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LANDSLIDE INVESTIGATION

Burrell Ranch
Portuguese Bend
Rancho Palos Verdes, California

Client

Tim Burrell

July 6, 1978

Job No. 377-540

Table of Contents

LANDSLIDE INVESTIGATION

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Introduction

Purpose and Scope

This report presents the results of our study of an ancient slide ("Slide F") within the large landslide complex immediately west of the active Portuguese Bend Slide. The purpose of the study was to supplement our Preliminary Report of a Geologic and Soils Investigation dated December 29, 1969 (Job No. 18-507 and 18-741), to better define the existing properties of the slide and to provide recommendations for stabilization of the slide and areas affected by the slide. The recommendations provided herein are intended to be used for feasibility evaluations so that developmental plans may be formulated. Further geologic study will be needed before remedial designs can be finalized.

The investigation included site inspection, test borings and engineering calculations. Preliminary developmental plans dated March 20, 1977 were supplied by Earth Associates, Inc., Santa Monica.

The geology was mapped in 1968 by Moore & Taber and Dr. Richard Jahns on a scale of one inch equals 200 feet. The 1969 study covered approximately 400 acres, about 70 acres of which are the subject of the present investigation. To supplement the surface mapping and analysis of aerial photographs, a total of 64 borings and 60 test pits were excavated in 1968. Reference was made to "Geology and Paleontology of Palos Verdes Hills" by Woodring, Bramlette & Kew (U.S.G.S. Professional Paper 207, published in 1946), which provided formational names and stratigraphic nomenclature used.

The present investigation included an extensive review of the 1969 data and a more detailed study of Slide F within the subject 70 acres. To supplement the 16 borings within the subject property associated with our earlier investigation, three additional rotary wash borings were drilled and logged by an engineering geologist to determine the depth of the slide and better define its direction of movement. Data and evaluations from our original study concerning "Slide C" were also reviewed and new stability calculations made; however no new subsurface information was obtained.

For convenience, and to minimize confusion, the designation of all slides, sections, boring numbers previously referred to in our 1969 report are used in this report.

Geology

General

The regional stratigraphy and structure and the history of landsliding for the subject area have been discussed in detail in our report of December, 1969. The site under consideration lies on the western edge of the ancient landslide complex and includes portions of three slides. Two slides in particular influence a large portion of the subject property - a long, southeast-dipping slide (Slide F) covers the northern quadrant (approximately 24 acres) and a slightly smaller, seaward-dipping slide (Slide C) in the south central area (approximately 21 acres). Since the direction of movement of Slide F most critically affects the development of the property, it was the primary subject of this study. However, as previously noted, since Slide C is also of concern and would influence project development, so it was also re-evaluated.

Slide F

Slide F appears to be a large mass of Monterey shale which has slid along an adversely oriented layer of bentonitic claystone. The slide mass consists generally of siliceous shales, siltstone and claystones, which are weathered and fractured. The undisturbed bedrock beneath the slide is predominantly dark gray to black marine shales and claystones, highly indurated with minor fracturing.

Data from the 1969 geologic investigation revealed the configuration of the slide surface nearest the head of the slide. The shear surface was found to be dipping about 10° to 15° in a southeasterly direction, paralleling bedding in the underlying undisturbed bedrock. Bucket auger borings had been ineffective, however, in penetrating the toe and central portions of the slide mass. To ascertain the depth of the slide in these areas, rotary wash borings were utilized. This information indicates that the slide mass is about 100 feet thick with a base which is dipping in a southeasterly direction at low angles (approximately 4° to 6°). Topographically, the ground surface of the slide roughly parallels the base of the mass - a gentle slope (approximately 5:1) at the head descends to a broad level terrace which joins an 8:1 slope at the toe.

As depicted in the attached geologic cross-section FF-FF', these relationships reflect an elongated, slightly tapered wedge-shaped mass bounded by two gently sloping planes. The slide thickness diminishes from about 100 feet near the toe to about 50 feet near the head of the ancient slide.

Slide C

Although Slide C was not a basic concern of this investigation, it was considered and reevaluated in light of the new data obtained from the investigation of Slide F. Slide C is comprised of two slides which have moved seaward in a south-southwesterly direction. The slide has overridden marine terrace deposits at the toe, and is well defined at its westerly edge in a canyon and at the toe at the southeast property line. The slide is independent of and younger than Slide F although its movement has probably involved the southerly edge of Slide F where it has eaten back into Slide F.

CONCLUSIONS AND RECOMMENDATIONS

Engineering analyses were made to evaluate the stability of Slides F and C and to design stabilization measures. Three possible locations for shear keys on Slide F - one at the toe of the slide and two across the center of the mass - and their advantages and disadvantages are presented. Calculations were also made for buttresses at the toe of Slide C. At several locations, evaluation considered the comparative value of standard compacted fill (untreated) or soil cement (treated), shear keys or buttresses. The stability of construction slopes is critical and will require precautions and special grading procedures to reduce the potential for failure during construction. Once the slide has been stabilized, every effort should be made to minimize the infiltration of water into the subsurface soils. It is assumed that sewers will be available.

Stability Analyses

Using the Ordinary Slice Method, Slide F was analyzed along Section FF-FF'. The cross-section parallels the general direction of slide movement and intersects the thickest and longest portion of the slide mass representing the most critical section through the mass. All calculations are shown in the appendix.

With regard to evaluating the existing stability of the slide, the most important, yet most difficultly defined variables are the shear strength parameters, ø (angle of internal friction) and c (cohesion), along the slide surface. Two general approaches were utilized to select parameters which are representative of the materials encountered. These yielded factors of safety within a range which are reasonable based on the geologic history of the slide.

The most conservative analysis assumes an existing factor of safety slightly greater than 1.0, representing the condition in which the forces which could cause sliding are nearly equal to those forces resisting movement. At the cessation of sliding, thousands of years ago, the factor of safety would have been 1.0. Since that time, the slide has been modified by erosion and deposition and has been subjected to severe rainfall and seismic shock, apparently without inducing renewed movement. Thus, it is probable that the existing safety factor is substantially greater than one.

