 18, a liquid limit less than 35, and not more than 20 percent passing the #200 sieve.

10. Soil suitable for engineered fill and not used at crossings may be used to form rolling dips.

11. In areas where the stream channel is to be restored, excavated stream channel shall be a minimum 4 feet wide with banks laid back to 1.5:1 (H:V) or flatter unless otherwise directed.

12. Engineered fill slopes should be inclined no steeper than 1.5:1 (horizontal to vertical) and not greater than 60 feet in height without approval of the project CEG or Geotechnical Engineer. Where shown on plans at the transitions to existing slopes that are steeper gradients, fill slopes may be blended with natural grades. Fill embankments situated on slopes between 20% or steeper in gradient should be drained, keyed and benched into sandstone bedrock or firm native material. All keys and benches should be drained as directed by project CEG or geotechnical engineer.

13. Cut and fill slopes should be protected from erosion by preventing runoff from spilling over fresh graded slopes. Lined V-ditches and/or berms at the top of the slope may be considered for the short and long term.

14. Cut slopes in rock may be inclined at 0.75:1 (H:V) slope for heights up to 20 feet. Natural slopes exposing soil may be temporarily cut no steeper than 1:1 or flatter for heights of 60 feet as directed by CEG. Steeper inclinations may be acceptable based on site review by CEG and/or geotechnical engineer.

15. Following grading exposed bare slopes and soil should be planted or covered as soon as possible with erosion resistant vegetation.

16. Trenches should be backfilled with granular-type material and uniformly compacted by mechanical means to not less than 85 percent. The relative compaction will be based on the maximum dry density obtained from a laboratory compaction curve run in accordance with ASTM Test Designation D1557.

17. After the earthwork operations have been completed and the geotechnical engineer has finished his observation of the work, no further earthwork operations shall be performed except with the approval of and under the observation of the geotechnical engineer.

Site Drainage

18. Proper drainage is key to this project. Control of runoff from the slopes above; control of infiltration and ponding adjacent to the edge of the road; and control of subsurface seepage is critical. Discharge collected water in a way so as not to cause erosion.

19. Surface water should not be allowed to flow towards improvements during construction and for the lifetime of the development. Surface drainage should be directed away from the edge of the road. Surface drainage should include provisions for positive gradients away from the outboard edge of the road.

20. Provide provisions for drainage control and dispersion. Surface drainage improvements may consist of lined surface swales situated upslope from improvements; catch basins or drain inlets in association with grading; all connected to a storm drain system consisting of solid rigid pipe and clean outs.

21. Runoff and discharge must not be allowed to spill over graded slopes. Water should be directed to drain inlets connected to a drainage system that discharges at least 5 feet horizontally beyond the base of the slope, or a storm drain system. Energy dissipaters should be installed at the discharge point beyond the base of the slopes.

22. Discharge should be conveyed via tight line down to the discharge point/energy dissipater, storm drain systems. Do not dissipate near top of a break in slope.

23. Install rock energy dissipater at culvert outlet. Use approved sound durable rock sized as indicated on plans. Rock to extend a minimum of 3 times culvert diameter downstream of culvert. Refer to standard specifications for rock energy dissipater installation on plan sheets.

24. Never connect subdrains and storm drain lines. Never surcharge one into the other.

Both systems should drain independently through discharge pipes.

25. Trenches should be capped with about 1½ feet of relatively impermeable soil.

Erosion Control

26. Do not discharge water directly on to slopes. Collected water to be dispersed on-site should be dispersed on energy dissipaters below the slope so as not to cause erosion and undermining, and at a location approved by geotechnical engineer.

27. All bare soil and cut and fill slopes should be seeded and mulched immediately after grading with barley, rye, grass and crimson clover or otherwise provided with erosion control measures.

28. Erosion control measures must be maintained during construction. Refer to construction timeframe constraints and requirements in the San Mateo County Erosion Control Ordinances.

Plan Review, Construction Observation and Testing

29. Haro, Kasunich and Associates should be provided an opportunity to review project plans prior to construction to evaluate if our recommendations have been properly interpreted and implemented. We should also provide foundation excavation observations and earthwork observations and testing during construction. This allows us to confirm anticipated soil conditions and evaluate conformance with our recommendations and project plans. If we do not review the plans and provide observation and testing services during the earthwork phase of the project, we assume no responsibility for misinterpretation of our recommendations.

Limitations and Uniformity of Conditions

30. The recommendations of this report are based upon the assumption that the soil conditions do not deviate from those disclosed in the borings. If any variations or undesirable conditions are encountered during construction, or if the proposed construction will differ from that planned at the time, our firm should be notified so that supplemental recommendations can be given.

31. This report is issued with the understanding that it is the responsibility of the owner, or his representative, to ensure that the information and recommendations contained herein are called to the attention of the Architects and Engineers for the project and incorporated into the plans, and that the necessary steps are taken to ensure that the Contractors and Subcontractors carry out such recommendations in the field.

The conclusions and recommendations contained herein are professional opinions derived in accordance with current standards of professional practice. No other warranty expressed or implied is made.

32. The findings of this report are valid as of the present date. However, changes in the conditions of a property can occur with the passage of time, whether they are due to natural processes or to the works of man, on this or adjacent properties. In addition, changes in applicable or appropriate standards occur whether they result from legislation or the broadening of knowledge. Accordingly, the findings of this report may be invalidated, wholly or partially, by changes outside our control. Therefore, this report should not be relied upon after a period of three years without being reviewed by a geotechnical engineer.

If you have any questions concerning this report, please contact our office.

Respectfully Submitted,

Reviewed By:

HARO, KASUNICH AND ASSOCIATES, INC.

