APPENDIX G

Coastal Bluff Evaluation
SANDERS & ASSOCIATES GEOSTRUCTURAL ENGINEERING, INC

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June 30, 2005
Project No. SE99-033 SC-RA2

Mr. Paul Rodrigues
Santa Cruz County Redevelopment Agency
701 Ocean St., Rm. 510
Santa Cruz, CA 95060

RE: COASTAL BLUFF EVALUATION
East Cliff Drive between 33rd And 36th Avenues
Santa Cruz County, California

Dear Paul:

We are pleased to present the results of our evaluation of the coastal bluff along East Cliff Drive between 33rd and 36th Avenues in Santa Cruz County, California. We understand that the County of Santa Cruz plans to submit an application to the California Coastal Commission for the construction of partial to full bluff protection along this section of bluff. The Coastal Commission's findings on a previous application for full bluff protection submitted by the Corps of Engineers in 2003 noted an incomplete threat evaluation had been performed. In particular, details were missing regarding the specific sections of East Cliff Drive classified as "in danger", and to what degree. As a result, we were retained to perform this evaluation to more precisely define the degree of threat along East Cliff Drive and attempt to address other Coastal Commission comments provided in the Consistency Determination report.

We are submitting three (3) copies of this report for your use. We appreciate the opportunity to provide geologic services to the County of Santa Cruz. Please call us should you have any questions.

Sincerely yours,
Sanders & Associates Geostructural Engineering, Inc.

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COASTAL BLUFF EVALUATION
East Cliff Drive between 33rd and 36th Avenues
Santa Cruz County, California

1.0 INTRODUCTION

Sanders & Associates Geostructural Engineering, Inc. (SAGE) is pleased to present the results of our evaluation of the coastal bluff along East Cliff Drive between 33rd and 36th Avenues in Santa Cruz County, California (Sheet 1). The coastal bluff has been and continues to be susceptible to erosion, which has resulted in the deterioration and partial collapse of the guardrail and shoulder along portions of East Cliff Drive. As a result, fencing has been locally erected for public safety and the roadway reconfigured from two lanes to a single lane. Emergency repair of three failing crib walls was performed in 2004 to provide immediate local crib wall stability and flank protection.

We understand that the County of Santa Cruz (County) plans to submit an application to the California Coastal Commission for the construction of partial to full bluff protection between 33rd and 36th Avenues. The Coastal Commission's findings on a previous application for full bluff protection submitted by the U.S. Army Corps of Engineers in 2003 noted an incomplete threat evaluation had been performed. In particular, details were missing regarding specific sections of East Cliff Drive classified as "in danger", and to what degree. We understand that the Coastal Commission has generally interpreted "in danger" to mean that an existing structure, in this case the road and associated underground utilities, would be unsafe to use or otherwise occupy within the next two to three storm season cycles (generally the next few years) if nothing were done. We were retained to more precisely define the degree of threat along East Cliff Drive and attempt to address other Coastal Commission comments provided in the Consistency Determination report, which summarizes the Coastal Commission's basis for rejection of the 2003 project.

For the purposes of clarity in this report, we herein refer to East Cliff Drive and the coastal bluff between 33rd and 36th Avenues as the site.

2.0 SCOPE OF WORK

We performed this evaluation in accordance with our proposal dated November 3, 2004, which included the following tasks:

- Reviewing available published and unpublished geologic and geotechnical data for the site.
- Reviewing long-term bluff erosion rates recently provided to the County by Dr. Gary Griggs of U.C. Santa Cruz, and contacting Dr. Griggs and others to document the methods used.
- Reviewing available historical stereo-paired aerial photographs on-file in the Map Room of the U.C. Santa Cruz Science Library.
- Performing a geologic site reconnaissance of the site and immediate site vicinity.
- Performing geologic analyses to evaluate the degree of threat to improvements along the bluff with respect to coastal erosion.
- Preparing this technical report.

3.0 FIELD INVESTIGATION

Geologic reconnaissance mapping of the site and site vicinity was performed on December 9, 2004 to document the geologic conditions along the bluff and to identify sections of the bluff with oversteepened slopes within the terrace deposits and/or areas where the underlying Purisima Formation have been undercut. These areas are potentially the least stable and, therefore, have the greatest likelihood of causing bluff retreat in the near future. Supplemental field mapping was performed on March 2, 2005 to document local changes in the bluff conditions since the December 2004 mapping was completed. Geologic field data was recorded on a topographic base map prepared by Andregg, Inc., dated November 2000. The results of our geologic reconnaissance mapping are shown on the Geologic Reconnaissance and Degree of Threat Evaluation Maps, Sheets 1 through 6, which are attached.

As part of our field investigation, we reviewed 15 sets of vertical stereo-paired aerial photographs flown between 1928 and 2003 to evaluate the magnitude and frequency of episodic bluff failures, and to estimate the largest historical bluff failure events. Tonal contrasts and/or prominent crescent shaped scarps visible in the aerial photographs can signify past bluff failures. We also reviewed five sets of oblique aerial photographs flown between 1972 and 2004 that are available at www.californiacoastline.org. A list of vertical and oblique aerial photographs reviewed is included in the references.

4.0 SITE CONDITIONS

4.1 <u>Bluff Geology</u>

In general, the bluff consists of Pliocene Purisima Formation overlain by Pleistocene terrace deposits (Brabb, 1989). The bluffs are locally covered with landslide deposits, slope deposits, and artificial fill. The geologic units are described below and the approximate limits are shown on Sheets 2 through 6.

Moderately cemented and cemented fine-grained sandstones, siltstones, and mudstones of the Purisima Formation comprise the lower 3.5 meters of the bluff. Depositional bedding in the Purisima bedrock varies from several centimeters to several meters, and is often difficult to distinguish. Other structural discontinuities include joints (fractures) and minor faults, both of which provide weak planes within the bedrock that promote block failure and can also be preferentially eroded by wave attack. The faults also locally offset individual layers or beds of differing wave erosion resistance within the Purisima Formation, resulting in the formation of embayments where softer and more easily eroded layers are present at beach level. Fracture spacing is on the order of 1.5 to 4.5 meters.

Terrace deposits overlie the Purisima bedrock, and are generally characterized by weakly to moderately cemented clayey sand and coarse sand with rounded gravels and small cobbles (Haro, Kasunich & Associates, 1997).

Numerous small landslides are mapped along the bluff within the terrace deposits, primarily in the embayment areas. The landslides appear to be shallow (less than 1 meter thick). Landslide deposits generally consist of a chaotic mixture of soil and debris that has been transported downslope by landsliding.

Slope deposits locally blanket the lower portions of the terrace slope and the Purisima Formation bench. The deposits consist of unconsolidated soil and organic material transported from the upper terrace slope by sheet wash or sloughing.

Minor fills are present locally along the bluff, primarily associated with construction of the existing retaining walls and storm drain outfalls. The fills were mapped in localized areas only.

4.2 Bluff Conditions

East Cliff Drive generally runs in a southwest to northeast direction for the area in question between 33rd and 36th Avenue, and is bordered on the southeast by a coastal bluff ranging up to 10 meters in height above mean sea level (MSL) (Sheets 1 through 6). The overall bluff configuration is relatively smooth with small-scale promontories and embayments at the southwestern and northeastern ends of the site. The bluff profile is generally characterized by an approximately 3.5-meter-high, near vertical slope within the Purisima Formation along the lower portion of the bluff, and a 45 to 60 degree slope (measured from horizontal) in the overlying terrace deposits that extends to the top of bluff (Figure 1). A topographic bench is locally present at the top of the Purisima Formation where the overlying terrace deposits have been removed. The width of this bench ranges up to 5 meters at the southwestern end of the site and 7 meters at the northeastern end, but is considerably less along the remainder of the bluff. The slopes within the terrace deposits are locally covered with low-lying vegetation that drapes over the Purisima Formation bench. Numerous storm drain outfalls are visible on the terrace slope.

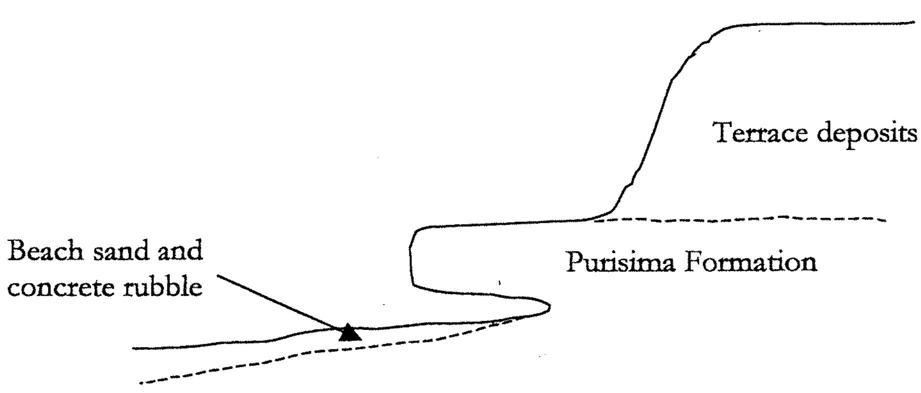


Figure 1 Schematic bluff profile showing the terrace deposits overlying the Purisima Formation. Wave-cut notches or undercuts are locally present in the Purisima Formation.

Wave-cut notches or undercuts are locally present in the Purisima Formation along the base of the bluff (Figure 1). Because the undercuts are locally filled with sand and concrete rubble, the full dimensions of the undercuts can only be approximated. Where measured from the face of the Purisima Formation bench, the undercuts are up to one meter high and extend up to 5.5 meters horizontally into the bluff.

Four existing retaining walls are present along the bluff, designated as Wall 1 through 4 moving from southwest to northeast (Sheets 2 through 6). Walls 1, 2, and 4 consist of soil nail walls constructed in 2004 as part of emergency stabilization of three failing crib walls. The crib walls were stabilized in place by drilling soil nails (ground anchors) directly through the existing structural frame of the walls and encasing the cribs with an integral shotcrete facing. Wall 3 consists of a crib wall approximately 5.5 meters in length. All four retaining walls are located above the Purisima Formation, except for a semi-circular, three-tiered concrete platform located at the eastern end of Wall 1. The platform appears to have been constructed to stabilize the Purisima Formation and act as a wall foundation.

An abandoned restroom structure is located at the top of the bluff between 35th and 36th Avenues, with a wood staircase that extends to the base of the bluff. A large riprap revetment fronts the restroom structure and staircase. Riprap locally fronts the bluff across the entire site, particularly on the western side of the site, where riprap is concentrated in the embayments.

5.0 BLUFF EROSION

5.1 Bluff History

A limited bluff history was developed using historic vertical and oblique aerial photographs reviewed as part of the field investigation.

In the earliest photographs reviewed (1928), the bluff configuration was irregular with numerous promontories and embayments. Most of the bluff appeared to be free of vegetation, which is suggestive of on-going erosion. Significant bluff erosion occurred between 1931 and 1940, primarily between 33rd and 34th Avenues. By 1948, the edge of bluff was locally within several meters of East Cliff Drive.

Riprap was placed along the base of bluff between 34th and 35th Avenues sometime between 1948 and 1963. Significant bluff erosion occurred between 1963 and 1965, primarily along unprotected bluff sections, including a slope failure at the western end of the site near the future location of Wall 1. The remnant scar in the bluff was approximately 9 meters wide and extended about 2 to 3 meters back into the face of the bluff. Debris was visible at the base of the bluff.

A significant quantity of riprap was subsequently placed along the base of the bluff between 1965 and 1970, followed by vegetation growth along much of the bluff where protected by the riprap.

Significant erosion occurred along the bluff between 1976 and 1984. We believe this is most likely the result of the 1982/83 El Niño winter storms. The most significant erosional feature was a large embayment within the terrace deposits at the future location of Wall 1. The embayment extended back into the bluff to near the edge of East Cliff Drive. Nearly continuous riprap protection was visible along the base of the bluff.

Continued episodes of localized bluff erosion occurred between 1986 and 2003, primarily along the section of bluff west of the abandoned restroom structure.

5.2 Long-Term Bluff Erosion Rates

The site bluff was designated by Griggs and Savoy (1985) as hazardous with a high erosion risk. Long-term bluff erosion rates previously measured for the site area generally average about 0.3 meters (1 foot) per year (Griggs and Savoy, 1985; Foxx, Nielsen and Associates, 1998).

Moore (1998) recently generated average long-term bluff erosion rates from 1953 to 1994 at the site using softcopy photogrammetry, geographical information system (GIS), and aerial photographs (Figure 2). Recent advances in shoreline mapping techniques described in Moore et al. (1999), Moore (2000), and Moore and Griggs (2002) allow for nearly complete removal of displacement and distortion errors common to traditional techniques using uncorrected aerial photographs. Bluff positions identified at a 5-meter spacing interval along the bluff using the these new techniques indicate that average erosion rates along the bluff are generally less than 0.2 meters (8 inches) per year. The discrepancy between the new rates and the previous rates may be due to displacement and distortion errors described above. The erosion rates also may have slowed due to the placement of riprap along the base of the bluff. However, as noted in the Consistency Determination, these long-term erosion rates only represent a long-term average, and are generally not well suited to estimate erosion over short-term intervals due to the episodic nature of bluff erosion.

5.3 Episodic (Short-Term) Bluff Erosion

Coastal bluff erosion is generally caused by wave-induced erosion that undercuts or weakens the bluff, ultimately causing the upper portion of the bluff to fail. As a result, bluff erosion most often occurs episodically as individual events rather than steadily over time. The primary modes of episodic bluff erosion at the site include:

- Undercutting of the Purisima Formation bench by wave erosion, as described by Weber (2000). The presence of rounded concrete rubble near the undercuts suggests that the rounded blocks abrade the base of the bluff during wave attack and contribute to undercutting. With the underlying support removed, the bench eventually collapses onto the beach. After failure, the rubble from the collapsed bench offers some limited bluff protection, but is generally broken down by wave action within several years. For example, a prominent Purisima bedrock finger at Wall 1 shown on the 2000 topographic map was completely removed by 2004 (Sheet 2). Following the collapse of the bench, the overlying terrace deposits are unsupported and subsequently fail. Wave erosion removes the debris and begins to cut a new notch at the base of the bluff, restarting the cycle.

- Surface erosion and shallow failures of the terrace deposits resulting from surface runoff and excessive groundwater seepage, which reduces soil strength and causes soil collapse.
- Undercutting of the terrace deposits by large waves that periodically overtop the Purisima bench, primarily within the embayments where wave energy is focused. Riprap in the embayments protects the Purisima Formation, but may actually ramp the wave run-up into the lower terrace deposits. Following the loss of toe support, the oversteepened terrace deposits generally fail.

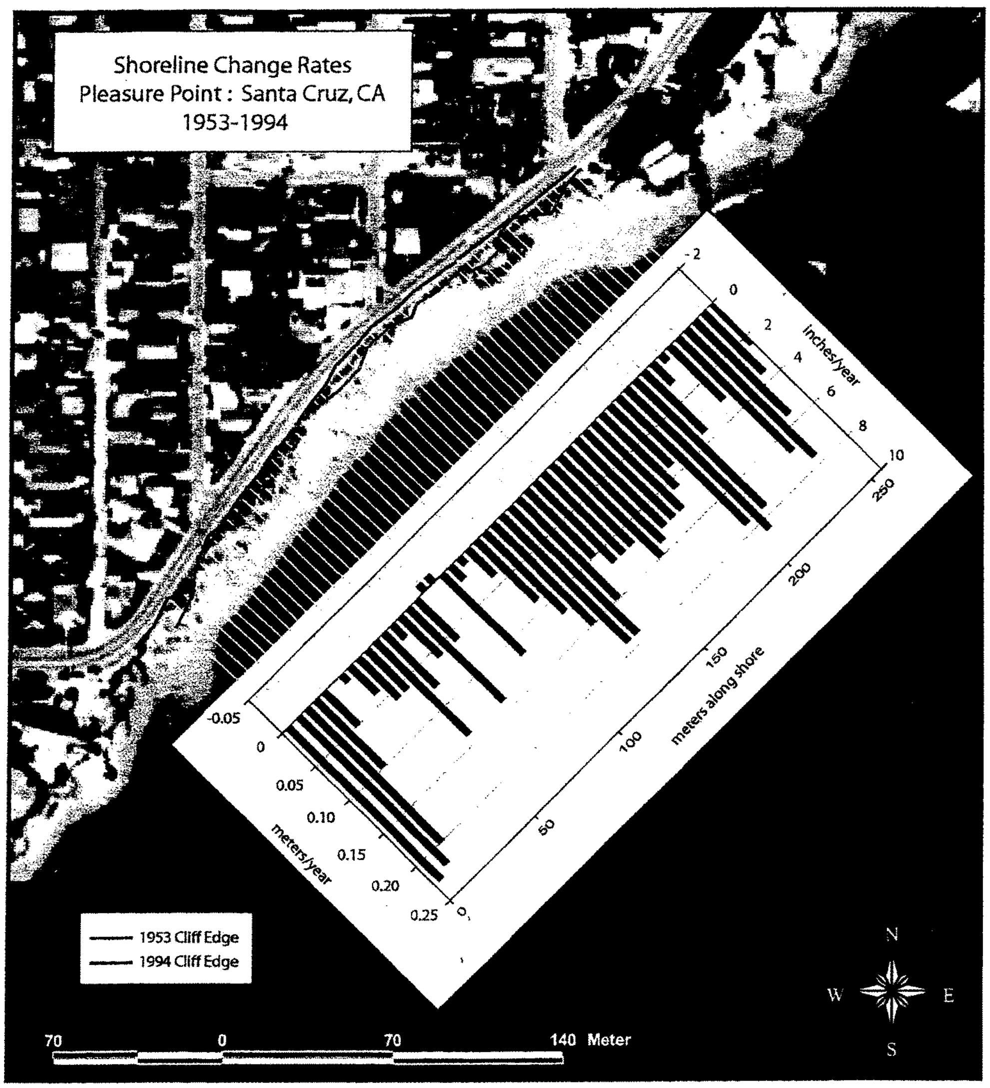


Figure 2 Long-term bluff erosion rates from 1953 to 1994 by Moore (1998). Positive values denote erosion.

Other contributing factors to bluff erosion include strong ground shaking during large magnitude earthquakes on nearby faults and human activity on the bluff.

The Consistency Determination noted that information on past episodic failure events, including locations and the nature/size of the bluff loss, had not been documented. We attempted to evaluate the magnitude and frequency of the bluff failures, and to estimate the largest bluff failure events using historic aerial photographs reviewed as part of the field investigation. However, the time interval between the available aerial photographs covering the site generally was 1 to 15 years making it difficult to establish whether the observed bluff erosion between photographs occurred entirely during a single large event or collectively during multiple smaller events.

We did observe a possible single event bluff failure that occurred between the August 1963 and November 1965 photographs at the western end of the site near the future location of Wall 1. As described above, the remnant scar in the bluff was approximately 9 meters wide and extended about 2 to 3 meters back into the face of the bluff. Given the remnant scar configuration and overall steepness of the slope, we believe the bluff failure likely occurred during a single event. The size of the bluff failure is consistent with the bluff failure that occurred east of the site near Larch Lane in 1995 (Tetra Tech, 2003), which reportedly extended up to 3 meters into the bluff face.

6.0 SLOPE STABILITY ANALYSES

The Consistency Determination reported that quantitative slope stability analysis should be performed to describe the threat in terms of bluff stability, potential bluff failure planes (and where they are located), and factors of safety.

Haro, Kasunich & Associates, Inc. (HKA) presented computer-based slope stability analyses in their geotechnical investigation report dated June 1997, and an addendum report dated May 1998. The slope stability evaluations were performed for both static and seismic conditions, and considered loading combinations including no surcharge, a vehicular traffic surcharge on East Cliff Drive, and water seepage pressures for up to 1.5 meters of water perched within the terrace deposits above the Purisima Formation bench.

Slope stability analyses, in general, are performed by assuming the geometry for a potential failure plane (either a sector of a circle or a wedge-like block) and computing the ratio of the net resisting force (soil strength) relative to the net driving forces (soil mass, surcharge, seepage pressures, and/or seismic accelerations). This ratio is defined as the "factor of safety". When the resisting forces are greater than the driving forces, the factor of safety is greater than 1.0. When the factor of safety is about 1.0 (i.e., the driving forces are equal to the resisting forces), failure is imminent. When the factor of safety is less than 1.0 (i.e., driving forces exceed resisting forces), failure is likely (i.e., under seismic conditions) and/or has already occurred.[1] Commercial slope stability programs utilize algorithms to check multiple failure plane geometries and the lowest factor of safety computed for a given combination of slope geometry and strength parameters is considered the most critical factor

1 In the case of a failure that has already occurred, it may be necessary to "back calculate" a factor of safety less than 1.0 in order to better estimate the possible range in soil strength parameters.

of safety under those conditions. Typically, a minimum factor of safety of 1.5 is considered acceptable for static conditions. Lower factors a safety, typically between 1.1 and 1.3, are often acceptable for seismic conditions.

The results of the slope stability analyses performed by HKA yielded factors of safety against slope failure ranging from 1.1 to 1.3 for static conditions, suggesting the slopes are marginally stable in their current configuration. For seismic conditions, the factors of safety reportedly range from 0.79 and 0.93, suggesting failure is likely during a large earthquake on a nearby fault. The graphical printouts included in the HKA reports depicted potential failure surfaces daylighting about 1.6 to 3.4 meters behind the edge of bluff for static conditions, and 1.6 to 4 meters behind the bluff edge for seismic loading conditions. In all cases the critical failure surfaces appeared to be contained entirely within the terrace deposits, and did not extend into the underlying Purisima Formation.

