#87

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4530 EAST LA PALMA AVENUE • ANAHEIM, CALIFORNIA 92807 • (714) 524-3350

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LANDSLIDE INVESTIGATION

Portuguese Bend Club
Rancho Palos Verdes, California

Client
Palos Verdes Properties

January 10, 1977

Job No. 2376-80

LANDSLIDE INVESTIGATION

In conjunction with a preliminary geologic and soils investigation of the adjoining 27 acres to the east, a preliminary study was made of the ancient landslide within the area of the Portuguese Bend Club. This report presents the results of the study, the purpose of which was to provide general information regarding the geologic conditions and geometric configuration of the slide and to discuss possible methods to increase the slide's stability.

Scope

The geology was originally mapped on an undated topographic map supplied by Palos Verdes Properties, with a scale of one inch equals 200 feet. Subsequently, the geology was transferred to a 200-scale topographic map dated March 1976, supplied by the City of Rancho Palos Verdes. Conclusions and recommendations contained in this report are based on the attached geologic map printed on the updated topographic map.

Basic information concerning bedrock and surficial deposits for this report was obtained from previous geologic mapping in the area by Karl Vonder Linden and observation and study by Moore & Taber of natural exposures and several series of stereographic aerial photographs dated 1927 (1"=1500'), 1945 (1"=600'), 1956 (1"=1200'), 1965 (1"=2000').

Field Investigation

In addition to surface mapping and analysis of aerial photographs, two, 24-inch diameter bucket auger borings were drilled to obtain subsurface data. The borings were entered, inspected and logged by an engineering geologist and subsequently backfilled. The boring logs appear as pages A-1 and A-2.

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 in this report. Reference was also made to "An Analysis of the Portuguese Bend Landslide, Palos Verdes Hills, California" by Karl Vonder Linden, July 1972. Data obtained from his work has been utilized with the permission of Dr. Vonder Linden.

Both bulk and undisturbed soil samples were obtained from the borings for laboratory testing. To obtain the undisturbed samples, a 2.5-inch I.D. thin wall sampler was driven with a 1500 pound weight dropping approximately 12 inches. Sample size, depth, penetration rate, and other details relating to the boring operations are shown on the Test Boring Logs, pages A-1 through A-2 of the appendix. Boring locations are shown on the attached plan.

Topography and Site Conditions

The subject slide, hereafter referred to as the Beach Club landslide, is situated about 600 feet east of the currently active Portuguese Bend landslide. Its scarp forms an arcuate cliff just north of Palos Verdes Drive South. The slide mass extends about 900 feet southward to the beach. The width of the slide ranges from 500 feet across its head to 750 feet at its toe. The ground surface slopes seaward from an elevation of 200 feet above sea level to the present tide line, with gradients from 5:1 to as steep as 1-1/4:1.

Approximately 40 small residential cottages occupy the central portion of the slide. These homes were essentially built to conform to the original topography but some fill (compacted?) was placed to make grade for some streets, driveways and pads. Sewage disposal is by individual seepage pits with effluent discharged into the subsurface. Cactus and grasses cover the remaining open areas north of the access road and on the natural slopes below the cottages.

GEOLOGY

Stratigraphy

Bedrock - The entire area is underlain by stratified sedimentary rocks that constitute a part of the Altamira member of the Monterey formation, a thick bedrock unit of Miocene age that is widely distributed in the Palos Verdes Hills. The local sequence of strata consists mainly of siltstones, sandstones, and siliceous shales. Thin, irregular bodies of highly altered volcanic ash (tuffs and claystones) are present locally.

Within the slide, siltstones with interbedded clays predominate. The actual plane of slippage is within the clay beds.

Terrace Deposits - Displaced Terrace deposits (Qt) cover most of the landslide and generally range in thickness from 10 to 15 feet. They are dark colored and fine grained and consist chiefly of sandy and silty material with numerous scattered rock fragments.

Topsoil - Dark colored topsoils of adobe-like appearance form a cover about two to three feet thick over most of the area. These soils are generally loose-textured and uncompacted, and moderately to highly expansive.

Structure

The bedrock in the area of the subject slide dips prevailingly to the south and southwest at low to moderate angles, averaging about 15 degrees. Within the slide area, the undisturbed bedrock below the slide surface dips about 8 to 12 degrees to the southwest. This seaward dipping structure appears to have been the controlling factor in sliding.

