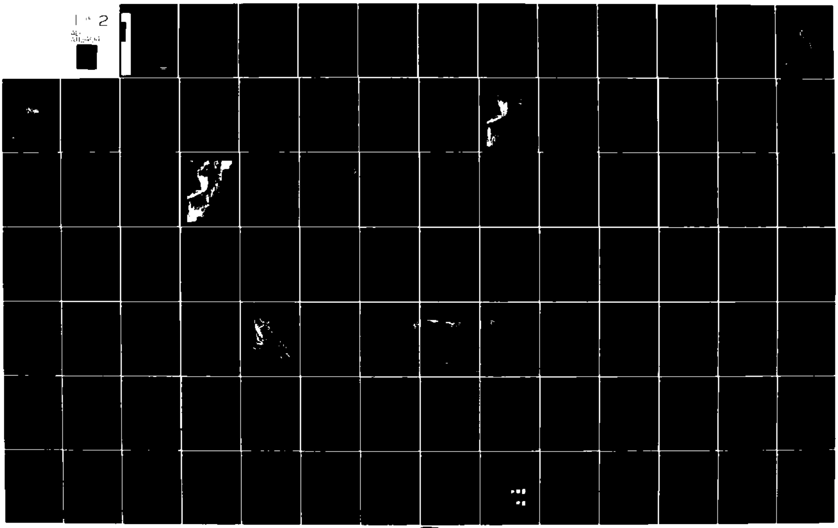
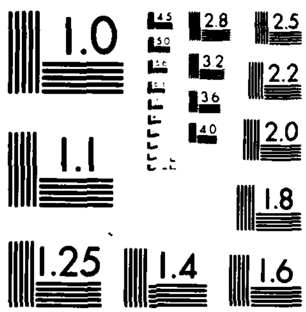
AD-A112 404 FUGRO NATIONAL INC LONG BEACH CA F/G 8/7
MX SITING INVESTIGATION. PRIME CHARACTERIZATION SITES RIO GRAND--ETC(U)
FEB 79 F04704-77-C-0010
UNCLASSIFIED FN-TR-26C NL

1 of 2
AD A112404





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MX SITING INVESTIGATION
GEOTECHNICAL SUMMARY

PRIME CHARACTERIZATION SITES
RIO GRANDE/HIGHLANDS
CANDIDATE SITING PROVINCE

PREPARED FOR

SPACE AND MISSILE SYSTEMS ORGANIZATION (SAMSO)

NORTON AIR FORCE BASE, CALIFORNIA

FUGRO NATIONAL, INC.
Consulting Engineers and Geologists

PHOTOGRAPH THIS SHEET

AD-A112 404

DTIC ACCESSION NUMBER

II

LEVEL

1

INVENTORY

EN TR 26C

DOCUMENT IDENTIFICATION

This document has been approved for public release and sale; its distribution is unlimited.

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS	GRA&I	☒
DTIC	TAB	☐
UNANNOUNCED		☐
JUSTIFICATION		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
A		

DISTRIBUTION STAMP

DTIC COPY INSPECTED

DTIC ELECTE MAR 24 1982 S E

DATE ACCESSIONED

"Original contains color plates: All DTIC reproductions will be in black and white"

82 03 1_ 0_3

DATE RECEIVED IN DTIC

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDA-2

DTIC FORM OCT 79 70A

DOCUMENT PROCESSING SHEET

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
FN TR 26C

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Prime Characterization Sites Rio Grande/Highlands Candidate Siting Provinces

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER
FN-TR-26C

7. AUTHOR(s)
Fugro National, Inc.

8. CONTRACT OR GRANT NUMBER(s)
FC4704-77-C-0010

9. PERFORMING ORGANIZATION NAME AND ADDRESS
[illegible]
PO Box [illegible]
[illegible]

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
64312 F

11. CONTROLLING OFFICE NAME AND ADDRESS
[illegible]

12. REPORT DATE
15 Feb 79 (rev)

13. NUMBER OF PAGES
64

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Distribution Unlimited

Copy available to DTIC does not permit fully legible reproduction

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
Distribution Unlimited

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
~~Jornada Del Muerto site, surficial Geology + Terrain, Basin Configuration, San Simon Site, Geo-physical Properties~~ [illegible]

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This report presents the results of geotechnical field investigations performed in the Jornada Del Muerto + San Simon Characterization sites, located in central New Mexico in the Rio Grande Candidate Siting Province + in southwestern Arizona in the Highlands.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

MX SITING INVESTIGATION
GEOTECHNICAL SUMMARY
PRIME CHARACTERIZATION SITES
RIO GRANDE/HIGHLANDS
CANDIDATE SITING PROVINCES

Prepared for:

U. S. Department of the Air Force
Space and Missile Systems Organization
(SAMSO)
Norton Air Force Base, California 92409

Prepared by:

Fugro National, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

29 September 1978
15 February 1979 (rev.)

FUGRO NATIONAL, INC.

PRIME CHARACTERIZATION SITES
RIO GRANDE/HIGHLANDS CSPs

ERRATA

Replace the following figures with revised ones which accompany this sheet: Figures 6 (p. 16), 7 (p. 18), 13 (p. 38), and 14 (p. 40).

Replace the following tables with revised ones which accompany this sheet: Tables 5 (p.19 and 20), 14 (p. 41), and 15 (p. 42).

The following corrections are to be made to the original text:

page 2, Figure 2: Generalized geologic map base revised, see Figure 6.

page 7, Section 2.2, line 3: Change "The..., intermediate..." to read "Fluvial deposits cover approximately six percent of the area, younger alluvial fan deposits cover approximately 14 percent, intermediate..."

page 25, first 3 lines: Delete first three printed lines, duplication from page 23.

page 33, Figure 10: Generalized geologic map base revised, see Figure 13.

FOREWORD

This report was prepared for the Department of the Air Force, Space and Missile Systems Organization (SAMSO) in compliance with conditions of Contract No. F04704-77-C-0010, and is a geotechnical summary of the prime Characterization sites in the Rio Grande and Highlands Candidate Siting Provinces (CSPs). The prime site in the Rio Grande CSP is Jornada del Muerto, New Mexico and the prime site in the Highlands CSP is San Simon Valley, Arizona.

The report presents representative data obtained from geotechnical field investigations performed at both sites as part of the Characterization program. The information obtained from these studies, in combination with data obtained in the Screening studies, has been used for geotechnical ranking (FN-TR-25).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

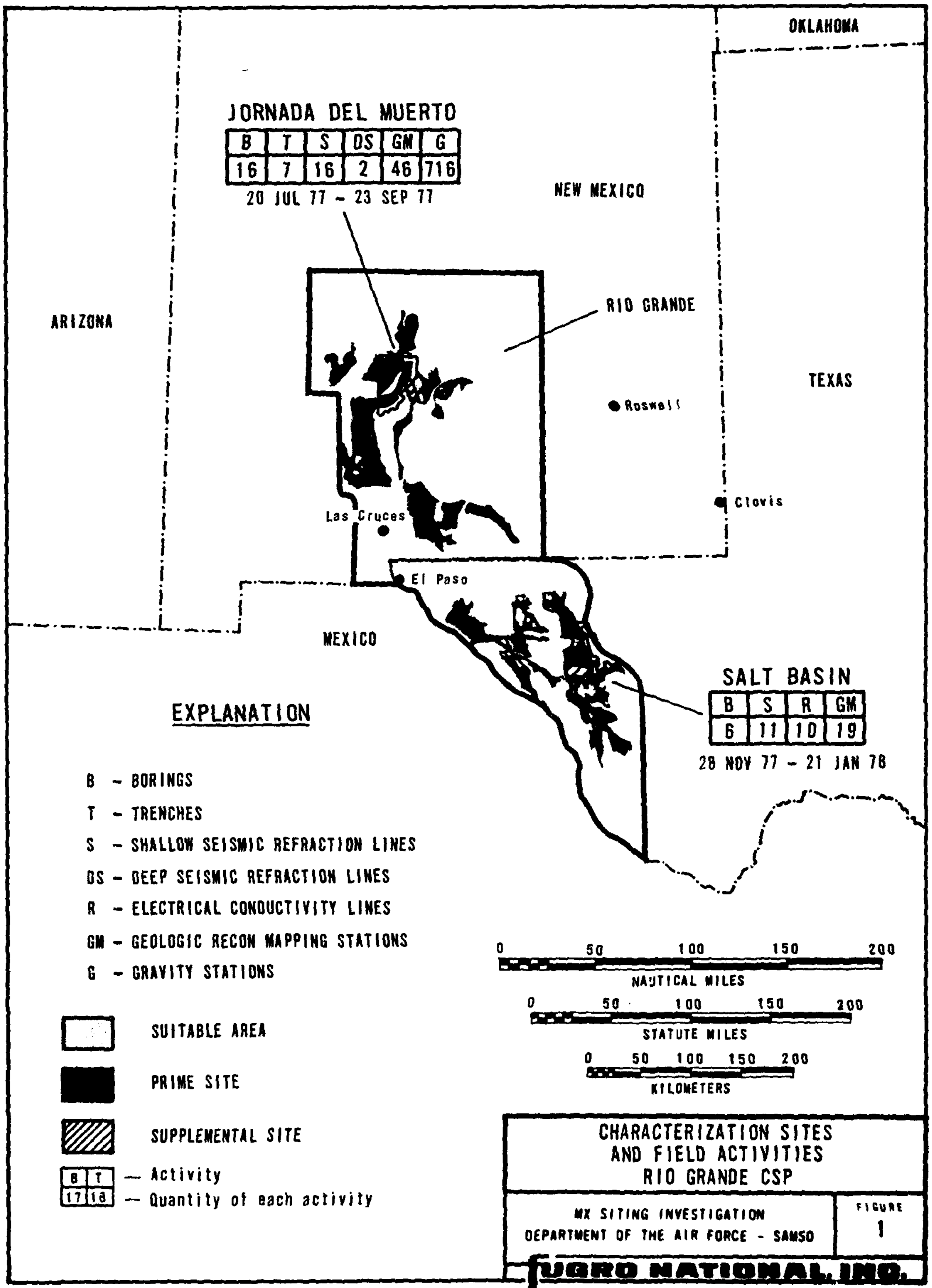
1.0 INTRODUCTION

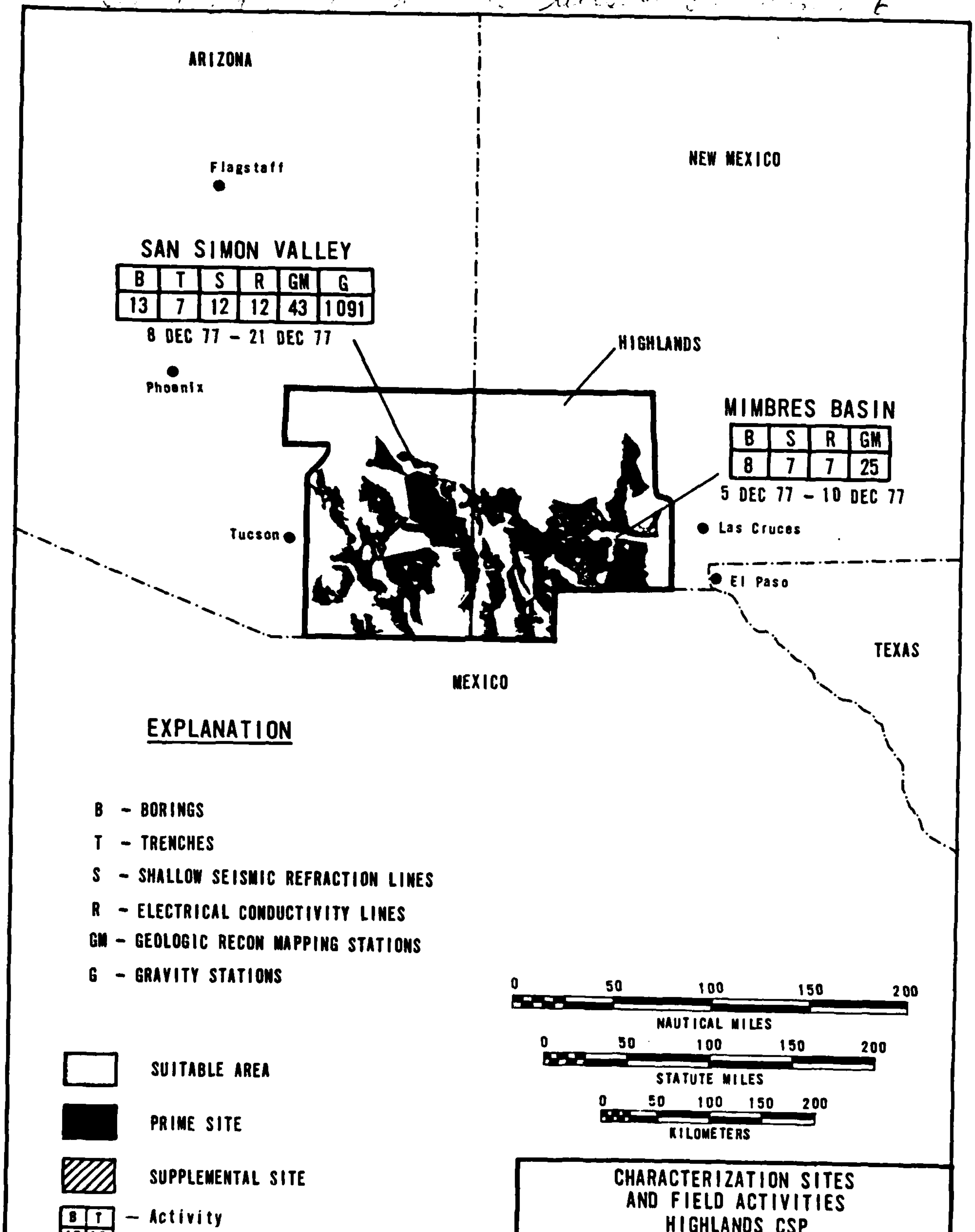
This report presents the results of geotechnical field investigations performed in the Jornada del Muerto and San Simon characterization sites, located in central New Mexico in the Rio Grande Candidate Siting Province (CSP) and in southeastern Arizona in the Highlands CSP, respectively. These provinces are two of six selected for geotechnical characterization studies. This report presents representative data collected and analyzed for these sites. Access to the remaining data can be arranged through SAMSO/MNND, Norton Air Force Base, California.

The Rio Grande CSP lies within the states of New Mexico and Texas (Figure 1). It is characterized by predominately north and northwest trending mountain ranges separated by fault controlled closed basins possessing a variety of geologic and engineering conditions.

The Highlands CSP lies within the states of New Mexico and Arizona (Figure 2) and is characterized by variable geologic structures and topography. North to northwest trending mountain ranges comprise from 25 to 33 percent of its area. Drainage is moderately well developed, however, a few basins are closed and contain playas.

Suitable areas for deployment of MX missile system remaining after Intermediate Screening were divided into CSPs based on similar geotechnical characteristics. The results of Intermediate Screening (FN-TR-17) indicated that existing data


OKLAHOMA
JORNADA DEL MUERTO
B | T | S | DS | GM | G
16 | 7 | 16 | 2 | 46 | 716
20 JUL 77 - 23 SEP 77
NEW MEXICO
ARIZONA
RIO GRANDE
TEXAS
Roswell
Clovis
Las Cruces
El Paso
MEXICO
SALT BASIN
B | S | R | GM
6 | 11 | 10 | 19
28 NOV 77 - 21 JAN 78
EXPLANATION
B - BORINGS
T - TRENCHES
S - SHALLOW SEISMIC REFRACTION LINES
DS - DEEP SEISMIC REFRACTION LINES
R - ELECTRICAL CONDUCTIVITY LINES
GM - GEOLOGIC RECON MAPPING STATIONS
G - GRAVITY STATIONS
SUITABLE AREA
PRIME SITE
SUPPLEMENTAL SITE
B | T — Activity
17 | 18 — Quantity of each activity
0 50 100 150 200
NAUTICAL MILES
0 50 100 150 200
STATUTE MILES
0 50 100 150 200
KILOMETERS
CHARACTERIZATION SITES
AND FIELD ACTIVITIES
RIO GRANDE CSP
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO
FIGURE
1
FUGRO NATIONAL, INC.