John E. Kasunich
G.E. 455

Andrew Kasunich
Staff Engineer

AK/JEK/sr
Attachments
Copies: 3 to Addressee + pdf timbest@coastgeo.com

ATTACHMENTS

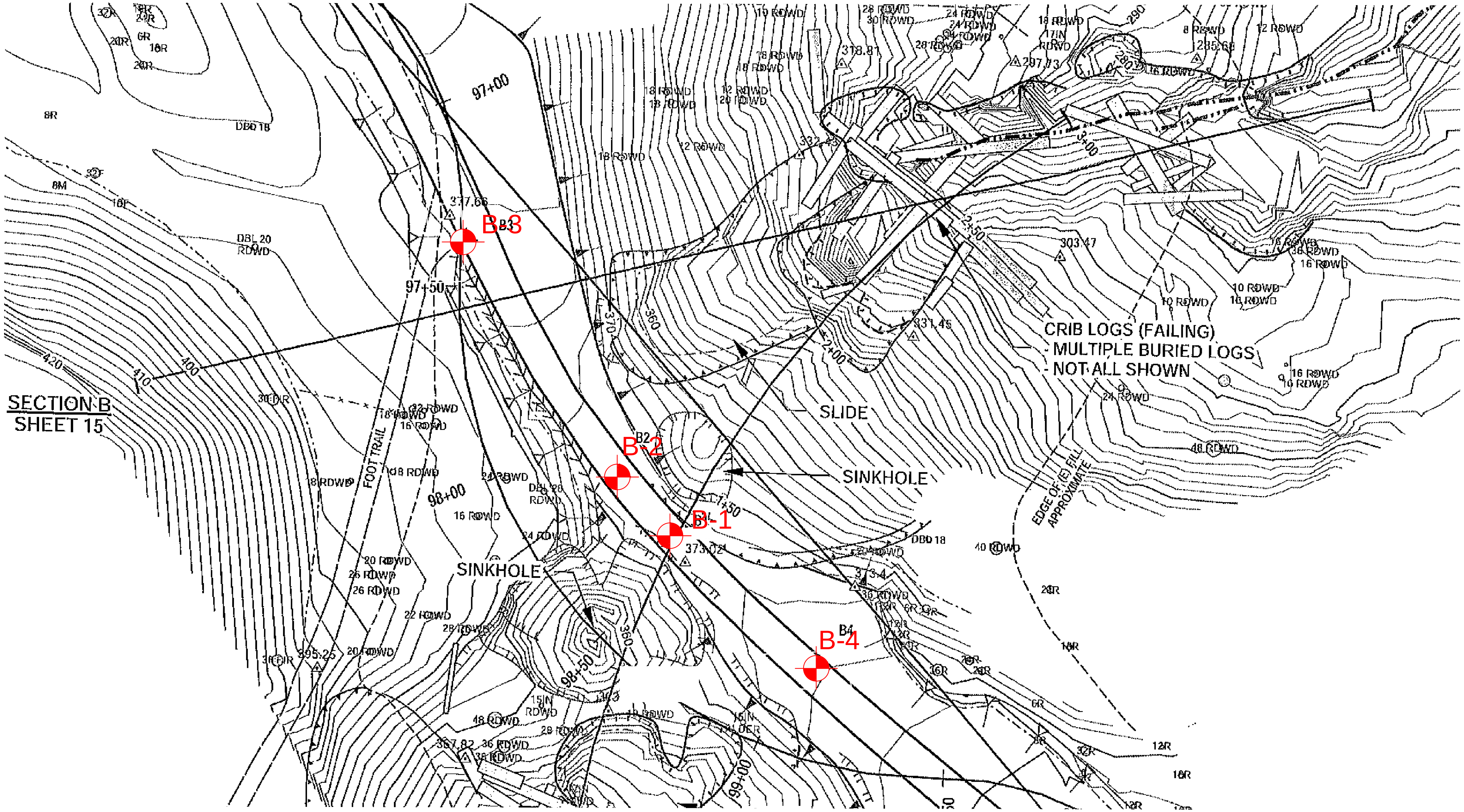
Boring Site Map – Figure 1

Key to Logs – Figure 2

Logs of Test Borings – Figures 3 thru 9

Lab Results – Figures 10 thru 14

Table 10.2, Stability Factor, $N_s = H_c\gamma/C$ by Limit Analysis



0 30' 60'

SCALE: 1" = 30'

NOTES:

1. BEST ENGINEERING GEOLOGY AND HYDROLOGY< DATED 6 SEPTEMBER 2017

KEY: B-1 = SOIL BORING LOCATION

BORING SITE PLAN OLD HAUL ROAD UPGRADE PROJECT DARK GULCH CREEK CROSSING SAN MATEO COUNTY	
SCALE: 1" = 30'	
DRAWN BY: AK	
DATE: FEB 2018	HARO, KASUNICH & ASSOCIATES, INC. GEOTECHNICAL AND COASTAL ENGINEERS 116 E. LAKE AVENUE, WATSONVILLE, CA 95076 (831) 722-4175
REVISED:	
JOB NO. SM11180	
FIGURE NO. 1	SHEET NO.

PRIMARY DIVISIONS			GROUP SYMBOL	SECONDARY DIVISIONS
COARSE GRAINED SOILS — MORE THAN HALF OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVELS — MORE THAN HALF OF COARSE FRACTION IS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (LESS THAN 5% FINES)	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.
		GRAVEL WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures, non-plastic fines.
			GC	Clayey gravels, gravel-sand-clay mixtures, plastic fines.
	SANDS — MORE THAN HALF OF COARSE FRACTION IS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (LESS THAN 5% FINES)	SW	Well graded sands, gravelly sands, little or no fines
			SP	Poorly graded sands or gravelly sands, little or no fines
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures, non-plastic fines.
			SC	Clayey sands, sand-clay mixtures, plastic fines.
FINE GRAINED SOILS — MORE THAN HALF OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS — LIQUID LIMIT IS 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 IS GREATER THAN 50%		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS			Pt	Peat and other highly organic soils.

GRAIN SIZES

U.S. STANDARD SERIES SIEVE: 200 — 40 — 10 — 4 — CLEAR SQUARE SIEVE OPENINGS: 3/4" — 3" — 12"

SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

RELATIVE DENSITY

SANDS AND GRAVELS	BLOWS PER FOOT*
VERY LOOSE	0 - 4
LOOSE	4 - 10
MEDIUM DENSE	10 - 30
DENSE	30 - 50
VERY DENSE	OVER 50

CONSISTENCY

SILTS AND CLAYS	STRENGTH (TSF)**	BLOWS PER FOOT*
VERY SOFT	0 - ¼	0 - 2
SOFT	¼ - ½	2 - 4
FIRM	½ - 1	4 - 8
STIFF	1 - 2	8 - 16
VERY STIFF	2 - 4	16 - 32
HARD	OVER 4	OVER 32

SAMPLING METHOD

STANDARD PENETRATION TEST	T	
MODIFIED CALIFORNIA	L or M	
PITCHER BARREL	P	
SHELBY TUBE	S	
BULK	B	

H_2O

Final	▽
Initial	▼
Water level designation	

*Number of blows of 140 lb hammer falling 30 inches to drive a 2" O.D. (1⅜" I.D.) split spoon sampler (ASTM D-1586)
**Unconfined compressive strength in tons/ft² as determined by laboratory testing or approximated by the Standard Penetration Test (ASTM D-1586), pocket penetrometer, torvane, or visual observation.

