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FIRST INTERIM REPORT
ON
SOILS INVESTIGATION

Mission-Escondido Line
San Diego County, California

San Diego Gas & Electric Company
Project 13-7275

Project No. 72-2-27A
April 6, 1972

BENTON ENGINEERING, INC.

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APPLIED SOIL MECHANICS — FOUNDATIONS
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FIRST INTERIM REPORT ON SOILS INVESTIGATION

Introduction

This is to present the results of a soils investigation conducted at certain tower sites for the proposed San Diego Gas & Electric Company Transmission Line from the Mission Substation to the Escondido Operating Center in San Diego County, California.

The objectives of the investigation were to determine the existing subsurface conditions and physical properties of the subsoils so that representative soil parameters could be recommended for the design of the proposed tower foundations. Also, the findings and the log of soil and rock conditions are to serve as a guide in determining the best probable type foundation to be used.

In addition to borings drilled for this report, refraction seismograph lines were run at Tower 151 since the test boring could be drilled no closer than 110 feet horizontally and 35 feet lower in elevation than the ground surface at the site. The velocity of the hammer induced shock waves are presented. Vertical supporting capacities for single 8 inch steel "H" piles for Tower 93, with assumptions of full submergence and 3 feet of scour, were prepared. These are shown on Drawing No. 21, entitled "Vertical Supporting Pile Capacity, Tower 93."

In order to accomplish the objectives of this interim report, sixteen borings were drilled at the tower sites as authorized, undisturbed samples were obtained, where possible, and laboratory tests were performed on these samples.

Field Investigation

Sixteen borings were drilled with a truck-mounted rotary bucket-type drill rig. The locations of the borings, relative to the staked centerline of the various tower locations, are

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described individually on Drawing Nos. 1 to 20, inclusive, each entitled "Summary Sheet." The borings were drilled to depths of 3.0 to 31.0 feet below the existing ground surface. A continuous log of the soils encountered in the borings was recorded at the time of drilling and is also shown in detail on the Summary Sheets. Several borings were stopped due to rock.

The soils were visually classified by field identification procedures in accordance with the Unified Soil Classification Chart. A simplified description of this classification system is presented in the attached Appendix A at the end of this report.

Undisturbed samples were obtained at frequent intervals, where possible, in the soils ahead of the drilling. The drop weight used for driving the sampling tube into the soils was the "Kelly" bar of the drill rig which weighs 1670 pounds, and the average drop was 12 inches. The general procedures used in field sampling are described under "Sampling" in Appendix B.

Laboratory Tests

Laboratory tests were performed on all undisturbed samples of the soils in order to determine the dry density and moisture content. The results of these tests are presented on Drawing Nos. 1 to 20, inclusive. Direct shear tests were performed on representative samples in order to determine the angle of internal friction and apparent cohesion of the soils. The samples were allowed to saturate and drain prior to being tested. The general procedures used for the laboratory tests are described briefly in Appendix B. The results of these tests are presented on the "Table of Shear Test Results" which are presented on pages 10 and 11.

DISCUSSION AND RECOMMENDATIONS

1. Soil Strata

Tower 43

A loose gravelly clayey fine to medium sand with approximately 30 percent gravel and cobbles to 6 inches in diameter was underlain at the depth of 1.8 feet by a firm gravelly fine to medium sandy clay with approximately 30 to 40 percent gravel and cobbles to 5 inches in diameter to the depth of 4.0 feet. Below 4.0 feet was a very firm clayey fine to medium sand with occasional gravel to 3 inches in diameter to the depth of 5.5 feet, that then merged to clayey fine to medium sandy gravel to the depth of 26.5 feet. The sandy gravel layer contained 50 to 60 percent gravel and cobbles to 9 inches in diameter between the depths of 5.5 feet and 13.0 feet and 15 to 20 percent gravel and cobbles to 12 inches between the depths of 13.0 feet and 26.5 feet. A very firm slightly silty fine to medium sand was encountered between the depths of 26.5 feet and 30.0 feet. Occasional zones had to be excavated by hand in order to remove large cobbles below a depth of 13.0 feet.

No ground water was encountered in this boring.

Tower 53

A loose gravelly silty fine to medium sand with approximately 40 percent gravel and cobbles to 6 inches in diameter was underlain at the depth of 1.0 foot by a firm gravelly fine to medium sandy clay with approximately 40 percent gravel to 3 inches to the depth of 1.8 feet. Below 1.8 feet was a very firm clayey fine to medium sandy gravel containing 50 to 60 percent gravel and cobbles to 6 inches in diameter to the end of the boring at 28.0 feet.

No ground water was encountered in this boring.

Tower 81

A loose gravelly clayey fine to medium sand with approximately 30 percent rock fragments up to 3 inches in diameter was underlain by a very firm and highly fractured Santiago Peak Metavolcanic rock to the end of the boring at 6.5 feet where no progress in drilling was being achieved. Only identification samples between the depths of 3.0 feet and 3.5 feet were taken from the boring.

No ground water was encountered in this boring.

Tower 82

A loose, clayey fine to medium sand was underlain at 0.8 foot by a firm fine to medium sandy clay to the depth of 1.8 feet. Below the depth of 1.8 feet, a very firm clayey fine to coarse sand derived from decomposed quartz diorite was encountered to the depth of 3.5 feet and then merged to very firm residual soils of slightly clayey fine to coarse sand to the end of boring at 6.5 feet. The rock became less weathered with depth below 3.5 feet.

No ground water was encountered in this boring.

Tower 92

A loose gravelly silty fine to medium sand with approximately 40 to 50 percent gravel and cobbles up to 5 inches in diameter was underlain at the depth of 1.0 foot by a very firm gravelly clayey fine to medium sand with approximately 40 to 50 percent gravel and cobbles to 6 inches to a depth of 6.0 feet. This was underlain by gravelly slightly silty fine to medium sand between 6.0 and 11.0 feet, then by a 6.0 feet thickness of very firm and slightly silty fine to medium sand with slight clay binder and by very firm gravelly slightly silty fine to medium sand with approximately 40 to 50 percent gravel and cobbles to 6 inches in diameter between the depths of 17.0 feet and 20.0 feet. Below a depth of 20.0 feet were alternating layers of very firm slightly clayey fine to medium sand and very firm claystone of 1.5 feet to 5.2 feet in thicknesses to the end of the boring at 31.0 feet.

No ground water was encountered in this boring.

Tower 93

A loose clayey fine to medium sand with scattered gravel to 3 inches in diameter was underlain at a depth of 8.0 feet by a medium firm fine to medium sandy clay to 10.0 feet. Below 10.0 feet were intermittent layers of clayey fine sand and fine sandy clay to a depth of 20.0 feet, with a lens of fine to medium sand between 18.5 and 19.0 feet. A compact fine to medium sandy gravel with 50 to 60 percent gravel and cobbles to 6 inches in diameter was encountered between the depths of 20.0 feet and the bottom of the boring at 22.0 feet. No progress in drilling was made below a depth of 22.0 feet due to large amounts of gravel and cobbles.

Water was encountered below a depth of 12.5 feet, and caving was encountered below a depth of 20.0 feet.

A pile design curve, for 8 inch square Steel "H" piles, was prepared for the foundation support of this tower. The vertical supporting capacity includes a factor of safety of 2 with assumptions of a full submergence and 3 feet of scour below existing ground surface. This design curve for downward loads in kips per single pile is shown on the attached Drawing No. 21, entitled "Vertical Supporting Pile Capacity, Tower 93." It may be assumed that end bearing below the depth of 22.0 feet could take up higher vertical downward supporting capacity if desired. For uplift, one-half of the vertical downward load allowed to 22.0 feet may be used. Battered piles welded for fixity at the pile cap are recommended for higher uplift resistances, if needed.

Tower 103

A loose and gravelly very fine sandy silt with approximately 30 percent rock fragments to 6 inches in diameter was underlain by a very firm and fractured metavolcanic rock to a depth of 3 feet where the boring was terminated because of the interconnected structure of the rock.

No ground water was encountered in this boring.

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Tower 114

A firm silty clay with layers of varying percentages of fractured metavolcanic rock fragments was encountered to 5.0 feet in depth. This merged into a very firm fine sandy clay matrix imbedded in increasingly larger rock fragments to 8.5 feet where the boring was stopped due to more massive fractured rocks. This formation compares favorably with the fractured rock exposed in an abandoned rock quarry approximately 1000 feet east.

No ground water was encountered in this boring.

Tower 125

A 1.5 feet thickness of loose silt with angular rock fragments to 10 inches in size was underlain by a firm silty clay containing occasional rock fragments up to 2 inches in diameter to the depth of 2.0 feet. A very firm silty very fine to fine sand of the residual soils of metavolcanic rock with fragments up to 4 inches was encountered between the depths of 2.0 feet and the bottom of the boring at 8.5 feet. The boring was terminated because of practical refusal due to the tightness of the interconnected rock fragments.

No ground water was encountered in this boring.

Tower 130

A 1.5 feet thickness of loose silty fine sand with rock fragments up to 10 inches was underlain by a firm silty clay containing rock fragments up to 4 inches in diameter to the depth of 2.0 feet. A very firm silty very fine to fine sand of the residual soils of the metavolcanic rock with fragments up to 14 inches was encountered between the depths of 2.0 feet and the bottom of the boring at 6.0 feet. The rock is less weathered with depth. The boring was terminated due to practical refusal on the rock.

No ground water was encountered in this boring.

Tower 131

A loose silty fine to medium sand was underlain at the depth of 1.0 foot by a firm silty clay to the depth of 4.5 feet that was underlain by a very firm silty very fine sand derived from metavolcanic rock to the end of boring at 14.0 feet. With depth, the rock grades to more intact and less weathering. The boring was ended due to practical refusal on the rock.

No ground water was encountered in this boring.

Tower 140

A loose silty fine sand with cobbles and boulders to 16 inches in diameter was underlain at the depth of 2.5 feet by a very firm silty fine sand containing rock fragments that increased in size with depth. The silty fine sand was a residual soil of metavolcanic rocks weathered in place. No undisturbed sample was obtainable from this boring. No progress in drilling was being achieved due to rock below a depth of 7.0 feet and the boring was terminated at that depth.

No ground water was encountered in this boring.

Tower 151

A loose silty fine to medium sand was underlain at the depth of 2.5 feet by a very firm slightly silty fine to medium sand derived from the in-place decomposed metavolcanic rock to the end of boring at 7.5 feet. No progress in drilling was being achieved below that depth because of rock.

No ground water was encountered in this boring.

Tower 153

A loose silty very fine to fine sand was underlain at the depth of 2.5 feet by a very firm silty very fine to fine sand derived from the in-place decomposed metavolcanic rock to the end of the boring at 4.5 feet. No progress in drilling was being achieved due to rock below that depth.

No ground water was encountered in this boring.

Tower 159

A loose silty fine sand topsoil was underlain by loose silty fine to medium sand between 1.0 and 3.0 feet. A very firm and slightly silty fine to coarse sand derived from the in-place decomposed granite was found between 3.0 and 19.5 feet, where practical refusal occurred.

No ground water was encountered in this boring.

Tower 163

A loose silty fine to medium sand was encountered to the depth of 10.5 feet. The upper 3.0 feet of the silty fine to medium sand layer was porous and graded to slightly porous with clay binder between the depths of 3.0 and 10.5 feet with approximately 3 inches of gravel up to 2 inches in diameter at a depth of 8.5 feet. Between the depths of 10.5 feet and 11.7 feet was a loose clayey fine to medium sand that was underlain by a very firm and slightly silty fine to coarse sand derived from the in-place decomposed granite to the end of boring at 26.0 feet. No progress in drilling was being made below that depth due to either the soundness of formation or a granite boulder at the bottom of the boring.

No ground water was encountered in this boring.

2. Soil Parameters

In plotting the direct shear test data, the peak values of all tested specimens were used. The test angle of internal friction and apparent cohesion values were determined from the average of the possible combinations of two or three tested peak values if the three tested specimens did not fall on the same resistance envelope. In some instances, where the direct shear test results were unusually high or quite inconsistent, the causes of variations were analyzed, and the recommended values for the angle of internal friction and cohesion presented in the "Table of Shear Test Results" have been reduced on the basis of the analyses, judgement and comparing the data of similar materials with similar densities, water contents and driving energies. Some of these factors, but not all of them, have been used in the analyses to arrive conclusions for the recommended values. The "Table of Shear Test Results" are tabulated on the attached pages 10 and 11 and the unit weights of the soils can be found from the Summary Sheets, Drawing Nos. 1 to 20, inclusive, at the end of this report.

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3. Driven Piles, Tower 93

The "Vertical Supporting Pile Capacity for Tower 93," for 8 inch Steel "H" piles is presented on the attached Drawing No. 21.

4. Seismic Refraction, Tower 151

The seismic refraction results for Tower 151 by Mr. T. Funnekotter are presented in Appendix C at the end of this report. The decomposed granite with a shock wave velocity of

3600 feet per second that has boulders inbedded in it at this location will make drilling very difficult if not impractical.

5. Metavolcanic Rock Conditions

Rock anchors may be considered for tower foundation support at locations where the metavolcanic rocks are encountered at relatively shallow depths, such as at Towers 103, 114, 125, 130, etc. in that it is understood considerable savings resulted by using these in similar rock on the Encina-Penasquitos 230/138 KV Line where the pullout capacities were successfully verified by your test program in 1968.

Respectfully submitted,

BENTON ENGINEERING, INC.

72-2-27A

By S. H. Shu
S. H. Shu, Civil Engineer

Reviewed by Philip H. Benton
Philip H. Benton, Civil Engineer

Distr: San Diego Gas & Electric Company
(3) Attention: Mr. John Burton
(2) Attention: Mr. C. Hjalmarson

SHS/PHB/ew

TABLE OF SHEAR TEST RESULTS

Tower No.	Sample No.	Depth in Feet	Soil Description	Shear Resistance in kips/sq ft Under Normal Load of 0.5	1.0	2.0 (Kips per sq ft)	Apparent Cohesion (lb/sq ft) Tested Range	Recommended	Angle of Internal Friction (Degrees) Test Range	Recommended
43	1	14.0	Clayey fine to medium sandy gravel	0.81	0.59	1.55	100-570	100	26.0-44.0	35.0
43	2	30.0	Slightly silty fine to medium sand	0.39	0.69	1.21	90-160	125	28.0-31.0	30.0
53				NO SAMPLE						
81				NO SAMPLE						
82	1	4.0	Clayey fine to coarse sand, granite decomposed in place	1.83	3.99	2.55	1580-3500	1580	26.0-78.0	26.0
92	1	14.0	Gravelly and slightly silty fine to medium sand	1.02	1.58	2.98	650	650	48.0-52.5	38.0
92	2	22.0	Slightly clayey fine to medium sand	1.05	1.67	2.09	700-1230	700	35.0	35.0
92	3	26.0	Slightly clayey fine to medium sand	1.83	2.24	3.80	1200-1420	1200	39.0	39.0
92	4	31.0	Claystone	0.93	1.83	2.05	800-1620	800	12.0-36.0	12.0
93	1	4.0	Clayey fine to medium sand	0.48	0.44	0.96	0-330	0	18.0-30.0	24.0
93	2	9.0	Fine to medium sandy clay	1.42	1.22	1.52	920-1750	920	4.0-17.0	17.0
93	3	12.0	Merging layers of clayey fine sand and fine sandy clay	0.88	1.11	1.20	650- 780	700	12.0-24.0	18.0
93	4	16.0	Merging layers of clayey fine sand and fine sandy clay	1.09	1.09	1.83	330-830	560	27.0-37.0	27.0
103				NO SAMPLE						

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TABLE OF SHEAR TEST RESULTS

				Shear Resistance in kips/ sq ft Under Normal Load of			Apparent Cohesion (lb/sq ft)		Angle of Internal Friction (Degrees)	
Tower No.	Sample No.	Depth in Feet	Soil Description	0.5	1.0	2.0 (Kips per sq ft)	Tested Range	Recommended	Tested Range	Recommended
114			NO GOOD SAMPLES COULD BE OBTAINED FOR TESTING, ALL ROCKS							
125			NO GOOD SAMPLES COULD BE OBTAINED FOR TESTING, ALL ROCKS							
130			NO SAMPLE							
131	1	4.0	Silty clay, firm	0.47	0.78	1.78	150	150	32.0-46.0	32.0
131	2	9.0	Silty very fine sand	2.49	3.94	7.50	1450-1990	1450	63.0-75.0	43.0
140			NO SAMPLE							
151	1	4.0	Slightly silty fine to medium sand from decomposed volcanic rock	1.88	3.42	3.80	370-3050	1680	21.0-72.0	21.0
153	1	4.0	Silty very fine to fine sand, decomposed volcanic rock in place	2.42	4.69	3.21	2170-4150	2170	28.0-78.0	28.0
159	1	4.0	Slightly silty fine to coarse sand, decomposed granite in place	1.95	3.34	5.06	580-1620	1500	60.0-70.0	43.0
159	2	9.0	Slightly silty fine to coarse sand, granite decomposed in place	7.50	7.50	7.50	7500	4000	-	42.0
163	1	4.0	Silty fine to medium sand, alluvium	0.51	0.33	0.81	0-420	0	12.0-26.0	19.0
163	2	9.0	Silty fine to medium sand, alluvium	0.65	0.60	2.33	0-80	0	31.0-49.0	31.0
163	5	21.0	Slightly silty fine to coarse sand, granite decomposed in place	6.07	7.50	7.50	4670-5600	4000	44.0-70.0	43.0

JOB NAME S.D.G. & E. 230 KV Mission - Escondido

SUMMARY SHEET

TOWER NO. 43

6' Southwest of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1			Brown, Dry, Loose, 30 Percent Gravel and Cobbles to 6 Inches, Topsoil	GRAVELLY CLAYEY FINE TO MEDIUM SAND					
2 3			Brown, Moist, Firm, 30 to 40 Percent Gravel and Cobbles to 5 Inches	GRAVELLY FINE TO MEDIUM SANDY CLAY					
4 5			Light Gray-brown, Slightly Moist, Very Firm, Occasional Gravel, Highly Cemented	CLAYEY FINE TO MEDIUM SAND					
6 7 8 9 10 11 12			Light Gray-brown, Slightly Moist, Very Firm, 50 to 60 Percent Gravel and Cobbles to 9 Inches	CLAYEY FINE TO MEDIUM SANDY GRAVEL					
13 14	①		9 Inch Layer with 15 to 20 Percent Gravel and Cobbles to 12 Inches		17.5	11.1	104.4		
15 16			Brown						

Continued on Drawing No. 2

○ - Indicates Undisturbed Drive Sample

□ - Indicates Loose Bag Sample

PROJECT NO.		DRAWING NO.
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JOB NAME S.D.G.&.E. 230 KV Mission - Escondido

SUMMARY SHEET

TOWER NO. 43 (Cont.)