A mass of Altamira shale, capped by Terrace deposits, slid along a section of adversely inclined, unsupported bentonitic clay probably in response to undercutting by past wave action. The siltstone and shale sections of the Monterey are relatively undisturbed, whereas the clay has been sheared and squeezed.

These relationships are illustrated in greater detail on the attached geologic map and cross-section C-C'. More complete stratigraphic information is contained in the boring logs.

Stability Characteristics

Analysis - Since it is evident that the Beach Club landslide is controlled by bedding plane structure and that the shear surface is reasonably well-located in two dimensions, a stability analysis along this surface can be made.

Using commonly accepted shear strength values of $\phi=10^{o}$ and C=150 psf (ϕ is the angle of internal friction, C is the cohesion of the material) and the stability analysis method of ordinary slices, a factor of safety of 1.09 was calculated. A factor of safety of 1.00 indicates that an equilibrium exists between the forces promoting sliding and the forces resisting sliding. A 1.5 factor of safety is generally considered adequate and indicative of a stable condition. A factor less than 1.00 indicates that the mass is in an unstable condition and subject to sliding.

The shear strength of the materials along the slide plane is the most critical factor in determining the stability of the Beach Club slide. These strengths are dependent upon the chemical and physical composition and character of the materials, the over-burden load and the degree of saturation with water.

The slide sheared along clayey beds called bentonitic tuffs. These clays are the weakest materials present in the slide mass and it is most likely that renewed sliding would occur in these clays.

Laboratory direct shear tests on saturated bentonitic tuff from a sample of Altamira shale obtained from an off-site location but typical of the clays found in the slide, indicate that residual shear values as high as $\phi=11^{o}$ and C=400 psf are possible in this material. Using these strengths, a factor of safety of 1.58 was calculated.

Work by others (Dames & Moore, 1957; and others as reported by Poppler, 1967) in the adjacent active Portuguese Bend landslide, indicate varying shear values averaging about 8^{o} and 300 psf. With these values, a factor of safety of 1.16 was determined.

Laboratory tests indicate that the materials within the slide mass are approximately 65% saturated. Tests by Stone Geological Services on bentonite in the nearby South Shores slide (1-1/2 miles east of the subject site) determined the dependency of shear strengths on percent saturation. Bentonite which is 65% saturated would have strength of $\phi=6^{o}$, C=150 psf. In the Beach Club slide, these values calculate to a factor of safety of 0.74.

Pseudostatic analyses, incorporating a horizontal driving force of 0.15g to simulate potential seismic forces were also made. Under these circumstances a factor of safety of 1.1 is considered adequately stable.

The following table summarizes these findings:

ϕ	C	Factor of Safety: Static	Factor of Safety: Pseudostatic
6^{o}	150 psf	0.74	
8^{o}	300 psf	1.16	
10^{o}	150 psf	1.09	0.62
11^{o}	400 psf	1.58	0.90

These results show the wide range possible in calculating factors of safety depending on the strength values used. Obviously, the lowest value (SF=0.74) is not representative as it would indicate present slide movement.

Interpretation - Due to the lack of reliable, representative shear strengths for the actual sheared slide surface, an evaluation of the above possibilities in light of the surrounding geologic conditions is necessary.

Since the slide at present, is obviously in a state of equilibrium or stable configuration, the strengths resulting in the 0.74 factor cannot be considered representative, as they would indicate the slide is presently moving.

The slide, then, may be adequately stable at 1.58 or nominally stable at about 1.1. The following factors affect the evaluation of that stability:

1) The slide material is presently 65% saturated, with no controls upon the infiltration of water into the subsurface soils. This could lead to greater saturation and consequently lower shear strengths.

2) Removal of material at the unprotected toe of the slide could occur due to wave action. This could reduce support of the slide and initiate renewed movement.

3) The probability of seismic activity in the area is high. This activity could be of a magnitude sufficiently large to affect the slide.

4) Man's activities, as recorded in the aerial photographs, have had generally adverse effects on the stability characteristics, through increasing the load at the head of the slide and the addition of subsurface water.

These factors imply that the more conservative figure of about 1.1 is probably most applicable to the slide's present stability condition.