Haro Kasunich & Associates	**KEY TO LOGS** **Dark Gulch Pescadero, California**	**Project No. SM11180** **February 2019**	**Figure No. 2**

Haro, Kasunich & Associates, Inc.

Dark Gulch
Old Haul Road

PROJECT NO. SM11180

LOGGED BY JEK **DATE DRILLED** 6-3-17 **BORING DIAMETER** 6" **BORING NO.** B-1

Depth, ft.	Sample No. and type	Symbol	SOIL DESCRIPTION	Unified Soil Classification	Blows/foot 350 ft - lbs.	Qu - t.s.f. Penetrometer	Dry Density p.c.f.	Moisture % dry wt.	MISC. LAB RESULTS
0			2" - 3" AB with 3/4" gravel, red brown Silty SAND	SM					
5	1-1 (T)		Damp medium dense clean FILL		10				
10									
15	1-2 (L)		Clean FILL, no change		24		98.8	28.7	In-Situ D.S. ϕ = 34 degrees C = 651 psf
			Color change to dark grey, increase in moisture, pieces of small redwood bits, Silty SAND with some clayey binder (minor)						
20									
25	1-3 (T)		Tan brown Silty SAND, moist, medium dense, no organics		16				
30			Fragment of redwood pices (minor), darker brown						
35			Less wood						

HARO, KASUNICH AND ASSOCIATES, INC.

BY: sr **FIGURE NO.** 3

Dark Gulch
Old Haul Road

Haro, Kasunich & Associates, Inc.

PROJECT NO. SM11180

LOGGED BY	DATE DRILLED	BORING DIAMETER	BORING NO.
JEK	6-3-17	6"	B-1

Depth, ft.	Sample No. and type	Symbol	SOIL DESCRIPTION	Unified Soil Classification	Blows/foot 350 ft - lbs.	Qu - t.s.f. Penetrometer	Dry Density p.c.f.	Moisture % dry wt.	MISC. LAB RESULTS
35									
40	1-4 (L)		Grey Silty SAND, moist, medium dense, clean FILL, some mixture with SILT lenses (brown)		30		95.9	23.0	In-Situ D.S. ϕ = 37 degrees C = 731 psf
45									
50									
55									
60									
65	1-5 (T)		Wood (pieces), mottled brown and grey Silty SAND, very moist, medium dense to dense		18				
	1-6 (T)				40				
			Light blue/grey, medium to fine grain sandstone, drier, (damp), very dense	BR					
70									

HARO, KASUNICH AND ASSOCIATES, INC.

BY: sr

FIGURE NO. 4

Haro, Kasunich & Associates, Inc.

Dark Gulch
Old Haul Road

PROJECT NO. SM11180

LOGGED BY JEK **DATE DRILLED** 6-3-17 **BORING DIAMETER** 6" **BORING NO.** B-1

Depth, ft.	Sample No. and type	Symbol	SOIL DESCRIPTION	Unified Soil Classification	Blows/foot 350 ft - lbs.	Qu - t.s.f. Penetrometer	Dry Density p.c.f.	Moisture % dry wt.	MISC. LAB RESULTS
70	1-7 (T)			BR	50/5"				
			Boring terminated at 71 feet						
75									
80									
85									
90									
95									
100									
105									

SuperLog CivilTech Software, USA www.civiltech.com File: C:\superlog4\HKALOGS\SM11180 Harwood Gulch.log Date: 3/8/2019

HARO, KASUNICH AND ASSOCIATES, INC.

BY: sr **FIGURE NO.** 5

Haro, Kasunich & Associates, Inc.

Dark Gulch
Old Haul Road

PROJECT NO. SM11180

LOGGED BY JEK **DATE DRILLED** 6-3-17 **BORING DIAMETER** 6" **BORING NO.** B-2

Depth, ft.	Sample No. and type	SOIL DESCRIPTION	Unified Soil Classification	Blows/foot 350 ft - lbs.	Qu - t.s.f. Penetrometer	Dry Density p.c.f.	Moisture % dry wt.	MISC. LAB RESULTS
0		Baserock and gravel 3" Fill, tan brown Silty SAND, damp, loose to medium dense	SM					
6.5		Lighter color at 6.5 feet						
		Very small bits of wood, moist, loose						
10	2-1 (T)			5				
		Color change to grey, moist						
25	2-2 (T)	Light brown and light grey Silty SAND, very damp, loose		8				
30	2-3 (L)	Medium dense		29				
	2-4 (T)	Moist dense		33				
33		Boring terminated at 33 feet						
35								

HARO, KASUNICH AND ASSOCIATES, INC.

BY: sr **FIGURE NO.** 6

Haro, Kasunich & Associates, Inc.
Coastal and Geotechnical Engineers

Dark Gulch
Old Haul Road

PROJECT NO. SM11180

LOGGED BY JEK **DATE DRILLED** 6-3-17 **BORING DIAMETER** 6" **BORING NO.** B-3

Depth, ft.	Sample No. and type	Symbol	SOIL DESCRIPTION	Unified Soil Classification	Blows/foot 350 ft - lbs.	Qu - t.s.f. Penetrometer	Dry Density p.c.f.	Moisture % dry wt.	MISC. LAB RESULTS
0			FILL, light brown Silty SAND, damp, loose to medium dense	SM					
8			NATIVE?, Colliuvum or FILL?	SM					
10	3-1 (T)				7				
11			Brown higly weathered siltstone/mudstone	BR					
15	3-2 (T)				42				
16.5			Boring terminated at 16.5 feet						

HARO, KASUNICH AND ASSOCIATES, INC.

BY: sr **FIGURE NO.** 7

Haro, Kasunich & Associates, Inc.