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
16			Brown, Slightly Moist, Very Firm, 50 to 60 Percent Gravel and Cobbles to 12 Inches	CLAYEY FINE TO MEDIUM SANDY GRAVEL					
17									
18									
19									
20									
21									
22			Light Gray						
23									
24									
25									
26									
27			Light Gray, Moist, Very Firm	SLIGHTLY SILTY FINE TO MEDIUM SAND					
28									
29									
30	②				12.5	10.6	108.8		

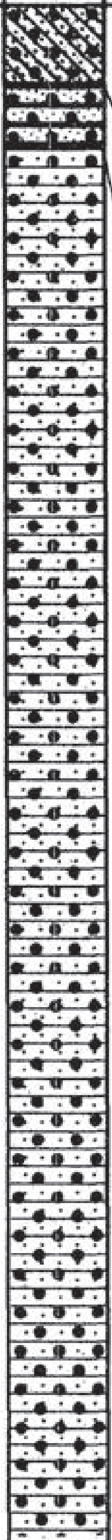
PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	2

JOB NAME S.D.G.&E. 230 KV Mission - Escondido

SUMMARY SHEET

TOWER NO. 53

4' West of Tower Centerline



DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0			Brown, Dry, Loose, 40 Percent Gravel and Cobbles to 6 Inches, Topsoil	GRAVELLY SILTY FINE TO MEDIUM SAND					
1									
2			Red-brown, Moist, Firm, 40 Percent Gravel	GRAVELLY FINE TO MEDIUM SANDY CLAY					
3			Light Gray-brown, Moist, Very Firm, 50 to 60 Percent Gravel and Cobbles to 6 Inches	CLAYEY FINE TO MEDIUM SANDY GRAVEL					
4									
5									
6									
7									
8	1								
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Continued on Drawing No. 4

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	3

JOB NAME S.D.G.&.E. 230 KV Mission - Escondido

SUMMARY SHEET

TOWER NO. 53 (Cont.)

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
20 21 22 23 24 25 26 27 28		▨	Light Gray-brown, Moist, Very Firm, 50 to 60 Percent Gravel and Cobbles to 6 Inches	CLAYEY FINE TO MEDIUM SANDY GRAVEL					

PROJECT NO.		DRAWING NO.
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JOB NAME S.D.G.&.E. 230 KV Mission - Escondido

SUMMARY SHEET

TOWER NO. 81

4' South of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0		▨	Brown, Dry, Loose, 30 Percent Rock Fragments, Topsoil	GRAVELLY FINE TO MEDIUM SAND					
1 2 3 4 5 6		▨	Light Brown, Dry, Very Firm	HIGHLY FRACTURED VOLCANIC ROCK					
7									

TOWER NO. 82

4' North of Tower Centerline

0		▨	Brown, Dry, Loose, Topsoil	CLAYEY FINE TO MEDIUM SAND					
1		▨	Brown, Moist, Firm	FINE TO MEDIUM SANDY CLAY					
2 3		▨	Light Brown, Slightly Moist, Very Firm, Granite, Decomposed In Place	CLAYEY FINE TO COARSE SAND (Merges)					
4 5 6	①	▨	Light Brown, Slightly Moist, Very Firm, Granite, Decomposed In Place, Less Weathered With Depth	SLIGHTLY CLAYEY FINE TO COARSE SAND	38.2	5.8	131.3		
7									

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	5

JOB NAME San Diego Gas & Electric Company - 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 92

4' Southof Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0		▨	Dark Brown, Slightly Moist, Loose, 40 to 50 Percent Gravel and Cobbles to 5 Inches	GRAVELLY SILTY FINE TO MEDIUM SAND					
1		▤	Light Brown, Slightly Moist, Very Firm 40 to 50 Percent Gravel and Cobbles to 6 Inches	GRAVELLY CLAYEY FINE TO MEDIUM SAND					
3		▤	Moist						
6		▨	Light Brown, Moist, Very Firm, 40 to 50 Percent Gravel and Cobbles to 6 Inches with Slight Clay Binder	GRAVELLY SLIGHTLY SILTY FINE TO MEDIUM SAND					
11		▧	Light Brown, Moist, Very Firm, with Slight Clay Binder	SLIGHTLY SILTY FINE TO MEDIUM SAND					
14	①	▧			22.1	7.5	107.6		
17		▨	Light Brown, Moist, Very Firm, 40 to 50 Percent Gravel and Cobbles to 6 Inches, with Slight Clay Binder	GRAVELLY SLIGHTLY SILTY FINE TO MEDIUM SAND					
20									

Continued on Drawing No. 7

PROJECT NO. 72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 6

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET
TOWER NO. 92 (Cont.)

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
20 21 22	②	░	Light Gray-brown, Moist, Very Firm	SLIGHTLY CLAYEY FINE TO MEDIUM SAND	15.3	23.0	105.0		
23		▤	Green, Moist, Very Firm	CLAYSTONE					
24 25 26	③	░	Brown, Moist, Very Firm	SLIGHTLY CLAYEY FINE TO MEDIUM SAND	18.7	10.8	120.1		
27 28 29 30 31	④	▤	Green, Moist, Very Firm	CLAYSTONE	19.6	22.0	105.6		

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	7

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 93

4' West of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0			Dark Gray-brown, Moist, Loose, Occasional Gravel						
1									
2									
3									
4	①			CLAYEY FINE TO MEDIUM SAND	1.7	13.6	84.8		
5									
6									
7									
8									
9	②		Dark Gray-brown, Moist, Medium Firm	FINE TO MEDIUM SANDY CLAY	3.4	19.1	108.7		
10			Gray-brown, Moist, Soft						
11									
12	③	Water ▽		CLAYEY FINE SAND AND FINE SANDY CLAY IN ALTERNATING MERGING LAYERS AND LENSES	0.8	25.2	100.5		
13			Saturated						
14									
15									
16	④				3.8	22.6	104.5		
17									
18									
19			6 Inch Lens of Fine to Medium Sand						
20									

Continued on Drawing No. 9

PROJECT NO. 72-2-27A	BENTON ENGINEERING, INC.	DRAWING NO. 8

JOB NAME San Diego Gas and Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET
TOWER NO. 93 (Cont.)

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL	SUMMARY SHEET TOWER NO. 93 (Cont.)		DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
20 21 22		▨	Brown, Saturated, Compact, 50 to 60 Percent Gravel and Cobbles to 6 Inches	FINE TO MEDIUM SANDY GRAVEL					

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	9

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 103

3' West of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE %·DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1			Brown, Slightly Moist, Loose, 30 Percent Rock Fragments to 6 Inches	GRAVELLY VERY FINE SANDY SILT					
2 3			Gray, Dry, Very Firm, Slightly Weathered	FRACTURED VOLCANIC ROCK					

PROJECT NO.
72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO.
10

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 114

5' West of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1 2	①	▨	Red-brown, Slightly Moist, Firm, Large Amount of Interbedded Layers of Highly Fractured Rock Fragments to 1 Inch	SILTY CLAY	16.2	119.0	108.2		
3 4	②	▨	Gray-brown, Moist, 9 Inch Layer with Few Rock Fragments		45.3	3.8	158.0	*	
5 6		▤	Light Brown, Slightly Moist, Rock Fragments to 3 Inches						
7 8 9	③	▤	Light Gray-brown, Slightly Moist, Very Firm, Slightly Cemented, with Interbedded Layers of Highly Fractured Rock Fragments to 3 to 4 Inches	FINE SANDY CLAY	43.3	6.8	141.4		

* Density of rock fragments of metavolcanic origin

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	11

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET
TOWER NO. 125
4' South of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1		▨	Dark Brown, Slightly Moist, Loose, Topsoil, Rock Fragments to 10 Inches	SILT					
2 3		▨	Gray-brown, Moist, Firm, Occasional Rock Fragment to 2 Inches	SILTY CLAY					
4 5 6 7 8	①	▨	Light Brown, Slightly Moist, Very Firm, with some Unweathered Framents to 4 Inches Less Weathered with Increasing Depth	SILTY VERY FINE TO FINE SAND (VOLCANIC ROCK WEATHERED IN PLACE)	68.0	5.4	147.0		
9									

PROJECT NO. 72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 12

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET
TOWER NO. 130
4' North of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1		▨	Brown, Slightly Moist, Loose, Topsoil, Rock Fragments to 10 Inches	SILTY FINE SAND					
2		▨	Red-brown, Moist, Firm, Rock Fragments to 4 Inches	SILTY CLAY					
3 4 5 6		▨	Light Brown, Slightly Moist, Very Firm, with Unweathered Dark Gray Fragments to 14 Inches	SILTY VERY FINE TO FINE SAND (VOLCANIC ROCK WEATHERED IN PLACE)					

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	13

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 131

3' North of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0		▨	Brown, Moist, Loose, Topsoil	SILTY FINE TO MEDIUM SAND					
1		▤	Brown, Moist, Firm	SILTY CLAY					
2									
3			Light Brown						
4	①				6.8	20.1	91.3		
5		▨	Light Brown, Moist, Very Firm	SILTY VERY FINE SAND (VOLCANIC ROCK WEATHERED IN PLACE)					
6									
7									
8									
9	②				58.3	11.2	129.0		
10			Less Weathered with Increasing Depth						
11									
12									
13									
14									

PROJECT NO. 72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 14

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 140
37' SW From Tower Centerline
and 5.5' Above Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1 2		▨	Brown, Slightly Moist, Loose, Topsoil, Fractured Cobbles and Boulders to 16 Inches	SILTY FINE SAND					
3 4 5 6 7	○ *	▨	Light Brown, Slightly Moist, Very Firm, Highly Weathered Matrix with Increasing In Size of Rock Fragments With Depth	SILTY FINE SAND (VOLCANIC ROCK WEATHERED IN PLACE)	57.1	-	-		

* Sample not retained

PROJECT NO.
72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO.
15

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL	SUMMARY SHEET TOWER NO. 151 110' From Tower Centerline and 35' Below Tower Centerline		DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1 2		▨	Brown, Slightly Moist, Loose, Topsoil	SILTY FINE TO MEDIUM SAND					
3 4 5 6 7	①	▨	Light Gray-brown, Dry to Slightly Moist, Very Firm	SLIGHTLY SILTY FINE TO MEDIUM SAND (DECOMPOSED VOLCANIC ROCK)	30.6	3.7	126.8		
8									

PROJECT NO. 72-2-27A	BENTON ENGINEERING, INC.	DRAWING NO. 16

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 153

3' Southeast of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1 2		▨	Brown, Dry, Loose, Topsoil	SILTY VERY FINE TO FINE SAND					
3 4	①	▨	Light Gray-brown, Dry, Very Firm	SILTY VERY FINE TO FINE SAND (DECOMPOSED VOLCANIC ROCK)	76.5	4.1	136.1		
5									

PROJECT NO. 72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 17

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET
TOWER NO. 159
3' Southeast of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0		▨	Brown, Slightly Moist, Loose, Topsoil	SILTY FINE SAND					
1		▨	Brown, Moist, Loose	SILTY FINE TO MEDIUM SAND					
2		▨							
3		▨	Brown, Moist, Very Firm						
4	①	▨			34.0	7.2	136.1		
5		▨	Gray						
6		▨							
7		▨							
8		▨							
9	②	▨		SLIGHTLY SILTY FINE TO COARSE SAND	61.2	3.5	147.8		
10		▨							
11	* ○	▨			68.0	-	-	-	
12		▨							
13		▨		(GRANITE DECOMPOSED IN PLACE)					
14		▨							
15		▨							
16		▨							
17		▨							
18		▨							
19		▨							
20									

* Sample not retained

NOTE: Boring was stopped because of practical refusal in granite formation.

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	18

JOB NAME San Diego Gas & Electric Company - 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 163

3.5' Northwest of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0		▨	Brown, Slightly Moist, Loose, Porous, Topsoil	SILTY FINE TO MEDIUM SAND (ALLUVIUM)					
1		▨	Moist						
2		▨							
3	①	▨	Light Brown, with Clay Binder, Slightly Porous		0.8	5.3	93.5		
4		▨							
5		▨							
6		▨							
7		▨							
8	②	▨	3 Inch Layer with Occasional Gravel to 2 Inches at 8.5 Feet		1.7	5.6	102.0		
9		▨							
10		▤	Light Brown, Very Moist, Loose	CLAYEY FINE TO MEDIUM SAND					
11	③	▨	Brown, Moist, Very Firm	SLIGHTLY SILTY FINE TO COARSE SAND (GRANITE DECOMPOSED IN PLACE)	15.3	9.5	120.6		
12		▨							
13		▨							
14		▨							
15	④	▨	Occasional Gray Streaks		87.4	5.0	138.4		
16		▨							
17		▨							
18		▨							
19		▨							
20	⑤	▨			76.5	3.9	136.6		
21									

Continued on Drawing No. 20

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	19

JOB NAME San Diego Gas & Electric Company - 230 KV Line Mission Substation, Escondido

SUMMARY SHEET

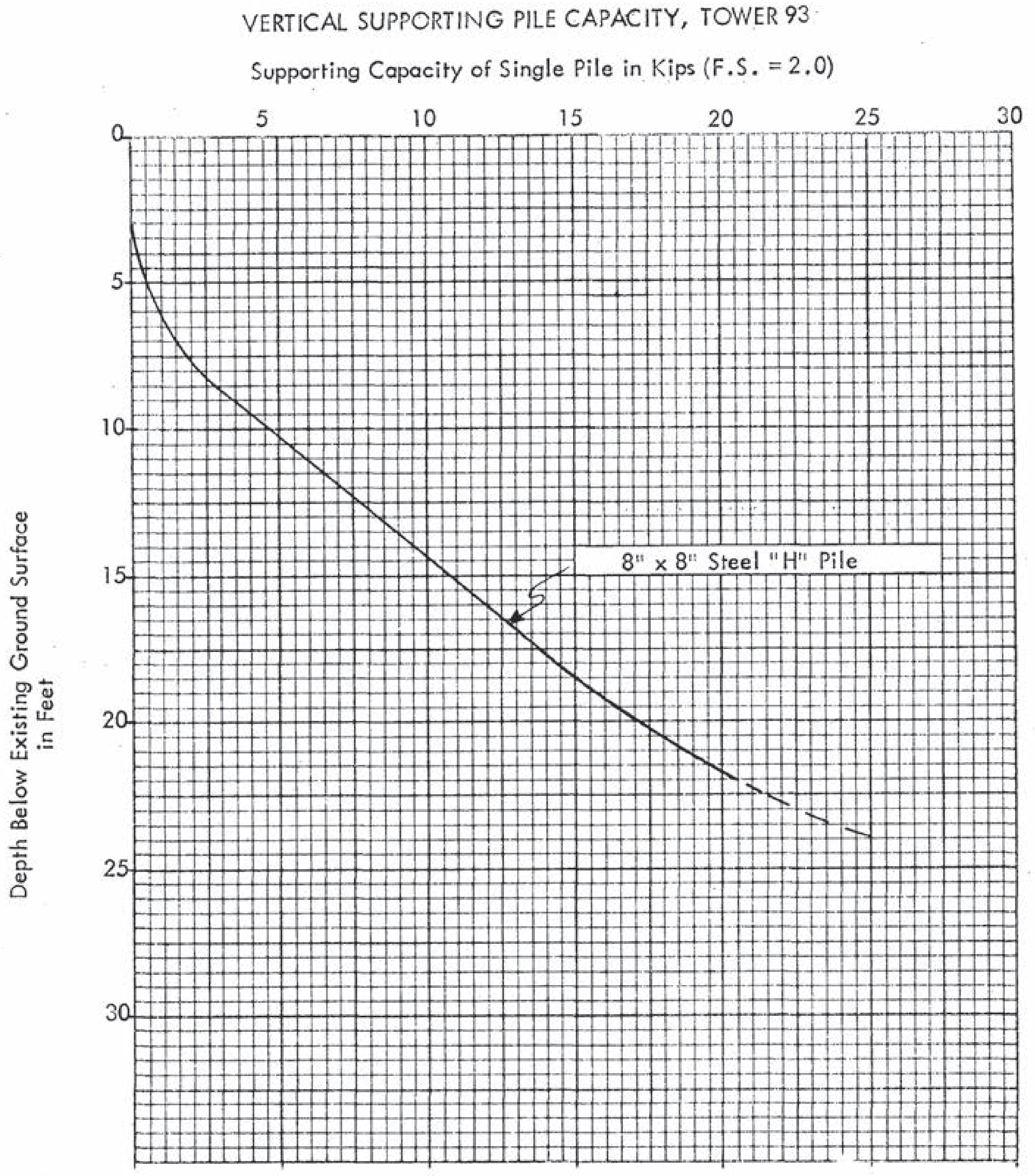
TOWER NO. 163 (Cont.)

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
21		▨	Brown, Moist, Very Firm, Occasional Gray Streaks	SLIGHTLY SILTY FINE TO COARSE SAND					
22		▨							
23		▨							
24		▨							
25		▨		(GRANITE DECOMPOSED IN PLACE)					
26	⑥	▨			87.4	14.3	**		

** Too rocky to take density test.

NOTE: Boring stopped on granite formation or boulder that could not be penetrated.

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	20



8" x 8" DRIVEN STEEL "H" PILE

Assumed Full Submergence Uplift Limit to 50 Percent of Vertical Load to 22 Feet.
Use Battered Piles if More Uplift Required.

PROJECT NO. 72-2-27A	**BENTON ENGINEERING, INC.**	DRAWING NO. 21

G403

T. FUNNEKOTTER
REGISTERED GEOLOGIST
CERTIFIED ENGINEERING GEOLOGIST
P. O. BOX 575 - ESCONDIDO, CALIF. 92025
746-2793

ENGINEERING GEOLOGY

GEOPHYSICAL INVESTIGATIONS
For
Subdivision Design
Pipelines - Roads
Seismic Rippability Studies

SUBSURFACE INVESTIGATION

TOWER SITES 230 KV LINE

San Onofre - Rainbow
Mission - Escondido

May 4, 1972

Purpose: To evaluate subsurface conditions at selected pole and tower sites for a 230 KV line in order to determine what excavation and drilling problems may be anticipated.

Method: Refraction Seismography. Geologic reconnaissance.

Discussion: This report includes 1 tower site in the Harmony Grove area, three sites in the San Onofre area, and 53 sites in the area from Mission Valley to Escondido. A variety of geologic units were encountered - these materials are identified by the predominant visible surface indications. The notation used to make this identification is as follows:

T - marine and non-marine deposits and alluvium. (clay,silt,sand and gravel with minor amounts of cobbles and boulders). Poorly consolidated.

C - conglomerate (cemented cobbles - loose to tight). Poor to good consolidation.

V - Volcanic (andesite to rhyolite).

Gr - Granite

The Seismic runs are all 100 feet long - the station is at the 50 feet mark unless noted otherwise. The direction of run is the compass direction, i.e., NE is North 45 degrees East.

A total of 72 Seismic runs were made crossing the pole and tower sites.

Discussion: (con't)

The velocity profile indicates the highest velocity measured to the depth shown. In other words, no higher velocity than that shown is within the depth indicated. Shock waves will not refract from a harder layer to a softer layer, so if a surface layer has a wave velocity of 4900 ft/sec and is only 4 feet thick and the material below is only 3500 ft/sec, no refraction occurs at this interface. Consequently, the thickness of the 4900 ft/sec layer is indeterminate; however, any layer with a higher velocity than 4900 ft/sec below would be detected. Several tests show that this condition actually exists in the conglomerate. This conglomerate is a cemented sand conglomerate cap measuring approximately 4900 ft/sec and appears to be from 3 feet to 5 feet in thickness overlying a softer material. The underlying softer conglomerate is not as rigid and probably has a velocity range of 3000 to 3500 ft/sec. However, there still can be 4900 ft/sec layers interspersed within this softer material. In any event, in this condition with 4900 ft/sec as the only velocity shown as at station 828+80, no higher velocity than 4900 ft/sec should be encountered to the maximum depth of penetration of 25 feet.