CHARACTERIZATION SITES AND FIELD ACTIVITIES HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 2

FUGRO NATIONAL, INC.

were not adequate in type or level of detail for follow-on geotechnical and geo-environmental evaluations, screening, site selection, and ranking studies. Therefore, the Characterization studies were developed to provide a rapid, relatively inexpensive method of gathering geotechnical data in small areas (maximum about 700 nm^2; 2400 km^2) which are considered to be representative of a larger area within the CSP.

Emphasis was placed on the collection of information allowing characterization of geological units with respect to the construction aspects of MX missile basing options. Objectives of the Characterization studies were to obtain data that address the following geotechnical aspects:

- o Surficial geology and terrain
- o Subsurface conditions
- o Geophysical properties
- o Engineering properties

Although the program originally emphasized data collection for the trench and horizontal shelter basing modes, the data were utilized for evaluation of the vertical shelter basing mode as well. Characterization was, therefore, a refinement of the screening process whereby the necessary geotechnical information was developed to support the broader MX system design activities. These activities were taking place concurrently and provided a more firm basis from which to geotechnically rank the remaining suitable area considering different alternative basing modes.

Two Characterization sites (one prime and one supplementary) were selected within each CSP (Figures 1 and 2). This report discusses only the prime site within each CSP. The characterization site selection process began with a delineation of geotechnically similar areas within each CSP having analogous depositional and geologic histories, rock and water depths, and tectonic settings. Once these areas had been identified, non-geotechnical factors were applied to delineate the actual Characterization site boundaries. These non-geotechnical selection factors included access, proximity to support facilities, environmental sensitivities, and local logistical requirements.

Geologic, geophysical, and soils engineering techniques were used to determine the surface and subsurface geotechnical conditions in Jornada del Muerto and San Simon. These include:

- Analysis of available data
- Aerial photo interpretation of surficial geologic units utilizing black and white stereographic pairs at scales of approximately 1:30,000 (Jornada del Muerto) and 1:60,000 (San Simon)
- Geologic field check of aerial photo interpretation and determination of physical properties of the surficial units at selected field stations
- Shallow and deep seismic refraction, down hole seismic velocity, and electrical conductivity surveys to obtain subsurface profile information

- o Gravity and ground magnetic surveys to aid in interpretation of basin configuration
- o Drilling and trenching to determine subsurface soil characteristics and obtain soil samples
- o Laboratory testing of soil samples to determine engineering properties

Prior to initiating any field work, an archeological and environmental inspection was conducted at each site to ensure minimal impact to the local environment and to avoid damage to archeologic and historic sites. To further minimize potential impacts, all field activities were performed adjacent to existing roads or other previously disturbed areas.

Site access to the Jornada del Muerto and Salt Basin characterization sites in the Rio Grande CSP was coordinated through the Base Engineers Office, White Sands Missile Range, and the U.S. Army Corps of Engineers, respectively. Access to characterization sites in the Highlands CSP was gained through BLM permits and the U.S. Army Corps of Engineers.

2.0 JORNADA DEL MUERTO SITE

The Jornada del Muerto characterization site covers an area of 330 nm^2 (1132 km^2) in Socorro and Sierra counties, New Mexico. The site is bounded by mountain ranges on the east and south. The Rio Grande River lies just outside the site area to the west. Chupadera Mesa lies to the north. A network of paved and graded roads as well as four-wheel drive trails provide access within the site.

2.1 SCOPE OF INVESTIGATION

Scope of geologic, geophysical, and soils engineering field activities performed at the site and laboratory tests performed on soil samples from the site is presented in Table 1. Detailed information about the soils engineering field activities (17 borings and seven trenches) is summarized in Tables 2 and 3. Locations of all the field activities are shown in Figure 3.

2.2 SURFICIAL GEOLOGY AND TERRAIN

Alluvial fan deposits of younger and intermediate age and eolian sheet sand are the predominant surficial geologic units within the Characterization site (Figure 3). Fluvial deposits cover approximately 6 percent of the area, younger alluvial fan deposits cover approximately 14 percent, intermediate alluvial fan deposits cover 22 percent, and eolian sheet sand covers approximately 45 percent. Playa and older lacustrine deposits cover approximately three and nine percent of the surface area, respectively. These deposits do not represent a large percentage of the surface area, but they are generally of great thickness and interfinger with alluvial

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geological mapping stations	46
Shallow refraction	16
Deep refraction	2
Downhole velocity	3
Gravity survey	716

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
13	100 (30)
3	300 (91)

NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
1	16 (5)
6	18 (6)

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	237
Specific gravity	19
Sieve analysis	130
Hydrometer	53
Atterberg limits	90
Consolidation	10

TYPE OF TEST	NUMBER OF TESTS
Unconfined compression	29
Triaxial compression	15
Direct shear	30
Compaction	7
CBR	3
Chemical analysis	8

SCOPE OF FIELD AND LABORATORY ACTIVITIES
JORNADA DEL MUERTO, NEW MEXICO, RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE 1

FUGRO NATIONAL, INC.

BORING NUMBER	TOTAL DEPTH FEET (METERS)	TYPE OF DRILL RIG USED	TYPE OF SAMPLES* OBTAINED
JM-B-1	102.0 (31.1)	Rotary Wash	B, P
JM-B-2	108.0 (32.9)	Rotary Wash	B, P, C
JM-B-3	105.0 (32.0)	Rotary Wash	B, P
JM-B-4	102.5 (31.2)	Rotary Wash	P
JM-B-5	100.0 (30.5)	Rotary Wash	B, P
JM-B-6	101.0 (30.8)	Rotary Wash	B, P
JM-B-7	102.5 (31.2)	Rotary Wash	P, D, C
JM-B-8	99.0 (30.2)	Rotary Wash	B, P
JM-B-9	102.5 (31.2)	Rotary Wash	B, P, SS
JM-B-10	301.5 (91.9)	Rotary Wash	B, P
JM-B-11	304.0 (92.7)	Rotary Wash	B, P
JM-B-12	102.5 (31.2)	Rotary Wash	B, P
JM-B-13	101.0 (30.8)	Rotary Wash	B, P
JM-B-14	102.5 (31.2)	Rotary Wash	B, P
JM-B-15	302.5 (92.2)	Rotary Wash	B, P
JM-B-17	102.0 (31.1)	Rotary Wash	B, P, SS

*P = Pitcher sample (undisturbed)
D = Fugro Drive sample (relatively undisturbed)
B = Bulk sample (disturbed, but representative)
SS = Split Spoon sample (disturbed, but representative)
C = Rock Core

ENGINEERING FIELD ACTIVITIES - BORINGS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE 2

FUGRO NATIONAL, INC.

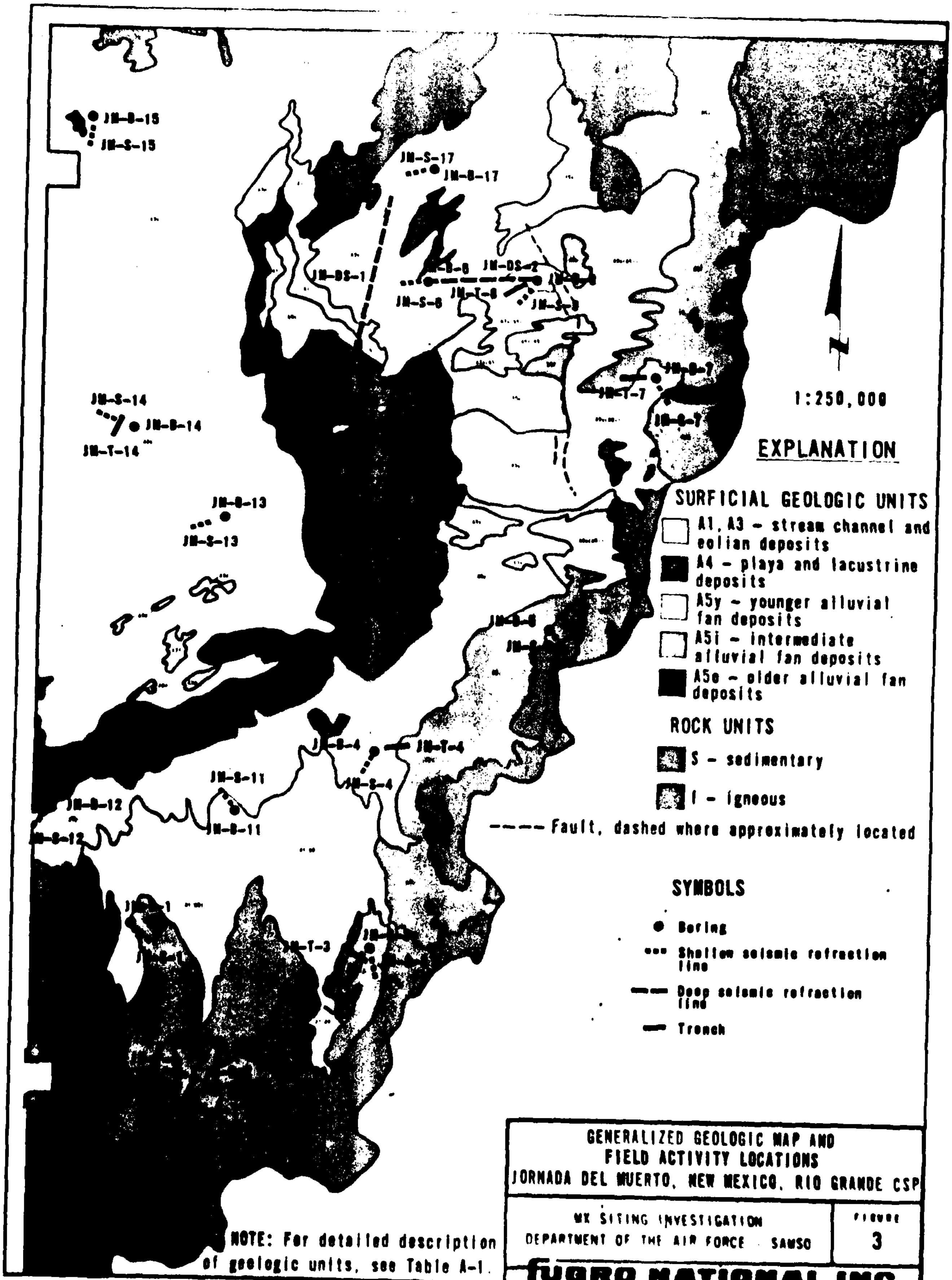
TRENCH NUMBER	TOTAL DEPTH FEET(METERS)	STABILITY OF VERTICAL EXCAVATION WALLS
JM-T-2	16.5 (5.0)	stable; 15.5-16.5' (4.7-5.0m), stage II Caliche
JM-T-3	18.0 (5.5)	stable; 16.5-18.0' (5.0-5.5m), stage II Caliche
JM-T-4	18.0 (5.5)	stable
JM-T-7	18.0 (5.5)	stable; 1-3' (0.3-0.9m), stage I Caliche
JM-T-8	18.0 (5.5)	stable; 0-7' (0-2m) some sloughing into trench: 7-17' (2.1-5.2m) stable; 17-18' (5.2-5.5m) stage I Caliche, 3-9' (0.9-2.7m)
JM-T-12	18.0 (5.5)	stable; 3-12' (0.9-3.7m), stage I Caliche
JM-T-14	18.5 (5.6)	unstable; heavy sloughing, 0-5' (0-1.5m) stable; stage I Caliche, 5-10' (1.5-3.0m) unstable; some sloughing into trench, 10-18.5' (3.0-5.6m)

ENGINEERING FIELD ACTIVITIES - TRENCHES
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE 3

FUGRO NATIONAL, INC.



GENERALIZED GEOLOGIC MAP AND FIELD ACTIVITY LOCATIONS
JORNADA DEL MUERTO, NEW MEXICO, RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 3

FUGRO NATIONAL, INC.

deposits in the subsurface within the construction zone. The alluvial fan deposits are typically silty sands with gravel, ranging from sandy gravels near the mountain fronts to sandy silts near the playas. Playa and older lacustrine deposits are generally clayey silts. These units along with the remaining surficial units are described in Table 4.

Surface slopes and depths of drainage incision vary with geologic units, both generally increasing with proximity to the mountain fronts (Table 4). Maximum surface slope is five percent with typical slopes of less than one percent. Drainages are typically shallow (less than 10 feet; 3 m), with gently sloping sides except near mountainous areas. Locally they may be deep (greater than 20 ft; 6 m) and steep sided.

2.3 SUBSURFACE CONDITIONS

2.3.1 Soil Profiles

Varying thicknesses of eolian sheet sand and alluvial fan deposits typically overlie several hundred feet of older lacustrine deposits in the Jornada site. The subsurface conditions and the composition of the soils with depth are illustrated by the soil profiles shown in Figures 4 and 5. Eolian sheet sand and alluvial deposits predominantly consist of coarse-grained soils whereas lacustrine deposits consist of fine-grained soils.

2.3.2 Depth to Shallow (<150 ft;<46 m) Rock and Water

Figure 6 shows the portions of the site in which rock and water are estimated to be encountered within a depth of 150 feet

SURFICIAL GEOLOGIC UNIT (a)	GEOLOGIC AGE	THICKNESS FEET (METERS)	DESCRIPTIVE NAME(S)	USCS SYMBOL(S) (b)	AREAL EXTENT (SITE)	
					nm^2 (km^2)	PERCENT
Fluvial Deposits (A1)	Quaternary	Unknown	Silty Sand with Clay	SM	20 (69)	6
Eolian Deposits Sheet and Dune Sand (A3s, A3d)	Quaternary	0-18 (0-6)	Sand, Silty Sand, Silty Sand with Clay	SP, SM	149 (511)	45
Playa Deposits (A4)	Quaternary	Unknown	Silt and Clay	ML, CL	10 (34)	3
Older Lacustrine and Playa Deposits (A4o)	Quaternary-Tertiary	Unknown	Clay, Gypsiferous Silt, Silty Sand	CL, ML, SM	30 (103)	9
Younger Alluvial Fan Deposits (A5y)	Quaternary	Unknown	Silty and Clayey Sand with Gravel, Silt, Clay	SM, SC	46 (158)	14
Intermediate Alluvial Fan Deposits (A5i)	Quaternary	Unknown	Silty Sand with Gravel and Cobbles	SM	73 (250)	22
Older Alluvial Fan Deposits (A5o)	Quaternary-Tertiary	Unknown	Sandy Gravel with Cobbles and Boulders	SP-GW	3 (10)	1

NOTES:

(a) For generic description of geologic units, see Table A-1.

(b) For description of USCS, see Table A-2.

(c) For description of stage of caliche, see Figure A-1.

(d) Mixed with A5i deposits in the southerm part of the site; designated A1 A5y on Figures 3 and 6

(e) Dune sands comprise one percent of the site area.

(f) This gypsiferous deposit occurs extensively in the subsurface.