Dark Gulch
Old Haul Road

PROJECT NO. SM11180

LOGGED BY JEK **DATE DRILLED** 6-3-17 **BORING DIAMETER** 6" **BORING NO.** B-4

Depth, ft.	Sample No. and type	Symbol	SOIL DESCRIPTION	Unified Soil Classification	Blows/foot 350 ft - lbs.	Qu - t.s.f. Penetrometer	Dry Density p.c.f.	Moisture % dry wt.	MISC. LAB RESULTS
0			Tan brown Silty SAND, damp, medium dense	SM					
5			Less density, clean FILL						
10									
			Clean tan, browqn Silty SAND, Sandy SILT, FILL						
15									
20									
			Color change to grey Silty SAND with CLAY binder and some small bits of redwood bark						
25									
30									
			Same, less wood bits						
			FILL						
			NATIVE, lighter color, mix of brown and grey, Sandy SILT, moist, medium dense, clean	ML					
35									

HARO, KASUNICH AND ASSOCIATES, INC.

BY: sr **FIGURE NO.** 8

Haro, Kasunich & Associates, Inc.

Dark Gulch
Old Haul Road

PROJECT NO. SM11180

LOGGED BY JEK **DATE DRILLED** 6-3-17 **BORING DIAMETER** 6" **BORING NO.** B-4

Depth, ft.	Sample No. and type	Symbol	SOIL DESCRIPTION	Unified Soil Classification	Blows/foot 350 ft - lbs.	Qu - t.s.f. Penetrometer	Dry Density p.c.f.	Moisture % dry wt.	MISC. LAB RESULTS
35				ML					
			Highly weathered siltstone/damp, very dense	BR					
40	4-1 (T)				44				
			Boring terminated at 41.5 feet						
45									
50									
55									
60									
65									
70									

HARO, KASUNICH AND ASSOCIATES, INC.

BY: sr

FIGURE NO. 9

Direct Shear

Project:	Dark Gulch		**Date**	8/21/2017
Sample #	1-2-1		**Tested By:**	RC/MA
Description	Yellowish Brown Sandy Clay			

Test Number	1	2	3	4
Normal Pressure (PSF)	530	1030	2030	4030
Max Shear Stress	32.1	49.8	68.3	
Shear Stress (PSF)	944.6	1464.5	2010.2	

Equation of Trendline	
Intercept	Slope
651.14	0.6869

C (PSF)	PHI
651	34

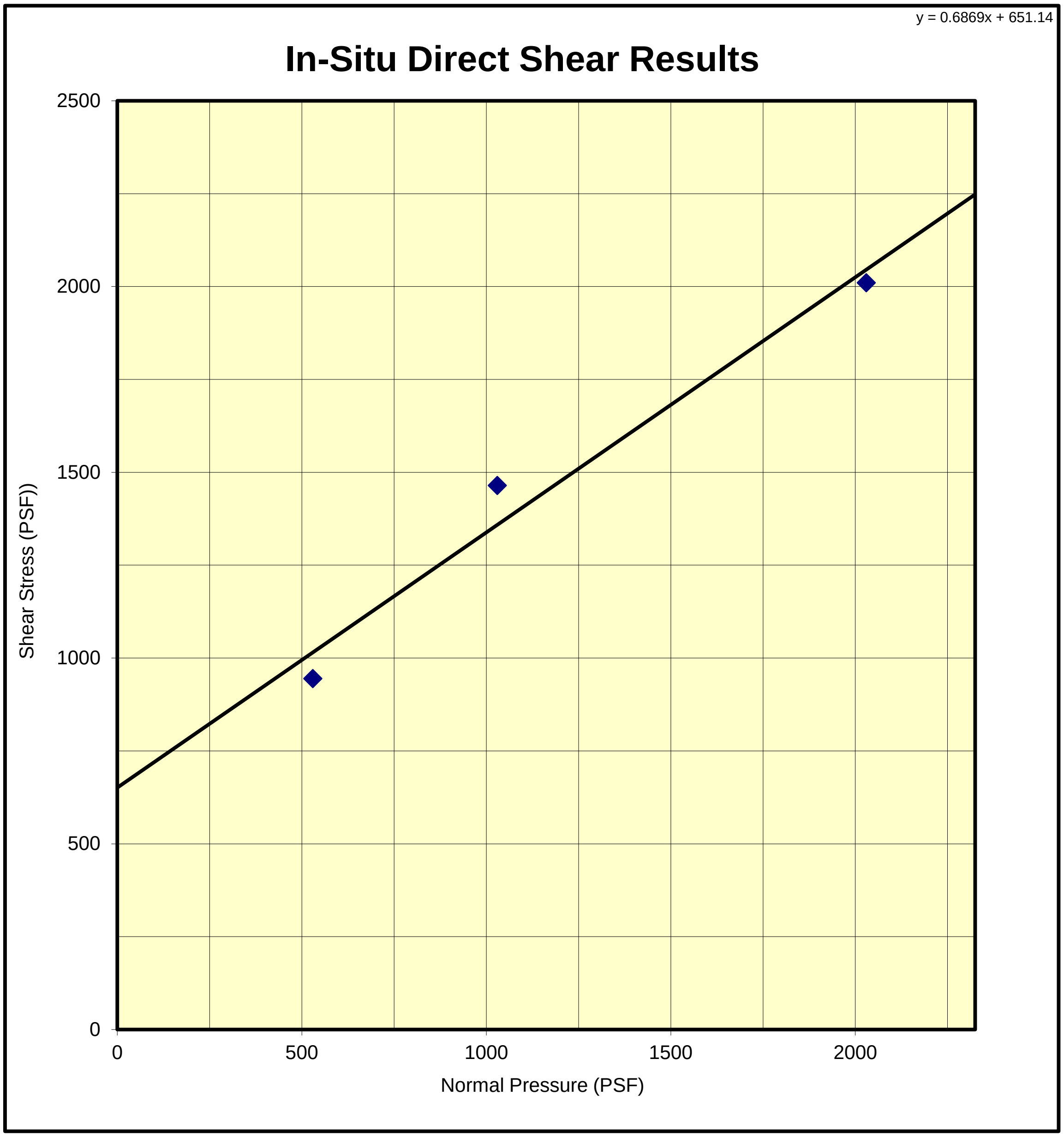


Figure No. 10

Direct Shear

Project:	Dark Gulch		**Date**	8/23/2017
Sample #	1-4-1		**Tested By:**	RC/MM
Description	Mottled Brown and Orange			