Discussion: (con't)

Tower site 151 indicates 3600 ft/sec decomposed granite and fractured granite with boulders and a few small dikes crossing the hill. Station 2364+26.70 is near the valley floor and is in the area of loose alluvium, cobbles and boulders. The velocity of 2600 ft/sec reflects this poorly consolidated condition. Station 2400+63.03 is in a conglomerate structure. The 4900 ft/sec material appears to be a cemented conglomerate about 3 feet thick. This material is visible below in the road cut. This velocity is the maximum measured to 30 feet depth. The conglomerate above the 4900 ft/sec layer is softer as is probably the material below. The area of station 2483+97.60 is low velocity silty sand.

From station 30 to 403 three geologic units were investigated; the marine and non-marine deposits, the conglomerate and the granite. The first category velocities fell within a range of 2000 to 2600 ft/sec indicating poor consolidation. The conglomerate fell within a velocity range of 2800 to 3600 ft/sec showing moderate consolidation. No hard rigid layers of this material were visible in any cuts. The granite velocities ranged all the way up to 9000 ft/sec.

Discussion: (con't)

High velocity granite was located on several runs as near as 9 feet from the surface.

From station 828+80 to 1050+40 all four geologic units were encountered. The velocity ranges of these four units were as follows:

T - 2400 to 3000 ft/sec
C - 3500 to 4900 ft/sec
Gr - 4200 to 8500 ft/sec
V - 2900 to 8500 ft/sec

The conglomerate in these runs shows an interesting variation - the 3500 ft/sec material is probably poorly cemented whereas the 4900 ft/sec material is well cemented. The presence, depth, and degree of rigidity of this member was ascertained. The harder cemented layer is visible on many cuts and appears to be a cemented sand conglomerate from approximately 3 to 5 feet in thickness. It does not appear to cover this area completely or is in a more advanced state of decomposition and weathering. The highest velocity measured in this member was 4900 ft/sec - this is the highest velocity material within the indicated depth. Granite was located at only one site - at 961+80 with the bedrock at approximately 10 feet. The volcanic material was located at several sites - most falls within a range of 4000 to 4900 ft/sec. One location,

Discussion: (con't)

however; indicates the volcanic bedrock at 14 feet - station 986+30.

Conclusion: Identification of the rock units is important because rippability varies with velocity and type of material. These materials were identified by the predominant surface material and nearby cuts, trenches, escarpments, etc. In some cases the underlying material may be different than the surface material because of lensing out of the upper layer - such may be the case at station 1050+40 where the lower layer may be volcanic.

All of the runs made in the marine and non-marine deposits and alluvium show velocities under 3000 ft/sec, most are below 2500 ft/sec. The granite and volcanic locations indicate the presence of bedrock at many sites. From station 828+80 to 948 the conglomerate structure appears both as a more rigid cemented cap about 3 to 5 feet thick and softer conglomerate both above and below in many cases. The variation in velocity in this material probably reflects the degree of cementation. This more rigid conglomerate cap also does not appear to be continuous throughout this area. It probably has been eroded through in several areas.

Conclusion: (con't)

In terms of rippability, two basic categories should be used as follows:

Velocity (ft/sec)	Excavation Method
For granite and volcanic andesite	
0 to 2000	Scraper
2000 to 5000	Ripper
5000 to 5500	Marginal
Over 5500	Drill & Shoot
For conglomerate	
0 to 2000	Scraper
2000 to 5000	Ripper
5000 to 7000	Marginal
Over 7000	Drill & Shoot

In most cases, conglomerate should be considered as a less rigid material than granite even when they have similar velocities. This means that both ripping and drilling can be accomplished at higher velocities than in granite. Drilling, however can become very difficult if the cobbles become very large.

Submitted by

T. Funnekotter

SEISMIC - RIPPABILITY INFORMATION

The following points should be considered when evaluating Seismic information:

1. All velocities, depths, and thicknesses are averages and qualified according to the following schedule:

   G - good
   F - fair
   P - poor
   VP - very poor
   ? - questionable

   Grades of G, F, and P can be considered reliable; VP and ? should be considered as indications only.

2. Each profile provides information in the immediate area of that profile - extrapolation outward from this area must be considered speculative unless additional information is available.

3. As the velocity of the material increases, ripping becomes progressively more difficult until at some point it is more economical to drill and shoot the material prior to excavation. This point occurs within the marginal zone. Rippability figures vary with the type of material, however, in general, D-9 ripper performance is as follows:

Velocity Range (ft/sec)	Excavation Method
0 to 2000	Scraper
2000 to 5000	Ripper
5000 to 5500	Marginal
Over 5500	Blasting

   These figures are based on several hundred job studies.

4. For trencher and backhoe operations the rippability figures must be adjusted downward, i.e., velocities as low as 3500 ft/sec may indicate material that is not rippable, depending on the homogeneity of that material, whereas material measuring over 4300 ft/sec almost certainly would require explosive work. As an average, materials measuring over 3800 ft/sec would mean difficult trenching and the economics of the situation would probably dictate explosive work first. The above figures are based on a machine similar to the Kohring 505.

G403

BENTON ENGINEERING, INC.
APPLIED SOIL MECHANICS — FOUNDATIONS
6741 EL CAJON BOULEVARD
SAN DIEGO, CALIFORNIA 92115

PHILIP HENKING BENTON
PRESIDENT - CIVIL ENGINEER

SAN DIEGO: 583-5654
LA MESA: 469-5654

May 9, 1972

San Diego Gas & Electric Company
P. O. Box 1831
San Diego, California 92112

Attention: Mr. John Burton

Subject: Project No. 72-2-27A
Second Interim Report
Rock Anchor Investigation
Mission-Escondido Line
San Diego County, California

Gentlemen:

In accordance with your request, we are transmitting three copies of our Project No. 72-2-27A entitled, "Second Interim Report, Rock Anchor Investigation, Mission-Escondido Line, San Diego County, California," dated May 9, 1972. Under separate cover, we are transmitting two copies to Mr. Lloyd Wilson of the Chula Vista office, and also one copy to Mr. William H. Oltman of the Construction Department.

On April 25, 26 and 27, 1972, rock anchor test holes were drilled at Towers 82, 103, 125, 131, 140, 153, 159 and 162 with a track-mounted "PAT-1" double-jack air drill. One test hole was drilled at each site to a depth of about 12 feet. The rate of penetration was recorded in seconds per foot for the various intervals penetrated, and the soils and bedrock were logged and sampled. (See Drawing Nos. 22 to 29, inclusive).

In general, we found that topsoils, colluvium and fractured bedrock drilled at a rate of 7.5 to 37.0 seconds per foot, and fresh bedrock drilled at 21.0 to 59.0 seconds per foot. The double jack and drill is designed for hard rock drilling, not softer soils. Therefore, it tends to "mush" in clayey topsoils, resulting in a slow rate of penetration which should not be confused with the slower rate of penetration in hard rock. A good example of this is from 2.8 to 6.4 feet at Tower 159 (Drawing No. 28.)

The best method of identification of the type of soil or bedrock being penetrated is the color of the cuttings and dust blown out of the hole as drilling progresses. Topsoils, colluvium, and highly fractured and weathered bedrock will produce cuttings and dust with brown tones, whereas fresh bedrock (either metavolcanic or granitic) will produce cuttings and dust with a light gray to white color. Thin weathered fractures in otherwise fresh bedrock will show a momentary change in the dust color from light gray to brown and then back to light gray.

Samples of representative soil and bedrock types were collected for Mr. William H. Oltman to use as a reference during tower line construction. These samples along with brief field descriptions are in Mr. Oltman's possession.

If you have any questions after reviewing this letter please do not hesitate to contact this office.

This opportunity to be of service is sincerely appreciated.

Respectfully submitted,

BENTON ENGINEERING, INC.

William J. Elliott

William J. Elliott, R. G. No. 1101

Distr: (3) Addressee
San Diego Gas & Electric Company
Chula Vista office
(2) Attention: Mr. Lloyd Wilson
San Diego Gas & Electric Company
Construction Department, Carlsbad office
(1) Attention: Mr. William H. Oltman

WJE/ew

JOB NAME San Diego Gas & Electric Co., Mission-Escondido Line

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL	SUMMARY SHEET TOWER NO. 82 Location: 5' South of Tower Centerline		DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	Sec./Foot *
0			Red-brown to Gray-brown, Dry, Compact, Topsoil and Loose Rock	CLAYEY FINE TO MEDIUM SANDY GRAVEL					
1									37
2			Light Gray-brown, Dry, Very Compact, with Occasional Fractures						
3	1								
4									34
5									
6									
7	2		Becomes Fresher with Depth	FRESH METAVOLCANIC BEDROCK					35
8									
9			Thin Fracture Zone						
10									27
11			Thin Fracture Zone						30
12			Stopped 11.5 feet						

☐ - Loose bag sample taken for identification purposes by San Diego Gas & Electric Company Personnel.

* - Rate of penetration in seconds/foot, by "Air-Track" PAT-1 track-mounted drill rig. All holes were air-drilled with a 3 inch diameter double-jack drill.

NOTE: In general, fresh rock (granitic or metavolcanic) will drill to a white to light gray dust, and weathered rock or weathered fracture seams will drill to a yellow-brown to red-brown to brown dust.

PROJECT NO. 72-2-27A	BENTON ENGINEERING, INC.	DRAWING NO. 22

JOB NAME San Diego Gas & Electric Co., Mission-Escondido Line

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL	SUMMARY SHEET TOWER NO. 103 Location: 5' East of Tower Centerline		DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	Sec./Foot *
0			Red-brown, Dry, Loose, Topsoil	CLAYEY FINE TO MEDIUM SAND					17
1			Light Gray, Dry, Very Compact	FRESH METAVOLCANIC BEDROCK					
2	1								
3									
4									29
5			Blue-gray, Becoming Harder						
6									
7									
8	2								55
9									
10									
11			Stopped 10.7 Feet						

PROJECT NO. 72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 23

JOB NAME San Diego Gas & Electric Co., Mission-Escondido Line

SUMMARY SHEET

TOWER NO. 125

Location: 5' West of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	Sec./Foot
0 1			Red-brown, Slightly Moist, Loose, Topsoil	SILTY CLAY					34
2 3 4	1		Light Yellow-brown, Dry, Compact, Occasional Very Hard Spots	SILTY CLAY (Weathered Metavolcanic Rock)					19.5
5 6	2		Light Gray to Gray, Dry, Very Compact	FRESH METAVOLCANIC BEDROCK					54
7 8 9 10			Light Gray with Brown, Weathered Fracture Zones						23
11			Becoming Harder						25
12			Stopped 11.5 Feet						

PROJECT NO. 27-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 24

JOB NAME San Diego Gas & Electric Co., Mission-Escondido Line

SUMMARY SHEET

TOWER NO. 131

Location: 5' East of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	Sec./Foot
0			Dark Brown, Moist, Soft, Topsoil	CLAYE FINE TO MEDIUM SAND					
1			Dark Brown, Moist, Soft, Clay Cap	SILTY CLAY					25
3			Light Yellow-brown, Dry, Medium Compact, Highly Weathered Metavolcanic Rock						
4	1								
5			Gray, Dry, Very Compact	FRESH METAVOLCANIC BEDROCK					41
6			Light Gray to Gray, Brown, Dry, Very Compact, Fractured	ALTERNATING ZONES OF FRESH AND HIGHLY WEATHERED METAVOLCANIC BEDROCK					26
11	2								29
12									30
13									27
14			Stopped 13.5 Feet						

PROJECT NO. 72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 25

JOB NAME San Diego Gas & Electric Co., Mission-Escondido Line

SUMMARY SHEET

TOWER NO. 140

Location: 13' South of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	Sec./Foot
0			Gray-brown, Dry, Loose, Topsoil	CLAYEY FINE TO MEDIUM SAND					
1 2			Gray, Dry, Compact	FRACTURED METAVOLCANIC BEDROCK					50
3 4	1		Gray, Dry, Very Compact	FRESH METAVOLCANIC BEDROCK					
5 6 7 8 9 10 11	2		Gray and Gray-brown, Dry, Compact, Fractures About 2 Feet Apart	FRACTURED METAVOLCANIC BEDROCK					28
12			Stopped 12 Feet						

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	26

JOB NAME San Diego Gas & Electric Co., Mission-Escondido Line

SUMMARY SHEET

TOWER NO. 153

Location: 5' Northeast of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	Sec./Foot
0 1			Light Brown, Dry, Loose, Topsoil Medium Brown, Moist	SILTY FINE TO MEDIUM SAND					8.5
2 3			Light Yellow-brown, Moist, Medium Compact	HIGHLY WEATHERED GRANITIC BEDROCK					21
4 5 6	1		Gray, Dry, Very Compact	FRESH GRANITIC BEDROCK					57
7			Light Yellow-brown, Dry, Compact	FRACTURED GRANITIC BEDROCK					13
8 9			Gray and Cream, Dry, Very Compact	FRESH GRANITIC BEDROCK					59
10 11 12	2		Gray to Brown to Cream, Dry, Compact	FRACTURED GRANITIC BEDROCK					13

Stopped 12 Feet

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	27

JOB NAME San Diego Gas & Electric Co., Mission–Escondido Line

SUMMARY SHEET

TOWER NO. 159

Location: 5' Northwest of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	Sec./Foot
0 1 2			Dark Brown, Moist, Soft, Topsoil	CLAYEY FINE TO MEDIUM SAND **					20
3 4 5 6	1		Yellow-brown, Slightly Moist, Medium Compact, Colluvium	CLAYEY FINE SAND **					35
7 8 9 10 11 12	2		Gray, Dry, Compact, "D.G."	WEATHERED GRANITIC BEDROCK					25

Stopped 12 Feet

** 0 to 6.4 feet is topsoil and colluvium and should not be used for rock anchor footings. 6.4 to 12.0 is good solid "D.G." and should be satisfactory for rock anchor footings.

PROJECT NO. 72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 28

JOB NAME San Diego Gas & Electric Co., Mission-Escondido Line

SUMMARY SHEET

TOWER NO. 162

Location: 4' North of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	Sec./Foot
0 1 2			Orange-brown, Dry, Loose, Topsoil	SILTY FINE TO MEDIUM SAND					7.5
3 4 5	1		Gray, Brown, Dry, Compact	SLIGHTLY SILTY FINE TO MEDIUM SAND (Weathered Granitic Rock)					10.0
6			Gray-brown, and Gray, Dry, Compact to Very Compact	ALTERNATING ZONES OF WEATHERED AND FRESH GRANITIC BEDROCK					21
7 8									12.5
9									24
10	2								23
11									24
12	3								40

Stopped 12 Feet

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	29

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 103

3' West of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1		▨	Brown, Slightly Moist, Loose, 30 Percent Rock Fragments to 6 Inches	GRAVELLY VERY FINE SANDY SILT					
2 3		▦	Gray, Dry, Very Firm, Slightly Weathered	FRACTURED VOLCANIC ROCK					

PROJECT NO. 72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 10

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 114

5' West of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.
0–2	①	▨	Red-brown, Slightly Moist, Firm, Large Amount of Interbedded Layers of Highly Fractured Rock Fragments to 1 Inch	SILTY CLAY	16.2	119.0	108.2	
3–4	②	▨	Gray-brown, Moist, 9 Inch Layer with Few Rock Fragments		45.3	3.8	158.0	*
5–6		▤	Light Brown, Slightly Moist, Rock Fragments to 3 Inches					
7–9	③	▤	Light Gray-brown, Slightly Moist, Very Firm, Slightly Cemented, with Interbedded Layers of Highly Fractured Rock Fragments to 3 to 4 Inches	FINE SANDY CLAY	43.3	6.8	141.4	

* Density of rock fragments of metavolcanic origin

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	11

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 130

4' North of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1		▨	Brown, Slightly Moist, Loose, Topsoil, Rock Fragments to 10 Inches	SILTY FINE SAND					
2		▤	Red-brown, Moist, Firm, Rock Fragments to 4 Inches	SILTY CLAY					
3 4 5 6		▨	Light Brown, Slightly Moist, Very Firm, with Unweathered Dark Gray Fragments to 14 Inches	SILTY VERY FINE TO FINE SAND (VOLCANIC ROCK WEATHERED IN PLACE)					

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	13

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 130

4' North of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0 1		▨	Brown, Slightly Moist, Loose, Topsoil, Rock Fragments to 10 Inches	SILTY FINE SAND					
2		▤	Red-brown, Moist, Firm, Rock Fragments to 4 Inches	SILTY CLAY					
3 4 5 6		▨	Light Brown, Slightly Moist, Very Firm, with Unweathered Dark Gray Fragments to 14 Inches	SILTY VERY FINE TO FINE SAND (VOLCANIC ROCK WEATHERED IN PLACE)					

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	13

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

SUMMARY SHEET

TOWER NO. 131

3' North of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0		▨	Brown, Moist, Loose, Topsoil	SILTY FINE TO MEDIUM SAND					
1 2 3		▤	Brown, Moist, Firm	SILTY CLAY					
4	①	▤	Light Brown		6.8	20.1	91.3		
5 6 7 8 9 10 11 12 13	②	▨	Light Brown, Moist, Very Firm Less Weathered with Increasing Depth	SILTY VERY FINE SAND (VOLCANIC ROCK WEATHERED IN PLACE)	58.3	11.2	129.0		
14									

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	14

JOB NAME San Diego Gas & Electric Company, 230 KV Line, Mission Substation, Escondido

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL	SUMMARY SHEET TOWER NO. 131 3' North of Tower Centerline		DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0		▨	Brown, Moist, Loose, Topsoil	SILTY FINE TO MEDIUM SAND					
1 2 3		▤	Brown, Moist, Firm	SILTY CLAY					
4	①	▤	Light Brown		6.8	20.1	91.3		
5 6 7 8 9 10 11 12 13 14	②	▨	Light Brown, Moist, Very Firm Less Weathered with Increasing Depth	SILTY VERY FINE SAND (VOLCANIC ROCK WEATHERED IN PLACE)	58.3	11.2	129.0		

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	14

G403

BENTON ENGINEERING, INC.
APPLIED SOIL MECHANICS — FOUNDATIONS
6741 EL CAJON BOULEVARD
SAN DIEGO, CALIFORNIA 92115

PHILIP HENKING BENTON
PRESIDENT - CIVIL ENGINEER

SAN DIEGO: 583-5654
LA MESA: 469-5654

May 25, 1972

San Diego Gas & Electric Company
P. O. Box 1831
San Diego, California 92112

Attention: Mr. John Burton

Gentlemen:

This is to transmit to you three copies of our report of Project No. 72-2-27A entitled, "Third Interim Report on Soils Investigation, Mission-Escondido Line, San Diego County, California," dated May 25, 1972.

We are transmitting under separate cover two copies to Mr. Lloyd Wilson of the Chula Vista office.

If you have any questions concerning any of the data presented in this report, please contact us.

Very truly yours,

BENTON ENGINEERING, INC.

Philip H. Benton

Philip H. Benton, Civil Engineer

THIRD INTERIM REPORT
ON
SOILS INVESTIGATION

Mission-Escondido Line
San Diego County, California

San Diego Gas & Electric Company

Project No. 72-2-27A
May 25, 1972

BENTON ENGINEERING, INC.