REAL EXTENT (SITE)		PROPERTIES OF SURFACE MATERIALS					SURFACE MORPHOLOGY		NOTES
n^2 (km^2)	PERCENT	GRADATION	CEMENTATION	MAXIMUM GRAIN SIZE	PAVEMENT/ PATINA	STAGE OF CALICHE (c)	SLOPE (PERCENT)	DRAINAGE DEPTHS FEET (METERS)	
!0 (69)	6	Well	None-Moderate	Sand	None/None	I	< 1	None	(d)
19 (511)	45	Poor-Moderately well	None-Weak	Sand	None/None	I	< 1	< 1	(e)
0 (34)	3	Poor	None-Weak	Silt	None/None	None	< 1	None	
0 (103),	9	Poor	Weak-Strong	Sand	None/None	None-II	< 1	0-5 (0-2)	(f)
6 (158)	14	Moderately well	None-Weak	Sand	None/None	I	1-4	<1-6 (<1-2)	
3 (250)	22	Moderately well-Well	Moderate-Strong	Cobble	Poor/Poor	II	2-9	5-25 (2-8)	
3 (10)	1	Moderately well	Moderate-Strong	Boulder	None/None	II-III	9-12	50-100 (16-33)	

DESCRIPTION OF SURFICIAL GEOLOGIC UNITS

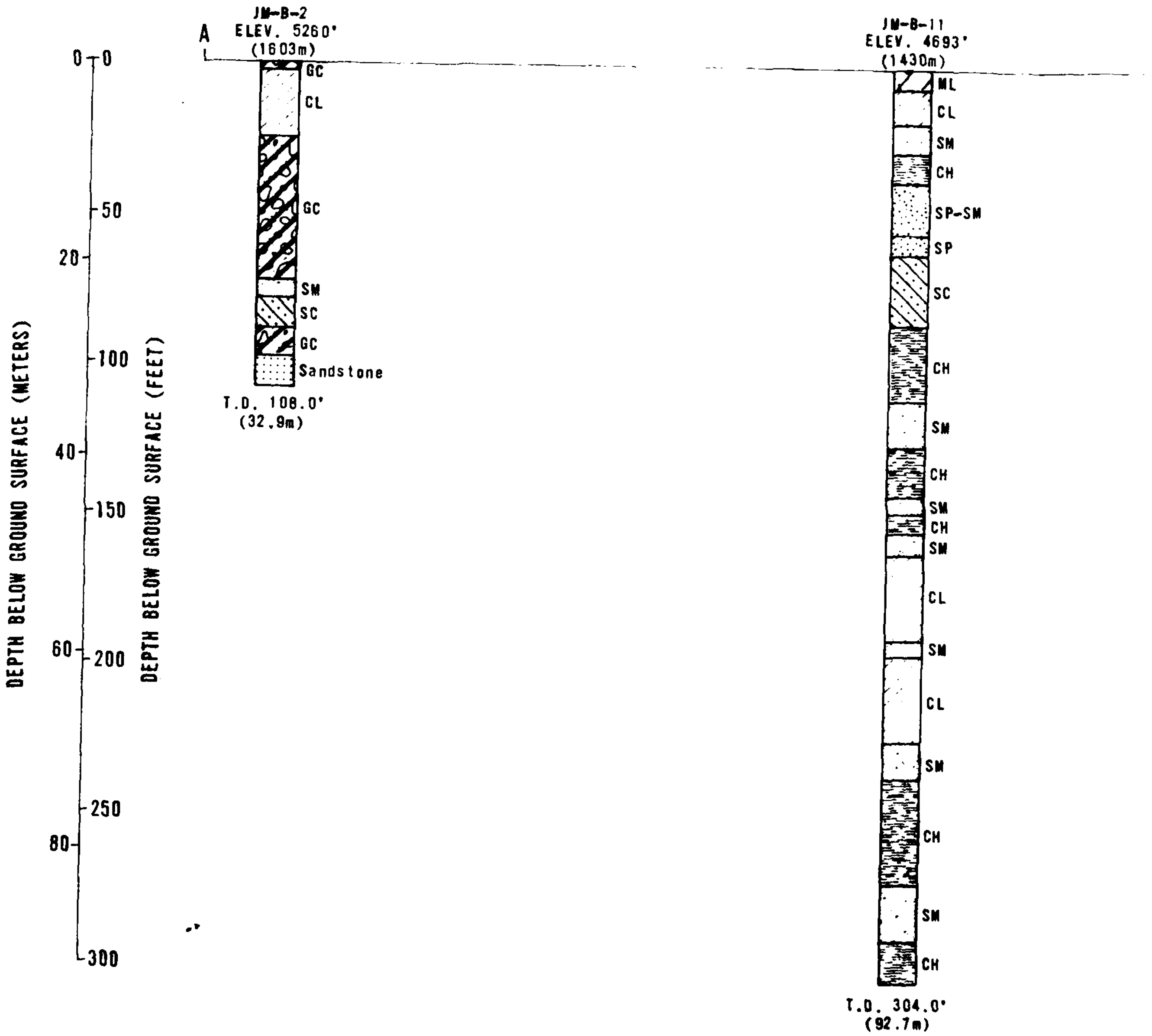
JORNADA DEL MUERTO, NEW MEXICO, RIO GRANDE CSP

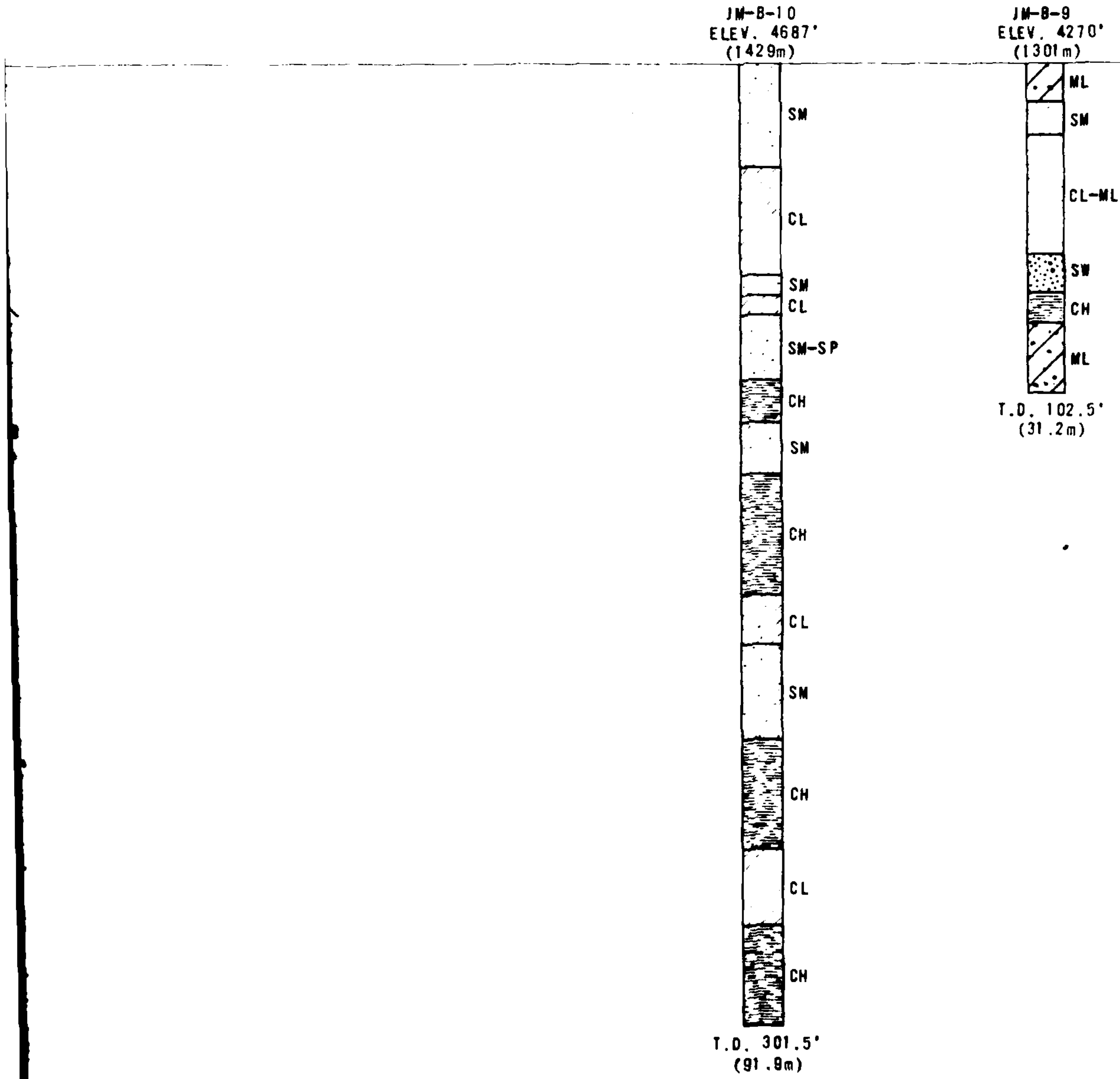
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

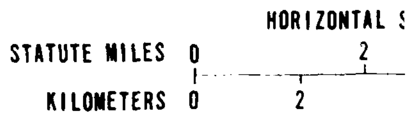
TABLE 4

FUGRO NATIONAL, INC.

2


A
JM-B-2
ELEV. 5260'
(1603m)
GC
CL
GC
SM
SC
GC
Sandstone
T.D. 108.0'
(32.9m)
JM-B-11
ELEV. 4693'
(1430m)
ML
CL
SM
CH
SP-SM
SP
SC
CH
SM
CH
SM
CH
SM
CL
SM
CL
SM
CH
SM
CH
T.D. 304.0'
(92.7m)
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
20
40
60
80
0
50
100
150
200
250
300



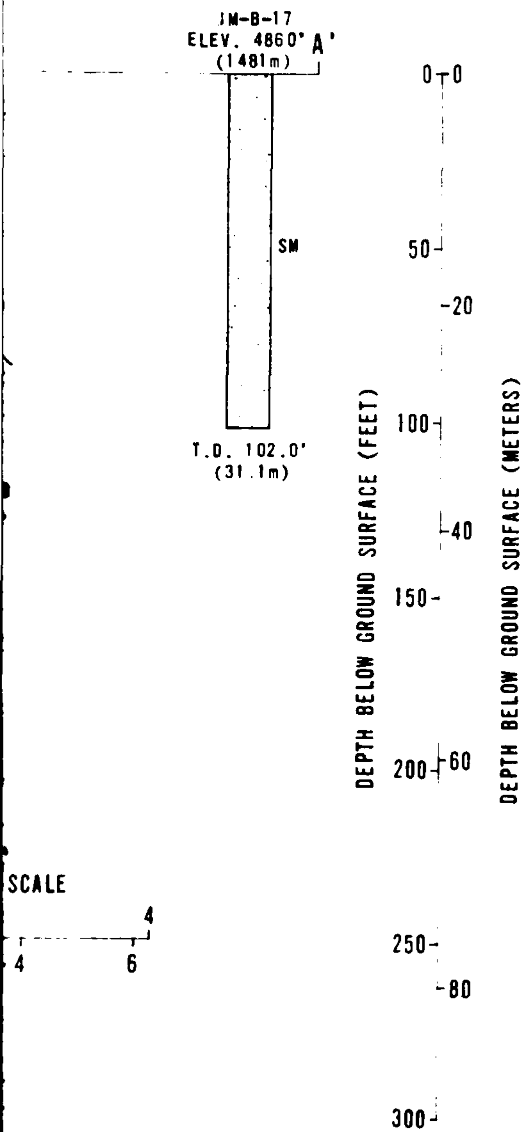


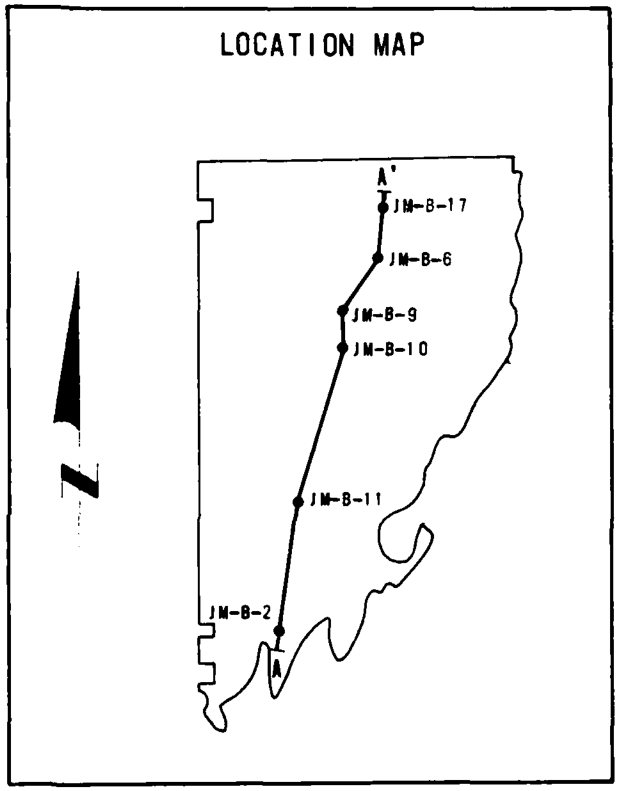
NOTES: 1. Ground surface elevations shown at locations of bori