Test Number	1	2	3	4
Normal Pressure (PSF)	530	1030	2030	4030
Max Shear Stress	39.1	50.4	77.3	0
Shear Stress (PSF)	1149.1	1481.8	2272.3	0

Equation of Trendline	
Intercept	Slope
731.197	0.754766

C (PSF)	PHI
731	37

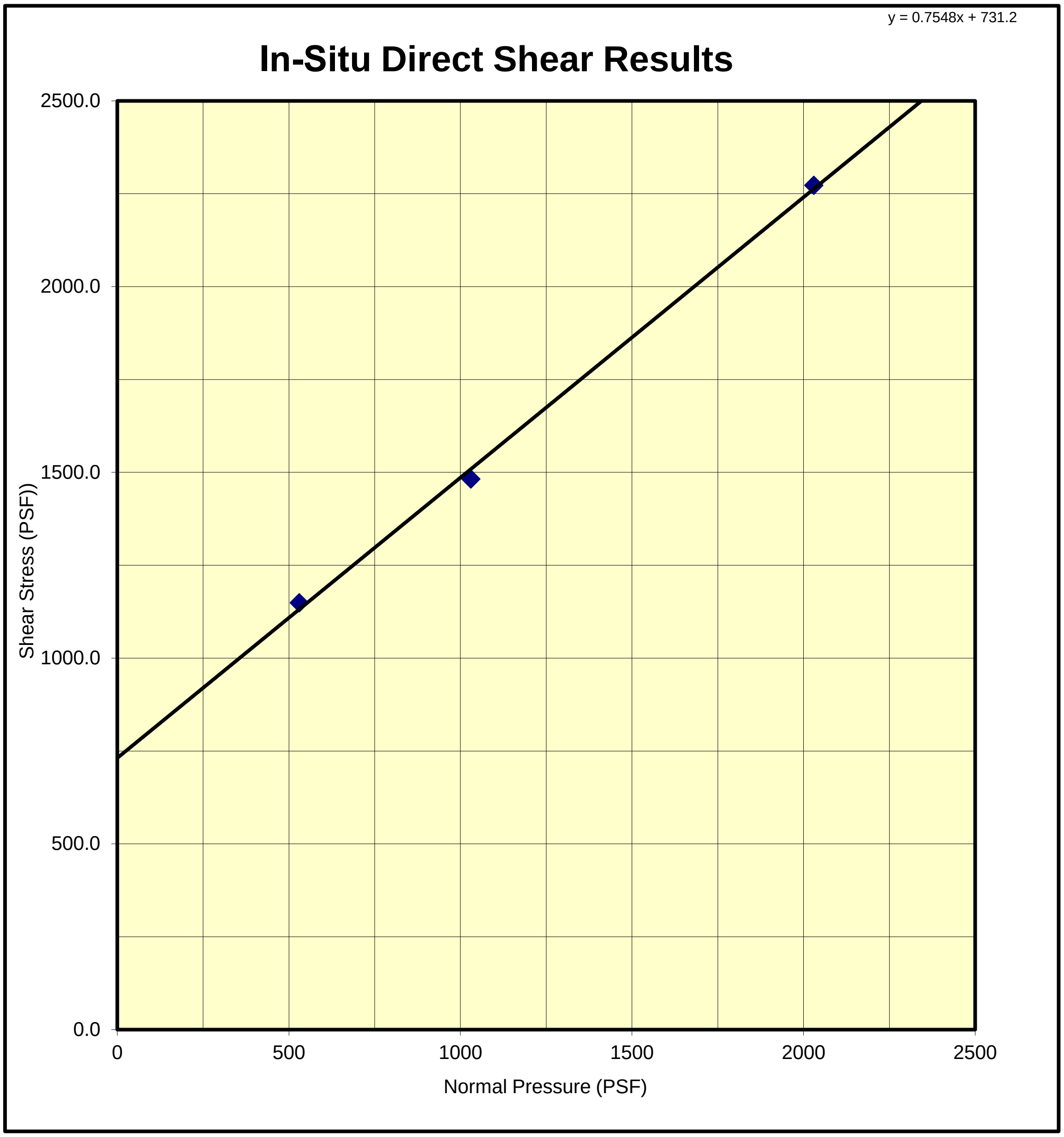
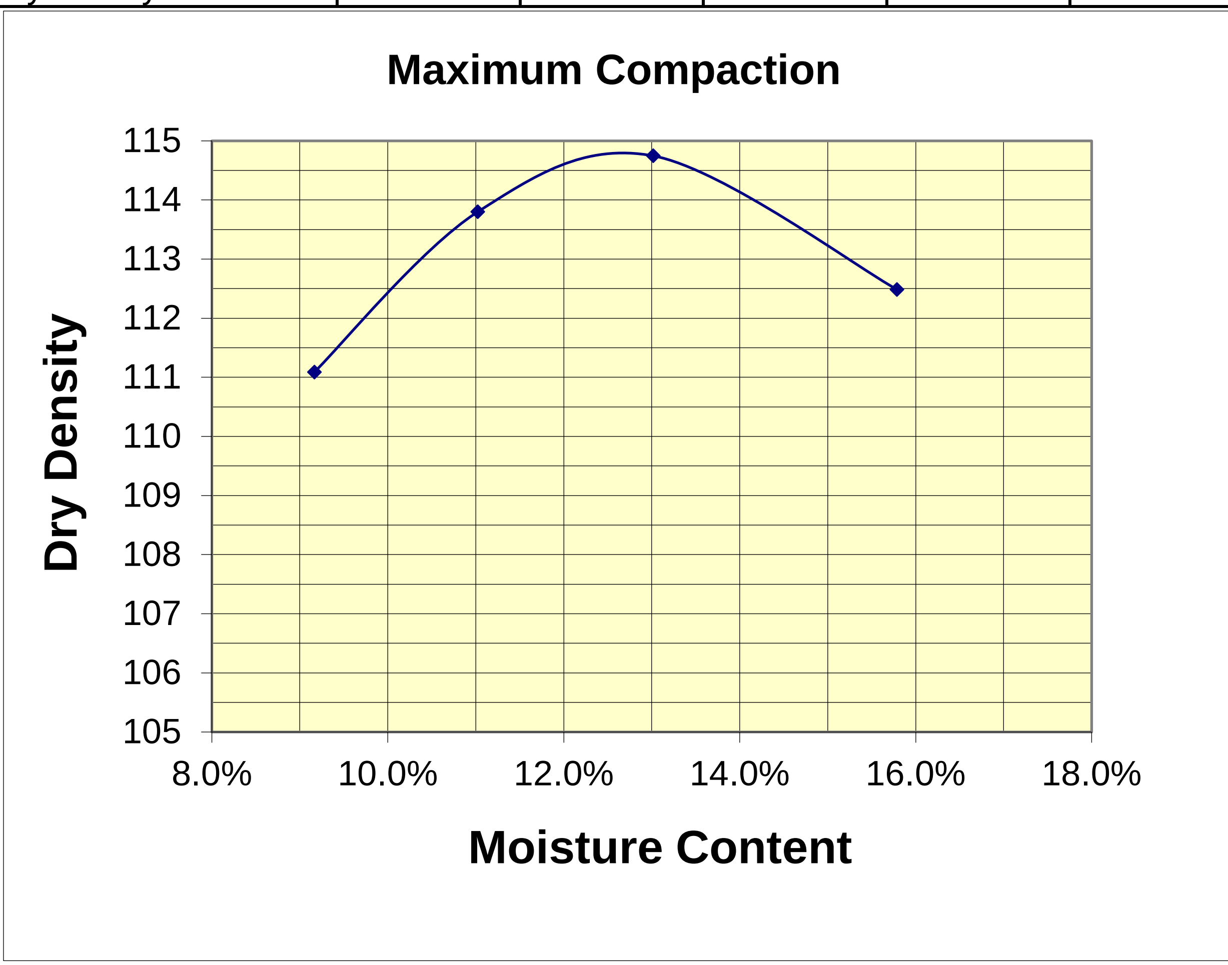