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BENTON ENGINEERING, INC.
APPLIED SOIL MECHANICS — FOUNDATIONS
6741 EL CAJON BOULEVARD
SAN DIEGO, CALIFORNIA 92115

PHILIP HENKING BENTON
PRESIDENT - CIVIL ENGINEER

SAN DIEGO: 583-5654
LA MESA: 469-5654

THIRD INTERIM REPORT
ON
SOILS INVESTIGATION

Introduction

This is to present the results of a soils investigation conducted at certain tower sites for the proposed San Diego Gas & Electric Company Transmission Line from the Mission Substation to the Escondido Operating Center in San Diego County, California .

This report is to serve as a supplement to our previous report entitled "First Interim Report, Soils Investigation, Mission-Escondido Line, San Diego County, California," for the San Diego Gas & Electric Company, April 6, 1972, under the same Project Number of 72-2-27A and our "Second Interim Report, Rock Anchor Investigation, Mission-Escondido Line, San Diego County, California," dated May 9, 1972.

The objectives of the investigation were to determine the existing subsurface conditions and physical properties of the subsoils so that representative soil parameters could be recommended for the design of the proposed tower foundations. Also, the findings and log of soil conditions are to serve as a guide in determining the best probable types of foundation to be used.

In addition to the borings drilled for this report, refraction seismograph lines were run at Tower 151 in the Harmony Grove area, three sites in the San Onofre area and 53 sites between Mission Valley and Escondido. The three refraction seismograph lines taken in the San Onofre area are to be incorporated into our previous report entitled "Interim Report, Soils Investigation, 230 KV San Onofre-Escondido Line, San Diego County, California," for the San Diego Gas & Electric Company, February 9, 1972, under Project No. 71-12-22A.

Field Investigation

Eight borings were drilled with a truck-mounted rotary bucket-type drill rig. The locations of the borings, relative to the staked centerline of the various tower locations, are described individually on Drawing Nos. 30 to 43, inclusive, each entitled "Summary Sheet." The borings were drilled to depths of 12.0 to 31.0 feet below the existing ground surface. A continuous log of the soils encountered in the borings was recorded at the time of drilling and is shown in detail on the Summary Sheets.

The soils were visually classified by field identification procedures in accordance with the Unified Soil Classification Chart. A simplified description of this classification system is presented in the attached Appendix A at the end of this report.

Undisturbed samples were obtained at frequent intervals, where possible, in the soils ahead of the drilling. The drop weight used for driving the sampling tube into the soils was the "Kelly" bar of the drill rig which weighs 1623 pounds, and the average drop was 12 inches. The general procedures used in field sampling are described under "Sampling" in Appendix B.

Laboratory Tests

Laboratory tests were performed on all undisturbed samples of the soils in order to determine the dry density and moisture content. The results of these tests are presented on Drawing Nos. 30 to 43, inclusive. Direct shear tests were performed on selected representative samples from possible foundation bearing soils in order to determine the angle of internal friction and apparent cohesion of the soils. The samples were allowed to saturate and drain prior to being tested. The results of these tests are presented on the "Table of Shear Test Results" which are presented on pages 8 and 9.

The general procedures used for the laboratory tests are described briefly in Appendix B.

DISCUSSION AND RECOMMENDATIONS

1. Soil Strata

Tower No. 1

A medium firm gravelly silty fine to medium sand was encountered to a depth of 4.0 feet. This layer contained slight clay binder and approximately 30 to 40 percent gravel, cobbles and boulders up to 24 inches in diameter. Below 4.0 feet was a very firm clayey fine to medium sand with occasional boulders up to 16 inches in diameter to the depth of 7.5 feet. This was underlain by very firm and gravelly clayey fine to medium sand with approximately 30 percent gravel and cobbles up to 6 inches in diameter to a depth of 8.5 feet that was underlain by very firm clayey very fine to fine sand to the limit of exploration at 27.0 feet, where further drilling could not be made due to cementation. Lenses of silty clay layers up to 1 inch thickness were encountered between the depths of 18.8 and 22.0 feet.

Neither ground water nor caving was encountered in the boring.

Tower No. 4

The upper 4.0 feet of the soils consisted primarily of gravelly silty fine to medium sand that were loose in the upper 1.5 feet and graded to very firm with clay binder and about 30 percent gravel and cobbles up to 4 inches in diameter between the depths of 1.5 feet and 4.0 feet. From 4.0 feet to 7.0 feet, the soils were very firm gravelly clayey fine to medium sand. These were underlain by a very firm clayey fine to medium sand with alternating merging layers of slightly clayey fine to medium sand to the depth of 10.0 feet. Very firm gravelly clayey fine to medium sand was found below 10.0 feet and to 24.0 feet where the boring was terminated due to large boulders. The gravelly clayey fine to medium sand layer contained approximately 30 percent gravel and cobbles up to 6 inches in diameter between the depths of 10.0 feet and 13.0 feet that increased to 40 to 50 percent gravel and cobbles up to 7 inches in diameter below that depth to 23.0 feet. Boulders up to 18 inches in diameter were encountered within the last foot of boring.

No ground water was encountered in the boring.

Tower No. 12

A loose and porous clayey very fine to fine sand was underlain at a depth of 4.8 feet by a firm clayey fine to medium sand to a depth of 8.0 feet. Below 8.0 feet was a medium compact fine to medium sand that was underlain by a medium compact fine to medium sand alternating with layers of clayey fine to medium sand to a depth of 21.0 feet. Gravelly fine to medium sand alternating with layers of clayey fine to medium sand were found below 21.0 feet and to the end of boring at 24.0 feet. Approximately 40 to 50 percent gravel and cobbles up to 7 inches in diameter were found within the last foot of the boring. No progress in drilling could be made due to large cobbles and caving below 24.0 feet.

Ground water was encountered below 19.0 feet in depth.

Tower No. 22

A very firm gravelly fine sandy clay with approximately 15 to 20 percent gravel and cobbles to 4 inches in diameter was encountered to a depth of 2.5 feet and was underlain by a medium firm fine sandy clay with lenses of white clayey very fine to fine sand to the depth of 5.0 feet. A very firm clayey very fine to fine sand was encountered between 5.0 and 13.5 feet and was underlain by silty clay between 13.5 and 19.5 feet. The silty clay layer between the depth of 13.5 feet and 19.5 feet was highly fractured and slickensided. Very firm clayey fine to medium sand was found between 19.5 and 23.5 feet and was underlain by very firm silty clay to 27.0 feet. A very firm and very fine to fine sandy clay was encountered between 27.0 feet and the end of boring at 30.0 feet.

Neither ground water nor caving was encountered in this boring.

Tower No. 26

A silty fine to medium sand derived from decomposed granite was encountered to a depth of 3.8 feet. This layer was medium firm and porous, and contained some coarse grains and clay binder in the upper 1.8 feet and graded to firm in consistency between 1.8 and 3.7 feet. Below 3.7 feet was a very firm and gravelly silty fine to coarse sand to the end of boring at 15.2 feet. This layer contained 20 to 25 percent gravel to 1 inch in diameter with chunks of less weathered granitic rock and slight clay binder between the depths of 3.8 and 6.0 feet. Some cemented layers up to 1 inch thickness with a silty clay coating were encountered between the depths of 6.0 and 8.7 feet. Zones of 1.5 inches thickness of a less weathered granitic formation were found below 13.5 feet. No progress in drilling could be made below a depth of 15.2 feet due practical refusal in the in place rock.

Neither ground water nor caving was encountered in this boring.

Tower No. 30

A firm silty fine to medium sand with slight clay binder was encountered to a depth of 2.8 feet. This was underlain by a very firm residual soil of decomposed granite in the form of gravelly and slightly clayey fine to coarse sand to the end of boring at 12.0 feet. This layer contained approximately 25 to 30 percent highly fractured but less weathered granitic fragments. No progress in drilling could be made below 12.0 feet due to practical refusal on the rock.

Neither ground water nor caving was encountered in the boring.

Tower No. 74

Loose, gravelly silty very fine to fine sand with 20 percent gravel and cobbles to 6 inches was encountered to 0.6 foot. Very firm clayey fine to medium sandy gravel with 50 to 60 percent well-graded gravel and cobbles up to 12 inches in diameter was encountered between 0.6 foot and 30.3 feet. The sandy gravel layer contained pockets of fine sandy clay between the depth of 2.5 and 3.5 feet. Below 30.3 feet was a very firm slightly clayey fine to medium sand to the end of boring at 31.0 feet.

Neither ground water nor caving was encountered during exploration.

Tower No. 78

A medium firm and slightly porous silty clay layer was underlain at a depth of 1.7 feet by a medium firm silty very fine to fine sand containing lenses of silty clay to a depth of 3.5 feet. Below this depth was a firm and highly fractured very fine sandy clay layer with white lenses of silty very fine to fine sand to a depth of 15.0 feet, that then merged to very firm clayey very fine to fine sand to the end of boring at 31.0 feet. The clayey sand layer contained pockets of brown fine sandy clay between the depths of 20.5 feet and 22.0 feet and lenses of white silty fine sand between the depths of 22.0 feet and 25.7 feet. Cemented fine sandy clay layers up to 3 inches in thickness were also encountered between the depths of 25.7 and 28.0 feet.

Neither ground water nor caving was encountered in the boring.

2. Soil Parameters

In plotting the direct shear test data, the peak values of all tested specimens were used. The tested angle of internal friction and apparent cohesion values were determined from the possible combinations of two or three tested peak values if the three tested specimens did not fall on the same resistance envelope. In some instances, where the direct shear test results were unusually high or quite inconsistent, the causes of variations were analyzed, and the recommended values for the angle of internal friction and cohesion presented in the "Table of Shear Test Results" have been reduced on the basis of the analyses, judgement and comparing the data of similar materials with similar densities and resistances to penetration (drive energy). Some of these factors, but not all of them, have been used in the analyses to determine the final recommended values. The "Table of Shear Test Results" are presented on the attached pages 8 and 9, and the unit weights of the soils are found on the Summary Sheets, Drawing Nos. 30 to 43, inclusive, at the end of this report.

The soil conditions at Tower No. 12 are recent alluvium and therefore the strengths of the soils are relatively low compared with other tower locations. The present water level on April 27, 1972 was measured at 19 feet below the present ground surface. If it is desired that the design at this location assume the water level rising to the point where normal footings may not be safely used, then supplemental calculations for driven 8 inch steel "H" piles can be made and a pile design curve submitted upon request.

Respectfully submitted,

BENTON ENGINEERING, INC.

By S. H. Shu

S. H. Shu, Civil Engineer

Reviewed by Philip H. Benton

Philip H. Benton, Civil Engineer

Distr: San Diego Gas & Electric Company, San Diego
(3) Attention: Mr. John Burton
San Diego Gas & Electric Company, Chula Vista
(2) Attention: Mr. Lloyd Wilson, Construction

SHS/PHB/ew

TABLE OF SHEAR TEST RESULTS

Tower No.	Sample No.	Depth in Feet	Soil Description	Shear Resistance in kips/sq ft. Under Normal Load of			Apparent Cohesion (lb/sq ft)		Angle of Internal Friction (Degrees)	
				0.5	1.0	2.0	Tested	Recommended	Tested	Recommended
				(Kips per sq. ft.)						
1	1	6.0	Clayey fine to medium sand	0.60	0.92	2.38	280	280	32	32
	2	10.0	Clayey very fine to fine sand	3.16	1.67	3.68	1050+	1050	32	32
	3	15.0	Clayey very fine to fine sand	0.83	2.08	4.84	520+	520	32+	32
4	1	9.0	Alternating layers of slightly clayey and clayey fine to medium sand	0.78	1.69	2.64	320	320	43	40
12	1	5.0	Clayey fine to medium sand	0.49	-	0.94	330	330	16	16
	2	10.0	Fine to medium sand	0.39	0.69	1.63	80	80	30	30
	3	15.0	Fine to medium sand alternating with layers of clayey fine to medium sand	0.58	-	1.39	310	310	28	28
22	2	4.0	Fine sandy clay	0.41	0.60	1.51	220	220	21	21
	4	10.0	Clayey very fine to fine sand	1.42	2.05	2.59	1150	1150	28	28
	5	15.0	Silty clay	1.21	1.30	2.29	1125	1125	9	9
26	2	5.0	Gravelly silty fine to coarse sand	TOO ROCKY AND FRACTURED, UNABLE TO TEST						43
	3	9.0	Gravelly silty fine to coarse sand	TOO ROCKY AND FRACTURED, UNABLE TO TEST						43
30	1	1.0	Silty fine to medium sand	0.33	0.94	1.17	60	60	29	29
	2	5.0	Gravelly slightly clayey fine to coarse sand, decomposed granite	TOO ROCKY AND FRACTURED, UNABLE TO TEST						43
	3	9.0	Gravelly slightly clayey fine to coarse sand, decomposed granite	TOO ROCKY AND FRACTURED, UNABLE TO TEST						43

TABLE OF SHEAR TEST RESULTS

Tower No.	Sample No.	Depth in Feet	Soil Description	Shear Resistance in kips/sq ft Under Normal Load of (Kips per sq ft)			Apparent Cohesion (lb/sq ft)		Angle of Internal Friction (Degrees)	
				0.5	1.0	2.0	Tested	Recommended	Tested	Recommended
74	2 3 4	7.0 11.0 16.0	All clayey fine to medium sandy gravel	ALL SAMPLES WERE EITHER TOO LOOSE, DISTURBED, OR TOO GRAVELLY TO BE TESTED						40
78	1	2.0	Silty very fine to fine sand	0.55	0.69	1.17	210	210	26	26
	2	6.0	Very fine sandy clay	1.66	1.85	3.24	1460	1460	21	21
	3	11.0	Very fine sandy clay	0.69	1.48	2.10	390	390	31	31
	4	16.0	Clayey very fine to fine sand	3.74	3.84	3.91	3620	3620	12	12

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Escondido

SUMMARY SHEET

TOWER NO. 1

30' East of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0	Ⓝ		Brown, Dry, Medium Firm, Slight Clay Binder, 30 to 40 Percent Gravel, Cobbles and Boulders to 24 Inches	GRAVELLY SILTY FINE TO MEDIUM SAND					
2			24 Inch Boulders						
4	①		Light Red-brown and Light Brown, Slightly Moist, Very Firm, Some Coarse Grains, Occasional Gravel to 1/2 Inch, Slightly Micaceous	CLAYEY FINE TO MEDIUM SAND	11.4	9.6	103.2		
7			16 Inch Boulder						
8			Light Red-brown, Slightly Moist, Very Firm, 30 Percent Gravel and Cobbles to 6 Inches	GRAVELLY CLAYEY FINE TO MEDIUM SAND					
9	②		Light Gray and Red, Slightly Moist, Very Firm	CLAYEY VERY FINE TO FINE SAND	30.8	17.2	105.6		
11			Red						
12			15 Inch Layer Slightly Cemented						
13	③		Light Gray and Light Brown		22.7	15.4	102.1		
17			Light Gray, Cemented 6 Inch Layer						
18									

Continued on Drawing No. 31

○ - Indicates undisturbed drive sample

Ⓝ - Sample not recovered

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Escondido

SUMMARY SHEET
TOWER NO. 1 (Cont.)

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL	SUMMARY SHEET TOWER NO. 1 (Cont.)		DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
18		▨	Light Gray, Slightly Moist, Very Firm	CLAYEY VERY FINE TO FINE SAND					
19		▨	Lenses of Moist Silty Clay to 1 Inch, to 22 Feet						
20	④	▨			27.6	19.3	106.2		
21		▨							
22		▨							
23		▨							
24		▨							
25	⑤	▨			54.5	13.5	103.5		
26		▨							
27									

PROJECT NO.
72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO.
31

JOB NAME San Diego Gas & Electric Co., 230 KV line, Escondido

SUMMARY SHEET

TOWER NO. 4

34 Feet Southwest of Station 65+80.33

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.
0			Brown, Dry, Loose, 20 to 30 Percent Gravel, Topsoil	GRAVELLY SILTY FINE TO MEDIUM SAND				
2			Very Firm with Clay Binder, 30 Percent Gravel and Cobbles to 4 Inches					
3			Slightly Moist					
4			Brown, Moist, Very Firm	GRAVELLY CLAYEY FINE TO MEDIUM SAND				
7			Brown, Moist, Very Firm, Occasional Gravel	CLAYEY FINE TO MEDIUM SAND & ALTERNATING AND MERGING LAYERS OF SLIGHTLY CLAYEY FINE TO MEDIUM SAND				
9	①				11.4	8.9	103.3	
11			Brown, Moist, Very Firm, 30 Percent Gravel and Cobbles to 6 Inches	GRAVELLY CLAYEY FINE TO MEDIUM				
13			40 to 50 Percent Gravel and Cobbles to 7 Inches					
20								

Continued on Drawing No. 33

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	32

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Escondido

SUMMARY SHEET
TOWER NO. 12

16 Feet South of Tower Centerline

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0			Dark Grey-brown, Dry, Loose, Porous, Topsoil	CLAYEY VERY FINE TO FINE SAND					
2			Slightly Moist						
5	①		Gray, Slightly Moist, Firm,	CLAYEY FINE TO MEDIUM SAND	5.7	12.2	92.6		
8			Gray, Moist, Medium Compact	FINE TO MEDIUM SAND					
10	②				3.2	4.7	93.4		
13			Gray, Moist, Medium Compact, Occasional Gravel to 1 Inch, Slightly Porous	FINE TO MEDIUM SAND ALTERNATING WITH LAYERS OF CLAYEY FINE TO MEDIUM SAND					
15	③				3.2	9.9	96.0		
19		Water ▽	Saturated						
20	④				3.2	26.2	98.1		
21									

Continued on Drawing No. 35

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	34

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Escondido

SUMMARY SHEET

TOWER NO. 12 (Cont.)

