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ACDC DEEP TUNNEL STUDY

SITE CONDITIONS

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SITE CONDITIONS REPORT

ACDC DEEP TUNNEL STUDY

MARICOPA COUNTY FLOOD CONTROL DISTRICT

ARIZONA

SEPTEMBER, 1988

DRAFT

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I. INTRODUCTION

1.01 General

Work on the subject project was performed in accordance with CRS Sirrine's (CRSS) proposal to the Flood Control District of Maricopa County (FCD) dated December 18, 1987. The primary purpose of CRSS's involvement with the project was to assist the FCD in evaluating an inverted siphon tunnel alternative to the Arizona Canal Diversion Channel (ACDC) for collecting and transmitting flood waters in the vicinity of the Biltmore Hotel. Both surface excavation and inverted siphon tunnel options were to be examined; taking into account such variables as subsurface conditions, cost, and community impact.

The project site is located in Sections 11, 10 and 14 T.2N, R.3E in the Sunnyslope 7.5 minute topographic quadrangle, U.S. Geological Survey (1965-73) within the City of Phoenix and is approximately bounded by Lincoln Drive to the north, the Arizona Canal to the south, 32nd Street to the east and 20th Street to the west. The location of the proposed project is shown herewith in Figure 1, Project Locust.

The purpose of the ACDC project is to collect flood waters flowing from north to south across the site area that tend to accumulate against the existing Arizona Canal. This objective is complicated in the vicinity of the Biltmore Hotel because of extensive urban development in that area. As a result, consideration is given herein to constructing this portion of the project as an inverted siphon tunnel. In particular, the cost and difficulty of constructing the project as a tunnel is compared to open-cut construction.

Several aspects of the project should be clearly described prior to discussion of subsurface conditions. As can be seen on Figure

1, the project is oriented more or less west to east beginning at Sta. 865+00 on the west and extending to Sta. 945+00 on the east. In general, two possible tunnel alignments are proposed for consideration; the first of which extends for the entire 8,000 ft described above (the long tunnel alternative) and the second of which begins at Sta. 895+00 and extends for a total length of 5,000 ft to the same end point (the short tunnel alternative). All open cut work for the proposed project must take place north of the Arizona Canal in order for the facilities to be correctly positioned to collect surface runoff. Finally, it is important to note that water in the proposed canal will flow from east to west or down station in the completed project. Hence, the water will enter at Sta. 945+00 and exit at either Sta. 895+00 for the short tunnel alternative or Sta. 845+00 for the long tunnel alternative.

1.02 Objective and Scope of Work

In order to evaluate the above alternatives it is necessary to begin with a reliable knowledge of ground conditions in the vicinity of the proposed project. Subsurface soil, rock and groundwater conditions at the site will determine to a large degree the cost of constructing the proposed tunnel. Hence, the primary objective of this investigation is to describe subsurface soil, rock, and groundwater conditions along the proposed tunnel alignment. In order to accomplish this objective CRSS undertook the following Scope of Services:

1. Accumulate all available information about the site area and devise a subsurface exploration program for the project.

2. Perform the subsurface exploration program and obtain additional detailed information about the site. Carefully log each test boring, monitor geophysical surveys and

perform geologic mapping operations. Select representative soil and rock samples for laboratory testing.

3. Make preliminary engineering analyses of available information and meet with representatives of the FCD in order to discuss results of the work. Obtain detailed design parameters from the project's hydraulic designer.

4. Summarize all available information and prepare a final report setting forth CRSS' recommendations for the proposed project.

Please note that information contained in this report is limited to a discussion of subsurface conditions only. A broader-based presentation of recommendations for the entire project will be submitted to the FCD under separate cover.

1.03 Report Organization

This report is divided into two chapters following the Introduction. Chapter II, entitled Subsurface Investigations, contains discussion of subsurface information obtained prior to this study and detailed discussion of work items used for completion of this study. Chapter III, entitled Summary of Site Conditions, contains a discussion of subsurface soil, rock and groundwater conditions encountered along the proposed alignment.

II. SUBSURFACE INVESTIGATIONS

2.01 Previous Investigations

A total of three previous studies as listed below were performed at or near the subject site.

1. "Environmental Geology of the Phoenix Mountains, Maricopa County, Arizona," by Douglas C. Shank and Troy L. Pewe of the Geology Department, Arizona State University, dated 1973, for the City of Phoenix.

2. "Gila River Basin, Phoenix, Arizona and Vicinity (Including New River), Arizona Canal Diversion Channel, 40th Street to Cactus Road (Including Cudia City Wash Sediment Basin, Cave Creek Sediment Basin, and Cave Creek Channel), Design Memorandum No. 12, Feature Design for Arizona Canal Diversion Channel -- 40th Street to Cactus Road" by U.S. Army Corps of Engineers dated April, 1986 for the Maricopa County Flood Control District.

3. "Arizona Canal Diversion Channel Tunnel Alternative Feasibility Study, Sta. 895+50 to Sta. 945+50" by CRS Sirrine, Inc., dated March, 1987, for the Maricopa County Flood Control District.

The "Environmental Geology of the Phoenix Mountains, Maricopa County, Arizona" is a study done by Douglas C. Shank and Troy L. Pewe of the Geology Department of Arizona State University. The report was commissioned by the City of Phoenix. The purpose of the report was to gather and document geological information for the Phoenix Mountains and the report contains geologic descriptions and maps of the Phoenix Mountains.

The "Gila River Basin, Phoenix, Arizona and Vicinity (Including New River, Arizona Diversion Canal, 40th Street to Cactus Road" is a report prepared by the U.S. Army Corps of Engineers for the Maricopa County Flood Control District. The ACDC has been divided into five reaches for the purpose of staged construction. The report presents a recommended plan to carry the 100-Year flood in a diversion canal north of the existing Arizona Canal. Conceptual level design and cost estimates are included for the project. The purpose of the report was to provide technical feature design for reaches 2, 3, and 4 of the ACDC as a basis for preparing the plans and specifications for construction.

The "Arizona Canal Diversion Channel Alternative Feasibility Study, Sta. 895+50 to Sta. 945+50" was prepared by CRSS, Inc. for the Maricopa County Flood Control District. The purpose of the report was to document a cost comparison of a gravity flow tunnel and a covered channel as proposed by the Corps of Engineers through the Arizona Biltmore property. The limits and location of the tunnel alternative were through the golf course around the north side of the Biltmore Hotel as specified by the FCD. The Scope of Work for this study included geotechnical investigations along the proposed tunnel alignment, conceptual level design of the tunnel, cost estimates for both the gravity tunnel and cover channel alternatives and preparation of a report documenting the results of the study.

Also contained herewith at the back of this report is a list of three additional geologic references that were used to obtain general background information about the site.

2.02 Geophysical Investigations

Prior to the start of test boring work, geophysical investigations were performed to learn as much about the ground as possible. In order to accomplish this objective a series of seismic refraction surveys were conducted along the proposed project alignment. In general, seismic refraction surveys are performed by inducing vibrations into the ground and recording the speed with which these vibrations propagate through the various layers of soil and rock. Analysis of the speed of transmission through the ground provides useful information about the stratification of ground deposits.

Seismic refraction survey work was completed at the subject site from June 17 through June 23, 1988. As completed, a total of ten survey lines numbered SL-101 through SL-110 comprising 2,600 lineal feet of survey were completed as shown on Figure 2a, 2b, and 2c, Test Boring Location Plan. Survey lines were located in areas where property access was possible and where a firm ground surface was available for performance of the test. In addition, maximum advantage was taken of existing test boring information for help in interpreting the results of the surveys. The surveys were conducted end to end as much as possible so as to provide continuous coverage along the proposed project.

Seismic refraction profiling utilized geophone receivers at each end of the seismic line which transmitted to a signal enhancement Bison Model 1570C seismograph. The induced vibrations or P-waves were generated through repeated impacts of either a 10 or 12-lb sledge at spacings of 1 to 25 ft along the seismic line. In all cases the impact energy was delivered to the seismic line from both directions so as to check reciprocity travel times. Difficulties were encountered during the seismic survey, when ambient noise levels interfered with P-wave reception. High noise levels were causes by vehicle or

pedestrian traffic near the seismic line, air traffic flying overhead, wind, and vibrations induced by machinery especially in the vicinity of the Squaw Peak Filtration Plant. Profiling difficulties were also encountered when the calichified material exhibited P-wave velocities at or above those of the bedrock. Alternating layers of highly cemented and poorly cemented caliche also affected P-wave transmission through the ground and the amount of energy that could be transmitted to deeper layers of caliche or bedrock. Detailed results of the geophysical investigation are contained herewith in Appendix A, Geophysical Investigations including time-distance graphs, best fit refractor interfaces, and ground velocities calculated in feet per second. Each data point is graded as good (g), fairly good (fg), fair (f), or poor (p) as noted on the charts. In general, the seismic data is rated as good or fairly good.

2.03 Geologic Mapping

The subject project is situated in an area where numerous bedrock outcrops are observable at ground surface. This is highly fortuitous and full advantage was taken of this fact during the field activities portion of the project. CRSS's field geologist spend 3 days observing and mapping rock outcrops and soil exposures in the vicinity of the project site between July 24, and 28, 1988. The results of this activity are presented herewith in Appendix B, Geologic Mapping. In general, rock outcrops and soil exposures were carefully mapped, strike and dip measurements of rock foliation and bedding surfaces were recorded, and representative samples of soil and rock deposits were obtained.

2.04 Test Borings

A total of three test borings were completed at the subject site during the period of July 21 through July 26, 1988. These

borings are identified as Test Borings B-201, B-202 and B-203 as shown on Figure 2, Test Boring Location Plan. The borings were advanced to depths of 99.9, 70.7 and 99.0 ft below ground surface, respectively, by Boyles Brothers Drilling Company of Phoenix, Arizona.

The borings were drilled with a Longyear Model 44 truck-mounted drill rig utilizing biodegradable liquid polymer drilling fluid. The borings were advanced with a 5-3/8-inch-diameter rock bit to a depth of 8.5 to 10.0 ft where a 4-1/2-inch-diameter surface casing was installed. The borings were then advanced with a 3-7/8-inch-diameter rock bit until the driller determined that continued rock bitting would cause excessive equipment wear. The three test borings were advanced by rock bitting in this manner to depths of 40.5, 11.5 and 38.0 ft, respectively.

Following rock bitting, the borings were advanced by wire-line diamond core drilling. Coring was accomplished through the use of a 5-ft-long, 1-7/8-inch-diameter NX Core Barrel with an impregnated diamond core bit. Coring was continued until 25 to 30 ft of bedrock had been cored or until a depth of 100 ft was approached. Upon completion, the borehole was backfilled with cement grout from the bottom to a point approximately 3 ft below ground surface. Natural soil was then placed in the borehole and compacted to bring the backfill to ground surface.

During both rock bitting and coring operations, observations were made of cutting return, circulation of drilling fluid, rate of penetration, vertical drilling pressure and drill rotation. These observations were used in a qualitative sense to describe the material being penetrated. While rock bitting, the rate of advance was controlled by the percentage of clasts present and did not necessarily reflect the degree of cementation. While coring the drilling rate was controlled by the driller in order

to obtain maximum core recovery and did not necessarily reflect the degree of either soil cementation or rock fracturing.

Upon the removal of core from the boring the core sample was inspected and logged in accordance with ASTM D2113-83. The procedures and terminology used for describing soil and rock samples are described at the beginning of Appendix C, Test Boring Reports. No Rock Quality Designation (RQD) was recorded for the core samples because it was simply not possible to determine which fractures were caused by the drilling.

All of the results of the test boring program are presented herewith in Appendix C. Subsurface profiles prepared as a result of test boring and seismic refraction data, both from this study and from the previous studies, are shown herewith in Figure 3, Subsurface Profile.

2.05 Laboratory Testing

Laboratory tests were performed on representative samples of soil and rock, both for the purpose of sample classification and to measure important engineering properties relative to tunneling operations. Samples of soil and rock were tested for unconfined compressive strength and tensile strength. The testing was conducted by CTL/Thompson, Inc. of Denver, Colorado and the Robbins Company of Kent, Washington. The results of these tests are presented in Appendix D.

III. SUMMARY OF SITE CONDITIONS

3.01 Regional Geology

The project is located in the Salt River portion of the "Phoenix Basin" which is part of the desert region of the Southern Basin and Range physiographic province. The Basin and Range province is characterized by numerous fault-block mountains separated by relatively broad graben-like basins that have been filled with thick deposits of alluvium eroded from adjacent ridges. The existing mountains are erosional remnants of uplifted blocks of folded, faulted and intruded Precambrian metasediments that first appeared during early Cenozoic Time.

The proposed project is located in a broad alluvial slope adjacent to the Phoenix Mountains where several knobs of bedrock protrude at ground surface. The general trend of both the mountains and the rock knobs is NE to SW. The alluvial slope is highly variable both in thickness and composition having been formed by a series of overlapping alluvial fans and colluvium. The majority of the soil deposits have also been cemented in place to various degrees by calcium carbonate.

Bedrock in the project area consists of weakly metamorphosed Precambrian volcanics and clastic sediments. Rock types are primarily quartzite, micaceous quartzite and quartz-mica schist. Bedding of the original deposits dips towards the west and foliated surfaces parallel to the relict bedding were observed. Bedrock deposits in the vicinity of the project are also noted as being dissected with veins of quartz, and with dikes of greenstone and basalt.

3.02 Soil Conditions

The alluvial soil overlying bedrock in the project area is composed of rock debris eroded from Squaw Peak Mountain. The soil is crudely stratified, is composed of a series of merged alluvial fans and colluvium, and slopes away from the mountains at angles of up to 15 degrees.

In general, soil at the site is described as coarse to fine gravel with little to some sand, occasional silt and clay layers, some cobbles, and a few boulders. The vast majority of soil at the subject site has been calcified or cemented with calcium carbonate to some degree. On the basis of observations made at this site and at other sites in the Phoenix area a classification system for caliche consisting of four categories has been devised as described below.

C_1 -- Uncemented -- Loose soil particles exhibiting a P-wave velocity of 880 to 1,900 ft per second.

C_2 -- Lightly Cemented -- Slightly cohesive mass that falls apart either when removed from the core barrel or when placed in the core box. The entire matrix reacts strongly when tested with diluted hydrochloric acid and individual grains were commonly cemented into small clusters that could be easily broken. Where the lightly cemented caliche was observed in outcrop it stood vertically, was capable of supporting an overhand, and was difficult to excavate with the point of a geologist's hammer. The seismic refraction survey yielded P-wave velocities in the lightly cemented caliche of approximately 2,500 to 3,850 fps with occasional higher values.

C_3 -- Moderately Cemented -- The moderately cemented caliche observed during coring could be removed from the core barrel and

handled without breaking but could be broken by hand. Core breaks in this material were generally at the clast-matrix interface. Moderately cemented caliche exhibited P-wave velocities of approximately 4,500 to 6,500 fps. A laboratory test on a sample of moderately cemented caliche exhibited a point load index of 130 psi. In addition, it was not unusual for the moderately cemented caliche to contain zones of lightly cemented and/or well cemented material.

C_4 -- Well Cemented -- The well cemented caliche observed while coring was quite hard, had a rock-like appearance with a whitish cast, and frequently fractured through the clasts. Core samples of well cemented caliche required a moderate to light blow of a rock hammer to break the core. The matrix in the well cemented caliche was moderately difficult to difficult to scratch with a pocket knife. Well cemented, rock-like caliche exhibited P-wave velocities of approximately 7,000 to 9,000 fps. Laboratory tests conducted on samples of well cemented caliche yielded an unconfined compressive strength of 2,730 psi and point load indices of 429 to 1,379 psi. Seismic Line SL-107 contained a particularly well-cemented zone of caliche at the NW end that yielded a P-wave velocity of 11,364 fps. Surface exposures of moderately or well cemented caliche within the vicinity of the project site had a concrete-like appearance.

Uncemented caliche occurred only at the ground surface at the subject site. In general, this deposit occurred as a discontinuous layer which at no sampled location extended to a depth of more than 14.0 ft below ground surface and which at many locations was not present at all.

At the bottom of the uncemented profile almost all of the soil was either moderately or well cemented with some zones of lightly cemented material. What this means is that soil directly overlying bedrock is hard and stable and that tunneling

operations in the soil profile should not be subjected to destabilizing tendencies. In general, soil at the subject site appears to be quite competent and capable of standing unsupported in small openings for a period of time.

A generalized profile of the soil is shown herewith in Figure 3, Subsurface Profile. The deepest soils occur at Sta. 865+/- and again at Sta. 932 +/- where the soil profile extends to depths below ground surface of approximately 95 and 80 ft, respectively, or to El. 1,145 at Sta. 865+00 and to El. 1,165 at Sta. 932+00. Throughout the entire middle one-half of the project the soil/rock contact-occurs everywhere above El. 1,200.

Laboratory tests were performed on samples of soil obtained from depths of up to 24 ft between ACDC Sta. 988+85 and Sta. 828+00 and the test results were reported by the Corps of Engineers in the Arizona Canal Division Channel Design Memorandum No. 12 dated April, 1986. The results indicate that the percent-by-weight passing a No. 4 sieve ranged from 42 to 66 percent, and the percent-by-weight passing a No. 200 sieve ranged from 11 to 27 percent. The fine material was not more than slightly plastic with Liquid Limits in the range of 23 to 37 percent and Plasticity Indices in the range of 1 to 15 percent.

3.03 Rock Conditions

As stated above, the deepest soil/bedrock contact along the proposed tunnel alignment occurs at El. 1,145 at Sta. 865+00 and at El. 1,165 at Sta. 932+00. Hence, on the basis of available information, bedrock exists along the entire proposed alignment at a depth of more than 100 ft below ground surface.

In general, bedrock along the proposed tunnel is composed of thick sequences of schist and quartzite. Beginning at the west end schist is encountered from Sta. 865+00 to Sta. 877+/- and

again from Sta. 893+/- to Sta. 920+/-. Conversely, quartzite is encountered from Sta. 877+/- to Sta. 893+/- and again from Sta. 921+/- to the end of the project at Sta. 945. Hence, for all practical purposes, the proposed tunnel would be located in approximately 1/2 schist and 1/2 quartzite if excavated for the entire distance from Sta. 865+00 to Sta. 945+00.

The quartz-mica schist is described as a fresh to slightly weathered, moderately fractured to shattered, fine to coarse grained, thin to massive bedded, slightly to strongly foliated, highly siliceous, micaceous or quartz-rich schist with locally interbedded quartz-pebble conglomerate. Foliation generally parallels the relict bedding but kink-banding and warping of the foliation was observed. Within the general vicinity of the ACDC project, the relict bedding generally strikes N 10 to 30° E and dips 40 to 75° W.

Fractures within the schist are generally parallel the foliation, relatively smooth, and approximately 70 to 80 percent healed with calcium carbonate and/or clay. The upper portions of the schist tend to be more fractured and weathered and contain more calcium carbonate. A zone of brecciated and cemented schist several feet thick may be present at the soil/rock interface. Shear zones and quartz veins may also be present and may be several feet thick. Locally, quartz pebbles and interbeds of quartz-talc schist and greenschist are present and large changes in composition and texture can occur over short distances.

The schist exhibited P-wave velocities of approximately 8,100 to 9,600 fps. Seismic lines conducted by the Corps of Engineers yielded P-wave velocities as high as 12,500 fps for a hard slightly weathered deposit of schist located near Sta. 742+00. Laboratory tests on sample of schist yielded unconfined compressive strengths of 5,496 and 9,131 psi and point load indices of 130, 130.5 and 262 psi.

The quartzite is described as a fresh to slightly weathered, blocky to shattered, fine to coarse grained, thick to massive bedded, slightly foliated metaorthoquartzite with locally interbedded phyllite and quartz-mica schist. Within the vicinity of the ACDC project the relic bedding strikes approximately N 10 to 30° E and dips 40 to 60° W.

Fractures within the quartzite generally parallel the relict bedding or foliation, contain thin brecciated zones, and are approximately 80 to 90 percent healed with calcium carbonate and/or clay. The upper portions of the quartzite, like the schist, tend to be more fractured and weathered, and to contain more calcium carbonate. A zone of brecciated and cemented quartzite several feet thick may also be present at the soil/rock interface.

As observed in surface exposures approximately 20 percent of the quartzite is massive and blocky with individual blocks as large as one cubic yard. Much of the observed quartzite is highly fractured to shattered, exhibits slight foliation and frequently contains interbeds of moderately to strongly foliated schist and phyllite. The quartzite frequently exhibits large extremes in composition and texture over short distances. Shear zones and quartz veins are present within the quartzite and individually may be several feet thick.

The quartzite exhibited P-wave velocities of approximately 10,200 to 16,000 fps. Laboratory tests on samples of quartzite yielded unconfined compressive strengths of 32,609 and 26,087 psi and point load indices of 319, 258, 256 and 206 psi.

Although not observed in either test borings or surficial exposures in the immediate vicinity of the ACDC alignment, Precambrian greenstone dikes are known to dissect the schist and

quartzite deposits. Thin dikes of Tertiary basaltic rock also occur infrequently in the general area. Contacts between the bedrock units are gradational with much interlayering and lensing in the vicinity of geologic contacts. Unit contacts as shown on Figure 3, Subsurface Profile are approximate.

3.04 Groundwater Conditions

The groundwater table was not encountered in any test boring made for this study. Perched water assumed to be seepage from the Arizona Canal was encountered in test borings DH82-1, DH82-2 and TH80-2 conducted by the Army Corps of Engineers for ACDC Design Memorandum No. 12. The Arizona Canal is unlined in this area and the water was encountered at shallow depth along a non-cemented to cemented alluvial interface. Test Boring B-201 conducted by CRSS encountered assumed perched groundwater at a depth of 68 ft where a sharp transition from poorly to well cemented alluvium occurred.

In the Phoenix Basin, the principle groundwater aquifer is located in the Quaternary and Tertiary alluvial fill deposits. Groundwater in these deposits is generally unconfined but local occurrences of fine-grained material may create semiconfined, confined or perched conditions. The ACDC Tunnel site is located on the periphery of the Phoenix Basin in an area which is not considered to be part of the principle aquifer and contains only limited groundwater data from existing water-wells.

Within the general vicinity of the project alignment water-well data is available from one well located near 7th Street and three wells located near the Cudia City Wash. In 1984, the depth to groundwater in the well located near 7th Street was 284 ft. The three wells located near the Cudia City Wash have exhibited a depth to groundwater varying from 23 and 54 ft below ground surface (El. 1,227 to El. 1,196) during the time period 1971 to

1984. Using a straight line interpolation of data between the well at 7th Street and the wells at the Cudia City Wash would give a depth to water table of approximately 105 ft at ACDC Sta. 945+00 and 170 ft at ACDC Sta. 865+00. Local occurrences of perched water or seepage from the Arizona Canal are possible above these depths.

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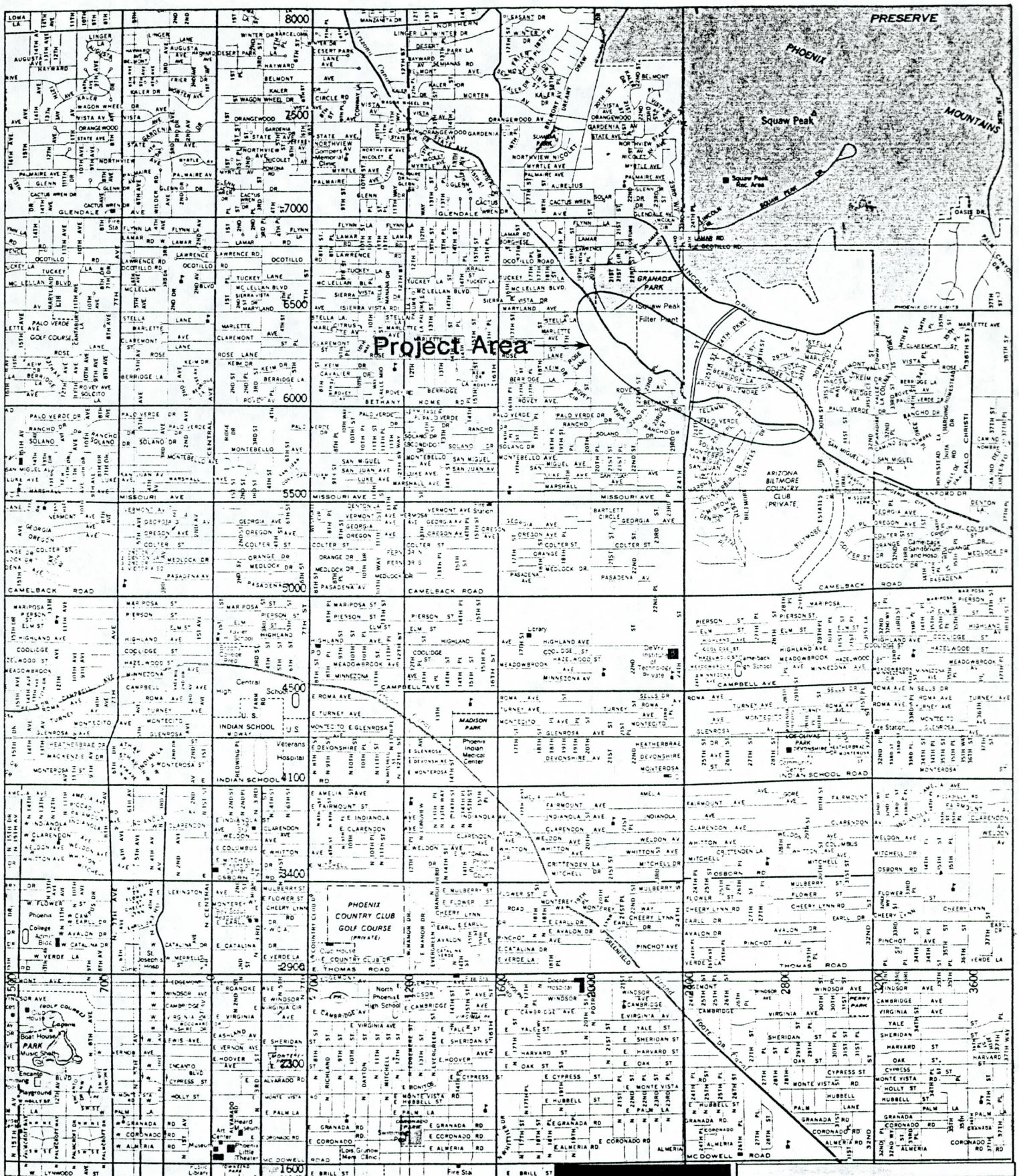
2. Reynolds, S.J., 1985, Geology of the South Mountains, Central Arizona: The Arizona Bureau of Geology and Mineral Technology, Geological Survey Branch, Bulletin 195.

3. Thorpe, D.G., Burt, D.M., 1978, "Precambrian Metavolcanic Rocks of the Squaw Peak Area, Maricopa County, Arizona", 74th Cordilleran Section Meeting of the Geological Society of America, Special Paper No. 2, State of Arizona, Bureau of Geology and Mineral Technology.

RP01638.ACD



SCALE OF MILES

0 ¼ ½ 1

ONE INCH EQUALS APPROX SEVEN TENTHS MILES

CRSS

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CLIENT
Maricopa Flood Control District

PROJECT
ACDC Tunnel

DWG TITLE
Project Locus

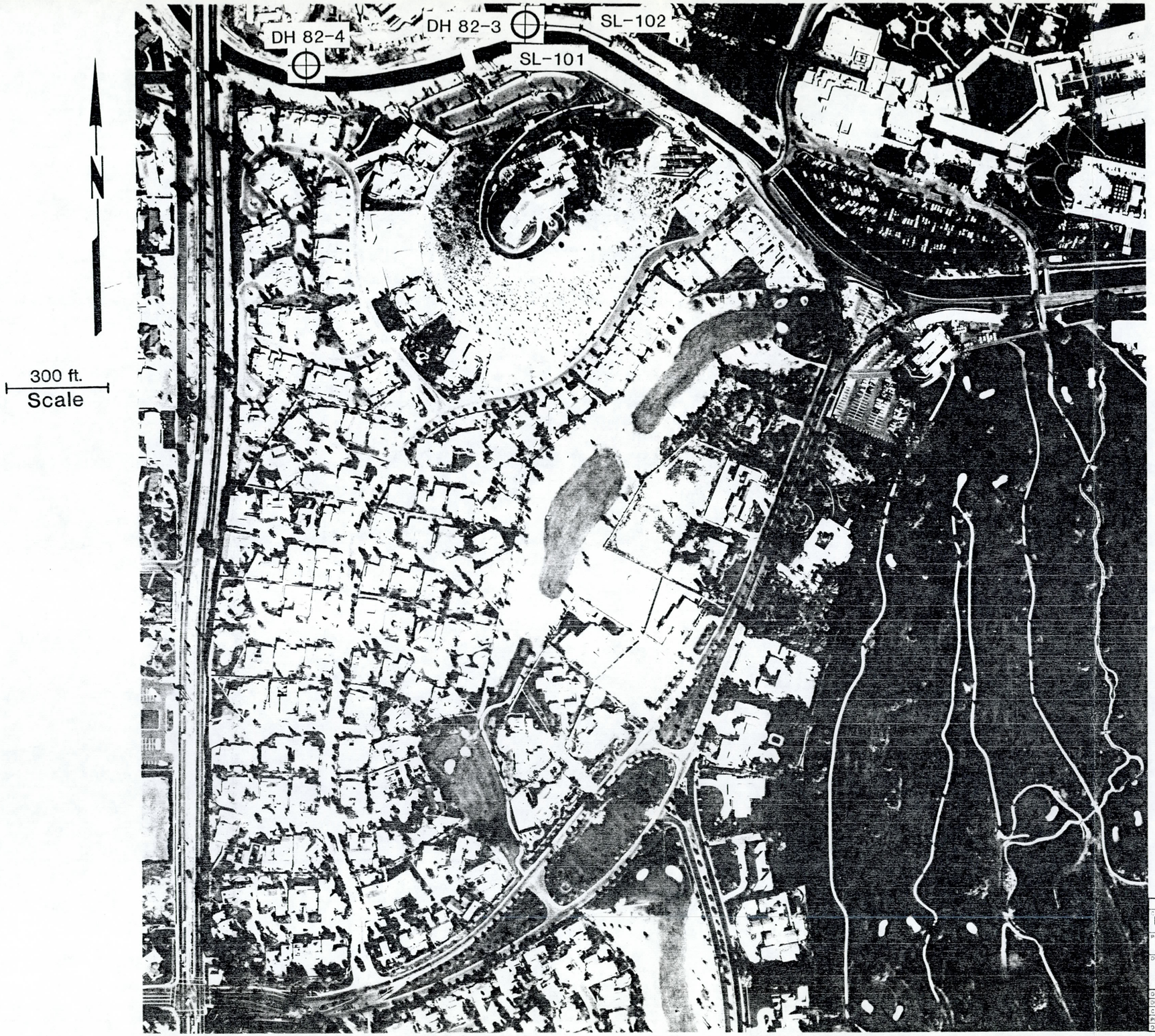
DESIGNED BY
DRAWN BY DSH
CHECKED BY
PROJ. NO. 11565
DATE 9-6-88

CRS SIRRINE, INC.
216 16TH ST - SUITE 1700
DENVER, COLO. 80202
(303) 820-5240

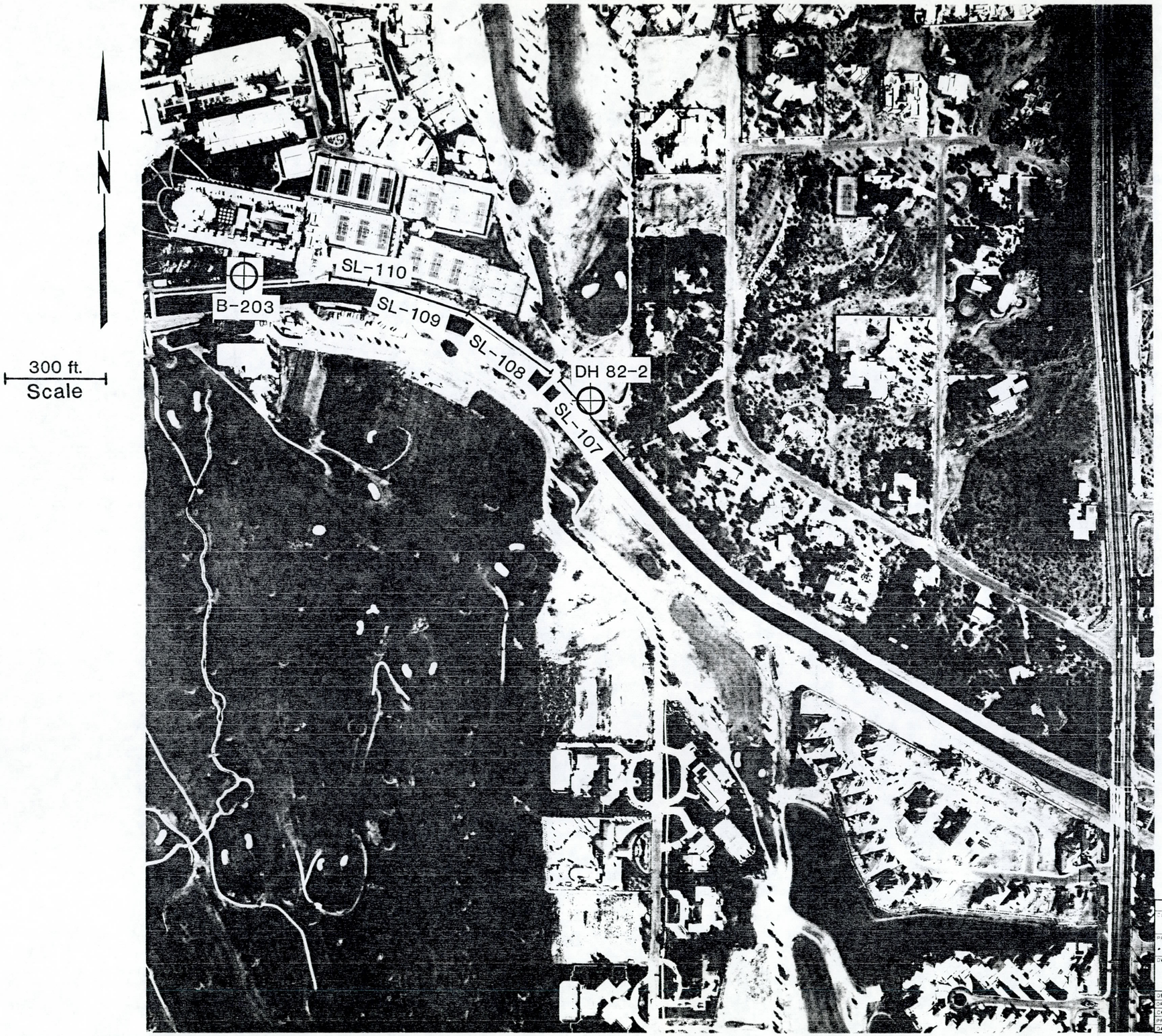
SCALE
HORIZ.
VERT.