Figure No. 11

Compaction Test

Project:	Old Haul Road/ Dark Mulch	**Project #**	SM 11180
Descriptn:	Yellow Brown Fine Grain Sand	**Date:**	May 31, 2017
From Existing Redwood log box colvert enbankme		**Tested By:**	AA
Type: 4" mold	**Curve:** 1	**Sample Wt.**	2000 gr.

Moisture		2	4	6	8		
Wt. Mold+Comp. Soil		3932.5	4009.3	4059.9	4068.4		
Wt. of Mold	2095.0	2095.0	2095.0	2095.0	2095.0		
Vol. Factor:	0.066	0.066	0.066	0.066	0.066		
Tare No.:		104	178	7	130		
Wet Wt.+Tare:		807.0	671.7	765.1	883.9		
Dry Wt.+Tare:		745.7	612.2	689.6	774.1		
Wt. Comp. Soil		1837.5	1914.3	1964.9	1973.4		
Tare Wt.		77.0	72.4	109.6	78.5		
Net Dry Wt.		668.7	539.8	580.0	695.6		
Wt. of Water		61.3	59.5	75.5	109.8		
Wet Density		121.3	126.3	129.7	130.2		
Water Content		0.092	0.110	0.130	0.158		
Water Content %		9.2%	11.0%	13.0%	15.8%		
Dry Density		111.1	113.8	114.7	112.5		



Laboratory
Max D.D.
114.7
Opt Moist.
13.0 %

Corrected
Max D.D.
115.0
Opt Moist.
13.0 %

Engineer
JK

Tech
AK

Figure No. 12

Direct Shear

Project:	Old Haul Rd.	**Date**	6/13/2017
Sample #	curve 1 %75	**Tested By:**	RC/AA
Description	Yellow Brown fine grain sand		

Test Number	1	2	3	4
Normal Pressure (PSF)	530	1030	2030	4030
Max Shear Stress	26.6	37.8	72.0	0
Shear Stress (PSF)	781.9	1113.1	2118.2	0