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
21		▨	Gray, Saturated, Medium Compact, 30 to 40 Percent Gravel	GRAVELLY FINE TO MEDIUM SAND ALTERNATING WITH LAYERS OF CLAYEY FINE TO MEDIUM SAND					
22									
23		▨	40 to 50 Percent Gravel and Cobbles to 7 Inches						
24									

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	35

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Escondido

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL	SUMMARY SHEET TOWER NO. 4 (Cont.)		DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
20			Brown, Moist, Very Firm, 40 to 50 Percent Gravel and Cobbles to 7 Inches	GRAVELLY CLAYEY FINE TO MEDIUM SAND					
21									
22			With Cobbles to 12 Inches						
23			With Boulders to 18 Inches						
24									

PROJECT NO. 72-2-27A	BENTON ENGINEERING, INC.	DRAWING NO. 33

BENTON ENGINEERING, INC.
APPLIED SOIL MECHANICS — FOUNDATIONS
6741 EL CAJON BOULEVARD
SAN DIEGO, CALIFORNIA 92115

PHILIP HENKING BENTON
PRESIDENT - CIVIL ENGINEER

SAN DIEGO: 583-5654
LA MESA: 469-5654

September 18, 1972

San Diego Gas & Electric Company
P. O. Box 1831
San Diego, California 92112

Attention: Mr. John Burton

Subject: Project No. 72-2-27A
Addendum to Supplement of
September 11, 1972
Mission-Escondido Line
San Diego County, California

Gentlemen:

In compliance with your telephonic request, we are submitting herewith our recommended values of apparent cohesion (c), angle of internal friction (Φ), and unit field density (γ), to be used in connection with the design of the foundation for the proposed Tower 12 of the San Diego Gas & Electric Company "Mission-Escondido Line." These values of c and Φ were obtained by first saturating and then shearing soil samples obtained from different depths of the boring drilled for that tower. (The detailed log of the soils encountered in that boring were presented in the form of Summary Sheets, Drawing Nos. 1A, 2A and 3A, in our report dated September 11, 1972.) After being saturated the samples were sheared under varying normal loads between plastic membranes to restrict drainage; the results of these shear tests are presented as follows:

	Normal Load in kips/sq ft	Maximum Shear Load kips/sq ft	Angle of Internal Friction Degrees	Apparent Cohesion lb/sq ft
Sample 1	0.5	0.31	16.0	150
Depth: 3.0 feet	1.0	0.34		
	2.0	0.83		
Sample 2	0.5	2.15	35.0	1225
Depth: 8.0 feet	1.0	1.95		
	2.0	3.21		
Sample 3	0.5	1.54	14.0	1410
Depth: 13.0 feet	1.0	1.69		
	2.0	1.83		
Sample 4	0.5	0.53	32.0	225
Depth: 18.0 feet	1.0	1.17		
	2.0	1.78		

	Normal Load in kips/sq ft	Maximum Shear Load kips/sq ft	Angle of Internal Friction Degrees	Apparent Cohesion lb/sq ft
Sample 5	0.5	2.35	40.0 *	1900
Depth: 28.0 feet	1.476	3.18		
	2.0	4.35		
Sample 6	0.5	1.02	38.0	640
Depth: 33.0 feet	1.0	1.14		
	2.0	2.19		

* Arbitrarily reduced

The values of unit weight (γ) to be used will depend on the intended use. Unit dry densities are shown on Drawing Nos. 1A, 2A and 3A referred to above. Unit weights at field moisture content (as of the date of our drilling) and unit weights under conditions of submergence in ground water, are presented as follows:

Sample No.	Depth in Feet	Soil Type	Unit Weight at Field Moisture * lb/cu ft	Buoyant Unit Weight lb/cu ft
1	3.0	Clayey fine sand	81.2	45.7
2	8.0	Clayey fine to medium sand	119.7	64.1
3	13.0	Fine to medium sandy clay	128.0	66.9
4	18.0	Fine to medium sand	110.5	62.1
5	28.0	Clayey fine to medium sand	129.0	69.0
6	33.0	Slightly clayey fine to medium sand	130.0	69.0

* As of August 28, 1972

It is recommended that the values of c, Φ and γ shown in the above tabulations be used for the soil strata from which the samples were obtained. For the stratum of gravelly fine to medium sand found between the depths of 21.5 and 27.0 feet, it is recommended that the values of c, Φ and γ pertaining to Sample 4 be used.

Respectfully submitted,

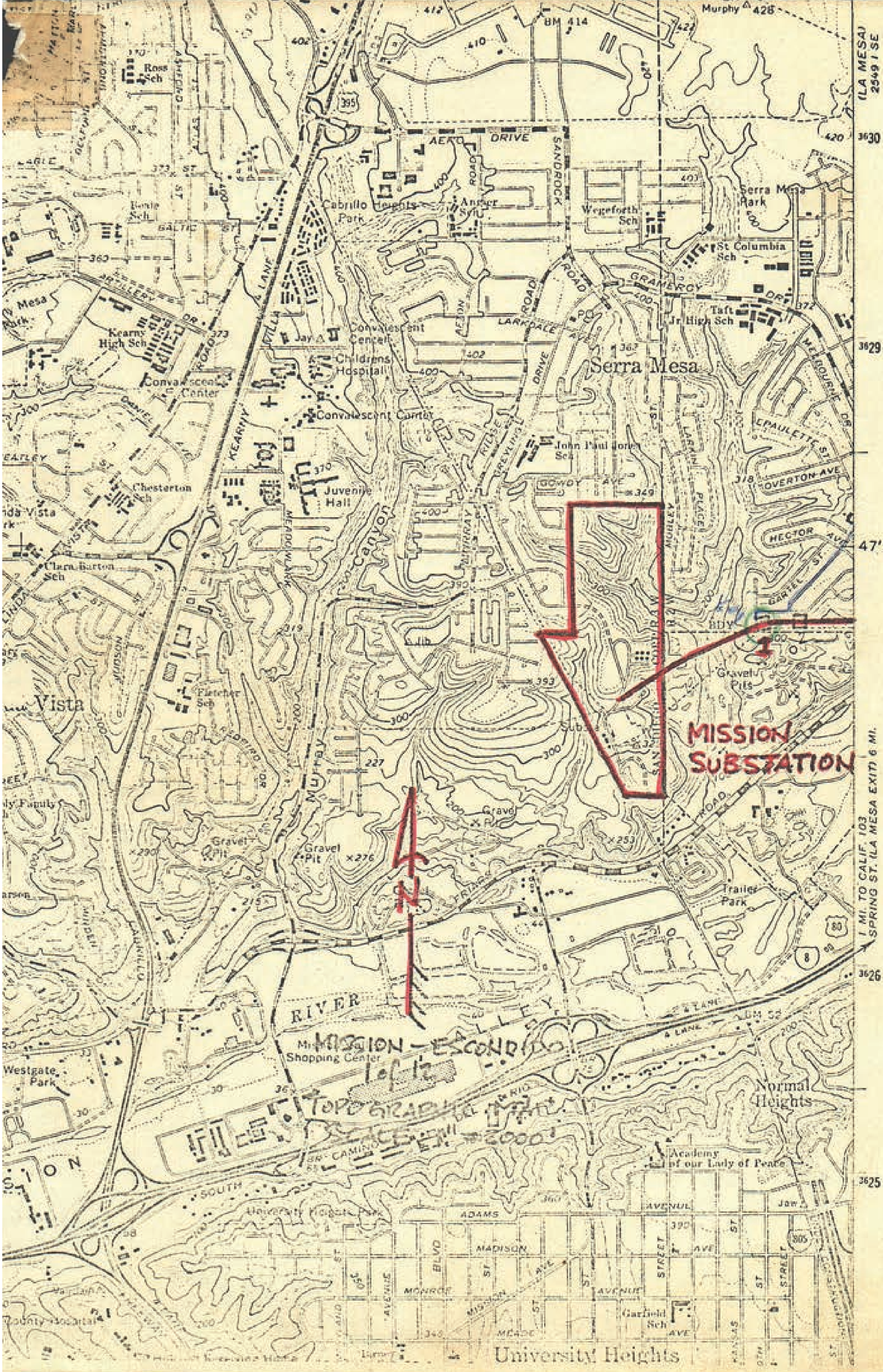
BENTON ENGINEERING, INC.

By MV Pothier
M. V. Pothier, Civil Engineer

Distr:
(1) Addressee
(2) Pioneer Service & Engineering Company
Attention: Mr. Stefan Trausch
(Enclosures - 2 copies of our report to San Diego Gas & Electric Company dated September 11, 1972)

MVP/ew

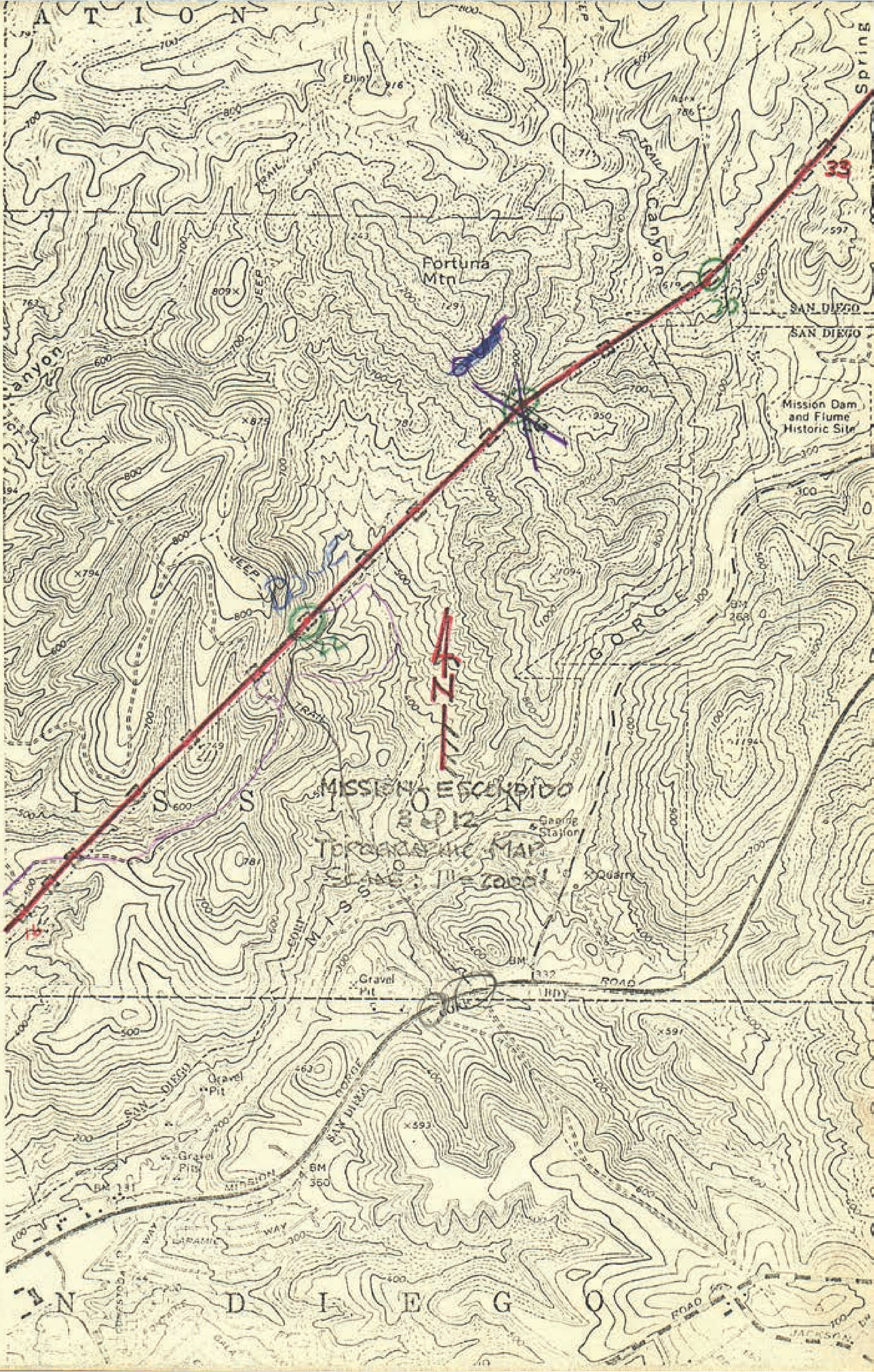
APPENDIX C



MISSION SUBSTATION

N

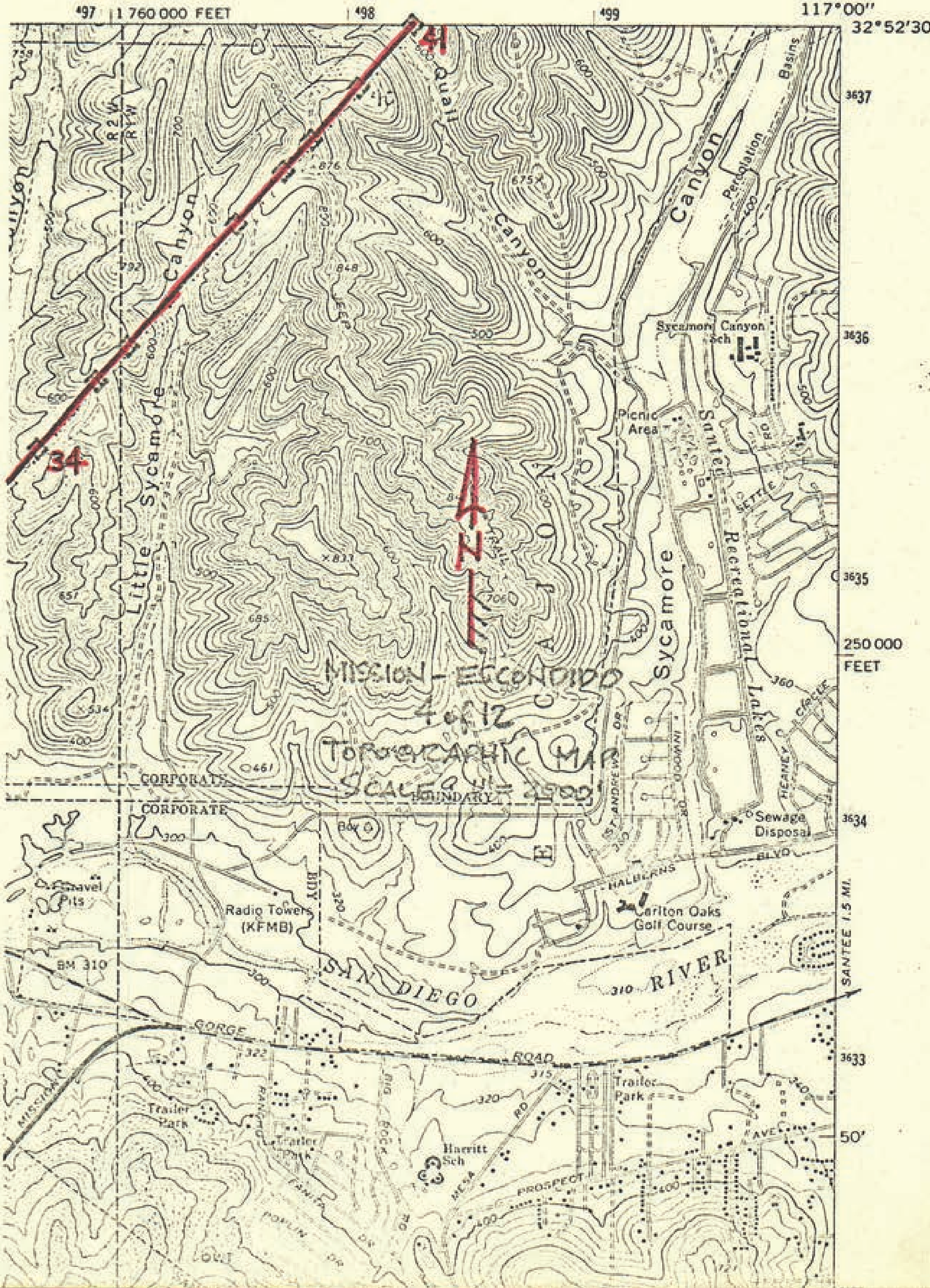
MISSION-ESCONDIDO
1 of 12
TOPOGRAPHIC MAP
SCALE 1" = 2000'


MISSION - ESCONDIDO
2-12
TOPOGRAPHIC MAP
SCALE: 1"=2000'
4
NLL
33
16
Fortuna Mtn
1291
Canyon
Mission Dam and Flume Historic Site
SAN DIEGO
GORGE
Gaging Station
Quarry
Gravel Pit
MISSION
SAN DIEGO
ROAD
JEEP
TRAIL
LAPARNIE
WAY
JACKSON
809
875
794
749
781
950
1094
1194
786
597
591
593
263
BM 268
BM 332
BM 350
BM 131
I S S I O N
M I S S I O N
N D I E G O
A T I O N
Spring

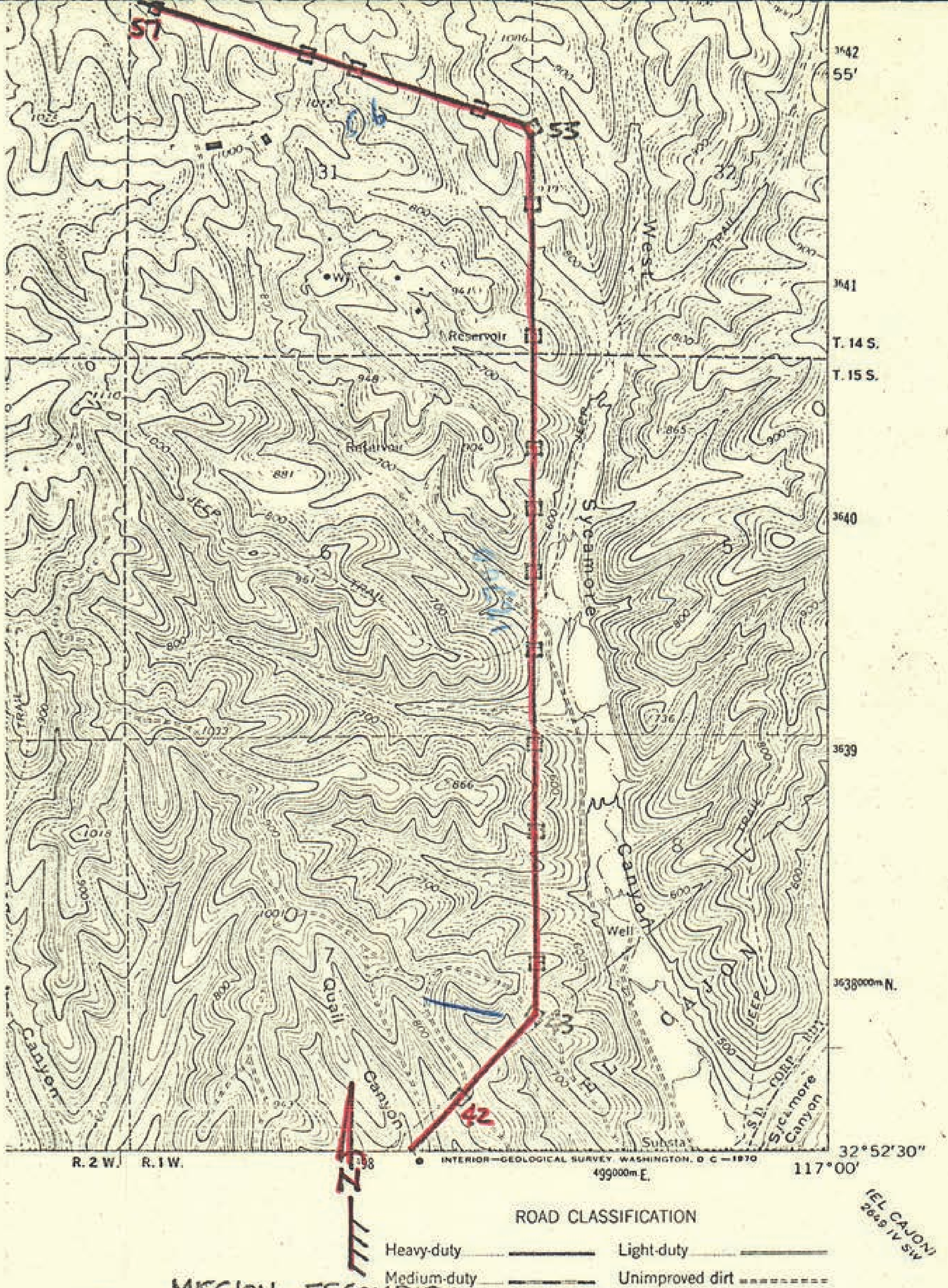
WHT
22

LA MESA QUADRANGLE
CALIFORNIA—SAN DIEGO CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
SE/4 LA JOLLA 15' QUADRANGLE

2649 IV NW
(SAN VICENTE RESER



MISSION-ESCONDIDO
4 of 12
TOPOGRAPHIC MAP
SCALE 1" = 2000'