Figure 1

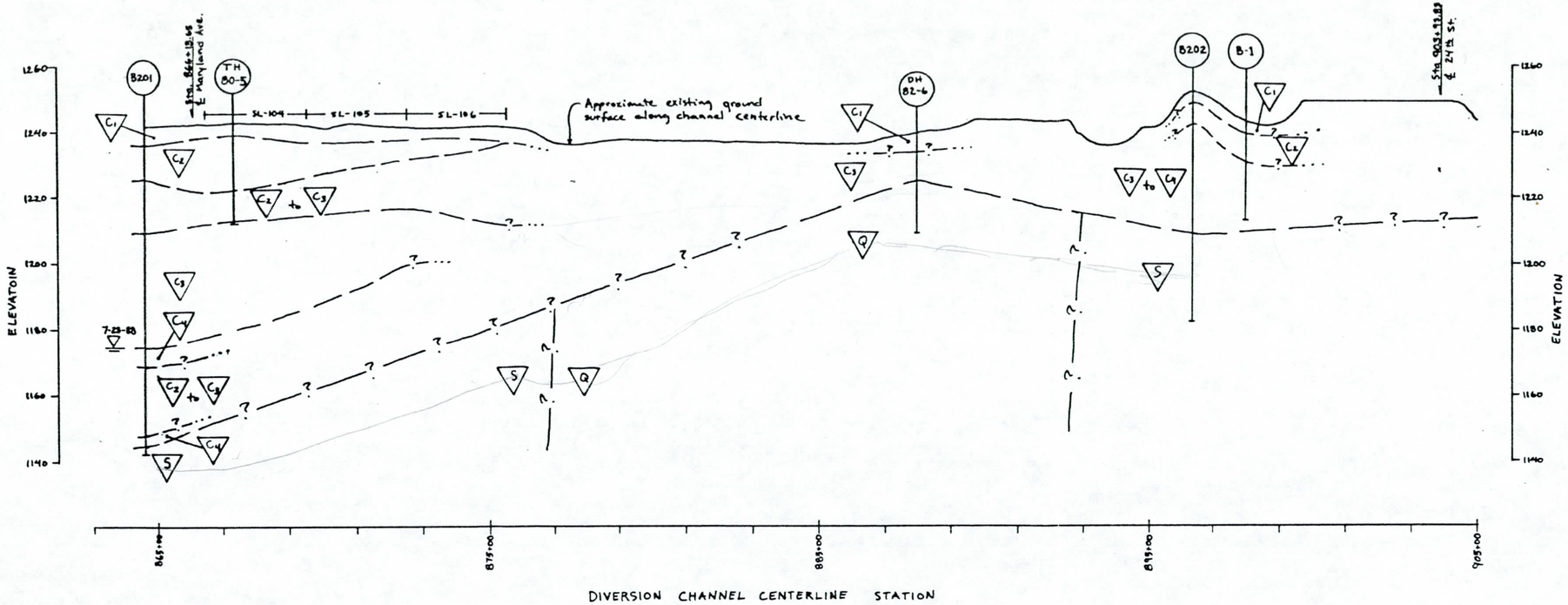
CLIENT	Maricopa Flood Control District
PROJECT	ACDC Tunnel
DWG. TITLE	Test Boring and Seismic Line Location Plan
DESIGNED BY DSH	CRS SIRRINE, INC. 216 16TH ST. SUITE 1700 DENVER, COLO. 80202 (303) 820-5240
DRAWN BY	SCALE as shown
CHECKED BY	
PROJ. NO. 11565	DWG. NO. Figure 2A
DATE 8-14-88	

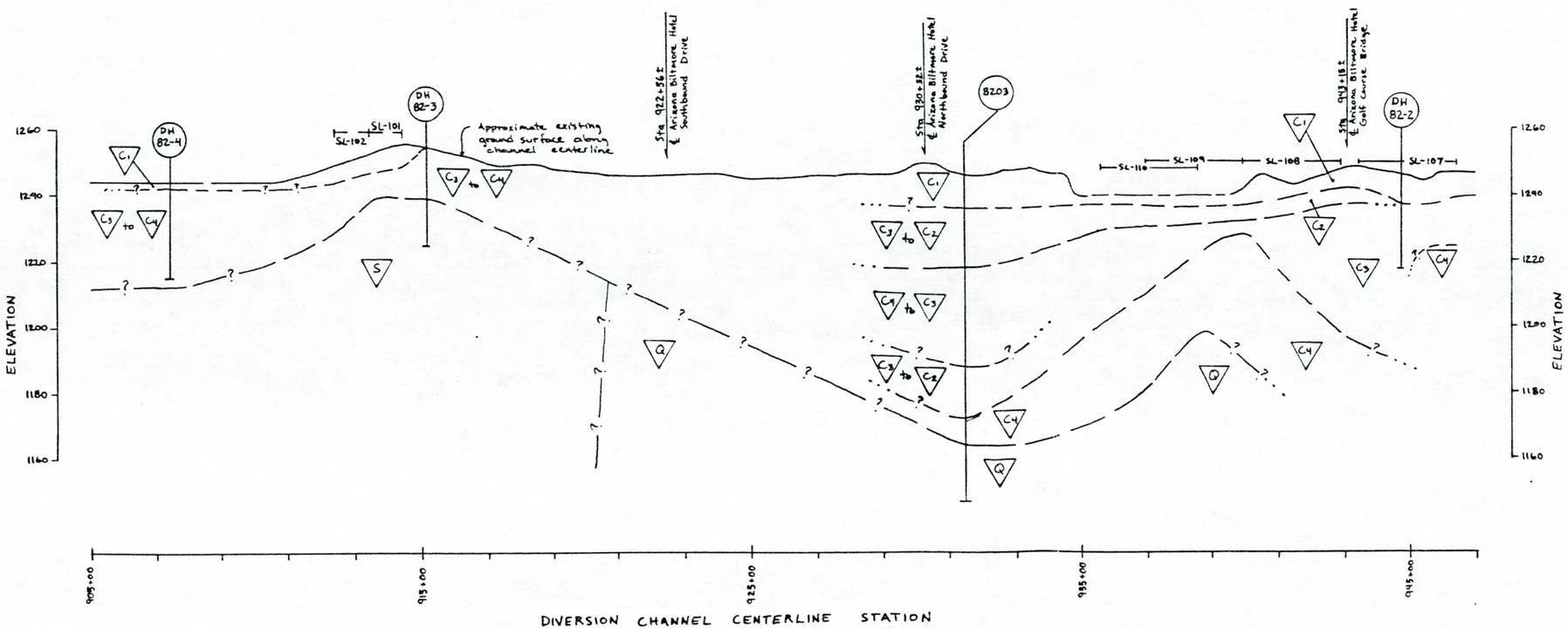


CLIENT	Maricopa Flood Control District
PROJECT	ACDC Tunnel
DWG. TITLE	Test Boring and Seismic Line Location Plan
DESIGNED BY DSH	CRS SIRRINE, INC. 216 6TH ST. SUITE 700 DENVER, COLO. 80202 (303) 820-5240
DRAWN BY	
CHECKED BY	
PROJ. NO. 11565	SCALE as shown
DATE 8-14-88	DWG. NO. Figure 2B



CLIENT	Maricopa Flood Control District
PROJECT	ACDC Tunnel
DWG. TITLE	Test Boring and Seismic Line Location Plan
DESIGNED BY DSH	CRS SIRRINE, INC. 216 16TH ST. SUITE 700 DENVER, COLO. 80202 (303) 820-5240
DRAWN BY	SCALE as shown
CHECKED BY	
PROJ. NO. 11565	DWG. NO. Figure 2C
DATE 8-14-88	





LEGEND

- C_1 Colluvium, non-cemented
- C_2 Colluvium, lightly cemented
- C_3 Colluvium, moderately cemented w/ occasional lightly or well cemented zones
- C_4 Colluvium, well cemented, "rock-like"
- S Schist, poorly to well foliated
- Q Quartzite, massive to slightly foliated
- Contact, approximate or gradational
- Contact, inferred
- Contact, uncertain
- Groundwater encountered

NOTES:
1. Horizontal to vertical scale exaggeration is 10 to 1.
2. Contacts between schist and quartzite bedrock units are based on outcrops in project vicinity and are very gradational with much interlayering and lensing.
3. Water encountered in test boring B-201 was perched. Possible seepage from Arizona Canal.
4. For more detail on subsurface profile see individual boring logs or seismic profiles.
5. Borings TH 80-5, DH 82-2,3,4+6 conducted by U.S. Army Corps of Engineers. Test borings B201, B203 and B205 conducted by CRSS July 1988, boring B-1 conducted by CRSS February 1987. Seismic Lines SL-101 through SL-110 conducted by CRSS June 1988.

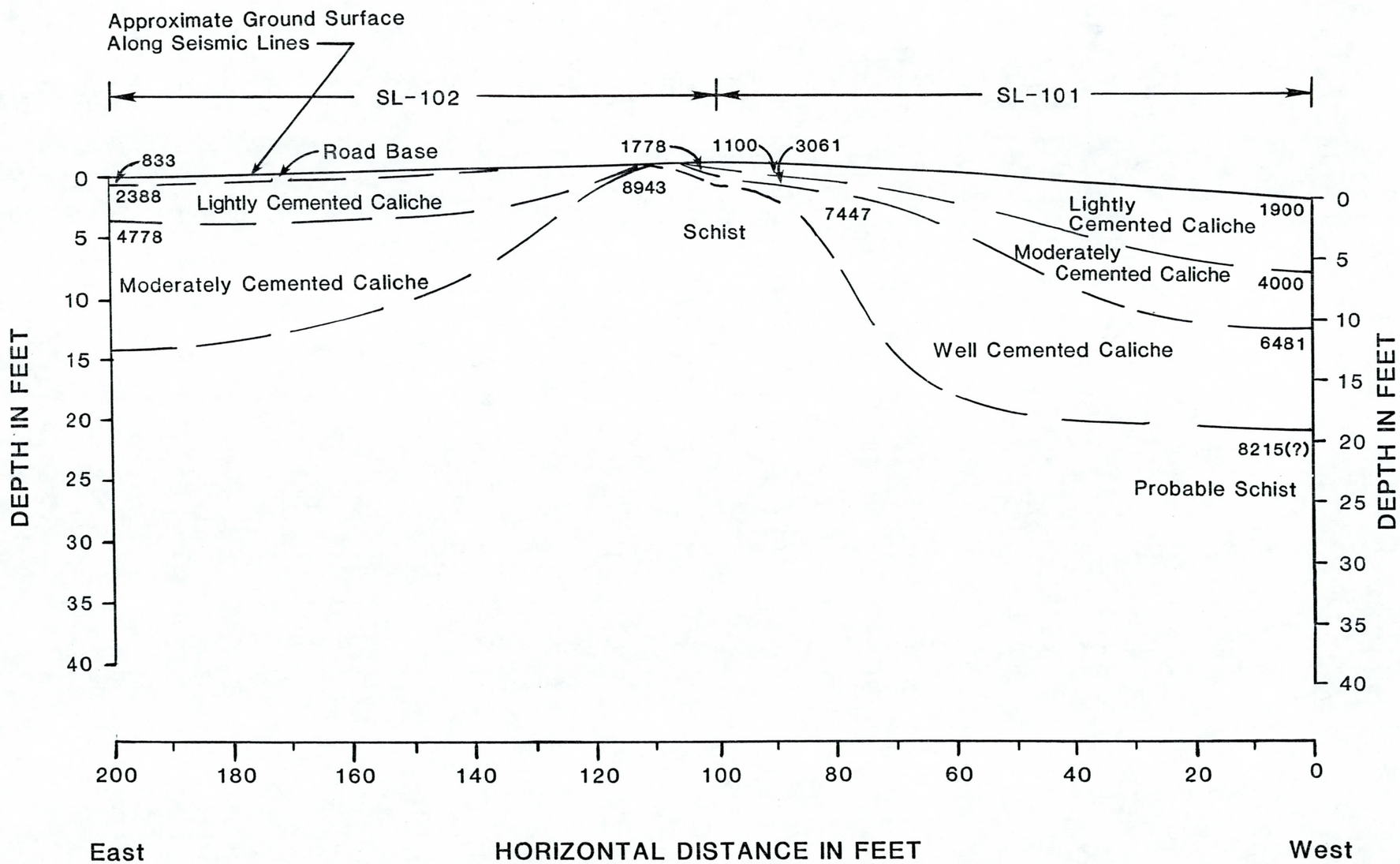
CRSS

CRS SIRRINE

CLIENT	Maricopa County Flood Control District
PROJECT	Arizona Canal Diversion Channel Tunnel
DWG TITLE	Subsurface Profile
DESIGNED BY DSH	CRS SIRRINE, INC. 216 16TH ST. SUITE 1700 DENVER, COLO. 80202 (303) 820-5240
DRAWN BY DSH	Original Scale 1"=200' HORIZ 1"=20' VERT
CHECKED BY	
PROJ NO 11869.24	DWG. NO. Figure 3
DATE 8-5-88	

APPENDIX A

GEOPHYSICAL INVESTIGATIONS



CRSS

CRS SIRRINE

CLIENT: Maricopa Flood Control District

PROJECT: ACDC Tunnel

DWG. TITLE: Geoseismic Section SL-101 & SL-102

DESIGNED BY DSH

DRAWN BY

CHECKED BY

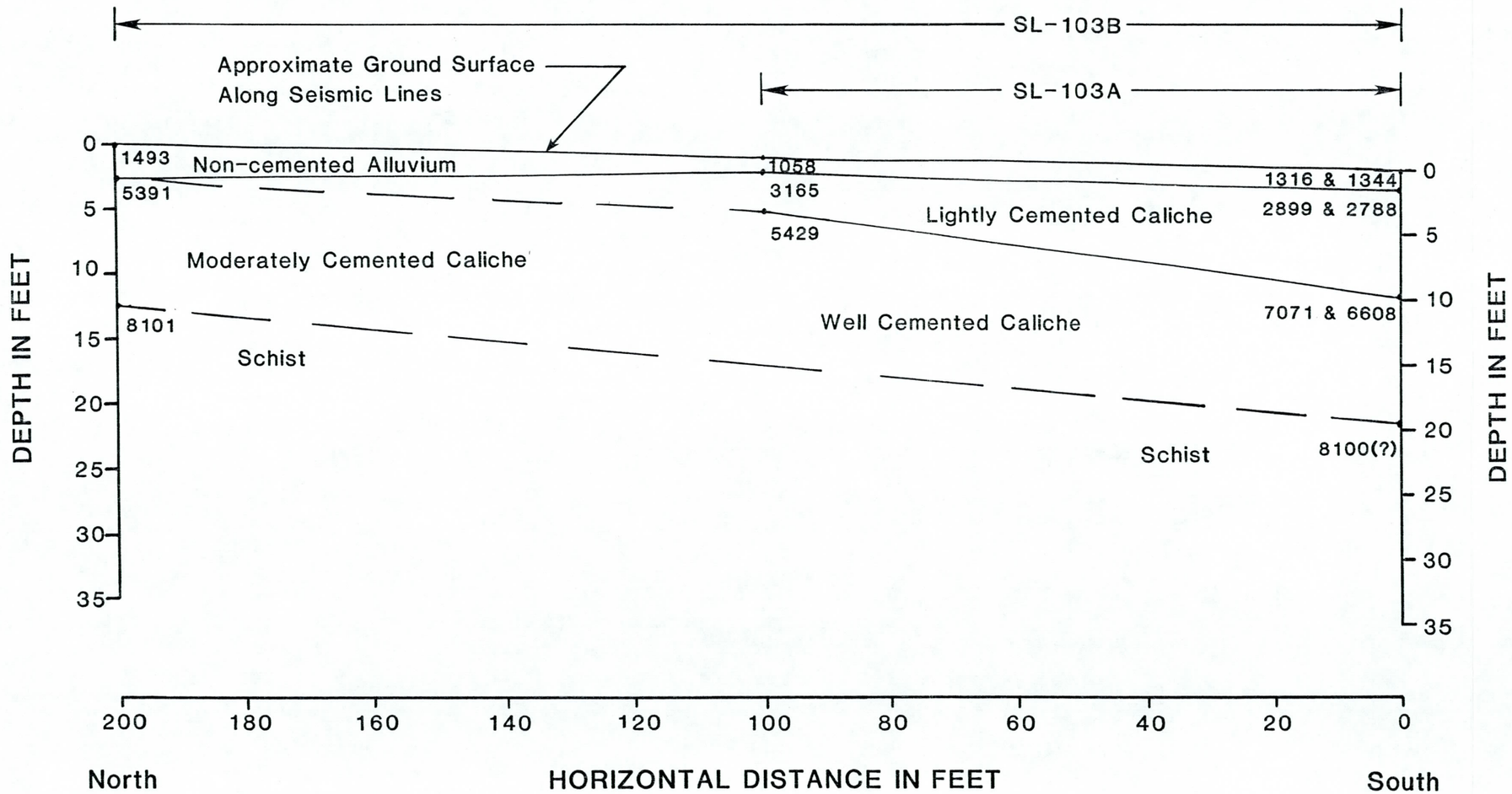
PROJ. NO. 11565

DATE 8-22-88

CRS SIRRINE, INC. 216 16TH ST. SUITE 1700 DENVER, COLO. 80202 (303) 820-5240

DWG. NO.

SCALE: as shown



CRSS

CRS SIRRINE

CLIENT: Maricopa Flood Control District

PROJECT: ACDC Tunnel

DWG. TITLE: Geoseismic Section SL-103A & SL-103B

DESIGNED BY DSH

DRAWN BY

CHECKED BY

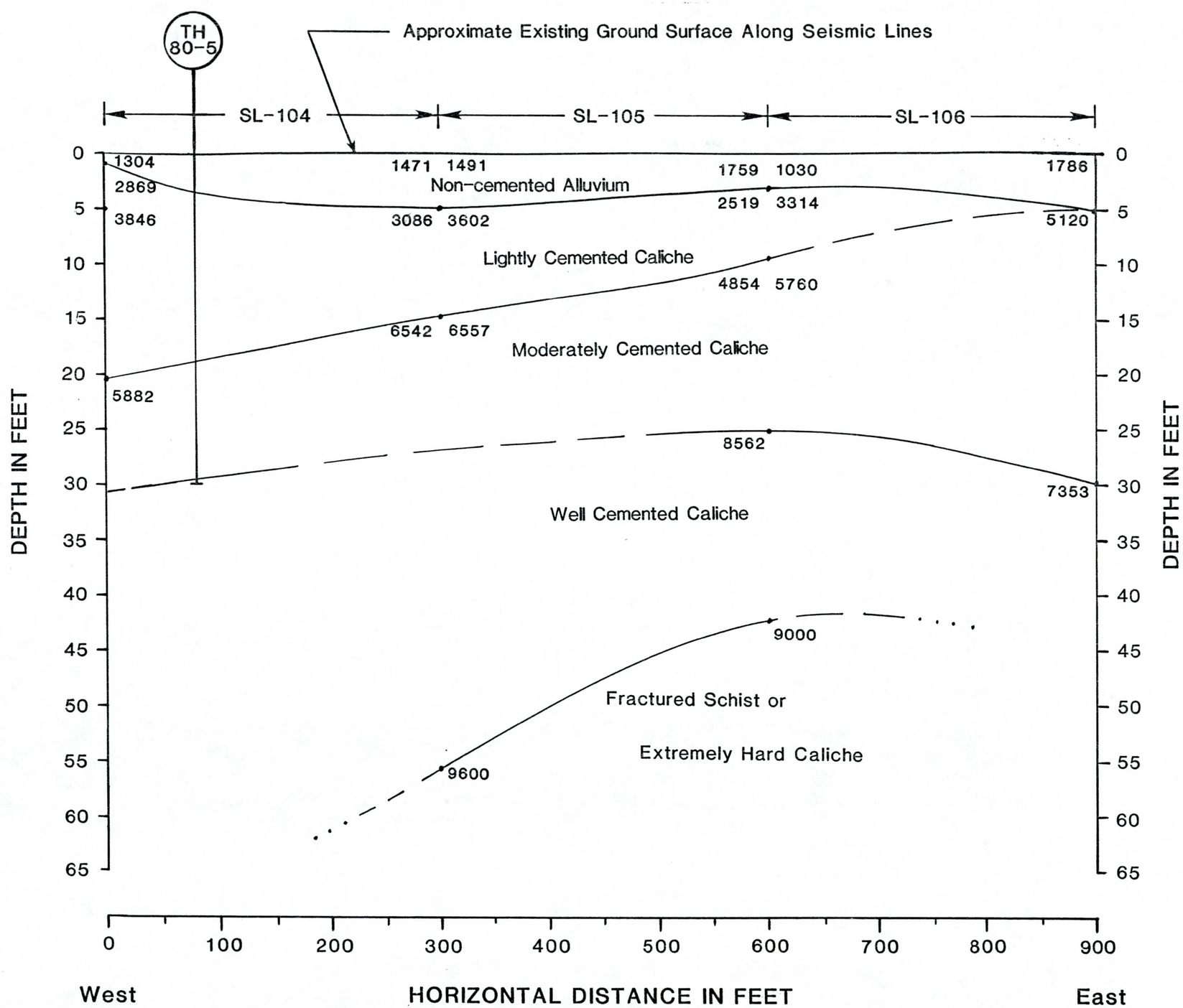
PROJ. NO. 11565

DATE 8-25-88

CRS SIRRINE, INC. 216 16TH ST. SUITE 1700 DENVER, COLO. 80202 (303) 820-5240

SCALE: as shown

DWG. NO.



CRSS

CRS SIRRINE

CLIENT: Maricopa Flood Control District

PROJECT: ACDC Tunnel

DWG. TITLE: Geoseismic Section SL-104, SL-105 & SL-106

DESIGNED BY: DSH

DRAWN BY:

CHECKED BY:

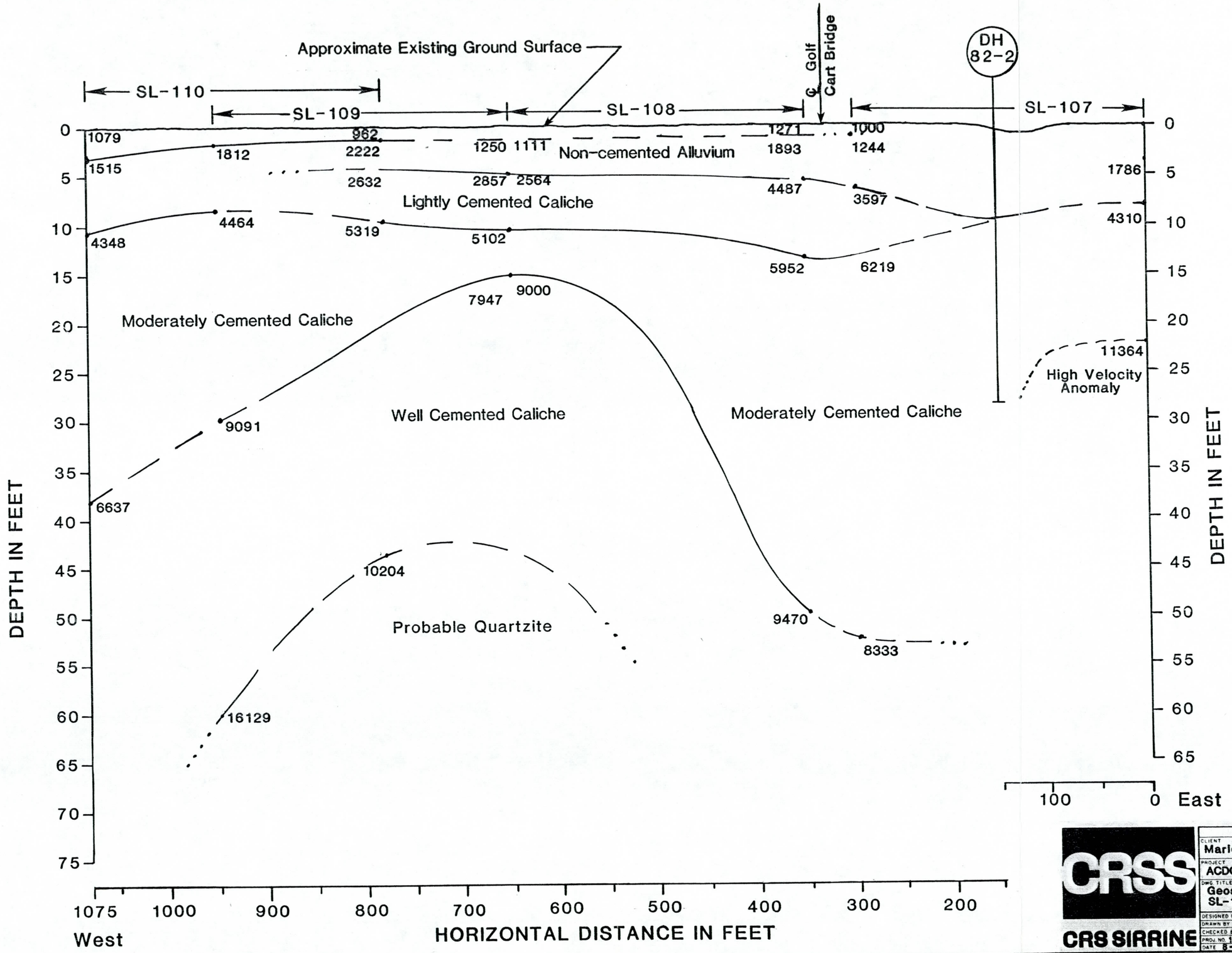
PROJ. NO. 11565

DATE 8-18-88

CRS SIRRINE, INC. 216 16TH ST. SUITE 1700 DENVER, COLO. 80202 (303) 820-5240

SCALE: as shown

DWG. NO.



CRS SIRRINE

CLIENT: Maricopa Flood Control District

PROJECT: ACDC Tunnel

DWG TITLE: Geoseismic Section SL-107 through SL-110

DESIGNED BY: DSH

DRAWN BY:

CHECKED BY:

PROJ. NO. 11565

DATE 8-22-88

CRS SIRRINE, INC. 216 16TH ST. SUITE 1700 DENVER, COLO. 80202 (303) 820-5240

SCALE: as shown

DWG. NO.

FINAL REPORT

SEISMIC REFRACTION SURVEY
ALONG OR IN CLOSE PROXIMITY TO
PROPOSED ARIZONA CANAL DIVERSION CHANNEL TUNNEL
MARICOPA COUNTY, ARIZONA

for

CRS SIRRINE, INC.

DENVER, COLORADO

by

Geo-Pro Consulting Company

Phoenix, Arizona

Survey June 1988

Report August 11, 1988

NOTE: Maps 1 and 2 originally contained in this geophysical report have been removed. They are available for viewing and/or copying at CRS Sirrine, Inc. 216 16th Street Mall, Suite 1700, Denver, Colorado 80202

Telephone Number: 303-820-5240

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CONFIDENTIAL

LETTER OF TRANSMITTAL

Geo-Pro Consulting Co.
1736 West Carol Avenue
Phoenix, Arizona 85021
August 11, 1988

TO: Mr. David Hallman, Geological Engineer
CRS Sirrine, Inc.
Suite 1700
216 Sixteenth Street Mall
Denver, Colorado 80202 - 5131

SUBJECT: Final Report on Seismic Refraction Geophysical Survey Conducted in June 1988.

PROJECT: Arizona Canal Diversion Channel Tunnel
Maricopa County Flood Control District

Dear Mr. Hallman:

As per agreement dated June 15, 1988 with CRS Sirrine, Inc. this confidential report is submitted for your exclusive use.

The report contains geological research data and maps, engineering excavation properties of the rock types, seismic data field sheets, refraction velocity plots, interpreted Geoseismic Sections which include Corp of Engineers seismic and drill hole information, photographic documentation, conclusions, and recommendations pertinent to the feasibility study for tunnelling in the subject area.

Please date, sign, and return one copy of this transmittal letter to Geo-Pro Consulting Company to confirm receipt of the Invoice, Final Report, and also the three preliminary reports .

ACKNOWLEDGED AND SUBMITTED BY:

David Hallman

Title Geological Engineer

Date 8-15-88

Thank you.

Sincerely yours,

Paul L. Scheffey

Paul L. Scheffey, P.E.
Consultant

cc: file

CONFIDENTIAL

SEISMIC REFRACTION SURVEY
ALONG OR IN CLOSE PROXIMITY TO
PROPOSED ARIZONA CANAL DIVERSION CHANNEL TUNNEL
MARICOPA COUNTY, ARIZONA

INTRODUCTION

Upon request of the client the following report is submitted detailing the results of the on-site inspection, seismic data acquisition, seismic interpretation, photo documentation, and geological research pertinent to the subject area. The seismic data acquisition was accomplished with the assistance of Mr. David Hallman on the nights of June 17, 18, 20, 21, 22, 23, 1988.

The proposed tunnel alignment traverses the north bank of the Arizona Canal in Sections 10, 11, and 14 of T.2N., R.3E., Maricopa County, Arizona. This alignment encompasses approximately 8000 linear feet some of which cuts across the Biltmore Hotel on the east end, 24th Street in the central portion, and the Squaw Peak Filtration Plant on the west end. As can be seen from Maps 1 and 2 this is a highly urbanized area. However, as an abrupt contrast, just 1½ miles northward Squaw Peak jutts skyward to an elevation of 2608 feet - a relief of about 1370 feet above the Arizona Canal.

Squaw Peak is a part of the Phoenix Mountains which trend NW-SE for about 15 miles from Moon Hill southeastward to Camelback Mountain near Scottsdale.

Rain runoff from these mountains is initially in all directions but the drainage eventually finds its way to the Salt River. Recorded rainfall for Phoenix averages about 7½ inches per annum. During heavy rainfall (it does happen) some areas along the mountain front are prone to heavy flooding - therefore, the rationale for the Arizona Canal Diversion Channel (ACDC).

Our main concern in this report is the nature of the subsurface structure and its composition along the proposed tunnel alignment. This information is to be used as part of the feasibility study for the tunnel.

Of prime importance is the geology of the Phoenix Mountains. These rocks are either buried by alluvium or are exposed at numerous locations along the proposed tunnel alignment. In this respect depth to bedrock and nature of alluvial deposits is crucial. One good outcrop example is the site of the Wrigley Mansion located directly south of our seismic lines 101 and 102 in the NW ¼ of Section 14.

For the geologic and excavation data of this report the writer has drawn freely from the excellent MS thesis (1973) of Douglas C. Shank entitled 'Environmental Geology in the Phoenix Mountains, Maricopa County, Arizona' Permission to use this material has been granted by Dr. Troy L. Pewe' of the Geology Department, Arizona State University.

GEOLOGY

The Phoenix Mountains are typical block-faulted mountains of the Basin and Range physiographic province. They consist of a complex of highly fractured Precambrian metasediments and intercalated metavolcanics which are overlain by tilted and faulted basalt flows and fanglomerates of probable Tertiary age. Alluvial and colluvial deposits of the late Cenozoic era occur on lower slopes and lowlands. Predominantly, the bedding strikes N30E and dips 60 - 85 degrees southeast. Cross-bedding in the quartzites suggests overturned bedding with tops to the west.

This discussion can best be followed by referring to Map 2 which shows the geology in detail across the Squaw Peak area. Also a generalized geologic cross-section across the entire mountain range is shown in Figure 1. Unit designation and color code correspond on both displays.

PRECAMBRIAN

No clearcut distribution pattern of the Precambrian sequence is evident but inspection of the cross-section suggests the following general observation. The northwest portion is underlain by granite gneiss. The central portion is dominated by phyllite and quartz-mica schist. In the Squaw Peak area note that quartzite predominates. Also observe that Precambrian greenstone dikes locally cut the other units.

The Precambrian sequence and intercalated volcanic rock exposure total more than 40,000 feet. The original thickness was much greater plus the possibility of isoclinal folding and repetition of beds by faulting. On a regional basis the Phoenix Mountains may overlie stratigraphically an older more highly metamorphosed and complex system of Precambrian strata.

Genesis of the Precambrian sequence probably arose from the metamorphism and deformation of sandstones, shales, granites, basaltic volcanics, and silty and sandy mudstones. The initial environment was likely a delta-floodplain and/or a shallow shifting sea.

Generally, metamorphic foliation is well-developed in all the rock types except the Tertiary dikes and the quartzites. The foliation usually parallels the relict bedding of the sediments which strike northeast and dip steeply southeast. All of the Precambrian sequence are considerably fractured by a system of north-south striking, steeply dipping joints. To further complicate this matter a series of local fractures overprint the system. These horizontal or gently dipping fractures may be related to unloading adjustment forces within the rock.

TERTIARY

During early Cenozoic time the Precambrian was subjected to partial burial by basalts and fanglomerates. The latter is a reddish-brown to gray, weakly consolidated, poorly sorted and stratified, moderately calichied coarse to very coarse alluvium.