Several conservative assumptions were made in the calculations: 1) that Slide F receives no support from the lower slide at its toe (i.e. as though the lower slide has resumed movement,) 2) that renewed sliding could occur in any of the predominantly tuffaceous claystones above the dark gray marine shales, thus the deepest possible shear surfaces were considered, and 3) that uniformly low shear strengths are present along the entire shear surface.

The minimum average strength parameters will vary depending on the factor of safety assumed for the existing conditions. The following table relates these values to several assumptions of the present factor of safety.

Factor of Safety	ø (degrees)	c (psf)
1.00	5.0	95
1.15	5.5	150
1.25	6.0	150

These strengths were compared to the extensive laboratory test data and strengths used in calculations available from the 1969 investigation. The laboratory test data on samples of tuff above and below the slide surface were all substantially higher than the calculated strengths, generally averaging ø = 30° to 40°, and c = psf to 1000 psf. The lowest strength obtained from bentonitic materials from the Portuguese Bend area was from the shear surface of the ancient small landslide within the existing Portuguese Bend Club, about two miles east of the subject property at Yacht Harbor Drive and Palos Verdes Drive South. Residual shear tests on saturated, remolded, sheared clay yielded a strength of ø = 8° and c = 150 psf. Calculations for the active landslide, assuming no cohesion, indicated ø = 7.3°.

All of these strengths are significantly higher than ø = 6° and c = 150 psf, which were used as representative, though conservative, strength parameters for Slide F. The existing factor of safety, therefore, is considered to be greater than or equal to 1.25. For consistancy, the same strength parameters were used in analyzing Slide C although calculations for existing conditions would indicate these values are conservative and slightly higher strengths might be used. Slope stability calculations for existing conditions as well as all subsequent stabiliztion measures (shear keys or buttresses) are shown on pages C-1 to C-6.

Stabilization Measures

It is generally recognized that a slide must have a factor of safety of at least 1.5 to be considered as suitably stable for development. This requires some corrective stabilization for Slide F to raise the safety factor from 1.25. Due to the planar, uniform shear surface, a shear key rather than unloading the head or loading the toe of the slide, appears to be the most effective remedial measure.

Commonly, shear keys are constructed of compacted fill. However, due to the large volume of material which would be required, consideration was given to incorporating soil cement into the critical portions of the shear key. The higher strengths available from soil cement cause significant reductions in the base width of the key. The smaller excavation volumes needed with soil cement probably offset its higher cost. The approximate volume, as well as base width and length of the various shear keys and/or buttresses, is given in Table I. Their location is shown on the accompanying plan and sections and is referenced by the following symbol: △.

Stability calculations for the various shear keys were made using the following strength parameters: compacted fill - ϕ = 25° and c = 400 psf, soil cement (4% by weight) - ϕ = 45° and c = 2000 psf, slide base - ϕ = 6° and c = 150 psf.

A shear key placed near the toe of Slide F, along the southeastern property line, would require a base width of 155 feet if constructed of compacted fill △1 or 57 feet if soil cement is used △2. The key would be about 110 feet deep at its deepest point, gradually thinning towards the southwest.

The slide mass was then divided into two blocks - its head, northwest of Section CC' and its toe, southeast of CC' - and each block analysed as an independent slide. Again, using ϕ = 6° and c = 150 psf, the factor of safety for the head block is 0.7 and for the toe is 1.6. This indicates that most of the driving force for Slide F lies within the upper portion of the slide, northwest of CC'. If the upper portion is stabilized with a shear key near the center of the slide, the lower remaining portion of the slide will have an adequate factor of safety.

A shear key placed northwest of CC', as shown in the cross-section, would require a base width of 223 feet if constructed of compacted fill △4 3, or 76 feet if a soil cement backfill is used △5. The key would be about 70 feet deep, resulting in the excavation volumes indicated in Table I.

Obviously, the soil-cement shear key placed near the center of the slide has a major advantage over the other shear key alternates presented in terms of excavation quantities. Two other advantages for this method are also apparent. The materials within the slide mass near the toe of the slide were generally impenetrable with a bucket auger due to the presence of very hard silicified shales. Excavation of these materials may be more difficult than an excavation nearer the head of the slide where borings were able to penetrate the slide material and extend well into the undisturbed materials below the slide. Another advantage of the central key is that it is further from existing structures and thus, should a failure occur in either construction slope during excavation, it would not jeopardize existing homes. The distance also results in fewer aesthetic disturbances to the surrounding residences.

Because of the limitations on excavation imposed by property lines, another location for a center shear key was considered that would allow greater lateral extension of the key to the east, still within property boundaries, thereby increasing the usable area below the key. This resulted in analysis of shear key △3 crossing section FF-FF' at section CC'. If either the upper shear keys (△4, △5) or mid-shear key △3 are used, consideration could be given to purchase of lots 33 and 34 on Fruit Tree or permission of access to the horse stable area across Narcissa Drive to permit further extension. A similar situation is present for the lower shear keys (△1 and △2), that is, extension across Narcissa Drive would minimize restriction on usable area on the subject property.

Analyses were made for Slide C considering both treated and untreated fill buttresses (6 and 7) at the toe of the slide where it daylights the existing natural slope. A calculation was also made to determine the effect on buttress width if a 2:1 fill slope was placed over a soil cement treated buttress (8).

Stability During Construction

Calculations along Section FF-FF' show that when a 1:1 backslope for the upper shear key is excavated to the base elevation, the factor of safety for the temporary slope is about 0.7. This indicates that the slope would be unstable during construction <u>if</u> the actual shear strengths of the materials are as low as the design strengths used in the calculations. The calculated safety factor for an excavation at the toe of the slide (shear key 1 or 2) is greater than one, indicating that landslide movement during construction is less likely. To reduce the chance of movement, any proposed shear key excavations should be made in sections.