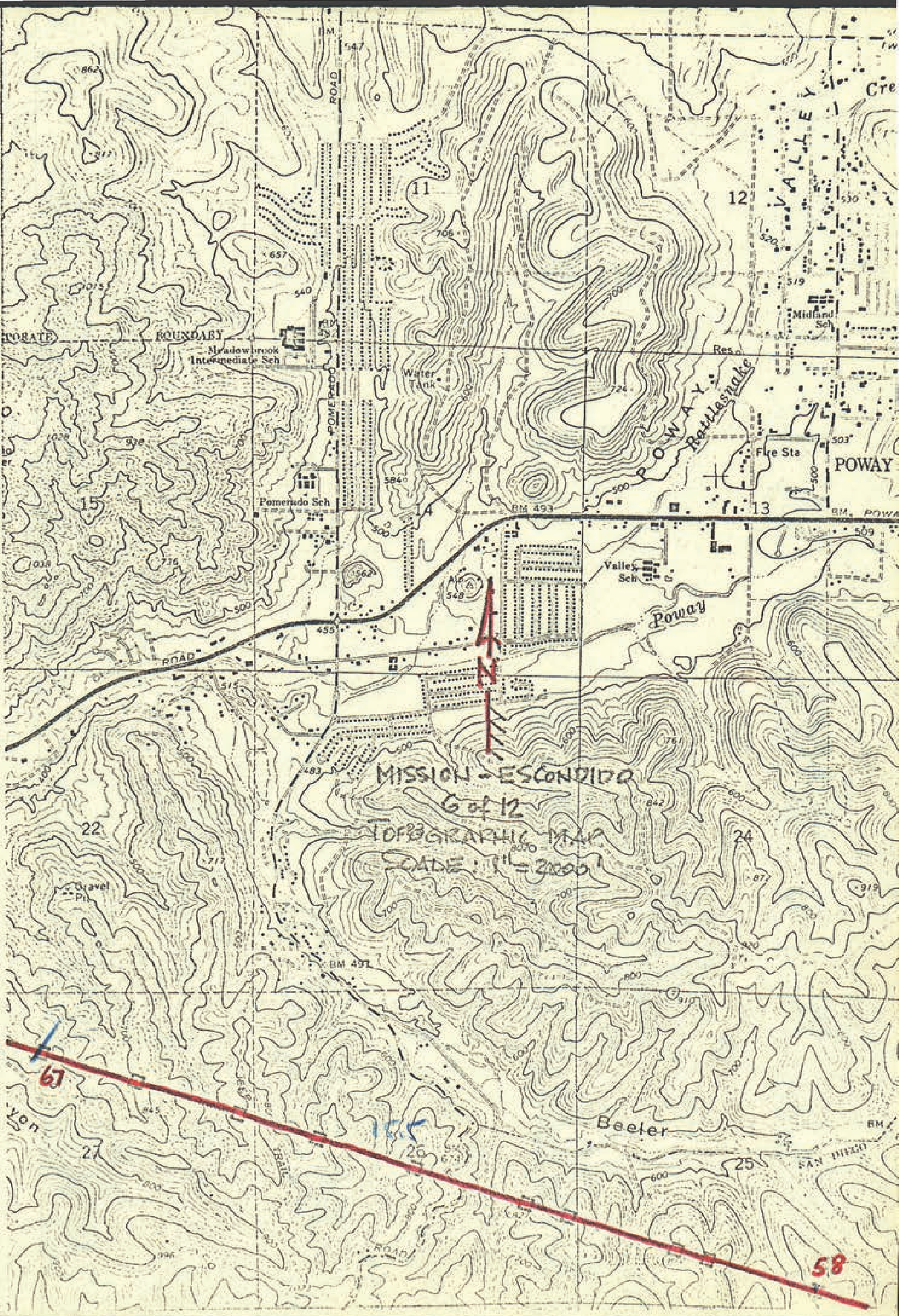
MISSION-ESCONDIDO
5 of 12
TOPOGRAPHIC MAP
SCALE: 1" = 2000'

QUADRANGLE LOCATION

POWAY, CALIF.
NE/4 LA JOLLA 15' QUADRANGLE
N3252.5—W11700/7.5

1967

AMS 2549 I NE—SERIES V895

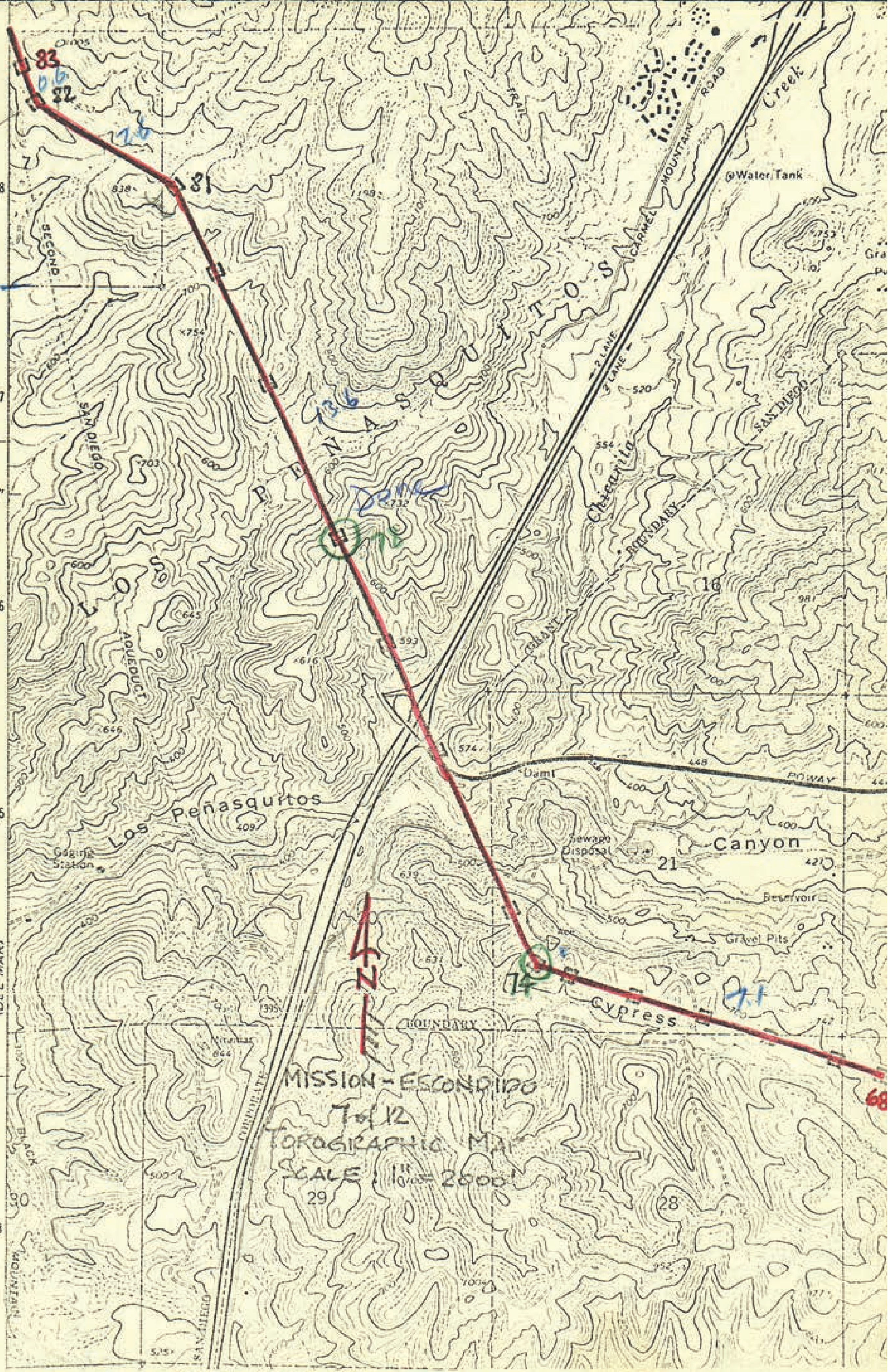


MISSION - ESCONDIDO
6 of 12
TOPOGRAPHIC MAP
SCALE: 1" = 2000'

69kV 862+20

473537

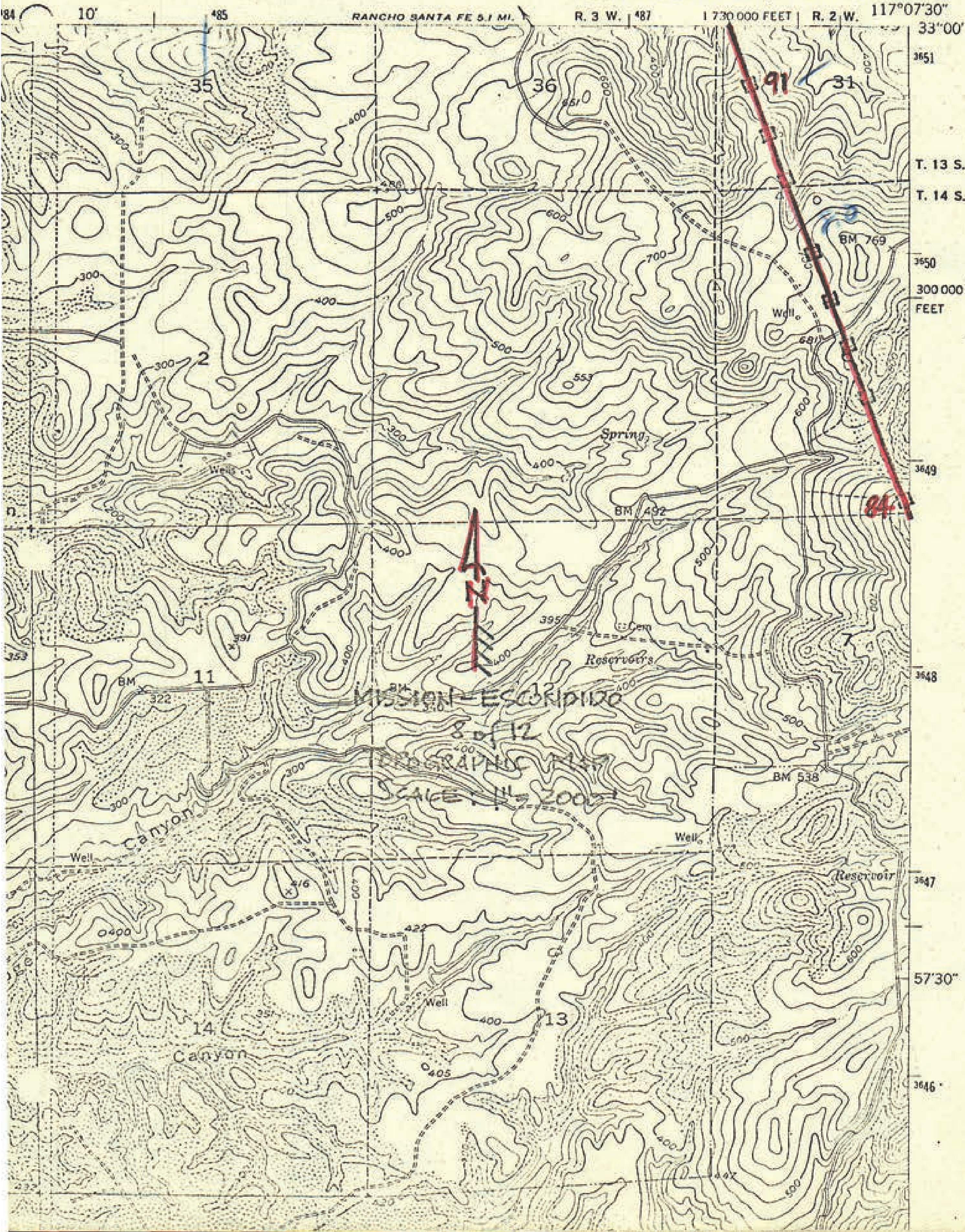
42.8
41.2
39.5 16
1.7



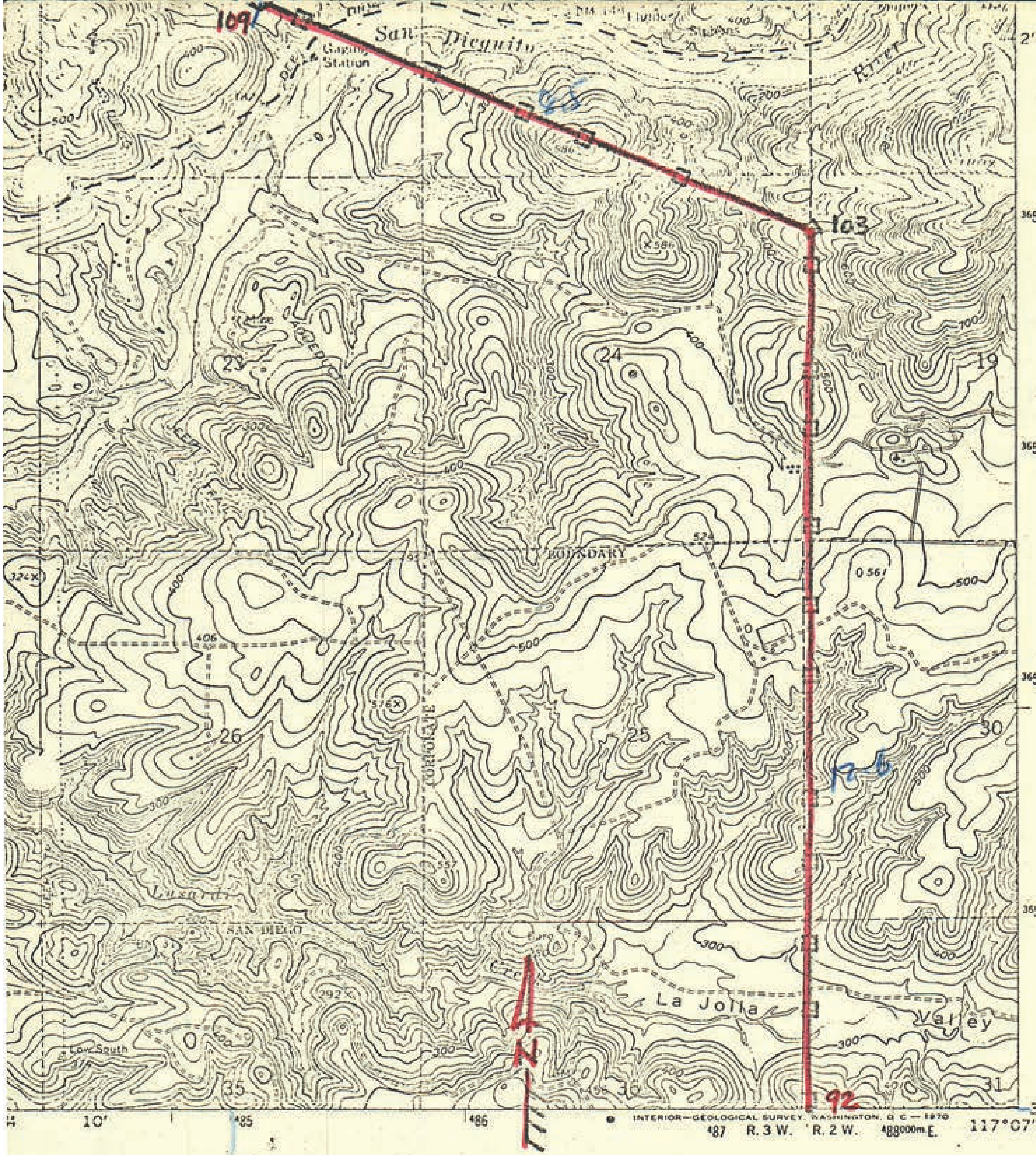
MISSION-ESCONDIDO
7 of 12
TOPOGRAPHIC MAP
SCALE: 1" = 2000'

DEL MAR QUADRANGLE
CALIFORNIA-SAN DIEGO CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

2550 II SE
(ESCONDIDO)



MISSION - ESCONDIDO
8 of 12
TOPOGRAPHIC MAP
SCALE: 1" = 2000'



(POWAY)
2549 I NE

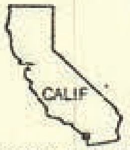
1 MILE

MISSION-ESCONDIDO
9 of 12
TOPOGRAPHIC MAP
SCALE: 1" = 2000'