2. T.D.=Total Depth

3. Soil types shown adjacent to soil column are based c (USCS) and are explained in the appendix

∂





ings are approximate

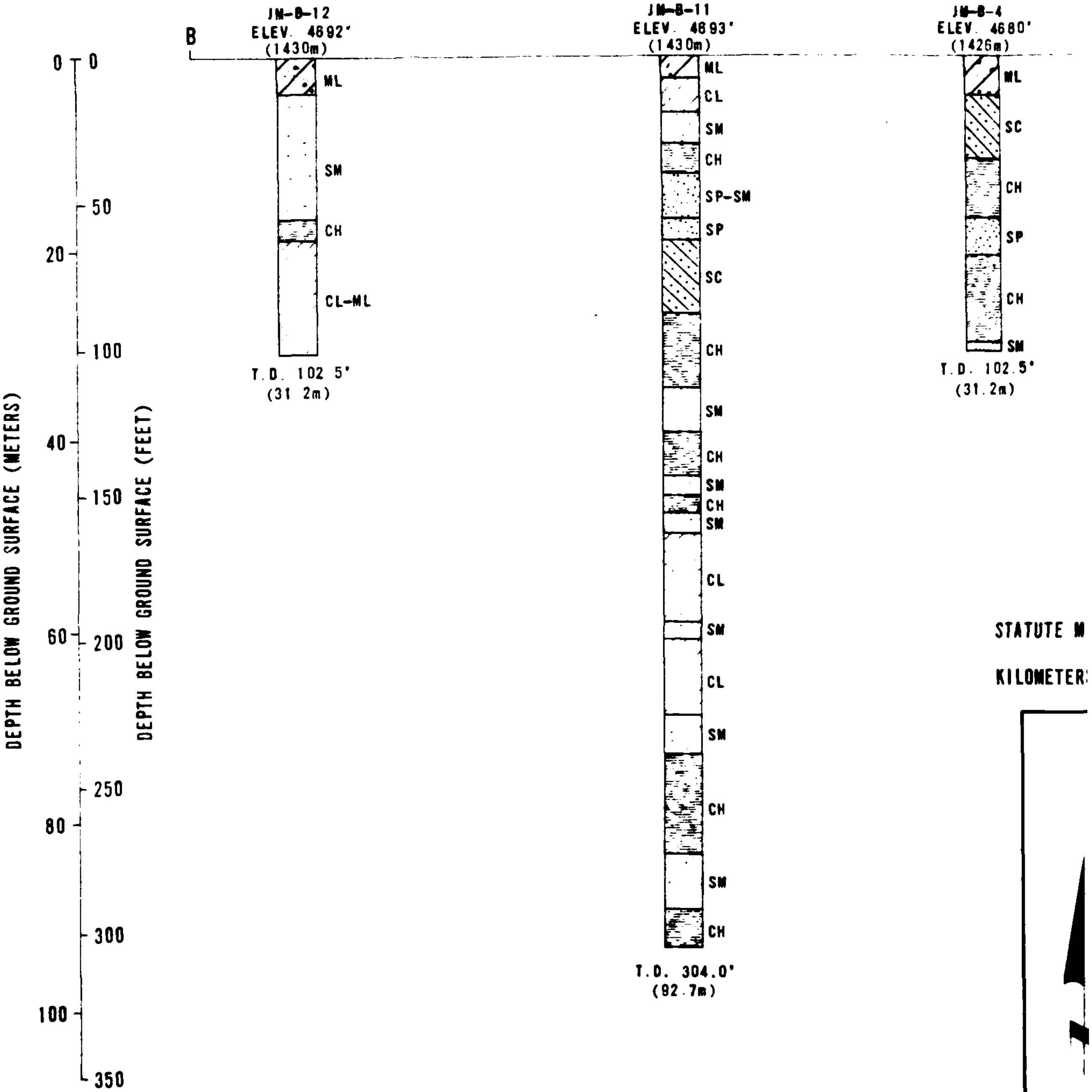
on Unified Soil Classification System

SOIL PROFILE AA'
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
4

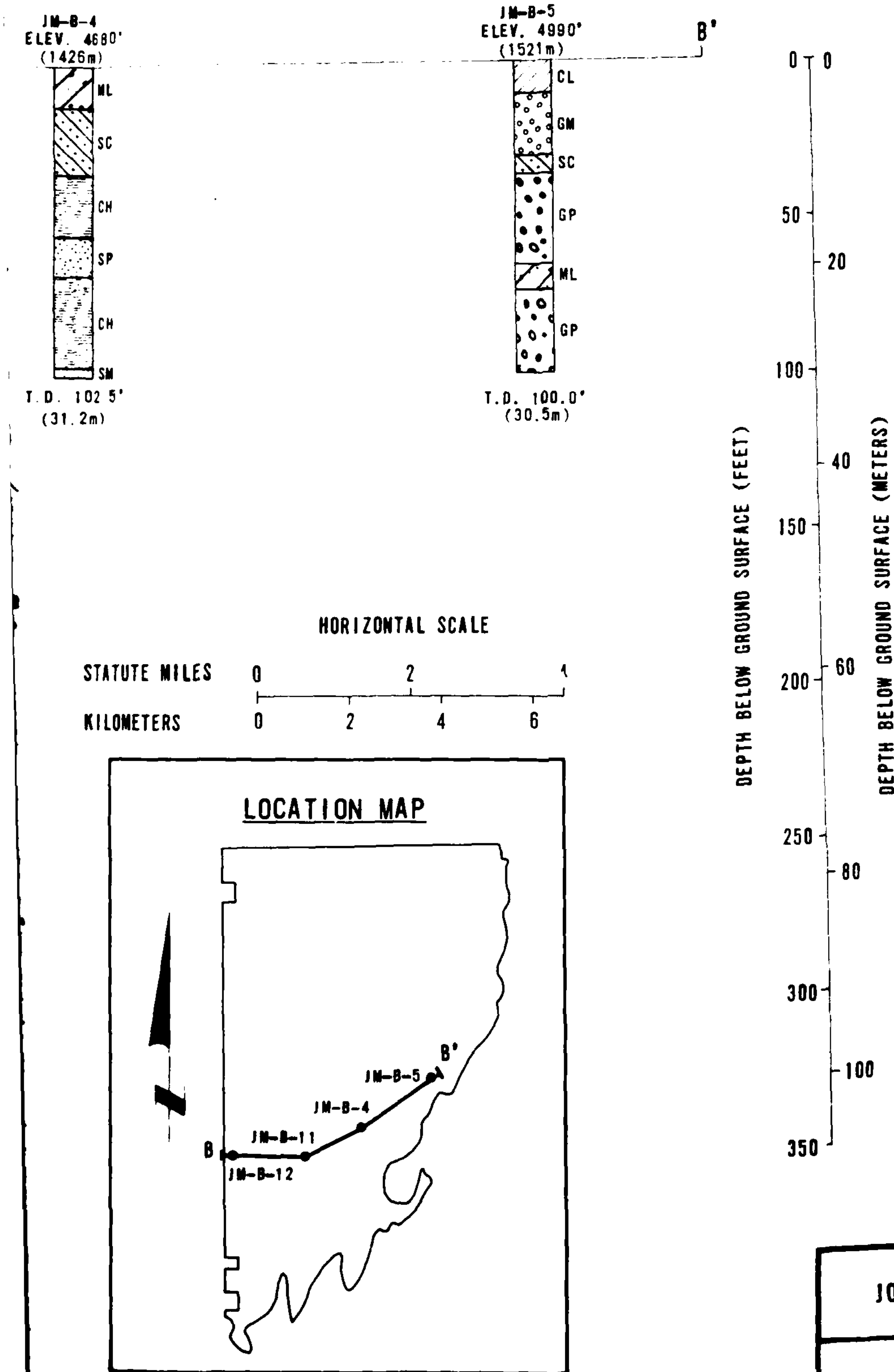
FUGRO NATIONAL, INC.



NOTES: 1. Ground surface elevations shown at locations of borings are approximate

2. T.D.= Total Depth

3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix



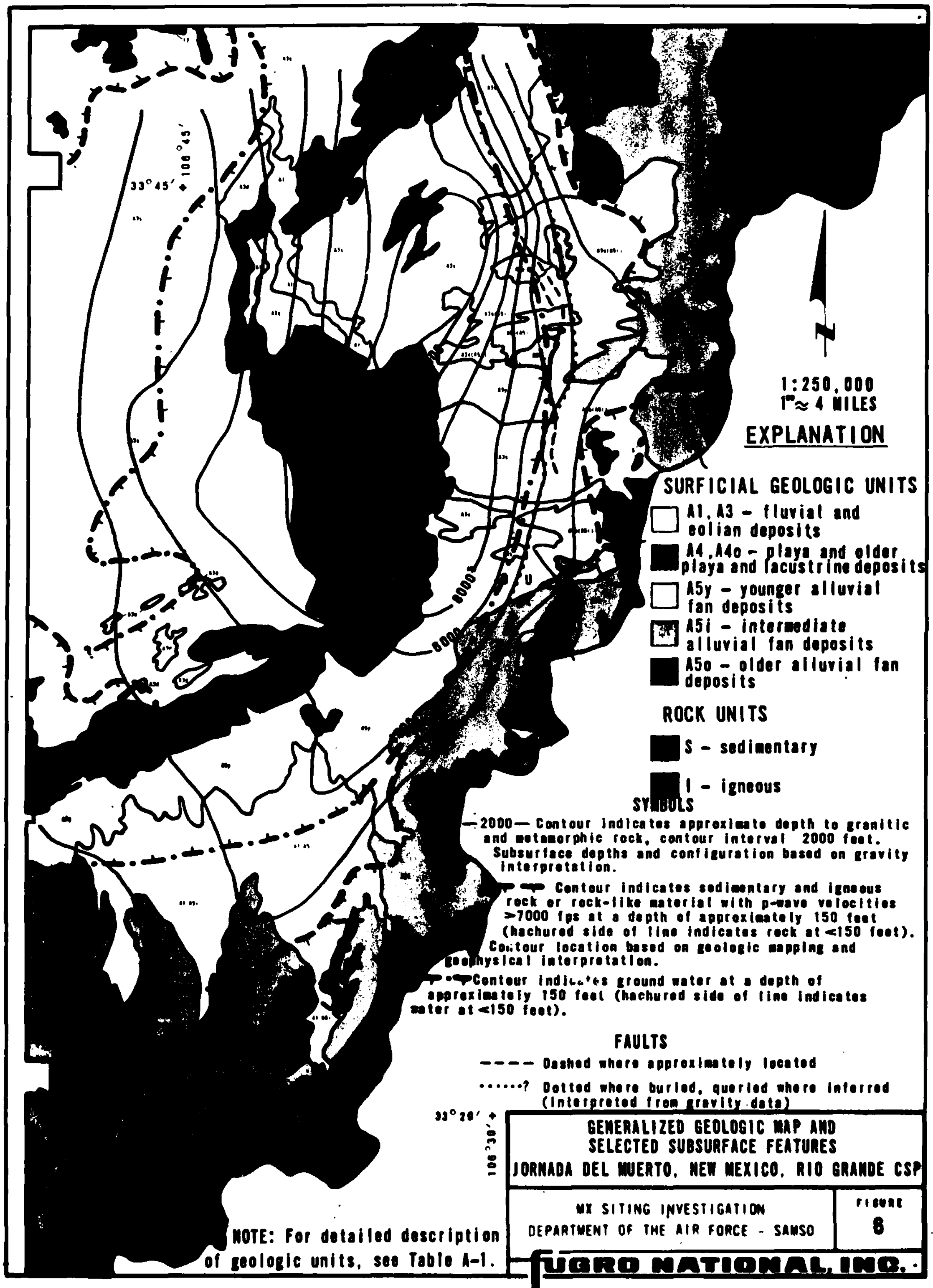
SOIL PROFILE BB'
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 5

FUGRO NATIONAL, INC.

2



GENERALIZED GEOLOGIC MAP AND SELECTED SUBSURFACE FEATURES
JORNADA DEL MUERTO, NEW MEXICO, RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 6

FUGRO NATIONAL, INC.

NOTE: For detailed description of geologic units, see Table A-1.

below ground surface. Shallow rock comprises approximately ten percent of the site based on boring, seismic, gravity, geologic, topographic and other available data. Ground water will be encountered at depths of less than 150 feet (46 m) over approximately 30 percent of the site area. Areas of shallow ground water will generally coincide with the surficial distribution of older lacustine and playa deposits. Elsewhere, local areas of perched water may also be encountered at depths of less than 150 feet (46 m).

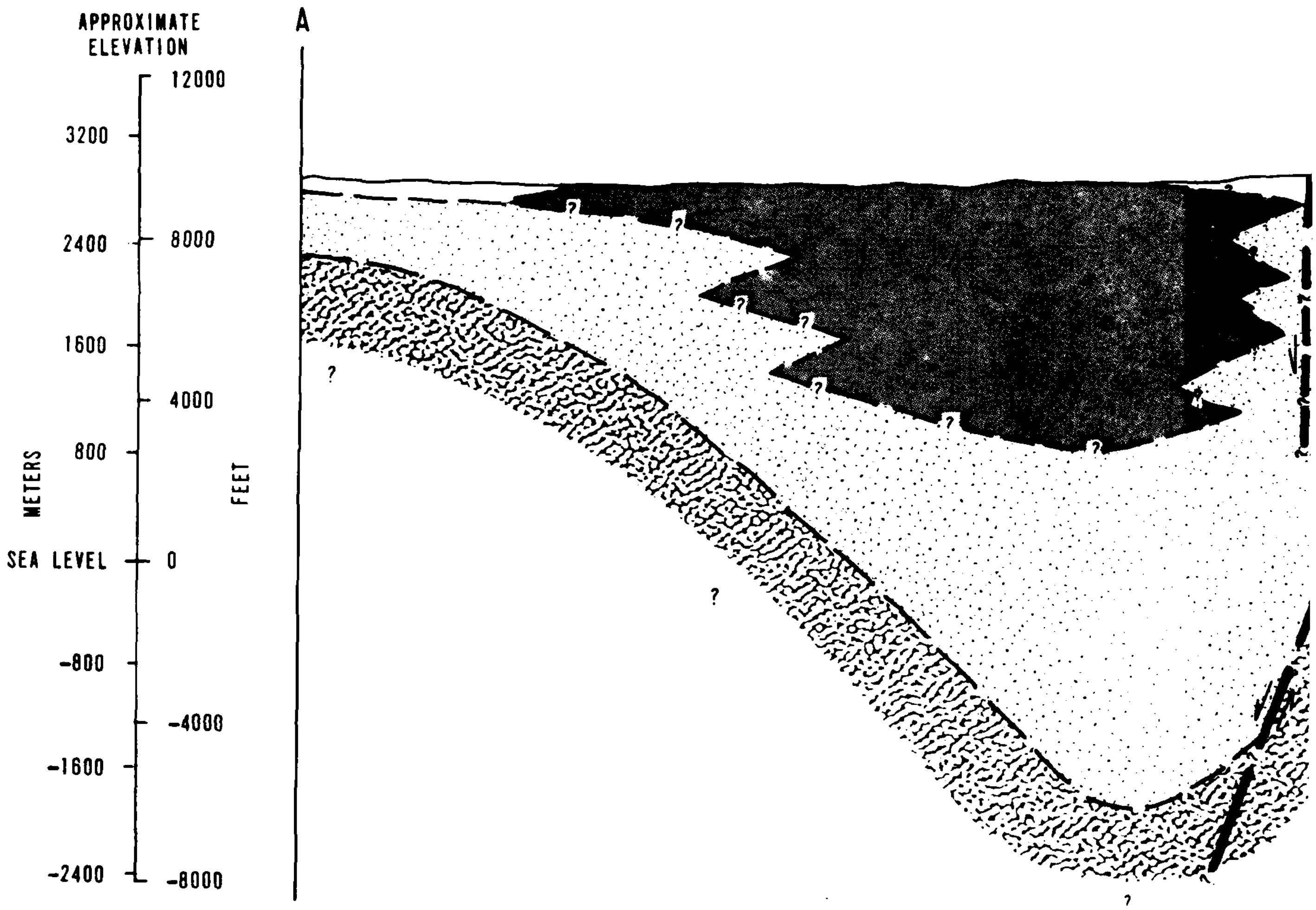
2.3.3 Basin Configuration

Geophysical investigations indicate bedrock within 50 feet (15 m) of the surface near the mountains in the southern part of the site. Deep seismic lines near the middle of the valley encountered high velocity materials, probably well indurated older alluvium, at a depth of 450 feet (140 m).

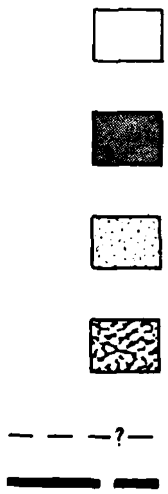
Gravity data indicate the basement topography of the site is dominated by a 16,000-foot (4900 m) deep basin that is bounded on the east by a steep fault and on the west by a gently sloping plane in the vicinity of the generalized geologic cross-section (Figure 7). Near the south end of the site, an east-west trending basement ridge separates the large basin from a smaller one. Buried basalt from the Jornada Malpais basalt field may overlie much of this ridge.

2.4 GEOPHYSICAL PROPERTIES

Results of shallow and deep seismic refraction surveys and downhole velocity surveys are presented in Tables, 5, 6 and 7.



EXPLANATION



Undifferentiated basin-fill deposits
Predominantly eolian (A3), fluvial (A1) and alluvial (A5) deposits with minor playa (A4) deposits

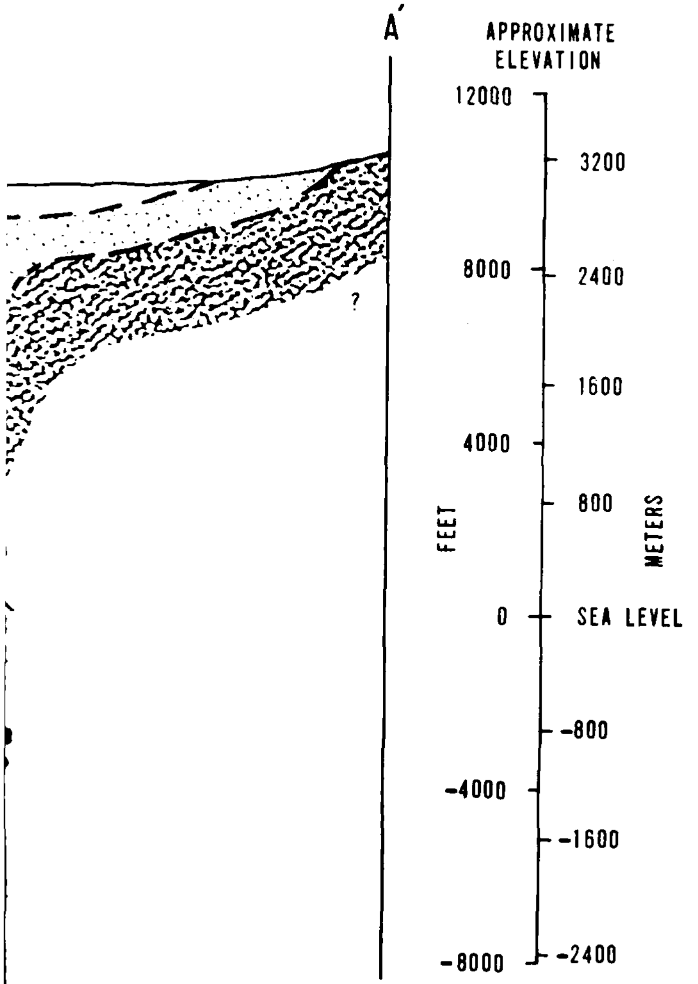
Older lacustrine and/or playa (A4o) deposits

Undifferentiated older basin-fill deposits and sedimentary rocks

Precambrian metamorphic rock

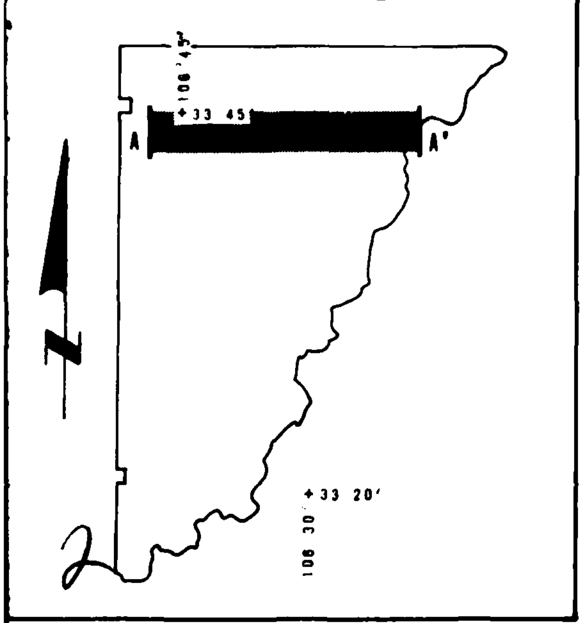
— — —?— Approximate geologic contact, queried where inferred

Fault, dashed where inferred



NOTES:
1. The cross section is generally representative of subsurface conditions within the band shown on the location map. Due to the limited density of available data and the sparseness of newly acquired data, the subsurface conditions are highly interpretive.
2. For a detailed description of geologic units see Table A-1.