Setback

Depending upon which alternate stabilization measure is selected, a setback line for construction may be required. Such a line would be located approximately 180' west of and trend essentially parallel to the east property line along Narcissa Drive if stabilization is obtained by the lower shear key (1 or 2). Using upper shear key 4 or 5 results in a greater setback from Narcissa Drive due to excavation limitations imposed by the westerly property lines of lots 33 and 34. This provides a buffer zone (restricted use area) between the edge of the stabilized slide and buildings, and accounts for possible movement of the ancient, unstabilized slide to the east and its effect on the property. The setback is based upon a line projected at 45° to the surface from the easterly end of the shear key base. A buffer zone would also need to be established for the area below Slide D along the northerly property line.

Drainage Control

Infiltration of surface waters into the slide mass can significantly reduce the safety factor of the slide, and possibly cause renewed movement. The additional weight of the water can increase the driving forces within the slide. Simultaneously, greater saturation of materials at the shear surface generally lowers the shear strength, reducing the forces resisting sliding. Thus, it is imperative that following stabilization of the slide, every effort be made to minimize the introduction of water into the slide mass. This requires well-designed sewage systems and highly controlled surface drainage and landscape watering.

General Conditions

This report has been prepared in accordance with generally accepted geotechnical practices, and makes no other warranties, either expressed or implied, as to the professional advice or data included in it. This report is for feasibility evaluation of the planned development and does not include sufficient information for final design of remedial measures. Additional geologic investigation, including subsurface exploration and laboratory testing, will be needed prior to final development plans. Buttress and/or shear key depths and widths will be modified based on the additional exploration and testing. Development of the property should consider stabilization of both slides rather than only one since movement of either one could affect the other by removal of lateral support. Remaining portions of the property are considered to be stable but additional investigation of these areas to confirm this will be needed.

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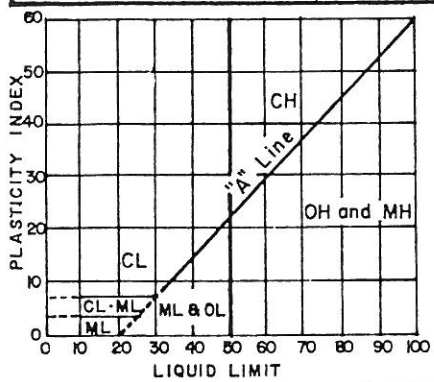
APPENDIX

UNIFIED SOIL CLASSIFICATION

Pt	OH	CH	MH	OL	CL	ML	SC	SM	SP	SW	GC	GM	GP	GW
Highly organic soils	Silts and clays Liquid limit greater than 50			Silts and clays Liquid limit less than 50			Sands with fines >12% fines		Clean sands <5% fines		Gravels with fines >12% fines		Clean gravels <5% fines	
							Sands - more than 50% of coarse fraction is smaller than Nº 4 sieve.				Gravels - more than 50% of coarse fraction is larger than Nº 4 sieve.			
Fine grained soils (More than 50% is smaller than Nº 200 sieve)							Coarse grained soils (More than 50% is larger than Nº 200 sieve)							



LABORATORY CLASSIFICATION CRITERIA

GW and SW - $C_u = \frac{D_{60}}{D_{10}}$ greater than 4 for GW & 6 for SW; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 & 3.

GP and SP - Clean gravel or sand not meeting requirements for GW and SW.

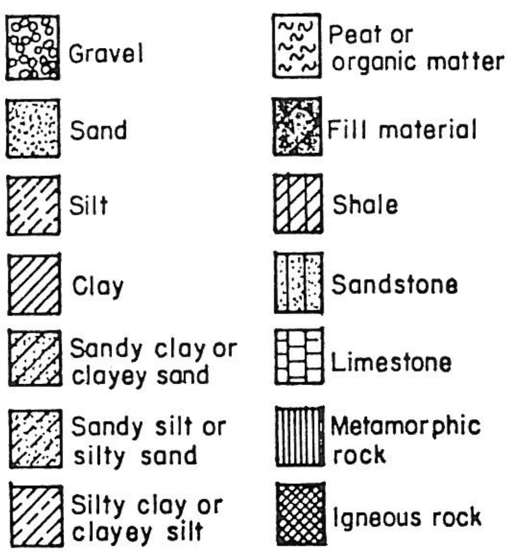
GM and SM - Atterberg limits below "A" line or P. I. less than 4.

GC and SC - Atterberg limits above "A" line with P. I. greater than 7.

Fines (silt or clay)	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobbles	Boulders
Sieve sizes	200	40	10	4	3/4"	3"	10"

Classification of earth materials shown on this sheet is based on field inspection and should not be construed to imply laboratory analysis unless so stated.

MATERIAL SYMBOLS

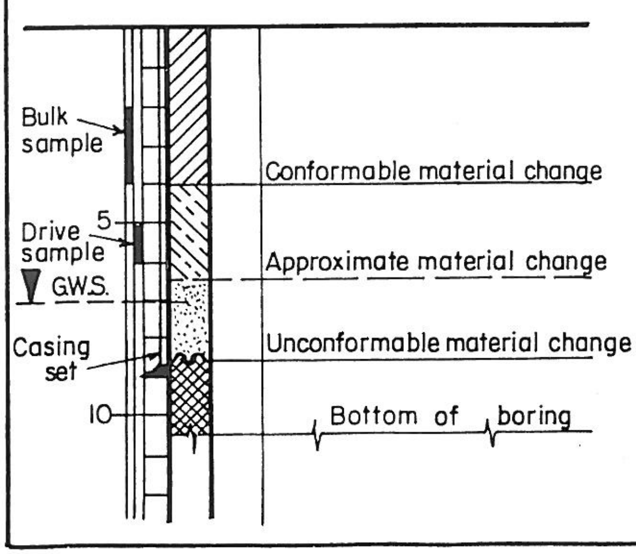


CONSISTENCY CLASSIFICATION FOR SOILS

According to the Standard Penetration Test

Nº of blows	Granular	Cohesive
0 - 5	Very loose	Very soft
6 - 10	Loose	Soft
11 - 20	Semicompact	Stiff
21 - 35	Compact	Very stiff
36 - 70	Dense	Hard
>70	Very dense	Very hard