ROAD CLASSIFICATION

Medium-duty ________ Light-duty ________

Unimproved dirt - - - - - - - -



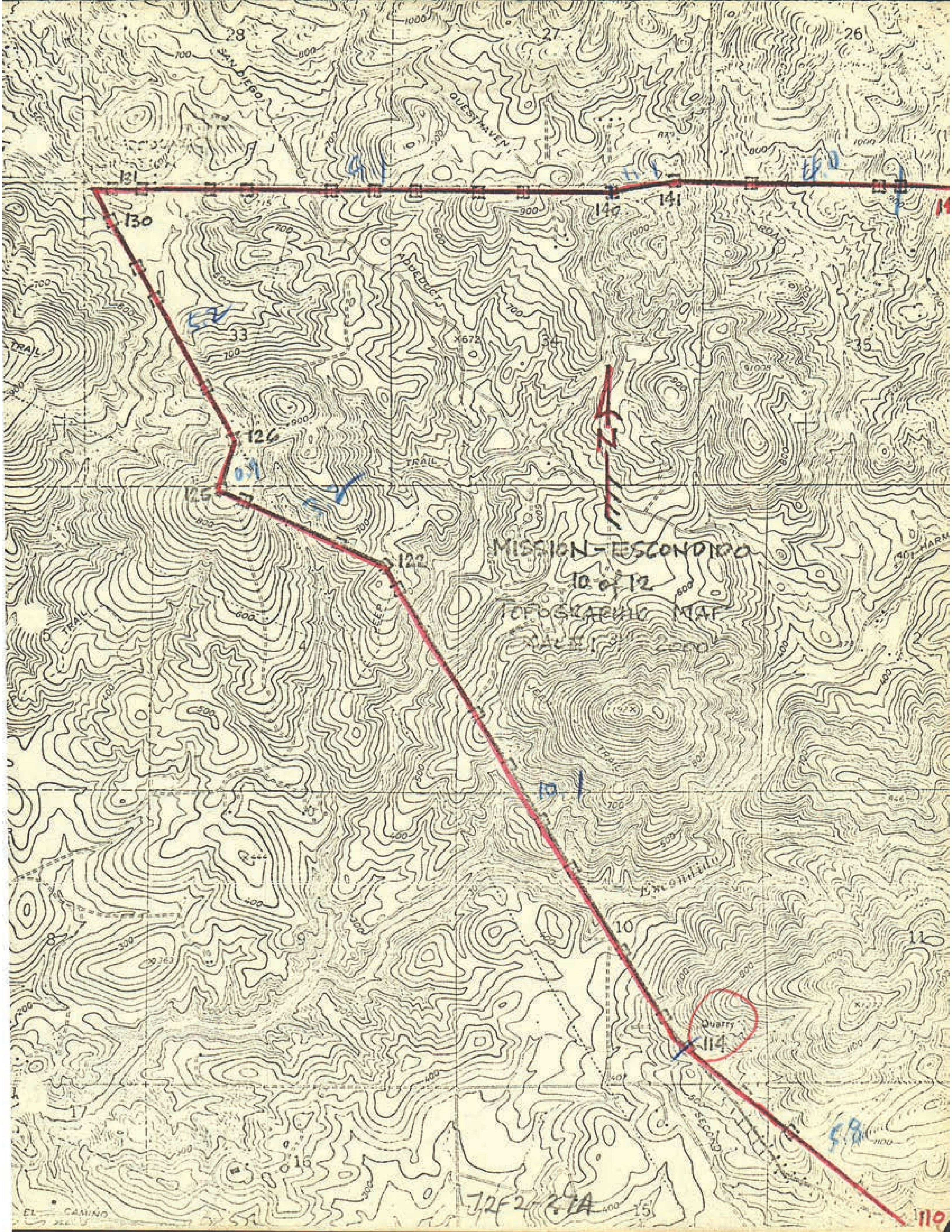
QUADRANGLE LOCATION

RANCHO SANTA FE, CALIF.
N3300—W11707.5/7.5

1968

AMS 2550 II SW—SERIES V895

20242

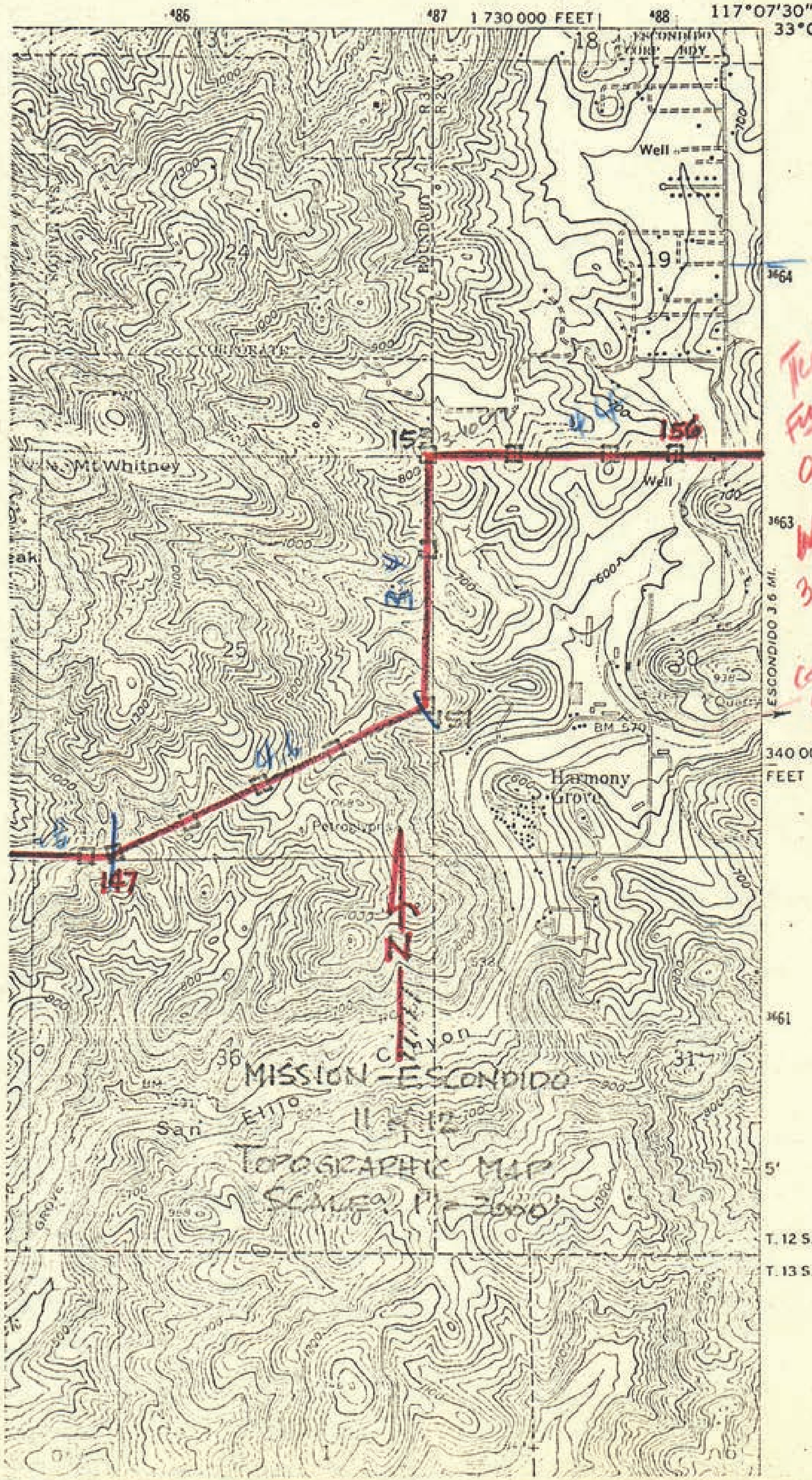


MISSION-ESCONDIDO
10 of 12
TOPOGRAPHIC MAP
SCALE 1" = 2000'

72F2-27A

RANCHO SANTA FE QUADRANGLE
CALIFORNIA–SAN DIEGO CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

2550 II NE
(VALLEY CENTER)



MISSION-ESCONDIDO
11-1-12
TOPOGRAPHIC MAP
SCALE: 1"=2000'

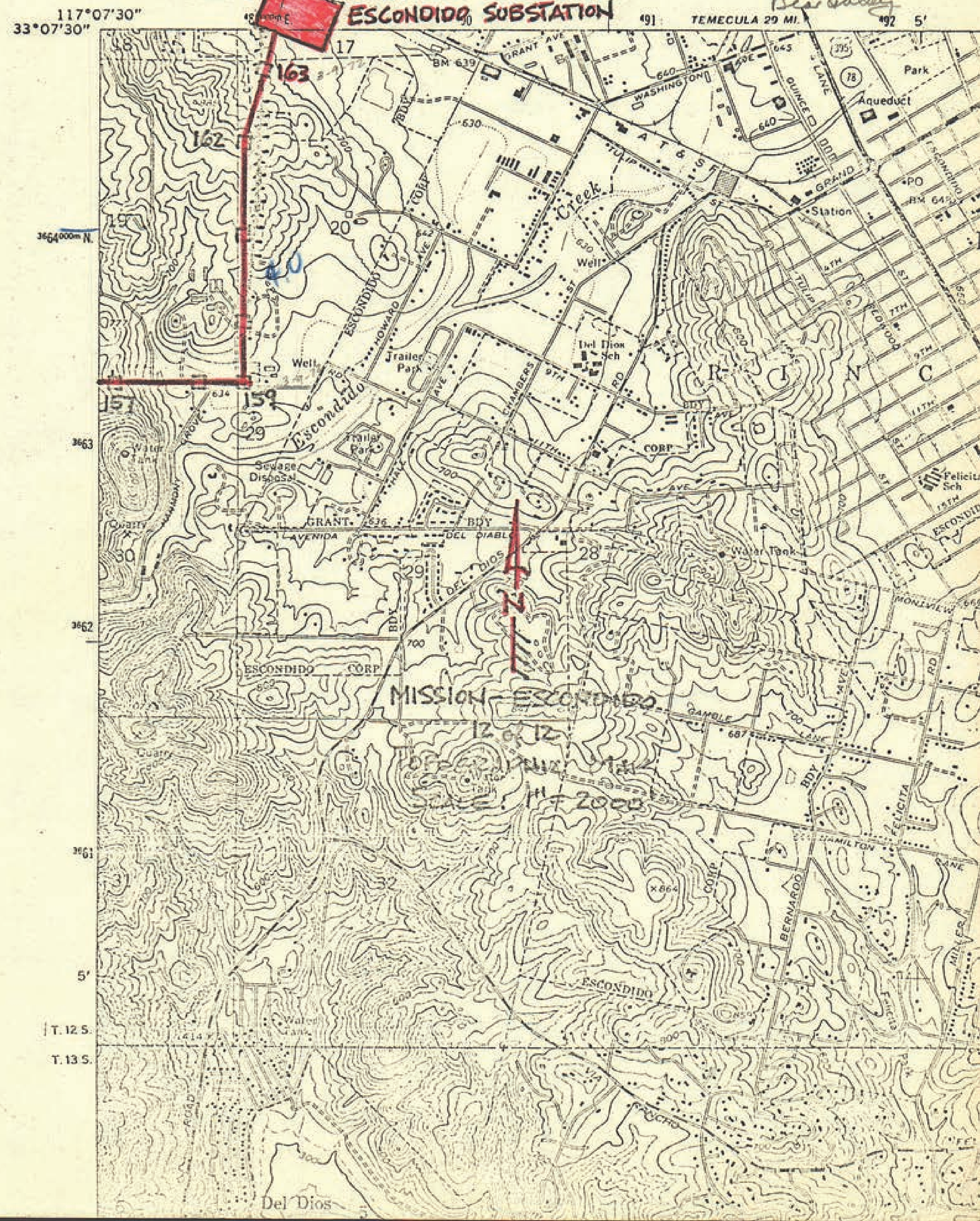
Ted Fammakotter

9AM
Wed
3-22-72

Continental Granite Co
Harmony Grove Road

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Stan Cod Station
Hwy 395
Bear Valley



G403

NSC

1A-3A

7 4A

9 Appendix

BENTON ENGINEERING, INC.
APPLIED SOIL MECHANICS — FOUNDATIONS
6741 EL CAJON BOULEVARD
SAN DIEGO, CALIFORNIA 92115

PHILIP HENKING BENTON
PRESIDENT - CIVIL ENGINEER

SAN DIEGO: 583-5654
LA MESA: 469-5654

September 11, 1972

San Diego Gas & Electric Company
P. O. Box 1831
San Diego, California 92112

Attention: Mr. John Burton

Subject: Project No. 72-2-27A, Supplement
Mission-Escondido Line
San Diego County, California

Gentlemen:

This is to present the results of a supplemental soils investigation conducted at your request at the site of the proposed Tower 12 of the San Diego Gas & Electric Company "Mission - Escondido Line." This supplemental investigation was necessitated by the fact that, during the overall investigation reported by us on May 25, 1972, the boring drilled at the site of Tower 12 had to be terminated at a depth of 24.0 feet due to a heavy concentration of gravel and cobbles, which prevented further penetration of the soils with the type of drill rig being used.

The specific objectives of this supplemental investigation were to determine the existing soil conditions and some of the major physical properties of those soils, to greater depth to enable the design of driven-pile support for the proposed tower. It is our understanding that the governing forces for which the proposed pile support must be designed are overturning couples on the order of 1000 foot kips, with piles spaced 10.0 feet center to center. In order to accomplish the stated objectives, a single boring was drilled at a location approximately 20.0 feet southeasterly of the center of the proposed tower, and representative soil samples were obtained from the boring for laboratory testing.

Field Investigation

The boring was drilled to a diameter of 6 inches with a truck-mounted rotary wash-type drill rig. The boring was drilled to a depth of 60 feet below the existing ground surface. A continuous log of the soils encountered in the boring was recorded at the time of drilling and is shown in detail on Drawing Nos. 1A to 3A, inclusive, each entitled "Summary Sheet."

The soils were visually classified by field identification procedures in accordance with the Unified Soil Classification Chart. A simplified description of this classification system is presented in the attached Appendix A at the end of this report.

Undisturbed samples were obtained at frequent intervals, where possible, in the soils ahead of the drilling. The drop weight used for driving the sampling tube into the soils weighs 300 pounds, and the average drop was 30 inches. The general procedures used in field sampling are described under "Sampling" in Appendix B.

Laboratory Tests

Laboratory tests were performed on all undisturbed samples of the soils in order to determine the dry density, moisture content, and shearing strength. The soil samples were saturated and then sheared under normal loads equivalent to those of the overlying soils at buoyant weights, for reasons which will be explained later in this report. The results of these tests are presented on Drawing Nos. 1A to 3A, inclusive.

The general procedures used for the laboratory tests are described briefly in Appendix B.

DISCUSSION AND RECOMMENDATIONS

Soil Strata

The upper 5.0 feet of soils at the boring location consisted of porous clayey fine sand that was loose to a depth of 2.0 feet and then medium loose. This layer contained some silt and rootlets, and was underlain to a depth of 10.0 feet by firm clayey fine to medium sand. Between the depths of 10.0 and 13.5 feet was firm fine to medium sandy clay with scattered gravel, and medium compact fine to medium sand was then found to a depth of 21.5 feet. From 21.5 to 27.0 feet was a stratum of medium firm to firm gravelly fine to medium sand containing some layers of clayey fine to medium sand, and then very compact clayey or slightly clayey fine to medium sand was found to a depth of 58.0 feet; this stratum contained lenses of fine sandy clay between 29.0 and 30.0 feet of depth, an intrusion of fine sand between 45.0 and 47.5 feet, and a cemented layer between 47.5 and 48.0 feet. The lower 2.0 feet of the boring, to the depth of 60.0 feet, was very compact clayey fine sand.

It is probable that the ground water level was at approximately 19 feet as previously encountered at the site but could not be verified because water and driller's mud were added at ground surface at the time of drilling.

We have been advised by the office of the San Diego County Engineer that their records indicate a water table as high as Elevation +96.0 feet during 100 year storms, at this location. For this reason it was felt that, for all practical purposes, the shearing strengths of the soils under overburdens of soils at buoyant weight should be used.

It is recommended that the necessary support be provided by driven H Bearing Piles (12 BP74 or BP53), designed in accordance with the attached Drawing No. 4A, entitled "Tower 12, Single Pile Vertical Supporting Capacities." As noted thereon, allowable resistance to uplift forces may be assumed as one-half of the vertical supporting capacities shown in the drawing. For example, a 48 feet long 12 BP74 or 12 BP53 pile should safely resist an upward force of 100 kips.

Respectfully submitted,

BENTON ENGINEERING, INC.

By MV Pothier

M. V. Pothier, Civil Engineer

BENTON ENGINEERING, INC.

Reviewed by

Philip H. Benton, Civil Engineer

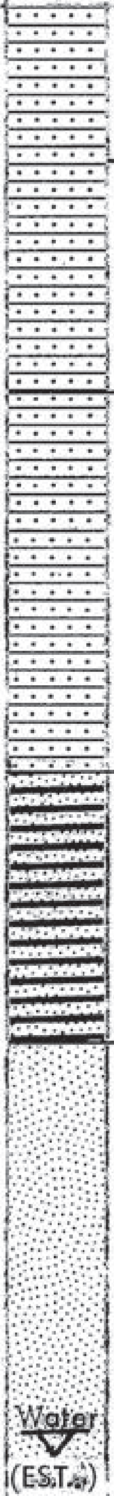
Distr: (3) Attention: Mr. John Burton
(2) Attention: Mr. Lloyd Wilson

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Escondido

SUMMARY SHEET

TOWER NO. 12

20 Feet Southeast of Tower Centerline



DEPTH IN FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.
0–2			Dark Gray-brown, Dry, Loose, Porous, Rootlets with Silt, Few Weeds on Surface	CLAYEY FINE SAND				
2–5	① (3 ft)		Slightly Moist, Medium Loose		4.5	10.5	73.5	0.13
5–10	② (8 ft)		Dark Gray-brown, Moist, Firm	CLAYEY FINE TO MEDIUM SAND	5.2	16.4	102.8	1.85
10–13½	③ (13 ft)		Dark Gray-brown with Brown, Very Moist, Firm, Occasional Gravel to 1 1/2 Inch	FINE TO MEDIUM SANDY CLAY	3.8	19.2	107.2	1.67
13½–19½	④ (18 ft)		Light Red-brown, Moist, Medium Compact, Slightly Micaceous	FINE TO MEDIUM SAND	6.0	10.6	99.9	0.80

Continued on Drawing No. 2A

○ - Indicates undisturbed drive sample.

(**) - Indicates sample not recovered.

PROJECT NO.		DRAWING NO.
72-2-27A	BENTON ENGINEERING, INC.	1A

San Diego Gas & Electric Co., 230 KV Line, Escondido

JOB NAME

SUMMARY SHEET

TOWER NO. 12 (Cont.)

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS/CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.
19								
20			Light Red-brown, Moist, Medium Compact, Slightly Micaceous	FINE TO MEDIUM SAND				
21								
22			Light Gray-brown, with Light Red-brown, Moist, Medium Firm to Firm, Layers of Clayey Fine to Medium Sand, 30 to 40 Percent Gravel, Cobbles and Boulders	GRAVELLY FINE TO MEDIUM SAND				
23	**				34.5			
24								
25								
26								
27								
28	⑤		Light Gray with Light Red, Moist, Very Compact, Slightly Micaceous	CLAYEY FINE TO MEDIUM SAND	40.5	16.5	111.0	3.18
29			Light Brown, Lenses of Gray and Brown, Fine Sandy Clay					
30								
31			Light Gray, Moist, Very Compact	SLIGHTLY CLAYEY FINE TO MEDIUM SAND				
32								
33	⑥				26.2	17.5	110.9	2.65
34								
35								
36								
37								
38	**				42.0			
39	**				115.7			
40	**				65.0			

Continued on Drawing No. 3A

JOB NAME San Diego Gas & Electric Co., 230 KV Line, Escondido

SUMMARY SHEET

TOWER NO. 12 (Cont.)

DEPTH, FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS/CU FT	SHEAR RESISTANCE KIPS/SQ FT.
40			Light Gray, Moist, Very Compact	SLIGHTLY CLAYEY FINE TO MEDIUM SAND				
41								
42								
43								
44								
45	⑦		Fine Sand Intrusion to 47.5 Feet		68.2	17.2	108.8	3.80
46								
47								
48			7 Inch Cemented Layer					
49								
50	⑧				49.5	19.2	109.9	3.67
51								
52								
53								
54								
55	⑨				65.2	18.3	107.5	5.51
56								
57								
58			Green-gray to Light Gray, Slightly Moist, Very Compact	CLAYEY FINE SAND				
59								
60	⑩				75.0	16.8	112.5	4.33

PROJECT NO. 72-2-27A

BENTON ENGINEERING, INC.