All slope stability analyses presented by HKA were based on generalized soil and rock parameters determined from five test borings drilled along East Cliff Drive between 33rd and 36th Avenues. However, the bluff geometry used for the slope stability analyses was based on a cross section constructed by Foxx, Nielsen and Associates (1997) for a section of bluff near 38th Avenue, which is located several hundred feet east of the site. While the thickness of the terrace deposits at The Hook are reasonably consistent with those at the site, the top of the Purisima bedrock at The Hook is elevated relative to the top of Purisima bedrock at the site. In addition, the geometry represented in the cross section does not include undercutting of the Purisima Formation, which could result in lower apparent factors of safety than those indicated in the HKA analyses.

Based on the foregoing, it is our opinion that the analyses performed to date by HKA are helpful in generally characterizing the slope stability of the coastal bluff at the site. However, we believe that the number of cross sections analyzed (one) and the location of the analyzed section relative to the site make the scope of the HKA analyses inadequate to quantify the slope stability of the bluff at the site to a degree that is likely to satisfy the criteria outlined in the Consistency Determination. A more site-specific analysis may result in an increased level of threat to the improvements, particularly with respect to seismic loading. However, we understand that the Coastal Commission criteria for degree of threat might discount seismic loading contributions.

We recommend that additional slope stability analyses be performed based on cross sections from the site. The cross sections should be representative of the current bluff conditions and geometry, and should include site-specific conditions such as undercutting of the bluff within the Purisima Formation. In addition, the slope stability analyses should consider recent procedures outlined in a paper by Ashford and Sitar (2002) for evaluating the seismic stability of steep coastal slopes composed of weakly cemented granular soils.

7.0 DEGREE OF THREAT

To evaluate the degree of threat to specific sections of East Cliff Drive between 33rd and 36th Avenues, we primarily considered the impacts of episodic (short-term) erosion. As noted in the Consistency Determination, the use of the long-term erosion rates for evaluating the degree of threat to improvements is problematic. The long-term erosion rates only represent a long-term average, and are generally not well suited to estimate erosion over short-term intervals due to the episodic nature of bluff erosion.

The Consistency Determination suggested that the degree to which improvements may be at risk could be best understood by evaluating the largest potential episodic bluff failure, the likelihood of such events, and the proximity of improvements to areas likely to experience such events. As previously discussed, episodic bluff failures have occurred at the site or in the immediate site vicinity. These episodic failures have typically extended about 2 to 3 meters back into the face of the bluff. However, it is unclear if these failures represent the largest potential episodic bluff failure. Although the slope stability analyses by HKA (1998) suggest that bluff failures up to 4 meters can potentially occur along the bluffs, we conclude that an episodic bluff failure of 3 meters is appropriate until supplemental slope stability analyses are performed.

Based on the information presented above, we evaluated the degree of threat to East Cliff Drive and assigned specific sections of the East Cliff Drive to one of the three threat zones, as shown on Sheets 2 through 6. The zones are described below.

1. **Active impact to improvements** – Includes sections of East Cliff Drive where the shoulder has been lost to erosion, and continued erosion will result in the further loss of road and other improvements.
2. **"In Danger"** – Existing structures may be unsafe to use within the next two or three storm season cycles (generally the next few years) if nothing were done (as defined by the Coastal Commission).
3. **Potentially "In Danger"** – Sections of East Cliff Drive beyond the Coastal Commission two to three storm season cycles criteria.

The sections of East Cliff Drive assigned to Zone 1 generally correspond to where the road shoulder has been lost to erosion. We also included a short 3-meter-long section of East Cliff Drive near Wall 3 where a 2-centimeter-wide tension crack was observed in the asphalt shoulder (Sheet 4). An active landslide on the bluff appears to be undermining the road at this location. We notified County personnel of this condition during a site meeting on March 2, 2005, and recommended that this section of the road shoulder be fenced off for public safety. We understand that this has been completed by the Public Works Department.

Zone 2 generally includes sections of East Cliff Drive that are within 3 meters of the present top of bluff, and therefore, within the assumed limits of potential episodic bluff failure. We locally adjusted the limits of Zone 2 to reflect bluff configuration, retaining walls, undercuts, and landsliding. For example, the top of bluff is within 1 meter of East Cliff Drive at Wall 2 and there is evidence of sizable undercuts within the Purisima Formation (Sheet 3). However, the terrace deposits are protected by a new soil nail wall and the undercuts are generally concealed by riprap. Therefore, we assigned this section of East Cliff Drive to Zone 3.

The remaining sections of East Cliff Drive are considered to be potentially "in danger," but beyond the Coastal Commission two to three storm season cycles criteria and have been designated as Zone 3. Although the existing improvements in Zone 3 are located greater than 3 meters from the present top of the bluff in these areas, we believe there are several scenarios that could occur that would result in the potential for these areas to be impacted. Two of these scenarios include:

- Strong Ground Shaking: The site is located in an area of historically high seismicity characterized by strong ground shaking. As suggested by the slope stability analyses performed by HKA, the size of the potential bluff failure under seismic loading conditions may exceed 3 meters, and therefore, larger areas of the site may be classified as "in danger" than currently shown using the 3 meter offset. Although the Coastal Commission criteria for degree of threat might discount seismic loading contributions, recent research by the U.S. Geological Survey (USGS) suggests the overall probability of moment magnitude 6.7 or greater earthquake occurring in the San Francisco Bay region between 2002 to 2031 is 62 percent (WGCEP, 2003).
- Undercuts in Purisima Formation: As noted previously, the Purisima Formation is locally undercut up to 5.5 meters horizontally from the face of the Purisima Formation bench. Although the Purisima Formation is relatively strong, field observations indicate that the bench will eventually collapse onto the beach after the underlying support has been removed. Where the Purisima Formation fails, the overlying terrace deposits would also potentially be subject to substantial vertical movement.

8.0 CONCLUSIONS

Based on the results of our coastal bluff evaluation, we believe that we have more precisely defined the degree of threat along specific sections of East Cliff Drive and addressed other Coastal Commission comments provided in the Consistency Determination report.

We recommend that additional slope stability analyses be performed based on cross sections from the site. Based on the results of the supplemental slope stability analyses, the degree of threat evaluation maps should be revised using the largest potential episodic bluff failure for both static and seismic loading conditions. The supplemental slope stability analyses may result in an increased level of threat to the improvements, particularly with respect to seismic loading. However, we understand that the Coastal Commission criteria for degree of threat might discount seismic loading contributions.

9.0 REFERENCES

Ashford, S.A., and Sitar, N., 2002, Simplified Method for Evaluating Seismic Stability of Steep Slopes: Journal of Geotechnical and Geoenvironmental Engineering, v. 128, no. 2, p. 119-128.

Brabb, E.E., 1989, Geologic Map of Santa Cruz County, California: U.S. Geological Survey Map 1-1905, scale 1:62,500.

California Coastal Commission, 2003, Federal Consistency Determination – Proposed Findings: consistency determination number CD-021-03, staff report prepared December 19, 2003.

Foxx, Nielsen and Associates, 1997, Geologic Map and Cross Sections, East Cliff Drive, Coastal Bluff Stabilization Project, dated March 18, 1997.

Foxx, Nielsen and Associates, 1998, Engineering geologic study of proposed coastal bluff stabilization, East Cliff Drive Seawall, 33rd to 36th Avenues, Santa Cruz County, California: correspondence to Carl Rom, Dept. of Public Works, Santa Cruz County, dated May 12, 1998.

Griggs, G., and Savoy, L., eds., 1985, Living with the California coast: Duke University Press.

Haro, Kasunich and Associates, Inc. (HKA), 1997, Geotechnical Investigation for Coastal Bluff Stabilization Project, East Cliff Drive: prepared for Santa Cruz County Public Works Department, dated June 1997.

Haro, Kasunich and Associates, Inc. (HKA), 1998, Addendum, Geotechnical and Coastal Engineering Investigation for Coastal Bluff Stabilization Project, East Cliff Drive, 33rd to 46th Avenue, Santa Cruz County, California: prepared for Santa Cruz County Public Works Department, dated May 1998.

Moore, L.J., 1998, Quantitative shoreline change assessment and identification of erosion hotspots in Santa Cruz County, California: Ph.D. dissertation, U.C. Santa Cruz.

Moore, L.J., 2000, Shoreline Mapping Techniques: Journal of Coastal Research 16:111-124.

Moore, L.J., Benumof, B.T., and Griggs, G.B., 1999, Coastal Erosion Hazards in Santa Cruz and San Diego Counties, California: Journal of Coastal Research, Special Issue 28: 121-139.

Moore, L.J., and Griggs, G.B., 2002, Long-term cliff retreat and erosion hotspots along the central shores of the Monterey National Marine Sanctuary: Marine Geology 181: 265-283.

Tetra Tech, Inc., 2003, Draft - East Cliff Drive Bluff Protection and Parkway, Environmental Impact Statement and Environmental Impact Report: State Clearinghouse No. 2001012097, prepared for US Army Corps of Engineers and County of Santa Cruz Planning Department, dated March 2003.

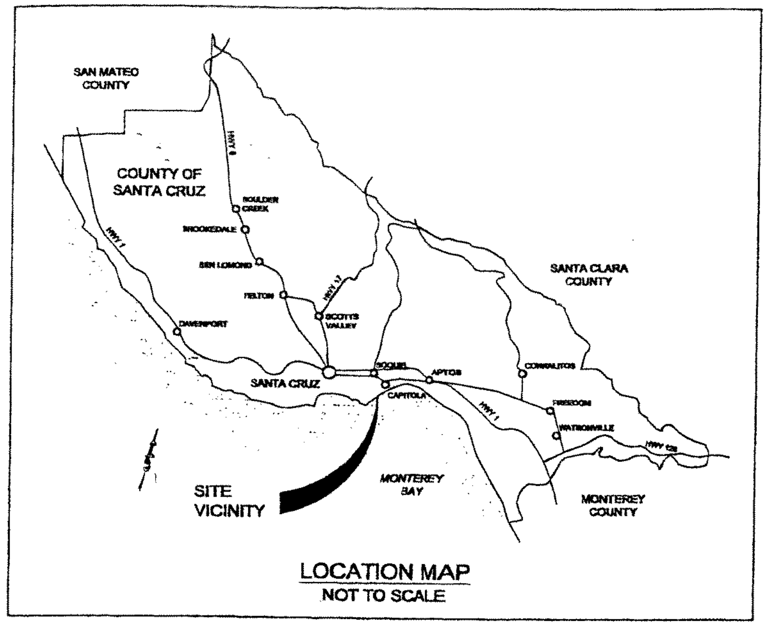
Weber, G.E., 2000, Coastal Geology in the Vicinity of Pleasure Point, Santa Cruz County, California: prepared for Santa Cruz County Redevelopment Agency, dated November 2000.

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

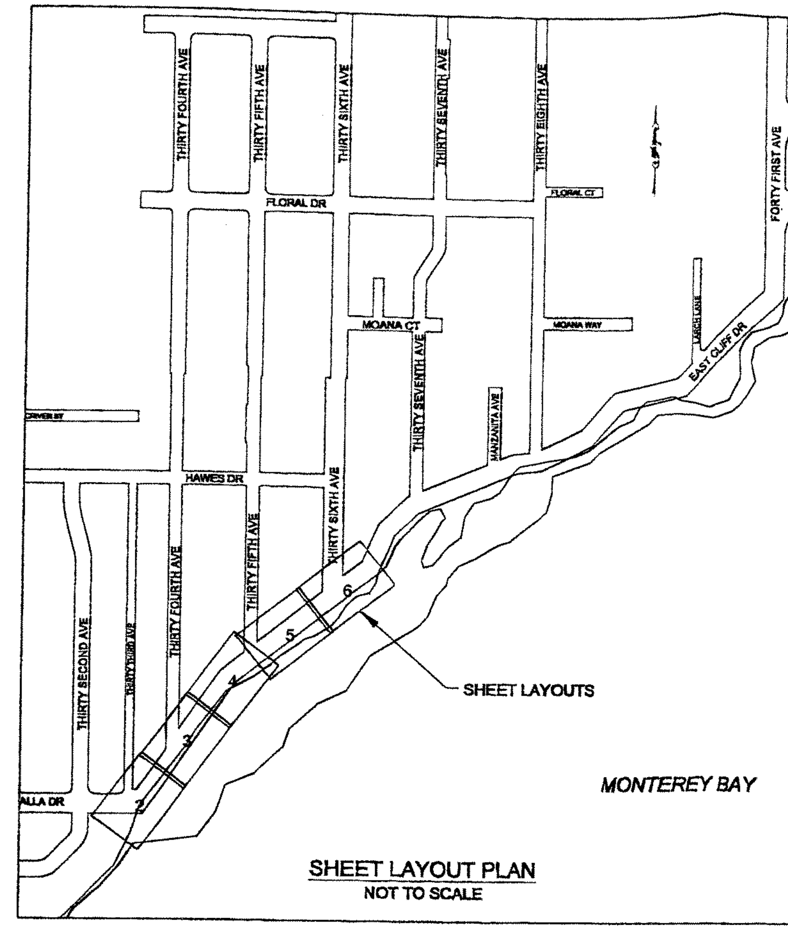
AERIAL PHOTOGRAPHS

DATE	PHOTO NUMBER	SCALE
	Vertical[2]	
6/27/03	AMBAG 214-05,06	1:4,200
6/7/01	CCC-BOK-C 123-1,2	1:12,000
6/22/94	Big Creek Lumber 13-1,13-2	1:15,480
5/14/90	WAC-Santa Cruz-90 9-117,118	1:15,480
3/26/86	CDBW-APU-C 222,223	1:12,000
4/12/84	Monterey 89,90	1:12,000
10/5/76	DNOD-AFU-C 168,169	1:12,000
10/14/75	SCZCO 1-40,41	1:12,000
4/2/70	76-5-93,94	1:12,000
11/30/65	SC1-27,29 (photo 28 missing)	1:3,600
8/27/63	SC1-1	1:3,600
5/14/48	CDF5-3-17,18	1:10,000
1/10/40	V-1-417,418	1:31,000
4/1/31	B-28,29	1:12,000
1928	SC-28,29,30	1:12,000
	Oblique[3]	
9/04	Images 200401505-200401511	No scale
9/02	Images 6660-6663	No scale
6/87	Images 8712177, 8712178	No scale
5/79	Images 7930127, 7931072, 7931075	No scale
1972	Images 7220086, 7220087	No scale

[2] On-file in the Map Room at the U.C. Santa Cruz Science Library.
[3] Available at www.californiacoastline.org



LOCATION MAP
NOT TO SCALE



SHEET LAYOUT PLAN
NOT TO SCALE

EXPLANATION

Geologic Units

- **Qf** Fill - mapped locally along bluff
- **Qsd** Slope deposits - mapped locally along bluff
- **Qls** Landslide deposits
- **Qt** Terrace deposits
- **Tp** Purisma Formation

Geologic Symbols

- Geologic contact, approximately located, queried where uncertain
- Topographic break in slope
- Undercut in Purisima Formation, approximately located, not shown where concealed
- Incised erosional gully, < indicates downslope direction
- Edge of Purisima Formation bench, approximately located
- Slough area
- Landslide, scarp area hachured, arrow in direction of downslope movement, tick marks indicate top of scarp (Qls)
- Soil nail wall (installed 2004), approximately located
- Crib Wall
- Threat Boundary with level of threat (2)

(1) Active impact to improvements - Includes sections of East Cliff Drive where the shoulder has been lost to erosion, and continued erosion will result in the further loss of road and other improvements.

(2) "In Danger" - existing structure may be unsafe to use within the next two or three storm season cycles (generally the next few years) if nothing were done (as defined by the Coastal Commission).

(3) Potentially "In Danger" - Sections of East Cliff Drive beyond the Coastal Commission two to three storm season cycles criteria.

Conventional Symbols

- Approximate Property (P/L), Right-of-Way (R/W) and Easement Lines
- County Stationing (Metric) — 0+060, 0+080
- Road
- Edge of Pavement — EP
- Guard Rail or Barricade
- Shrubbery
- Existing Utilities:
  - Water (Plan) — W
  - Gas (Plan) — G
  - Sanitary Sewer (Plan) — SS
  - Storm Drain (Plan) — SD
  - Drop Inlet
  - Manhole — MH
  - Water Meter — WM
  - Water Valve — WV

Notes

1. Geologic features approximately located using standard tape and compass techniques.
2. Site conditions may have changed since geologic reconnaissance mapping was performed in December 2004 and March 2005.
3. Geologic reconnaissance mapping performed along bluff areas only.
4. Fill and slope deposits shown in select areas only. Comprehensive mapping of fill and slope deposits not performed.

Reference

Topographic map, prepared by Andregg, Inc., dated November 2000. Site conditions may have changed since date of photo base and topography.

Metric
UNITS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.

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F (626) 792-8440

GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS

East Cliff Drive
33rd Avenue to 36th Avenue

County Of Santa Cruz, California

REV	BY	DATE	DESCRIPTION
0			

DATE: 06/30/05
SCALE: AS SHOWN
DESIGNED BY: DGK
DRAFTED BY: CAH
CHECKED BY: DAM
JOB NO.: SE99-033 SC-RA2
FILE: EASTCLIFF-FINAL.DWG

GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS

East Cliff Drive
33rd Avenue to 36th Avenue

County Of Santa Cruz — California

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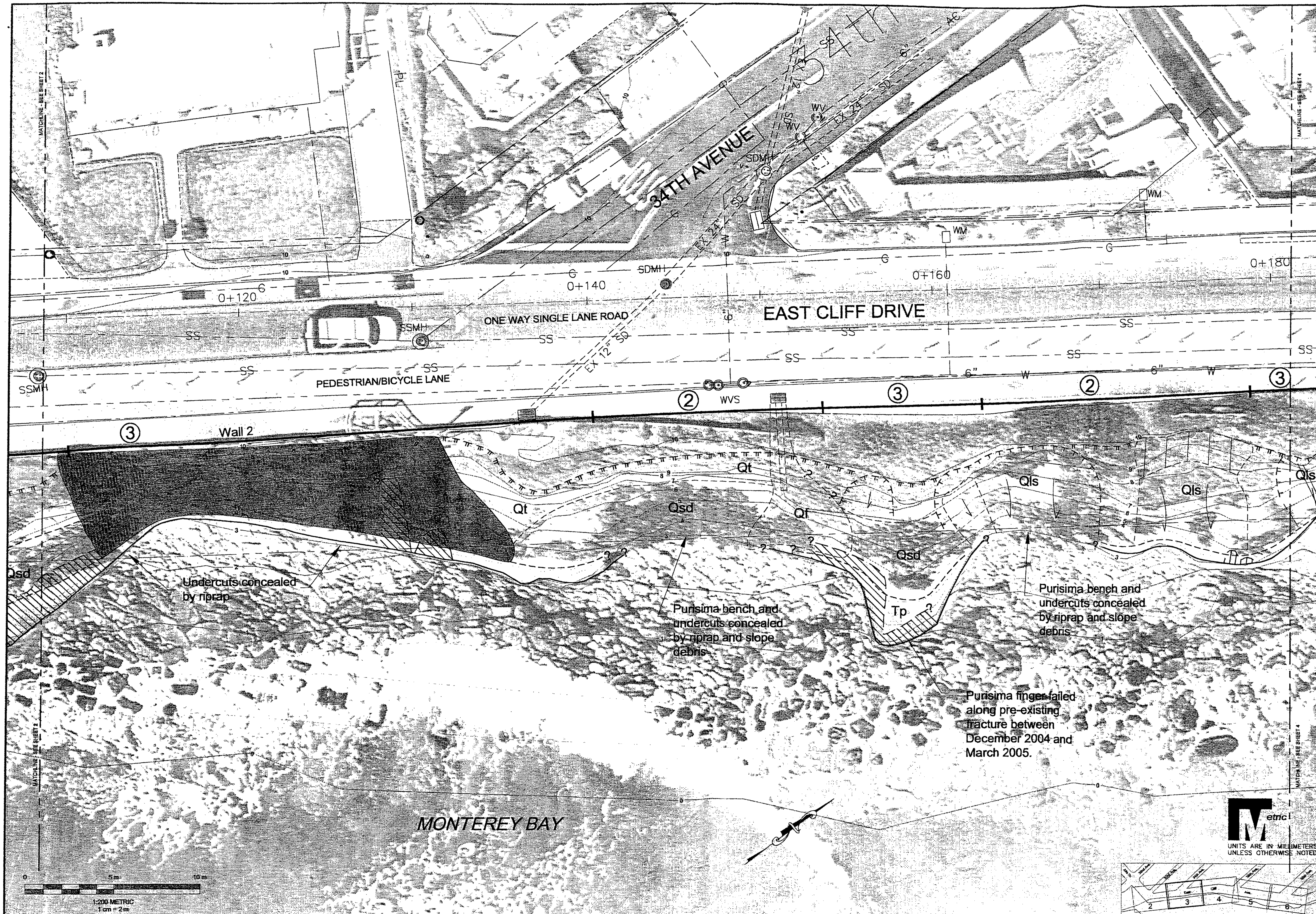
F (626) 792-8440

REV	BY	DATE	DESCRIPTION
0			

DATE: 06/30/05
SCALE: 1:200 METRIC
DESIGNED BY: DGK
DRAFTED BY: CAH
CHECKED BY: DAM
JOB NO.: SE99-033 SC-RA2
FILE: EASTCLIFF-FINAL.DWG

2

SHEET 2 OF 6



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GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS

East Cliff Drive
33rd Avenue to 36th Avenue

County Of Santa Cruz
California

REV	BY	DATE	DESCRIPTION
0			

DATE: 06/30/05
SCALE: 1:200 METRIC
DESIGNED BY: DGK
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JOB NO.: SE99-033 SC-RA2
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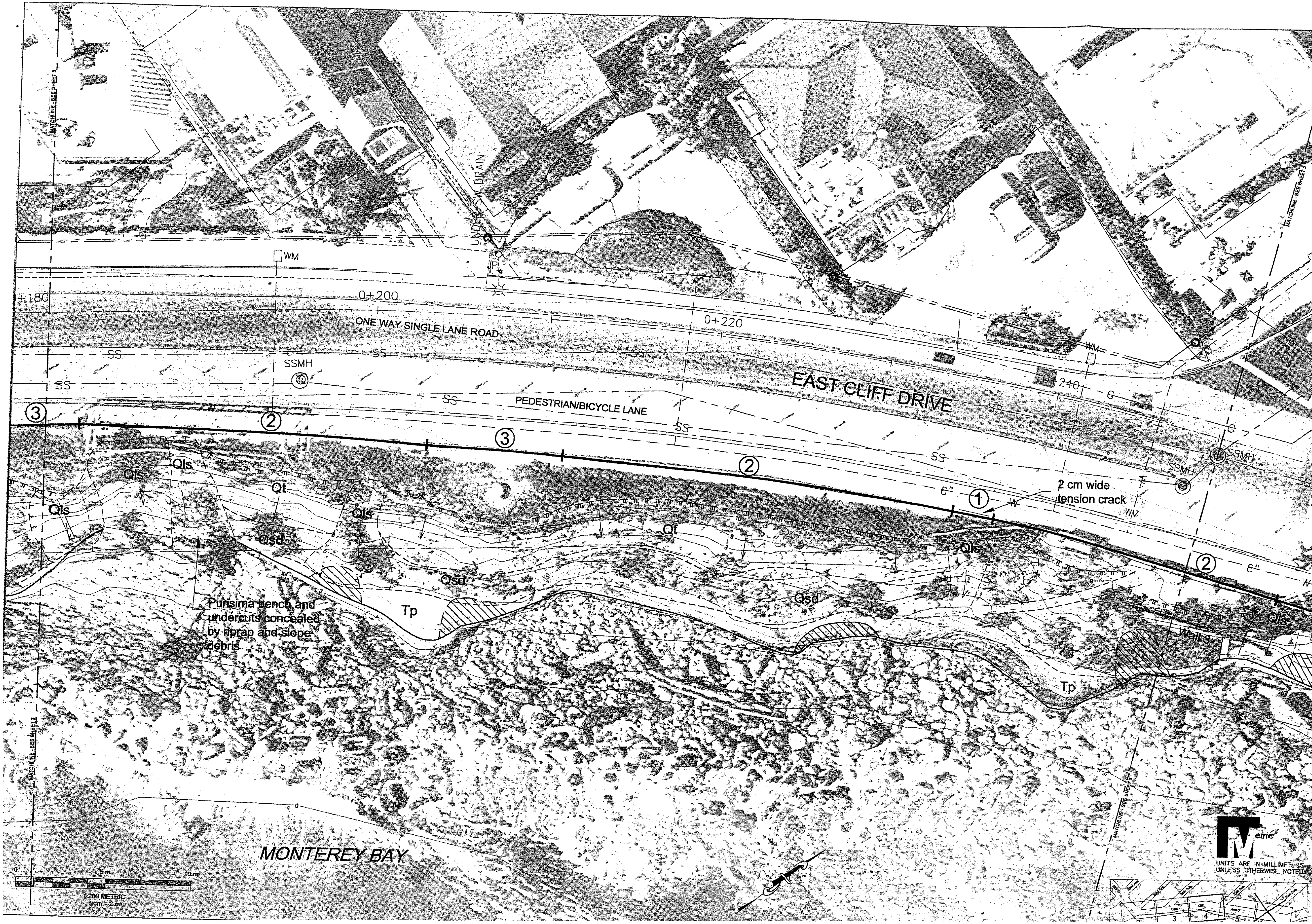

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GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS

East Cliff Drive
33rd Avenue to 36th Avenue

County of Santa Cruz, California

REV	BY	DATE	DESCRIPTION
0			

DATE: 06/30/05
SCALE: 1:200 METRIC
DESIGNED BY: DGK
DRAFTED BY: CAH
CHECKED BY: DAM
JOB NO.: SE99-033 SC-RA2
FILE: EASTCLIFF-FINAL.DWG

4

GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS

East Cliff Drive
33rd Avenue to 36th Avenue

County of Santa Cruz — California

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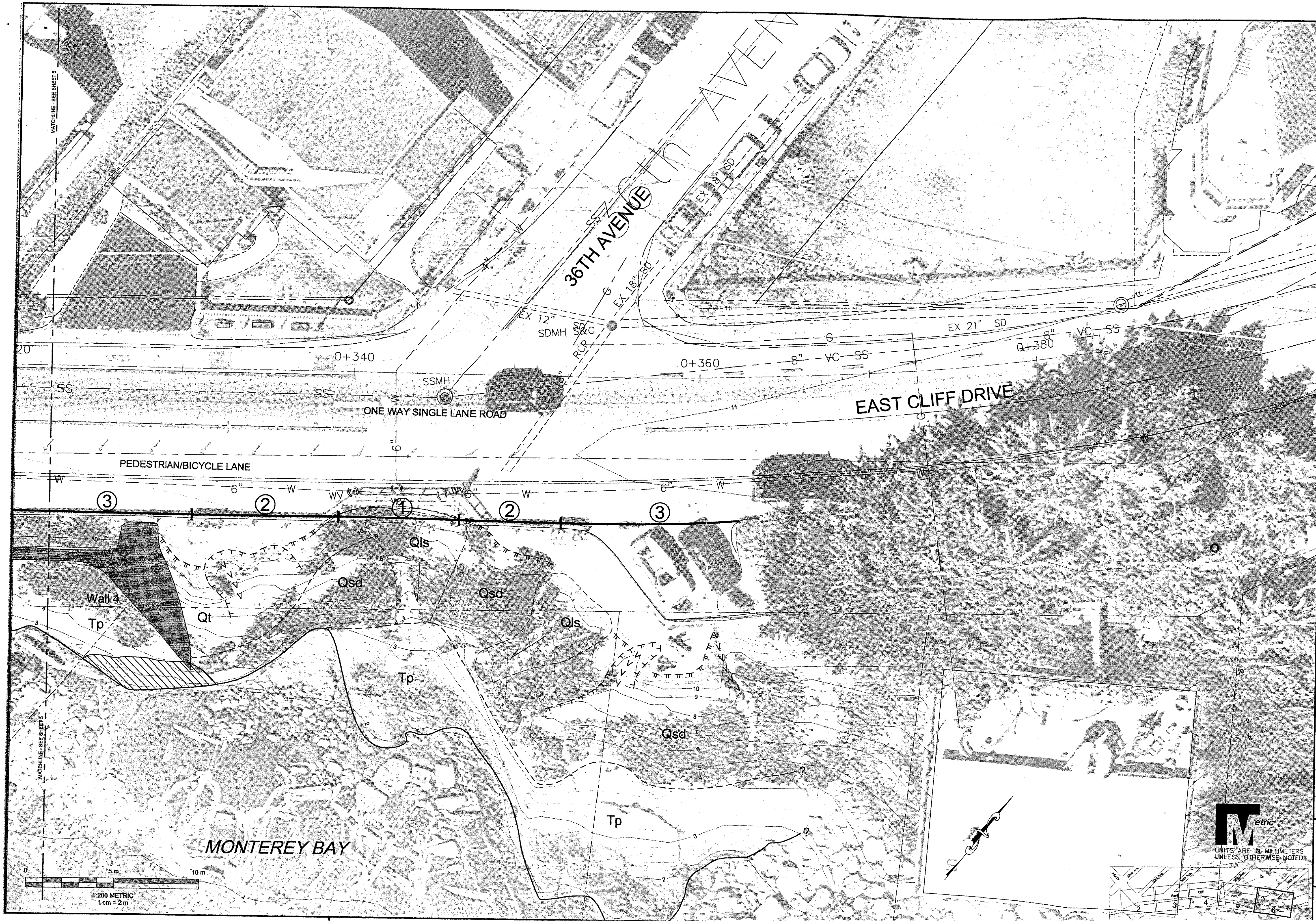
REV	BY	DATE	DESCRIPTION
0	.	.	

DATE: 06/30/05
SCALE: 1:200 METRIC
DESIGNED BY: DGK
DRAFTED BY: CAH
CHECKED BY: DAM
JOB NO.: SE99-033 SC-RA2
FILE: EASTCLIFF-FINAL.DWG



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GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS

East Cliff Drive
33rd Avenue to 36th Avenue

County Of Santa Cruz — California

REV	BY	DATE	DESCRIPTION

DATE: 06/30/05
SCALE: 1:200 METRIC
DESIGNED BY: DGK
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October 26, 2005
Project No. SE99-033 SC-PW Task 7

Mr. Ralph Norberg
Santa Cruz County Department of Public Works
701 Ocean St., Rm. 410
Santa Cruz, CA 95060

RE: Summary of Supplemental Slope Stability Analyses (Revised)
East Cliff Drive between 33rd and 36th Ave. and the end of 41st Ave. ("The Hook")
Santa Cruz County, CA

Dear Ralph:

In accordance with our April 27, 2005 proposal, we have completed supplemental slope stability analyses for East Cliff Drive between 33rd and 36th Avenues and the end of 41st Avenue ("The Hook"). We performed supplemental slope stability analyses to estimate the largest potential episodic bluff failure and factors of safety against bluff failure for both static and seismic conditions. In their Consistency Determination (2003), the Coastal Commission noted that quantitative slope stability analysis should be performed to describe the degree of threat to the improvements in terms of bluff stability, potential failure planes, and minimum factors of safety. The information presented in this letter will be utilized to update the degree of threat evaluation maps included in our recent Coastal Bluff Evaluation reports and re-classify, if necessary, the limits of the zone defined as "in danger".

We previously prepared a Coastal Bluff Evaluation report for the section of bluff between 33rd and 36th Avenues, dated June 30, 2005. The updated maps for East Cliff Drive between 33rd and 36th Avenues are pending and will be presented separate from this letter. We are currently performing a Coastal Bluff Evaluation for The Hook under a separate contract, and submitted a draft report to the County of Santa Cruz (County) on September 2, 2005. The final report is pending and will incorporate the results of these supplemental slope stability analyses.

We have revised our original letter dated October 6, 2005 to address several comments by the County.

METHODOLOGY

Slope stability analyses, in general, are performed by assuming the geometry for a potential failure plane (either a sector of a circle or a wedge-like block) and computing the ratio of the net resisting force (soil strength) relative to the net driving forces (soil mass, surcharge, seepage pressures, and/or seismic accelerations). This ratio is defined as the "factor of safety". When the resisting forces are greater than the driving forces, the factor of safety is greater than 1.0. When the factor of safety is about 1.0 (i.e., the driving forces are equal to the resisting forces), failure is imminent. When the factor of safety is less than 1.0 (i.e., driving forces exceed resisting forces), failure is likely (i.e., under seismic conditions) and/or has already occurred.[1]

Commercial slope stability programs utilize algorithms to check multiple failure plane geometries and the lowest factor of safety computed for a given combination of slope geometry and strength parameters is considered the most critical factor of safety under those conditions. Typically, a minimum factor of safety of 1.5 is considered acceptable for static conditions, and the County of Santa Cruz Planning Department defines the minimum factor of safety for static stability as 1.5. Lower factors of safety, typically between 1.1 and 1.3, are often acceptable for seismic conditions. The County of Santa Cruz Planning Department defines the minimum factor of safety for seismic stability as 1.2.

We performed the slope stability analysis using the program STEDwin 2.64, which is an editor for the PCSTABL5/6 analysis program. This program analyzes slope stability by limit equilibrium methods. Specifically, we used the Bishop Method of Slices, which assumes that the side forces between slices are acting horizontally. Our methods included both circular failure surfaces and wedge type failures with a tension crack.

CROSS-SECTIONS

For the section of bluff between 33rd and 36th Avenues, we analyzed three (3) representative cross-sections constructed using the existing topographic base prepared by Andregg, Inc. (2000). The three cross-sections were located at County Stations 0+102, 0+212, and 0+278 along the East Cliff Drive. For the three sections, we used soil properties derived by Haro, Kasunich and Associates, Inc. (HKA, May 1998) during a previous geotechnical investigation of this section of bluff.

The slopes between 33rd and 36th Avenues are characterized by slope heights of approximately nine meters with slope angles ranging between 48° and 57° from horizontal. The slopes are comprised of moderately cemented to cemented fine-grained sandstones, siltstones, and mudstones of the Purisima Formation overlain by terrace deposits. The terrace deposits are subdivided into an upper unit consisting of approximately 2 to 2–½ meters of lightly cemented clayey/silty sands and a lower unit consisting of approximately 4 to 5 meters of coarse sand with rounded gravels and small cobbles. The elevation delineating the upper terrace deposits from the lower terrace deposits was obtained from HKA (May 1998). The top of the Purisima Formation was based on the existing topographic base prepared by Andregg, Inc. (2000).

One (1) cross-section, developed by County surveyors, was analyzed at The Hook. The cross section was located at County Station 0+817. Soil properties for The Hook were based on a geotechnical and coastal engineering investigation by HKA (January 1998) for a nearby storm drain outfall. In

---

1 In the case of a failure that has already occurred, it may be necessary to "back calculate" a factor of safety less than 1.0 in order to better estimate the possible range in soil strength parameters.

addition, the stability analyses were checked using soil properties developed for Larch Lane at East Cliff Drive (HKA, 1995). However, these analyses were not used.[2]

The slope geometry considered at The Hook was approximately 11 meters in height with a slope angle as steep as 55° from horizontal. As described above for the section of bluff between 33rd and 36th Avenues, the soils are characterized by moderately cemented to cemented fine-grained sandstones, siltstones, and mudstones of the Purisima Formation overlain by upper and lower terrace deposits. The upper terrace and lower terrace deposits were modeled as 2 and 5.3 meters thick, respectively. The elevation delineating the upper terrace deposits from the lower terrace deposits was obtained from HKA (1995). The top of the Purisima Formation was surveyed by the County surveyors in June 2005, and was field checked as part of our on-going Coastal Bluff Evaluation at The Hook.

STATIC SLOPE STABILITY

Static slope stability was performed using a circular failure plane search with the Bishop Method of Slices. The groundwater was modeled as perched 5 feet above the top of the Purisima Formation with a gentle downward slope toward the exposed cliff face. The water was modeled as exiting the slope face two feet above the Purisima Formation, which is consistent with the seepage observed during our prior geologic reconnaissance mapping. The existing static factor of safety for the four cross-sections ranges from 1.14 to 1.26. Therefore, the results suggest the bluffs are marginally stable, which is consistent with the history of bluff retreat at the site. Our ultimate objective was to determine the maximum bluff failure distance, defined as a maximum potential failure surface with a factor of safety less than or equal to 1.5. Therefore, we increased the size of the failure circle until a factor of safety of 1.5 was achieved for static conditions. The results of this analysis are presented later in this letter.

SEISMIC SLOPE STABILITY

In addition to the static slope stability, we checked seismic slope stability in general accordance with the procedures outlined by Ashford and Sitar (2002) for evaluating seismic stability of steep coastal slopes composed of weakly cemented granular soils. Ashford and Sitar note that steep slopes, standing at angles of 30° to near vertical, are subject to topographic amplification of seismic waves and that the seismic-induced failure of these slopes tend to be brittle in nature. The Ashford and Sitar procedure can be characterized by the following:

1. Perform a one-dimensional equivalent linear site response analysis or use representative nearby strong motion data. In this case, a horizontal peak ground acceleration of 0.54g was recorded at the City of Capitola Fire Station during the 1989 Loma Prieta Earthquake (HKA, 1995).
2. The free-field motion is then increased by 50 percent to account for topographic effects ($a_{max} = 0.54g \times 1.5 = 0.81g$).

---

[2] The Larch Lane parameters suggested the slope should be failing critically under the current configuration, and therefore, did not appear to represent actual conditions.

3. Utilizing published charts by Makdisi and Seed (1978), the ratio of maximum seismic coefficient (k_{max}) versus maximum site acceleration (a_{max}) is selected based on the ratio of the depth to the base of the failure surface to the slope height. In our cases, the ratio of heights ranges between 0.67 and 0.78. Therefore, the ratio, k_{max}/a_{max}, ranges from 0.45 to 0.5.
4. The value of k_{max} is then multiplied by 0.65 to obtain the value of the average seismic coefficient, k_{av}, as suggested by Seed and Martin (1966). The average value obtained for the slope geometries between 33rd and 36th Avenues and The Hook was 0.25g.
5. This value of k_{av} represents the average seismic coefficient for use in a traditional pseudostatic slope stability analyses.

Besides providing a method for determining the seismic coefficient for steep slopes in weakly cemented granular soils, Ashford and Sitar discuss failure plane geometries characteristic of slopes of these nature. Specifically, they mention the method proposed by Hoek and Bray (1981) for planar sliding surfaces. The failure wedges considered in our seismic slope stability analysis are similar to the methodology proposed by Hoek and Bray with some modifications. Our analysis assumed the tension crack extended through the entire depth of the cohesive upper terrace deposits. The tension crack was not modeled with water in the crack, since we anticipate the failure to be rapid. In addition, the exit point of the failure wedge was set at the top of the Purisima Formation. Our analysis consisted of re-locating the tension crack further back from the slope face until a factor of safety of 1.2 was achieved. A failure wedge of this geometry appeared to represent the upper bound of a feasible failure surface.

In addition to the specified failure wedge surface, we also reviewed potential circular failure surfaces using the Bishop Method of Slices. At all four cross-sections, the critical circular failure surface corresponded closely with the main variation being the tension crack. The tension crack assumption actually causes the wedge failure to have less impact on the improvements at the top of slope.

The results of our analyses suggest that the risk for a bluff failure during a seismic event on a nearby fault is relatively high. The minimum estimated factor of safety for a k_{avc} value of 0.25 g varied between 0.8 and 0.9 for the various cross sections evaluated. These values suggest that the bluffs are unstable under these types of seismic loading conditions. However, it should be noted that bluff failures were not reported during the nearby 1989 Loma Prieta Earthquake. Although past seismic performance is generally a good indicator of potential future performance, the common misconception is that lack of failures in the past precludes the potential for future failures. Some possible reasons why the bluff did not fail in 1989 include:

- **Duration of Strong Ground Shaking:** Although the Loma Prieta Earthquake had a moment magnitude of 6.9, the duration of shaking was only about 15 seconds. Typically, one would expect a duration of strong ground shaking on the order of 30 to 40 seconds for this magnitude of earthquake. Because the duration of shaking was shorter than expected, the amount of seismic energy imparted into the slope was also less than would typically be expected. As the energy imparted to the slope increases, so does the potential for slope failure.

- **Frequency Content:** Each earthquake event has a characteristic frequency content that is dependent on the type of movement (strike-slip, oblique, etc.), magnitude, and depth, and can be defined by a predominant frequency (or predominant period, the inverse of the frequency). Each site also has a natural period of vibration that is based on soil type, strength, and depth. When these periods coincide, resonance occurs and the impacts of strong ground shaking are greatly amplified. Similarly, if the periods are significantly different, the potential for damage can be less. Therefore, it may be that the frequency content of the Loma Prieta earthquake did not match the period of the site, although this may not be the case during future events.

- **Soil Strengths:** The slope stability analyses were performed using limited soil strength data previously collected by HKA. Therefore, it is possible these strengths represent the lower bound of the range of strengths that could be encountered, and that that average soil strengths are slightly higher that assumed for our analyses. Higher strengths would result in a larger factor of safety (i.e., more stable slopes).

CONCLUSIONS

The results of the slope stability analysis are presented in the Table 1, below. The results are presented by individual cross-section, type of analysis, failure surface, and maximum potential bluff failure distance. For static conditions, the failures were all assumed to be circular in nature, with a target factor of safety of 1.5. The distance noted is the horizontal distance from the crest of the bluff to the estimated failure plane. For seismic conditions, results are presented for both wedge and circular failures surfaces, with the distance representing the distance from the bluff crest to the failure plane. The slope stability analysis output, which graphically shows the relationship between the bluff crest and the failure planes for each of the cross sections and conditions, is also attached.

TABLE 1
Estimated Bluff Failure Distance and Corresponding Factor of Safety (FS)

Location (Station)	Static Conditions		Seismic Conditions (k_{ave} = 0.25 g)			
	Circular Failure		Wedge Failure		Circular Failure	
	Distance	FS	Distance	FS	Distance	FS
33rd – 36th Sta. 0+102	3.6 m	1.49	5.9 m	1.20	8 m	1.20
33rd – 36th Sta. 0+212	5 m	1.5	6.6 m	1.20	9.3 m	1.20
33rd – 36th Sta. 0+278	3.9 m	1.5	5.8 m	1.19	7.9 m	1.20
The Hook Sta. 0+817	5.2 m	1.5	7.5 m	1.20	8.2 m	1.20

"FS" = Factor of Safety
"Distance" = Horizontal distance from crest of bluff to failure plane

Based on our review of the Ashford & Sitar paper and our knowledge of the bluff conditions, we believe a wedge-type failure is the most likely mode of failure at the site. Furthermore, considering the formation of a tension crack is likely, we believe that even if a circular failure occurred, it would most likely be truncated to a similar shape as the wedge failures. Therefore, we recommend the offset determined from the wedge geometry be used to redefine, if necessary, the limits of the zones as defined as "in danger" in the Coastal Bluff Evaluation reports.

If you have any questions please call us.

Sincerely yours,
Sanders & Associates Geostructural Engineering, Inc.

Renée L. Fippin
Project Engineer

Darren A. Mack
Senior Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER DARREN A. MACK GE2634 Exp. 6/30/07 GEOTECHNICAL STATE OF CALIFORNIA

Attachments: Slope Stability Analyses (8 pages)
References (1 page)

cc: Mr. Paul Rodrigues, Santa Cruz County Redevelopment Agency

REFERENCES

Andregg, Inc., 2000, *Topographic Map*.

Ashford, S.A, and Sitar, N., 2002, *Simplified Method for Evaluating Seismic Stability of Steep Slopes*: J. Geotech. and Geoenviron. Eng. Div., Am. Soc. Civ. Eng, Vol. 128, No. 2, 119-128.