LOCATION MAP



Horizontal Scale: 1" ~ 2 Miles (3km)
Vertical Scale: 1" — 4000' (1219m)
Vertical Exaggeration: 2.6X

HORIZONTAL SCALE

STATUTE MILES 0 2 4

KILOMETERS 0 2 4 6

GENERALIZED GEOLOGIC CROSS SECTION
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
7

FUGRO NATIONAL, INC.

SEISMIC LINE NO.	VELOCITY DISTRIBUTION FPS (MPS)			DEEPER REFRACTORS DEPTH / VELOCITY	*ROCK EXCLUSION DEPTH TO 7000 FPS (2134 MPS)
JM-S-1	1700 (518)	4800 (1463)		340 (104) / 8300 (2530)	
JM-S-2	1700 (518)	7500 (2286)	10600 (3231)		
JM-S-3	1850 (564)	4450 (1356)	7200 (2195)		
JM-S-4	1700 (518)	6050 (1844)			133 (41)
JM-S-5	1700 (518)	2600 (792)			272 (83)
JM-S-6	1740 (530)	3460 (1055)			264 (80)
JM-S-7	1500 (457)	3100 (945)			246 (75)
JM-S-8	1500 (457)	2800 (853)			261 (80)
JM-S-9	1200 (366)	3750 (1143)			243 (74)
JM-S-10	1560 (475)	4500 (1372)	7200 (2195)		
JM-S-11	1700 (518)	3800 (1158)	6450 (1966)		215 (66)
JM-S-12	4750 (1448)				246 (75)
JM-S-13	1200 (366)	7000 (2134)			
JM-S-14	1500 (457)	3300 (1006)			313 (95)
				FT (M) / FPS (MPS)	FEET (M)

METERS 0 5 10 15 20 25 30 35 40 45

FEET 0 5 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

DEPTH INTERVAL

* If no refracting interface or layer with a velocity greater than 7000 fps (rock/rock-like material) was detected, a rock exclusion depth calculation was performed to determine the minimum depth at which rock could occur.

SHALLOW SEISMIC REFRACTION RESULTS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE 5

FUGRO NATIONAL, INC.

SEISMIC LINE NO.	VELOCITY DISTRIBUTION FPS (MPS)		DEEPER REFRACTORS DEPTH / VELOCITY	*ROCK EXCLUSION DEPTH TO 7000 FPS (2134 MPS)
JM-S-15	1600 (488)	3050 (930)	-	251 (76)
JM-S-17	3900 (1189)		-	240 (73)
			FT (M) / FPS (MPS)	FEET (M)

METERS 0 5 10 15 20 25 30 35 40 45

FEET 0 5 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

DEPTH INTERVAL

* If no refracting interface or layer with a velocity greater than 7000 fps (rock/rock-like material) was detected, a rock exclusion depth calculation was performed to determine the minimum depth at which rock could occur.

SHALLOW SEISMIC REFRACTION RESULTS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE 5

FUGRO NATIONAL, INC.

VELOCITY LAYER	COMPRESSIONAL WAVE VELOCITY FPS (MPS)	AVERAGE THICKNESS FT (M)	COMMENTS
1	2000 (610)	20 (6)	
2	4000 (1219)	150 (46)	
3	6200 (1890)	300 (91)	Begin Saturated Sediments
4	7500 (2286)	700 (213)	
5	9000 (2743)	Undetermined	

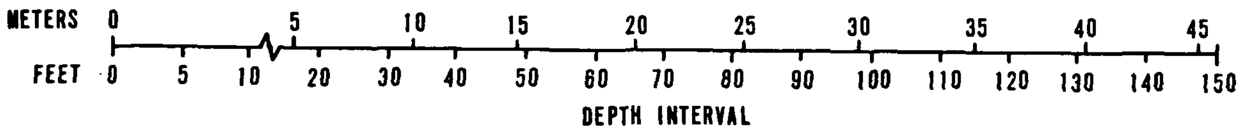
DEEP SEISMIC REFRACTION RESULTS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE 6

FUGRO NATIONAL, INC.

DOWNHOLE SURVEY NO.	VELOCITY DISTRIBUTION FPS (MPS)				WAVE TYPE
JM-DH-15	2010 (613)	5000 (1524)			P
	1120 (341)	2030 (619)	2930 (893)		S
JM-DH-2	1650 (503)	4150 (1264)	6600 (2012)		P
	1000 (305)	1650 (503)	2725 (830)		S
JM-DH-10	3080 (939)	2120 (646)	4500 (1372)	6000 (1829)	P
	1840 (561)	1200 (366)	1460 (445)		S



DOWNHOLE VELOCITY SURVEY RESULTS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE 7

FUGRO NATIONAL, INC.

Shallow refraction results (Table 5) indicate a surficial layer having a velocity range between 1200 and 1850 fps (366 and 564 mps) with an average thickness of eight feet (2.5 m). Velocities greater than 7000 fps (2134 mps) were encountered at the location of four lines. Five major velocity zones were observed on the deep seismic lines (Table 6). Velocities representative of crystalline basement were not observed.

The compressional wave velocities from downhole surveys (Table 7) do not correspond with those from shallow seismic refraction (Table 5) due to the anisotropy of the soils and method of measurement. However, shear wave velocities of the site soils were obtained from the downhole surveys.

2.5 ENGINEERING PROPERTIES

Engineering properties of the subsoils representing various geologic units were determined from laboratory tests. The tests consisted of the following: classification, consolidation, shear strength, compaction, CBR, and chemical. The range of engineering properties and compressional wave velocityes are presented in Table 8.

Eolian sheet sand consists of medium dense to dense poorly graded sands and silty and clayey sands with little gravel. Intermediate alluvial fan deposits consist of dense to very dense sands and gravels. Younger alluvial fan deposits are comprised of medium dense to dense silty and clayey sands with some stiff silts and clays. Older lacustrine deposits consist of stiff to very stiff silts and clays which are

ENGINEERING AND GEOPHYSICAL PROPERTIES	Eolian sheet sand (A3s)	Intermediate alluvial fan
UNIFIED SOIL CLASSIFICATION SYMBOL(S)	SP, SM, SC	SP, SM, SC, GP, GM
GENERAL PROPERTIES		
DRY DENSITY pcf(kg m^3)	100-120 (1602-1922)	95-133 (1522-213
MOISTURE CONTENT (%)	7-17	7-19
DEGREE OF SATURATION (%)	30-78	47-83
SPECIFIC GRAVITY	2.64-2.66	2.68-2.77
DEGREE OF CEMENTATION	None to moderate	Moderate to st
COMPRESSIONAL WAVE VELOCITIES fps(mps)	1420-3220 (433-981)	1000-7200 (305-
ELECTRICAL CONDUCTIVITY (mhos m)	DNA	DNA
GRAIN SIZE DISTRIBUTION (%)		
BOULDERS >12 inches(30cm)	0-5	0-3
COBBLES 3 to 12 inches(8to 30cm)	0-5	0-10
GRAVEL	0-12	0-90
SAND	50-97	5-95
SILT AND CLAY	3-50	5-48
PLASTICITY DATA		
LIQUID LIMIT	20±	24-26
PLASTICITY INDEX	NP-7	NP-12
COMPRESSIBILITY DATA		
COMPRESSION AT 4 ksf(192kN/m^2) (%)	DNA	DNA
SWELL OR COLLAPSE UPON SATURATION (%)	DNA	DNA
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION ksf(kN m^2)	DNA	2.0± (96±)
CD TRIAXIAL COMPRESSION	c = 0-1.0 ksf (48 kN m^2), ϕ = 34°-39°	DNA
DIRECT SHEAR ksf(kN m^2)	0.7-5.5 (34-263)	2.5-7.7 (120-36
COMPACTION AND CBR DATA		
MAXIMUM DRY DENSITY pcf(kg m^3)	125-138 (2002-2211)	DNA
OPTIMUM MOISTURE CONTENT (%)	6.0-8.5	DNA
CBR AT 90% RELATIVE COMPACTION	16±	DNA

DNA - DATA NOT AVAILABLE (INSUFFICIENT DATA OR TESTS NOT PERFORMED)

GEOLOGIC UNITS		
ediate alluvial fan deposits (A5i)	Younger alluvial fan deposits (A5y)	Older lacustrine deposits (A4o)
SP, SM, SC, GP, GM, GC	SM, SC, ML, CL	CL, ML, SC
95-133 (1522-2130)	80-116 (1281-1858)	84-120 (1346-1922)
7-19	4-20	3-43
4,-83	19-49	10-89
2.68-2.77	2.67-2.72	2.59-2.73
Moderate to strong	None to weak	Weak to strong
1000-7200 (305-2195)	1500-3100 (457-945)	1700-6750 (518-2057)
DNA	DNA	DNA
0-3	0-3	0
0-10	0-10	0
0-90	0-20	0-15
5-95	7-75	5-95
5-48	10-85	5-95
24-26	24-27	21-66
NP-12	NP-13	NP-31
DNA	DNA	1.5-4.5
DNA	DNA	0.1-3.0 (Swell)
2.0 ± (96 ±)	0.75 ± (36 ±)	0.5-8.2 (24-393)
DNA	DNA	c = 0-1.5 ksf (72 kN m^2), ϕ = 18°-34
2.5-7.7 (120-369)	DNA	1.7-6.7 (81-321)
DNA	136 ± (2179 ±)	121-126 (1938-2018)
DNA	6.0 ±	9.0-9.5
DNA	18 ±	7 ±

2

RANGE OF ENGINEERING AND GEOPHYSICAL PROPERTIES
JORNADA DEL MUERTO, NEW MEXICO, RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

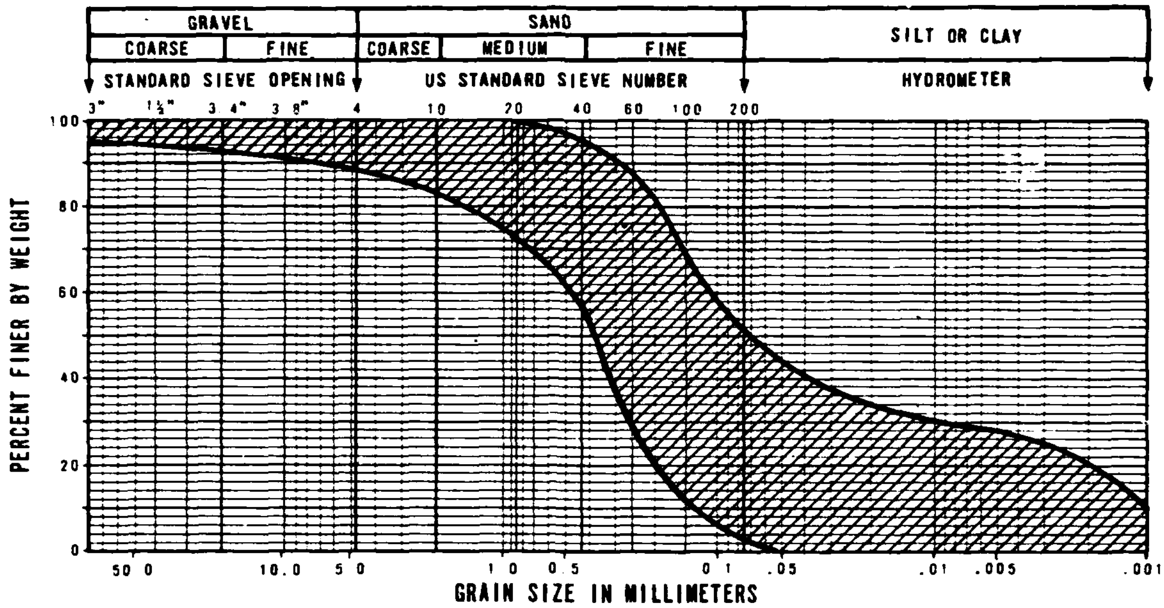
TABLE 8

FUGRO NATIONAL, INC.

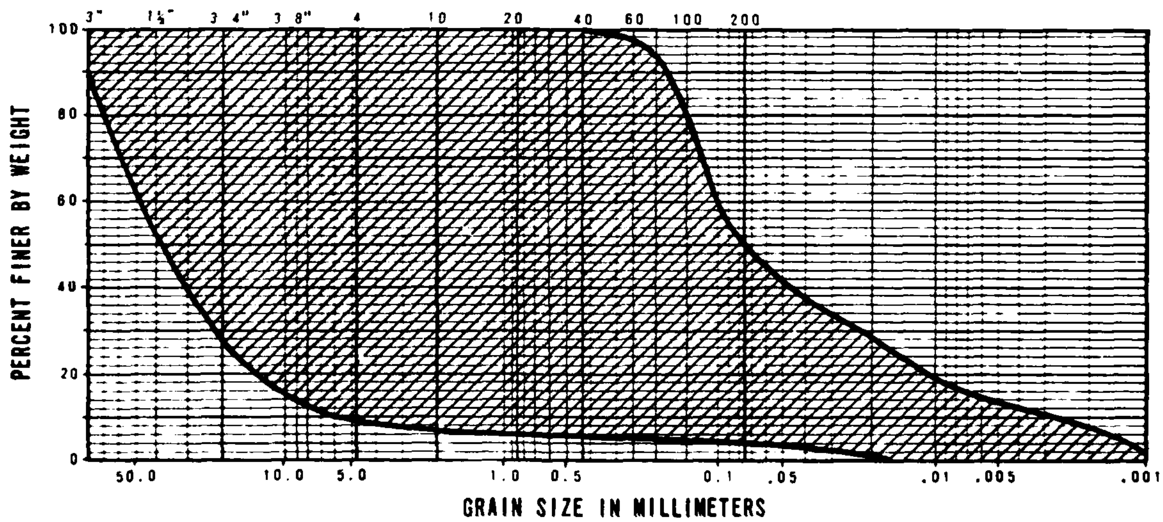
comprised of medium dense to dense silty and clayey sands with some stiff silts and clays. Older lacustrine deposits consist of stiff to very stiff silts and clays which are moderately compressible. Eolian sheet sand and intermediate alluvial fan deposits possess moderately high shear strengths; younger alluvial fan and older lacustrine deposits possess moderate shear strengths. The site soils are generally neither expansive nor collapsible. Range of the gradation of the four geologic units is shown in Figures 8 and 9.

Results of chemical tests on soil samples are shown in Table 9. The test results indicate that sulfate attack of soils on concrete will be "severe."

Representative logs of three borings and three trenches from the site are contained in Appendix B. Results of the shear strength and CBR tests performed on soil samples from the site and a summary of all the laboratory tests performed on soil samples obtained from boring JM-B-11 are also included in Appendix B.