Basalt/fanglomerate time relationships are still cloudy, but the flows appear to overlie the metamorphic rock directly whereas the fanglomerate contain both metamorphic clasts and basalt. This relationship indicates an older age for the basalt. Erosion has taken its toll and the basalt remains as a capping over the metamorphics and the fanglomerate are seen as rounded hills of moderate relief.

GEOLOGY

Although positive identification of fault contacts has been elusive their presence has been inferred from residual Bouguer maps which show steep gravity gradients. Other tell-tale hints of major faulting are fault gouge zones (untraceable), minor fault displacements, and unexplainable topographic lineations and tilting.

QUATERNARY

The latest period of deposition in the Phoenix Mountains is represented by extensive deposits of very late Cenozoic (Quaternary ?) alluvial fan and colluvial accumulations. These deposits lie on lower slopes and floor all the major valleys. The colluvium forms a belt or apron of wedge-shaped rock fall and slope wash debris (30' + thick) on the steep bedrock slopes.

The alluvium (valley fill) has been subdivided on the basis of clast size as follows:

1. Boulder - poorly stratified, poorly sorted, blocky torrential fan deposit containing clasts ½ to 6 feet in diameter.

2. Coarse grained - poorly sorted, moderately stratified material with blocks ranging 3 to 12 inches in diameter.

3. Medium grained - poorly sorted, well stratified deposit containing angular gravel ¼ to 3 inches in diameter.

4. Fine grained - moderately sorted, well stratified silt and sand with few clasts larger than ¼ inch diameter.

At the southeast and northwest ends of the range are the most extensive and best developed colluvium, boulder and coarse grained alluvium residing below the quartzite and basalt slopes.

The medium and fine grained alluvium encircle the mountains on all sides. Also the valley fill consists of this same material. These unconsolidated deposits range from one to several score feet in thickness. They give no evidence of faulting or other structural disturbance.

****

CALICHE

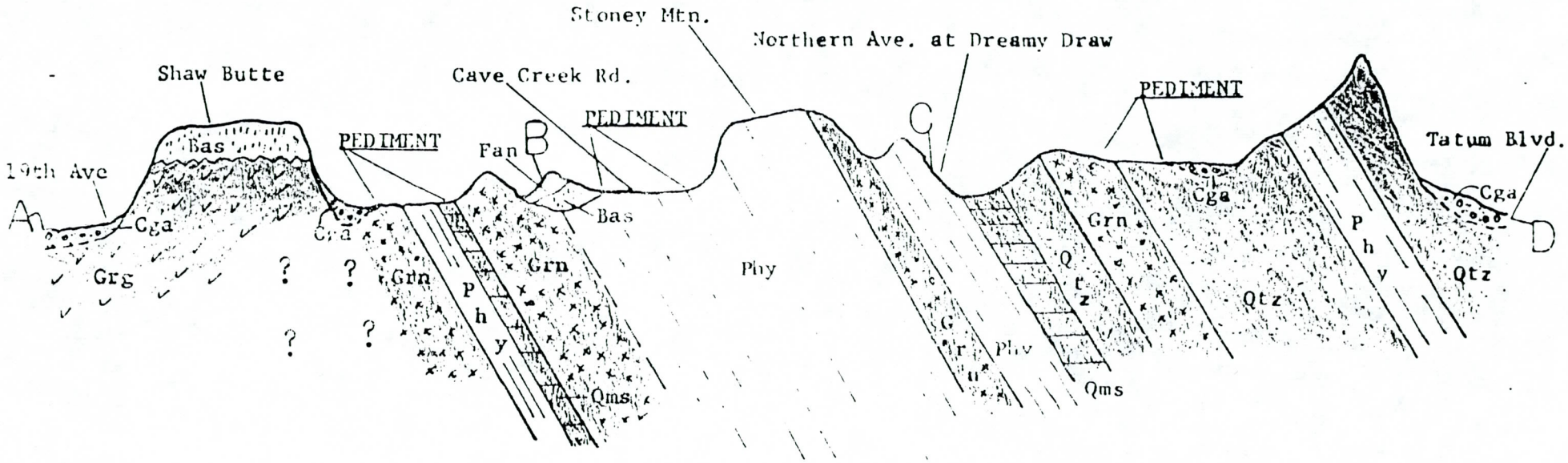
Caliche takes on considerable engineering significance in the Southwest. The amount of indurated caliche controls the excavation method for unconsolidated earth materials. Some caliche-rich areas have required blasting in order for bulldozer work to proceed. Detection of these areas requires expensive core-drilling and/or the use of the more cost effective seismic refraction method.

Caliche deposits are the accumulation of calcium carbonate where evaporation exceeds the precipitation rate.

All unconsolidated deposits in the Phoenix Mountain area contain varying amounts of caliche. The colluvium, coarse grained alluvium, and fanglomerate units are moderatly to highly calichified throughout their upper 10 to 20 feet (see Fig. 2). In turn the medium grained alluvium generally contains indurated caliche 3 to 5 feet below the surface and the fine grained deposits usually show a caliche layer 6 to 10 feet below ground surface. This information has been gathered from stream cuts, excavation/construction sites, and seismic refraction data.

*FIGURE 1

Geologic Cross-Section



SCALE

1 0 2 4
.5 1 3 5 thousand feet

Vertical exaggeration - 6.25:1

EXPLANATION*

- Cga - Coarse grained alluvium
- Fan - Fanglomerate
- Bas - Basalt
- Phy - Phyllite
- Qms - Quartz-mica schist
- Qtz - Quartzite
- Grn - Greenstone
- Grg - Granite gneiss

*Unit designation and color code correspond to Geology Map

SECTION A-D

Generalized geologic cross-section and topographic profile across the Phoenix Mountains, Maricopa County, Arizona - showing relatively flat-lying bedrock pediment surfaces in relationship with geologic units.

*NOTE: This cross-section taken from MS Thesis of Douglas C. Shank entitled 'Environmental Geology in the Phoenix Mountains, Maricopa County, Arizona'. Permission to use material granted by Dr. Troy L. Péwé, Geology Department, ASU.

FIGURE 2

INDURATED CALICHE ALLUVIUM

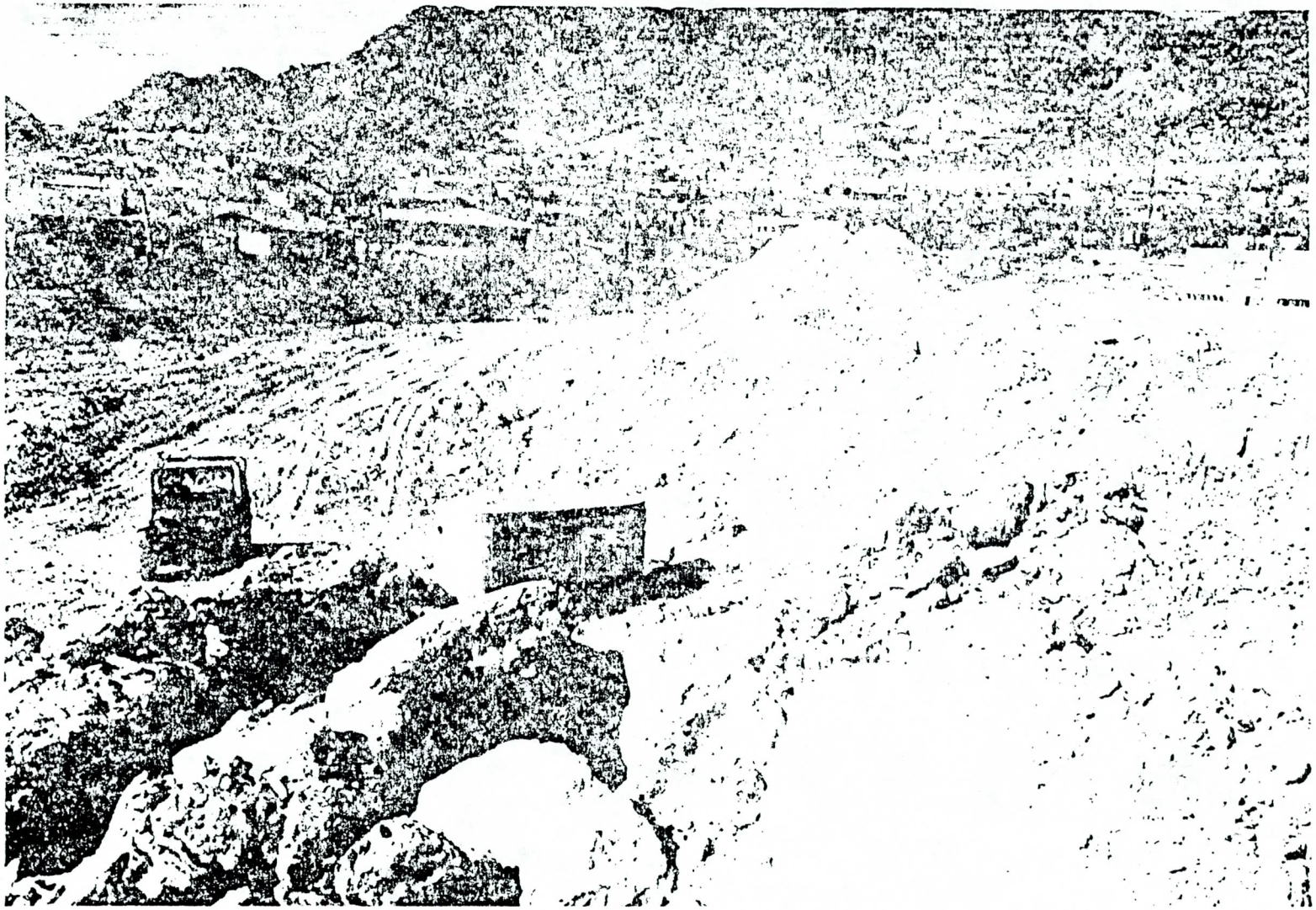


Figure 5.- Large blocks of caliche-cemented alluvium (up to 5 feet in diameter) blasted from the ground during excavation for septic tank pit, SE¼, SE¼, Sec. 6, T. 2 N., R. 4 E. (Photograph No. 3396 by T. L. Péwé, Feb. 3, 1973).

GEOPHYSICS

SEISMIC REFRACTION SURVEY

A. Objective of Seismic Refraction Survey:

Specifically, the survey was conducted to determine subsurface features and to compute the corresponding depths to these features in order to assess the feasibility of tunnelling through the area.

B. Acquisition of Seismic Refraction Data:

Seismic data was obtained by using a Bison Signal Enhancement Seismograph Model 1570C. Energy source was a 12 pound sledge hammer.

Field crew consisted of David Hallman and Paul L. Scheffey.

Seismic field operations commenced at 6:00 PM and varied from 3 to 7 hours each evening. Night operations were necessary because of intense daytime temperatures and excessive ambient noise level during the day.

Windy conditions made it necessary to bury the geophones in order to reduce signal noise level.

All of the refraction profiles were reversed (i.e. seismic energy received in both directions) in order to check reciprocity travel times.

Sledge hammer impacts varied from 1 foot to 25 foot spacings as imposed by field conditions.

A total of twelve seismic profiles were layed out. In order to obtain a representative sampling along the tunnel alignment three areas were chosen. Namely, these areas were located on the eastern end, central portion, and the western end of the project. Refer to Maps 1 and 2 for profile locations. Three of the profiles or spreads were 100' in length, one was 200', and the remaining eight were 300' in length. The longer profile afforded a deeper look into the subsurface.

The profiles are identified as Seis Lines (SL) 101 through 110 with the ends of each line bearing a number - Example: Seis Line 101 with end numbers of 1 and 2. All of these profiles have been carefully plotted on a time-distance graph and are listed as Figures 3 through 12. Note also that the seismic profiles are identified on the photographs. The refractor interfaces were determined as a 'best fit line' and the corresponding velocities calculated in feet per second. These velocities are so indicated on the refraction profile graphs. In addition each plot has been graded either good (g), fairly good (fg), fair (f) or poor (p) as noted in the field when the p-wave signal was received at the seismograph. The field data are compiled in the Appendix of this report.

SEISMIC REFRACTION SURVEY

The intercept times noted on the plots such as Ti_2, Ti_3, etc. are obtained from the graph and are used in the formula for computing strata or bed thickness symbolized as Z_1, Z_2, etc.

The standard formula utilized was -- $Z_1 = \dfrac{(Ti_2)\, V_1}{2 \cos\left(\sin^{-1} \dfrac{V_1}{V_2} \right)}$

where Z_1 is bed thickness of the first layer, Ti_2 is the intercept time, V_1 and V_2 are the respective velocities of layer one and layer two. Formulae for the deeper beds are similar but carry more velocity terms.

C. Quality of Seismic Refraction Data:

The overall quality of the seismic data was good considering the heterogeneous and complex nature of the subsurface material along the tunnel alignment. This is attested to by the varying near surface velocities across the profiles. The reciprocity times across each profile checked fairly well except for SL 109 which traversed segments of paved material.

Satisfactory data on SL 111 could not be obtained because of ambient noise interference from discharge pipes and/or a nearby transformer station. Photograph 16 shows the 'noise makers'. When the pipes discharge there is quite a surge of water into the canal. These 'offenders' apparently originate from within the Squaw Peak Filtration Plant. Just for the record the ambient noise was recorded on the CRT and found to contain a primary signal of 30 Hertz with higher frequencies (156 Hertz) superimposed on the primary. Please see field data for configuration of noise signal. Photo 15 was taken in the same area (looking northward) and shows a filtration plant holding reservoir in the middle foreground and Squaw Peak on the horizon.

GEOSEISMIC SECTIONS

From the seismic data four Geoseismic Depth Sections were generated as follows:

1. Line 101 - 102, Figure 13.
2. Line 103A - 103B, Figure 14.
3. Line 104 - 106, Figure 15.
4. Line 107 - 110, Figure 16.

These sections combine the geological and geophysical data into a cross-section representation of the subsurface configuration.

Interpretation Of The Geoseismic Sections

1. Line 101 - 102 (Refer to Figure 13)

These two profiles revealed a complex structure of outcropping schist projecting through a calichified alluvial covering.

Drill hole control (DH 82-3) about midpoint of SL 102 logged schist at a depth of 15 feet. Also weathered schist outcropped about 30 feet east of the drill hole. The seismics showed a near surface high velocity of 8943 ft./sec. on the east end of SL 102. The resulting interpretation revealed a narrow plug-like feature near midpoint of the profiles.

GEOSEISMIC SECTIONS

Inspection of the outcrop indicated a calichified schist containing quartzite clasts. Configuration of this bedrock feature along SL 101 is inferred from shallow seismic data at points 1 and 2. The depth (19') to the competent schist on the east end of SL 101 was projected from the same marker on the south end of SL 103A, a distance of about 175 feet. The weathered schist 'a' in Photo 8 measured about 5 feet down from the top of the canal bank. Top of bank to water surface was 11 feet.

The schist outcrop is marked in Photograph 4. Note below point 2 in the same picture a thick sequence of calichified alluvium. The velocity of this material was 7447 ft./sec.

SL 82-3 (Corp of Engineers) located about 200 feet west of DH 82-3 found a high velocity layer (8215 ft./sec.) which was presumed to be schist bedrock. Inspection of Map 2 shows that the quartz-mica schist outcrop in Section 11 could easily be projected southwestward into the subject area.

Photographs 1 through 7 show the near surface rocks exposed along the canal. Photo 8 shows weathered schist at 'a' near the east end of SL 101 and Photo 4 indicates a boulder 'b' of cemented alluvium containing some sizable quartz clasts. An upclose view of the latter can be seen in Photo 9.

At points 2 and 3 the drop from canal bank to water surface was approximately 12 feet.

2. Line 103A - 103B (Refer to Figure 14)

These two N-S overlapping profiles were located about 175 feet north of Profiles 101 and 102. See Photographs 10 and 11 for their location along the parking lot.

The seismic interpretation revealed a high velocity layer (8101 ft./sec.) on the north end of SL 103B. A similar velocity was not detected on the south end of SL 103A. This high velocity suggested basement rock - probably schist.

Velocity interfaces showed south dip with an overall slope of 3 degrees along the probable competent schist layer.

The top two layers are alluvium but the third layer registers fairly high velocities on the south end. This material may be calichified alluvium mixed with fractured schist.

3. Line 104 - 106 (Refer to Figure 15)

The most striking subsurface feature across these three seismic profiles is the apparent anomaly cresting at Station 9. This anomaly represents velocities close to or above 9000 ft./sec. which suggests basement rock. The interpretation shows a probable fractured quartzite contact at a depth of 25 feet and a corresponding probable competent quartzite contact at a depth of 42 feet. Furthermore, this anticlinal configuration is supported by similar velocities (7353 ft/sec., east flank) and 9600 ft./sec., west flank) either side of the crest.

Note that DH 82-6 located about 1400 feet east of SL 106 encountered quartzite at a depth of 14 feet with auger refusal at 10 feet.

GEOSEISMIC SECTIONS

This quartzite was light gray, hard, fresh to slightly weathered and highly fractured. SL 82-9 at this location did not detect the quartzite bedrock probably because of similar velocities (6900 ft./sec.) between the bedrock and the caliche cemented alluvium in this area. Observe that a small hill (see Photo 17) on the south canal bank projects above the surrounding ground. Its relief is about 16 feet and it expresses basement outcrop.

The surface velocities ranged between 1030 and 1786 ft./sec. thus indicating a varied canal embankment fill. In general the surface velocities increased from west to east across the refraction profiles.

Beneath this fill the velocities ranged from 2869 to 6557 ft./sec. This wide spectrum of velocities inferred varying degrees of caliche cementation of the alluvium. To draw attention to this subsurface scenario a possible caliche lens is illustrated on the NW end of SL 104.

Drill hole control (TH 80-5) in close proximity to station 7 on the NW terminus of the profiles drilled through an alluvial sequence of gravels and sands down to a TD of 30 feet. At station 7 a seismic interface (5882 ft./sec.) at 20.5 feet apparently marks the lithologic change from sandy gravel to a more compacted gravelly sand with larger cobbles as noted on the drill log at 21 feet. Also this may be indicative of increased moisture.

Photographs 13 through 17 give an excellent view of the seismic profile layout and the existing surface conditions in the area. Note that the sides of the canal are cement lined throughout this reach.

4. Line 107 - 110 (Refer to Figure 16)

On the east end of the project (Sector "B") the predominant subsurface feature is a probable basement projection of quartzite which may represent a narrow horst. Quartzite could be a reasonable assumption since the geologic Map 2 shows the quartzite outcropping 3/4 mile to the north just before it plunges southward plus the fact that the seismic velocities within the feature range from 9000 to 16129 ft./sec. At station 14 the crest of the possible quartzite subcrops at approximately 15 feet. Below this crest is the probable competent quartzite contact at a depth of about 38 feet (interpretation - no actual seismic interface recorded). This contact is based on seismic velocity breaks at station 17 (10204 ft./sec.) and station 15 (16129 ft./sec.) Added seismic control for the quartzite configuration occurs at station 13 (9470 ft./sec.) , station 14 (9000 ft./sec.), and at station 15 (9091 ft./sec.). Across this anomaly and on its flanks appear alluvial deposits displaying velocities of 1111 to 6637 ft./sec. These deposits range from virtually no caliche to highly calichified alluvium.

In Sector "A" the seismic data indicated a sequence of gravels with one exception. This exception was the high velocity marker of 11364 ft./sec. (depth 22 feet) at station 12 of SL 107. This high velocity is supported by the far arrival times from station 11. These arrivals displayed apparent velocities of 10714 ft./sec. This anomaly has been interpreted as a very dense stringer within the gravel sequence. This picture needs confirmation to check on the possibility of basement rock.

GEOSEISMIC SECTIONS

In Sector "A" about midpoint of SL 107 a drill hole (DH 82-2) logged alluvium down to TD of about 30 feet. The silty sandy gravel sequence at about 10 foot depth changed to a more dense, damp to moist condition. This condition probably represents the seismic break at approximately the same depth along the profile. These velocities ranged from 4310 to 6219 ft./sec. and averaged 4913 ft./sec. The corresponding velocity average from SL 82-1, SL 82-2, and SL 82-12 (Corp of Engineers) gave 5000 ft./sec. Also this is a low drainage area with the canal sides being unlined. These gravels may also be very wet to saturated since the velocities displayed are also those of the hydro p-wave which approaches 5000 ft./sec. Photographs 18 and 19 show this sector very well.

In Sector "C" the high velocity material (9000 - ft./sec.) appeared to dip westward - suggesting a trough - like sequence of gravels. Seismic data at station 16, west end of SL 110, produced velocities ranging from 1079 to 6637 ft./sec., thus supporting the contention of alluvial deposits possessing varying amounts of cementation.

Some seismic signal deterioration was evident on the west end of SL 110. Perhaps subsurface complexities coupled with man-made structures (i.e. surface pavement, possible underground installations) contributed to questionable data below 20 feet. This sector certainly needs more attention since the proposed tunnel alignment runs through this area. The surface material showed moderate variance with velocities ranging from 962 to 1786 ft./sec. Photographs 20 through 24 show the area across SL 108, 109, and 110.

****

A word of clarification on the interpretations ---

Solid lines indicate a strong justification for their use as supported by seismic and/or drill hole data, longer dashed lines suggest some reservations on the structural configuration because of less firm data, and short dashed lines suggest inference from the surrounding structural attitudes all coupled with good geological savvy.

CONCLUSIONS

The results of the seismic survey can be summarized as follows:

1. Overall quality of the seismic data was good and it can be considered reliable.

2. The seismic time-distance graphs showed good linear coherence for the individual refracting layers.

3. The subsurface structure within the project area can be effectively mapped by the refraction seismic method.

4. The subsurface structure along the proposed tunnel alignment is complex as attested to by seismic data, drill hole information, and the geological history of the Phoenix Mountains. The travel-time graphs show patterns typical of laterally varying structures.

5. Three probable anticlinal anomalies were detected on the areas explored. These are likely basement features and each has been discussed in this report.

CONCLUSIONS

6. The alluvial deposits show a wide range of velocities which indicate the degree of calichification. Some of the indurated alluvium will require blasting for effective removal

7. According to information supplied by Shank in his environmental report all of the formations encountered in the Phoenix Mountains are generally good for tunnels except the boulder alluvium and colluvium. The younger alluvium usually requires shoring. See Map 2 for details of excavation conditions.

RECOMMENDATIONS

In order to properly evaluate the subsurface conditions within the project area the following seismic and drill program is submitted for your consideration.

This proposed program is designated on Map 2 (in blue) as outlined below.

A. Extend seismic profile eastward another 600 feet from SL 107 in order to evaluate the high velocity anomaly. Select a drill hole location to help ascertain the nature of this anomaly.

B. Extend seismic profile westward another 300 feet from SL 110 to help evaluate the trough-like sequence of alluvial gravels. Place a drill hole at or near station 16.

C. Extend seismic profile northward (about 300') from station 14, if possible, to help clarify the attitude of the high velocity anomaly in Sector "B". Place a drill hole at station 14 to check validity of basement subcrop.

D. Conduct a seismic survey of 600 feet along the canal in front of the Biltmore Hotel. Select a drill hole location along this profile.

E. Extend seismic control northward from SL 103B to the paved road. This would be about another 100 feet. Place a drill hole at the north end to check depth of schist.

F. Place a drill hole at station 1 to check depth to competent schist.

G. Conduct a seismic survey of 600 feet northward from DH 82-5 along the west side of 24th Street. Place a drill hole on the north end of this line.

H. Extend the seismic survey along the canal to tie points 10 and 18 (about 575') and then join this profile at or about point 18 with another seismic profile running north or northeastward for approximately 600 feet. Place a drill hole on the north end of this line.

RECOMMENDATIONS

I. Select a drill hole location about 600 feet east of station 19 in order to clarify basement depth north of DH 82-6 and the adjacent quartzite outcrop on the hill south of the canal,

J. Conduct a seismic survey eastward from point 7 (along north side of Maryland Ave.) for about 1200 feet. Place drill hole on the east end of this line.

K. Place a drill hole at point 9 to check validity of depth to competent quartzite. This location is on the crest of the feature mapped as quartzite.

I trust this report will assist you in the assessment of the project logistics.

If you have any questions on this matter please feel free to give me a call.

Very truly yours,
Geo-Pro Consulting Company

Paul L. Scheffey

Paul L. Scheffey, P.E.
Consultant

cc: file
encl. 20
photos 24
appendix - seismic field data
Corp of Engineers data

Registered Professional Engineer (Geophysical)
CERTIFICATE NO. 11623
PAUL L. SCHEFFEY
Date Signed 8/11/88
TUCSON, ARIZ. U.S.A.

Table A2. Approximate range of velocities of longitudinal waves for representative materials found in the earth's crust.[a]

A. *Classification According to Material*

Material	*Velocity** Ft./Sec.	*Velocity** M./Sec.
Weathered surface material	1,000— 2,000	305— 610
Gravel, rubble, or sand (dry)	1,500— 3,000	468— 915
Sand (wet)	2,000— 6,000	610— 1,830
Clay	3,000— 9,000	915— 2,750
Water (depending on temperature and salt content)	4,700— 5,500	1,430— 1,680
Sea water	4,800— 5,000	1,460— 1,530
Sandstone	6,000—13,000	1,830— 3,970
Shale	9,000—14,000	2,750— 4,270
Chalk	6,000—13,000	1,830— 3,970
Limestone	7,000—20,000	2,140— 6,100
Salt	14,000—17,000	4,270— 5,190
Granite	15,000—19,000	4,580— 5,800
Metamorphic rocks	10,000—23,000	3,050— 7,020
Ice	12,050	

B. *Classification According to Geologic Age*

Age	*Type of Rock*	*Velocity* Ft./Sec.	*Velocity* M./Sec.
Quaternary	Sediments (various degrees of consolidation)	1,000— 7,500	305— 2,290
Tertiary	Consolidated Sediments	5,000—14,000	1,530— 4,270
Mesozoic	Consolidated Sediments	6,000—19,500	1,830— 5,950
Paleozoic	Consolidated Sediments	6,500—19,500	1,980— 5,950
Archeozoic	Various	12,500—23,000	3,810— 7,020

C. *Classification According to Depth*†

	0—2000 ft. (0—600 M.) Ft./Sec.	2000—3000 ft. (600—900 M.) Ft./Sec.	3000—4000 ft (900—1200 M.) Ft./Sec.
Devonian	13,300	13,400	13,500
Pennsylvanian	9,500	11,200	11,700
Permian	8,500	10,000	.....
Cretaceous	7,400	9,300	10,700
Eocene	7,100	9,000	10,100
Pleistocene-to-Oligocene	6,500	7,200	8,100

* The higher values in a given range are usually obtained at depth.

† Data from B. B. Weatherby and L. Y. Faust, *Bull. Amer. Assoc. Petrol. Geologists*, 19 (1935) 1.

[a]Reprinted from pg. 660 of Jakosky[2].

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GEOPHYSICS - GEOLOGY - GEOCHEMISTRY

SCHEFFEY ENTERPRISES
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PHOENIX, ARIZONA 85021

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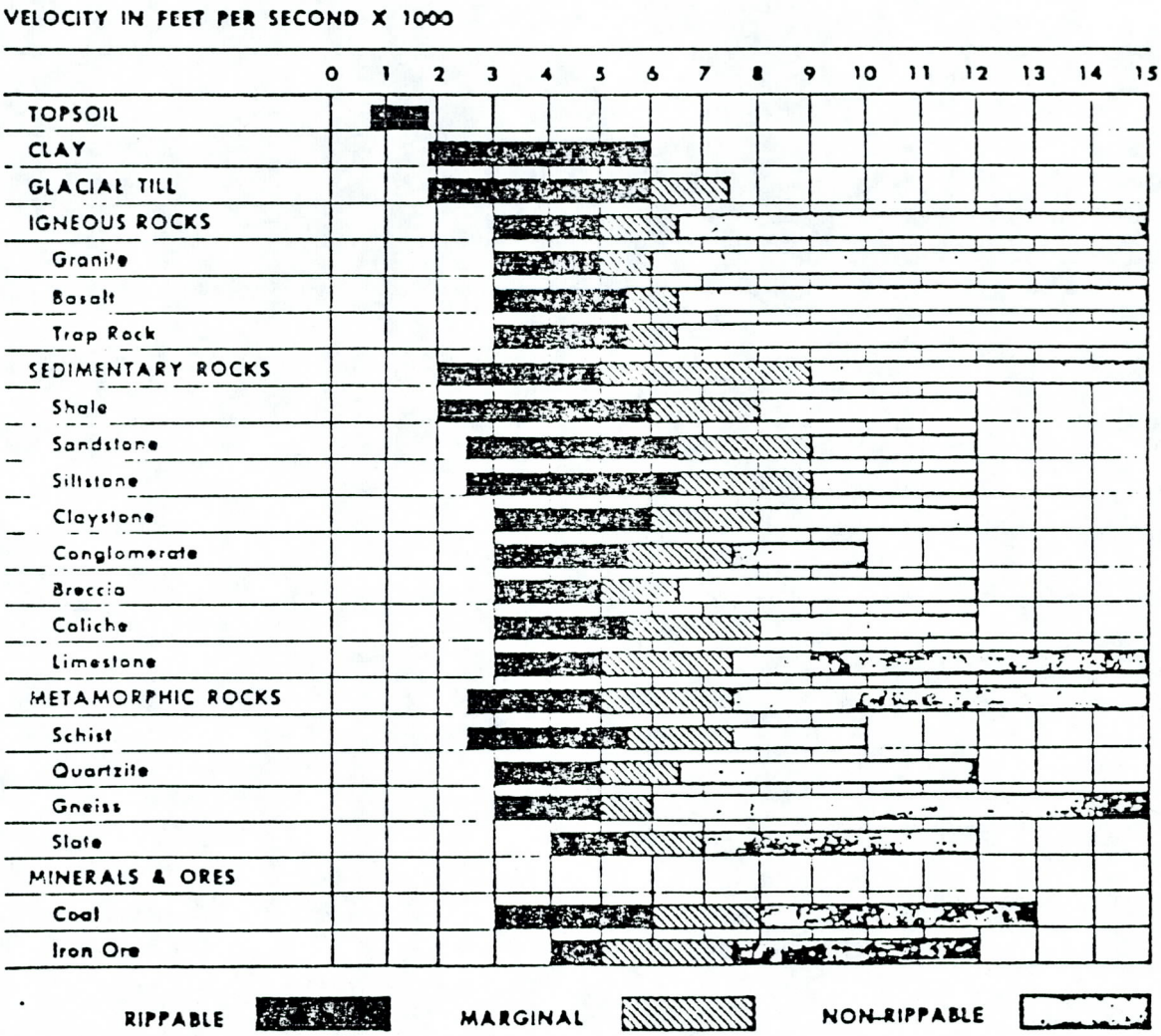
Table 2