CONCLUSIONS AND RECOMMENDATIONS

The landslide is presently stable insofar as it is not moving. However, preliminary calculations indicate that it cannot be demonstrated to have an adequate factor of safety (1.5). If the slide area is used for development, actions should be taken to increase its stability. The following are some possible remedial measures and a brief evaluation of each:

1) Buttress - Materials at the toe of the slide could be removed and replaced with those of a higher strength. Preliminary design analyses indicate that a buttress would have to extend below the slide surface, to an elevation of approximately 35 feet above sea level, about 40 feet below the existing topography. It would include an area about 100 feet wide extending across the toe of the slide (about 800 feet). This would require the removal of lots 121 and 122.

   The excavation for the buttress, through the removal of material at the toe of the slide could initiate movement of the slide. Therefore, the excavation and replacement should be done in sections to minimize this possibility. The excavation would also endanger the existing houses and should not be performed without their removal or abandonment.

2) Shear Key - Removal and replacement of materials in the central portion of the slide would require grading where houses are presently located.

3) Shear Pins - These would extend about 20 to 25 feet below the slide surface. Generally, the shear pins are three feet in diameter

and placed on 6 to 7 feet centers in two staggered rows. These specifications are based on generalized standard procedures and represent only rough approximations of what may be needed for the subject slide. Further investigation, testing, and design would be necessary to give recommendations appropriate to the Beach Club landslide.

The large number of shear pins which would be required, the high cost of their emplacement and the limitations placed on the maneuverability of the drilling and pouring equipment because of the current location of the houses would contribute to a high cost for this type of stabilization.

4) Chemical Stabilization - Chemicals could be injected into the slide mass to increase the strength of the in-situ soils. The experimental nature and unpredictable results of this treatment should be considered.

Further Investigation

Considering the intended scope of the study and the limited field investigation, a good analysis of the slide along a cross-section has been possible. To better evaluate the condition and stabilization of the mass, necessitates more information over a greater areal extent thus improving the three-dimensional geometric understanding of the slide. This could be accomplished with a series of 3 or 4 more borings to investigate the geologic and soils conditions present.

General Conditions

This report is based on the project as described and the geotechnical data obtained from the field tests performed at the locations indicated on the plan. The conclusions and recommendations do not reflect any variations which may occur between the field tests. This report has not been prepared for use by parties or projects other than those named or described above. It may not contain sufficient information for other parties or other purposes.

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.

MOORE & TABER

Phyllis Anwyl

Phyllis Anwyl
PA/JTE:pa

Jack Eagen

Reviewed by Jack T. Eagen
Certified Engineering Geologist 231

Attachments: A-1 through A-4
Section C-C' and Geologic Map

(3) Copies to Client
Attn: Mr. Mike Kochan

REFERENCES

Dames and Moore, 1957, "Report of Soil Sampling and Laboratory Tests, Portuguese Bend Area, Palos Verdes, California", Unpublished Report, 10 p.

Poppler, Dave, July 31, 1967, "Preliminary Geologic Investigation Palos Verdes Drive East - 25th Street Road Alignments", Unpublished Report 33 p.

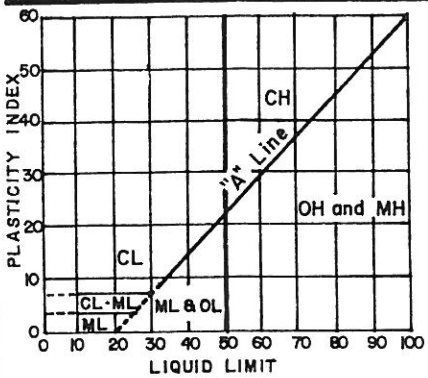
Stone Geological Services, 1967, "Geologic and Soils Report, South Shores Mobile Home Park", Unpublished Report, 36 p.

Vonder Linden, Karl, July 1972, "An Analysis of the Portuguese Bend Landslide, Palos Verdes, California", Unpublished Report, 260 p.

Woodring, Bramlette and Kew, 1946, "Geology and Paleontology of Palos Verdes Hills," U.S.G.S. Professional Paper 207.