Equation of Trendline	
Intercept	Slope
252.144	0.9072

C (PSF)	PHI
252	42

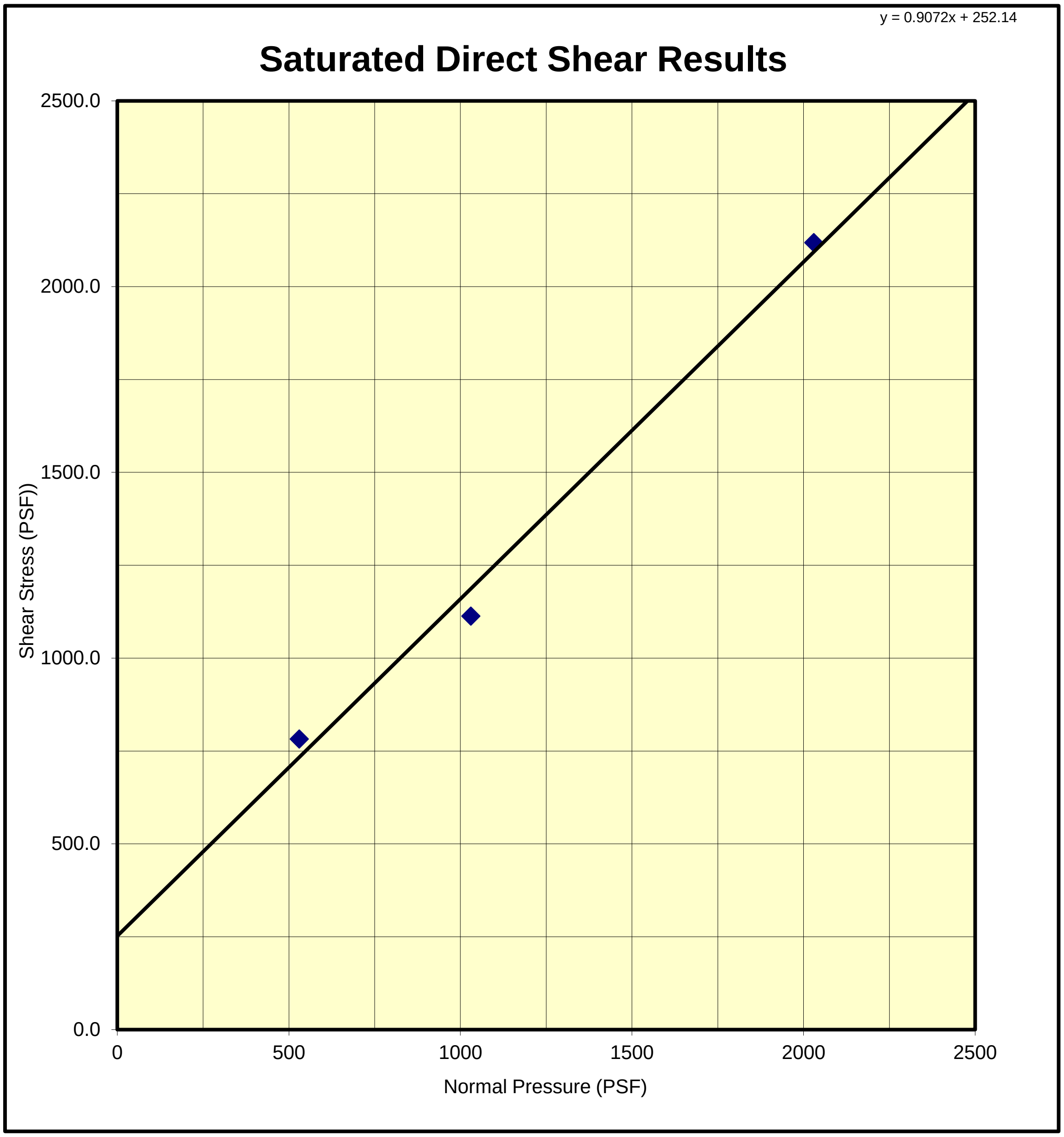


Figure No. 13

Direct Shear

Project:	Old Haul Rd.
Sample #	curve 1 %85
Description	Yellow Brown Fine grain sand

Date	6/13/2017
Tested By:	RC/AA

Test Number	1	2	3	4
Normal Pressure (PSF)	530	1030	2030	4030
Max Shear Stress	29.3	50.0	67.5	0
Shear Stress (PSF)	861.1	1471.7	1984.3	0

Equation of Trendline	
Intercept	Slope
583.3481	0.715063

C (PSF)	PHI
583	36

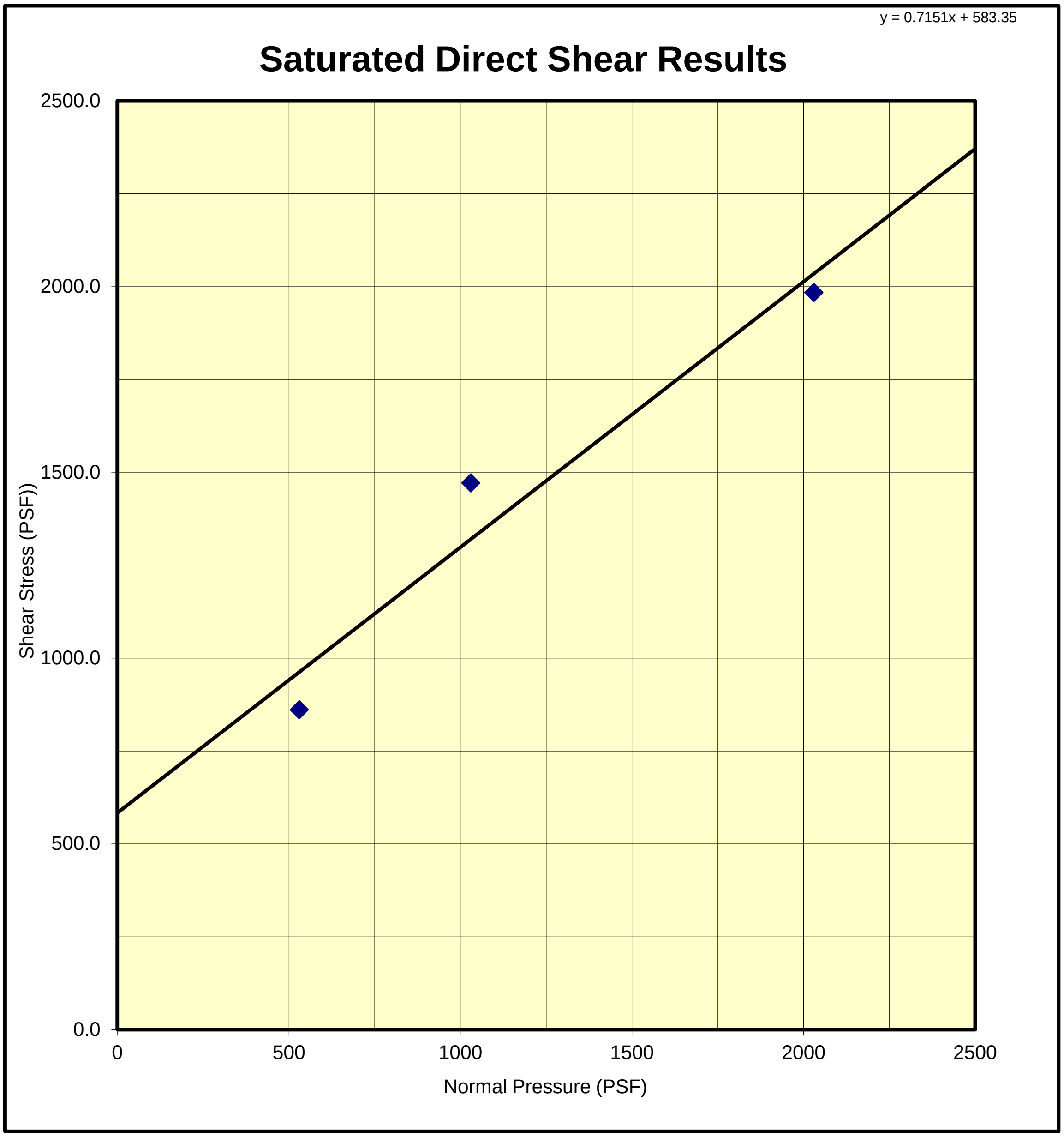


Figure No. 14

$H_c = \frac{N_s c}{\gamma}$

TABLE 10.2 STABILITY FACTOR, $N_s = H_c \gamma / c$ BY LIMIT ANALYSIS.