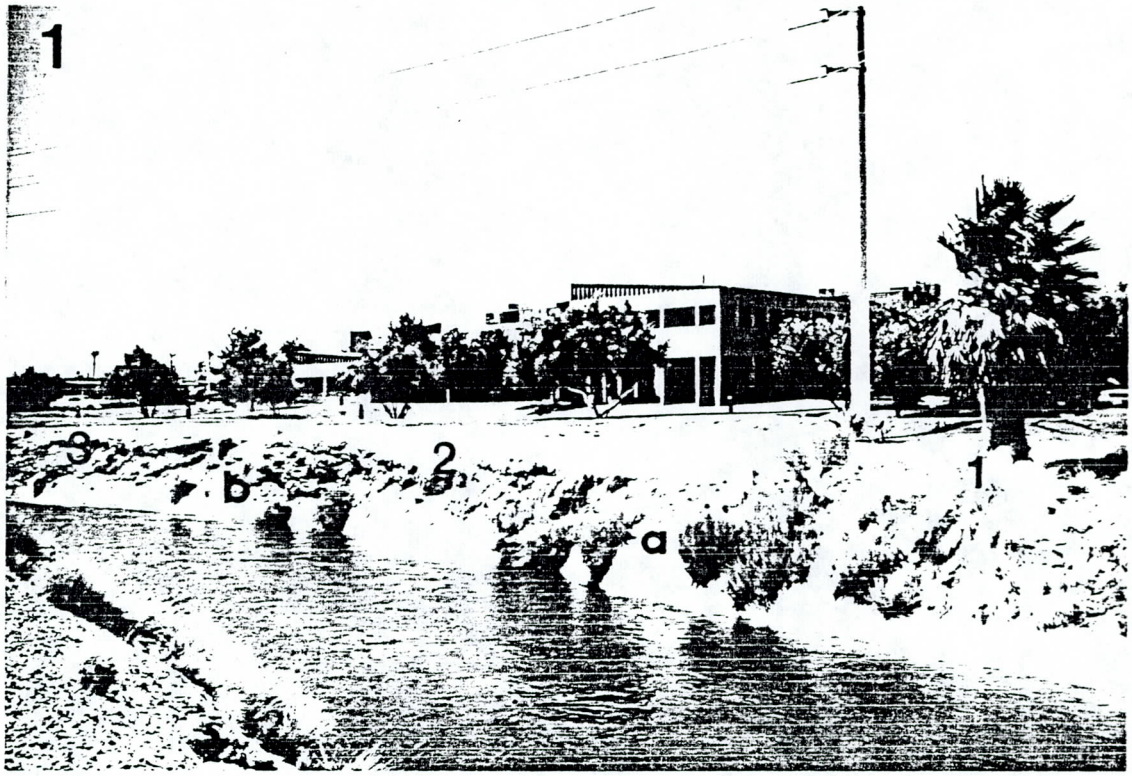
SEISMIC RIPPABILITY CHART*

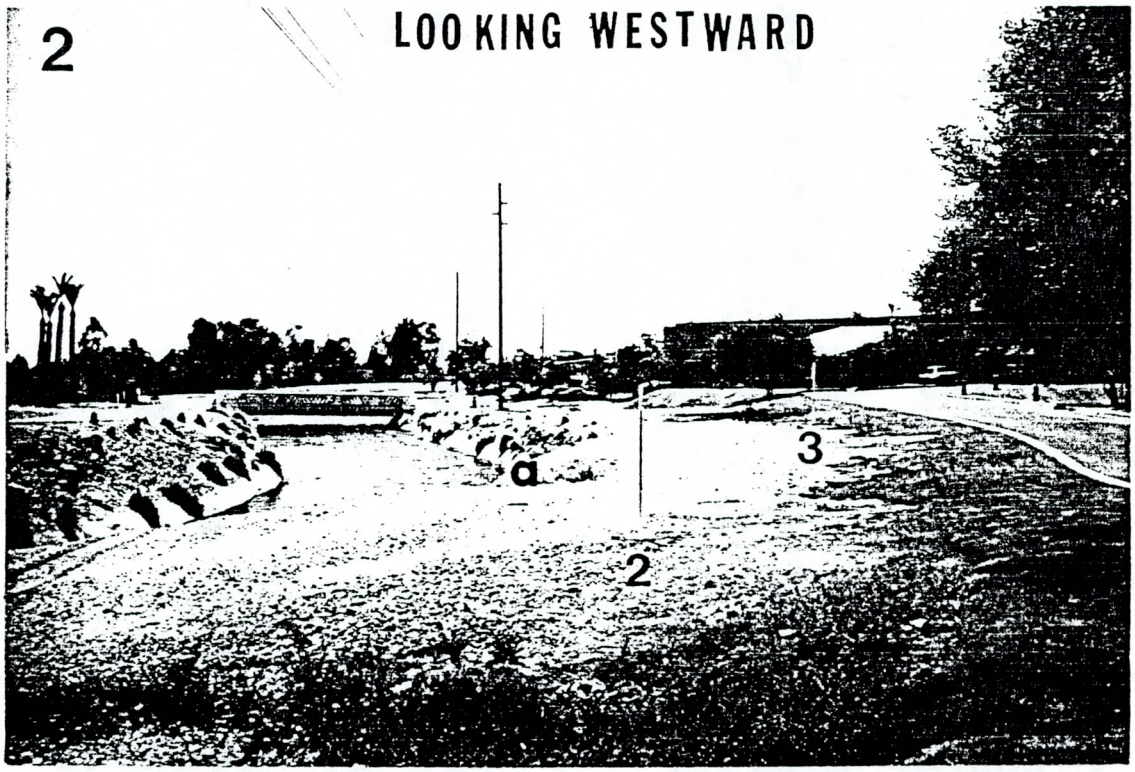


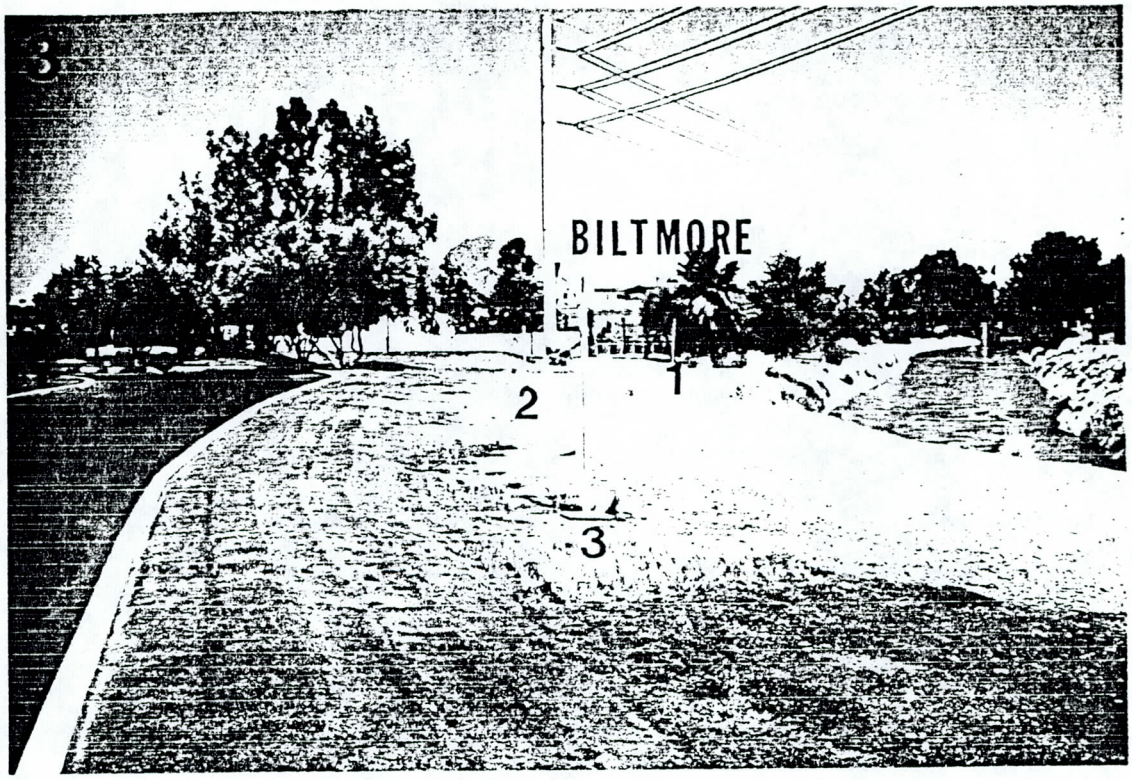
* Developed by Caterpillar Tractor Company for the Caterpillar D9 with mounted hydraulic No.9ripper.

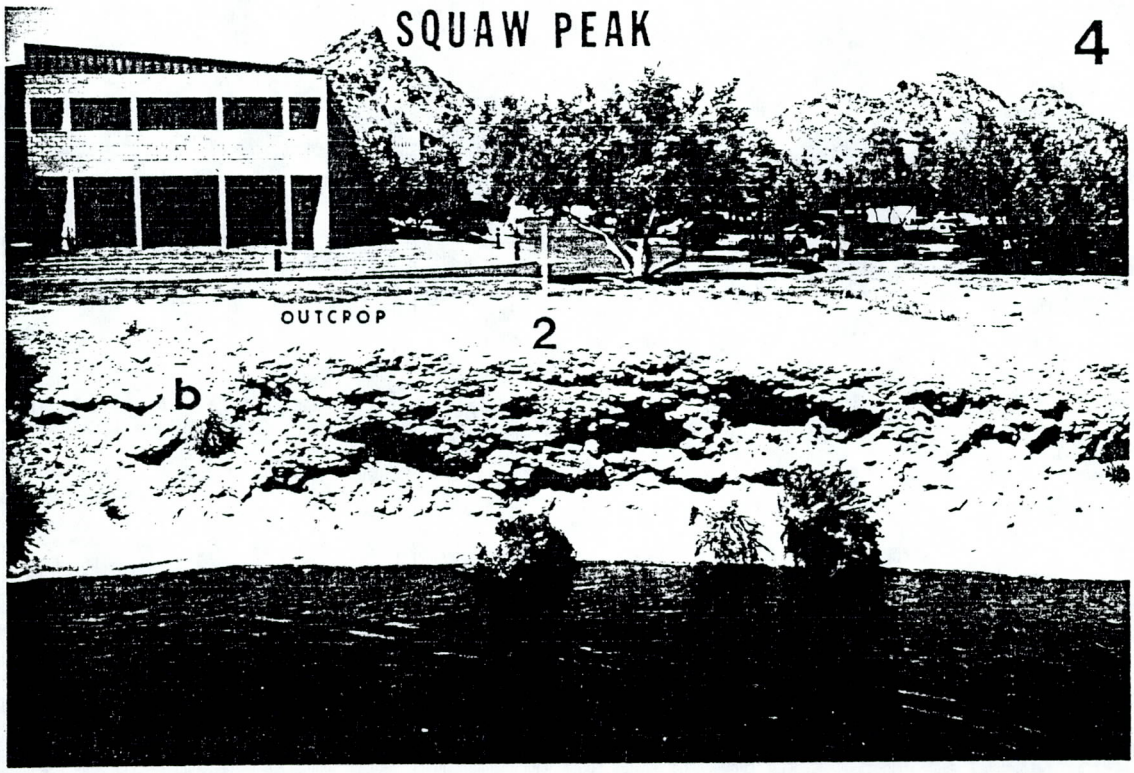
Note: The upper limit of rippability for most earth materials falls between 5000 to 6000 feet per second. Marginal cases can extend this range to 9000 feet per second.

A seismic survey can assist in the economic evaluation of most excavation programs.

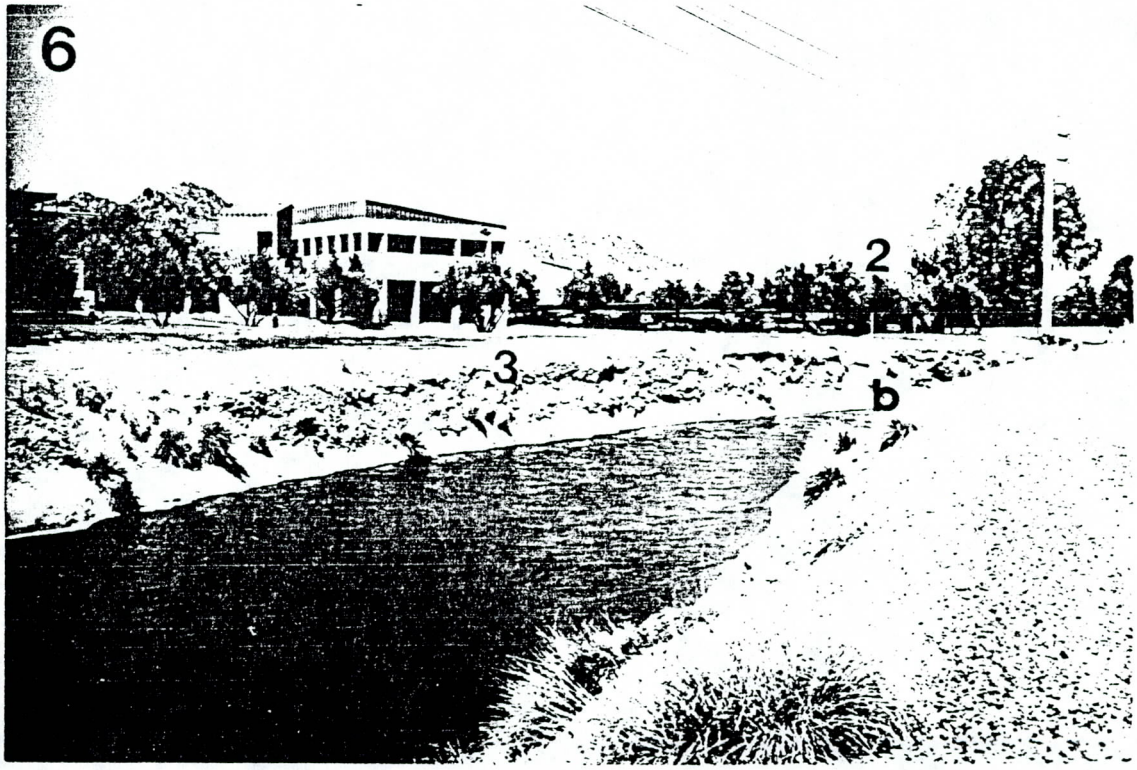

1
3
b
2
a
1

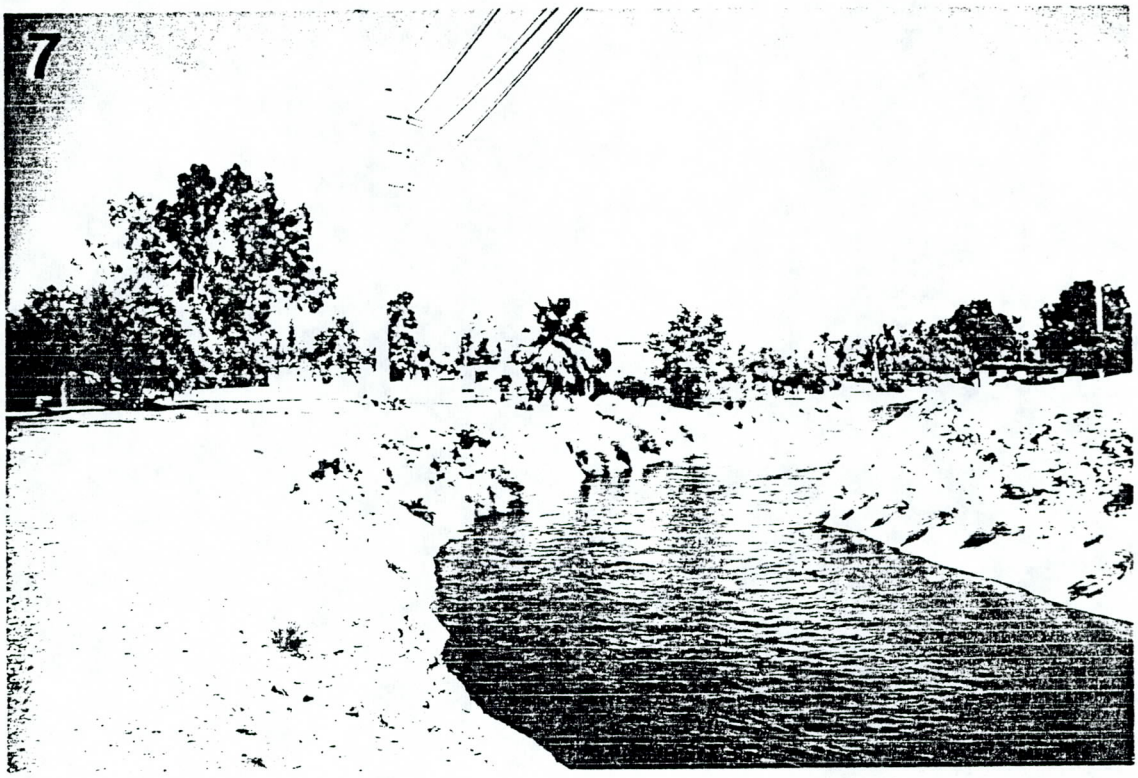

2
LOOKING WESTWARD
a
3
2


3
BILTMORE
1
2
3


SQUAW PEAK
4
OUTCROP
2
b

5
3


6
2
3
b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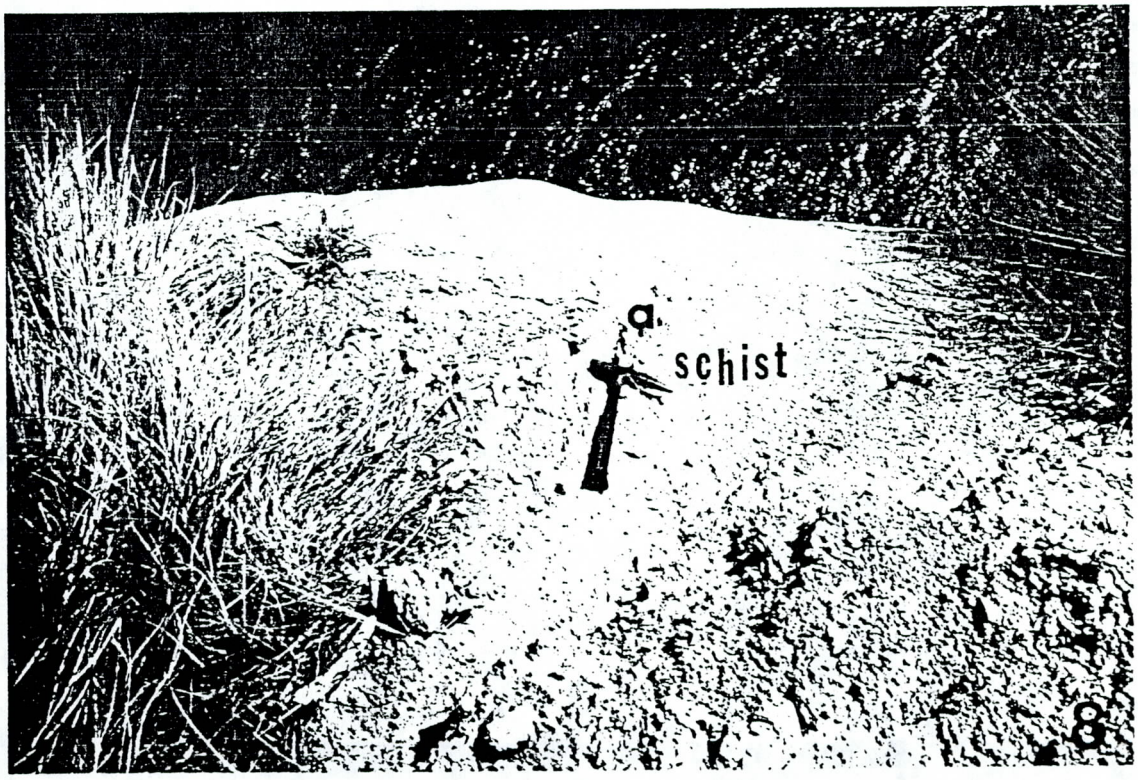
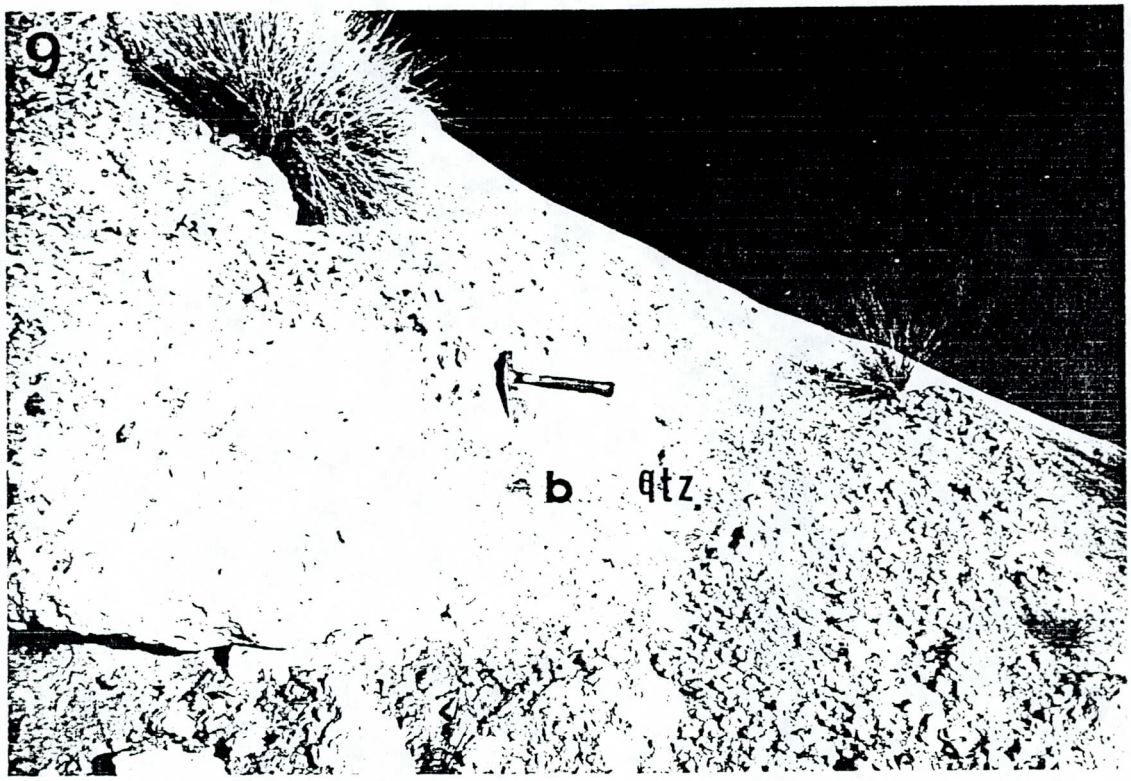

a.
schist
8

9



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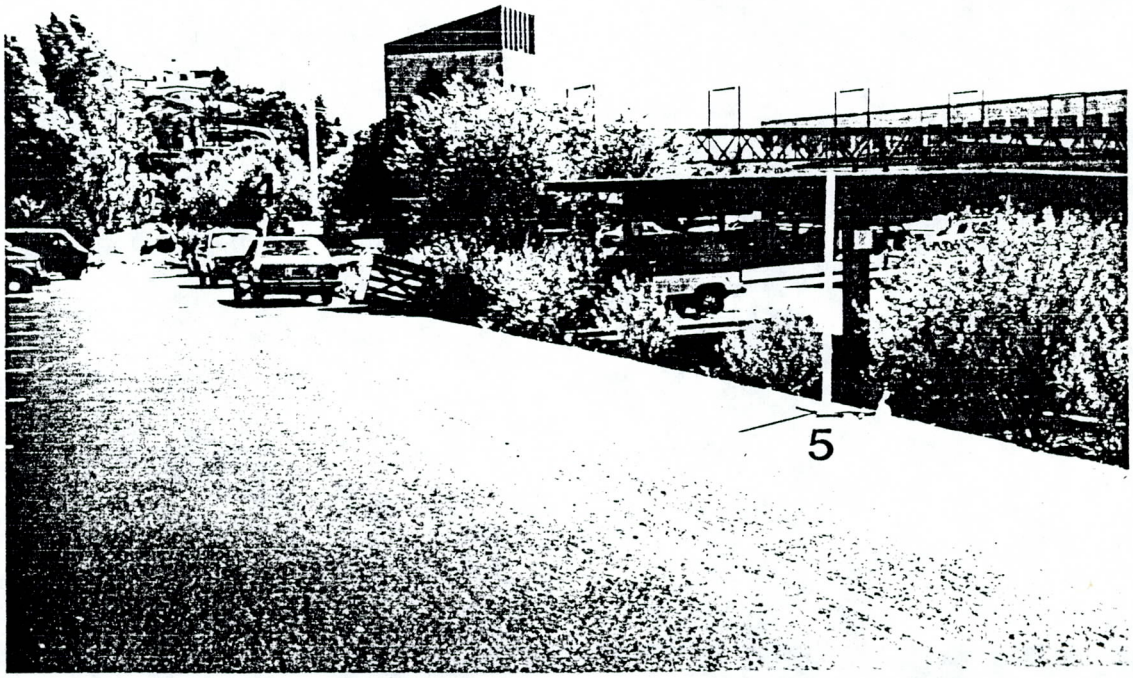

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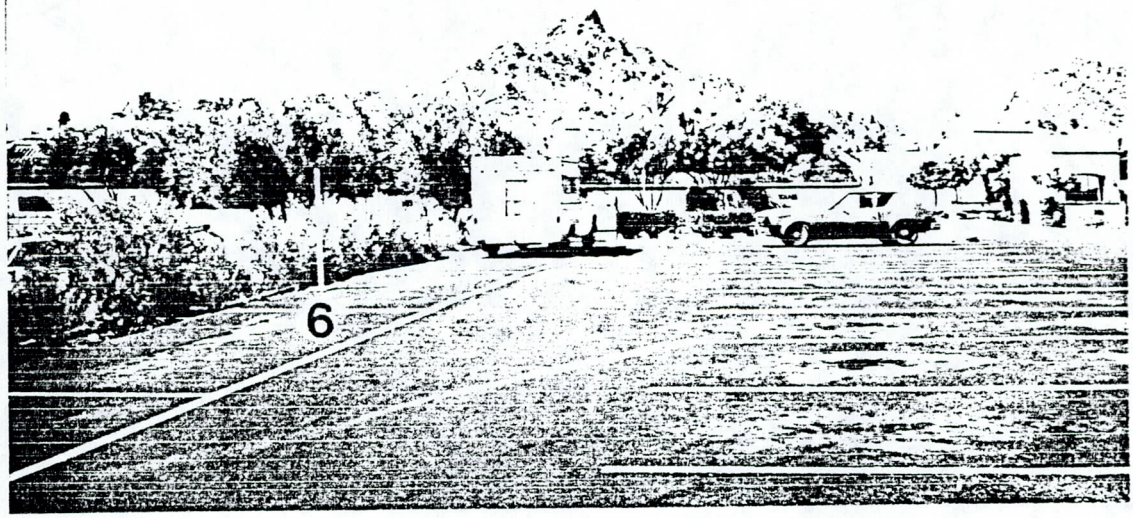
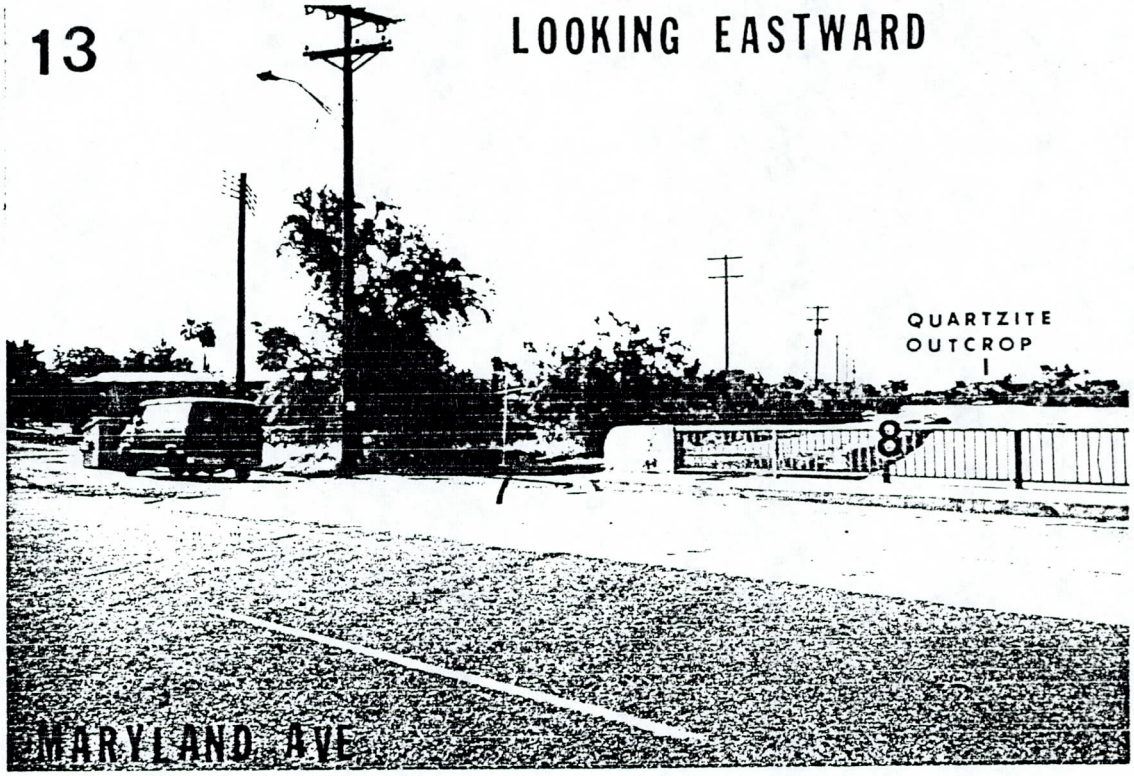
SQUAW PEAK



12

WRIGLEY MANSION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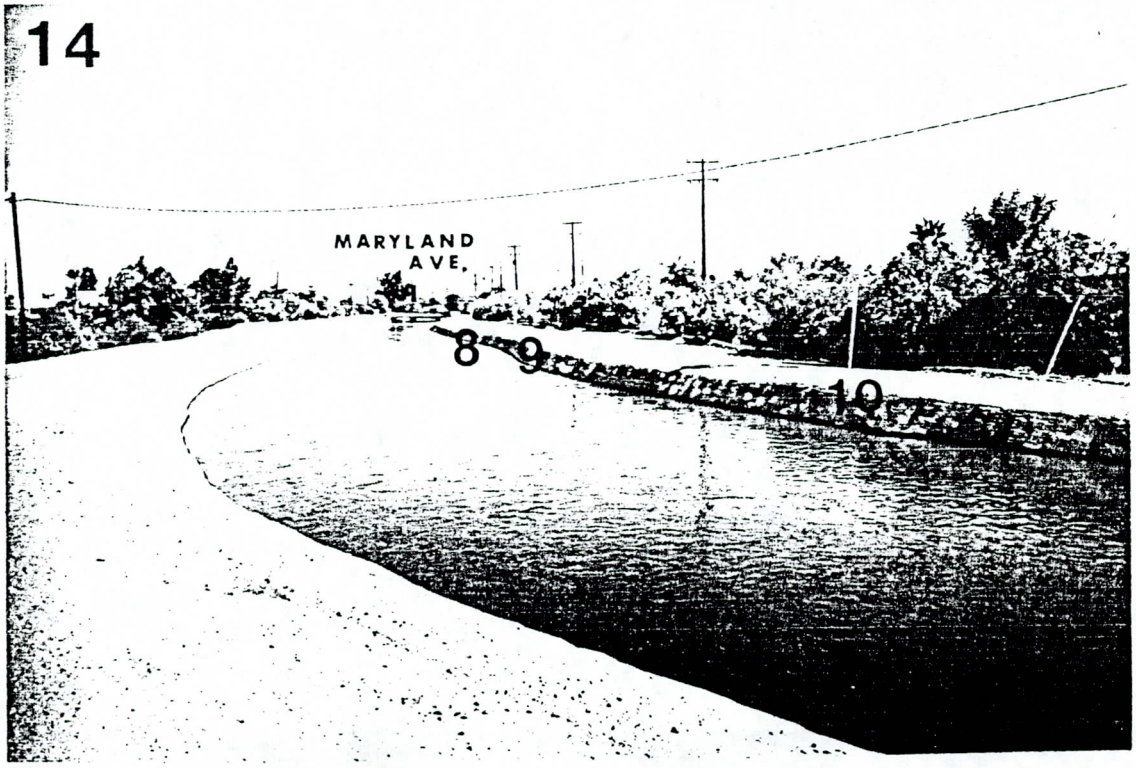
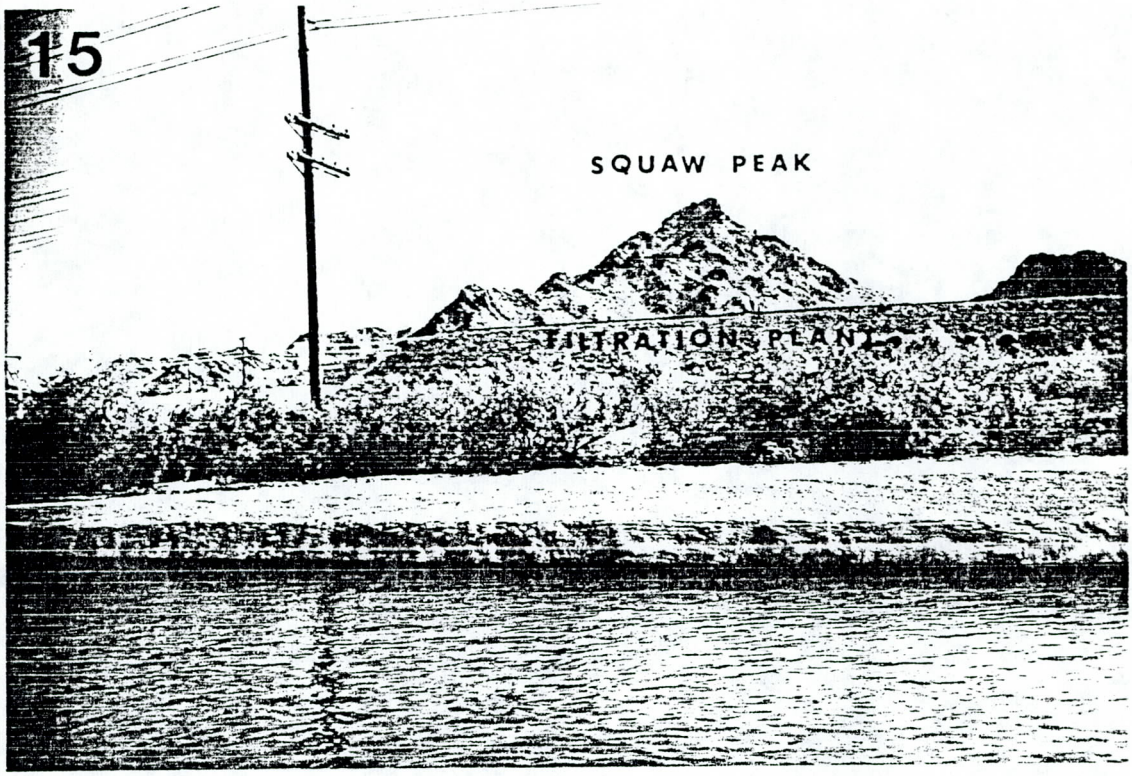
LOOKING EASTWARD
QUARTZITE
OUTCROP
8
MARYLAND AVE