LEGEND OF BORING



LEGEND OF PENETRATION TEST

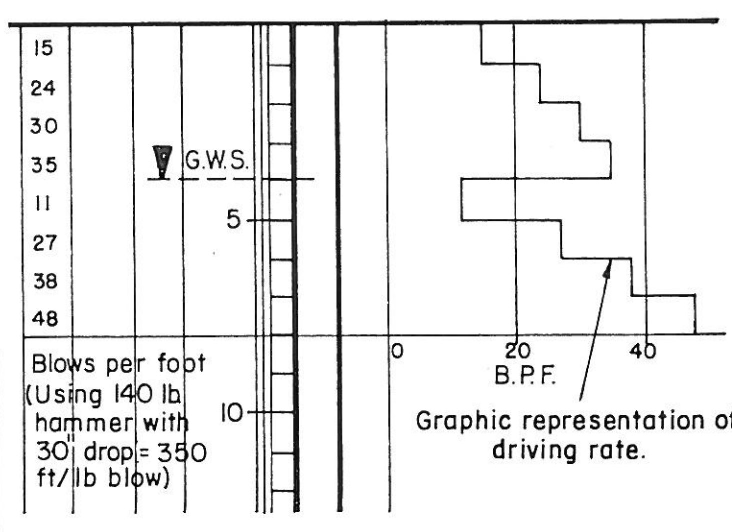


TABLE I

Location and Type	Base Width	Base Length	Excavation Volume Yd.^{3}
Slide F			
1 Lower/Compacted Fill	155'	570	∿520,000
2 Lower/Soil Cement	57'	570	∿290,000
3 Middle/Soil Cement	75'	555	∿270,000
4 Upper/Compacted Fill	223'	470	∿330,000
5 Upper/Soil Cement	76'	470	∿150,000
Slide C			
6 Toe Buttress/Compacted Fill	272'	1450	∿660,000
7 Toe Buttress/Soil Cement	112'	1450	∿160,000
8 Toe Buttress/Soil Cement with 2:1 Slope	85'	1450	∿120,000

Excavation volume includes front and back slopes and ten feet deep key below slide surface.

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 5" Rotary

ELEVATION 422'

BORING 201

Depth in feet	Material	Description
0	LANDSLIDE DEBRIS	LANDSLIDE DEBRIS: Dark brown SILTY CLAY with SILICEOUS SILTSTONE chips (~1/2")
5		Yellow-brown SILTY CLAY with SILICEOUS SILTSTONE chips (~1/2')
		. . . increasing SILICEOUS chips (~1")
10		Dark brown SILTY CLAY with minor SILICEOUS chips
15		Light yellow-brown SILT (no SILICEOUS chips)
25		Yellow-brown SILT
50		

continued

STRIKE / DIP	RELATIVE COMPACTION	DRY DENSITY (LBS/CU.FT)	MOISTURE (%)	BLOWS/FOOT	SAMPLE SIZE (INCHES)	SAMPLE Nº	DEPTH IN FEET	MATERIAL SYMBOL

THIS BORING LOG SUMMARY APPLIES ONLY AT THE TIME AND LOCATION INDICATED. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND TIMES.

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DATE 1/30/78 and 2/3/78

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 5" Rotary | ELEVATION 422' | BORING 201

Blows/Foot	Sample Size (inches)	Sample No	Depth in Feet	Formation	Description
			55–60	LANDSLIDE DEBRIS	Yellow-brown SILT
			60–69	LANDSLIDE DEBRIS	Reddish-brown CLAYEY SILT
70	2.5	1	70	ALTIMIRA MEMBER / MONTEREY FORMATION	DISTURBED BEDROCK: Brecciated TUFF. Angular white BENTONITE and gray and yellow SANDSTONE in a red CLAY matrix.
42	2.5	2	75		Brecciated SANDSTONE - Light yellow and tan angular clasts of SANDSTONE and SILICEOUS SHALE in yellow-brown SANDY matirx. Some black manganese staining around clasts.
56	2.5	3	80		Brecciated SANDSTONE and TUFF - red and orange SANDSTONE clasts in gray, yellow and rust BENTONITE matrix. Angular clasts (1/4" to 1")
30	2.5	4	85		Brecciated SANDSTONE, TUFF and SHALE - Yellow-brown and gray SANDSTONE and SILICEOUS SHALE clasts (1/4" - 2") in rust and white BENTONITE matrix. Few manganese stains.
32	2.5	5	90		
13	2.5	6	95		Brecciated TUFF and SANDSTONE - yellow-brown and beige small (1/4' to 1/2") SANDSTONE clasts in olive-gray CLAY matrix.
42	2.5	7	100		

continued

STRIKE / DIP | RELATIVE COMPACTION | DRY DENSITY (LBS/CU.FT.) | MOISTURE (%) | BLOWS/FOOT 350 ft.lbs. | SAMPLE SIZE (INCHES) | SAMPLE Nº | DEPTH IN FEET | MATERIAL SYMBOL

THIS BORING LOG SUMMARY APPLIES ONLY AT THE TIME AND LOCATION INDICATED. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND TIMES.