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 № 4 sieve.				Gravels - more than 50% of coarse fraction is larger than № 4 sieve.			
Fine grained soils (More than 50% is smaller than № 200 sieve)							Coarse grained soils (More than 50% is larger than № 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

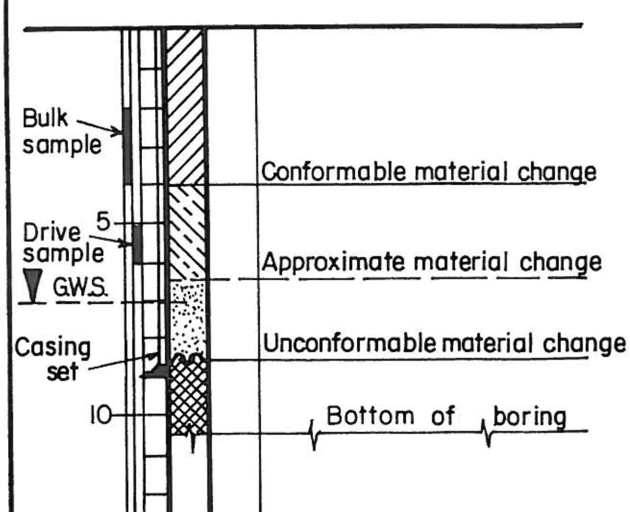
- Gravel
- Sand
- Silt
- Clay
- Sandy clay or clayey sand
- Sandy silt or silty sand
- Silty clay or clayey silt
- Peat or organic matter
- Fill material
- Shale
- Sandstone
- Limestone
- Metamorphic rock
- Igneous rock

CONSISTENCY CLASSIFICATION FOR SOILS

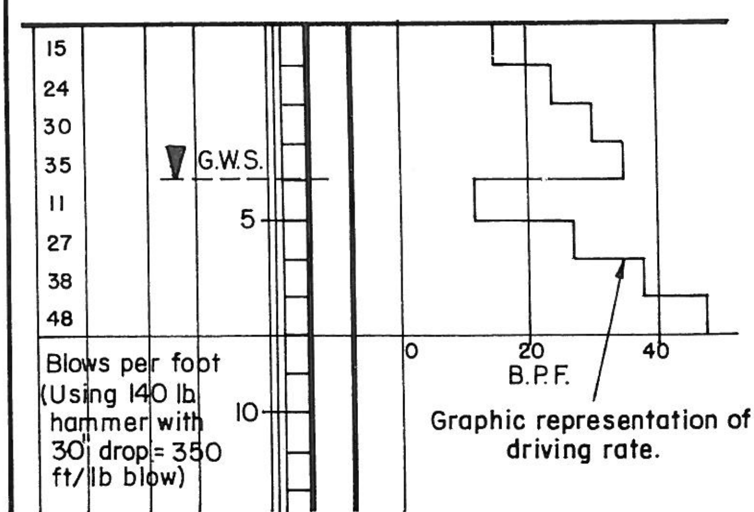
According to the Standard Penetration Test

№ 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



TEST BORING LOG

TYPE	ELEVATION	BORING
24" Bucket Auger	122	6

STRIKE / DIP	GEOLOGIC UNIT	DRY DENSITY (LBS/CU FT)	MOISTURE (%)	BLOWS/FOOT 1500 ft./lbs.	SAMPLE SIZE (INCHES)	SAMPLE Nº	DEPTH IN FEET
	Landslide Mass				Bag	1	
	Landslide Mass	83	18.2	2	2.5	2	5
	Landslide Mass	81	23.5	1	2.5	3	10
65W / 11S	Landslide Mass	97	23.6	16	2.5	4	15
	Landslide Mass	106	14.2	8	2.5	5	20
60W / 8S							25
35W / 12S	Undisturbed Altamira Shale						
							30
							35

Disturbed Terrace Deposits -

Reddish-brown fine SANDY SILT with SHALE fragments

Gray and orange CLAY with SHALE fragments

Disturbed Altamira Shale -
Gray, orange and brown interbedded SANDSTONE, SILTSTONE & CLAY. Many gypsum seams and minor shear planes.
Damp material

Shear Surface
1/2" GYPSUM layer in BENTONITE seam.
Some water seeping at 24-1/2 to 25-1/2'

Gray-brown and orange interbedded SANDSTONE, SILTSTONE & CLAY with gypsum seams. Material denser than that above 24'

NOTES:

1. No groundwater
2. No caving.

MATERIAL SYMBOL | UNIFIED SOIL CLASS.