14
MARYLAND
AVE.
8
9
10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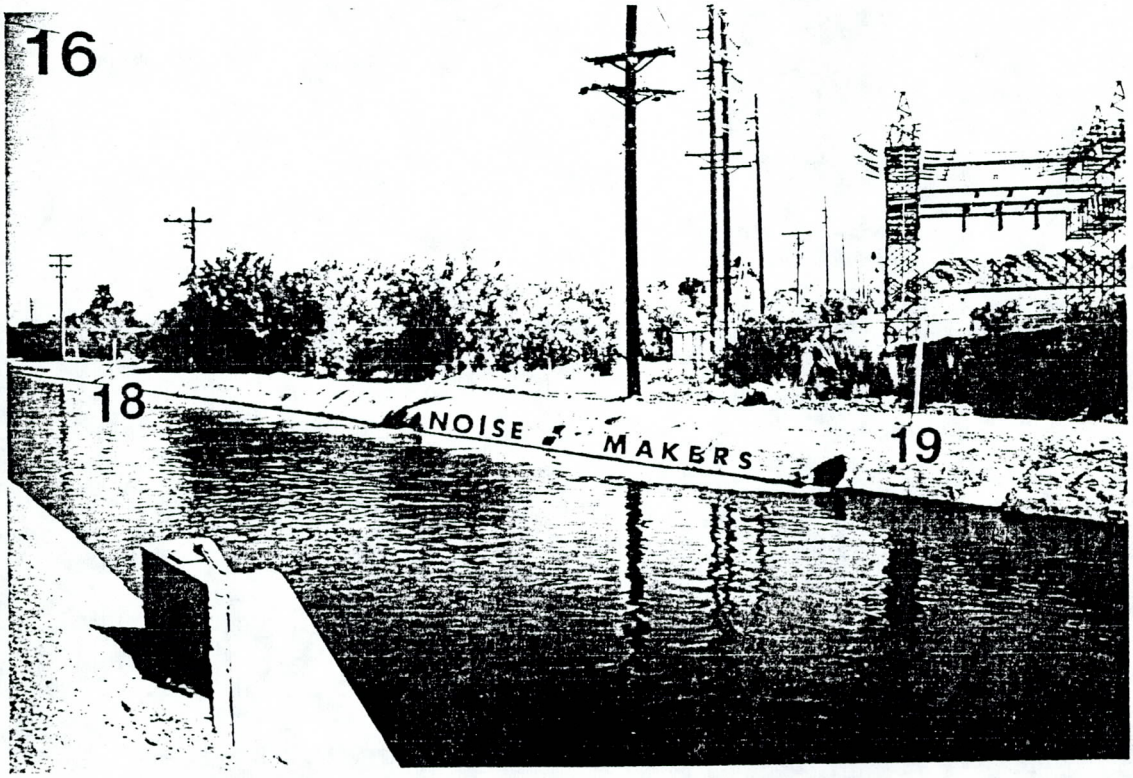
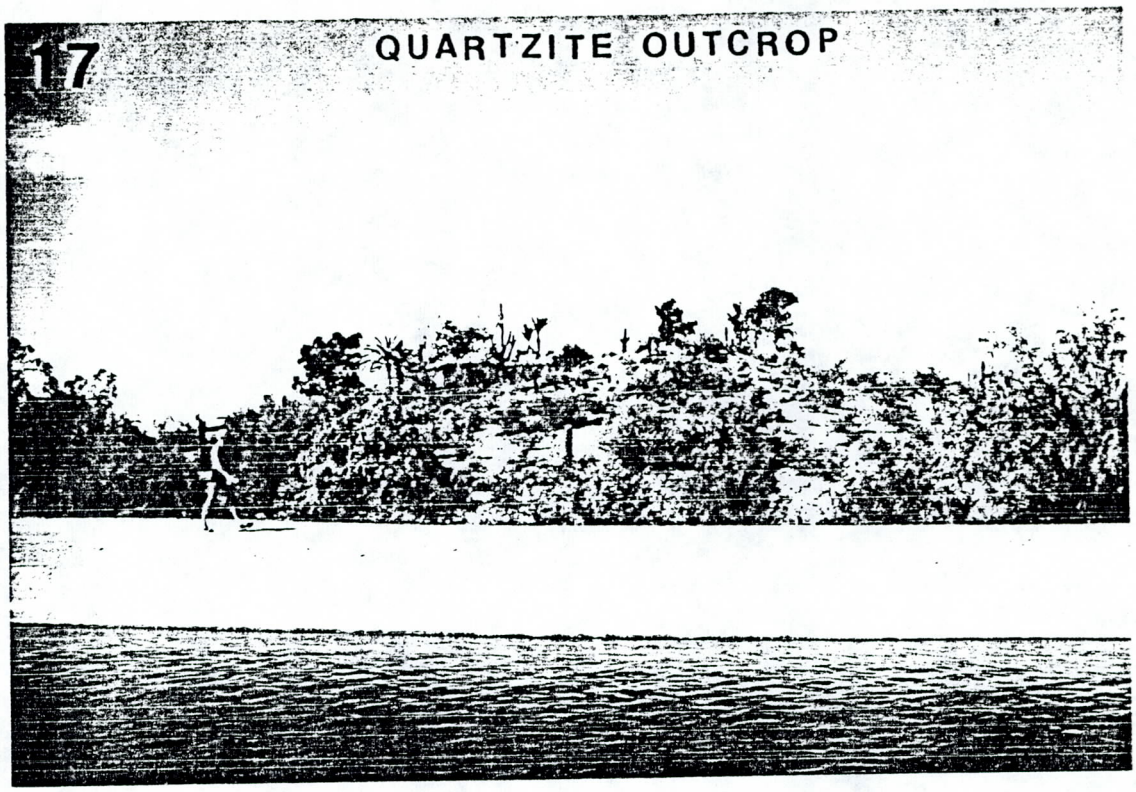
SQUAW PEAK
FILTRATION PLANT


16
18
NOISE MAKERS
19



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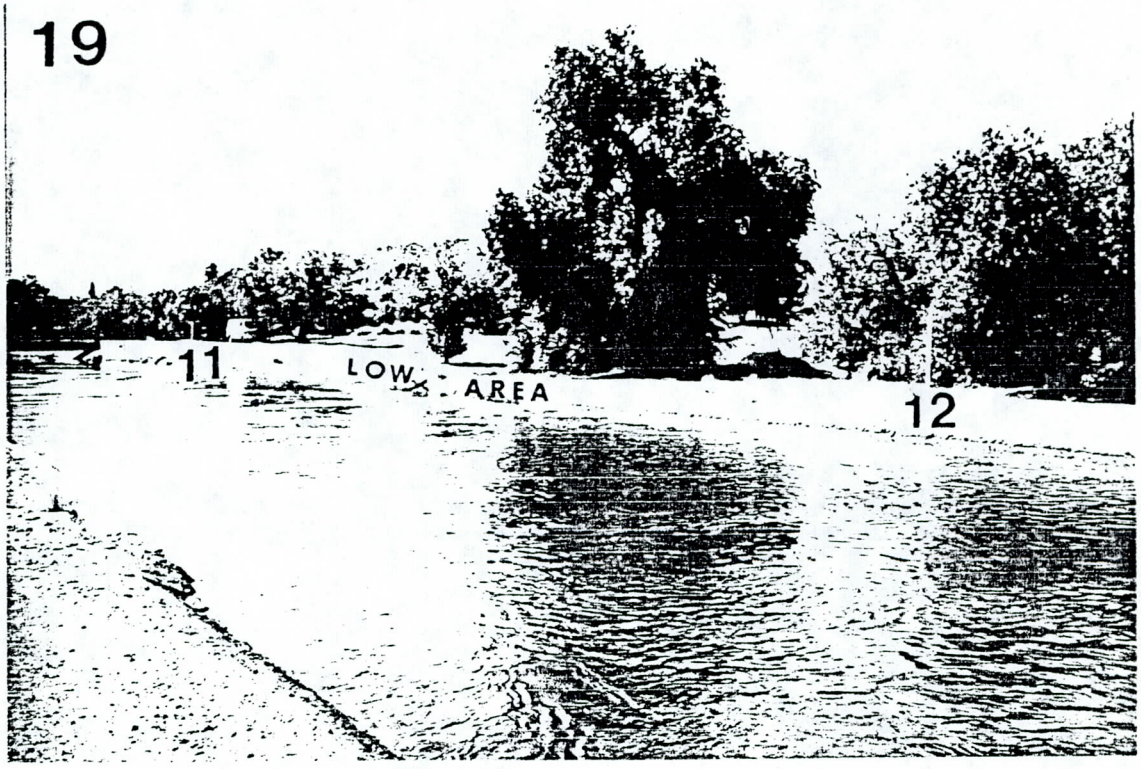

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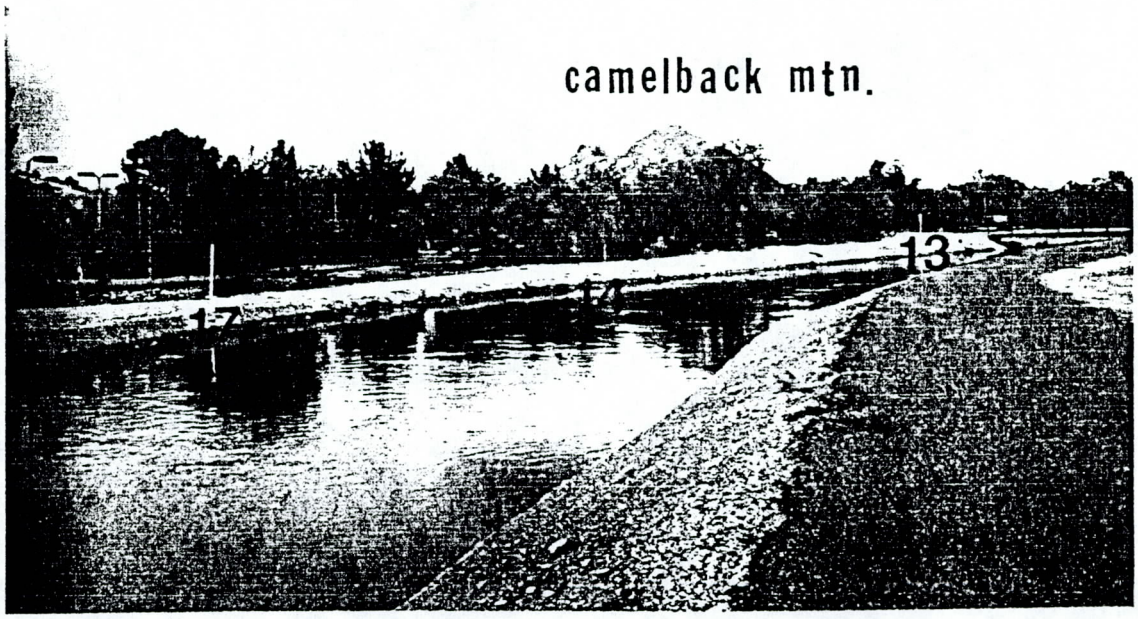

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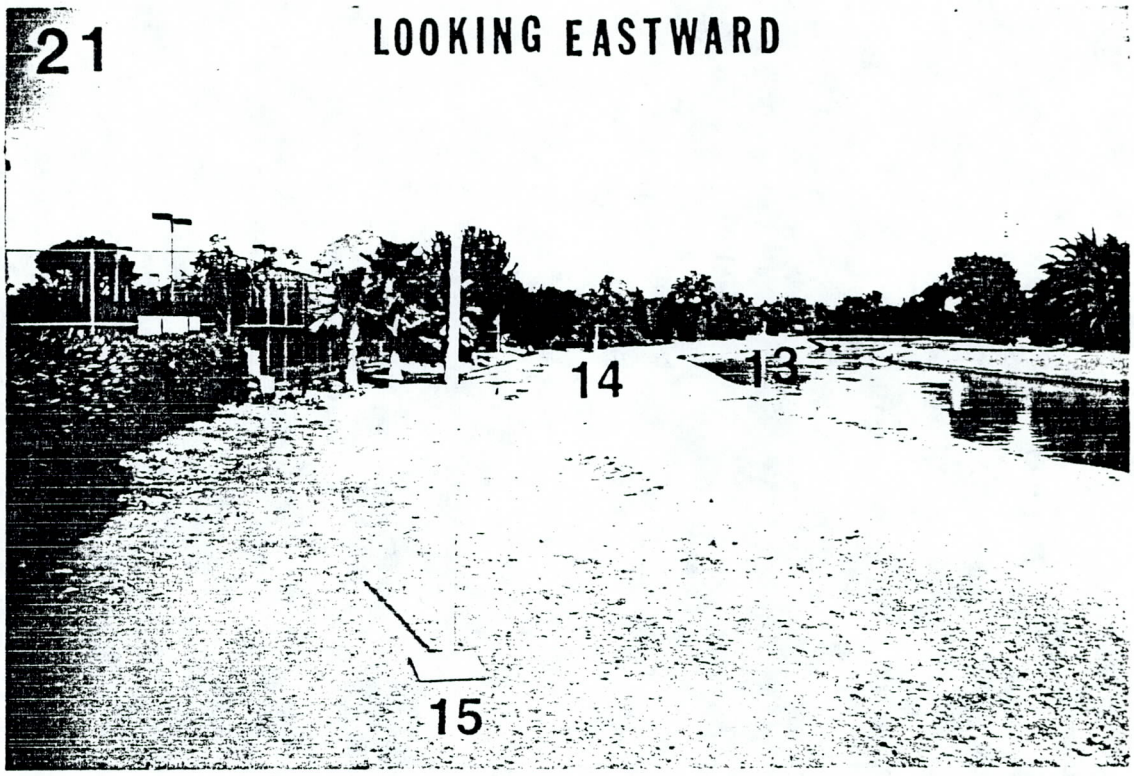
LOOKING EASTWARD



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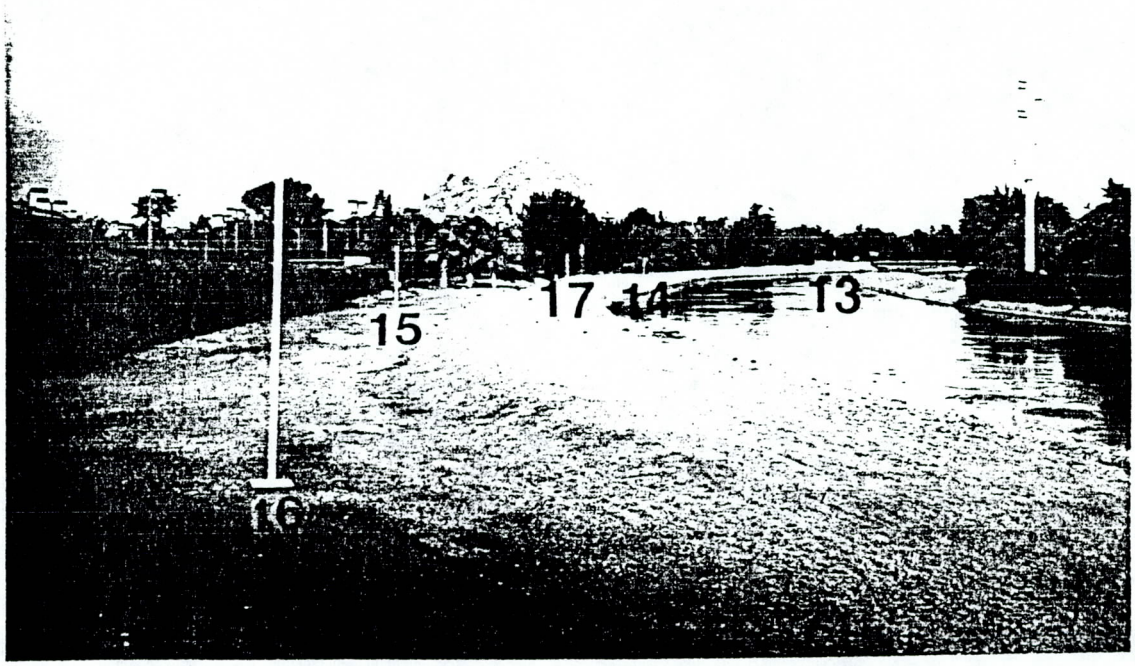

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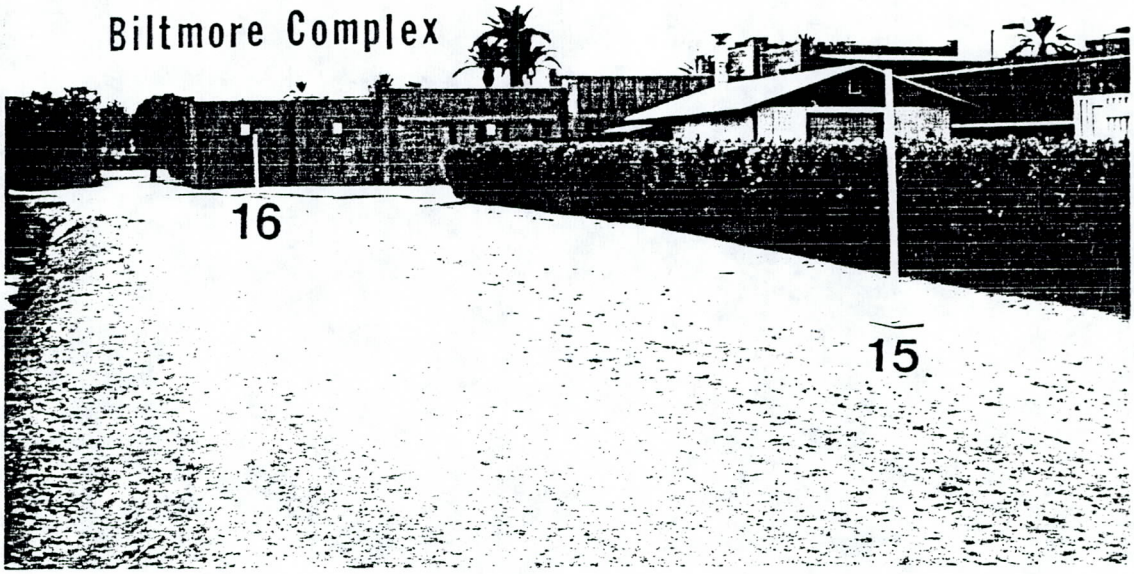
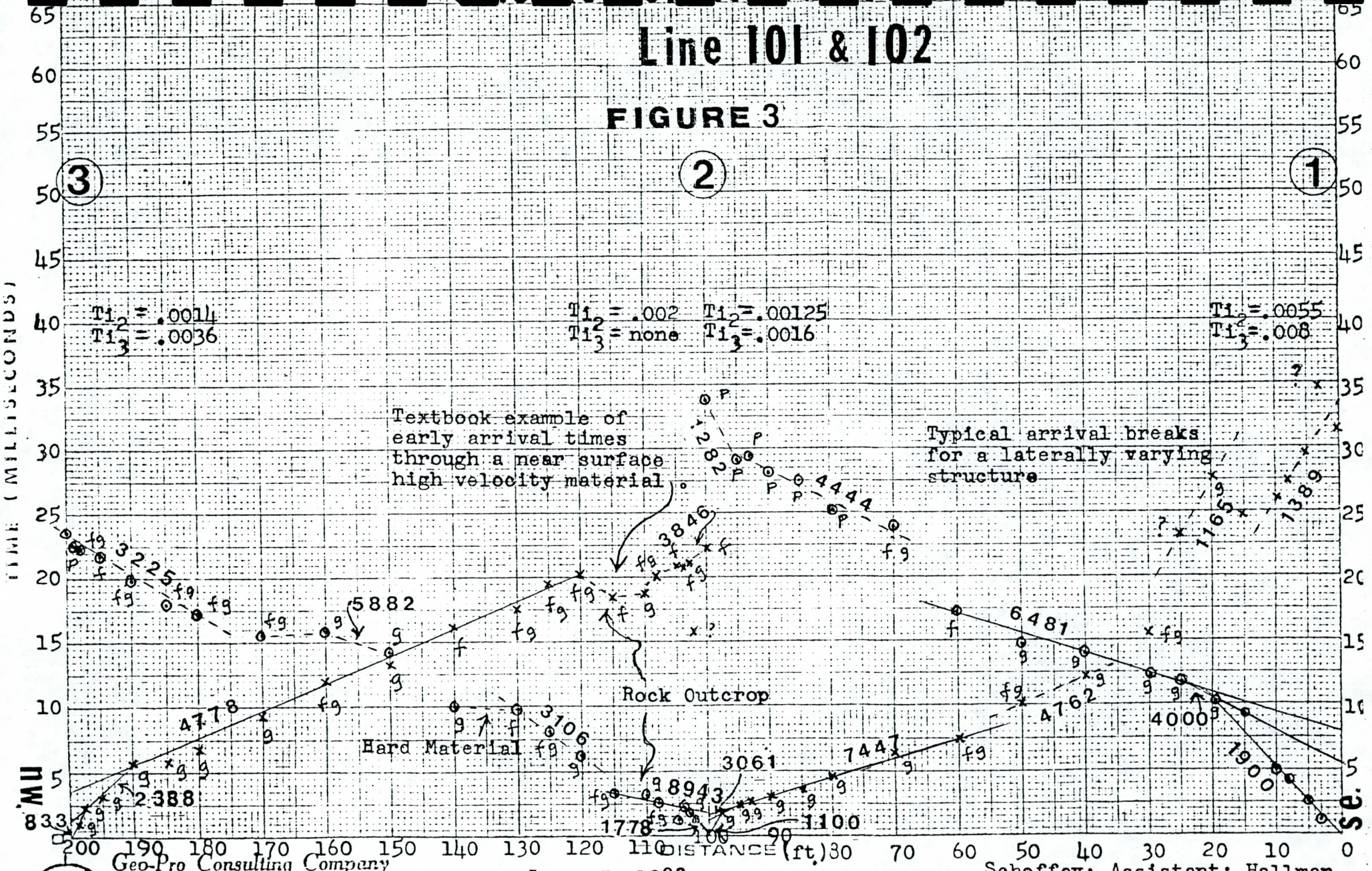


24

Seismic Refraction Profile

Line 101 & 102

FIGURE 3



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GEOPHYSICS - GEOLOGY - GEOCHEMISTRY

SCHEFFEY ENTERPRISES
1736 W. Carol Ave.
TELEPHONE 943-5597

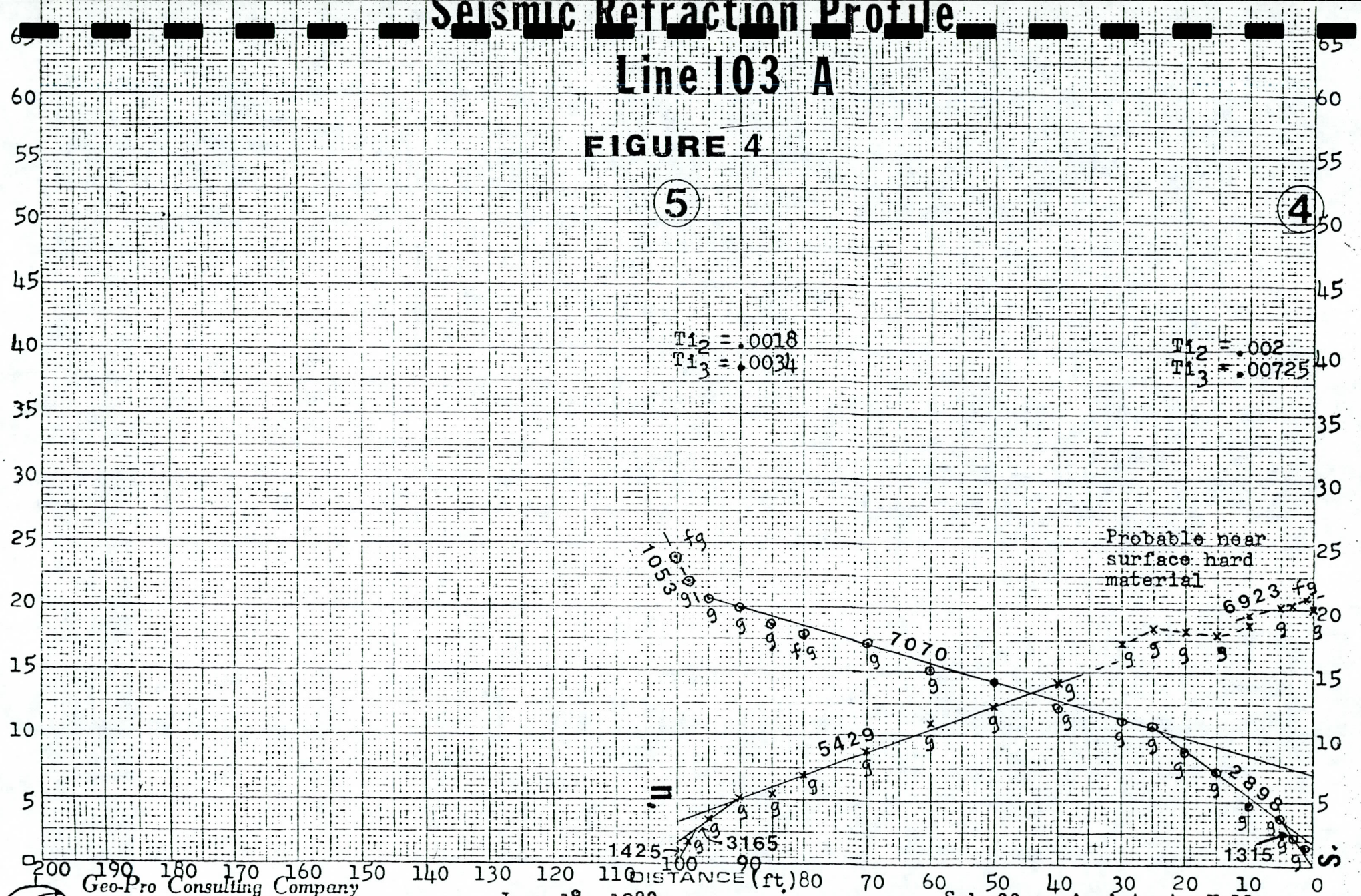
DATE June 17, 1988
OPERATOR Scheffey; Assistant: Hallman
JOB ACDC Tunnel
Security check at 7:35 PM
TRAVERSE SL 101, NW-SE; SL 102, E-W
Both are 100' spreads.
LOCATION/DESCRIPTION SW¼, Sec.11, T2N, R3E, Maricopa Co. Az.
¼ mile west of Biltmore Hotel

Started work at 6 PM
Windy gusts, some airplane noise
Hot summer night

Seismic Refraction Profile

Line 103 A

FIGURE 4



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GEOPHYSICS - GEOLOGY - GEOCHEMISTRY

DATE June 18, 1988 OPERATOR Scheffey; Assistant: Hallman

JOB ACDC Tunnel TRAVERSE SL 103A, N-S, 100' spread

SW¼, Sec. 11, T2N, R3E, Maricopa Co., Az.

Approx. ¼ mile west of Biltmore Hotel.

SCHEFFEY ENTERPRISES
1736 W. Carol Ave.
Phoenix, Az 85021
TELEPHONE 943-5597

LOCATION/DESCRIPTION

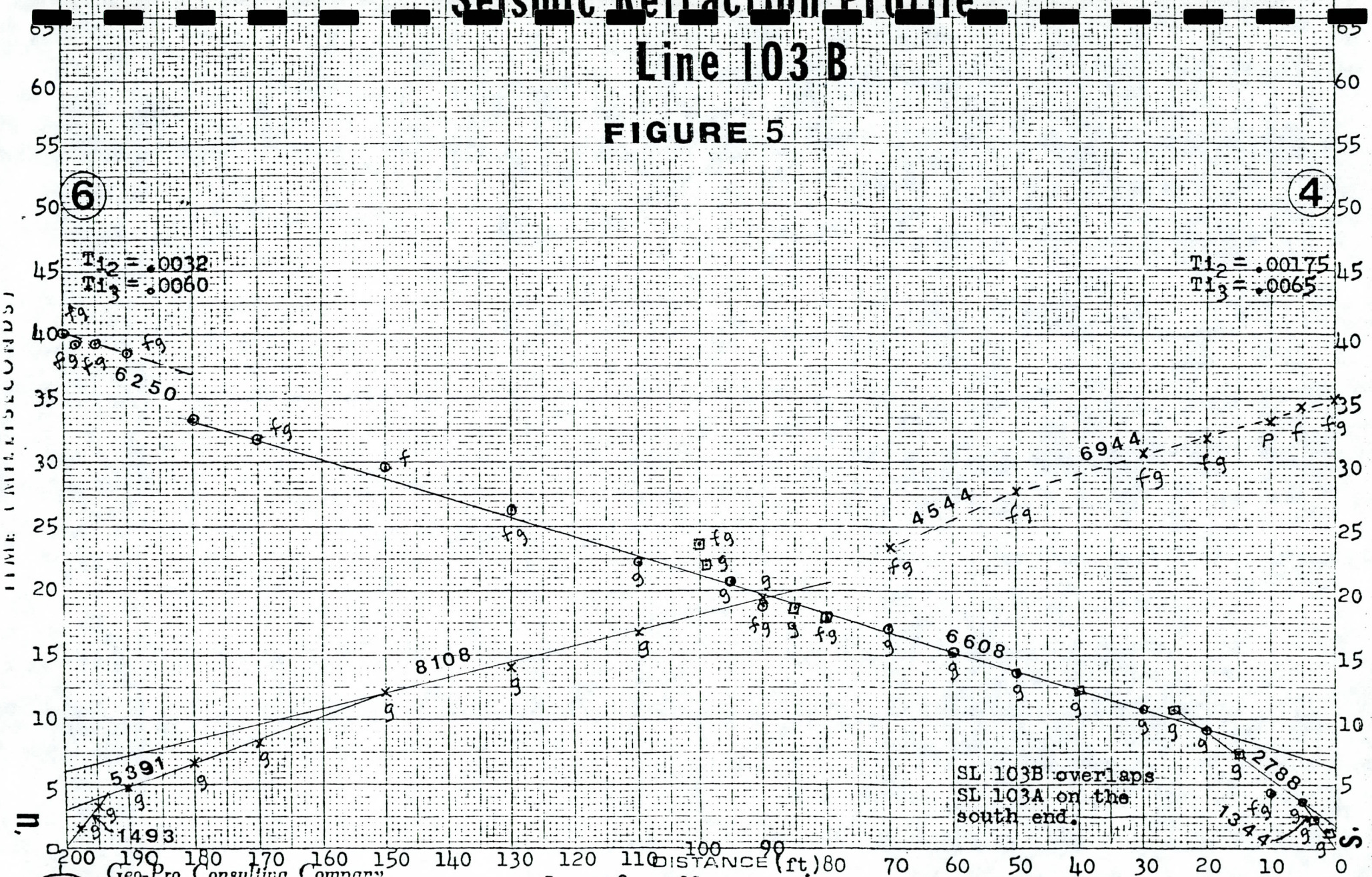
Started work at 6:00 PM.

Overcast, Buried geophones due to wind.

Seismic Refraction Profile

Line 103 B

FIGURE 5



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SCHEFFEY ENTERPRISES
1736 W. Carol Ave.
Phoenix, Az. 85021

TELEPHONE 943-5597

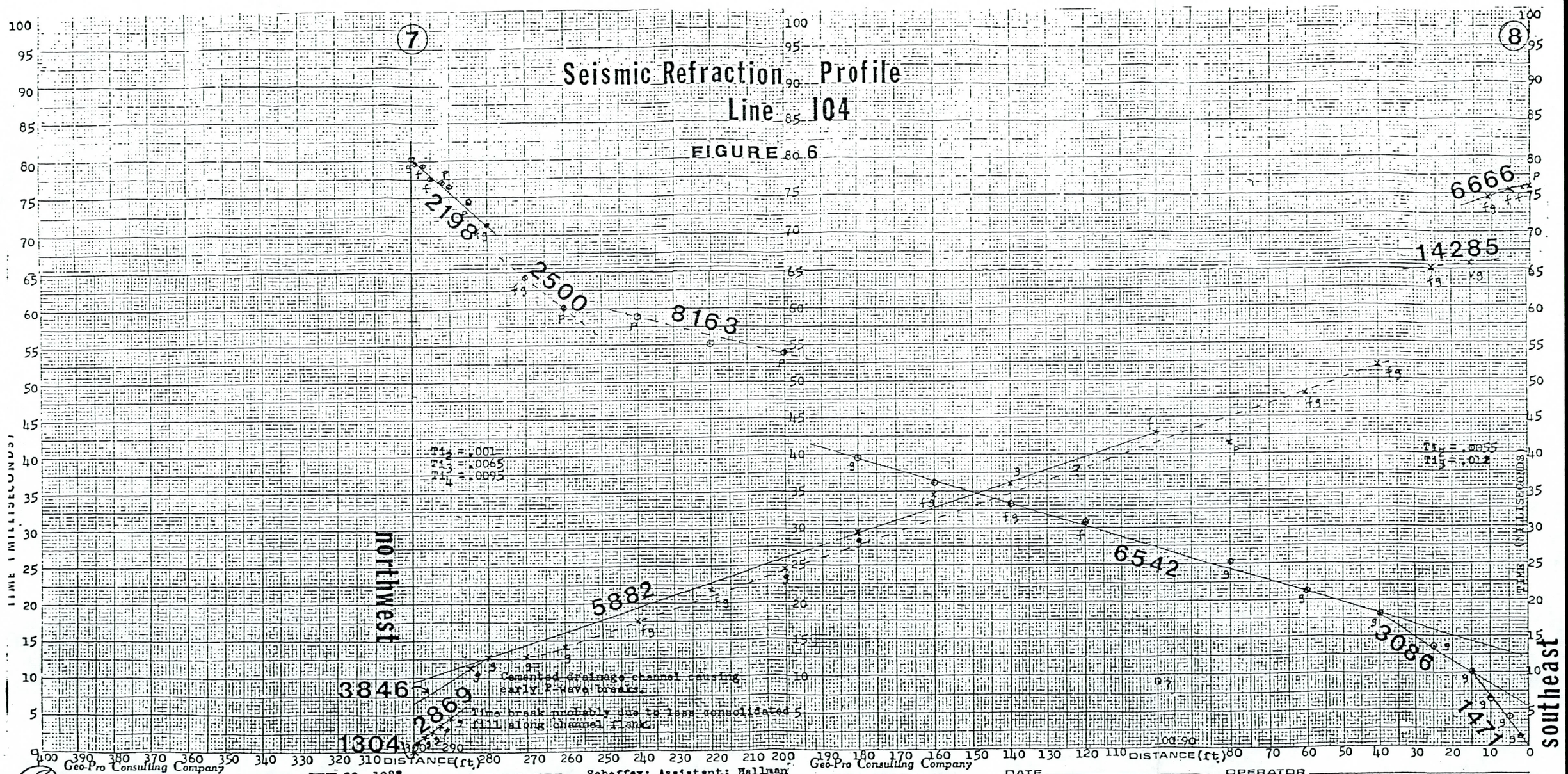
DATE June 18, 1988

JOB ACDC Tunnel

LOCATION/DESCRIPTION
Buried geophones due to wind.
Hot summer night

OPERATOR Scheffey; Assistant: Hallman

TRAVERSE SL 103B, N-S, 200 spread
SW¼, Sec. 11, T2N, R3E, Maricopa Co., Az.
Approx. ¼ mile west of Biltmore Hotel.