LOGGED BY PJA | DATE 1/30/78 and 2/3/78

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 5" Rotary | **ELEVATION** 422' | **BORING** 201

STRIKE / DIP	RELATIVE COMPACTION	DRY DENSITY (LBS/CU.FT)	MOISTURE (%)	BLOWS/FOOT 350 ft./lbs.	SAMPLE SIZE (INCHES)	SAMPLE Nº	DEPTH IN FEET	DESCRIPTION
								DISTURBED BEDROCK: (continued)
								Very hard rock at 103'
				82	2.5	8		Brecciated SANDSTONE and CLAYSTONE - brown, green & gray large (>2.5") SANDSTONE fragments. Reddish-gray CLAY, somewhat plastic (sheared ?) at 106'
				50	2.5	9	105	
				48	2.5	10	110	Brecciated TUFF and SANDSTONE - Light gray SANDSTONE clasts in green-white BENTONITE (some red staining in CLAY)
				40	2.5	11	115	Sheared BENTONITE - carmel and white BENTONITE with variously oriented sheared and slicked surfaces. Minor gypsum.
					NSR		120	... Hard light gray SANDSTONE
				50	2.5	12	125	UNDISTURBED BEDROCK: Dark gray SILTSTONE and SANDSTONE. Minor gypsum. No apparent bedding.
				54	2.5	13	130	Blue-gray SILTY CLAYSTONE. Minor mica No apparent bedding
							135	. . . becomes harder and sandier
				34	2.5	14	140	Blue-gray fine to medium-grained SANDSTONE Dipping ~10° - 15° . . . becomes black-gray . . . hard SANDSTONE layer at the bottom of the hole
							145	
					NSR			
							150	

MONTEREY FORMATION / ALTAMIRA MEMBER

MATERIAL SYMBOL

NOTES:

1) Minor caving at 15' to 20' and 85' to 95'.
2) Groundwater encountered about 142'
3) Backfilled 2/3/78

THIS BORING LOG SUMMARY APPLIES ONLY AT THE TIME AND LOCATION INDICATED. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND TIMES.

LOGGED BY PJA | **DATE** 1/30/78 and 2/3/78

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 5" Rotary | ELEVATION 424' | BORING 202

Depth in feet	Sample size (inches)	Sample No.	Formation	Description
			LANDSLIDE DEBRIS	LANDSLIDE DEBRIS: Upper 40' not continuously logged
40			LANDSLIDE DEBRIS	Yellow-brown SILTY SAND with many SILICEOUS SHALE chips (generally yellow-brown, white and rust) Some beige BENTONITE
45–50	2.5	1	LANDSLIDE DEBRIS	Dark brown to carmel SILICEOUS SHALE and SANDSTONE angular clasts (>2") in 'sulphur' yellow SILTY SAND matrix Several angular gray BENTONITE inclusions
55				
60	2.5	2	ALTIMIRA MEMBER/ MONTEREY FORMATION	DISTURBED BEDROCK: Mottled light gray, light gray-green and rust fine SANDY SILTSTONE. FeO stains along joints. Scattered seams of gypsum (Planar orientation of single gypsum seam ∿ 15^{o} from horizontal).
65	2.5	3		
70	2.5	4	ALTIMIRA MEMBER/ MONTEREY FORMATION	Light gray CLAYEY SILTSTONE with interbedded yellow gritty TUFF and light green BENTONITE. Scattered gypsum seams. Generally coherent mass.
75	2.5	5	ALTIMIRA MEMBER/ MONTEREY FORMATION	Yellow-white blocky BENTONITE. Moderately indurated. Upper 2" of sample is light gray CLAYEY SILTSTONE with dark brown (rust) and gray SILICEOUS SHALE fragments with gypsum seams and iron staining.
80	2.5	6	ALTIMIRA MEMBER/ MONTEREY FORMATION	Light gray-green, rust & chocolate SANDSTONE. Some CLAY and SILT. Highly indurated mottled with minor gypsum crystals.
85	2.5	7	ALTIMIRA MEMBER/ MONTEREY FORMATION	Light purple-gray CLAYEY SILTSTONE with interbedded carmel and white SILTSTONES and BENTONITIC CLAYSTONES. Well-indurated well-defined bedding. Some SILICEOUS SANDSTONES, slightly fractured.

continued

Column headings: STRIKE / DIP | RELATIVE COMPACTION | DRY DENSITY (LBS/CU FT) | MOISTURE (%) | BLOWS/FOOT 350 ft/lbs. | SAMPLE SIZE (INCHES) | SAMPLE Nº | DEPTH IN FEET | MATERIAL SYMBOL

THIS BORING LOG SUMMARY APPLIES ONLY AT THE TIME AND LOCATION INDICATED. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND TIMES.

LOGGED BY PJA | DATE 2/21-22/78

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 5" Rotary | ELEVATION 424' | BORING

Sample Size (inches)	Sample №	Depth in Feet	Description
			DISTURBED BEDROCK: (continued)
		90	Medium orange gritty TUFF ~ 1/8" clasts of white BENTONITE in sand-like orange matrix. Massive. Minor gypsum.
2.5	8		Carmel, white and scarlet interbedded BENTONITE. Fractures easily along color contacts. Gypsum seams, red CLAY
		95	
2.5	9		... probable slide surface, shears
			UNDISTURBED BEDROCK: White BENTONITE with cream, brick-red and black stringers. Blocky with planar but undulatory thin stringers oriented ~ vertically. Minor gypsum seams.
		100	
2.5	10		
		105	Orange gritty BENTONITE ~ 1/16" clasts of white BENTONITE in SAND-like orange matrix. Some red and white interbeds of BENTONITE. Minor gypsum.
2.5	11		
		110	Salmon pink and orange BENTONITE. Somewhat gritty. Scattered 1/2" gypsum seams.
2.5	12		
		115	Mottled white brick-red and orange-yellow BENTONITE with some 1/2" gypsum seams. Orange gritty TUFF at tip of sample.
2.5	13		
		120	Same with gray SILTY CLAYSTONE at tip.
2.5	14		
			UNDISTURBED BEDROCK: Blue-gray SILTY CLAYSTONE with minor white CLAYSTONE speckles. Some intercalated orange gritty TUFF and sea green and white CLAYSTONE. Massive, solid not blocky.
		125	
2.5	15		
		130	Dark blue-gray SILTY CLAYSTONE with white ~ 1/8" CLAYSTONE clasts.
2.5	16		
		135	

ALTIMIRA MEMBER/MONTEREY FORMATION

NOTES:

1) No caving
2) No groundwater
3) Capped hole 2/23/78

STRIKE / DIP | RELATIVE COMPACTION | DRY DENSITY (LBS/CU.FT) | MOISTURE (%) | BLOWS/FOOT 350 ft/lbs. | SAMPLE SIZE (INCHES) | SAMPLE № | DEPTH IN FEET | MATERIAL SYMBOL

THIS BORING LOG SUMMARY APPLIES ONLY AT THE TIME AND LOCATION INDICATED. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND TIMES.