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 10/27/76

[Job No. 2376-80 - January 10, 1977]

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 24" Bucket Auger	ELEVATION 197	BORING 7

STRIKE / DIP	GEOLOGIC UNIT	DRY DENSITY (LBS/CU.FT)	MOISTURE (%)	BLOWS/FOOT 1500 ft.lbs	SAMPLE SIZE (INCHES)	SAMPLE Nº	DEPTH IN FEET	MATERIAL SYMBOL	UNIFIED SOIL CLASS.	DESCRIPTION
	Landslide Mass						0–2		ML	SOIL Reddish-brown fine SANDY SILT with SHALE fragments
							2–9			Disturbed Terrace Deposits - Yellow-brown fine SANDY SILT with SHALE fragments
		92	14.8	3	2.5	1	9–45			Orange-brown fine SANDY SILT with SHALE fragments
		93	15.7	3	2.5	2				
							45–50			Gray and brown thickly bedded SILTSTONE with many 2" beds and gypsum seams
							50			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 10/27/76

[Job No. 2376-80 - January 10, 1977]

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 24" Bucket Auger | ELEVATION 197 | BORING 7 Con't

STRIKE / DIP	GEOLOGIC UNIT	DEPTH IN FEET	DESCRIPTION
	Landslide Mass	50	Sheared Material - Yellow, brown and gray mottled CLAY with many SILTSTONE fragments
		55	
55E / 7N 45E / 6N 60E / 9N	Undisturbed Altamira Shale		Altamira Shale - Gray and brown thickly bedded SILTSTONE with many 1/2" siltstone beds and gypsum seams
		60	

NOTES:

1. No groundwater
2. No caving

STRIKE / DIP	GEOLOGIC UNIT	DRY DENSITY (LBS/CU.FT)	MOISTURE (%)	BLOWS/FOOT	SAMPLE SIZE (INCHES)	SAMPLE Nº	DEPTH IN FEET	MATERIAL SYMBOL	UNIFIED SOIL CLASS.

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 10/27/76

[Job No. 2376-80 - January 10, 1977]

MOORE & TABER CONSULTING ENGINEERS AND GEOLOGISTS

TEST BORING LOG

TYPE 24" Bucket Auger | ELEVATION 212 | BORING 8

STRIKE / DIP	GEOLOGIC UNIT	DRY DENSITY (LBS/CU.FT)	MOISTURE (%)	BLOWS / FOOT	SAMPLE SIZE (INCHES)	SAMPLE Nº	DEPTH IN FEET
	Landslide Mass	97	16.0	8	2.5	1	5
	Landslide Mass	73	25.3	6	2.5	2	15
	Landslide Mass	83	21.5	13	2.5	3	30
55W / 19S							46
50W / 12S	Undist. Altamira Shale						50

FILL: Gray SAND with trash debris (concrete, bricks)

Reddish-brown SILTY SAND with SHALE fragments, including scattered boulders

OLD SOIL: Black CLAYEY SAND with SHALE fragments

DISTURBED TERRACE DEPOSITS: Brown SILTY SAND

... Reddish-brown SILTY SAND with SHALE fragments

... Yellow SILTY SAND with many SHALE fragments

... Larger SHALE fragments (6")

BASE OF SLIDE: Thin sheared zone of orange CLAY overlain by 3" layer of sheared CLAY and SAND

ALTAMIRA SHALE: Gray, black and brown thinly-bedded SILTSTONE. Dense hard material (very slow drilling)

MATERIAL SYMBOL | UNIFIED SOIL CLASS.