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Phoenix, Az. 85021

TELEPHONE
943-5597

DATE JUNE 20, 1988

OPERATOR Scheffey: Assistant: Hallman

JOB ADOT Tunnel

TRAVERSE SL 104, SE-NW; 300' spread NW¼, SE¼, Sec.10, T2N, R3E., Maricopa Co., Az. Along north bank ~~of the Arizona Canal.~~ Approx. ¼ mile west of the filtration plant.

LOCATION/DESCRIPTION
Buried geophones because of gusty winds. Still a hot summer evening.

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GEOPHYSICS - GEOLOGY - GEOCHEMISTRY

TELEPHONE
943-5597

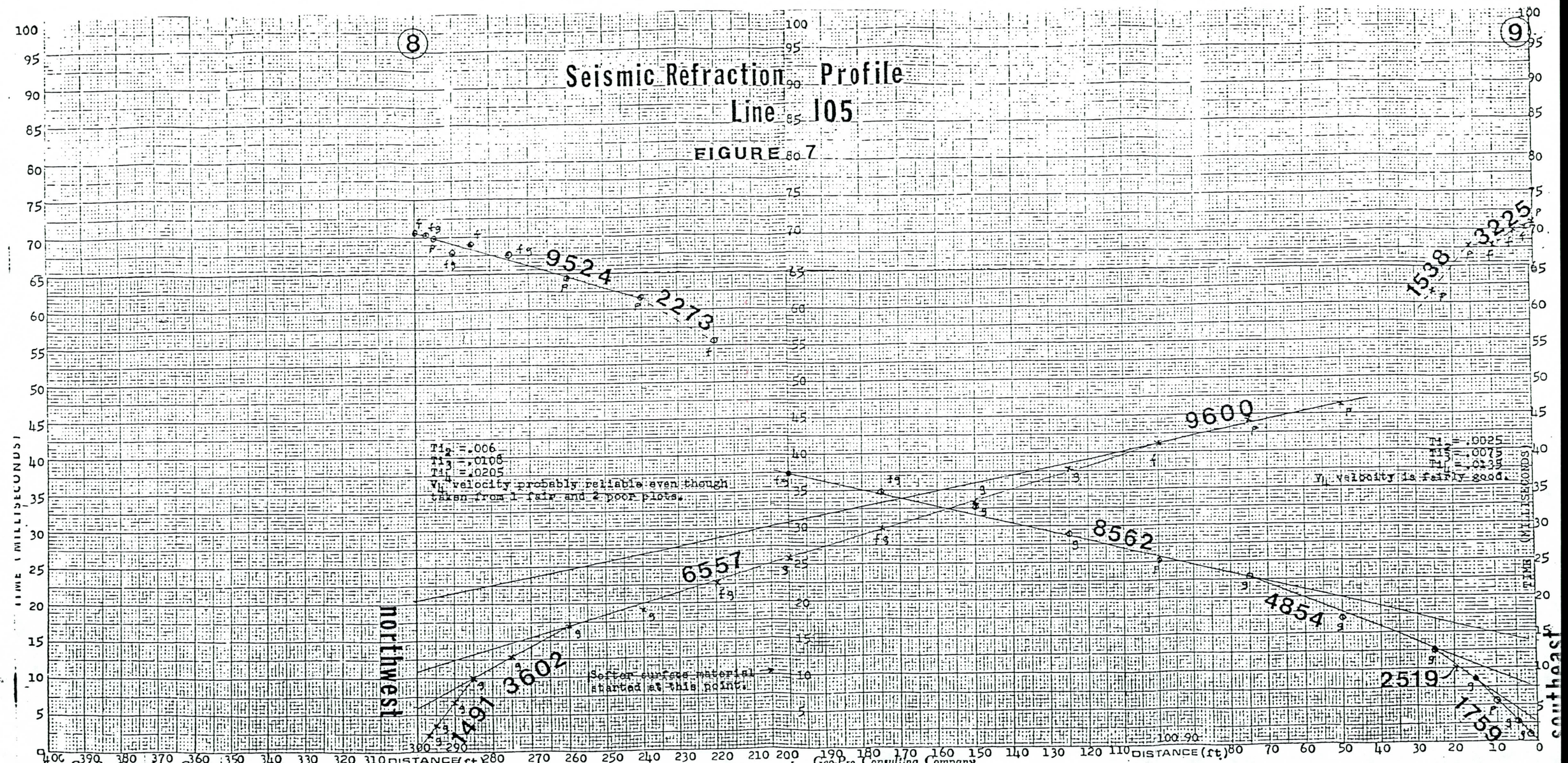
DATE

OPERATOR

JOB

TRAVERSE

LOCATION/DESCRIPTION



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SCHEFFEY ENTERPRIZES
1736 W. Carol Ave.
Phoenix, Az. 85021

TELEPHONE
943-5597

DATE JUNE 20, 1988

OPERATOR Scheffey; Assistant: Mallman

JOB ACDC TUNNEL

TRAVERSE SL 105, SE-NW; 300' spread
NW¼, SE¼, Sec.10, T2N, R3E., Maricopa Co., Az.
Along north bank of the Arizona Canal.
Approx. ¼ mile west of the filtration plant.

LOCATION/DESCRIPTION

Buried geophones because of gusty winds. Had a security check by PPD at about 10:00 PM. Still a hot summer evening.

Geo-Pro Consulting Company
PAUL L. SCHEFFEY, P.E.
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TELEPHONE
943-5597

DATE

OPERATOR

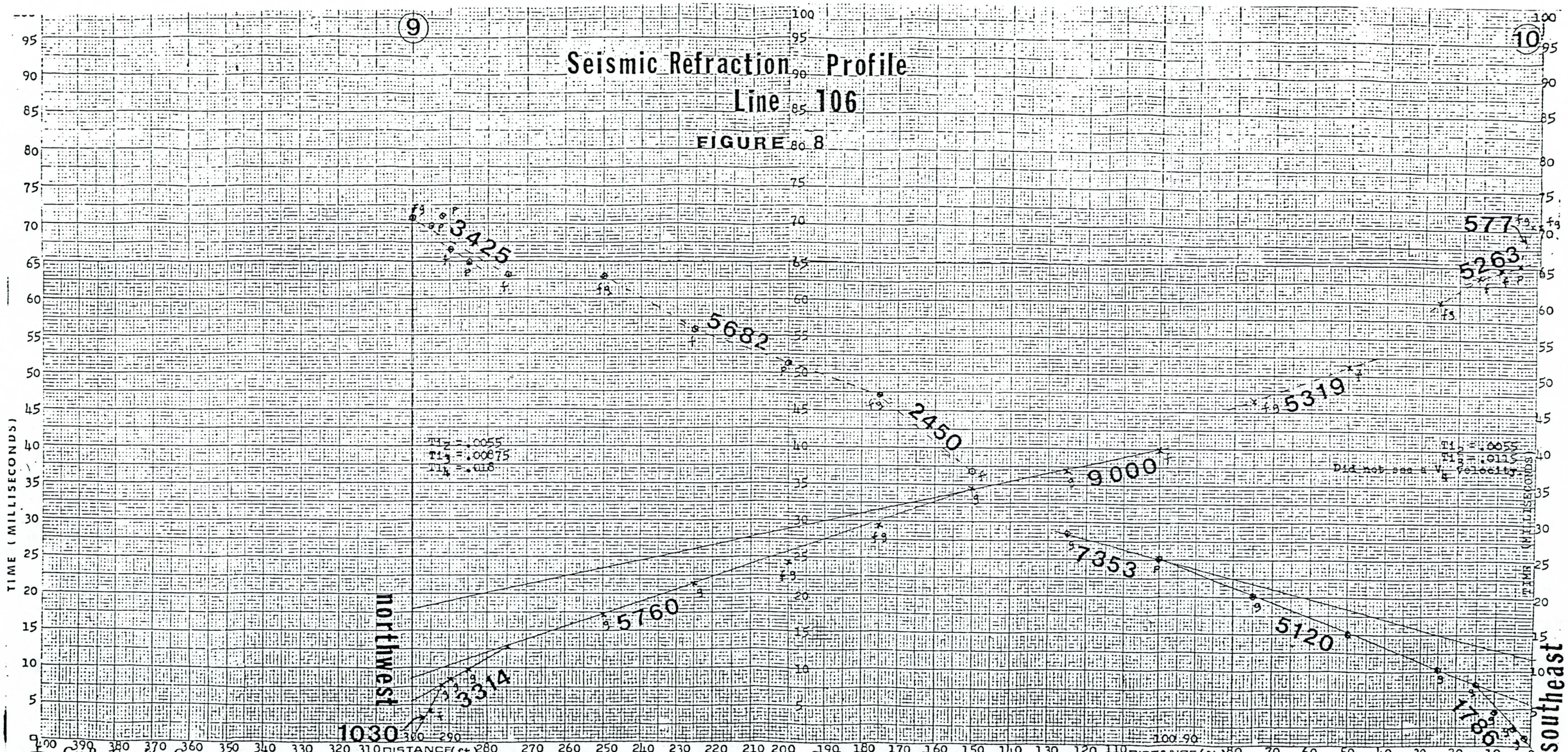
JOB

TRAVERSE

LOCATION/DESCRIPTION

Seismic Refraction Profile
Line 106

FIGURE 8



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1736 W. Carol Ave.
Phoenix, Az. 85021

TELEPHONE
943-5597

DATE JUNE 20, 1988

OPERATOR Scheffey; Assistant: Hallman

JOB ACDC TUNNEL

TRAVERSE SL 106, SE-NW; 300' spread
NW¼, SE¼, Sec10, T2N, R3E., Maricopa Co., Az.
Along north bank of the Arizona Canal
Approx. ¾ mile west of the filtration plant.

LOCATION/DESCRIPTION
Buried geophones because of gusty winds. Operations proceeded nicely. Midnight somewhat cooler.

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GEOPHYSICS - GEOLOGY - GEOCHEMISTRY

TELEPHONE
943-5597

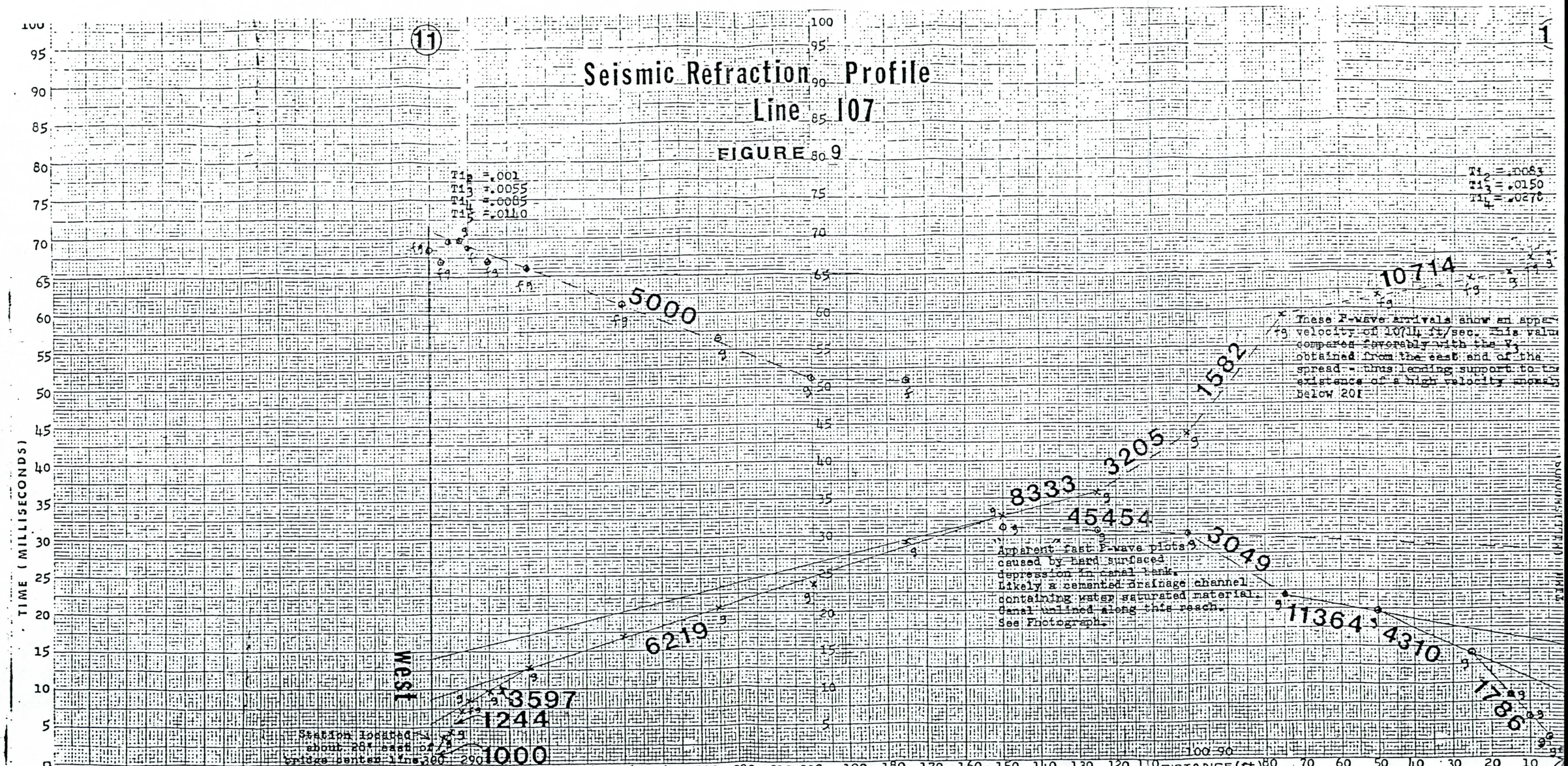
DATE

OPERATOR

JOB

TRAVERSE

LOCATION/DESCRIPTION



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1736 W. Carol Ave.
Phoenix, Az. 85021

TELEPHONE
943-5597

DATE JUNE 21, 1988

OPERATOR Scheffey; Assistant: Mallman

JOB ACDO TUNNEL

TRAVERSE SL 107, SE-NW, 300' spread
NE¼, Sec. 14, T2N, R3E, Maricopa Co., Az.
Approx. ½ mile east of Biltmore Hotel.

LOCATION/DESCRIPTION
Buried geophones in case of wind gusts. Love this hot weather.

Geo-Pro Consulting Company
PAUL L. SCHEFFEY, P.E.
GEOPHYSICS - GEOLOGY - GEOCHEMISTRY

TELEPHONE
943-5597

DATE

OPERATOR

JOB

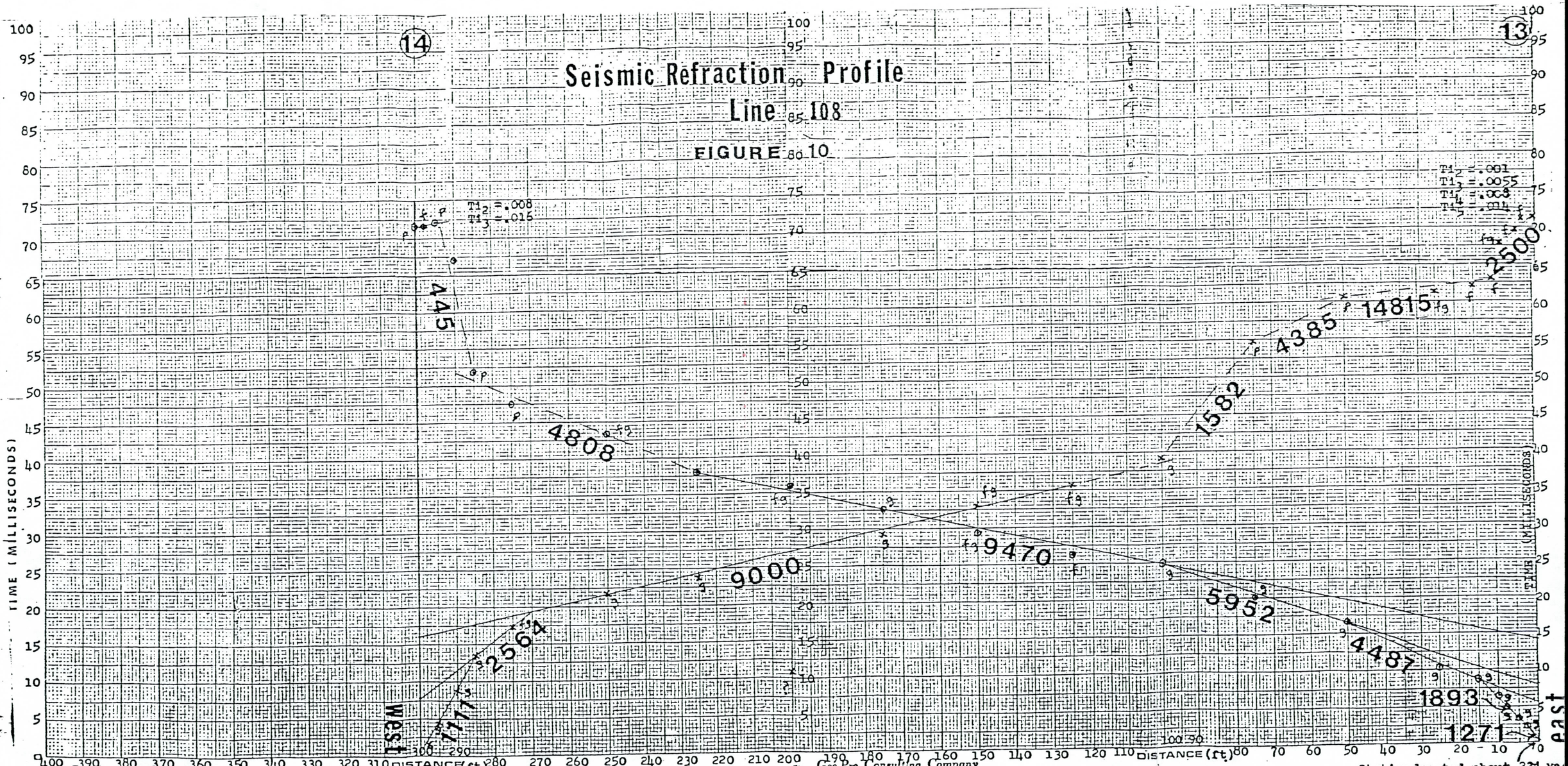
TRAVERSE

LOCATION/DESCRIPTION

Seismic Refraction Profile

Line 108

FIGURE 10



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SCHEFFEY ENTERPRISES
1736 W. Carol Ave.
Phoenix, Az. 85021

TELEPHONE 943-5597

DATE JUNE 21, 1988

OPERATOR Scheffey: Assistant: Hallman

JOB ACDC TUNNEL

TRAVERSE SL 108, SE-NW, 300' spread, NE¼, Sec. 14, T2N, R3E, Maricopa Co., Az. Approx. ½ mile east of Biltmore Hotel.

LOCATION/DESCRIPTION
No wind but buried geophones just in case. Summer weather holding up nicely - hot.

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PAUL L. SCHEFFEY, P.E.
GEOPHYSICS · GEOLOGY · GEOCHEMISTRY

TELEPHONE 943-5597

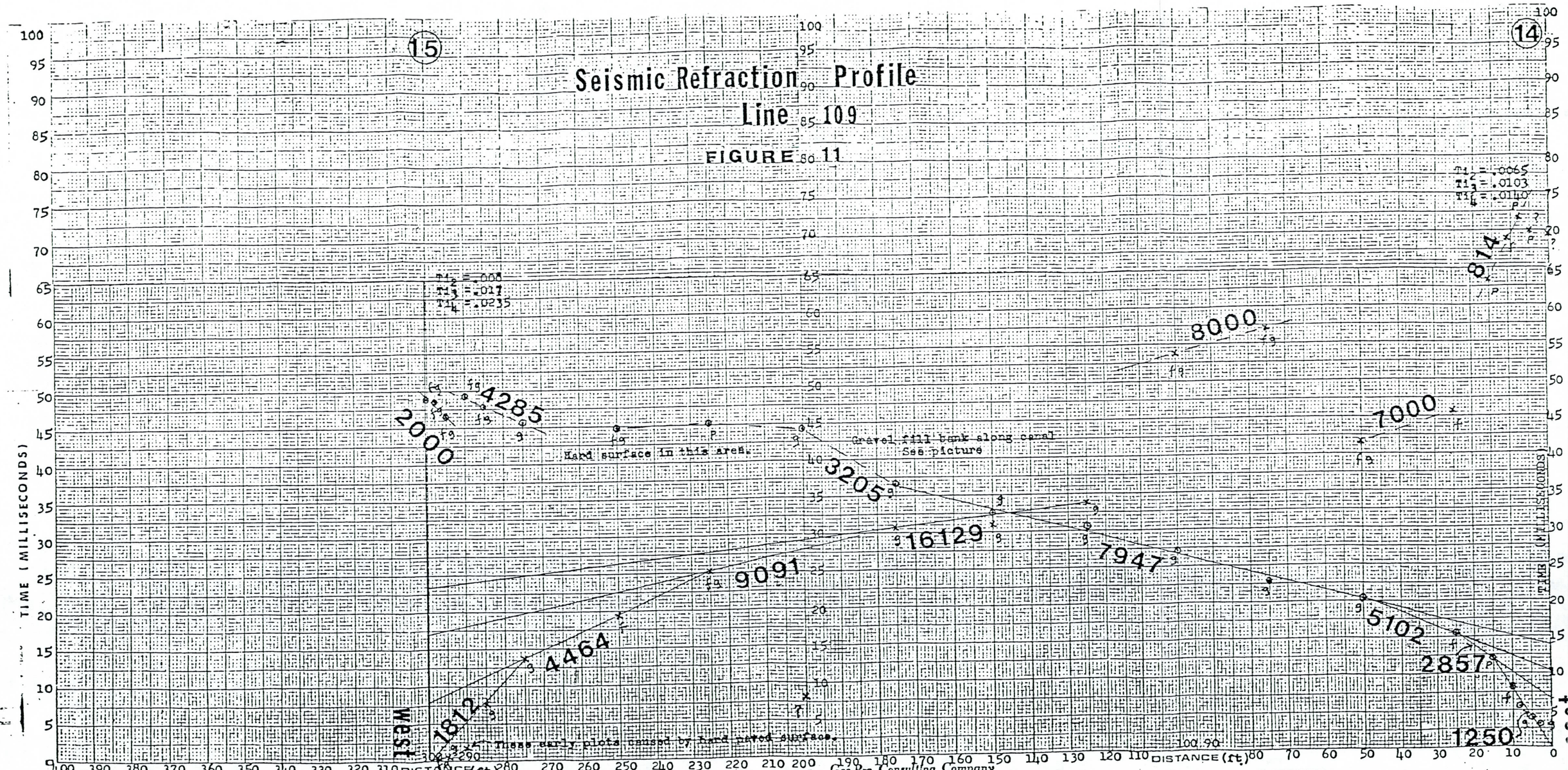
DATE

JOB

OPERATOR Station located about 22' west of Center line of bridge over

TRAVERSE

LOCATION/DESCRIPTION


15
14
Seismic Refraction Profile
Line 109
FIGURE 11
TIME (MILLISECONDS)
DISTANCE (ft.)
West
Hard surface in this area.
Gravel fill bank along canal
See picture
These early plots caused by hard packed surface.
2000
4285
3205
16129
7947
9091
4464
1812
8000
7000
5102
2857
1250
814
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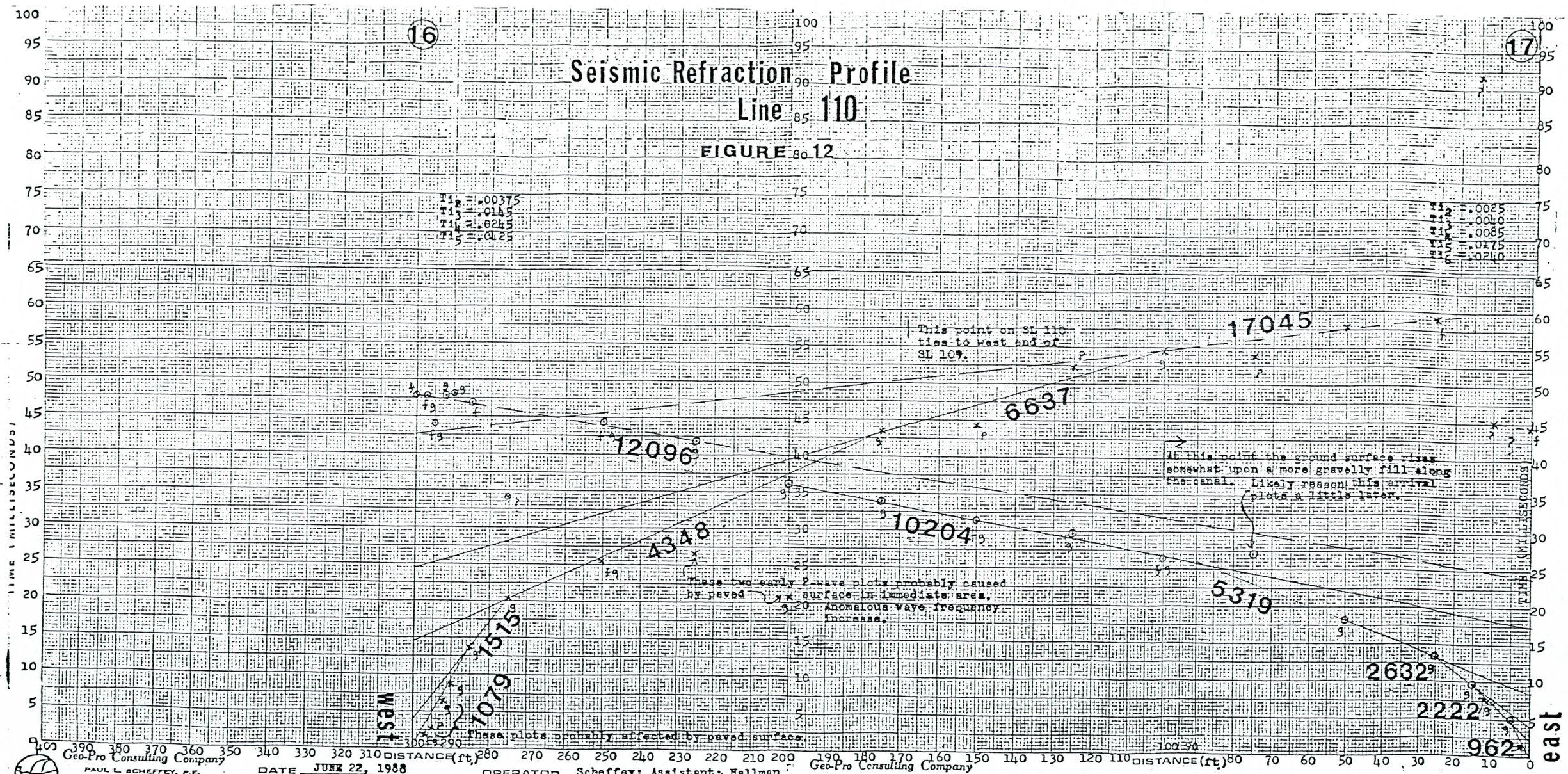
PAUL L. SCHEFFEY, P.E.
GEOPHYSICS • GEOLOGY • GEOCHEMISTRY
DATE JUNE 21, 1988
OPERATOR Scheffey; Assistant: Hallman
JOB ACDC TUNNEL
TRAVERSE SL 109, SE-NW, 300' spread
NE ¼, Sec. 14, T2N, R3E, Maricopa Co., Az.
Approx. ½ mile ~~east of Biltmore Hotel.~~
LOCATION/DESCRIPTION
Buried geophones because of wind.
Real hot summer night.
SCHEFFEY ENTERPRISES
1736 W. Carol Ave.
Phoenix, Az. 85021
TELEPHONE
943-5597

Seismic Refraction Profile
Line 110

FIGURE 12



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TELEPHONE 943-5597

DATE JUNE 22, 1988 OPERATOR Scheffey: Assistant: Hallman

JOB ACDC Tunnel TRAVERSE SL 110, SE-NW, 300' spread

LOCATION/DESCRIPTION NE¼, Sec. 14, T2N, R3E, Maricopa Co., Az. Approx. ½ mile east of Biltmore Hotel.

Buried geophones because of wind.
Weather is good and hot.

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TELEPHONE 943-5597

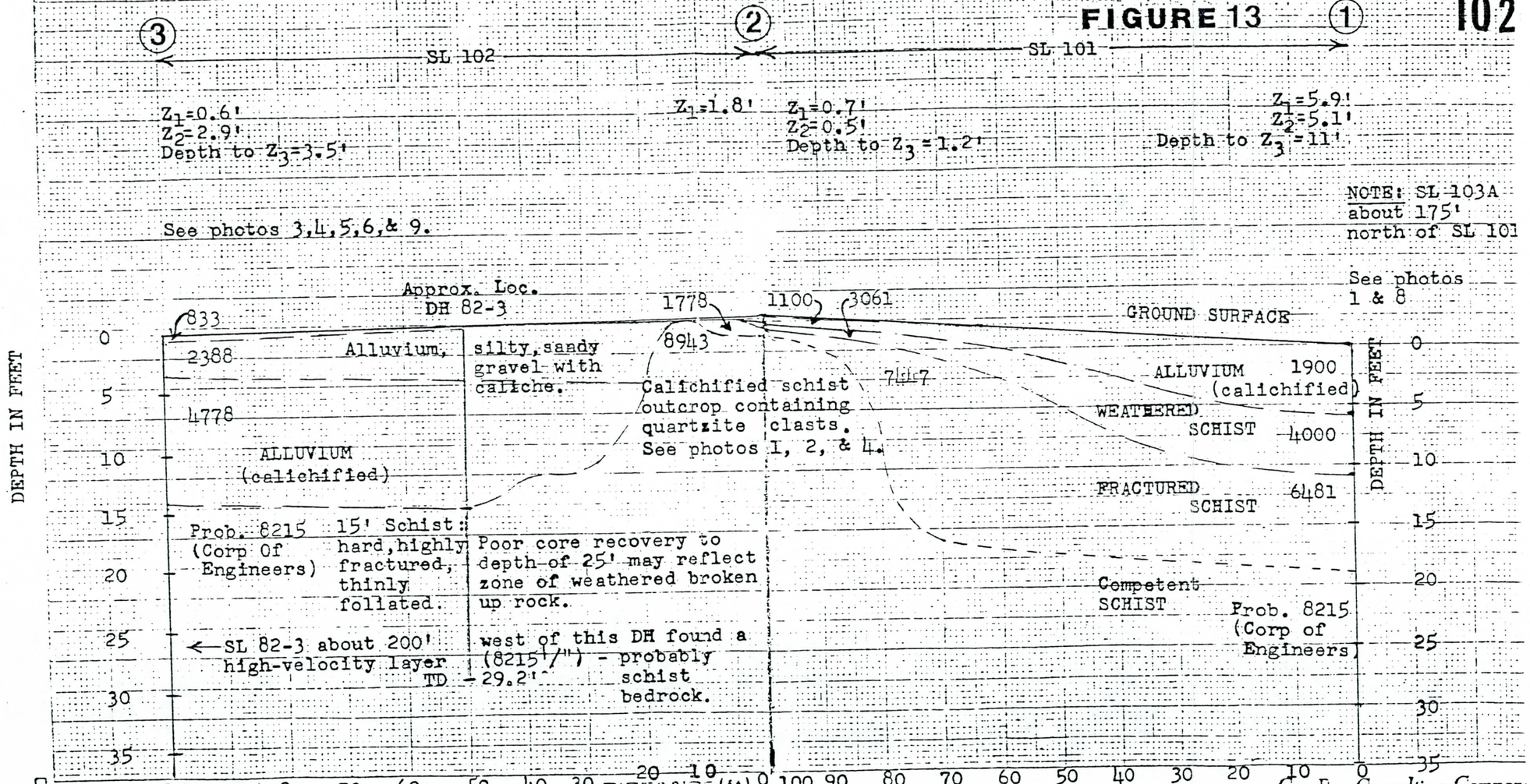
DATE OPERATOR

JOB TRAVERSE

LOCATION/DESCRIPTION

Geoseismic Depth Section — Line 101 102

FIGURE 13



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SCHEFFEY ENTERPRISES

DATE June 17, 1988

JOB ACDC Tunnel

LOCATION/DESCRIPTION

OPERATOR Scheffey; Assistant: Hallman

TRAVERSE SL 101, SE-NW; SL 102, E-W. Both are 100' spreads. SW¼, Sec. 11, T2N, R3E, Maricopa, Co., Ariz. ¼ mile west of Biltmore Hotel

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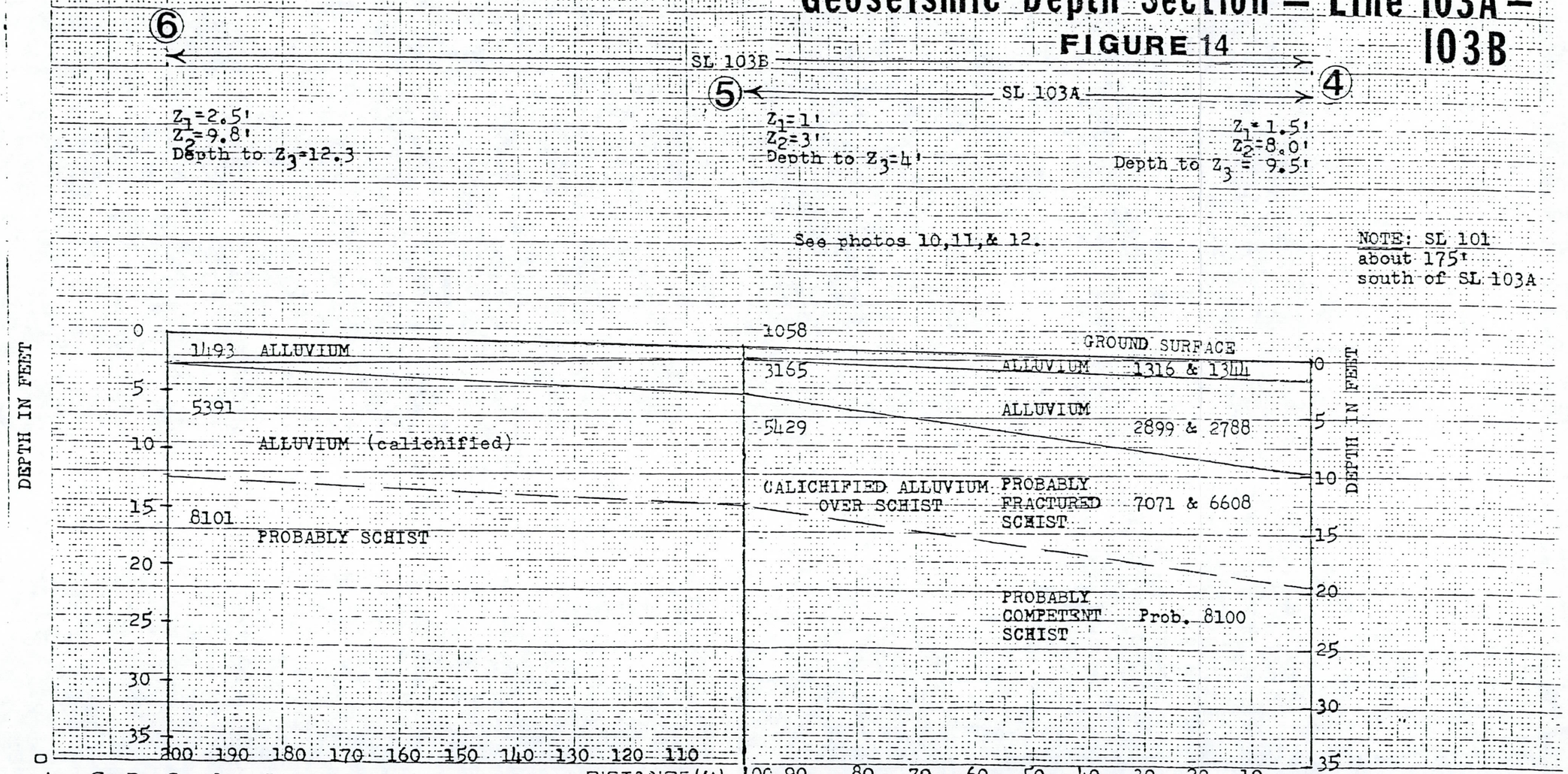
Geoseismic Depth Section — Line 103A — 103B

FIGURE 14



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SCHEFFEY ENTERPRISES
1736 WEST CAROL AVENUE
TELEPHONE (602) 943-7707

DATE June 18, 1988 OPERATOR Scheffey; Assistant: Hallman

JOB ACDC Tunnel TRAVERSE SL 103A, N-S, 100' spread; SL 103B, N-S, 200' spread

LOCATION/DESCRIPTION SW¼, Sec.11, T2N, R3E, Maricopa Co., Az. Approx. ¼ mile west of Biltmore Hotel.