Friction Angle φ, Degrees	Slope Angle α, Degrees	Slope Angle β, Degrees: 90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15
0	0	3.83	4.081	4.325	4.57	4.789	5.026	5.25	5.462	5.760	5.86	6.063	6.249	6.51	6.602	6.787	7.35
5	0	4.19	4.502	4.818	5.14	5.469	5.807	6.17	6.526	6.920	7.33	7.839	8.414	9.17	10.130	11.668	14.80
	5	4.14	4.436	4.740	5.05	5.366	5.691	6.03	6.384	6.764	7.18	7.645	8.194	8.93	9.821	11.271	14.62
10	0	4.59	4.971	5.375	5.80	6.249	6.732	7.26	7.844	8.515	9.32	10.298	11.606	13.53	16.636	23.137	45.53
	5	4.53	4.907	5.300	5.72	6.153	6.625	7.14	7.717	8.375	9.14	10.129	11.416	13.26	16.368	22.785	45.15
	10	4.47	4.829	5.207	5.61	6.031	6.487	6.98	7.543	8.180	8.93	9.872	11.109	12.97	15.839	21.957	44.56
15	0	5.02	5.498	6.012	6.57	7.176	7.854	8.64	9.537	10.642	12.05	13.972	16.829	21.71	32.108	69.404	
	5	4.97	5.437	5.940	6.49	7.084	7.754	8.52	9.418	10.513	11.91	13.816	16.652	21.50	31.850	69.047	
	10	4.90	5.363	5.853	6.39	6.971	7.628	8.38	9.262	10.339	11.73	13.591	16.383	21.14	31.378	68.256	
	15	4.83	5.270	5.743	6.28	6.825	7.460	8.18	9.045	10.088	11.42	13.228	15.916	20.59	30.254	65.173	
20	0	5.51	6.099	6.751	7.48	8.299	9.253	10.39	11.799	13.628	16.18	19.998	26.655	41.27	94.632		
	5	5.46	6.040	6.681	7.40	8.212	9.157	10.30	11.687	13.506	16.04	19.850	26.485	41.06	94.377		
	10	5.40	5.969	6.598	7.31	8.105	9.038	10.15	11.542	13.346	15.87	19.641	26.232	40.73	93.776		
	15	5.33	5.882	6.496	7.20	7.970	8.886	9.98	11.347	13.122	15.59	19.322	25.818	40.16	92.898		
	20	5.25	5.773	6.366	7.04	7.793	8.681	9.78	11.066	12.785	15.17	18.770	25.011	39.19	88.632		
25	0	6.06	6.793	7.624	8.59	9.696	11.048	12.75	14.972	18.098	22.92	31.333	50.059	120.0			
	5	6.01	6.735	7.556	8.52	9.611	10.955	12.65	14.864	17.981	22.78	31.188	49.887	119.8			
	10	5.96	6.666	7.475	8.41	9.508	10.842	12.54	14.727	17.829	22.60	30.986	49.635	119.5			
	15	5.89	6.584	7.378	8.30	9.382	10.700	12.40	14.547	17.623	22.37	30.687	49.234	118.7			
	20	5.81	6.483	7.258	8.16	9.220	10.514	12.17	14.297	17.325	21.98	30.198	48.503	117.4			
	25	5.71	6.354	7.104	7.97	9.003	10.257	11.80	13.922	16.851	21.35	29.245	46.759	115.5			
30	0	6.69	7.607	8.675	9.96	11.485	13.439	16.11	19.712	25.413	35.63	58.274	144.199				
	5	6.63	7.550	8.607	9.87	11.400	13.348	16.00	19.607	25.298	35.44	58.127	144.011				
	10	6.58	7.483	8.529	9.79	11.301	13.239	15.87	19.475	25.151	35.25	57.924	143.738				
	15	6.53	7.404	8.436	9.67	11.180	13.104	15.69	19.305	24.956	34.99	57.629	143.307				
	20	6.44	7.309	8.323	9.54	11.029	12.931	15.48	19.076	24.682	34.64	57.159	142.538				
	25	6.34	7.190	8.181	9.37	10.833	12.700	15.21	18.744	24.265	34.12	56.302	140.842				
	30	6.22	7.038	7.995	9.15	10.561	12.369	14.81	18.216	23.544	33.08	54.252	134.524				
35	0	7.43	8.581	9.969	11.68	13.857	16.774	20.94	27.448	39.109	65.53	166.378					
	5	7.38	8.524	9.902	11.60	13.774	16.685	20.84	27.344	38.995	65.39	166.220					
	10	7.32	8.458	9.825	11.51	13.676	16.578	20.71	27.216	38.851	65.22	166.003					
	15	7.26	8.382	9.735	11.41	13.560	16.448	20.55	27.053	38.662	65.03	165.720					
	20	7.18	8.291	9.627	11.28	13.417	16.285	20.36	26.836	38.401	64.74	165.188					
	25	7.11	8.180	9.494	11.12	13.234	16.072	20.07	26.533	38.015	64.18	164.298					
	30	6.99	8.041	9.325	10.93	12.990	15.778	19.73	26.071	37.384	63.00	162.333					
	35	6.84	7.858	9.098	10.66	12.641	15.337	19.21	25.271	36.150	60.80	154.978					
40	0	8.30	9.771	11.608	14.00	17.152	21.724	28.99	41.887	71.485	185.6						
	5	8.26	9.713	11.541	13.94	17.069	21.635	28.84	41.784	71.370	185.5						
	10	8.21	9.649	11.465	13.85	16.974	21.530	28.69	41.657	71.226	185.3						
	15	8.15	9.574	11.377	13.72	16.860	21.405	28.54	41.498	71.038	185.0						
	20	8.06	9.487	11.273	13.57	16.723	21.249	28.39	41.290	70.780	184.6						
	25	7.98	9.382	11.147	13.42	16.551	21.049	28.16	41.002	70.406	184.0						
	30	7.87	9.252	10.989	13.21	16.326	20.779	27.88	40.578	69.812	183.2						
	35	7.76	9.086	10.784	12.95	16.016	20.391	27.49	39.885	68.728	182.3						
	40	7.61	8.863	10.501	12.63	15.551	19.773	26.91	38.525	66.119	181.1						

$F.S. = \frac{H_c}{H_{slope}}$