LOGGED BY PJA | DATE 2/22-23/78

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 5" Rotary	ELEVATION 395'	BORING 203

Depth in feet	Description
0	LANDSLIDE DEBRIS:
	Black CHERT and SILICEOUS SHALE
5	
10	. . . brown SILICEOUS SANDSTONE well indurated
15	. . . becomes less indurated brick-red CLAYEY SANDSTONE
20	. . . orange CLAYEY SANDSTONE
	. . . red SANDY CLAYSTONE
25	Yellow-brown SILICEOUS SHALE and light gray SILICEOUS SHALE
30	Light gray CLAYSTONE
	. . . black CHERT
	Yellow-brown SANDSTONE
35	
40	Yellow-brown CLAYEY SANDSTONE with angular (>2") SILICEOUS SANDSTONE. Iron stains along fractures and around inclusions.
45	
	. . . black CHERT chips
50	
	continued

←←← LANDSLIDE DEBRIS →→→ (0–28 ft)

STRIKE / DIP	RELATIVE COMPACTION	DRY DENSITY (LBS/CU.FT)	MOISTURE (%)	BLOWS/FOOT 350 ft/6s	SAMPLE SIZE (INCHES)	SAMPLE Nº	DEPTH IN FEET	MATERIAL SYMBOL

THIS BORING LOG SUMMARY APPLIES ONLY AT THE TIME AND LOCATION INDICATED. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND TIMES.

LOGGED BY PJA DATE 2/23/78

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE Rotary | ELEVATION 395' | BORING 203

Strike / Dip	Relative Compaction	Dry Density (lbs/cu ft)	Moisture (%)	Blows/Foot 350 ft. lbs.	Sample Size (inches)	Sample Nº	Depth in Feet	Material Symbol		Description
										SLIDE DEBRIS (cont): Brown yellow-brown and black interbedded SILICEOUS SANDSTONE and CHERT
							55			. . . some orange CLAYSTONE
							60			
					2.5	2				Orange and yellow-brown BRECCIA SILICEOUS chips in CLAYEY SAND.
							65			
							70			. . . black CHERT
					2.5	NSR	75		LANDSLIDE DEBRIS	
							80			. . . scattered beds of yellow SANDSTONE and beige CLAYSTONE
							85			
					2.5	NSR	90			Yellow beige to light orange interbedded SILICEOUS SANDSTONE and gray-pink SANDSTONE. Moderately fractured.
							95			Orange-brown medium to coarse grained SANDSTONE with limey streaks and gypsum filled fractures.
					2.5	NSR	100			
										continued

THIS BORING LOG SUMMARY APPLIES ONLY AT THE TIME AND LOCATION INDICATED. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND TIMES.

LOGGED BY PJA | DATE 2/24/78 and 3/21/78

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 5" Rotary	ELEVATION 395'	BORING 203

Depth in feet	Sample size (inches)	Material	Description
			. . . probable slide surface
105		MONTEREY FORMATION	UNDISTURBED BEDROCK: Black and dark gray interbedded SILTSTONE, SANDSTONE and CLAYSTONE Steeply dipping (~60°)
110	2.5 NSR		
115			NOTES: 1) No caving 2) No groundwater encountered 3) Capped 3/21/78

STRIKE / DIP	RELATIVE COMPACTION	DRY DENSITY (LBS/CU FT)	MOISTURE (%)	BLOWS/FOOT 350 ft. lbs.	SAMPLE SIZE (INCHES)	SAMPLE Nº	DEPTH IN FEET	MATERIAL SYMBOL

THIS BORING LOG SUMMARY APPLIES ONLY AT THE TIME AND LOCATION INDICATED. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND TIMES.

LOGGED BY PJA | DATE 3/21/78

SLIDE FF-FF'
STABILITY ANALYSIS : ORDINARY SLICE METHOD

N = 16 k = .00 R = 1000

	w	h	b	a	ø	c	hw	Fr	Fd
1	120	12.0	24.0	50.0	6.0	150	0.0	7935	26474
2	120	29.5	31.0	38.0	6.0	150	0.0	14989	67562
3	120	39.0	51.0	24.0	6.0	150	0.0	31291	97079
4	120	50.5	40.0	17.0	6.0	150	0.0	30638	70870
5	120	52.5	62.0	8.0	6.0	150	0.0	50045	54361
6	120	54.0	202.0	8.0	6.0	150	0.0	166836	182172
7	120	58.0	147.0	8.0	6.0	150	0.0	128754	142390
8	120	58.0	76.0	8.0	6.0	150	0.0	66566	73617
9	120	67.0	82.0	8.0	6.0	150	0.0	81039	91754
10	120	77.0	75.0	8.0	6.0	150	0.0	83488	96446
11	120	85.0	82.0	7.0	6.0	150	0.0	99646	101931
12	120	105.0	480.0	5.0	6.0	150	0.0	705526	527117
13	120	108.0	330.0	3.0	6.0	150	0.0	498461	223830
14	120	96.0	98.0	3.0	6.0	150	0.0	133215	59085
15	120	90.0	57.0	3.0	6.0	150	0.0	73175	32218
16	120	74.0	294.0	3.0	6.0	150	0.0	318182	136634
							Total	2489786	1983547

F.S. = 1.25 for existing conditions, no stabilization measures.