California Coastal Commission, 2003, *Federal Consistency Determination – Proposed Findings*: Consistency Determination Number CD-021-03.

Haro, Kasunich and Associates, Inc., 1995, *Geotechnical Investigation, Larch Lane at East Cliff Drive*: dated November 1995.

Haro, Kasunich and Associates, Inc., 1998, *Geotechnical and Coastal Engineering Investigation, APN 033-171-18, Storm Drain Outfall at 41st Avenue*: dated January 1998.

Haro, Kasunich and Associates, Inc., 1998, *Addendum Geotechnical and Coastal Engineering Investigation for Coastal Bluff Stabilization Project, East Cliff Drive, 33rd to 36th Avenue*: dated January 1998.

Hoek, E. and Bray, J., 1981, *Rock Slope Engineering*, 3rd edn., Inst. Mining and Metallurgy, London, UK.

Makdisi, F.I., and Seed, H.B., 1978, *Simplified procedure for estimating dam and embankment earthquake-indued deformations*: J. Geotech. Eng. Div., Am. Soc. Civ. Eng., 104(GT7), 849-867.

Sanders & Associates Geostructural Engineering, Inc., 2005, *Proposal for Supplemental Slope Stability Analyses*: dated April 27, 2005.

Seed, H.B., and Martin, G.R., 1966, *The seismic coefficient in earth dam design*: J. Soil Mech. Found. Div., 92(SM3), 25-58.

East Cliff Dr. Threat Evaluation Sta. 0+10? (FS = 1.5)

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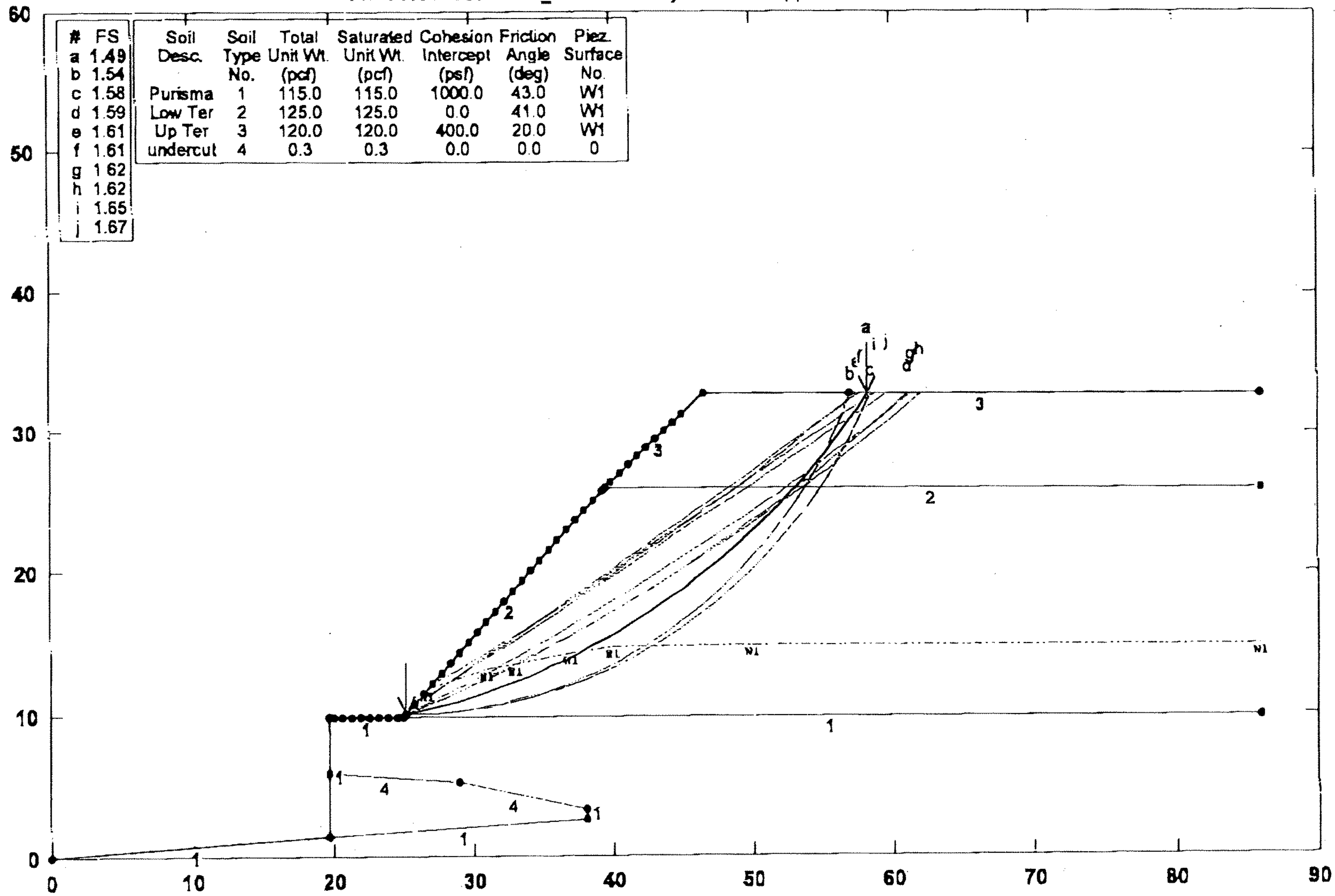

STABL6H FSmin=1.49

Safety Factors Are Calculated By The Modified Bishop Method

STED

East Cliff Dr. Threat Evaluation Sta. 0+102 (19.5 ft)

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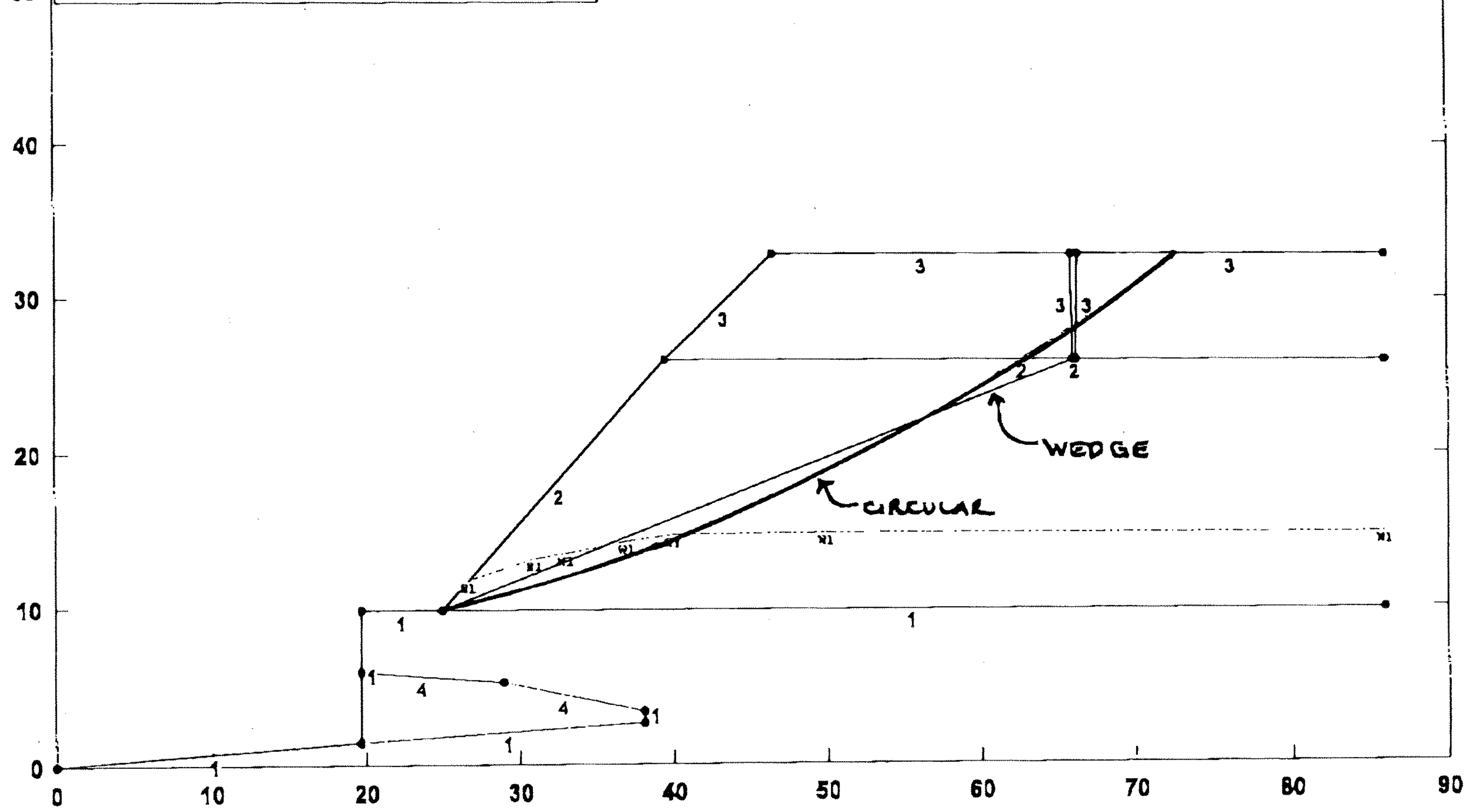
Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez Surface No.
Purisma	1	115.0	115.0	1000.0	43.0	W1
Low Ter	2	125.0	125.0	0.0	41.0	W1
Up Ter	3	120.0	120.0	400.0	20.0	W1
undercut	4	0.3	0.3	0.0	0.0	0

Load	Value
Horiz Eqk	0.250 g<



STABL6H FSmin=1.20

Factor Of Safety Is Calculated By The Modified Bishop Method

STED

East Cliff Dr. Threat Evaluation Sta. 0+212 - FS = 1.5

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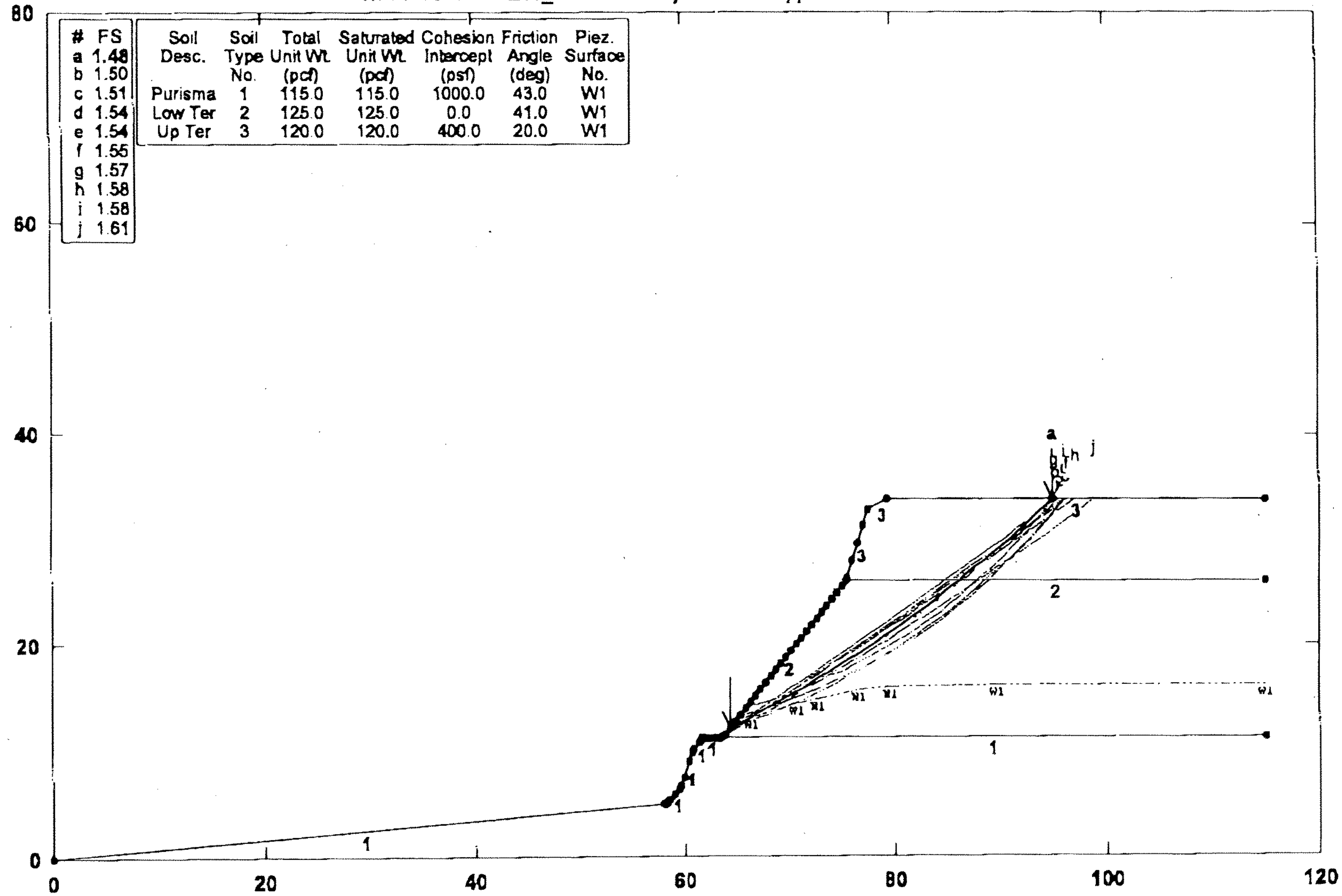

#	FS
a	1.48
b	1.50
c	1.51
d	1.54
e	1.54
f	1.55
g	1.57
h	1.58
i	1.58
j	1.61

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Purisma	1	115.0	115.0	1000.0	43.0	W1
Low Ter	2	125.0	125.0	0.0	41.0	W1
Up Ter	3	120.0	120.0	400.0	20.0	W1

STABL6H FSmin=1.48

Safety Factors Are Calculated By The Modified Bishop Method

STED

East Cliff Dr. Threat Evaluation Sta. 0+212 (21.5 ft)

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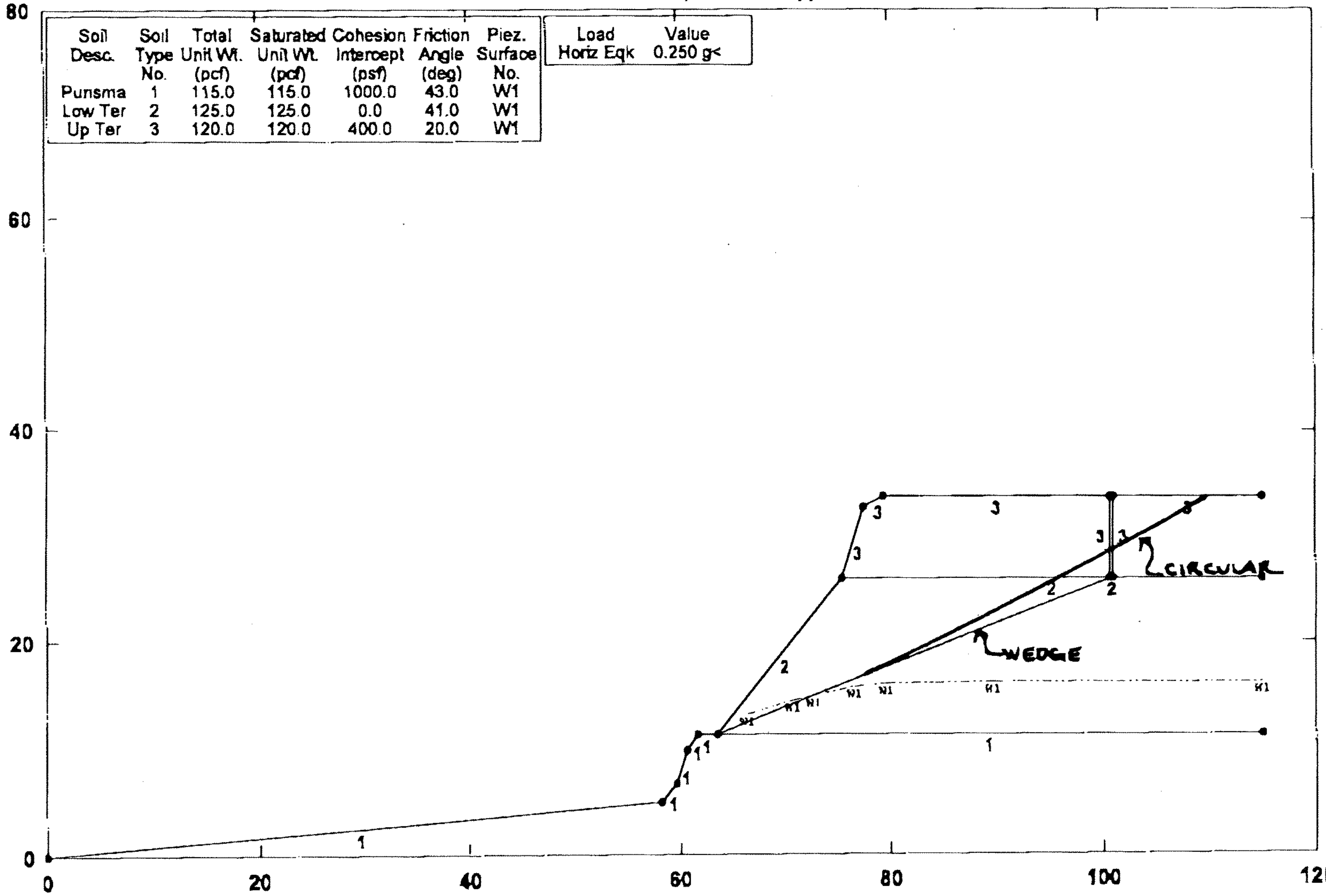
Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Punsma	1	115.0	115.0	1000.0	43.0	W1
Low Ter	2	125.0	125.0	0.0	41.0	W1
Up Ter	3	120.0	120.0	400.0	20.0	W1

Load	Value
Horiz Eqk	0.250 g<



STABL6H FSmin=1.20

Factor Of Safety Is Calculated By The Modified Bishop Method

STED

East Cliff Dr. Threat Evaluation Sta. 0+279 (FS = 1.5)

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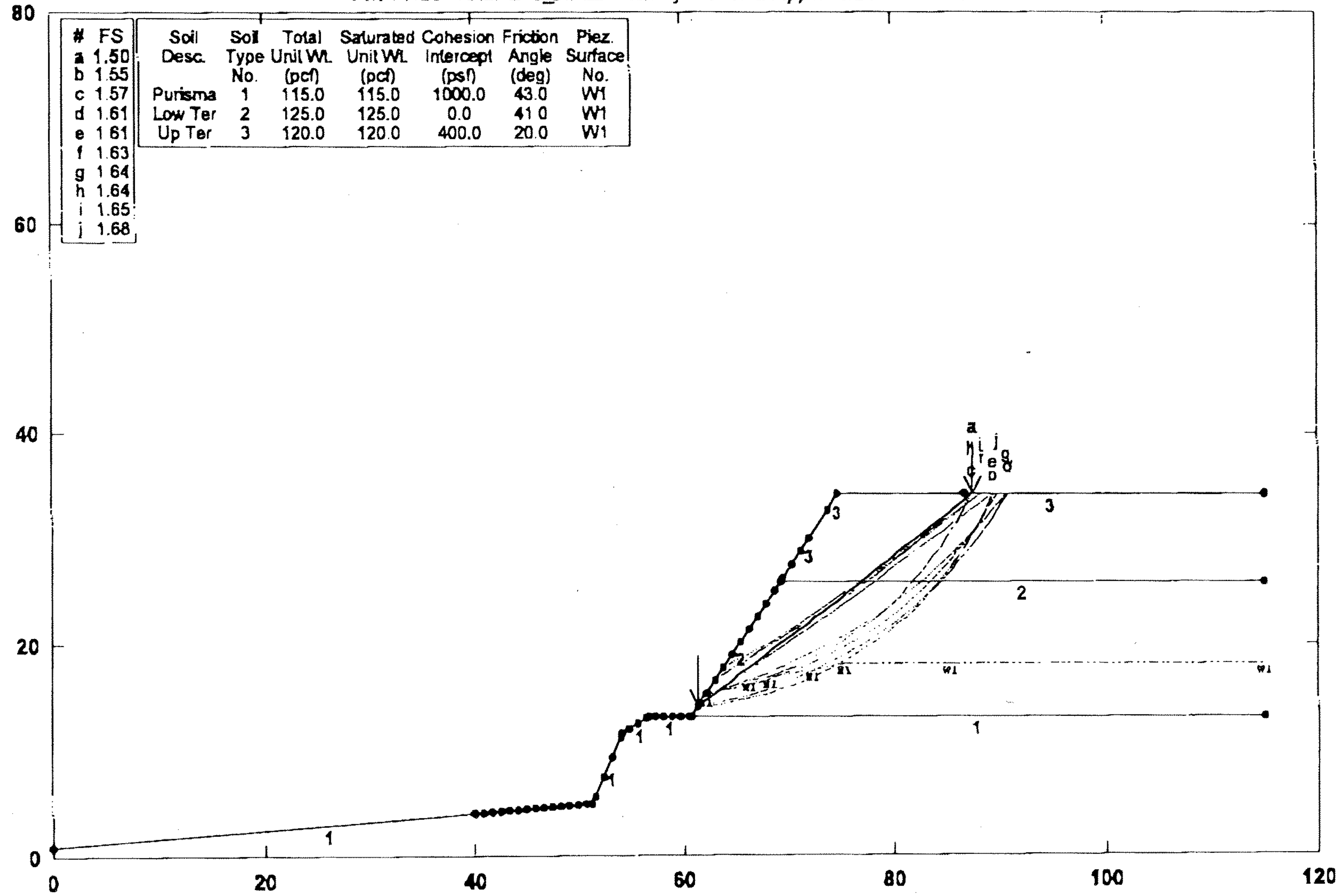