A3s



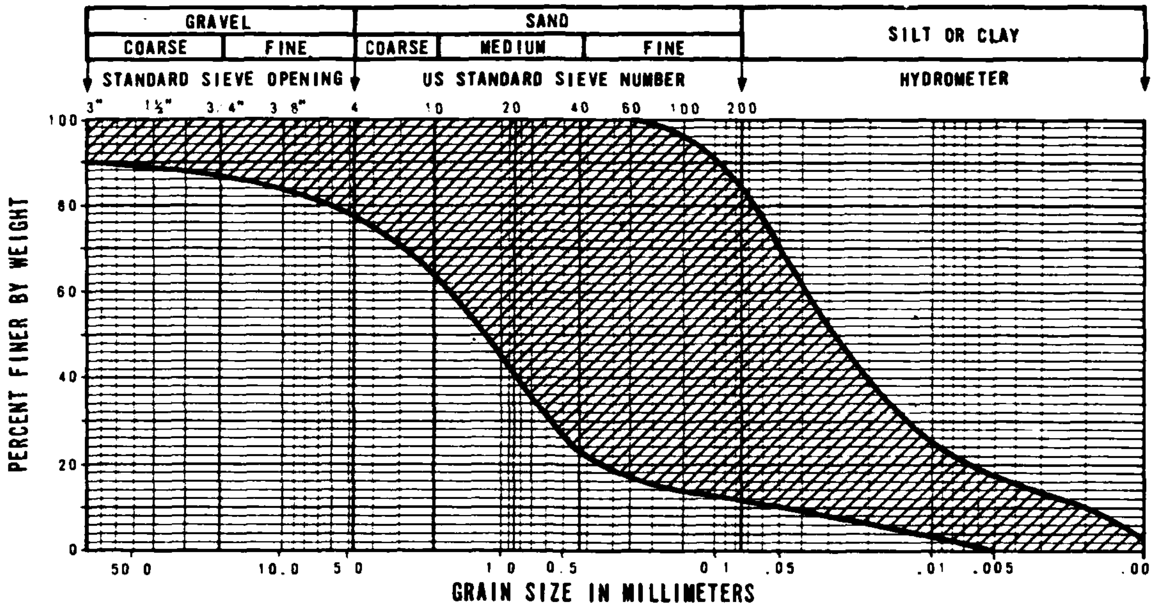
A5i

RANGE OF GRADATION OF GEOLOGIC UNITS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

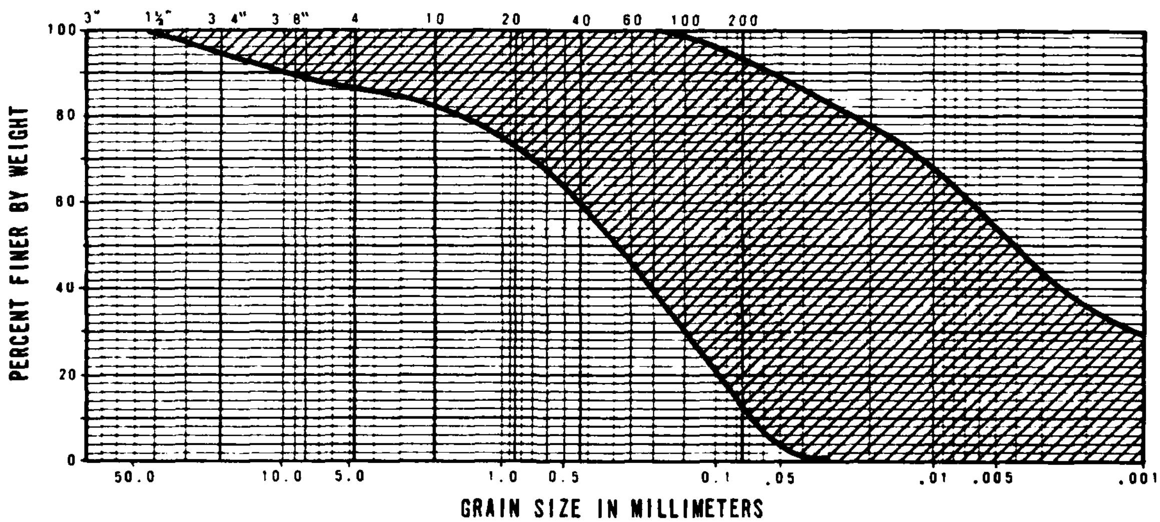
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
8

FUGRO NATIONAL, INC.



A5y



A4o

RANGE OF GRADATION OF GEOLOGIC UNITS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 9

FUGRO NATIONAL, INC.

BORING/TRENCH NO.	SAMPLE NO.	SAMPLE INTERVAL		SOIL TYPE	pH	WATER SOLUBLE				CALCIUM CARBONATE
		FEET	METERS			SODIUM	CHLORIDE	SULPHATE	CALCIUM	
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
JM-B-4	P-3	15.8-17.3	4.82-5.27	CL	7.4	345	109	9600	2900	7250
JM-B-9	P-2	10.8-11.8	3.29-3.60	ML	7.6	75	33	7940	3150	7875
JM-B-10	P-2	10.0-10.7	3.05-3.26	ML	7.4	975	195	10500	3580	8950
JM-B-13	P-2	10.0-11.8	3.05-3.60	CL	7.4	500	242	11000	3100	7750
JM-B-14	P-1	5.0-7.5	1.52-2.29	SM	8.0	185	29	377	77	192
JM-B-17	P-3	10.0-11.1	3.05-3.38	SM	7.5	61	10	9600	2920	7300
JM-T-4	B-2	3.5-6.0	1.07-1.83	ML	7.3	83	38	8340	3220	8050
JM-T-12	B-1	3.0-5.0	0.91-1.52	ML	7.4	116	43	9260	3300	8250

SUMMARY OF CHEMICAL TEST RESULTS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE 9

FUGRO NATIONAL, INC.

3.0 SAN SIMON SITE

The San Simon characteriztion site covers an area of 715 nm^2 (2452 km^2) in Graham and Cochise counties, Arizona. The site is bounded by mountain ranges on the east and west. The valley extends beyond the bounds of the site to the north and south. Major streams within the site drain toward the Gila River to the north. The site is accessible via Interstate 10 along the southern edge and via state route 666 along the western edge. A network of graded roads and four-wheel drive trails provides access within the site.

3.1 SCOPE OF INVESTIGATION

Scope of geologic, geophysical, and soils engineering field activities performed at the site and laboratory tests performed on soil samples from the site are presented in Table 10. Detailed information about the soils engineering field activities (13 borings and seven trenches) is summarized in Tables 11 and 12. Locations of all the field activities are shown in Figure 10.

3.2 SURFICIAL GEOLOGY AND TERRAIN

Alluvial fan deposits of younger and intermediate age and older lacustrine deposits are the predominant surficial geologic units within the San Simon site (Figure 10). Younger alluvial fans cover approximately 35 percent of the area, intermediate alluvial fans cover 25 percent, and older lacustrine deposits cover 30 percent. The alluvial fan deposits are typically silty sands with gravel, ranging from sandy gravels near the mountain front to sandy silts near the valley interiors. The lacustrine

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geological mapping stations	43
Shallow refraction	12
Conductivity	12

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
1	25 (8)
9	50 (15)
2	100 (30)
1	300 (91)

NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
2	10 (3)
5	12 (4)

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	135/99
Specific gravity	4
Sieve analysis	66
Hydrometer	50
Atterberg limits	37
Consolidation	4

TYPE OF TEST	NUMBER OF TESTS
Unconfined compression	9
Triaxial compression	4
Direct shear	24
Compaction	6
CBR	2
Chemical analysis	6

SCOPE OF FIELD AND LABORATORY ACTIVITIES

SAN SIMON VALLEY, ARIZONA, HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE 10

FUGRO NATIONAL, INC.

BORING NUMBER	TOTAL DEPTH FEET (METERS)	TYPE OF DRILL RIG USED	TYPE OF SAMPLES* OBTAINED
SS-B-1	302.5 (92.2)	Rotary wash	D, P
SS-B-2	72.5 (22.1)	Rotary wash	D, P
SS-B-3	50.9 (15.5)	Hollow Stem Auger	SS, D
SS-B-4	51.0 (15.5)	Hollow Stem Auger	D
SS-B-5	55.5 (16.9)	Hollow Stem Auger	D
SS-B-6	51.0 (15.5)	Hollow Stem Auger	D
SS-B-7	45.0 (13.7)	Hollow Stem Auger	D
SS-B-8	54.0 (16.5)	Rotary Wash	D
SS-B-9	48.0 (14.6)	Hollow Stem Auger	D
SS-B-10	20.0 (6.1)	Hollow Stem Auger	B, D
SS-B-11	101.5 (30.9)	Rotary Wash	D, P
SS-B-12	61.0 (18.6)	Rotary Wash	D
SS-B-13	50.0 (15.2)	Hollow Stem Auger	D

* P = Pitcher sample (undisturbed)
D = Fugro Drive sample (relatively undisturbed)
B = Bulk sample (disturbed, but representative)
SS = Split Spoon sample (disturbed, but representative)

ENGINEERING FIELD ACTIVITIES - BORINGS
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE 11

FUGRO NATIONAL, INC.

TRENCH NUMBER	TOTAL DEPTH FEET(METERS)	STABILITY OF VERTICAL EXCAVATION WALLS
SS-T-1	11.5 (3.5)	stable
SS-T-2	12.5 (3.8)	stable
SS-T-3	12.0 (3.7)	stable
SS-T-4	10.2 (3.1)	stable , some sloughing at 3.5-9.5'(1.1-2.9m)
SS-T-5	12.5 (3.8)	stable
SS-T-6	12.8 (3.9)	stable
SS-T-7	10.2 (3.1)	stable

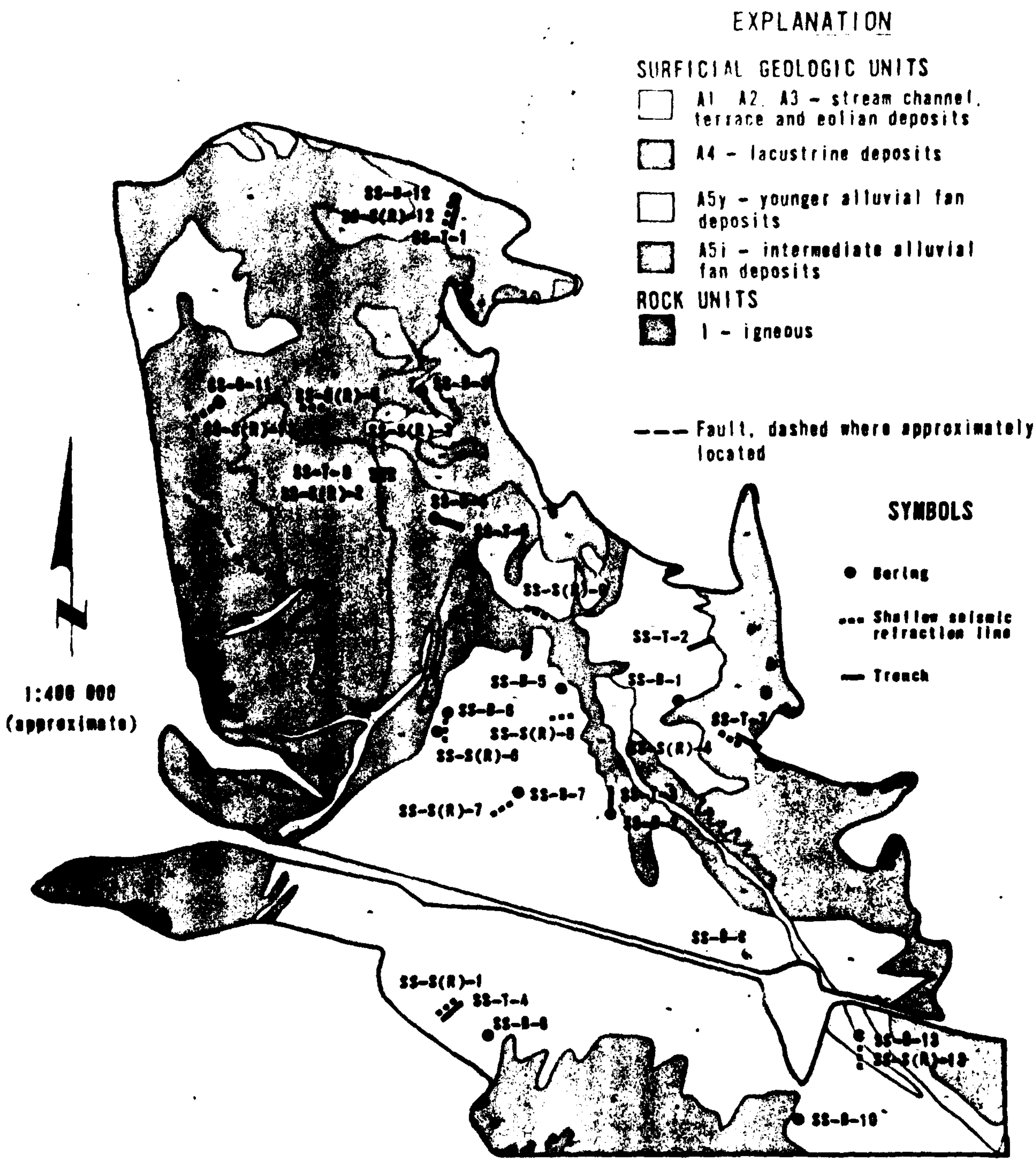
ENGINEERING FIELD ACTIVITIES - TRENCHES
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE 12

FUGRO NATIONAL, INC.

FN-TR-26c



NOTE: For detailed description of geologic units, see Table A-1.

GENERALIZED GEOLOGIC MAP AND FIELD ACTIVITY LOCATIONS
SAN SIMON, ARIZONA, HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE 10

FUGRO NATIONAL, INC.

deposits are very coarse along the periphery of the valley but are fine grained along the valley axis. These units along with the remaining surficial units are described in Table 13.

Surface slopes and depths of drainage incision vary with geologic units, both generally increasing with proximity to the mountain fronts (Table 13). Maximum observed surface slope was three percent with typical slopes of less than one percent. Drainages are typically shallow (less than 10 ft; 3 m) with gently sloping sides except near mountainous areas and in the older lacustrine material.

3.3 SUBSURFACE CONDITIONS

3.3.1 Soil Profiles

Silty and clayey sands and gravels are the predominant surficial soils which are typically underlain by several hundred feet of clay and silty clay deposits throughout much of the valley. The general subsurface conditions are illustrated by two representative soil profiles shown in Figures 11 and 12. The percentage of fines generally increases towards the valley basin. Cobbles and boulders are encountered only in the close proximity of mountain fronts.

3.3.2 Depth to Shallow (<150 ft; <46 m) Rock and Water

Figure 13 shows portions of the site in which rock and water are estimated to be encountered within a depth of 150 feet (46m) below ground surface. Shallow rock exists in approximately five percent of the site based on boring, seismic, gravity, geologic, topographic, and other available data.