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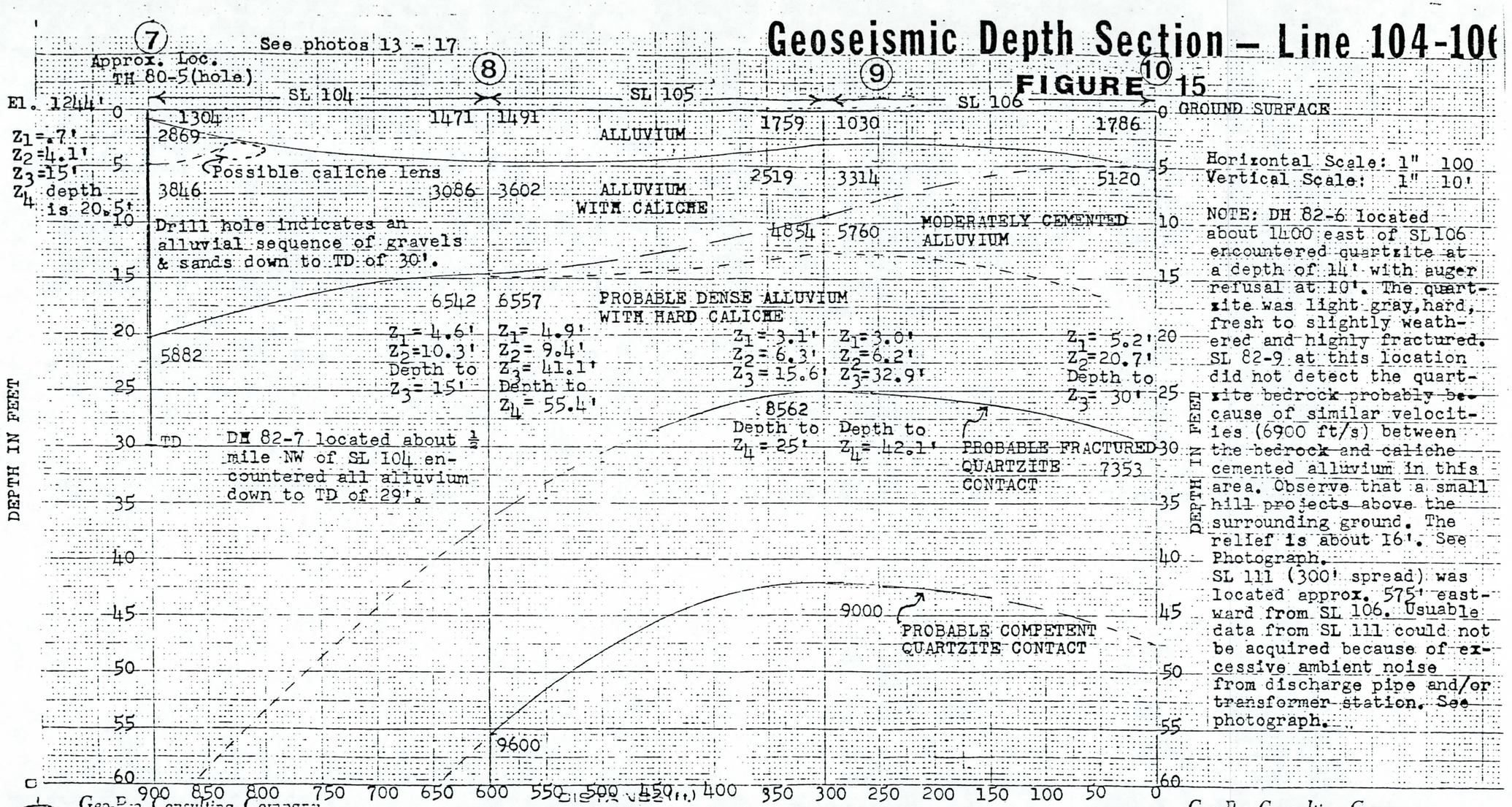
GEOPHYSICS · GEOLOGY · GEOCHEMISTRY
TELEPHONE

Geoseismic Depth Section — Line 104-106

FIGURE 15



Horizontal Scale: 1" 100
Vertical Scale: 1" 10'

NOTE: DH 82-6 located about 1400 east of SL106 encountered quartzite at a depth of 14' with auger refusal at 10'. The quartzite was light gray, hard, fresh to slightly weathered and highly fractured. SL 82-9 at this location did not detect the quartzite bedrock probably because of similar velocities (6900 ft/s) between the bedrock and caliche cemented alluvium in this area. Observe that a small hill projects above the surrounding ground. The relief is about 16'. See Photograph.

SL 111 (300' spread) was located approx. 575' eastward from SL 106. Usuable data from SL 111 could not be acquired because of excessive ambient noise from discharge pipe and/or transformer station. See photograph.

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1736 WEST CAROL AVENUE

TELEPHONE
(602) 947-5907

DATE JUNE 20, 1988

OPERATOR Scheffey; Assistant: Hallman

JOB ACDC TUNNEL

TRAVERSE SL 104, 105, & 106 continuous inline profiling. All 300' spreads for a total of 900'. SE-NW.

LOCATION/DESCRIPTION NW¼, SE¼, Sec. 10, T2N, R3E., Maricopa Co., Az. Approx. ½ mile west of the filtration plant.

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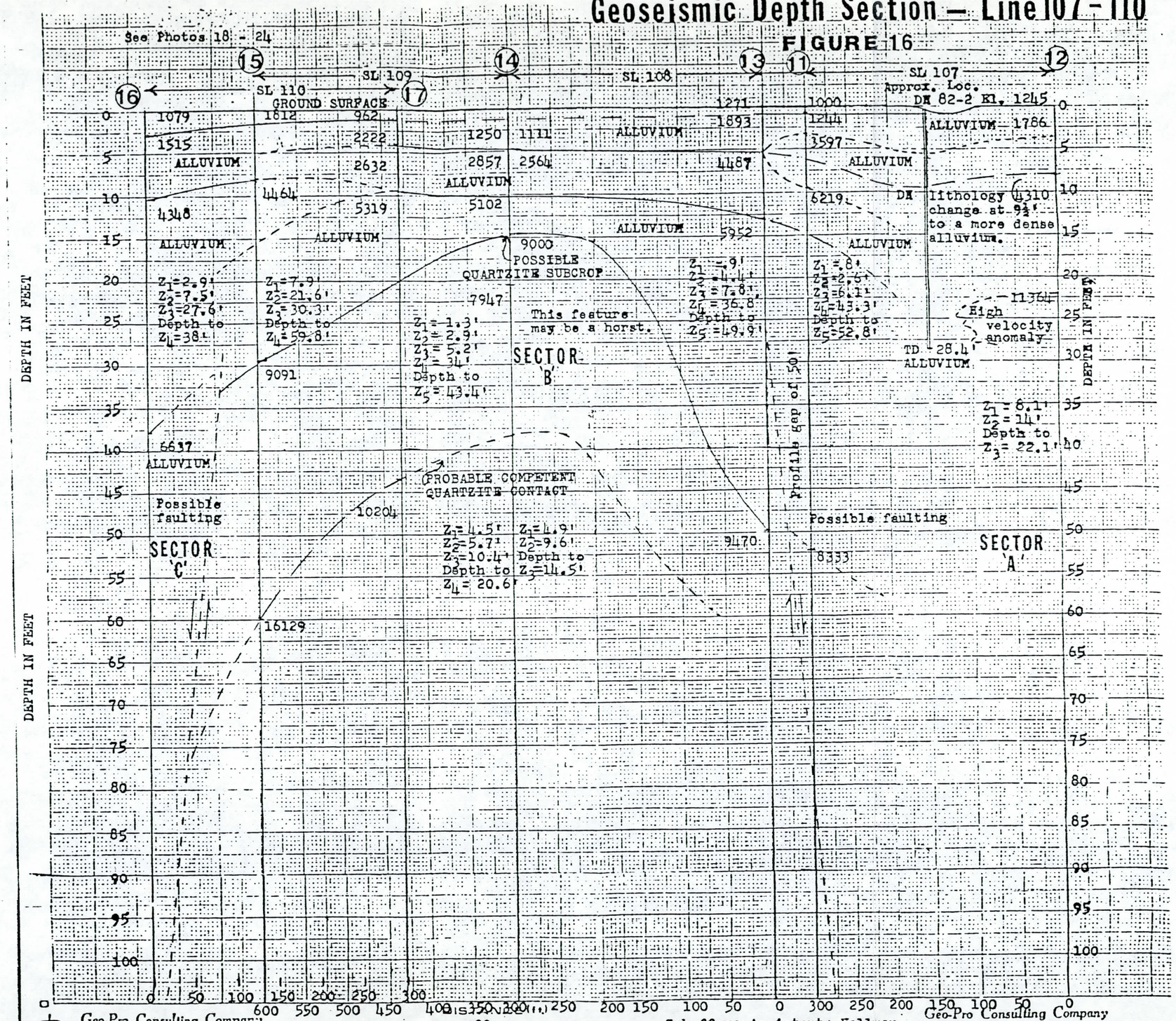
Geoseismic Depth Section — Line 107 - 110

FIGURE 16



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SCHEFFEY ENTERPRISES
1736 WEST CAROL AVENUE
TELEPHONE (602) 945-7557

DATE JUNE 21,22, 1988 OPERATOR Scheffey; Assistant: Hallman

JOB ACDC TUNNEL TRAVERSE SL 107, 108, 109, & 110 inline profiling with one 50' gap on the east end and a profile overlap of 168' on the west end

LOCATION/DESCRIPTION NE¼, Sec. 14, T2N, R1E, Maricopa County, Az. Approx. ¼ mile east of Biltmore Motel.

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Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SL 101 W **Date:** 6/17/88

Quad: Sunnyslope **County:** Maricopa **State:** Az

Survey 50

GEOPHONE 1 STAKE

End Line Distance	ms. Time	Comments; wave form
0	00.00	
1		
2		
3	1.35	✓
4		
5	2.81 2.6	✓
8	6.3	✓
10	5.1	✓
15	9.3	✓
19½	10.3G	✓
24.9	11.8G	✓
30	12.4G	✓
40	14.0G	✓
50	14.7G	✓
60	17.2F	✓
70	23.7FG	
79.5	25.2P	
85	27.5P	
90	28.1P	
95	29.2P	
93	29.5P	
98	17.41	10.9-21.5-29.1-24.5
1	19.3	12.5 Hard Ripping
100	33.7P	
		6.29 N Battery

GEOPHONE 1 STAKE

End Line Distance	ms. Time	Comments; wave form
0 31.27	00.00	✓
1	3	
2		
3	34.8?	✓
4		
5	29.6	✓
8	27.4	✓
10	26.0	✓
15	24.9	✓
19½	27.7G	✓
25	23.4?	✓
30	15.5FG	
40	12.2G	✓
50	10.1FG	✓
60	7.5FG	
70	6.5G	✓
79.5	4.7G	✓
85	3.7G	✓
90	3.3G	✓
95	2.8G	✓
93	2.99G	
98	1.82G	
100	0	

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Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SL 102 W **Date:** 6/17/88

Quad: Sunnyslope **County:** Maricopa **State:** Az

GEOPHONE 2 STAKE

End Line Distance	ms. Time	Comments; wave form
0	00.00	
1		
2	1.45 G	✓
3	1.83 G	✓
4	2.25 G	✓
5	1.17	✓
8	2.60 FG	✓
10	3.26	✓
14.5	3.98 FG	✓
20	4.55 G	✓
25	8.12 FG	✓
30	9.97 F	✓
40	12.08 G	✓
50	14.1 G	✓
60	15.8 G	✓
70	15.65 G	✓
80	17.2 FG	✓
85	18.0 FG	✓
90	19.9 FG	✓
95	21.8 F	
98	22.4 FG	
99	22.6 F	
100	23.6	

GEOPHONE 3 STAKE

End Line Distance	ms. Time	Comments; wave form
0	00.00	22.3 F
	15.78 G	16.6 ✓ 3.00 G
	21.1 F	✓
	20.9	✓
	21.0 F	✓
	20.3 FG	✓
	18.9 G 21.1 15.0 F	
	14.0 F 12.2 F	✓
	20.4 FG	
	19.6 FG	✓
	17.6 FG	✓
	16.1 F	✓
	13.2 G	✓
	12.0 FG	✓
	9.4 G	✓
	7.00 G	✓
	6.05 G	✓
	5.75 G	✓
	3.29 G	✓
	2.4 FG	✓
	1.0 G	✓
	0	

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Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SL 103A N-S **Date:** 6/18/88

Quad: Sunnyslope **County:** Maricopa **State:** Az

End Line Buried Geophones due to windy overcast

Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
0	00.00		0	00.00	19.9G
1	1.37G	✓		20.8	FG
2					
3	2.33G	✓		20.4	✓
4					
5	3.8G	✓		20.2G	✓
8					
10	4.76G	✓		19.5	19.7
15	7.45G	✓		18.0G	✓
20	9.07G	✓		18.2G	✓
25	10.70G	✓		18.5	✓
30	11.03G	✓		17.3G	✓
40	12.18G	✓		17.3G	✓
50	14.2	✓		12.46	✓
60	15.1G	✓		10.8G	✓
70	17.2G	✓		8.8G	✓
80	17.95G	✓		7.0G	✓
85	18.7G	✓		5.5G	✓
90	20.0G	✓		5.09G	✓
95	20.1G	✓		3.51	✓
98	22.0G	✓		1.89G	✓
100	23.9	✓		0	
	24.8				
		Batt 6.19V	Time 9:45 PM Finish		

GEOPHONE / STAKE

GEOPHONE / STAKE

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Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SR 103 B N-S **Date:** 6/18/83

Quad: Sunnyslope **County:** Maricopa **State:** Az

Start 10:15 PM

End Line Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
0	00.00		0	00.00	✓35.0 FG Gain 3
5	3.72 G	✓		34.5 F	✓
10	4.39 FG	✓		33.3 F	✓
20	9.10 G	✓		31.9 F	✓
30	10.98 G	✓ Battery		30.9 F	✓
50	13.6 G	✓		29.3 FG	✓
70	17.5 G	✓		28.4 FG	✓
90	18.9 FG	✓		19.5 G	✓
110	22.1 G	✓ Stopped battery @ 11:15 PM 6.5 V		16.8 G	✓
130	26.2 FG	✓		14.2 G	✓
150	29.6 F	✓		12.1 G	✓
170	31.8 FG	✓		8.3 G	✓
180	33.3	✓		6.8 G	✓
190	38.5 FG			4.68 G	✓
195	39.3 FG			3.35 G	✓
198	39.3 FG			1.57 G	✓
200	40.1 FG			0	

GEOPHONE – STAKE

GEOPHONE + STAKE

Geophysical Company
PAUL L. SCHOLEY, P.E.
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Seismic Refraction Survey – Field Data

Project: AC DC Tunnel **Line:** SL 104 E-W 300' spread **Date:** Monday 6/29/88

Quad: Sunnyslope **County:** Maricopa **State:** Az

Batt 6.72V
6:25 PM start

GEOPHONE 1 STAKE 1

End Line Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
0	00.00		0 300	00.00	80.3
1	0.93 G	✓	299	79.1 G	
2					
3	2.30 G	✓	297	79.4 F	✓
4					
5	2.96 G	✓ 2.96 G	295	77.6 P	
6	3.8 P	✓	293	77 F	✓
7	4.74 G	✓	290	76.3 77.9	✓
15	11.4 G	✓	285	74.3 P	✓
20	12.7 G	✓	280	71.2 FG	✓
30	12.9 G		270	64.2 FG	✓
40	14.3 G		260	60.2 P	✓
60	17.6 FG	✓	240	56.9 P	✓
80	21.9 FG	✓	220	55.1	✓
100	24.5 G	✓	200	54.0 F	✓
120	29.7 G		180	39.7 G	
140	34.7 FG	✓	160	36.3	✓
160	36.1 G	✓	140	33.2 FG	
180	?	✓	120	30.8 F	✓
200	43.1 F		100	9.3 G	
220	51.5 P		80	25.3 G	✓
240	48.4 FG	✓	60	21.3 G	✓
260	51.9 F		40	18.3 G	✓
275	65.2 F	✓	25	13.7 G	✓
285	65.9		15	10.2 G	✓
290	74.7 FG		10	6.6 G	✓
295	75.6 F	✓	5	4.07 G	✓
298	76.0 F		2	1.32 G	✓
300	76.2 P	1. Battery 6.30 Time 8:45 PM	0	0	✓

Geo-Pro Consulting Company
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Seismic Refraction Survey -- Field Data

Project: ACDC Tunnel **Line:** SL105 E-W 300' spread **Date:** Friday 6/20/88

Quad: Sunnyslope **County:** Maricopa **State:** Az

Battery 1.79V 9:25 AM

STAKE 4 / GEOPHONE

End Line Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
0	00.00		0 300	00.00	70.7 F
1					
2					
3	2.36 G	✓	297	70.3 F	✓
4					
5	3.76 G	✓	295	69.3 F	✓
8					
10	6.92 G	✓	290	69.7 F	✓
15	10.86 G	✓	285	69.0 F	✓
25	12.99 G	✓	275	67.6 F	✓
40	17.06	✓	260	64.4 F	✓
60	19.36	✓	240	61.6	✓
80	22.7 G	✓	220	55.6 F	✓
100	25.7 G	✓	200	37.2 F	
125	29.8 G	✓ changed battery	175	30.8 G	✓
150	33.4 G	✓	150	32.4 G	✓
175	38.8 G	✓	125	29.4 G	✓
200	41.2 F	✓	100	25.0 P	✓
225	42.8	✓	75	22.8	✓
250	46.3	✓	50	17.0	✓
275	61.5	✓	25	12.5	✓
285	68	✓	15	8.5 G	✓
290	69.7	✓	10	5.64 P	✓
295	69.9	✓	5	3.94 G	✓
298	70.3	✓	2	1.96 G	✓
300	70.8	✓ Batt 6.43 Finish 10:45	0	0	✓

Geo-Pro Consulting Company
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Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SL106 E-W **Date:** 6/20/98 (Monday)

Quad: Sunnyslope **County:** Maricopa **State:** Az

Start 11:45 PM
Batt 6.5V

Seismograph Station

GEOPHONE 2 STAKE 1

End Line Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
0	00.00	✓	300	00.00	70.6 FG ✓
5	4.32	✓	295		66.9 P ✓
10	7.76	✓	290		71.0 P ✓
[illegible]	8.5 G	✓	290		66.6 = ✓
[illegible]	9.9 G	✓	285		66.0 P ✓
20	12.9	✓	275		63.3 = ✓
50	17.1 G	✓	250		63.0 FG ✓
75	21.5	✓	225		55.9 F ✓
100	24.4 F	✓	200		51.3 P ✓
125	29.5 FG	✓	175		47.1 FG ✓
150	34.6 G	✓	150		36.9 F ✓
175	37.1 G	✓	125		30.8 G ✓
200	40.0 F	✓	100		25.1 P ✓
225	46.6 FG	✓	75		20.2 G ✓
250	51.3 F	✓ ~ 57.8	50		15.0 ✓
275	60.2 FG	✓	25		10.3 G ✓
285	63.6 F	✓	15		8.4 G ✓
290	64.8 F	✓	10		7.5 G ✓
295	65.5 P	✓	5		2.96 G ✓
298	70.7 FG		2		1.02 G ✓
300	70.7 FG	Finish 12:19 Batt 6.34V	0		0 ✓

Geo-Pro Consulting Company
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Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SL 107 E-W **Date:** 6/21/88

Quad: Spring Slope **County:** Maricopa **State:** Az

Batt 6.70V

Time 6:40 PM

GEOPHONE / STAKE

End Line Distance	ms. Time	Comments; wave form
0	00.00	
1		
2		
3	3.5G	✓
4		
5	4.4G	✓
6	7.3FG	
	8.53F	✓
	9.8G	
25	12.7G	
50	17.1	✓
75	20.6G	✓
100	23.5G	
125	29.2G	✓
150	32.9G	✓
175	35.8G	✓
200	43.6	✓
225	59.4FG	✓
250	61.9FG	✓
275	64.3	F ✓
285	65.0	
290	67.1	
295	67.5	
298	68.2	G ✓
300	68.3	

End Line Distance	ms. Time	Comments; wave form
0	00.00	100 68.5 FG
	297	6.9 FG
	295	✓ 69.7
	292	✓ 69.9
	290	✓ 68.8 F
	285	✓ 66.7 FG
	275	✓ 66.2 FG
	250	61.6 FG
	225	✓ 56.6 G
	200	✓ 51.2 G
	175	✓ 44.9 FG
	150	✓ 37.2 G
	125	✓ 30.6 G
	100	✓ 30.2G
	75	✓ 22.0G
	50	✓ 19.2G
	25	✓ 14.0G
	15	✓ 9.3G
	0	✓ 5.5G
	5	✓ 2.6G
	2	.85G
	0	0

Finish 7:40 PM

Batt. 6.55V

Geo-Pro Consulting Company
PAUL L. SCHEY, P.E.
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Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SL-108 E-W **Date:** 6/21/85

Start 8:20 PM

Quad: Sunnyslope Bat. 6.5V **County:** Maricopa **State:** Az

GEOPHONE STAKE 2

End Line Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
Geophone 2 0 300	00.00	7.5 ✓	Geophone 1 0	00.00	✓
			1		
			2		
297	71.2	✓	3	2.266	✓
			4		
95	6.99	✓			✓
92			9		✓
90	63.24		10	6.55	✓
285		✓	15		✓
275		✓	20		✓
250		✓			✓
225		✓	25		✓
200		✓	300		✓
175		✓	325		✓
150		✓			✓
125		✓	375		✓
100	10.82	✓	400		✓
75		✓	425		✓
50		✓	450		✓
25		✓	475		✓
15	12.56	✓	500	51.3	✓
10		✓	525	67.1	✓
5		✓	575		✓
2	1.66		598		✓
0	0	✓	300		✓
		Bat. 8.22 Bank 5.3			

Geo-Pro Constr. Eq Company
PAUL L. BCH. EY. P.E.
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Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SL 109 E-W **Date:** 6/21/83

Quad: Sunnyslope **County:** Maricopa **State:** Az

Start 10:00 PM
Batt. 6.40 V

GEOPHONE STAKE

End Line Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
0	00.00		0	00.00	
			1		
			2		
			3	3.30 G	
			4		
			5	4.05	
			6	5.66	
			7		
			8		
			9		
			10		
			15		
			20		
			25		
			30		
			35		
			40		
			45		
			50		
			55		
			60		
			65		
			70		
			75		
			80		
			85		
			90		
			95		
			100		
			105		
			110		
			115		
			120		
			125		
			130		
			135		
			140		
			145		
			150		
			155		
			160		
			165		
			170		
			175		
			180		
			185		
			190		
			195		
			200		
			205		
			210		
			215		
			220		
			225		
			230		
			235		
			240		
			245		
			250		
			255		
			260		
			265		
			270		
			275		
			280		
			285		
			290		
			295		
			298		
			300		

Batt 6.35
Finish 11:30 PM

Geo-Pro Consulting Company
PAUL L. BCH EY. P.E.
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Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SL 110 E 300' Spread **Date:** 6/22/80

Quad: Sunny Slope **County:** Maricopa **State:** Az

Batt 6.66
Start 7:10 PM

End Line Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
0	00.00		300	00.00	
1					
2					
3	2.26 P		297	[illegible]	
4					
5	2.82 P		295	[illegible]	
6	6.63 G		292	[illegible]	
7	8.7 G		290	32.1 G	
10	13.9 G		285	46.9 G	
15	20.5 G		275	34.1	
50	25.7 G		250	42.6 G	
75	26.5		225	41.9	
100	[illegible]		200	36.4 G	
125	[illegible]		175	[illegible]	
150	44.6		150	[illegible]	
175	52.51 P		125	[illegible]	
200	[illegible]		100	[illegible]	
225	[illegible] P		75	[illegible]	
250	[illegible]		50	18.2	
275	59.2		25	[illegible]	
290	[illegible]		15	[illegible]	
295	15.1		10	[illegible]	
297	[illegible]		5	[illegible]	
300	41.6	Batt 6.33	0	0	

STAKE

GEOPHONE

Geo-Pro Consl. ng Company
PAUL L. BCH EY, P.E.
GEOPHYSICS · GEOLOGY · GEOCHEMISTRY

Seismic Refraction Survey – Field Data

Project: AC DC Tunnel **Line:** SL 111 EW **Date:** 6/23/9[illegible]

Quad: Sunnyslope **County:** Maricopa **State:** Az

start 7:50 pm
fin. 5:56 pm

300' spread

GEOPHONE & STAKE!

End Line Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
0	00.00		0	00.00	
			1		NOISE SIGNAL
			2		[illegible]
THE SEISMIC PROFILE			3		[illegible]
[illegible] CORRUPTED BECAUSE			4		[illegible]
[illegible] NOISE FROM DISCHARGES					[illegible]
[illegible] AND/OR TRANSFORMERS			8		[illegible]
[illegible] TION.			12	60	[illegible]
			15		
		[illegible] down			
		SEISMIC [illegible]		[illegible]	
		[illegible]			
[illegible]		[illegible] = 1 / [illegible] .033		Hertz	(Primary)
[illegible]		Frequency = 1 / Period = 1 / .0064		= 156 Hertz	(Secondary)

Geo-Tra Consulting Company
PAUL L. BC FEY, P.E.
GEOPHYSICS · GEOLOGY · GEOCHEMISTRY

Seismic Refraction Survey – Field Data

Project: ACDC Tunnel **Line:** SL111-E-W **Date:** 6/23/88

Quad: Sunnyslope **County:** Maricopa **State:** Az

Start 6:50
Stop 6:67 U

300' spread

GEOPHONE / STAKE #

End Line Distance	ms. Time	Comments; wave form	End Line Distance	ms. Time	Comments; wave form
0	00.00		0	00.00	
			1		
			2		
			3	[illegible]	
			4		
	5.28G		5	[illegible]	
	6.62G		9	33.3F	
	7.9G		10	[illegible]	
	6.62G		15		

THIS LINE RESET ABOUT 100' FURTHER WEST – STILL TOO MUCH NOISE FROM DISCHARGE PIPE AND LOW TRANSFORMER STATION

Geophysics Company
PAUL L. SC FEY, P.E.
GEOPHYSICS · GEOLOGY · GEOCHEMISTRY

APPENDIX B

GEOLOGIC MAPPING

GEOLOGIC MAPPING

Field Investigation Sites

Site	Description
1	Quartzite - very hard, severely to moderately fractured, 75-80% of fractures at least partially healed. Some brecciated/shattered zones. Couldn't accurately determine strike and dip.
2	Quartzite - brecciated/shattered, healed with calcium carbonate. Contains an 18-inch wide vertical shear of brecciated quartzite. Couldn't accurately determine strike and dip.
3	Quartzite - shattered and partially to well healed with calcium carbonate. Couldn't accurately determine strike and dip but dips to northwest.
4	Schist - moderately to high fractured, weakly to moderately foliated, quartz rich. Strike N 30 E, dip 56° W. Orientation of foliations vary in area by approximately 10 degrees from those measured.
5	Schist - moderately hard, slightly weathered, well foliated, highly fractured, highly micaceous with frequent interlensed fine grained quartzite. Foliations strike N 20° E and dip 88° W. Rock appears to be quite broken up to the northwest. Abundant quartz vein float to northwest including one "outcrop" approximately 8 ft. wide by 20 ft. long.
6	Schist - moderately hard, moderately weathered, highly fractured, weakly to moderately foliated, quartz-mica schist. Mica grains partially altered to clay. Contains zones of fine grained quartzite particularly in lower reaches of hillside. Much quartz veining present, up to three feet thick.
7	Caliche - lightly cemented, angular to

subangular sand and gravel with alternating one to two foot thick layers with and without cobbles up to 10 inches. Crudely stratified, dips approximately 12 to 15 degrees to south.

8 Caliche - lightly cemented, angular to subangular sand and gravel. Stands vertically approximately 15 ft. in gulley with 2-3 ft. overhang at base. Difficult to excavate with point of rock hammer.

9 Quartzite - hard, slightly to moderately weathered, highly fractured to shattered/brecciated. Iron oxide stained. Contains occasional brecciated fracture, up to 16 inches thick, parallel to relict bedding. Quartz veins up to 6 inches thick. Relict bedding strikes N 40° E and dips 68° N W.

10 Quartzite - same as Number 9.

11 Quartzite and caliche - moderately well cemented sand and gravel caliche overlying very hard, shattered quartzite cemented with calcium carbonate. Dissected by 6 inch thick quartz vein and a quartz bleb several feet across. Could not accurately determine strike and dip of relict bedding.

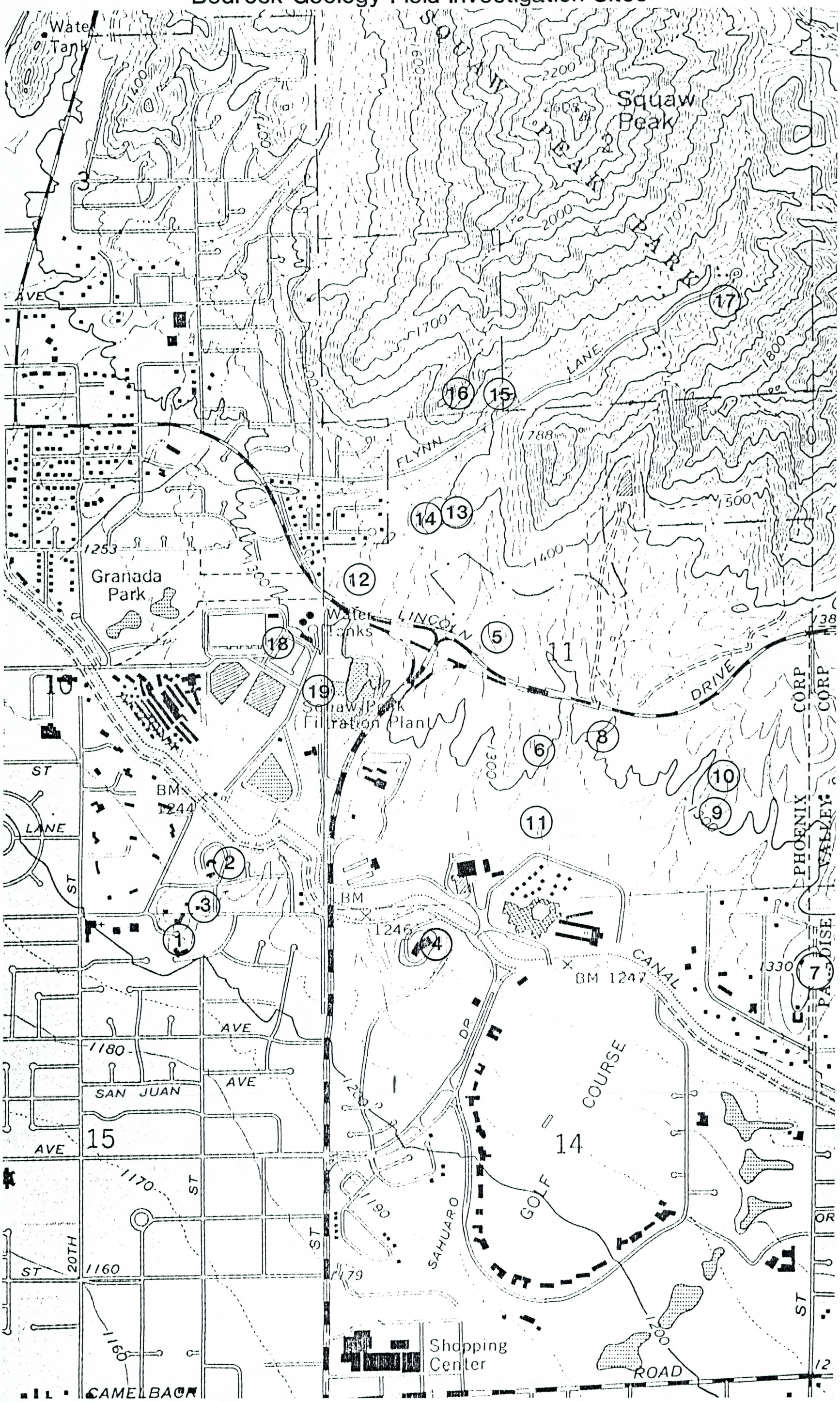
12 Schist and Quartzite - schist along western edge of bedrock knob/hill is well foliated and highly micaceous. Strike and dip of foliation varies, measured N 27 E, 84° E and N 17 E, vertical to 88° E. Approximately 100 ft. to east encounter highly fractured quartzite with strike of N 5° W and dip 70° W. Evidence of large quartz vein in small depression/saddle between quartzite and schist. No direct evidence of shearing but schist and quartzite dip in opposite directions.