#	FS
a	1.50
b	1.55
c	1.57
d	1.61
e	1.61
f	1.63
g	1.64
h	1.64
i	1.65
j	1.68

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Purisma	1	115.0	115.0	1000.0	43.0	W1
Low Ter	2	125.0	125.0	0.0	41 0	W1
Up Ter	3	120.0	120.0	400.0	20.0	W1

STABL6H FSmin=1.50

Safety Factors Are Calculated By The Modified Bishop Method

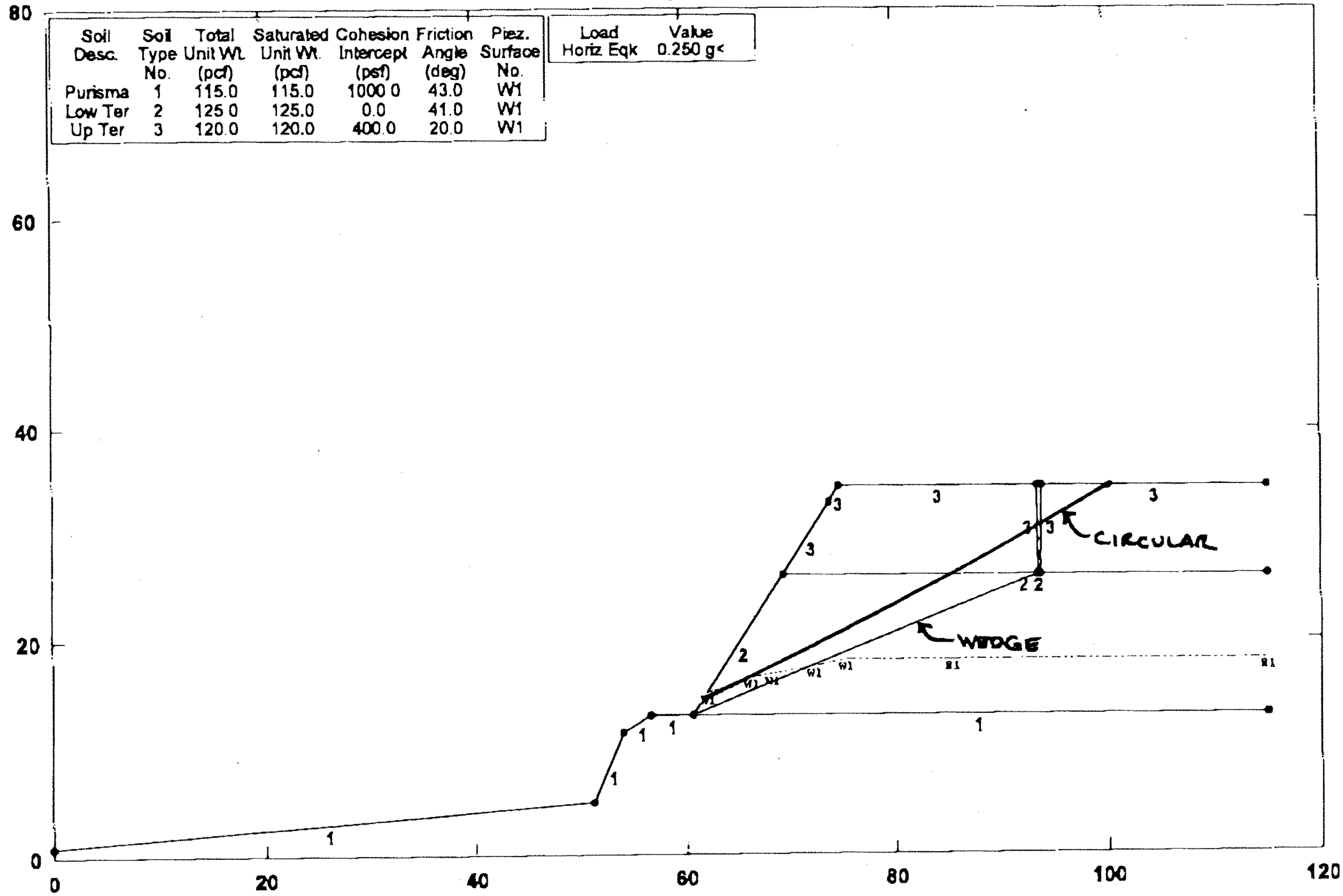
STED

East Cliff Dr. Threat Evaluation Sta. 0+279 - (19 ft)

F:\1-PROJ~1\RLF\279SJ.PLT Run By: Renée L Fippin 9/30/2005 10:25AM

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Purisma	1	115.0	115.0	1000.0	43.0	W1
Low Ter	2	125.0	125.0	0.0	41.0	W1
Up Ter	3	120.0	120.0	400.0	20.0	W1

Load	Value
Horiz Eqk	0.250 g<



STABL6H FSmin=1.19

Factor Of Safety Is Calculated By The Modified Bishop Method

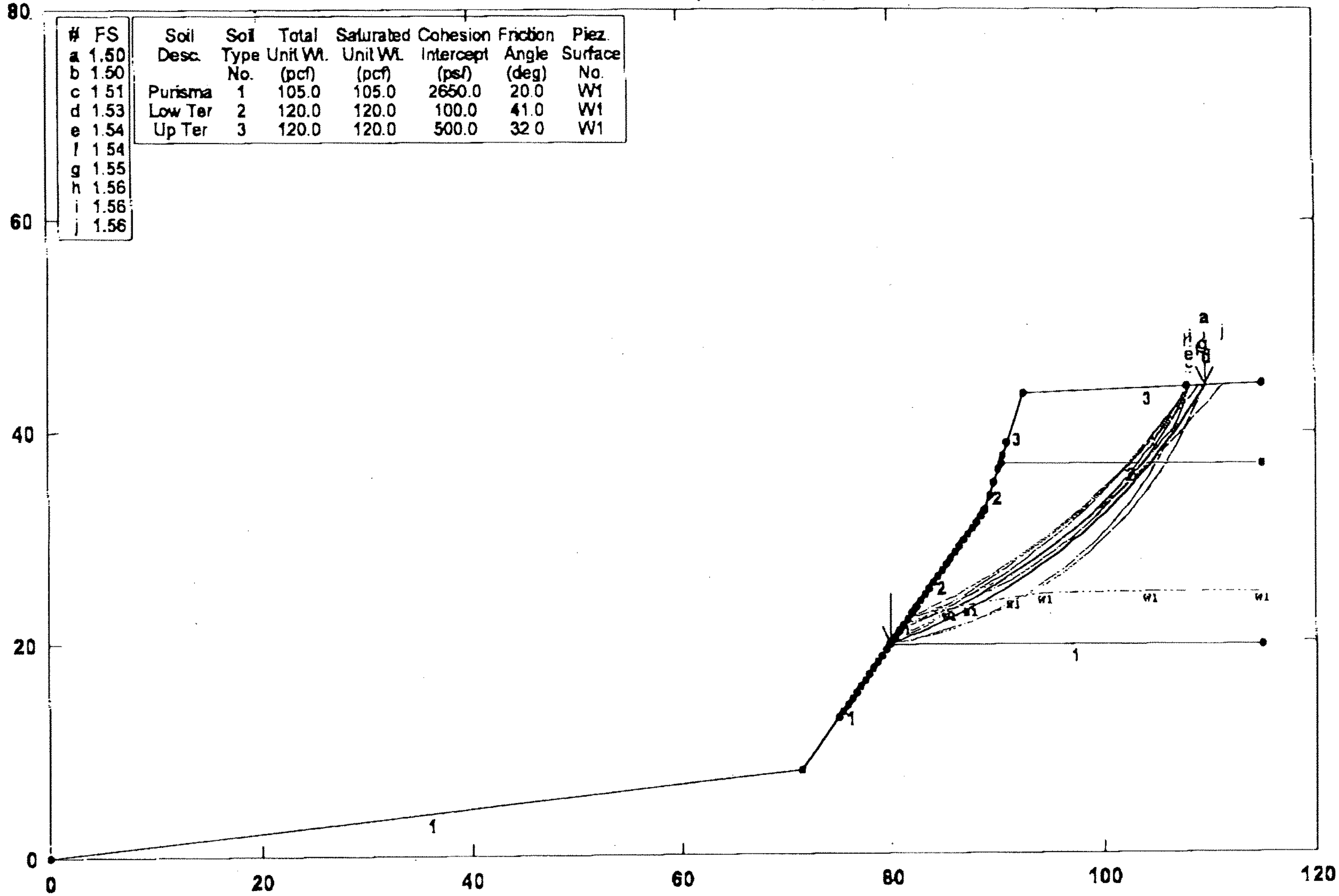
STED

East Cliff Dr. Threat Evaluation The Hook

F:\1-PROJ~1\RLF\HOOKWAT6.PL2 Run By: Renée L Fippin 9/23/2005 9:44AM

#	FS
a	1.50
b	1.50
c	1.51
d	1.53
e	1.54
f	1.54
g	1.55
h	1.56
i	1.56
j	1.56

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Purisma	1	105.0	105.0	2650.0	20.0	W1
Low Ter	2	120.0	120.0	100.0	41.0	W1
Up Ter	3	120.0	120.0	500.0	32.0	W1



STABL6H FSmin=1.50
Safety Factors Are Calculated By The Modified Bishop Method

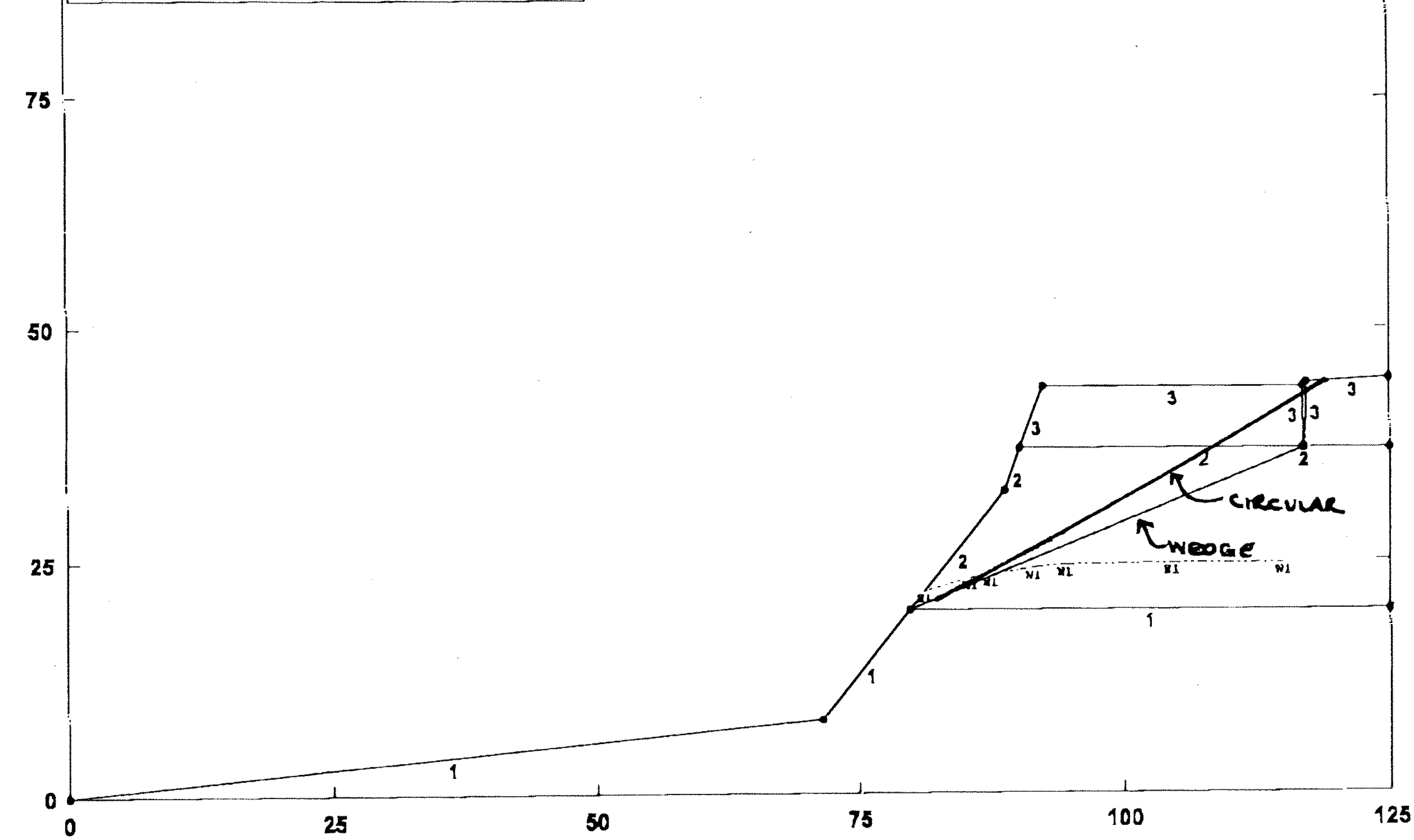
STED

East Cliff Dr. Threat Evaluation The Hook - 24.5 ft

F:\1-PROJ~1\RLF\HOOKI2.PLT Run By: Renée L Fippin 9/30/2005 10:27AM

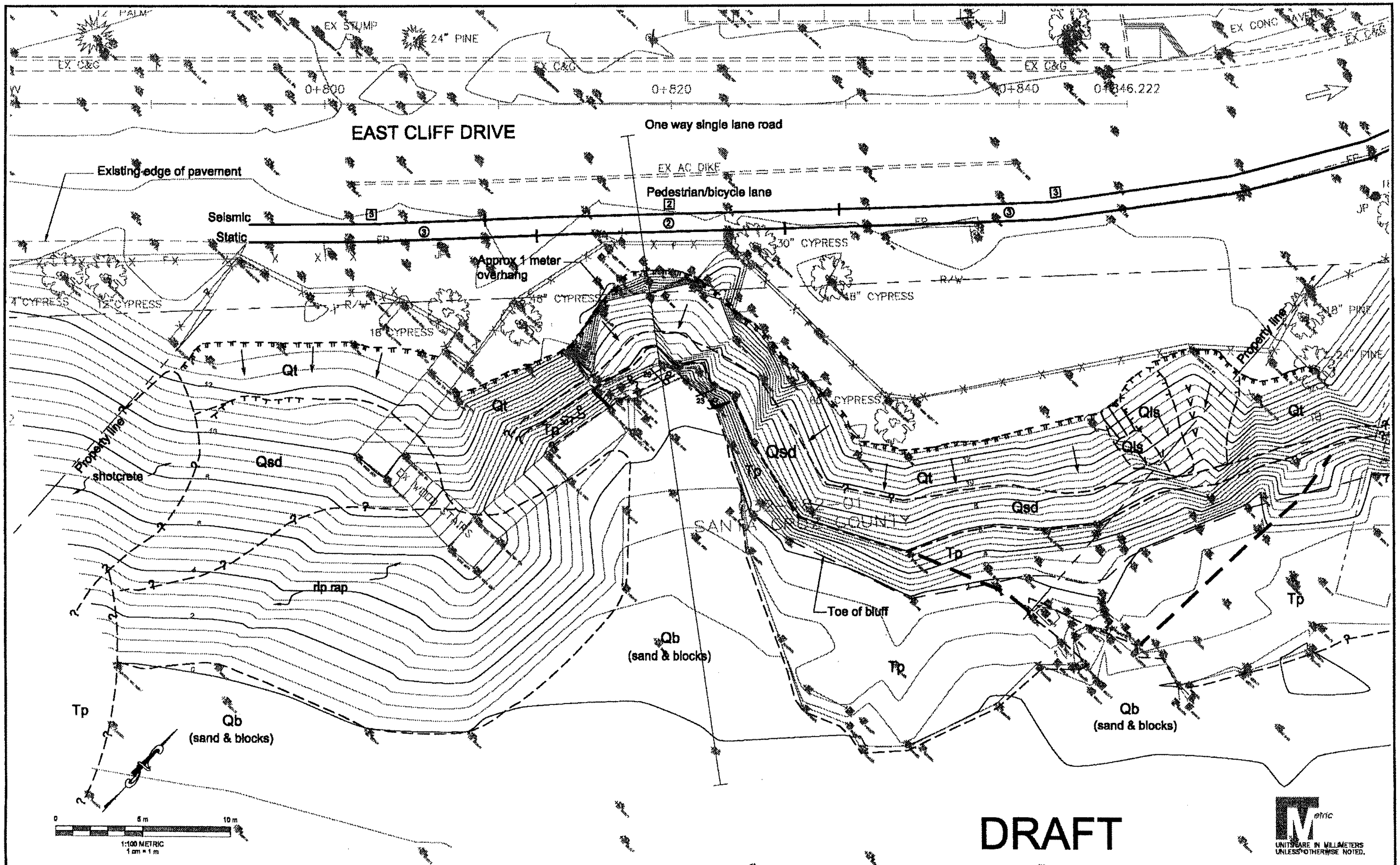
Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Purisma	1	105.0	105.0	2650.0	20.0	W1
Low Ter	2	120.0	120 0	100.0	41.0	W1
Up Ter	3	120.0	120 0	500.0	32.0	W1

Load	Value
Horiz Eqk	0.250 g<



STABL6H FSmin=1.20
Factor Of Safety Is Calculated By The Modified Bishop Method

STED



REV	BY	DATE	DESCRIPTION

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Coastal Bluff Evaluation
East Cliff Drive at 41st Avenue ("the Hook")
County Of Santa Cruz, California

GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAP

SHEET 2 of 2

DATE: 11/11/05 | FILE: Eastcliff-GJB | SCALE: As Shown | JOB NO.: SE99-033 SCPW TASK 6.8

F:\1-PROJECTS\1999\99-033 SC-PW Task 7 Stability Analyses\Survey data from County\DWG\ECLIFF- GJB.dwg, 11/11/2005 9:12:57 AM, George

SAGE

SANDERS & ASSOCIATES GEOSTRUCTURAL ENGINEERING, INC.

Geotechnical • Structural • Geological

January 26, 2006
Project No. SE99-033 SC-PW Task 6.8/SC-RA2 Task 2

Mr. Ralph Norberg, Senior Civil Engineer
County of Santa Cruz Department of Public Works
701 Ocean Street, Room 410
Santa Cruz, CA 95060

RE: COASTAL BLUFF EVALUATION AND THREAT ANALYSIS
East Cliff Drive at the End of 41st Avenue ("The Hook")
Santa Cruz County, California

Dear Ralph:

We are pleased to present the results of our evaluation of the coastal bluff along East Cliff Drive at the end of 41st Avenue (commonly referred to as "The Hook"). We understand that the County of Santa Cruz plans to submit an application to the California Coastal Commission for the construction of full bluff protection along this section of bluff and between 33rd and 36th Avenues. The Coastal Commission's findings on a previous application for a similar project submitted by the U.S. Army Corps of Engineers in 2003 noted an incomplete threat evaluation had been performed. In particular, details were missing regarding the specific sections of East Cliff Drive classified as "in danger", and to what degree. As a result, we were retained to perform this evaluation to more precisely define the degree of threat along East Cliff Drive at The Hook, and attempt to address other Coastal Commission comments provided in the Consistency Determination report. We previously performed a similar evaluation of the coastal bluff along East Cliff Drive between 33rd and 36th Avenues.

We are submitting four (4) copies of this report for your use. We appreciate the opportunity to provide geologic services to the County of Santa Cruz. Please call us should you have any questions.

Sincerely yours,
Sanders & Associates Geostructural Engineering, Inc.

REGISTERED GEOLOGIST — DREW G. KENNEDY No. 2127 CERTIFIED ENGINEERING GEOLOGIST — STATE OF CALIFORNIA

Drew G. Kennedy, C.E.G. 2127
Senior Engineering Geologist

REGISTERED PROFESSIONAL ENGINEER — DARREN A. MACK GE2634 Exp 6/30/07 — GEOTECHNICAL — STATE OF CALIFORNIA

Darren A. Mack, G.E. 2634
Senior Geotechnical Engineer

cc: Mr. Paul Rodrigues, Santa Cruz County Redevelopment Agency (1 copy)

No. California: **4180 Douglas Blvd., Suite 100 • Granite Bay, CA 95746 • P (916) 729-8050 • F (916) 729-7706**
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COASTAL BLUFF EVALUATION AND THREAT ANALYSIS
East Cliff Drive at the End of 41st Avenue ("The Hook")
Santa Cruz County, California

1.0 INTRODUCTION

Sanders & Associates Geostructural Engineering, Inc. (SAGE) is pleased to present the results of our evaluation of the coastal bluff along East Cliff Drive at the end of 41st Avenue (commonly referred to as "The Hook") in Santa Cruz County, California (Sheet 1). Specifically, we evaluated approximately 65 meters (212 feet) of coastal bluff on an undeveloped parcel owned by the County of Santa Cruz (County) that is used as a public park (Sheet 2). The approximately 11-meter (36-foot) high bluff has been and continues to be susceptible to erosion, which has resulted in retreat of the bluff to within approximately 2 meters (6.5 feet) of East Cliff Drive. Due to local undermining of East Cliff Drive between 33rd and 36th Avenues, the roadway has been reconfigured between 32nd and 41st Avenues from two lanes to a single lane.

We understand that the County plans to submit an application to the California Coastal Commission for the construction of partial to full bluff protection between 33rd and 36th Avenues and The Hook. The Coastal Commission's findings on a previous application for a similar project submitted by the U.S. Army Corps of Engineers in 2003 noted an incomplete threat evaluation had been performed. In particular, details were missing regarding specific sections of East Cliff Drive classified as "in danger", and to what degree. We understand that the Coastal Commission has generally interpreted "in danger" to mean that an existing structure, in this case the road and associated underground utilities, would be unsafe to use or otherwise occupy within the next two to three storm season cycles (generally the next few years) if nothing were done.