Quaternary	Unknown	Sand and Silt	SM, ML	50 (172)	7
Quaternary-Tertiary	Unknown	Clay, Silt, Sand, Gravel with cobbles and boulders	CL, ML, SP-SW, GP-GW	215 (737)	30
Quaternary	Unknown	Silty sand, Sand with Gravel	SM, SP	243 (833)	35
Quaternary	Unknown	Silty Sand with Gravel	SM	179 (614)	25

AL EXTENT (SITE)		PROPERTIES OF SURFACE MATERIALS					SURFACE MORPHOLOGY		NOTES
(km^2)	PERCENT	GRADATION	CEMENTATION	MAXIMUM GRAIN SIZE	PAVEMENT/ PATINA	STAGE OF CALICHE (c)	SLOPE (PERCENT)	DRAINAGE DEPTHS FEET(METERS)	
(48)	2	Poor-Moderately well	Weak-Moderate	Gravel	None/None	I-II	< 1	12-15 (4-5)	(d)
(24)	1	Poor	Strong	Boulder	None/None	II-III	< 1	0-5 (0-1.5)	
(172)	7	Poor	None-Weak	Sand	None/None	None	≤ 1	0-5 (0-1.5)	
(737)	30	Poor	Weak-Strong	Cobble	None/None	I-III	1-2	10-15 (3-5)	(e)
(833)	35	Poor-Moderately well	None-Weak	Gravel	None/None	None-I	≤ 1	0-2 (0-0.6)	(f)
(614)	25	Well	Weak-Moderate	Boulder	Poor/Poor	None-III	1-3	0-6 (0-2)	(f)

2

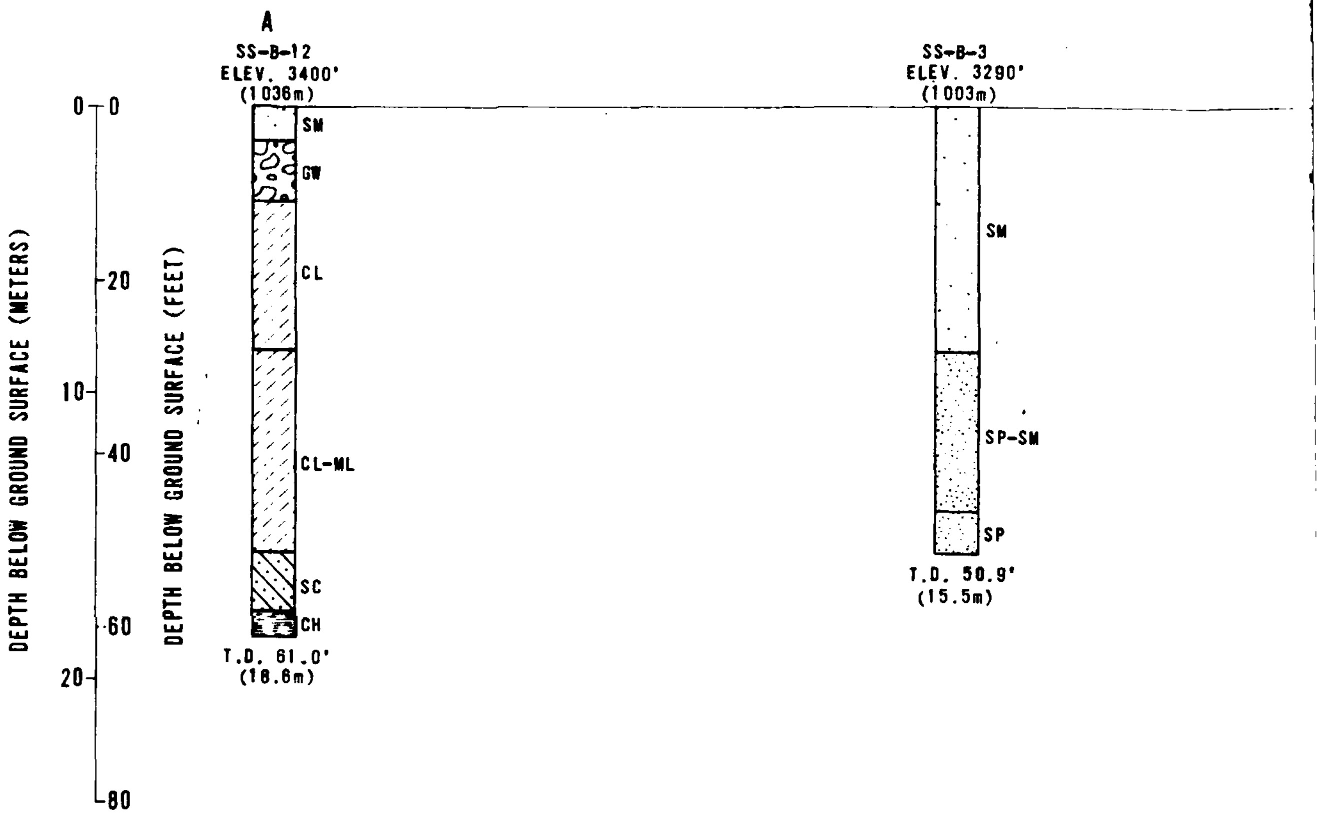
DESCRIPTION OF SURFICIAL GEOLOGIC UNITS

SAN SIMON VALLEY, ARIZONA, HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE 13

FUGRO NATIONAL, INC.

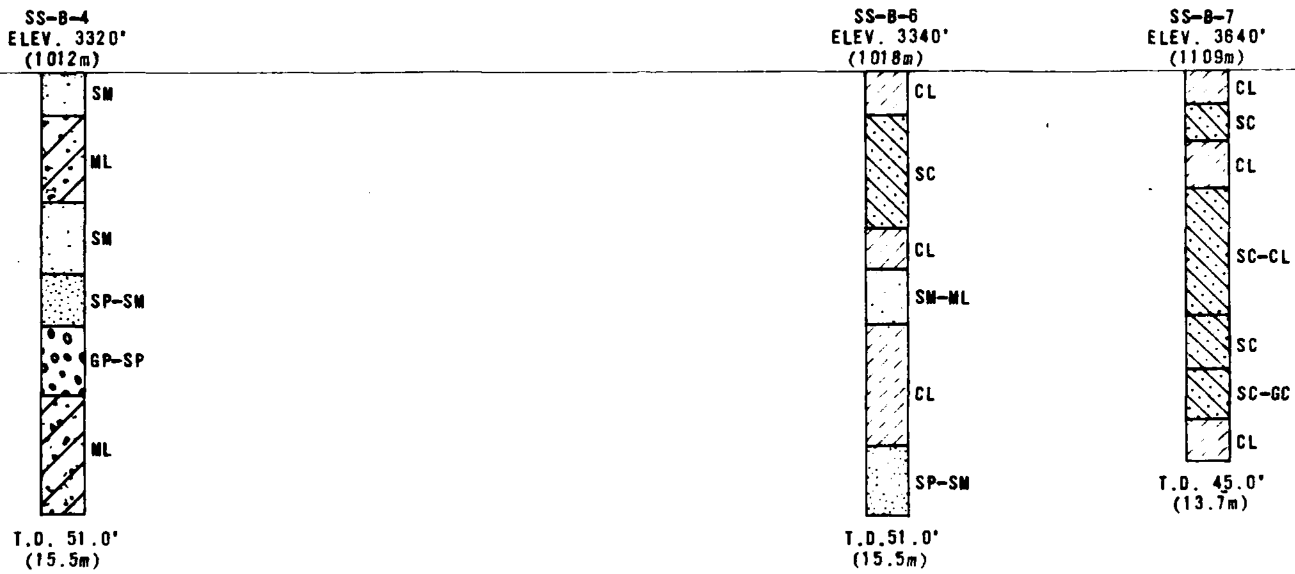


NOTES: 1. Ground surface elevations

2. T.D.=Total Depth

3. Soil types shown adjacent

(USCS) and are explained

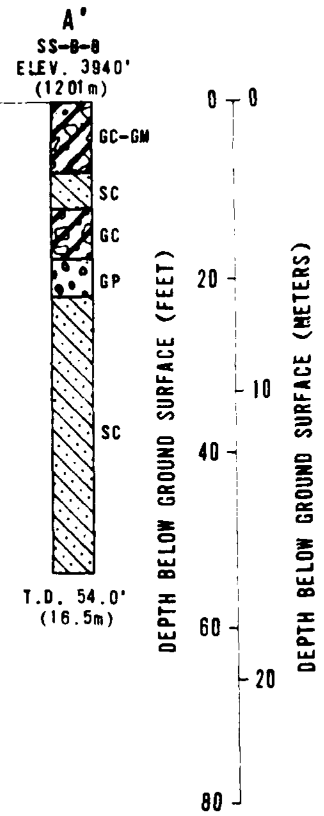


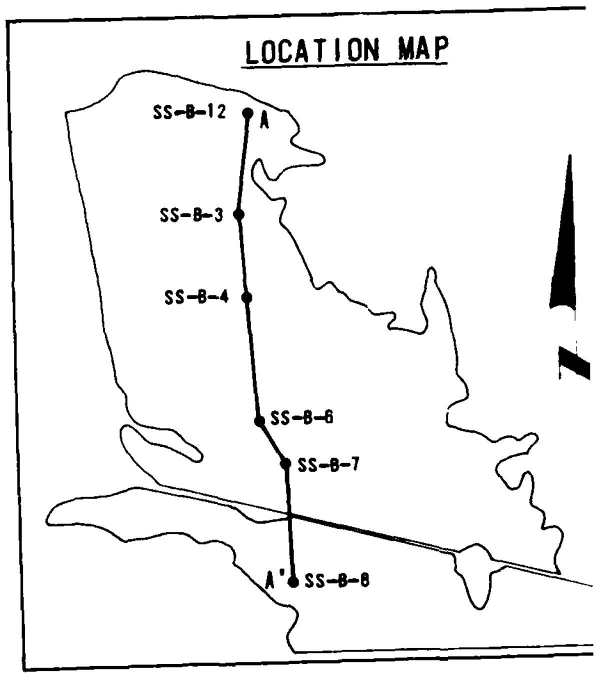
STATUTE MILES

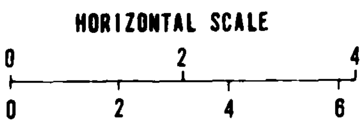
tions shown at locations of borings are approximate

KILOMETERS

acent to soil column are based on Unified Soil Classification System
ained in the appendix





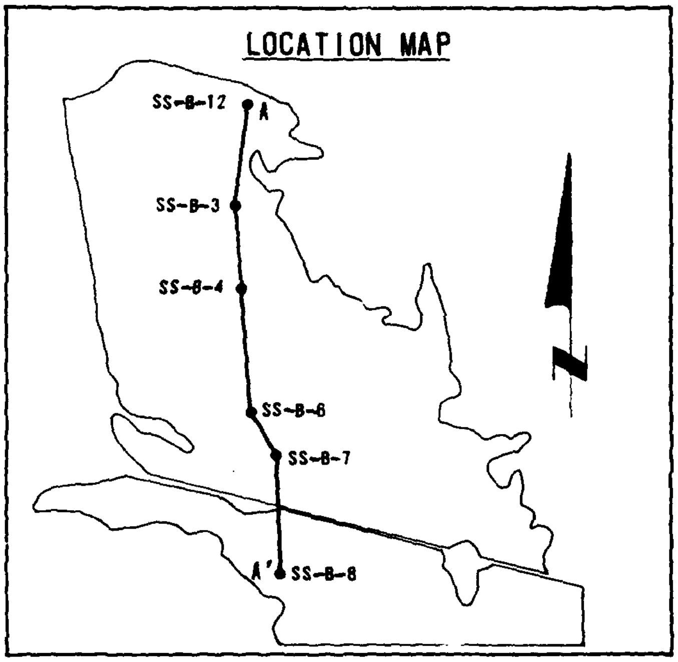


SOIL PROFIL
SAN SIMON, A
HIGHLANDS

MX SITING INVESTIGATI
DEPARTMENT OF THE AIR FORCE

FUGRO NATIO

3



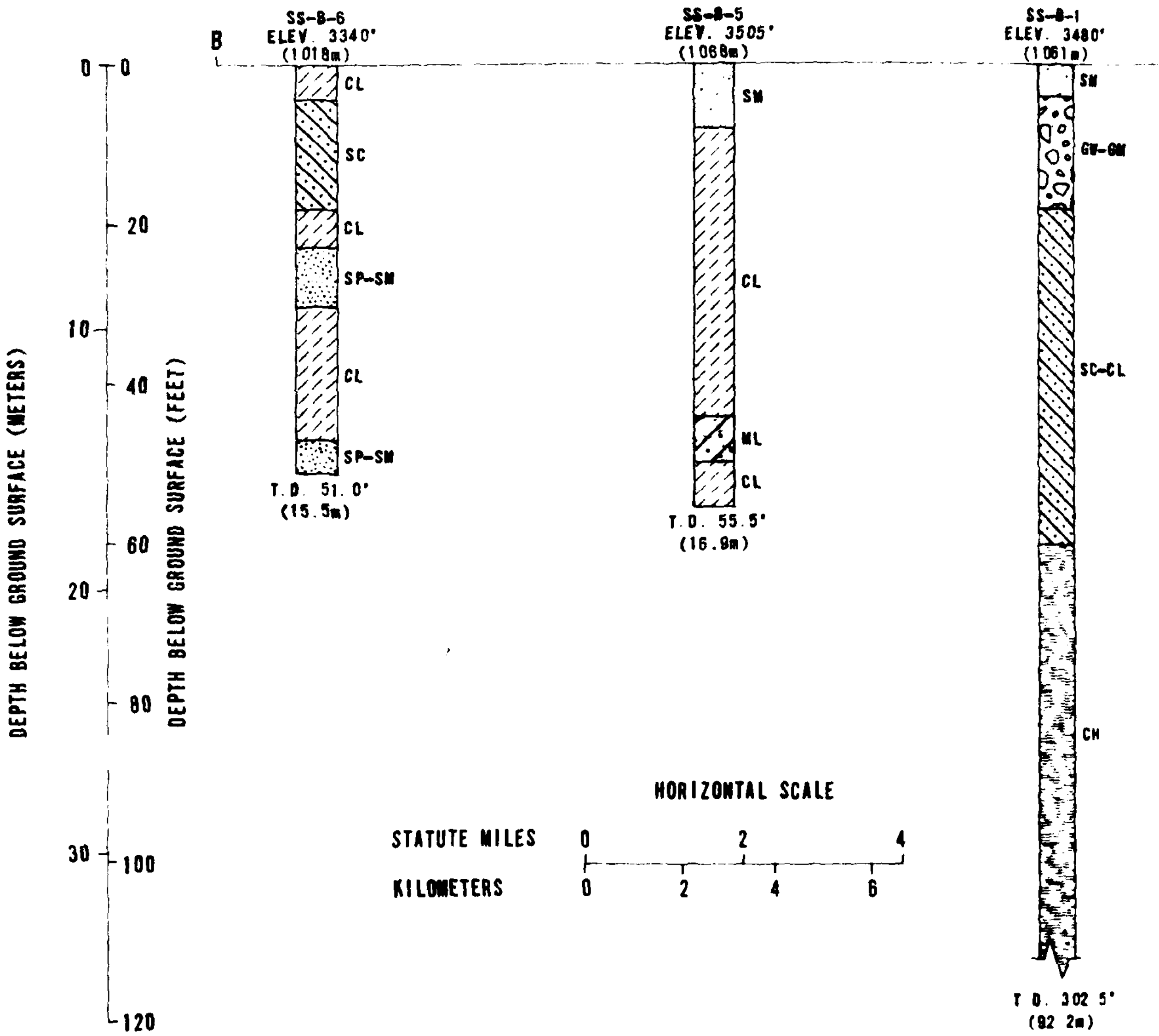
SOIL PROFILE AA'
SAN SIMON, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE 11

FUGRO NATIONAL, INC.

4

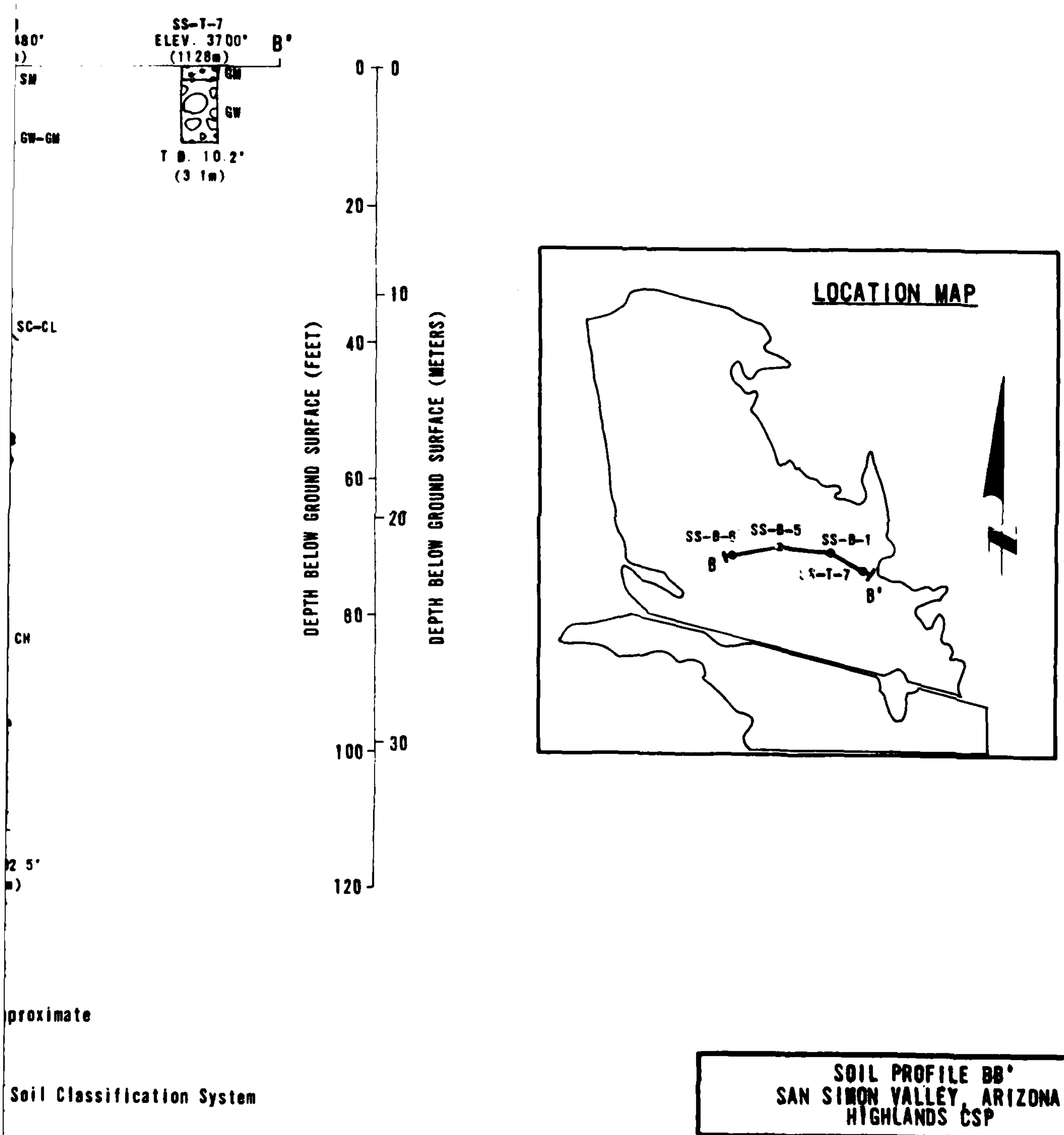


NOTES: 1. Ground surface elevations shown at locations of borings are approximate

2. T.D. = Total Depth

3. Soil types shown adjacent to soil column are based on Unified Soil Clas

(USCS) and are explained in the appendix



proximate

Soil Classification System

2

SOIL PROFILE BB'
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMSO	FIGURE 12

FUGRO NATIONAL, INC.