SLIDE FF-FF'
STABILITY ANALYSIS : ORDINARY SLICE METHOD

N = 15 k = .00 R = 1000'

	w	h	b	a	ø	c	hw	Fr	Fd
1	120	12.0	24.0	50.0	6.0	150	0.0	7935	26474
2	120	29.5	31.0	38.0	6.0	150	0.0	14989	67562
3	120	39.0	51.0	24.0	6.0	150	0.0	31291	97079
4	120	50.5	40.0	17.0	6.0	150	0.0	30638	70870
5	120	52.5	62.0	8.0	6.0	150	0.0	50045	54361
6	120	54.0	202.0	8.0	6.0	150	0.0	166836	182172
7	120	58.0	147.0	8.0	6.0	150	0.0	128754	142390
8	120	58.0	76.0	8.0	6.0	150	0.0	66566	73617
9	120	67.0	82.0	8.0	6.0	150	0.0	81039	91754
10	120	77.0	75.0	8.0	6.0	150	0.0	83488	96446
11	120	85.0	82.0	7.0	6.0	150	0.0	99646	101931
12	120	105.0	480.0	5.0	6.0	150	0.0	705526	527117
13	120	108.0	330.0	3.0	6.0	150	0.0	498461	223830
14	120	96.0	98.0	3.0	25.0	400	0.0	564974	59085
15	120	90.0	57.0	3.0	25.0	400	0.0	309496	32218
16	120	76.0	296.0	3.0	6.0	150	0.0	327803	141281
							Total	3167487	1988193

F.S. = 1.59 for lower untreated compacted fill shear key

SLIDE FF-FF'

STABILITY ANALYSIS : ORDINARY SLICE METHOD

2

N = 15 k = .00 R = 1000

	w	h	b	a	ø	c	hw	Fr	Fd
1	120	12.0	24.0	50.0	6.0	150	0.0	7935	26474
2	120	29.5	31.0	38.0	6.0	150	0.0	14989	67562
3	120	39.0	51.0	24.0	6.0	150	0.0	31291	97079
4	120	50.5	40.0	17.0	6.0	150	0.0	30638	70870
5	120	52.5	62.0	8.0	6.0	150	0.0	50045	54361
6	120	54.0	202.0	8.0	6.0	150	0.0	166836	182172
7	120	58.0	147.0	8.0	6.0	150	0.0	128754	142390
8	120	58.0	76.0	8.0	6.0	150	0.0	66566	73617
9	120	67.0	82.0	8.0	6.0	150	0.0	81039	91754
10	120	77.0	75.0	8.0	6.0	150	0.0	83488	96446
11	120	85.0	82.0	7.0	6.0	150	0.0	99646	101931
12	120	105.0	480.0	5.0	6.0	150	0.0	705526	527117
13	120	108.0	330.0	3.0	6.0	150	0.0	498461	223830
14	120	96.0	98.0	3.0	6.0	150	0.0	133215	59085
15	120	90.0	57.0	3.0	45.0	2000	0.0	728912	32218
16	120	76.00	296.0	3.0	6.0	150	0.0	327803	141281
							Total	3155144	1988193

F.S. = 1.59 for lower treated soil cement shear key.

STABILITY ANALYSIS : ORDINARY SLICE METHOD

3

N = 10 k = .00 R = 1000

	w	h	b	a	ø	c	hw	Fr	Fd
1	120	12.0	24.0	50.0	6.0	150	0.0	7935	26474
2	120	29.5	31.0	38.0	6.0	150	0.0	14989	67562
3	120	39.0	51.0	24.0	6.0	150	0.0	31291	97079
4	120	50.5	40.0	17.0	6.0	150	0.0	30638	70870
5	120	52.5	62.0	8.0	6.0	150	0.0	50045	54361
6	120	54.0	202.0	8.0	6.0	150	0.0	166836	182172
7	120	58.0	147.0	8.0	6.0	150	0.0	128754	142390
8	120	58.0	76.0	8.0	6.0	150	0.0	66566	73617
9	120	67.0	82.0	8.0	6.0	150	0.0	81039	91754
10	120	77.0	75.0	8.0	45.0	2000	0.0	837729	96446
11-16	(see page C-4)							1828205	1080817
							Total	3244027	1983546

F.S. = 1.64 for middle treated soil cement shear key

SLIDE FF-FF'

STABILITY ANALYSIS : ORDINARY SLICE METHOD

4

N = 8 k = .00 R = 1000

	w	h	b	a	ø	c	hw	Fr	Fd
1	120	12.0	24.0	50.0	6.0	150	0.0	7935	26474
2	120	29.5	31.0	38.0	6.0	150	0.0	14989	67562
3	120	39.0	51.0	24.0	6.0	150	0.0	31291	97079
4	120	50.5	40.0	17.0	6.0	150	0.0	30638	70870
5	120	52.5	62.0	8.0	6.0	150	0.0	50045	54361
6	120	54.0	202.0	8.0	6.0	150	0.0	166836	182172
7	120	58.0	147.0	8.0	25.0	400	0.0	531823	142390
8	120	58.0	76.0	8.0	25.0	400	0.0	274956	73617
9-16	(see page C-1)							1992732	1269015
						Total		3101245	1983543

F.S. = 1.56 for untreated compacted fill
shear key in upper section

STABILITY ANALYSIS : ORDINARY SLICE METHOD

5

N = 8 k = .00 R = 1000

	w	h	b	a	ø	c	hw	Fr	Fd
1	120	12.0	24.0	50.0	6.0	150	0.0	7935	26474
2	120	29.5	31.0	38.0	6.0	150	0.0	14989	67562
3	120	39.0	51.0	24.0	6.0	150	0.0	31291	97079
4	120	50.5	40.0	17.0	6.0	150	0.0	30638	70870
5	120	52.0	62.0	8.0	6.0	150	0.0	49658	53843
6	120	54.0	202.0	8.0	6.0	150	0.0	166836	182172
7	120	58.0	147.0	8.0	6.0	150	0.0	128754	142390
8	120	58.0	76.0	8.0	45.0	2000	0.0	677305	73617
9-16	(see page C-1)							1992732	1269015
						Total		3100138	1983026