We previously performed a coastal bluff evaluation to more precisely define the degree of threat along East Cliff Drive between 33rd and 36th Avenues and attempt to address other Coastal Commission comments provided in the Consistency Determination report, which summarizes the Coastal Commission's basis for rejection of the 2003 project. The results of our previous evaluation were presented in a report dated June 30, 2005. This evaluation addresses similar issues but is focused on the coastal bluff at The Hook.

We recently performed supplemental slope stability analyses of the bluff at The Hook and between 33rd and 36th Avenues under a separate scope of work with the Department of Public Works. The purpose of the analyses was to estimate the largest potential episodic bluff failure and factors of safety against bluff failure for static and seismic conditions. The results of these analyses were presented in a letter report dated October 26, 2005, and have been incorporated into this evaluation report.

For the purposes of clarity in this report, we herein refer to East Cliff Drive, the public park, and the coastal bluff at the end of 41st Avenue as the site.

2.0 SCOPE OF WORK

We performed this evaluation in accordance with our Proposal for Supplemental Engineering Services, dated August 8, 2005, which included the following tasks:

- Performing geologic analyses to evaluate the degree of threat to improvements along the bluff with respect to coastal erosion.
- Preparing this evaluation report.

We also performed the following tasks as part of this evaluation under a separate contract with the Santa Cruz County Redevelopment Agency:

- Reviewing available published and unpublished geologic and geotechnical data for the site.
- Reviewing available historical stereo-paired aerial photographs covering the site on-file at the Map Room of the U.C. Santa Cruz Science Library.
- Performing a site reconnaissance of the site and immediate site vicinity.

3.0 FIELD INVESTIGATION

Geologic reconnaissance mapping of the site and site vicinity was performed on July 12, 2005 to document the geologic conditions along the bluff. In addition, we identified sections of the bluff with oversteepened slopes within the terrace deposits and/or areas where the underlying Purisima Formation has been undercut. These areas are potentially the least stable and, therefore, have the greatest likelihood of causing bluff retreat in the near future. Geologic field data was recorded on a topographic base map prepared by the Department of Public Works in April 1999. Supplemental surveying was performed at our request by the County in June 2005 to more accurately define the top and toe of bluff. The results of our geologic reconnaissance mapping are shown on the Geologic Reconnaissance and Degree of Threat Evaluation Maps, Sheets 1 and 2, which are attached.

As part of our field investigation, we reviewed 15 sets of vertical stereo-paired aerial photographs flown between 1928 and 2003 to evaluate the magnitude and frequency of episodic bluff failures, and to estimate the largest historical bluff failure events. Tonal contrasts and/or prominent crescent shaped scarps visible in the aerial photographs can signify past bluff failures. We also reviewed an oblique aerial photograph flown by Andregg, Inc., dated December 29, 2000, and six sets of oblique aerial photographs flown between 1972 and 2005 that are available at www.californiacoastline.org. A list of vertical and oblique aerial photographs reviewed is included in the references.

4.0 SITE CONDITIONS

4.1 <u>Bluff Geology</u>

In general, the bluff consists of Pliocene Purisima Formation overlain by Pleistocene terrace deposits (Brabb, 1989). The bluff is locally covered with landslide deposits and slope deposits. The geologic units are described below and the approximate limits are shown on Sheet 2.

Moderately cemented and cemented fine-grained sandstones, siltstones, and mudstones of the Purisima Formation comprise the lower 6 meters (20 feet) of the bluff. Depositional bedding in the

Purisima bedrock varies from several centimeters to several meters, and is often difficult to distinguish. Other structural discontinuities include joints (fractures) and minor faults, both of which provide weak planes within the bedrock that promote block failure and can also be preferentially eroded by wave attack. The faults also locally offset individual layers or beds of differing wave erosion resistance within the Purisima Formation, resulting in the formation of embayments where softer and more easily eroded layers are present at beach level. Joint spacing is on the order of 1.5 to 4.5 meters (5 to 15 feet).

Terrace deposits overlie the Purisima bedrock, and are generally characterized by clayey/silty sand and coarse sand (Haro, Kasunich and Associates, 1998). Rounded gravel and small cobbles are present in the lower portion of the terrace deposits.

Several small landslide scars are mapped along the bluff within the terrace deposits. Given the steep slopes, little to no landslide debris remains in the bluff. Therefore, the landslides are generally only marked by these remnant scars or indentations on the bluff face.

Slope deposits are mapped on the bluff face along a small ledge locally present at the top of the Purisima Formation bedrock. The ledge forms where the terrace deposits erode at a faster rate than the underlying bedrock. Once formed, the ledge tends to collect loose soil and organic debris shed from the upper terrace deposits by sheet wash or sloughing. Slope deposits also cover the top of a riprap revetment along the southwest section of the bluff.

Beach deposits consisting primarily of beach sand with occasional concrete and riprap blocks front the bluff.

4.2 **Bluff Conditions**

East Cliff Drive generally runs in a southwest to northeast direction at the site, and is bordered on the southeast by the up to 11-meter (36-foot) high coastal bluff (Sheet 2). The inclination of the bluff face is generally about 65 degrees (from horizontal) within the Purisima Formation along the base of the bluff, and about 50 degrees in the overlying terrace deposits. The upper bluff face within the terrace deposits is locally covered with vegetation and dissected (eroded) with small erosional gullies.

The general bluff configuration changes across the site. On the northeast side of the site, the bluff is generally linear and characterized by a steep bluff face with a prominent Purisima Formation bedrock bench at the toe of the bluff (Figure 1). The bedrock bench is about 1 to 2 meters (3 to 6.5 feet) above mean sea level (MSL) and extends up to 8 meters (26 feet) out from the toe of bluff (Sheet 2). Limited undercutting along the base of the bedrock bench is visible. In addition, preferential erosion of a bedrock fault by wave action has formed a sand-filled notch in the bedrock bench (Sheet 2). Faults generally represent weaker zones in the bedrock that may erode at a faster rate than the surrounding unfaulted bedrock.

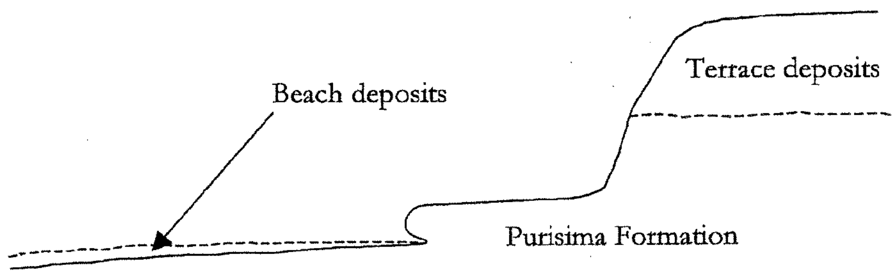

Figure 1 - Schematic profile of the coastal bluff on the northeast side of site.

On the southwest side of the site, the bedrock bench is no longer present and the bluff configuration is somewhat irregular with two embayments separated by a small promontory (Sheet 2). The embayment to the northeast is the largest and extends approximately 10 meters (33 feet) into the bluff. Several faults are visible in the Purisima bedrock at the back of the embayment (Sheet 2). The bedrock in this zone is highly fractured with several seeps. It is likely that the embayment was formed because of preferential erosion of the fractured and faulted bedrock. The overlying terrace deposits have eroded further back leaving a prominent ledge at the top of the bedrock, which is covered with slope debris. Above this ledge, the terrace deposits are locally standing at a near vertical to vertical slope inclination with little to no vegetation growth, which is suggestive of on-going bluff erosion. In addition, the top of bluff has been undermined on the southwestern side of the embayment leaving an overhang extending approximately 1 meter (3 feet) into the bluff (Sheet 2).

The embayment to the southwest of the promontory has been filled with riprap, which conceals the Purisima Formation bedrock. Slope deposits locally cover the top of the riprap.

A wood staircase supported on concrete piles is located on the small promontory (Sheet 2). The staircase has one switchback and extends down to the beach at the rear of the embayment northeast of the promontory.

An existing shotcrete seawall covers much of the bluff southwest of the site. Although the location of the property boundary was difficult to determine during our geologic reconnaissance, it appears that the shotcrete seawall might extend onto the County parcel. At the time of our reconnaissance, the shotcrete seawall appeared to be in poor condition with the base of the shotcrete locally undermined. It was unclear whether the shotcrete seawall is anchored to the bluff with soil nails or tiebacks. In addition, no drains or weep holes were visible in the shotcrete.

Several large cypress trees are located within several meters of the top of bluff, and tree roots locally protrude from the bluff face.

5.0 BLUFF EROSION

5.1 Bluff History

We attempted to develop a partial bluff history using historic vertical aerial photographs reviewed as part of the field investigation, but were limited by tree cover at the site. Oblique aerial photographs generally provided better viewpoints of the bluff, but the availability and quality of the photographs was limited.

In the earliest photographs reviewed (1928), the bluff configuration was generally similar to the present day configuration with a somewhat linear bluff along the northeast side of the site. Two embayments were visible on the southwest section of the bluff, and were separated by a small bedrock promontory. The larger of the two embayments was located to the northeast of the small promontory, consistent with the present day site conditions. Portions of the bluff face appeared to be free of vegetation, particularly within the embayments, which is generally suggestive of on-going bluff erosion.

The bluff conditions appeared to be relatively unchanged through the 1948 aerial photographs reviewed. Starting with the next available aerial photographs, dated May 1963, the bluff was generally obscured by tree coverage in the remaining vertical aerial photographs reviewed.

In the 1972 and 1987 oblique aerial photograph reviewed, the bluff appeared to be undercut or oversteepened at the back of the embayments on the southwest section of the bluff. Based on the next oblique aerial photograph (2002) and observations during the geologic reconnaissance, it appears that the existing staircase was built on the small bedrock promontory between these two embayments, and the riprap was placed around the promontory and within the smaller embayment to the southwest. The existing staircase and riprap revetment were reportedly built in 1987 sometime after the June 1987 oblique aerial photograph was flown. The improvements are visible in subsequent aerial photographs.

5.2 Long-Term Bluff Erosion Rates

Because tree cover obscures the bluff in most of the available vertical aerial photography, long-term bluff erosion rates are generally unavailable. This includes erosion rates calculated by Moore (1998) using soft copy photogrammetry methods, which were previously used in our coastal bluff evaluation between 33rd and 36th Avenues. Long-term rates previously measured in the immediate site vicinity average about 9 centimeters (4 inches) per year (Haro, Kasunich and Associates, 1998) to 14 centimeters (5.5 inches) per year (Gary Griggs, personal communication, August 2005). However, as noted in the Consistency Determination, these long-term erosion rates only represent a long-term average, and are generally not well suited to estimate erosion over short-term intervals due to the episodic nature of bluff erosion.

5.3 Episodic (Short-Term) Bluff Erosion

Coastal bluff erosion is generally caused by wave-induced erosion that undercuts or weakens the bluff, ultimately causing the upper portion of the bluff to fail. As a result, bluff erosion most often occurs episodically as individual events rather than steadily over time. The primary modes of episodic bluff erosion at the site include:

- Undercutting of the Purisima Formation by wave erosion, followed by block failure of the bedrock along structural discontinuities (e.g., bedding, joints, faults, etc.). Following the collapse of the bedrock, the overlying terrace deposits are unsupported and prone to slope failures. Depending on the strength and moisture content of the terrace deposits, they may be able to stand at a near vertical to vertical slope inclination for some time, as is the case in the embayment near the center of the site. Eventually the terrace deposits fail until they reach a more stable configuration. Wave erosion removes the debris at the base of the bluff and begins to cut a new notch, restarting the cycle.
- Surface erosion and shallow slump failures of the terrace deposits resulting from surface runoff and excessive groundwater seepage, which reduces soil strength and causes soil collapse.

Other contributing factors to bluff erosion include strong ground shaking during large magnitude earthquakes on nearby active faults and human activity on the bluff.

The Consistency Determination noted that information on past episodic failure events, including locations and the nature/size of the bluff loss, had not been documented. We attempted to evaluate the magnitude and frequency of the bluff failures, and to estimate the largest bluff failure events using historic aerial photographs reviewed as part of the field investigation. However, tree cover at the site generally concealed the bluff in the aerial photographs reviewed.

The site bluff was designated by Griggs et al. (2005) as hazardous with a high erosion risk. In addition, a large bluff failure occurred southwest of the site near Larch Lane in 1995 (Tetra Tech, 2003), which reportedly extended up to 3 meters (10 feet) into the bluff face.

6.0 SLOPE STABILITY ANALYSES

The Consistency Determination reported that quantitative slope stability analysis should be performed to describe the threat in terms of bluff stability, potential bluff failure planes (and where they are located), and factors of safety.

Slope stability analyses, in general, are performed by assuming the geometry for a potential failure plane (either a sector of a circle or a wedge-like block) and computing the ratio of the net resisting force (soil strength) relative to the net driving forces (soil mass, surcharge, seepage pressures, and/or seismic accelerations). This ratio is defined as the "factor of safety". When the resisting forces are greater than the driving forces, the factor of safety is greater than 1.0. When the factor of safety is about 1.0 (i.e., the driving forces are equal to the resisting forces), failure is imminent. When the factor of safety is less than 1.0 (i.e., driving forces exceed resisting forces), failure is likely (i.e., under seismic conditions) and/or has already occurred.[1]

Commercial slope stability programs utilize algorithms to check multiple failure plane geometries and the lowest factor of safety computed for a given combination of slope geometry and strength parameters is considered the most critical factor of safety under those conditions. Typically, a minimum factor of safety of 1.5 is considered acceptable for static conditions, and the County of Santa Cruz Planning Department defines the minimum acceptable factor of safety for static stability as 1.5. Lower factors of safety, typically between 1.1 and 1.3, are often acceptable for seismic conditions. The County of Santa Cruz Planning Department defines the minimum acceptable factor of safety for seismic stability as 1.2.

Haro, Kasunich and Associates, Inc. (HKA) presented computer-based slope stability analyses in their geotechnical and coastal engineering investigation report, dated January 1998, for a new storm drain outfall immediately northeast of the site. The slope stability evaluations were performed for both static and seismic loading conditions, with no traffic surcharge, and partially saturated conditions in the terrace deposits above the Purisima Formation.

The results of the slope stability analyses performed by HKA yielded factors of safety against slope failure ranging from 1.5 to 1.63 for static conditions, suggesting the slopes are stable in their current configuration. For seismic conditions, the factors of safety reportedly range from 0.82 and 0.97, suggesting failure is likely during a large earthquake on a nearby active fault. The HKA slope stability analyses suggest that bluff failures up to 2 meters (7 feet) can potentially occur along the bluffs for static loading conditions, and up to 6 meters (20 feet) for earthquake loading conditions. The distance noted is the horizontal distance from the crest of the bluff to the estimated failure plane. In all cases the critical failure surfaces appeared to be contained entirely within the terrace deposits, and did not extend into the underlying Purisima Formation.

We recently performed supplemental slope stability analyses to confirm the HKA results for both static and seismic conditions utilizing bluff geometry specific to the site. The results of our slope stability analyses are presented in a letter report, dated October 26, 3005, and are briefly summarized here.

One cross-section, developed by County surveyors, was analyzed. The cross section was located at County Station 0+817 (Sheet 2). Soil properties were based on the geotechnical and coastal engineering investigation by HKA (1998) for the nearby storm drain outfall. In addition, the stability analyses were checked using soil properties developed for a coastal bluff stabilization project southwest of the site near Larch Lane (HKA, 1995). However, these analyses were not used.[2]

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1 In the case of a failure that has already occurred, it may be necessary to "back calculate" a factor of safety less than 1.0 in order to better estimate the possible range of soil strength parameters.

2 The Larch Lane parameters suggested the slope should be failing critically (i.e., the factor of safety was much less than 1.0) under the current configuration, and therefore, did not appear to represent actual conditions at The Hook.

The results of the supplemental slope stability analysis are presented in the Table 1, below. The results are presented by type of analysis, failure surface, and maximum potential bluff failure distance. For static conditions, the results suggest the bluff is marginally stable under static conditions, which is consistent with the history of bluff retreat at the site. The failure surface was assumed to be circular in nature, with a target factor of safety of 1.5. The distance noted is the horizontal distance from the crest of the bluff to the estimated failure plane. For seismic conditions, results are presented for both wedge and circular failures surfaces, with the distance representing the distance from the bluff crest to the failure plane. Based on our review of a recent paper regarding evaluating seismic stability in steep coastal bluffs and our knowledge of the bluff conditions, we believe a wedge-type failure is the most likely mode of failure at the site.

TABLE 1
Estimated Bluff Failure Distance and Corresponding Factor of Safety (FS)

Location (Station)	Static Conditions		Seismic Conditions			
	Circular Failure		Wedge Failure		Circular Failure	
	Distance	FS	Distance	FS	Distance	FS
The Hook Sta. 0+817	5.2 m (17 ft)	1.5	7.5 m (~25 ft)	1.20	8.2 m (~27 ft)	1.20

"FS" = Factor of Safety
"Distance" = Horizontal distance from crest of bluff to failure plane

7.0 DEGREE OF THREAT

To evaluate the degree of threat to specific sections of East Cliff Drive at The Hook, we primarily considered the impacts of episodic (short-term) erosion. As noted in the Consistency Determination, the use of the long-term erosion rates for evaluating the degree of threat to improvements is problematic. The long-term erosion rates only represent a long-term average, and are generally not well suited to estimate erosion over short-term intervals due to the episodic nature of bluff erosion.

The Consistency Determination suggested that the degree to which improvements may be at risk could be best understood by evaluating the largest potential episodic bluff failure, the likelihood of such events, and the proximity of improvements to areas likely to experience such events. As previously discussed, an episodic bluff failure occurred in the immediate site vicinity at Larch Lane. The failure reportedly extended about 3 meters back into the face of the bluff. However, it is unclear if this failure represents the largest potential episodic bluff failure. This failure is somewhat smaller than the largest potential failure estimated by our supplemental slope stability analyses for static conditions. This is largely due to the fact that an actual failure will occur when the factor of safety is less than 1.0; however, we have determined that improvements are "in danger" whenever the factor of safety is below recognized County standards.

Based on the information presented above, we evaluated the degree of threat to East Cliff Drive and assigned specific sections of the roadway to one of the three threat zones, as shown on Sheet 2. The zones are described below.

1. **Active impact to improvements** – Includes sections of East Cliff Drive where the shoulder has been lost to erosion, and continued erosion will result in the further loss of road and other improvements.
2. **"In Danger"** – Existing structures may be unsafe to use within the next two or three storm season cycles (generally the next few years) if nothing were done (as defined by the Coastal Commission).
3. **Potentially "In Danger"** – Sections of East Cliff Drive beyond the Coastal Commission two to three storm season cycles criteria.

No portion of East Cliff Drive has not been damaged or lost at the site due to erosion. Therefore, no section of the roadway was classified as Zone 1.

Zone 2 generally includes sections of East Cliff Drive that are within 5.2 meters (about 17 feet) of the present top of bluff, and therefore, within the assumed limits of the largest potential episodic bluff failure for static loading conditions. We locally adjusted the limits of the zone to reflect bluff configuration and geologic conditions.

The remaining sections of East Cliff Drive are considered to be potentially "in danger," but beyond the Coastal Commission two to three storm season cycles criteria and have been designated as Zone 3.

We understand that the Coastal Commission criteria for degree of threat might discount seismic loading contributions. We believe that it is important to consider seismic loading conditions, given the following:

- The site is located in an area of historically high seismicity characterized by strong ground shaking, and
- Recent research by the U.S. Geological Survey suggests the overall probability of large moment magnitude 6.7 or greater earthquake occurring in the San Francisco Bay region between 2002 and 2031 is 62 percent (WGCEP, 2003).

Our supplemental slope stability analyses suggest larger areas of the site may be classified as "in danger" than currently shown under static conditions. We estimated the size of the largest potential bluff failure under seismic loading conditions is 7.5 meters (about 25 feet), assuming a wedge type failure. The degree of threat to East Cliff Drive under seismic conditions is shown on Sheet 2.

Please note that the degree of threat has been determined from the edge of pavement along East Cliff Drive; however, the line depicting the degree of threat under seismic conditions has been offset from the edge of pavement for clarity.

8.0 CLOSURE

Based on the results of our coastal bluff evaluation and threat analysis, we believe that we have more precisely defined the degree of threat along specific sections of East Cliff Drive at The Hook and addressed other Coastal Commission comments provided in the Consistency Determination report.

9.0 REFERENCES

Ashford, S.A., and Sitar, N., 2002, Simplified Method for Evaluating Seismic Stability of Steep Slopes: Journal of Geotechnical and Geoenvironmental Engineering, v. 128, no. 2, p. 119-128.

Brabb, E.E., 1989, Geologic Map of Santa Cruz County, California: U.S. Geological Survey Map 1-1905, scale 1:62,500.

California Coastal Commission, 2003, Federal Consistency Determination – Proposed Findings: consistency determination number CD-021-03, staff report prepared December 19, 2003.

Griggs, G., Patsch, K., and Savoy, L., eds., 2005, Living with the changing California coast: University of California Press.

Haro, Kasunich and Associates, Inc. (HKA), 1995, Geotechnical Investigation for Larch Lane at East Cliff Drive, Santa Cruz County, California: prepared for Moffatt and Nichol Engineers, dated November 1995, Project No. SC4963.

Haro, Kasunich and Associates, Inc. (HKA), 1998, Geotechnical and Coastal Engineering Investigation for APN 033-171-18, Storm Drain Outfall, 41st Avenue, Santa Cruz County, California: prepared for Santa Cruz County Public Works Department, dated January 1998, Project No. SC5983.

Moore, L.J., 1998, Quantitative shoreline change assessment and identification of erosion hotspots in Santa Cruz County, California: Ph.D. dissertation, U.C. Santa Cruz.

Tetra Tech, Inc., 2003, Draft - East Cliff Drive Bluff Protection and Parkway, Environmental Impact Statement and Environmental Impact Report: State Clearinghouse No. 2001012097, prepared for US Army Corps of Engineers and County of Santa Cruz Planning Department, dated March 2003.