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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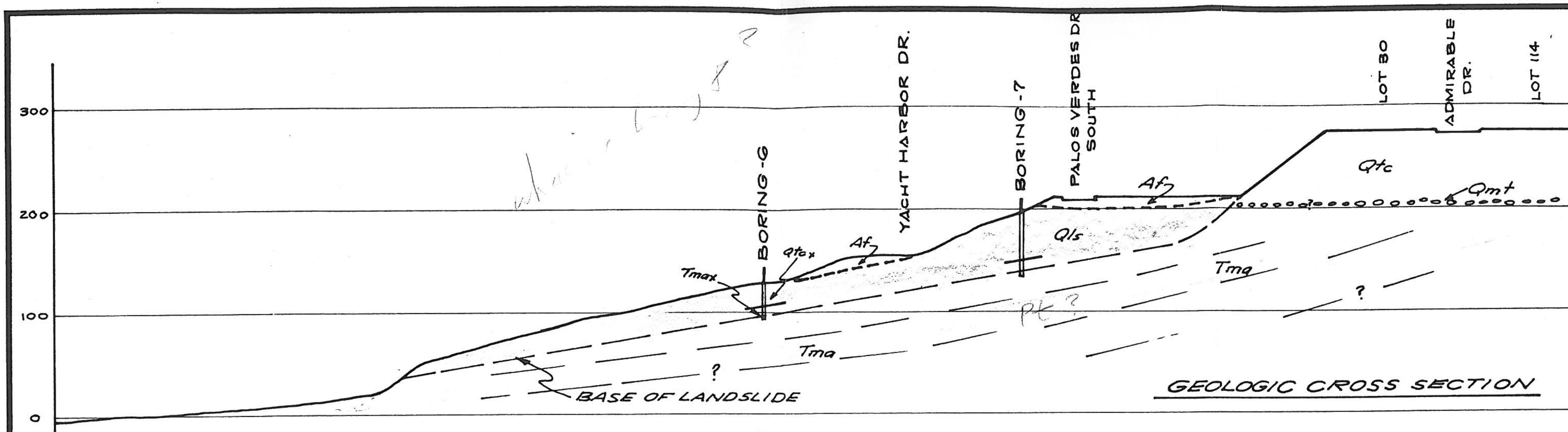
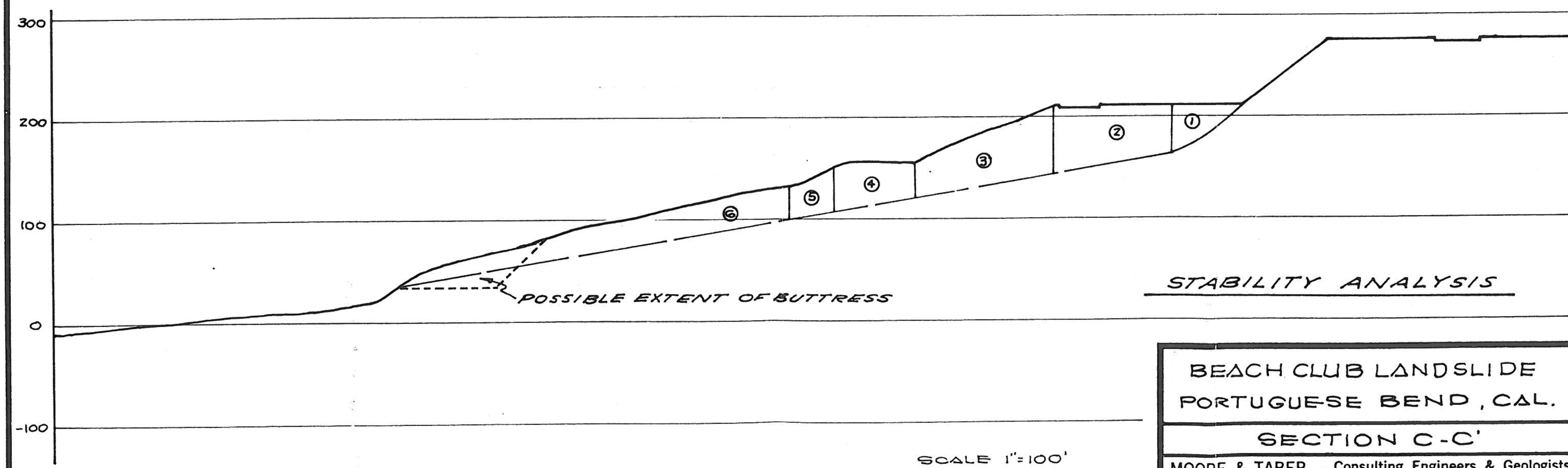


Qls LANDSLIDE DEBRIS { Tmax - DISTURBED ALTAMIRA SHALE; Qtcx - DISTURBED TERRACE DEPOSITS-NON MARINE }



SCALE 1"=100'

BEACH CLUB LANDSLIDE
PORTUGUESE BEND, CAL.

SECTION C-C'

MOORE & TABER — Consulting Engineers & Geologists

FIELD	DRAFT.	APPROVED	DATE	JOB No.
P.J.A.	A.L.S.	GTE	Jan. 11, 1977	2376-80