DRAWING NO. 3A

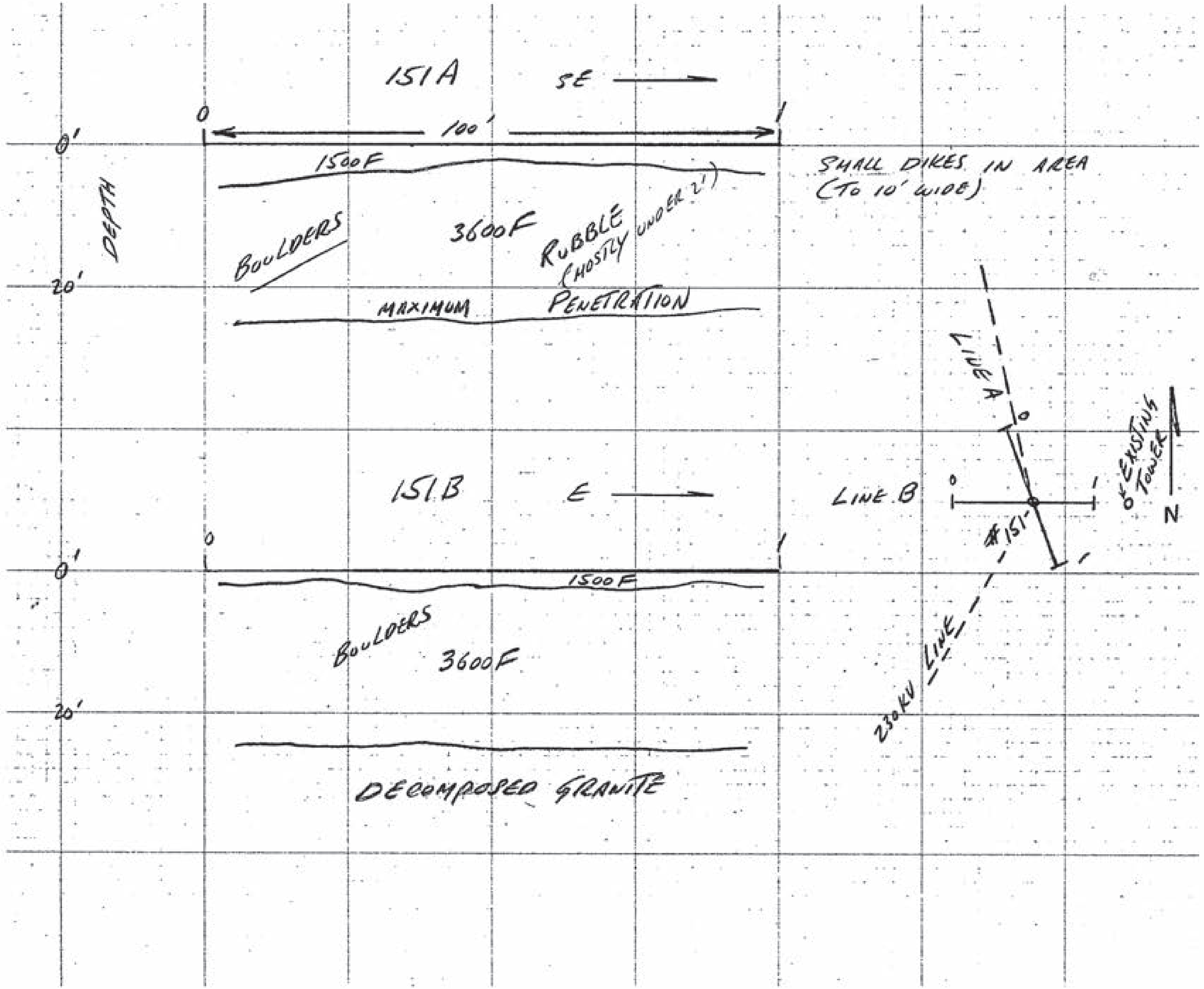
Pool ______
Foundation ______
Sewer ______
Cut-fill ______
Well ______
Soil ______
Other ______

Complete Seismic Service
For
Highways — Subdivisions — Dams
Foundations — Water — Etc.
T. FUNNEKOTTER
P. O. BOX 575
ESCONDIDO, CALIF., 92026
746-2793

File copy - do not use

Job SDG&E 230KV LINE
Location TOWER #151
Date 3-22-72

Material for excavation can be classified as to the method of removal by the use of Seismic shock waves. The harder the material, the faster shock waves travel. At a velocity of approximately 2500 ft/sec "ripping" or deep plowing is necessary --- at velocities upwards of 5000-5500 ft/sec in granitic areas ripping itself with a D-9 Caterpillar Bulldozer becomes too difficult and explosive work is needed. It is possible, then, to decide whether the ground is rippable, marginal, or non rippable by the use of Seismic shock waves. The presence and high cost of removing rock can be anticipated to help predict total costs before excavation.



G403

BENTON ENGINEERING, INC.
APPLIED SOIL MECHANICS — FOUNDATIONS
6741 EL CAJON BOULEVARD
SAN DIEGO, CALIFORNIA 92115

PHILIP HENKING BENTON
PRESIDENT — CIVIL ENGINEER

SAN DIEGO: 583-5654
LA MESA: 469-6654

September 18, 1972

San Diego Gas & Electric Company
P. O. Box 1831
San Diego, California 92112

Attention: Mr. John Burton

Subject: Project No. 72-2-27A
Addendum to Supplement of
September 11, 1972
Mission-Escondido Line
San Diego County, California

Gentlemen:

In compliance with your telephonic request, we are submitting herewith our recommended values of apparent cohesion (c), angle of internal friction (Φ), and unit field density (γ), to be used in connection with the design of the foundation for the proposed Tower 12 of the San Diego Gas & Electric Company "Mission-Escondido Line." These values of c and Φ were obtained by first saturating and then shearing soil samples obtained from different depths of the boring drilled for that tower. (The detailed log of the soils encountered in that boring were presented in the form of Summary Sheets, Drawing Nos. 1A, 2A and 3A, in our report dated September 11, 1972.) After being saturated the samples were sheared under varying normal loads between plastic membranes to restrict drainage; the results of these shear tests are presented as follows:

	Normal Load in kips/sq ft	Maximum Shear Load kips/sq ft	Angle of Internal Friction Degrees	Apparent Cohesion lb/sq ft
Sample 1	0.5	0.31	16.0	150
Depth: 3.0 feet	1.0	0.34		
	2.0	0.83		
Sample 2	0.5	2.15	35.0	1225
Depth: 8.0 feet	1.0	1.95		
	2.0	3.21		
Sample 3	0.5	1.54	14.0	1410
Depth: 13.0 feet	1.0	1.69		
	2.0	1.83		
Sample 4	0.5	0.53	32.0	225
Depth: 18.0 feet	1.0	1.17		
	2.0	1.78		

	Normal Load in kips/sq ft	Maximum Shear Load kips/sq ft	Angle of Internal Friction Degrees	Apparent Cohesion lb/sq ft
Sample 5	0.5	2.35	40.0 *	1900
Depth: 28.0 feet	1.476	3.18		
	2.0	4.35		
Sample 8, Depth 50.0 feet	0.5	1.02	38.0	360
Sample 6, Depth 33.0 feet	1.0	1.14		
	2.0	2.19		

* Arbitrarily reduced

The values of unit weight (γ) to be used will depend on the intended use. Unit dry densities are shown on Drawing Nos. 1A, 2A and 3A referred to above. Unit weights at field moisture content (as of the date of our drilling) and unit weights under conditions of submergence in ground water, are presented as follows:

Sample No.	Depth in Feet	Soil Type	Unit Weight at Field Moisture * lb/cu ft	Buoyant Unit Weight lb/cu ft
1	3.0	Clayey fine sand	81.2	45.7
2	8.0	Clayey fine to medium sand	119.7	64.1
3	13.0	Fine to medium sandy clay	128.0	66.9
4	18.0	Fine to medium sand	110.5	62.1
5	28.0	Clayey fine to medium sand	129.0	69.0
6	33.0	Slightly clayey fine to medium sand	130.0	69.0
8	50.0	Slightly clayey fine to medium sand	131.2	68.4

* As of August 28, 1972

It is recommended that the values of c, Φ and γ shown in the above tabulations be used for the soil strata from which the samples were obtained. For the stratum of gravelly fine to medium sand found between the depths of 21.5 and 27.0 feet, it is recommended that the values of c, Φ and γ pertaining to Sample 4 be used.

Respectfully submitted,

BENTON ENGINEERING, INC.

By MV Pothier
M. V. Pothier, Civil Engineer

Distr:
(1) Addressee
(2) Pioneer Service & Engineering Company
Attention: Mr. Stefan Trausch
(Enclosures - 2 copies of our report to San Diego Gas & Electric Company dated September 11, 1972)

MVP/ew

G404

Geotechnical Report

SOILS INVESTIGATION

Proposed Steel Pole
Oceanside Tie Line 697
(San Luis Rey-Oceanside 69KV Line)
617 San Luis Rey Drive
Oceanside, California

for the
San Diego Gas & Electric Company

Project No. 74-7-10A
August 22, 1974

BENTON ENGINEERING, INC.

BENTON ENGINEERING, INC.
APPLIED SOIL MECHANICS — FOUNDATIONS
6717 CONVOY COURT
SAN DIEGO, CALIFORNIA 92111

PHILIP HENKING BENTON
PRESIDENT - CIVIL ENGINEER

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SOILS INVESTIGATION

Introduction

This is to present the results of a soils investigation conducted near the proposed steel pole site located at 617 San Luis Rey Drive, Oceanside, California. The proposed steel pole is for Oceanside Tie Line 697 or San Luis Rey-Oceanside 69 KV Line of San Diego Gas & Electric Company.

The objectives of this investigation were to determine the general subsurface conditions of the site, and certain physical properties of the soils so that appropriate soil parameters could be presented for the design of proposed steel pole foundation.

In order to accomplish these objectives, one boring was drilled 11 feet north of the proposed pole location and undisturbed soil samples were obtained for laboratory testing.

Field Investigation

The boring was drilled 11 feet northerly of the proposed pole location with a truck-mounted rotary bucket-type drill rig. The drilled location is approximately 30 feet to the top of the existing steep slope. The boring was drilled to a depth of 29.5 feet below the existing ground surface. A continuous log of the soils encountered in the boring was recorded at the time of drilling and is shown in detail on Drawing Nos. 1 and 2, each entitled "Summary Sheet."

The soils were visually classified by field identification procedures in accordance with the Unified Soil Classification Chart. A simplified description of this classification system is presented in the attached Appendix A at the end of this report.

Undisturbed samples were obtained at frequent intervals, where possible, in the soils ahead of the drilling. The drop weight used for driving the sampling tube into the soils was the "Kelly" bar of the drill rig which weighs 1623 pounds, and the average drop was 12 inches. The general procedures used in field sampling are described under "Sampling" in Appendix B.

Ripper was used to aid in drilling between depths of 7.0 and 20.5 feet, and between 25.0 and 29.5 feet because of the presence of high gravel content and high rock fragments. Upon completion of drilling, the boring was backfilled and the backfilled soils were tamped by the "Kelly" bar and the bucket of the drill rig.

Laboratory Tests

Laboratory tests were performed on all undisturbed samples of the soils in order to determine the dry density and moisture content. The results of these tests are presented on Drawing Nos. 1 and 2.

The general procedures used for the laboratory tests are described briefly in Appendix B.

Direct shear tests were performed on selected undisturbed samples that were all saturated and drained prior to testing. The results of these tests are presented below:

	Normal Load in kips/sq ft	Maximum Shear Load kips/sq ft	Angle of Internal Friction Degrees	Apparent Cohesion lb/sq ft
Boring 1, Sample 1	0.5	1.05	40 *	1080
Depth: 5.0 feet	1.0	2.23		
	2.0	3.84		
Boring 1, Sample 5	0.5	0.66	36	300
Depth: 24.0 feet	1.0	1.37		
	2.0	2.09		

* Arbitrarily reduced

Attempts were made to determine the strength characteristics of the samples obtained at the depths of 10.0, 14.5, and 19.5 feet, respectively, from this boring. However, the soil samples at these depths are too rocky to obtain a good testing specimen, and therefore the strength tests of these rocky samples were omitted. It is believed that the strength characteristics of these rocky samples are more favorable than those tested.

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Soil Strata

A medium firm, slightly silty fine to medium sand fill was found in the upper 1.5 feet of the boring. The fill soils are underlain by a medium loose, slightly silty fine to medium sand to 2.3 feet, and then merged to very firm, slightly clayey fine to medium sand to 4.8 feet. Between depths of 4.8 and 20.5 feet, a very firm gravelly fine sandy clay layer was encountered. The gravelly fine sandy clay layer contained approximately 15 to 50 percent of rock fragments. Approximately 2 feet thickness of solid rock was encountered between depths of 10.0 and 12.0 feet in feet in this layer.

Below 20.5 feet, a very firm sandy clay layer was encountered to the end of boring at 29.5 feet. No progress in drilling could be made below 29.5 feet because of the presence of a hard rock layer.

No ground water was encountered in the boring.

Conclusions and Recommendations

The field exploration indicates that the boring location is underlain by an existing man-made fill and a medium loose slightly silty fine to medium sand topsoil to a depth of 2.3 feet. These upper fill and medium loose soils are considered not suitable for foundation support.

Field measurements indicate that the ground surface elevation at the boring location is approximately 6 inches higher than the ground surface elevation at the proposed steel pole location.

Assuming the soil conditions in the proposed steel pole location are similar to those encountered in the boring drilled, the recommended soil parameters for pole footing design are on the following page.

1. Strength Parameters and Unit Weight of Soils

Depth Below Existing Ground Surface in Feet	Tested Moist Unit Weight of Soils lb/cu ft	Recommended Angle of Internal Friction in Degrees	Recommended Apparent Cohesion lb/sq ft
0- 2.3	*	*	*
2.3- 4.8	135	40	1080
4.8-12.0	141.6	36	300
12.0-17.5	148.6	36	300
17.5-23.0	129.5	36	300
23.0-29.5	123.3	36	300

2. Passive Resistance of Soils

The recommended passive resistance of soils surrounding the proposed pole footings are presented below:

Depth Below Existing Ground Surface in Feet	Recommended Passive Earth Pressure lb/sq ft
0	0
2.3	0
4.8	500
12.0, and deeper	1800

The recommended maximum value is 1800 pounds per square foot.

* Not recommended for footing support

Respectfully submitted,

BENTON ENGINEERING, INC.

By S. H. Shu
S. H. Shu, Civil Engineer

Distr: San Diego Gas & Electric Company, San Diego
(2) Attention: Mr. Ed Brancheau
San Diego Gas & Electric Company, Carlsbad
(3) Attention: Mr. Lloyd Wilson

SHS/ew

San Diego Gas & Electric Company Oceanside Tie Line 697

NAME

SUMMARY SHEET

BORING NO. 1

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0–1.6			Light Brown, Dry, Medium Firm, Occasional Gravel and Cobbles to 5 Inches	SLIGHTLY SILTY FINE TO MEDIUM SAND					FILL
			Light Brown, Dry, Medium, Loose, Occasional Gravel and Cobbles to 5 Inches	SLIGHTLY SILTY FINE TO MEDIUM SAND					
			Red-brown, Moist, Very Firm, Occasional Gravel and Cobbles to 4 Inches, Partially Cemented	SLIGHTLY CLAYEY FINE TO MEDIUM SAND					
5	①				15.6	11.6	121.2		
			Gray-brown with Red-brown, Moist, Very Firm, Occasional Medium and Coarse Sand Grains, 15 to 20 Percent Rock Fragments to 2 Inches, Highly Cemented	GRAVELLY FINE SANDY CLAY					
			20 to 30 Percent Rock Fragments to 2 Inches						
			Light Olive-gray with White Streaks						
10	②				39.0	7.8	131.5		
			2 Foot Layer of nearly Solid Rock						
			40 to 50 Percent Rock Fragments to 2 Inches						
14	③				43.3	5.5	141.0		
15									

Continued on Drawing No. 2

○ - Indicates Undisturbed Drive Sample

(NR) - Indicates Sample Not Recovered

PROJECT NO.		DRAWING NO.
74-7-10A	BENTON ENGINEERING, INC.	1

San Diego Gas & Electric Com[illegible]y, Oceanside Tie Line 697

NAME

SUMMARY SHEET

BORING NO. 1 (Cont.)

DEPTH/FEET	SAMPLE NUMBER	SOIL CLASSIFICATION SYMBOL			DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WT.	DRY DENSITY LBS./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
15 16 17 18			Light Olive-gray with White Streaks, Moist, Very Firm, Occasional Medium and Coarse Sand Grains, 40 to 50 Percent Rock Fragments and Cobbles to 8 Inches, Highly Cemented	GRAVELLY FINE SANDY CLAY					
19 20	④		30 to 40 Percent Rock Fragments and Cobbles to 4 Inches		64.9	10.8	117.0		
21 22			Light Olive-gray, Moist, Very Firm, Slightly Cemented	FINE SANDY CLAY					
23 24 25 26 27 28	⑤		Light Olive-gray with Light Gray-brown, Occasional Medium and Coarse Sand Grains and Gravel to 3/4 Inch		60.0	60.0	77.2		
29	(NR)				64.0	-	-	-	
30				ROCK					

PROJECT NO. 74-7-10A

BENTON ENGINEERING, INC.

DRAWING NO. 2

BENTON ENGINEERING, INC.
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APPENDIX A

Unified Soil Classification Chart*

SOIL DESCRIPTION		GROUP SYMBOL	TYPICAL NAMES
I. COARSE GRAINED, More than half of material is larger than No. 200 sieve size.**			
GRAVELS More than half of coarse fraction is larger than No. 4 sieve size but smaller than 3 inches	CLEAN GRAVELS	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
		GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
	GRAVELS WITH FINES (Appreciable amount of fines)	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.
		GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.
SANDS More than half of coarse fraction is smaller than No. 4 sieve size	CLEAN SANDS	SW	Well graded sand, gravelly sands, little or no fines.
		SP	Poorly graded sands, gravelly sands, little or no fines.
	SANDS WITH FINES (Appreciable amount of fines)	SM	Silty sands, poorly graded sand-silt mixtures.
		SC	Clayey sands, poorly graded sand-clay mixtures.
II. FINE GRAINED, More than half of material is smaller than No. 200 sieve size.**	SILTS AND CLAYS	ML	Inorganic silts and very fine sands, rock flour, sandy silt or clayey-silt-sand mixtures with slight plasticity.
	Liquid Limit Less than 50	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
	Liquid Limit Greater than 50	CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity
III. HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils.

* Adopted by the Corps of Engineers and Bureau of Reclamation in January, 1952.

** All sieve sizes on this chart are U. S. Standard.

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APPENDIX B

Sampling

The undisturbed soil samples are obtained by forcing a special sampling tube into the undisturbed soils at the bottom of the boring, at frequent intervals below the ground surface. The sampling tube consists of a steel barrel 3.0 inches outside diameter, with a special cutting tip on one end and a double ball valve on the other, and with a lining of twelve thin brass rings, each one inch long by 2.42 inches inside diameter. The sampler, connected to a twelve inch long waste barrel, is either pushed or driven approximately 18 inches into the soil and a six inch section of the center portion of the sample is taken for laboratory tests, the soil being still confined in the brass rings, after extraction from the sampler tube. The samples are taken to the laboratory in close fitting waterproof containers in order to retain the field moisture until completion of the tests. The driving energy is calculated as the average energy in foot-kips required to force the sampling tube through one foot of soil at the depth at which the sample is obtained.

Shear Tests

The shear tests are run using a direct shear machine of the strain control type in which the rate of deformation is approximately 0.05 inch per minute. The machine is so designed that the tests are made without removing the samples from the brass liner rings in which they are secured. Each sample is sheared under a normal load equivalent to the weight of the soil above the point of sampling. In some instances, samples are sheared under various normal loads in order to obtain the internal angle of friction and cohesion. Where considered necessary, samples are saturated and drained before shearing in order to simulate extreme field moisture conditions.

Consolidation Tests

The apparatus used for the consolidation tests is designed to receive one of the one inch high rings of soil as it comes from the field. Loads are applied in several increments to the upper surface of the test specimen and the resulting deformations are recorded at selected time intervals for each increment. Generally, each increment of load is maintained on the sample until the rate of deformation is equal to or less than 1/10000 inch per hour. Porous stones are placed in contact with the top and bottom of each specimen to permit the ready addition or release of water.

Expansion Tests

One inch high samples confined in the brass rings are permitted to air dry at 105° F for at least 48 hours prior to placing into the expansion apparatus. A unit load of 500 pounds per square foot is then applied to the upper porous stone in contact with the top of each sample. Water is permitted to contact both the top and bottom of each sample through porous stones. Continuous observations are made until downward movement stops. The dial reading is recorded and expansion is recorded until the rate of upward movement is less than 1/10000 inch per hour.