Weber, G.E., 2000, Coastal Geology in the Vicinity of Pleasure Point, Santa Cruz County, California: prepared for Santa Cruz County Redevelopment Agency, dated November 2000.

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

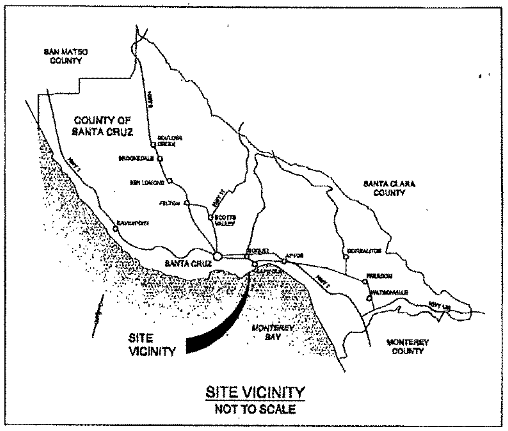
AERIAL PHOTOGRAPHS

DATE	PHOTO NUMBER	SCALE
	Vertical*	
6/27/03	AMBAG 213-10,11	1:4,200
6/7/01	CCC-BOK-C 123-1,2	1:12,000
6/22/94	Big Creek Lumber 13-1,13-2	1:15,480
5/14/90	WAC-Santa Cruz-90 9-117,118	1:15,480
3/26/86	CDBW-APU-C 222,223	1:12,000
4/12/84	Monterey 88,89	1:12,000
10/5/76	DNOD-AFU-C 168,169	1:12,000
10/14/75	SCZCO 1-40,41	1:12,000
4/2/70	76-5-93,94	1:12,000
11/30/65	SC1-29 (SC1-28 missing)	1:3,600
8/27/63	SC1-7	1:3,600
5/14/48	CDF5-3-17,18	1:10,000
1/10/40	V-1-417,418	1:31,000
4/1/31	B-28 (mono coverage only)	1:12,000
1928	SC-28,29	1:12,000
	Oblique	
10/05	Image 200507129**	No scale
9/04	Image 200401518**	No scale
9/02	Image 6668**	No scale
12/29/00	112250BL.DWG***	No scale
6/87	Image 8712176**	No scale
5/79	Images 7930129, 7931076**	No scale
1972	Image 7220089**	No scale

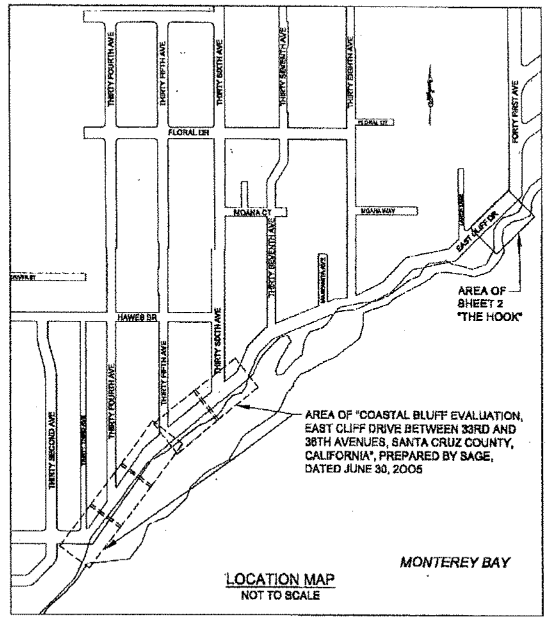
* On-file in the Map Room at the U.C. Santa Cruz Science Library.

** Available at www.californiacoastline.org

*** Oblique aerial photograph flown by Andregg, Inc. for Sanders & Associates Geostructural Engineering, Inc.



SITE VICINITY
NOT TO SCALE



LOCATION MAP
NOT TO SCALE

EXPLANATION

Geologic Units

Qb	Beach deposits
Qsd	Slope deposits - mapped locally along bluff
Qls	Landslide deposits
Qt	Terrace deposits
Tp	Purisima Formation

Geologic Symbols

- Geologic contact, approximately located, queried where uncertain
- Fault, approximately located
- Topographic break in slope
- Toe of bluff
- Strike and dip (in degrees) of stratigraphic beds (23)
- Incised erosional gully, < indicates downslope direction
- Slough area
- Seep
- Slope stability analysis cross section, approximately located
- Landslide, scarp area hachured, arrow in direction of downslope movement, tick marks indicate top of scarp (Qls)
- Degree of threat for static and seismic conditions. Lines are schematic only and are intended to represent the general degree of threat to East Cliff Drive. Degree of threat has been evaluated at edge of pavement; however, the line for seismic conditions has been offset from edge of pavement for clarity. (Seismic 3 2; Static 3 2)

① Active impact to improvements - Includes sections of East Cliff Drive where the shoulder has been lost to erosion, and continued erosion will result in the further loss of road and other improvements.

② "In Danger" - existing structure may be unsafe to use within the next two or three storm season cycles (generally the next few years) if nothing were done (as defined by the California Coastal Commission).

③ Potentially "In Danger" - Sections of East Cliff Drive beyond the California Coastal Commission two to three storm season cycles criteria.

Conventional Symbols

- Approximate Property (P/L), Right-of-Way (R/W) and Easement Lines
- County Stationing (Metric) (0+800, 0+820)
- Road
- Edge of Pavement (EP)
- Fence

Notes

1. Geologic features approximately located using standard tape and compass techniques.
2. Site conditions may have changed since geologic reconnaissance mapping was performed in July 2005.
3. Geologic reconnaissance mapping performed along bluff areas only.

Reference

Topographic map, prepared by County of Santa Cruz Department of Public Works, dated April 1999 (revised July 2005). Site conditions may have changed since date of map.

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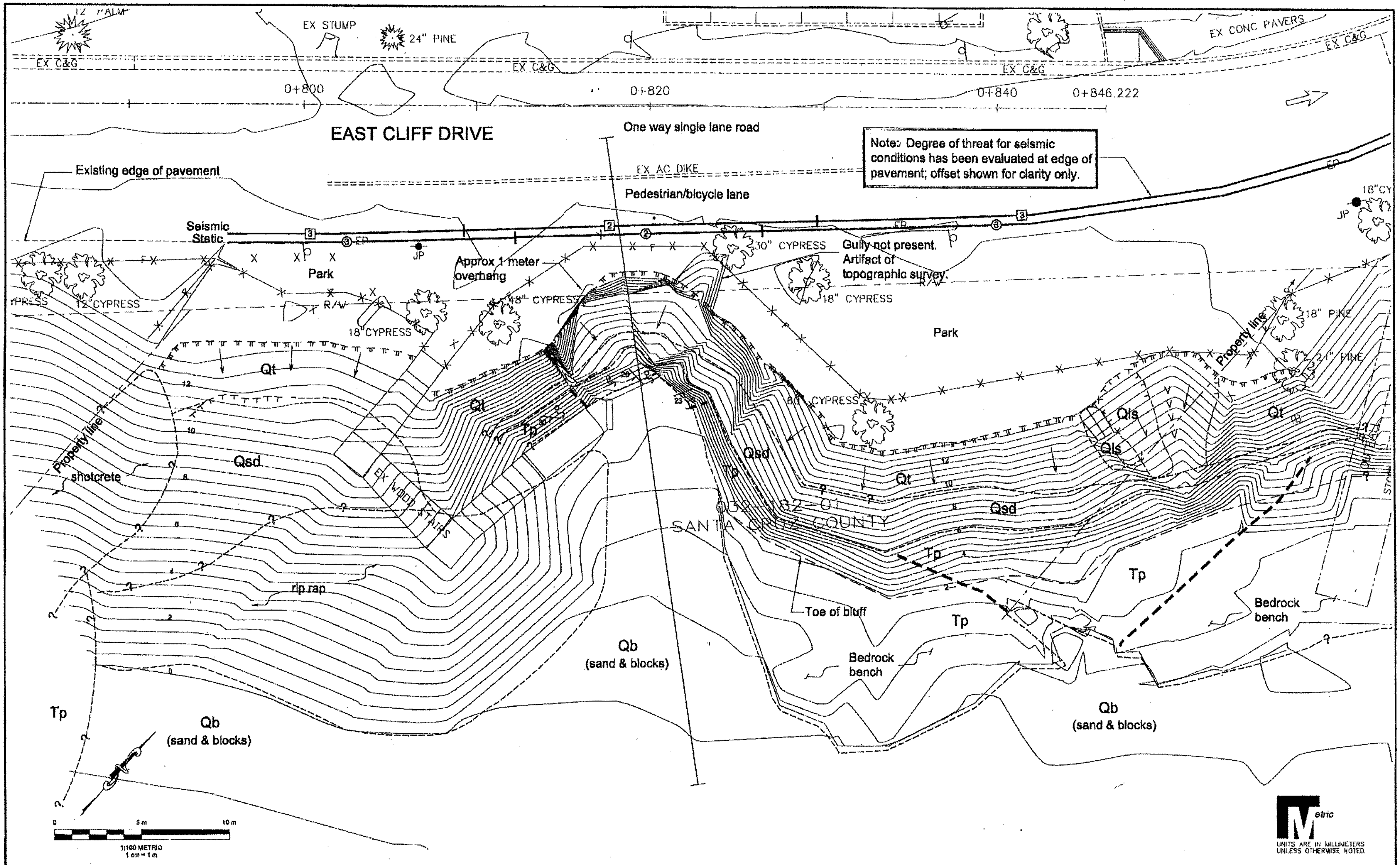
Coastal Bluff Evaluation and Threat Analysis
East Cliff Drive at 41st Avenue ("The Hook")
County of Santa Cruz — California

LOCATION MAP AND EXPLANATION

SHEET 1 (1 of 2)

DATE: 01/26/06 | FILE: Eastcliff-GJB-A | SCALE: As Shown | JOB NO.: SE99-033 SCPW TASK 6.8

F:\1-PROJECTS\1999\99-033 SC-PW Task 6.8 The Hook threat analysis\dwg\ECLIFF- GJB-a.dwg, 1/26/2006 11:31:19 AM, gbaker



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Coastal Bluff Evaluation and Threat Analysis
East Cliff Drive at 41st Avenue ("The Hook")
County of Santa Cruz, California

GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAP

SHEET 2 (2 of 2)

DATE: 01/26/06 | FILE: Eastcliff-GJB-A | SCALE: As Shown | JOB NO.: SE99-033 SCPW TASK 6.8

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February 24, 2006
Project No. SE99-033 SC-PW Task 7.2

Mr. Ralph Norberg, Senior Civil Engineer
County of Santa Cruz Department of Public Works
701 Ocean Street, Room 410
Santa Cruz, CA 95060

RE: REVISED GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS
East Cliff Drive between 33rd and 36th Avenues
Santa Cruz County, California

Ref:
1. *Coastal Bluff Evaluation, East Cliff Drive between 33rd and 36th Avenues, Santa Cruz County, California*, prepared by Sanders & Associates Geostructural Engineering, Inc., dated June 30, 2005.
2. *Summary of Supplemental Slope Stability Analyses (Revised), East Cliff Drive between 33rd and 36th Ave. and the end of 41st Ave. ("The Hook"), Santa Cruz County, CA*, prepared by Sanders & Associates Geostructural Engineering, Inc., dated October 26, 2005.
3. *Geotechnical and Coastal Engineering Investigation for Coastal Bluff Stabilization Project, East Cliff Drive, 33rd to 46th Avenue, Santa Cruz County, California, Addendum*, prepared by Haro, Kasunich and Associates, Inc., dated May 1998.

Dear Ralph:

We are pleased to present the attached revised geologic reconnaissance and degree of threat evaluation maps for the coastal bluff along East Cliff Drive between 33rd and 36th Avenues. These maps were originally prepared during a previous evaluation to more precisely define the degree of threat to East Cliff Drive from bluff erosion under static conditions (Ref. 1). In accordance with our April 27, 2005 proposal, we have revised the maps to incorporate the results of our recent supplemental slope stability analyses (Ref. 2) in which we estimated the largest potential episodic bluff failure and factors of safety against bluff failure for static and seismic loading conditions using bluff geometry specific to the site. Using the results of our analyses, we have re-evaluated the limits of the areas classified as "in danger" as defined by Coastal Commission policies under static conditions. We understand that the Coastal Commission has generally interpreted "in danger" to mean that an existing structure, in this case the road and associated underground utilities, would be unsafe to use or otherwise occupy within the next two to three storm season cycles (generally the next few years) if nothing were done. We have also evaluated the degree of threat to East Cliff Drive under seismic conditions although we understand that the Coastal Commission generally discounts seismic loading contributions.

Slope Stability Analyses

The results of the slope stability analyses were previously presented in a letter report (Ref. 2), and are briefly summarized here.

We analyzed three (3) representative cross sections located at Stations 0+102, 0+212, and 0+278 (shown on attached Sheets 2, 4, and 5). For the three sections, we used soil properties derived by Haro, Kasunich and Associates, Inc. (Ref. 3) during a previous geotechnical investigation of this section of bluff.

Slope stability analyses, in general, are performed by assuming the geometry for a potential failure plane (either a sector of a circle or a wedge-like block) and computing the ratio of the net resisting force (soil strength) relative to the net driving forces (soil mass, surcharge, seepage pressures, and/or seismic accelerations). This ratio is defined as the "factor of safety". When the resisting forces are greater than the driving forces, the factor of safety is greater than 1.0. When the factor of safety is about 1.0 (i.e., the driving forces are equal to the resisting forces), failure is imminent. When the factor of safety is less than 1.0 (i.e., driving forces exceed resisting forces), failure is likely (i.e., under seismic conditions) and/or has already occurred.[1]

Commercial slope stability programs utilize algorithms to check multiple failure plane geometries and the lowest factor of safety computed for a given combination of slope geometry and strength parameters is considered the most critical factor of safety under those conditions. Typically, a minimum factor of safety of 1.5 is considered acceptable for static conditions, and the County of Santa Cruz Planning Department defines the minimum acceptable factor of safety for static stability as 1.5. Lower factors of safety, typically between 1.1 and 1.3, are often acceptable for seismic conditions. The County of Santa Cruz Planning Department defines the minimum acceptable factor of safety for seismic stability as 1.2.

The results of the supplemental slope stability analysis are presented in Table 1, below. The results are presented by type of analysis, failure surface, and maximum potential bluff failure distance (as measured from the crest of the bluff to the estimated failure plane). For static conditions, the results suggest the bluff is marginally stable under static conditions, which is consistent with the history of bluff retreat along this section of East Cliff Drive. The failure surface was assumed to be circular in nature, with a target factor of safety of 1.5. For seismic conditions, results are presented for both wedge and circular failures surfaces, with the distance representing the distance from the bluff crest to the failure plane. Based on our review of a recent paper regarding evaluating seismic stability in steep coastal bluffs and our knowledge of the bluff conditions, we believe a wedge-type failure is the most likely mode of failure at the site.

1 In the case of a failure that has already occurred, it may be necessary to "back calculate" a factor of safety less than 1.0 in order to better estimate the possible range of soil strength parameters.

TABLE 1
Estimated Bluff Failure Distance and Corresponding Factor of Safety (FS)

Location (Station)	Static Conditions		Seismic Conditions			
	Circular Failure		Wedge Failure		Circular Failure	
	Distance	FS	Distance	FS	Distance	FS
Sta. 0+102	3.6 m (~12 ft)	1.49	5.9 m (~19 ft)	1.20	8 m (~26 ft)	1.20
Sta. 0+212	5 m (~16 ft)	1.5	6.6 m (~22 ft)	1.20	9.3 m (~31 ft)	1.20
Sta. 0+278	3.9 m (~13 ft)	1.5	5.8 m (~19 ft)	1.19	7.9 m (~26 ft)	1.20

"FS" = Factor of Safety
"Distance" = Horizontal distance from crest of bluff to failure plane

Degree of Threat

Our slope stability analyses suggest larger areas of East Cliff Drive may be classified as "in danger" than was previously shown on the geologic reconnaissance and degree of threat evaluation maps. Using the results presented in Table 1, we have re-evaluated the degree of threat to East Cliff Drive under static conditions and revised the attached maps accordingly. Discussion of the methods used to determine the degree of threat to specific sections of East Cliff Drive was previously provided in Ref. 1.

As previously discussed, we understand that the Coastal Commission criteria for degree of threat might discount seismic loading contributions. We believe that it is important to consider seismic loading conditions, given the following:

- The site is located in an area of historically high seismicity characterized by strong ground shaking, and
- Recent research by the U.S. Geological Survey suggests the overall probability of large moment magnitude 6.7 or greater earthquake occurring in the San Francisco Bay region between 2002 and 2031 is 62 percent (Working Group on California Earthquake Probabilities, 2003).

We have included the degree of threat to East Cliff Drive under seismic conditions on the attached revised maps. Please note that the degree of threat under both static and seismic conditions has been determined from the edge of pavement along East Cliff Drive; however, the line depicting the degree of threat under seismic conditions has been offset from the edge of pavement for clarity.

We are submitting four (4) copies of this letter and maps for your use. We appreciate the opportunity to provide geologic services to the County of Santa Cruz. Please call us should you have any questions.

Sincerely yours,
Sanders & Associates Geostructural Engineering, Inc.

Drew G. Kennedy, C.E.G. 2127
Senior Engineering Geologist

REGISTERED GEOLOGIST
DREW G. KENNEDY
No. 2127
CERTIFIED
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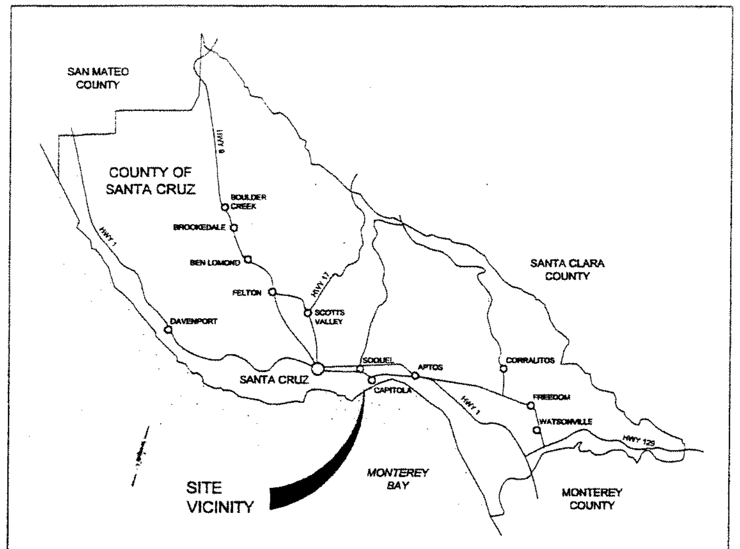
Darren A. Mack, G.E. 2634
Senior Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
DARREN A. MACK
GE2634
Exp. 6/30/07
GEOTECHNICAL
STATE OF CALIFORNIA

Attachments: Geologic Reconnaissance and Degree of Threat Evaluation Maps, dated June 30, 2005, revised February 24, 2006, Sheets 1 through 6

cc: Mr. Paul Rodrigues, Santa Cruz County Redevelopment Agency (1 copy)



LOCATION MAP
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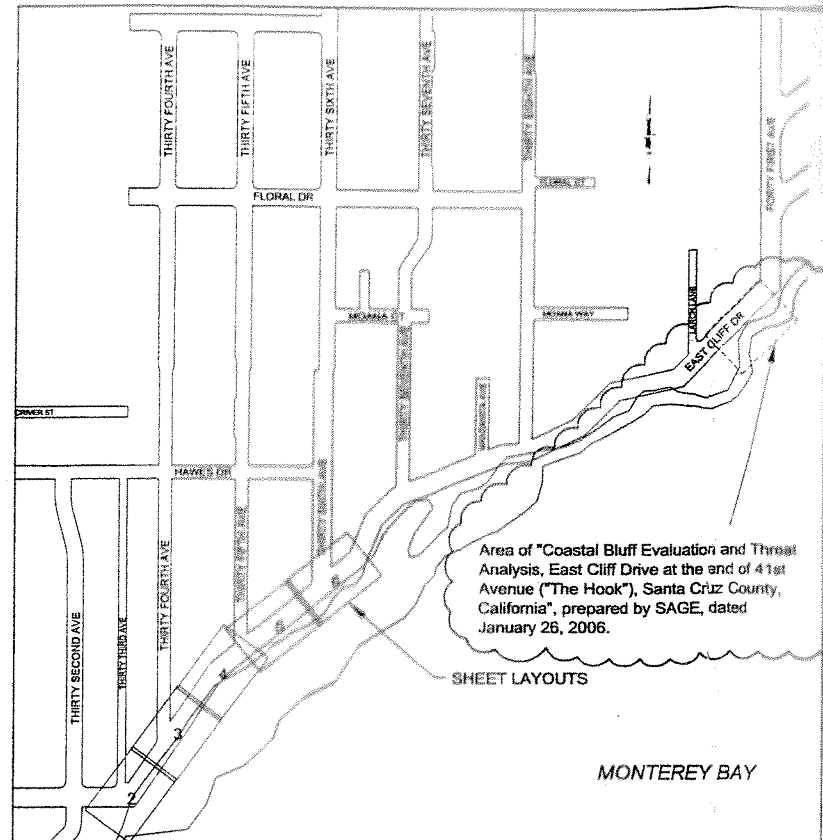

SHEET LAYOUT PLAN
NOT TO SCALE

EXPLANATION

Geologic Units

- Qf — Fill - mapped locally along bluff
- Qsd — Slope deposits - mapped locally along bluff
- Qls — Landslide deposits
- Qt — Terrace deposits
- Tp — Purisma Formation

Geologic Symbols

- Geologic contact, approximately located, queried where uncertain
- Topographic break in slope
- Undercut in Purisima Formation, approximately located, not shown where concealed
- Incised erosional gully, < indicates downslope direction
- Edge of Purisima Formation bench, approximately located
- Slough area
- Slope stability analysis cross section, approximately located — STATION 0+102
- Landslide, scarp area hachured, arrow in direction of downslope movement, tick marks indicate top of scarp — Qls
- Soil nail wall constructed in 2004 as part of emergency repair of crib wall, approximately located
- Crib Wall

Degree of threat for static and seismic conditions. Lines are schematic only and are intended to represent the general degree of threat to East Cliff Drive. Degree of threat has been evaluated at edge of pavement; however, the line for seismic conditions has been offset from edge of pavement for clarity.