F.S. = 1.56 for upper treated soil cement
shear key

SLIDE FF-FF'
STABILITY ANALYSIS ; ORDINARY SLICE METHOD

N = 6 k = .00 R = 1000

	w	h	b	a	ø	c	hw	Fr	Fd
11	120	85.0	82.0	7.0	6.0	150	0.0	99646	101931
12	120	105.0	480.0	5.0	6.0	150	0.0	705526	527117
13	120	108.0	330.0	3.0	6.0	150	0.0	498461	223830
14	120	96.0	98.0	3.0	6.0	150	0.0	133215	59085
15	120	90.0	57.0	3.0	6.0	150	0.0	73175	32218
16	120	74.0	294.0	3.0	6.0	150	0.0	318182	136634
							Total	1828205	1080817

F.S. = 1.69 for portion of slide below middle treated soil cement shear key

SLIDE FF-FF'
STABILITY ANALYSIS : ORDINARY SLICE METHOD

N = 8 k = .00 R = 1000

	w	h	b	a	ø	c	hw	Fr	Fd
9	120	67.0	82.0	8.0	6.0	150	0.0	81039	91754
10	120	77.0	75.0	8.0	6.0	150	0.0	83488	96446
11	120	85.0	82.0	7.0	6.0	150	0.0	99646	101931
12	120	105.0	480.0	5.0	6.0	150	0.0	705526	527117
13	120	108.0	330.0	3.0	6.0	150	0.0	498461	223830
14	120	96.0	98.0	3.0	6.0	150	0.0	133215	59085
15	120	90.0	57.0	3.0	6.0	150	0.0	73175	32218
16	120	74.0	294.0	3.0	6.0	150	0.0	318182	136634
							Total	1992732	1269018

F.S. = 1.57 for portion of slide below upper treated soil cement shear key and/or untreated compacted fill shear key

SLIDE C-C'
STABILITY ANALYSIS : ORDINARY SLICE METHOD

N = 9 k = .00 R = 1000

	w	h	b	a	ϕ	c	hw	Fr	Fd
1	120	20.0	16.0	70.5	6.0	150	0.0	8537	36197
2	120	52.0	44.0	39.0	6.0	150	0.0	30919	172786
3	120	63.0	244.0	6.5	6.0	150	0.0	229469	208819
4	120	64.0	98.0	5.0	6.0	150	0.0	93560	65596
5	120	56.0	100.0	5.0	6.0	150	0.0	85418	58568
6	120	49.0	25.0	5.0	6.0	150	0.0	19155	12811
7	120	35.0	160.0	5.0	6.0	150	0.0	94452	58568
8	120	15.0	100.0	5.0	6.0	150	0.0	33904	15688
9	120	8.0	12.0	-24.5	6.0	150	0.0	3079	-4777
							Total	598493	624259

F.S. = .95 for existing conditions, no stabilization measures.

SLIDE C-C'
STABILITY ANALYSIS : ORDINARY SLICE METHOD

6

N = 9 k = .00 R = 1000

	w	h	b	a	ϕ	c	hw	Fr	Fd
1	120	20.0	16.0	70.5	6.0	150	0.0	8537	36197
2	120	52.0	44.0	39.0	6.0	150	0.0	30919	172786
3	120	63.0	244.0	6.5	6.0	150	0.0	229469	208819
4	120	64.0	98.0	5.0	6.0	150	0.0	93560	65596
5	120	56.0	100.0	5.0	6.0	150	0.0	85418	58568
6	120	49.0	25.0	5.0	6.0	150	0.0	19155	12811
7	120	35.0	160.0	5.0	25.0	400	0.0	376419	58568
8	120	15.0	100.0	5.0	25.0	400	0.0	123768	15688
9	120	8.0	12.0	-45.0	25.0	400	0.0	10586	-8145
							Total	974822	620891

F.S. = 1.57 for untreated compacted fill buttress

SLIDE C-C'
STABILITY ANALYSIS : ORDINARY SLICE METHOD

△7

N = 9 k = .00 R = 1000

	w	h	b	a	ø	c	hw	Fr	Fd
1	120	20.0	16.0	70.5	6.0	150	0.0	8537	36197
2	120	52.0	44.0	39.0	6.0	150	0.0	30919	172786
3	120	63.0	244.0	6.5	6.0	150	0.0	229469	208819
4	120	64.0	98.0	5.0	6.0	150	0.0	93560	65596
5	120	56.0	100.0	5.0	6.0	150	0.0	85418	58568
6	120	49.0	25.0	5.0	6.0	150	0.0	19155	12811
7	120	35.0	160.0	5.0	6.0	150	0.0	94452	58568
8	120	15.0	100.0	5.0	45.0	2000	0.0	380078	15688
9	120	8.0	12.0	-45.0	40.0	2000	0.0	42086	-8145
							Total	983674	620891

F.S. = 1.58 for treated soil cement buttress

SLIDE C-C'
STABILITY ANALYSIS : ORDINARY SLICE METHOD

△8

N = 10 k = .00 R = 1000

	w	h	b	a	ø	c	hw	Fr	Fd
1	120	20.0	16.0	70.5	6.0	150	0.0	8537	36197
2	120	52.0	44.0	39.0	6.0	150	0.0	30919	172786
3	120	63.0	244.0	6.5	6.0	150	0.0	229469	208819
4	120	64.0	98.0	5.0	6.0	150	0.0	93560	65596
5	120	56.0	100.0	5.0	6.0	150	0.0	85418	58568
6'	120	43.0	94.0	5.0	6.0	150	0.0	64939	42274
7'	120	42.0	106.0	5.0	6.0	150	0.0	71897	46562
8'	120	43.0	12.0	5.0	6.0	150	0.0	8290	5396
9'	120	25.0	73.0	5.0	45.0	2000	0.0	364723	19087
10'	120	5.0	12.0	-45.0	45.0	2000	0.0	39032	-5091
							Total	996784	650197

F.S. = 1.53 for treated soil cement buttress
with 2:1 overlying fill