13 Schist - moderately hard, slightly weathered, well foliated, highly micaceous. Foliations strike N 3° W and dip 78° E.

14	Quartzite - very hard, moderately fractured, blocky. Relict bedding oriented N 12° E, 87° E. Prominent joint with smooth surface oriented N 20 W, 10° E. Minor joint with irregular surface oriented approximately N 65° W, 68° S.
15	Schist - moderately hard to hard, slightly weathered, moderately to highly fractured, moderately well to well foliated quartz-muscovite schist. Contains thin, shattered and calcium carbonate cemented zones. Contains interlayered and interlensed fine grained quartzite. Foliations strike N 25 E and dip 88° E.
16	Quartzite - hard to very hard, moderately to highly fractured, fine grained, micaceous. Zones high in mica content exhibit slight foliation, other zones are blocky, as large as one cubic yard. No strike and dip taken.
17	Quartzite - hard, slightly weathered, highly fractured, fine grained, thinly laminated. Relict bedding strikes N 15 E and dips 65° E.
18	Quartzite - hard, highly fractured to shattered, brecciated zones. Fractures cemented with calcium carbonate. Could not accurately determine strike and dip but appears to dip northwest.
19	Quartzite - hard, highly fractured slightly schistose, fine grained. Approximately 80% of fractures are cemented with calcium carbonate. Relict bedding strikes N 15° E and dips 74° W.

09168803.dh/k

Bedrock Geology Field Investigation Sites

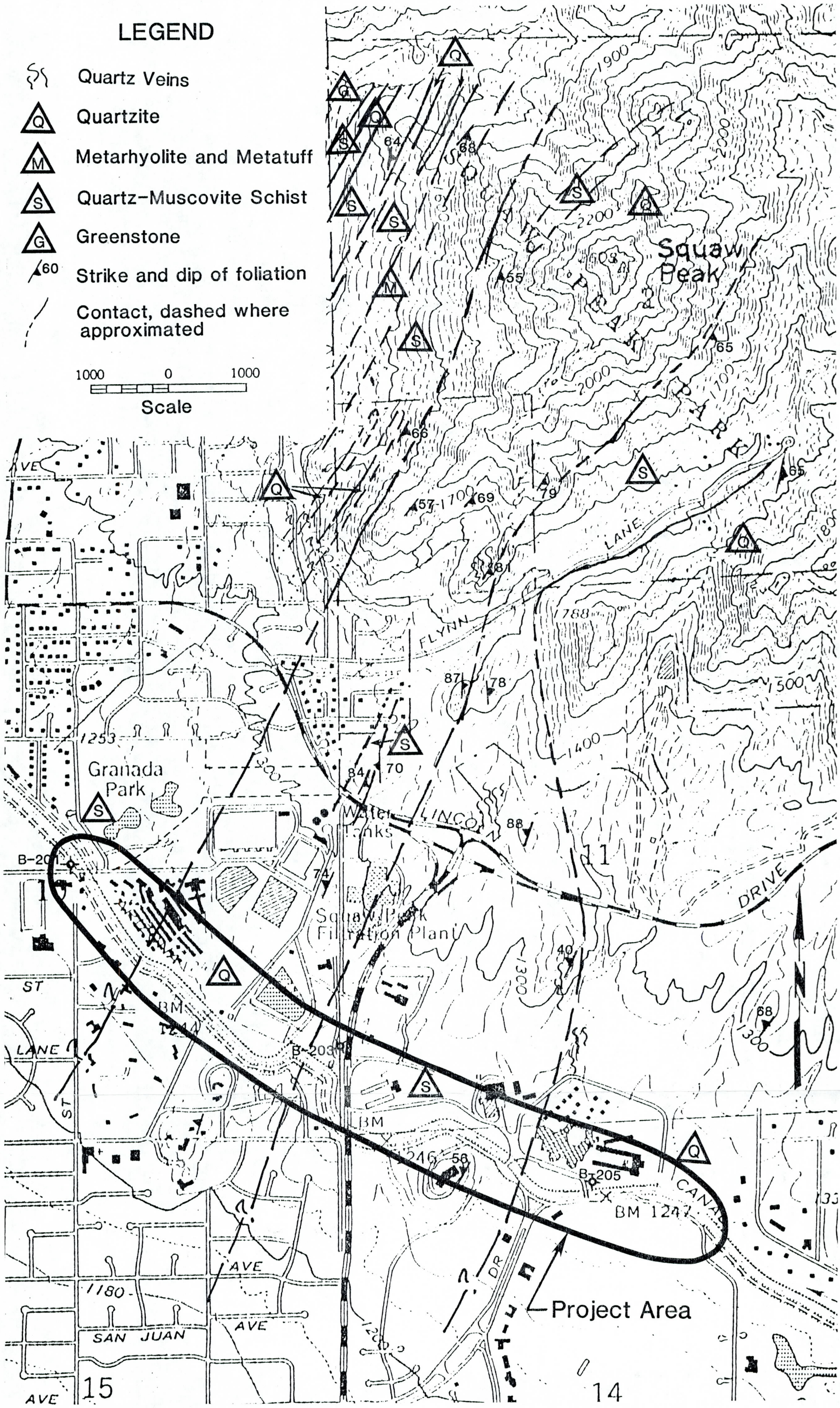


BEDROCK GEOLOGY

LEGEND

- Quartz Veins
- Q — Quartzite
- M — Metarhyolite and Metatuff
- S — Quartz-Muscovite Schist
- G — Greenstone
- 60 — Strike and dip of foliation
- Contact, dashed where approximated

1000 0 1000
Scale



APPENDIX C

TEST BORING LOGS

B201, B202, AND B203

CORE BORING REPORT

CRSS

BORING NO. B-201

PROJECT: ARIZONA CANAL DIVERSION CHANNEL TUNNEL
CLIENT: Maricopa County Flood Control District
CONTRACTOR: Boyles Bros. Drilling Company
EQUIPMENT USED: Longyear 44 truck mounted drill rig

JOB NO.: 11565.24
PAGE NO.: 1 of 4
LOCATION: see plan
ELEVATION: 1243 ft.
DATE START: 7-23-88
DATE FINISH: 7-23-88
DRILLER: Kleigh Hirschi
PREPARED BY: Dave Hallman

CORE BARREL	
TYPE	5 ft. NXWL
ID	1-7/8 inches

ORIENTATION

[X] VERTICAL [ ] INCLINED
BEARING
[ ] HORIZONTAL ANGLE FROM VERTICAL

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
						Rock Fill Dense, angular cobbles and gravel with lesser amounts of sand. Arizona Canal access road embankment. -FILL- Notes: 1) Used 5-3/8" rock bit from 0 to 9 ft. 2) Used 3-7/8" rock bit from 9 to 40.5 ft. 3) Placed 4-1/2" O.D. casing to 9 ft.
5						
						6
						Sandy Gravel with cobbles Dry, brown, mostly angular to subrounded coarse to fine gravel, some angular to subrounded coarse to fine sand, little angular to subangular cobbles, few silt, trace clay. Calcium carbonate rinds and occasional lightly cemented zones present. -COLLUVIUM/ALLUVIUM- Notes: 1) Drill rate while rock bitting not recorded. Rate controlled by cobble frequency rather than material properties. 2) Fewer cobbles below 14 ft.
10						
15						
						17
						Colluvium/Alluvium as above but is lightly to moderately cemented with calcium carbonate. Contains no cobbles from 17 to 21 ft. -CALICHE-
20						
25						

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"		

PREPARED BY: D. Hallman

CORE BORING REPORT

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
						Cemented Sandy Gravel Brown, dry, mostly subangular to subrounded coarse to fine gravel, some subangular to rounded coarse to fine sand, few cobbles and silt. Lightly to moderately cemented with calcium carbonate. Encounter alternating 2-3 foot thick layers of sand and gravel with and without cobbles. Occasional layers contain only fine gravel and coarse to fine sand. -CALICHE- 33
30						
						Cementation and cobble content increased below 33 ft. Possibly contains occasional small boulders. Notes: 1) Begin coring at 40.5 ft. 2) No RQD calculated for core runs in caliche. 3) Coring with low rpm's and fluid pressure for maximum core recovery. Drilling rate not indicative of material properties and not recorded.
35						
40						
		40.5 C1 43.5	3.0	100	NA	Cemented Cobbles with sand and gravel Gray schist cobbles and small boulders with matrix of clayey, coarse to fine sand, little fine gravel , few coarse gravel throughout. Slight calcium carbonate cementation. -CALICHE-
45		C2 48.5	4.5	90	NA	Cemented Sandy Gravel Hard to crumbly, tan, gray and white, mostly coarse to fine gravel, some coarse to fine sand, few silt . Lightly to well cemented with calcium carbonate. Lightly cemented zones contain few clay. Core breaks around clasts in well cemented zones. Lightly cemented from 43.5 - 43.8, 44.4 - 44.8 and 45.8 - 46.3 ft. -CALICHE-
50		C3 53.5	5.0	100	NA	Core run C3 is lightly to moderately cemented. Lightly cemented from 48.5 to 49.8 ft. Core can be broken by hand with difficulty to very easily.
55		C4 57.0	3.5	100	NA	Core run C4 is moderately cemented from 53.5 to 55.3 ft. Lightly cemented and contains clay from 55.3 to 57.0 ft.
		C5 62.0	5.0	100	NA	Core run C5 is moderately cemented from 57.2 to 60.2 ft. Lightly cemented from 57.0 to 57.2 ft. and 60.2 to 62.0 ft.

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-201

PREPARED BY: D. Hallman

CORE BORING REPORT

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
		C4 57.0	3.5	100	NA	Cemented Sandy Gravel Hard to crumbly, tan, gray and white, mostly subangular to subrounded coarse to fine gravel, some subangular to rounded coarse to fine sand, few silt, occasional small cobble. Contains light to moderate calcium carbonate cementation. Lightly cemented from 55.3 to 57.2 and 60.2 to 62.0 ft. Moderately cemented from 57.2 to 60.2 ft. -CALICHE-
60		C5 62.0	5.0	100	NA	
65		C6 67.0	5.0	100	NA	Core run C6 is the same as above except contains little to few small cobbles. Entire run is lightly cemented. Note: Encountered a weak source of water at a depth of approximately 68 ft. Sharp transition from lightly to well cemented material at 67.8 ft. Source of water diminished in several feet. Probably a small body of perched water not groundwater table.
70		C7 71.3	4.3	100	NA	Core run C7 is moderately to well cemented. Well cemented zones are quite hard and "rock-like". -CALICHE/BRECCIA-
75		C8 75.2	3.9	100	NA	Core run C8 is well cemented from 71.3 to 72.8 ft. then grades to lightly cemented and contains clay. Cobble content increased to "few", generally small, less than 6 " diameter.
		C9 79.3	4.1	100	NA	Core run C9 is lightly to moderately cemented, contains a slight increase in coarse gravel fraction and a decrease in sand fraction.
80		C10 80.3	0.8	80	NA	Core run C10 is lightly to moderately cemented.
85		C11 85.3	5.0	100	NA	Core run C11 is lightly to moderately cemented from 80.3 to 81.2 ft. and 83.7 to 85.3 ft. Moderately well cemented from 81.2 to 83.7 ft. Overall decease in coarse gravel fraction from run C9.
		C12 90.3	5.0	100	NA	Core run C12 is lightly to moderately cemented.

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-201

PREPARED BY: D. Hallman

CORE BORING REPORT

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
		85.3				Cemented Sandy Gravel Moderately hard to crumbly, tan to brown, mostly subangular to subrounded coarse to fine gravel, some subangular to rounded coarse to fine sand, few small angular cobbles and silt. Moderately to lightly cemented with calcium carbonate. -CALICHE-
		C12	5.0	100	NA	
90		90.3				
		C13	5.0	100	NA	Core run C13 is the same as run C12 to 93.8 ft.
		95.3				93.8 Schist Breccia Moderately hard, brecciated schist composed of angular gravel and sand sized fragments moderately well cemented with calcium carbonate. -BRECCIA-
95						
		C14	4.6	100	NA	97.8 Schist Soft, gray, brown and white, shattered, moderately weathered, well foliated, quartz-mica schist. Fractures predominantly parallel foliations and are approximately 80% healed with calcium carbonate. Occasional brecciated zones up to 1" thick present. Slight iron oxide staining of fractures from 97.8 to 98.7 ft -QUARTZ-MICA SCHIST-
		99.9				
100						Bottom of Exploration at 99.9 ft.
105						Note: No RQD calculated for core runs in breccia or schist. Not applicable to breccia. Impossible to accurately determine degree of fracture healing and to differentiate between partially healed or non-healed fractures and drilling induced core breaks within the schist.
110						
115						

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-201

CORE BORING REPORT

BORING NO. B-202

PROJECT: ARIZONA CANAL DIVERSION CHANNEL TUNNEL
CLIENT: Maricopa County Flood Control District
CONTRACTOR: Boyles Bros. Drilling Company
EQUIPMENT USED: Longyear 44 truck mounted drill rig

JOB NO.: 11565.24
PAGE NO.: 1 of 3
LOCATION: see plan
ELEVATION: 1252 ft.
DATE START: 7-21-88
DATE FINISH: 7-22-88
DRILLER: Kleigh Hirschi
PREPARED BY: Dave Hallman

	CORE BARREL	ORIENTATION
TYPE	5 ft. NXWL	[X] VERTICAL [ ] INCLINED
ID	1-7/8 inches	[ ] HORIZONTAL BEARING ____ ANGLE FROM VERTICAL ____

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
	2, 2, 3, 10, 6, 4, 5, 5, 5, 5, 8					Cobbly Gravel with sand Dry, light brown, mostly angular to subrounded coarse to fine gravel, little subangular to rounded coarse to fine sand, little to few angular cobbles and silt. Contains frequent calcium carbonate rinds and crusts. 3.5 -ALLUVIUM/COLLUVIUM- Same as above except is moderately cemented with calcium carbonate. -CALICHE- Notes: 1) Used a 5-3/8" rock bit from 0 to 8.5 ft. 2) Used a 3-7/8" rock bit from 8.5 to 11.5 ft. 3) Placed a 4-1/2" O.D. casing to 8.5 ft. 4) Drilling rate while rock bitting controlled by cobble frequency and size rather than mechanical properties of the material. 5) Encountered 1 or 2 cobbles per foot from 0 to 10.5 ft. 6) Begin coring at 11.5 ft. 10.5
5, 10						
	12, 8, ?, 4, 3, 3	11.5 – 16.5 C1	5.0	100	NA	Cemented Sandy Gravel Moderately hard to hard, gray to light brown, mostly angular to subangular coarse to fine gravel, some subangular to subrounded coarse to fine sand, few small angular cobbles, matrix contains silt and clay. Moderately to well cemented with calcium carbonate. Highly cemented and "rock-like" from 11.5 - 14.0 ft and 16.0 - 16.5 ft. -CALICHE/BRECCIA- Core run C2 is the same as C1 except is slightly less cemented and contains thin zones of moderate to light cementation. Notes: 1) Drill rate while coring not indicative of material properties. Driller keeping rotation and circulation down to obtain maximum core recovery. 2) RQD not recorded for caliche - not applicable for unconsolidated materials. Core run C3 is well cemented caliche/breccia.
15						
	3, 3, ?, 6	16.5 – 20.0 C2	3.5	100	NA	
20						
	6, 6, 5, 5, 6	20.0 – 25.0 C3	5.0	100	NA	
25						
	5, 5	25.0 – 29.0 C4	4.0	100	NA	Core run C4 is lightly to moderately cemented caliche.

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-202

PREPARED BY: D. Hallman

CORE BORING REPORT

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
	5, 5, 4, 4	C4 29.0	4.0	100	NA	Cemented Sandy Gravel Moderately hard to soft, brown, dry, mostly subangular to subrounded coarse to fine gravel, some subangular to rounded coarse to fine sand, few cobbles and silt, occasional boulder. Lightly to moderately cemented with calcium carbonate. Encountered a boulder of quartzite from 25.3 to 27.0 ft. -CALICHE-
30	4, 3, 4	C5 32.2	3.2	100	NA	Core run C5 is moderately to well cemented . Notes: 1) Minor loss of drilling fluid into formation at approximately 31 ft. 2) Experienced caving of borehole walls between approximately 32 and 35 ft. Quick setting casting plaster used to hold and seal walls.
35	5, 5, 5, 5, ?	C6 36.5	4.3	100	NA	Core run C6 is moderately cemented sandy gravel caliche/breccia. Contains frequent, thin (2 inch thick) sandier zones which are lightly cemented and contain trace clay. Note: Encountered a boulder of slightly schistose, granitic gneiss from 35.3 to 36.5 ft.
40	7, 8, 7	C7 40.0	2.8	80	NA	Cemented Gravelly Cobbles with sand Hard, white to tan, some cobbles and coarse to fine gravel, little to few coarse to fine sand as matrix. Very well cemented with calcium carbonate. -CALICHE/BRECCIA-
	4, 5, 6, 5, ?	C8 45.0	5.0	100	NA	Core run C8 is the same as C7 to 42.8 ft. Encountered lightly cemented, white, clayey, coarse to fine sand from 42.8 to 43.2 ft. 43.2
45	?, ?, 6, 5, 5	C9 50.0	5.0	100	NA	Schist Hard to moderately hard, gray, highly fractured to brecciated, quartz-mica schist with well developed foliations. Fractures are tight, very closely to closely spaced and are healed with calcium carbonate. Some alteration of mica to talc, particularly in highly micaceous zones. Foliations dip at 55 to 60 degrees from horizontal. Healed brecciated zones at 47.0 - 47.6 ft. and 48.4 - 49.0 ft. Core broke along foliations, brecciated zones and healed/partially healed fractures. -QUARTZ-MICA SCHIST-
50	4, 4, 5, 5, 6	C10 55.0	5.0	100	NA	Core run C10 is highly fractured to shattered, healed with calcium carbonate in top half of run. Shattered and cemented 50.8 - 51.2 ft. and 51.8 - 52.0 ft. Shattered 52.3 - 53.6 ft. and 54.8 - 55.4 ft. Notes: 1) No RQD calculated for cores in schist. Impossible to determine mechanical drilling induced core breaks from non-healed fractures existing within the rock mass. 2) Drilling rate not indicative of material properties. Driller keeping rotation and circulation down to maximize core recovery.
55	?, ?, ?, ?	C11 58.7	3.5	95	NA	Core run C11 is highly fractured to shattered, partially healed with calcium carbonate and gray clay, and contains slight iron oxide staining on some fractures. Foliations dip at 45 to 50 degrees from horizontal. Run contains approximately 4 inches of shattered material in every foot of core.

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-202

CORE BORING REPORT

PREPARED BY: D. Hallman

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
	?					Schist
	?	C11	3.5	95	NA	Hard to soft, gray, highly fractured to shattered, quartz-mica schist with well developed foliations. Fractures are tight, very closely to closely spaced, primarily parallel foliations and are partially healed with calcium carbonate and gray clay. Some fractures are slightly iron oxide stained. Some alteration of mica to talc, particularly in highly micaceous zones. Foliations dip at 45 to 50 degrees from horizontal. Contains approximately 4 inches of shattered material in every foot of core.
	?					
	?	58.7				
	?					
60	5	C12	5.0	100	NA	-QUARTZ-MICA SCHIST-
	4					Core run C12 is the same as C11. Shattered from 58.7 to 58.8 ft., 59.5 to 59.7 ft. and 61.2 to 63.7 ft., held together with gray clay from 61.2 to 63.7 ft.
	?					
	?	63.7				
	NR					
65	NR	C13	5.0	100	NA	Core run C13 consists of extremely fractured to shattered schist. Contains gray clay in shattered portions. Fractures primarily along foliations except in shattered zones. Foliations dip at 40 to 50 degrees from horizontal. Contained a quartz vein from 63.7 to 63.9 ft.
	NR					
	NR	67.5				
	NR					
	NR	C14	3.2	100	NA	Core run C14 is extremely fractured to shattered. Shattered zones contain light gray to white, highly plastic clay. Fractures are partially to "completely" healed with clay and calcium carbonate. Slight iron oxide staining of some fractures.
70		70.7				
						Bottom of Exploration at 70.7 ft.
75						
80						
85						

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-202

CORE BORING REPORT

BORING NO. B-203

PROJECT: ARIZONA CANAL DIVERSION CHANNEL TUNNEL
CLIENT: Maricopa County Flood Control District
CONTRACTOR: Boyles Bros. Drilling Company
EQUIPMENT USED: Longyear 44 truck mounted drill rig

JOB NO.: 11565.24
PAGE NO.: 1 of 4
LOCATION: see plan
ELEVATION: 1246.5 ft.
DATE START: 7-25-88
DATE FINISH: 7-26-88
DRILLER: Kleigh Hirschi
PREPARED BY: Dave Hallman

CORE BARREL		ORIENTATION
TYPE	5 ft. NXWL	[X] VERTICAL [ ] INCLINED
ID	1-7/8 inches	BEARING ____ [ ] HORIZONTAL ANGLE FROM VERTICAL ____

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
						Gravelly Cobbles with sand Light brown, dry, some cobbles and coarse to fine gravel, little coarse to fine sand, few silt and clay, occasional boulder. -COLLUVIUM/ALLUVIUM- Notes: 1) Used 5-3/8" rock bit from 0 to 11 ft. 2) Used 3-7/8" rock bit from 11 to 38 ft. 3) Placed 4-1/2" O.D. casing to 11 ft. 4) Drill rate while rock bitting not recorded. Rate controlled by cobble size and frequency rather than mechanical properties of the material.
5						
10						10 ?
						Sandy Gravel with cobbles Dry, brown, mostly coarse to fine gravel, some coarse to fine sand, little cobbles, few silt, trace clay (?). Calcium carbonate rinds and occasional lightly cemented zones present. -ALLUVIUM/CALICHE- Note: Driller noted that below 10 ft. the cobbles seem to be predominantly flat. Cobbles primarily composed of schist ?
15						
20						20 ? Same as above except contains light to moderate calcium carbonate cementation. -CALICHE-
25						

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-203

PREPARED BY: D. Hallman

CORE BORING REPORT

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
						Cemented Sandy Gravel with cobbles Brown, dry, mostly coarse to fine gravel, some coarse to fine sand, little to few cobbles and silt. Lightly to moderately cemented with calcium carbonate. Encounter alternating 2-3 foot thick layers of moderately and lightly cemented material. -CALICHE-
30						Cementation and cobble content increased below 28 ft. Becomes moderately to well cemented. -CALICHE- Notes: 1) Cementation increased with depth from 35 to 39 ft. 2) Begin coring at 38.0 ft. 3) Coring with low rpm's and fluid pressure for maximum core recovery. Drilling rate not indicative of material properties and not recorded. 4) RQD not calculated for core runs in caliche. Not applicable for unconsolidated materials.
35						
40		38.0 C1 43.0	5.0	100	NA	Cemented Sandy Gravel Hard to moderately hard, light brown and gray, mostly angular to subangular coarse to fine gravel, some subangular to subrounded coarse to fine sand, little to few small cobbles, few silt. Well cemented with calcium carbonate. -CALICHE/BRECCIA-
45		C2 48.0	5.0	100	NA	Core run C2 is the Same as C1 except is slightly less cemented (moderately well to well) and contains trace clay in several zones. Core breaks at clast/matrix interface.
50		C3 53.0	5.0	100	NA	Cemented Sandy Gravel Hard, tan and gray, some fine gravel and coarse to fine sand, little to few coarse gravel, few silt. Well cemented with calcium carbonate. Core breaks through some clasts. -CALICHE/BRECCIA-
55		C4 58.0	4.7	94	NA	Core run C4 is moderately to well cemented, contains more coarse gravel than run C3 and also contains occasional small cobbles.
		C5	2.1	75	NA	

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-203

PREPARED BY: D. Hallman

CORE BORING REPORT

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
		C4 58.0	4.7	94	NA	Cemented Sandy Gravel Hard to crumbly, tan, gray and white, mostly subangular to subrounded coarse to fine gravel, some subangular to rounded coarse to fine sand, few silt, occasional small cobble. Moderately to well cemented with calcium carbonate. -CALICHE-
60		C5 60.8	2.1	75	NA	Core run C5 is lightly to moderately well cemented. Matrix washed out leaving gravel behind from 58.6 to 60.8 ft. Moderately well cemented from 58.0 to 58.6 ft.
65		C6 65.6	5.0	100	NA	Core run C6 is the same as C5. Matrix washed out at top and bottom of run. Middle of run contains 2.1 ft. of moderately well cemented caliche. Note: Driller commented that core runs C4, C6 and C7 drilled as quickly as he wanted the drill to advance.
70		C7 69.8	4.0	95	NA	Core run C7 is lightly cemented with occasional 6 inch zone of moderately cemented material.
75		C8 74.5	4.9	104	NA	Core run C8 is well cemented from 71.3 to 72.8 ft. then grades to lightly cemented and contains clay. Cobble content increased to "few", generally small, less than 6 " diameter.
80		C9 79.1	4.6	100	NA	Core run C9 is moderately to moderately well cemented from 74.5 to 75.5 ft., Lightly cemented from 75.5 to 76.8 ft. and is very well cemented, hard and "rock-like" from 76.8 to 79.1 ft.
		C10 83.4	4.3	100	NA	Core run C10 is well cemented caliche/breccia to 81.5 ft. 81.5 / 82.1 Quartzite Breccia Hard, gray, angular sand and gravel sized fragments of quartzite well cemented with calcium carbonate. -BRECCIA-
85		C11 87.0	3.6	100	NA	Quartzite Hard, fresh, gray, highly fractured to shattered, fine grained, micaceous quartzite. Exhibits slight foliation at 50 degrees from horizontal. Fractures are close to very closely spaced, relatively smooth, tight, primarily parallel foliation/relict bedding, and are healed with calcium carbonate and clay. Contains thin shears filled with white, highly plastic clay and calcium carbonate at 82.5, 82.7 and 83.1 ft. -QUARTZITE-
		C12 90.3	3.3	100	NA	

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-203

PREPARED BY: D. Hallman

CORE BORING REPORT

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
		C11 87.0	3.4	100	NA	Micaceous Quartzite Hard, fresh, gray, highly fractured to shattered, fine grained micaceous quartzite. Exhibits slight foliation at 50 degrees from horizontal. Fractures are close to very closely spaced, relatively smooth, tight, primarily parallel foliation/relict bedding, and are healed with calcium carbonate and clay. Contains thin, 1/4" to 1/2" thick, brecciated shears parallel to relict bedding which are filled with white, highly plastic clay and small amounts of calcium carbonate at 82.5, 82.7, 83.1, 88.4, 89.6, 89.8, 90.0 and 90.2 ft. Core is shattered and cemented from 83.4 to 84.3 ft., shattered and partially held together with tan to brown clay from 84.3 to 88.2 ft., highly fractured and healed with calcium carbonate from 88.2 to 89.4 and is highly fractured from 89.4 to 90.3 ft. -QUARTZITE-
90		C12 90.3	3.3	100	NA	
95		C13 95.3	5.0	100	NA	Core run C13 is highly fractured to shattered. Fractures are approximately 90% healed with red and gray, moderately to highly plastic clay. Some fractures exhibit slight iron oxide staining.
		C14 99.0	3.7	100	NA	Core run C14 is highly fractured to shattered. Fractures and shattered portions contain gray and rust colored clay.
100						Bottom of Exploration at 99.0 ft.
105						Notes: 1) No RQD calculated for core runs in breccia or quartzite. Not applicable to breccia. Impossible to accurately determine degree of fracture healing and to differentiate between partially healed or non-healed fractures and drilling induced core breaks within the quartzite. 2) Drill rate while coring quartzite was not recorded. Driller kept rotation and circulation down to maximize core recovery, rate not indicative of material properties
110						
115						

FIELD HARDINESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	- KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	- SCRATCHES DIFFICULT	THIN	2" - 12"	CLOSE	2" - 12"	V. SLIGHT	SEVERE
MOD. HARD	- SCRATCHES EASILY	MEDIUM	12" - 36"	MOD. CLOSE	12" - 36"	SLIGHT	V. SEVERE
SOFT	- GROOVES	THICK	36" - 120"	WIDE	36" - 120"	MODERATE	COMPLETE
V. SOFT	- CARVES	V. THICK	> 120"	V. WIDE	> 120"	BORING NO.	B-203

APPENDIX D

Laboratory Test Results

CTL/THOMPSON, INC.
CONSULTING GEOTECHNICAL AND MATERIALS ENGINEERS

August 22, 1988

CRS Sirrine, Inc.
216 - 16th Street Mall
Suite 1500
Denver, Colorado 80202

Attention: Mr. Dave Hallman

Subject: Lab Testing or Core Samples
ACDC Tunnel
CRS Sirrine Job No. 11565.24
Job No. 15,444

Dear Dave:

This letter transmits the results of laboratory tests we performed on core samples you delivered to our office. We understand the samples were from the ACDC Tunnel site (your Job No. 11565.24). As requested, we performed point load tests on selected samples and an unconfined compression test on one sample.

The point load tests were performed on irregular core samples in accordance with instructions for point load tests published by Terrametrics, Inc. The results of these tests are presented in Table I.

TABLE I

Sample	Boring	Depth (Feet)	Point Load Index (psi)	Correction Factor	Apparent Unconfined Compressive Strength (psi)
A	B-201	68.5-69.3	429	22.4	9,580
B	B-201	92.2-93.1	130	22.4	2,920
C	B-20~~5~~3	78.5-79.0	1,379	22.4	38,830
D	B-20~~5~~3	88.8-89.5	256	22.4	5,730
E	B-20~~5~~3	92.9-93.5	206	22.4	4,600
F	B-20~~5~~3	92.0-92.5	258	22.4	5,760
G	B-20~~3~~2	46.0-46.7	130	22.4	2,910
H	B-20~~3~~2	68.7-69.1	262	22.4	5,850

Sample G was also tested in unconfined compression with a measured strength of 1,860 psi.

Please feel free to call if you have any questions concerning the results of these tests. Thank you for the opportunity to provide these services.

Very truly yours,

CTL/THOMPSON, INC.

Paul S. Hunsader
Laboratory Manager

Reviewed By:

Ronald M. McOmber, P.E.
Principal, Senior Engineer

PSH:RMM:gl

(3 copies sent)

Sep-16-1988 2/2 ROBBINS ROCK REPORT: 2135

CUSTOMER: CRS SIRRINE
LOCATION: ARIZONE
MACHINE:

PROJECT: ARIZONA CANAL
COUNTRY: U.S.A.
DIAMETER:

SAMPLE NUMBER	DESCRIPTION & IDENTIFICATION	UCS psi	@° TO	POINT LOAD	⋇	% HARDNESS 1-4	5-6	7	QUALITY	DENSITY
5791	CALICHIFIED ALLUVIUM BRECCIA SAMPLE A - NO TESTS DUE TO POOR ROCK QUALITY					30	40	30	LOW	2.379
5792	CALICHIFIED ALLUVIUM BRECCIA SAMPLE B	2730				20	50	30	LOW	2.422
5793	QUARTZITE SAMPLE C			2.2		10		90	MED	2.536
5794	QUARTZITIC SCHIST SAMPLE D	6496	45			15		85	MED	2.629
5795	MICA SCHIST SAMPLE E (SAMPLE F MISSING)			0.9		50	30	20	MOD	2.468
5806	QUARTZITE SAMPLE H	32609 26087				5		95	HIGH	2.656
5807	POORLY FOLIATED SCHIST SAMPLE G	9131				40	30	30	MED	2.583

UCS: Unconfined Compressive Strength (psi) of 1 in.Ø x 2 in.length cores (usually).
Point Load (MegaPascals; MPa * 145 = psi) scaled to nominal 50 mm core diameter.

- ⋇ core foliation orientation to core diameter and point load platens
- – parallel to core axis, normal to point load
- | parallel to core axis, parallel to point load
- 0 normal to core axis, parallel to point load
- / oblique to core axis, oblique to point load
- [blank] isotropic, or orientation not recorded