Seismic — 3 | 2
Static — ③ | ②

① Active impact to improvements - Includes sections of East Cliff Drive where the shoulder has been lost to erosion, and continued erosion will result in the further loss of road and other improvements.

② "In Danger" - existing structure may be unsafe to use within the next two or three storm season cycles (generally the next few years) if nothing were done (as defined by the California Coastal Commission).

③ Potentially "In Danger" - Sections of East Cliff Drive beyond the California Coastal Commission two to three storm season cycles criteria.

Conventional Symbols

- Approximate Property (P/L), Right-of-Way (R/W) and Easement Lines
- County Stationing (Metric) — 0+060 0+080
- Road
- Edge of Pavement — EP
- Guard Rail or Barricade
- Shrubbery
- Existing Utilities:
  - Water (Plan) — W — Drop Inlet — DI
  - Gas (Plan) — G — Manhole — MH
  - Sanitary Sewer (Plan) — SS — Water Meter — WM
  - Storm Drain (Plan) — SD — Water Valve — WV

Notes

1. Geologic features approximately located using standard tape and compass techniques.
2. Site conditions may have changed since geologic reconnaissance mapping was performed in December 2004 and March 2005.
3. Geologic reconnaissance mapping performed along bluff areas only.
4. Fill and slope deposits shown in select areas only. Comprehensive mapping of fill and slope deposits not performed.

Reference

Topographic map, prepared by Andregg, Inc., dated November 2000. Site conditions may have changed since date of photo base and topography.

GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS
East Cliff Drive
33rd Avenue to 36th Avenue
County Of Santa Cruz, California

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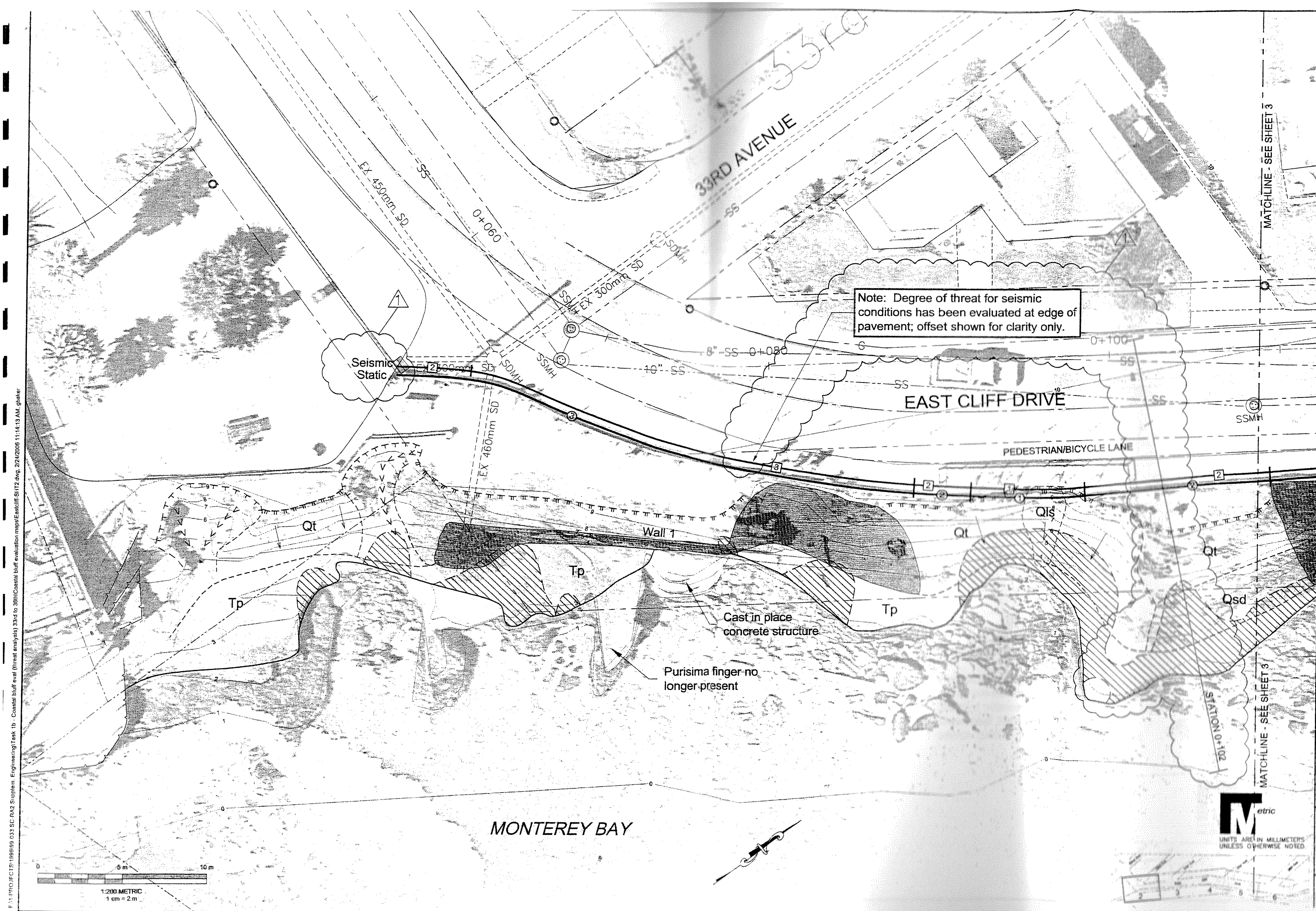

REV	BY	DATE	DESCRIPTION
1	DGK	2/24/06	Revised degree of threat to East Cliff Drive based on supplemental slope stability analyses (SAGE, 2005)

DATE: 06/30/05
SCALE: 1:200 METRIC
DESIGNED BY: DGK
DRAFTED BY: CAH
CHECKED BY: DAM
JOB NO.: SE99-033 SC-RA2
FILE: SHEET 2.dwg

GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS

East Cliff Drive
33rd Avenue to 36th Avenue

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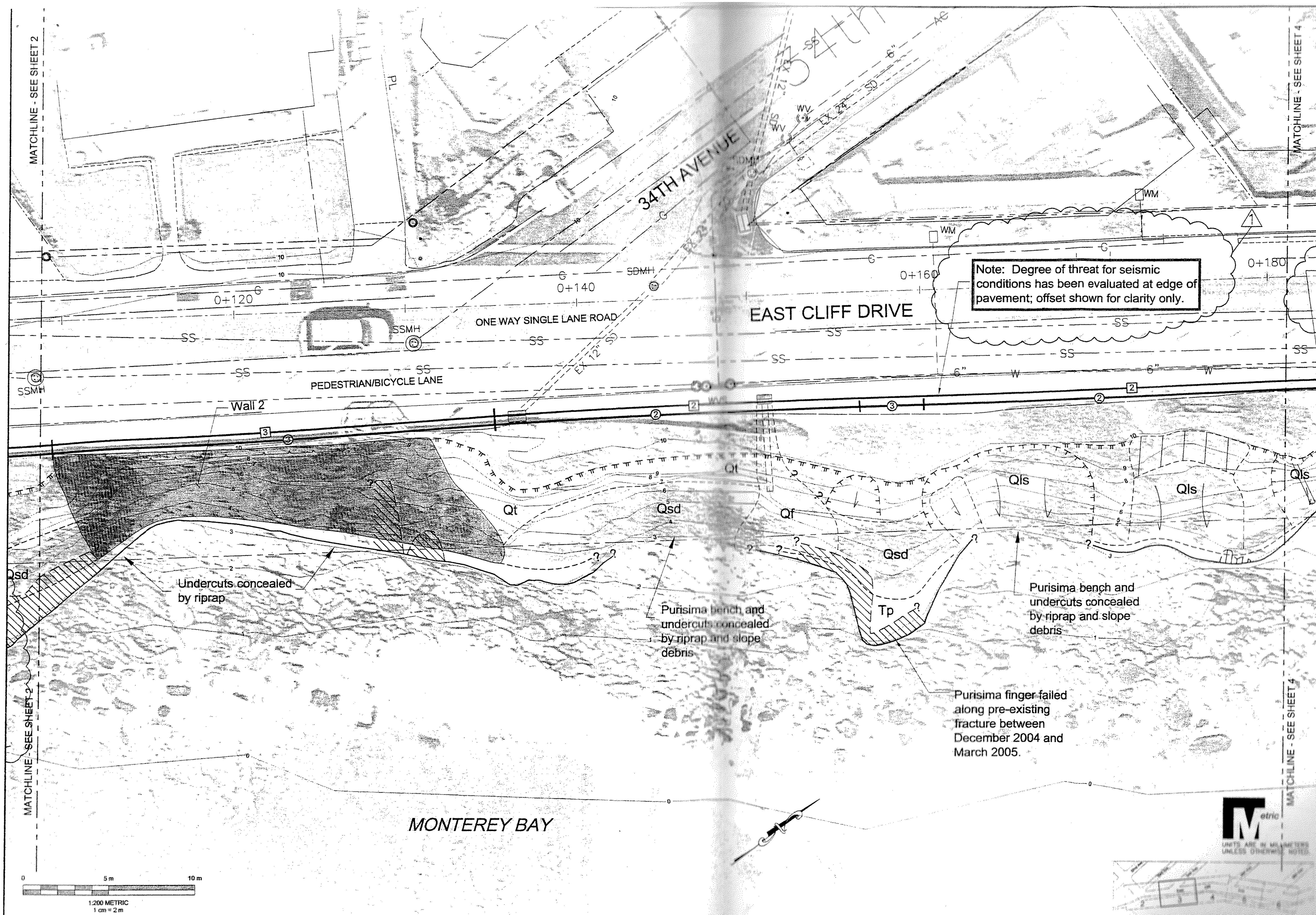

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GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS

East Cliff Drive
33rd Avenue to 36th Avenue

County Of Santa Cruz
California

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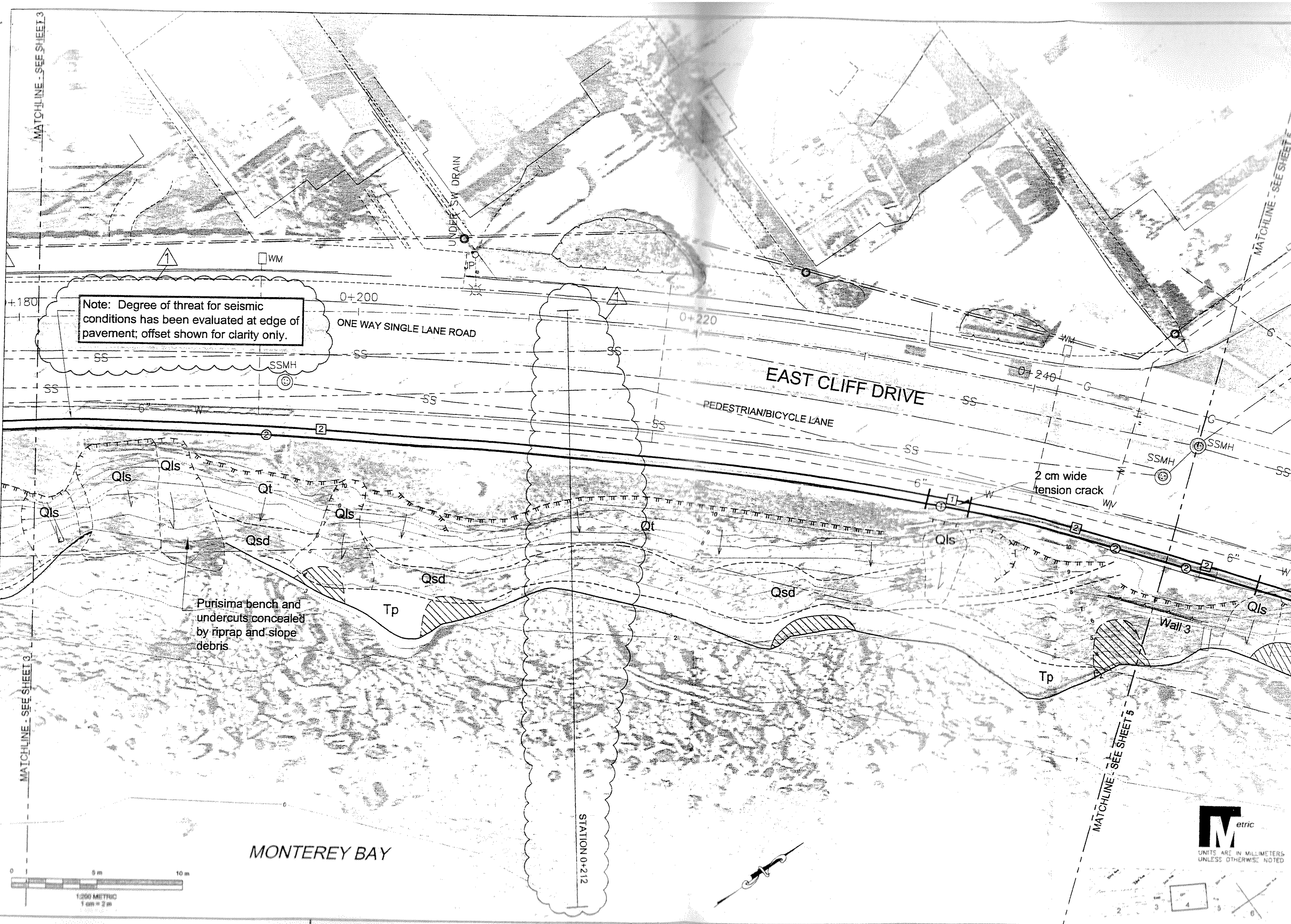

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GEOLOGIC RECONNAISSANCE AND DEGREE OF THREAT EVALUATION MAPS

East Cliff Drive
33rd Avenue to 36th Avenue

County of Santa Cruz — California

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DATE: 06/30/05
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SHEET 4 OF 6

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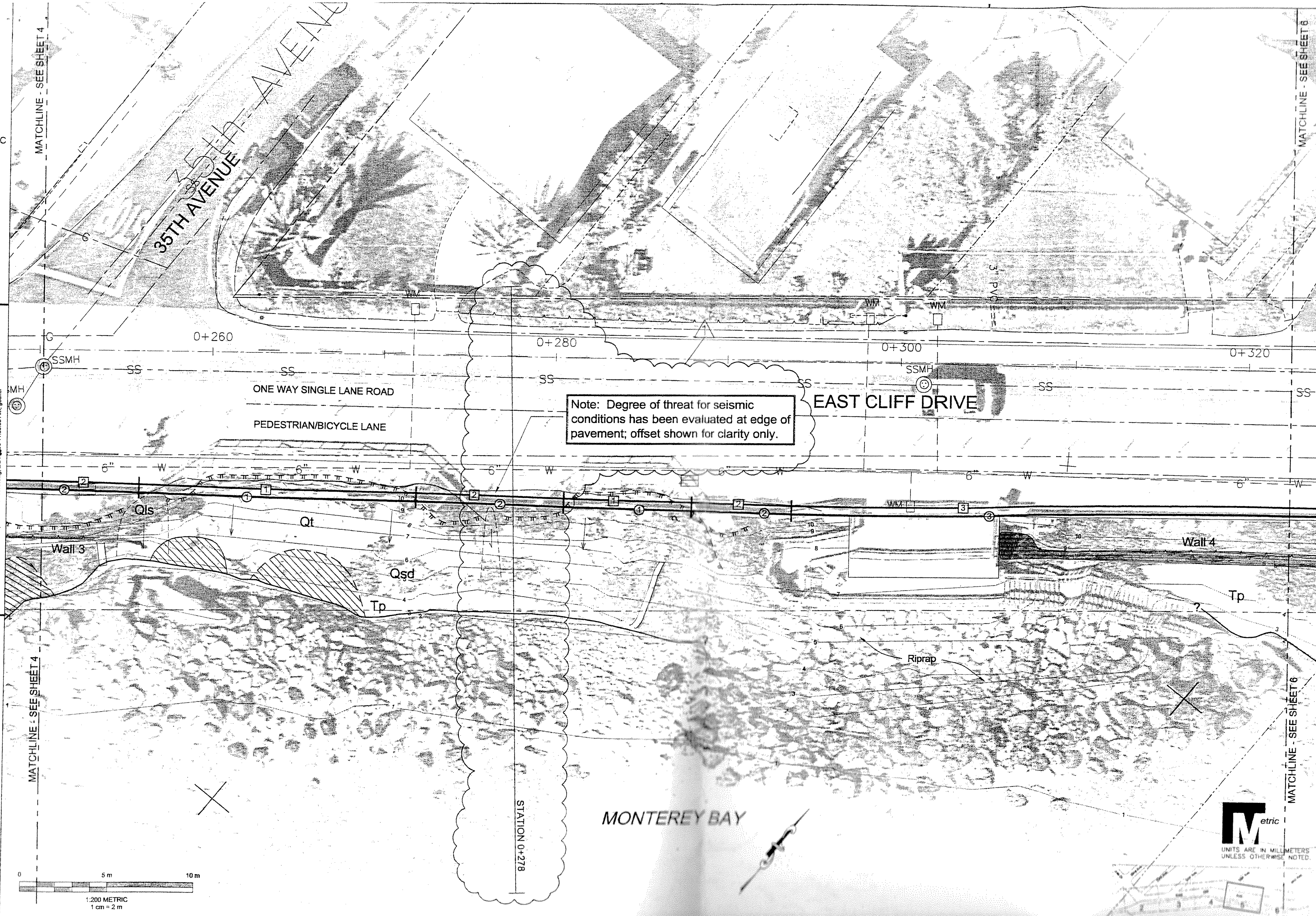

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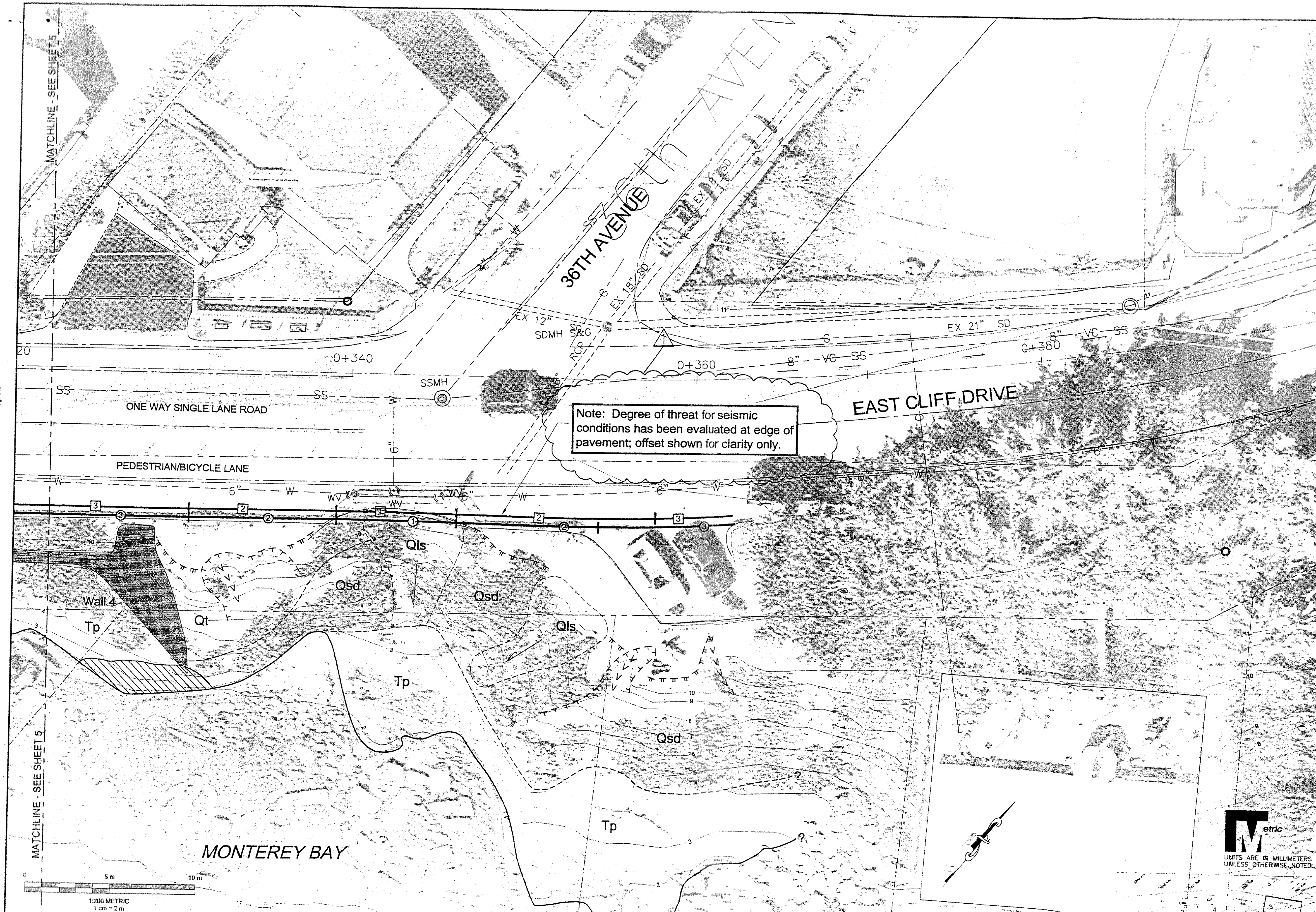

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Metric

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33rd Avenue to 36th Avenue

County Of Santa Cruz — California

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