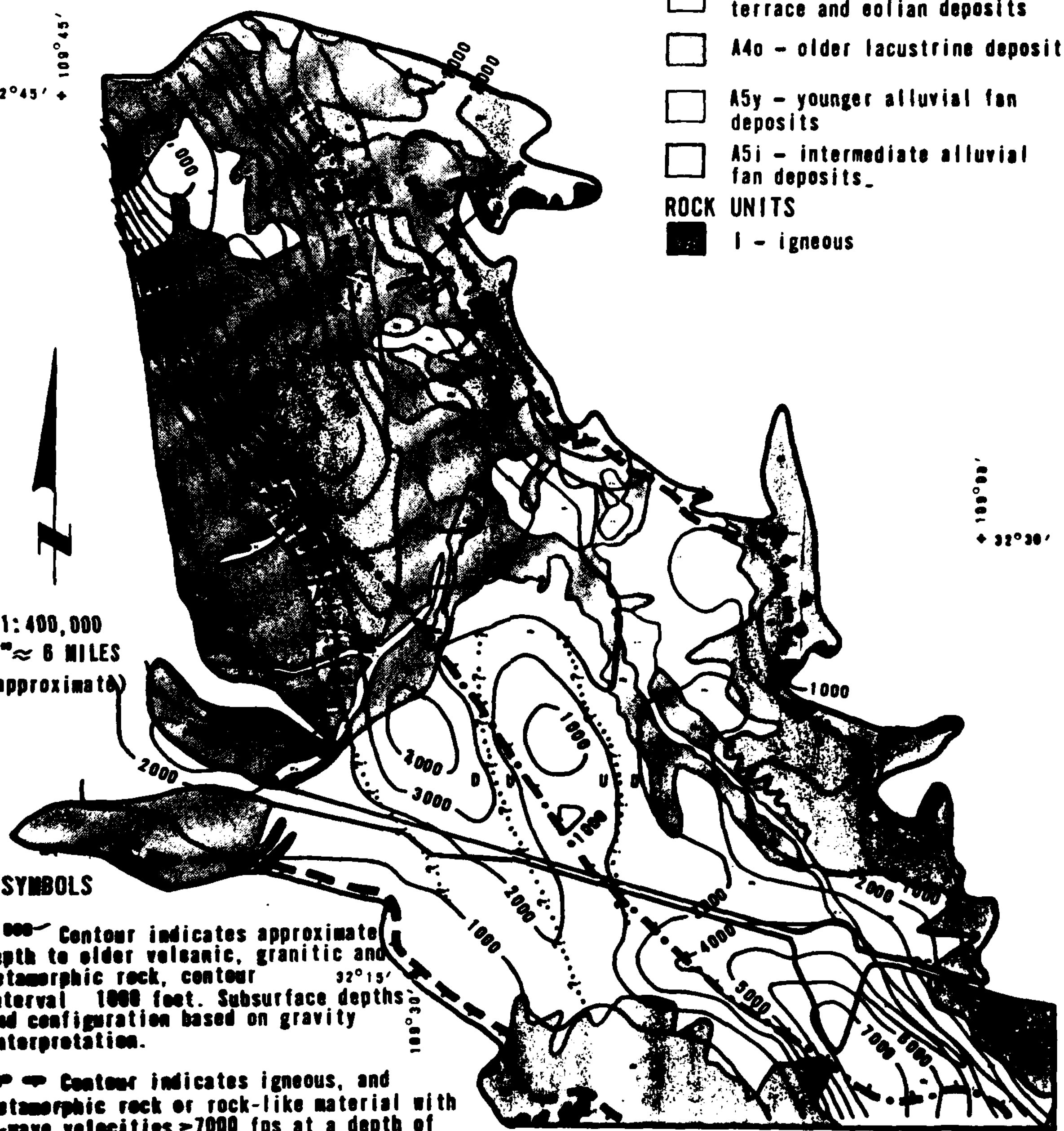
EXPLANATION

SURFICIAL GEOLOGIC UNITS

- A1o, A2, A3 – older fluvial, terrace and eolian deposits
- A4o – older lacustrine deposits
- A5y – younger alluvial fan deposits
- A5i – intermediate alluvial fan deposits

ROCK UNITS

- I – igneous



SYMBOLS

—1000— Contour indicates approximate depth to older volcanic, granitic and metamorphic rock, contour interval 1000 feet. Subsurface depths and configuration based on gravity interpretation.

Contour indicates igneous, and metamorphic rock or rock-like material with p-wave velocities >7000 fps at a depth of approximately 150 feet (hachured side of line indicates rock at <150 feet). Contour location based on geologic mapping and geophysical interpretation.

Contour indicates ground water at a depth of approximately 150 feet (hachured side of line indicates water at <150 feet, queried where data insufficient).

FAULTS

– – – – Dashed where approximately located

……? Dotted where buried, queried where inferred (interpreted from gravity data)

NOTE: For detailed description of geologic units, see Table A-1.

GENERALIZED GEOLOGIC MAP AND SELECTED SUBSURFACE FEATURES SAN SIMON, ARIZONA, HIGHLANDS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMSO	FIGURE 13

FUGRO NATIONAL, INC.

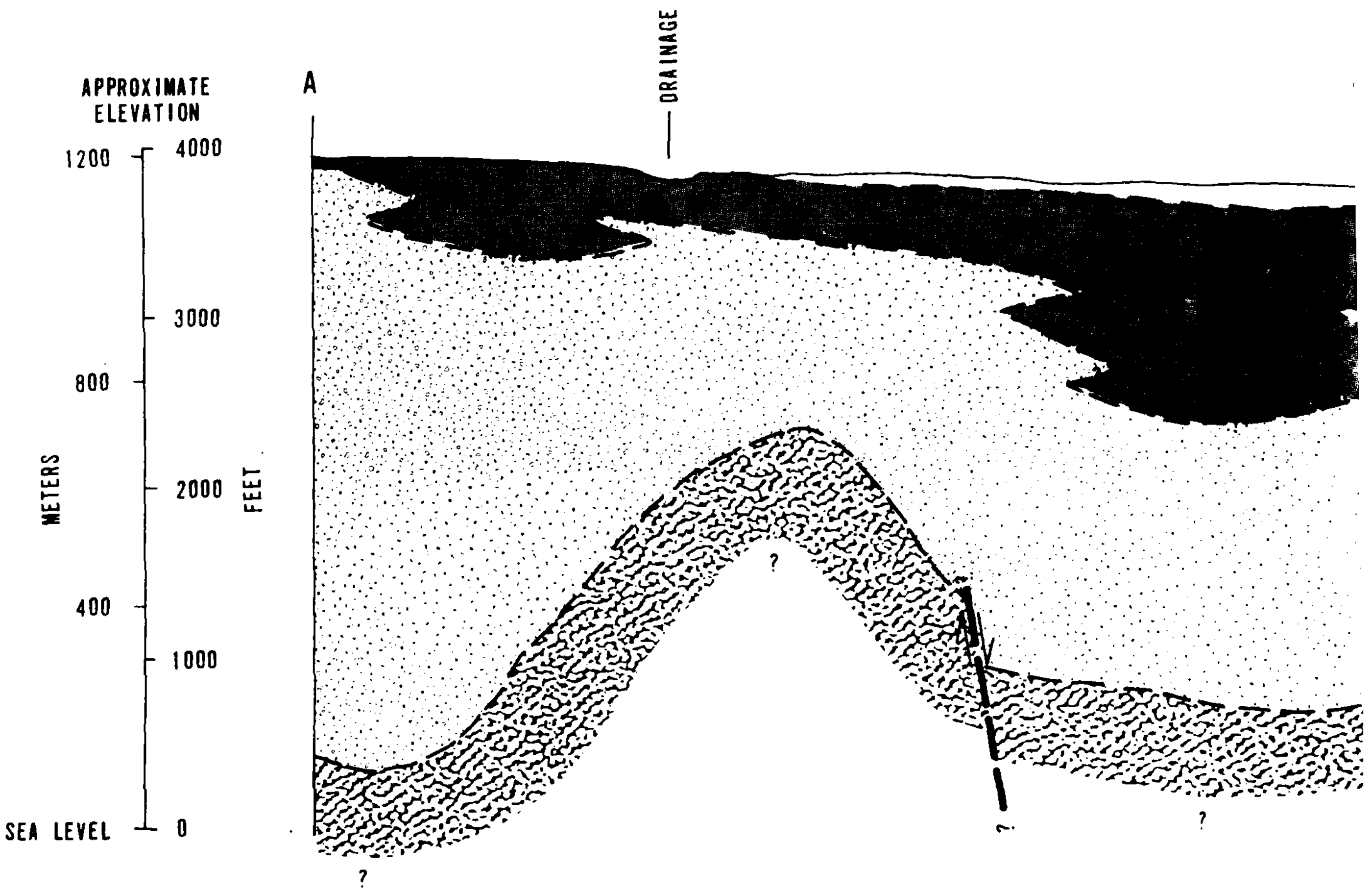
Ground water occurs at depths of less than 150 feet (46 m) over approximately 45 percent of the San Simon site. However, extrapolation of known data indicates shallow ground water may be encountered over an additional 20 percent of the site.

3.3.3 Basin Configuration

Results of the gravity survey were used to define the basin configuration (Figure 13). The basin appears to be a deep trough which has been uplifted and faulted in the central part of the valley (Figure 14). The trough is approximately [illegible] feet deep (3050m) in the northern portion and 7000 feet deep (2130 m) in the southern portion. Steep gradients on both sides of the valley indicate that the basin is fault controlled. A section through the central portion of the valley perpendicular to the valley axis shows a horst-graben structure with a maximum depth of about 4500 feet (1377 m) in the graben. This structure is located in the uplifted area in the south-central portion of the trough. The subsurface basin configuration is illustrated in Figure 14.

3.4 GEOPHYSICAL PROPERTIES

Results of the shallow seismic refraction and electrical conductivity surveys are shown in Tables 14 and 15. Observed seismic velocities ranged from 1000 to 6330 fps (305 mps to 1930 mps). Surface layer velocities ranged from 1000 to 1440 fps (305 mps to 439 mps). This layer is 25 feet (8 m) thick, although it is typically about 5 feet (1.5 m) thick at other locations. Low velocity (<2000 fps; 610 mps) layers at SS-S-6 and 9 extend to



EXPLANATION

Undifferentiated basin-fill deposits
Predominantly alluvial (A5) deposits, with eolian (
and stream terrace (A2) deposits

Older lacustrine (A4o) deposits

Undifferentiated older basin-fill deposits

Undifferentiated igneous and metamorphic rock

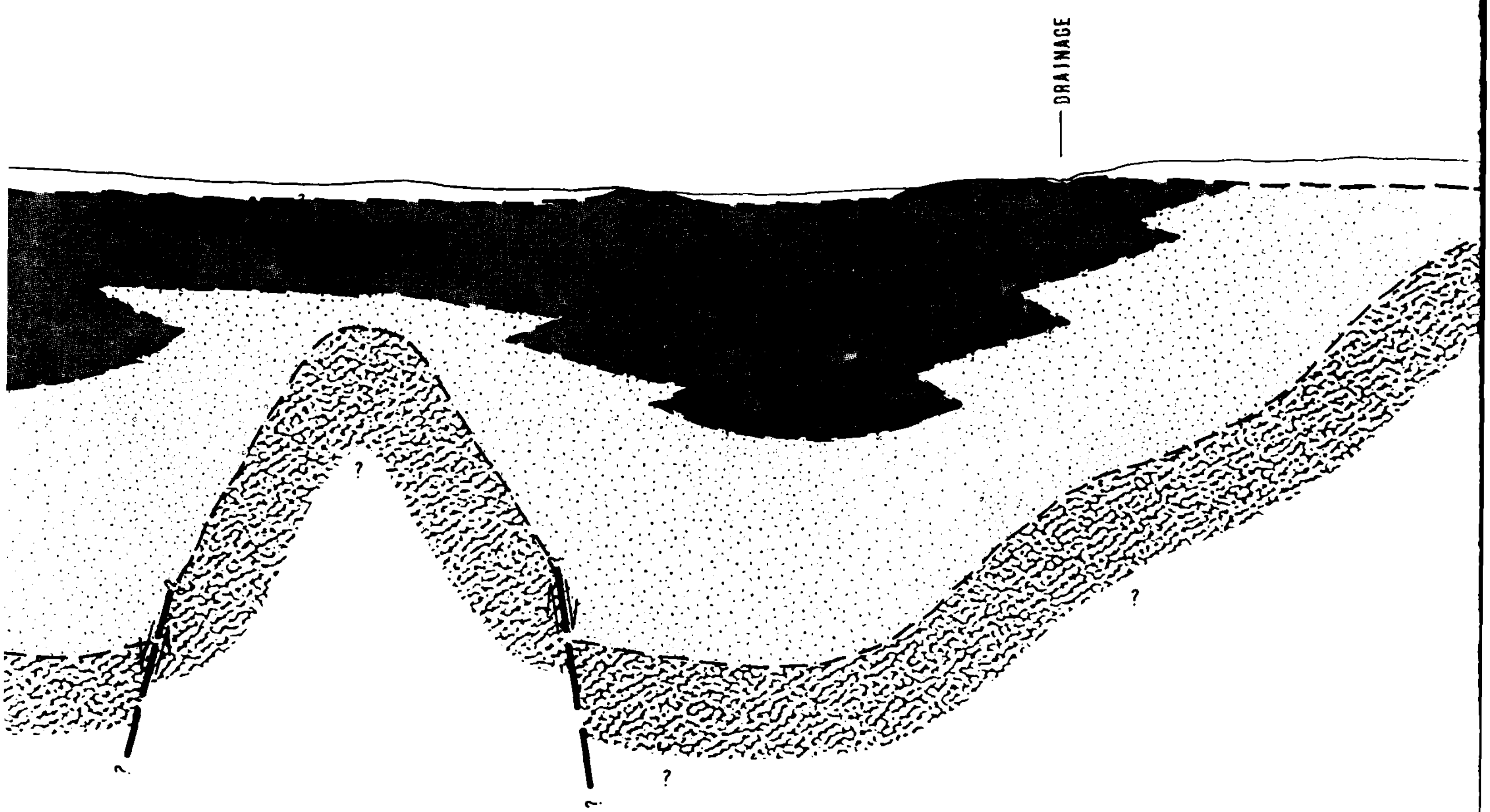
— — —?— Approximate geologic contact, queried where inferred

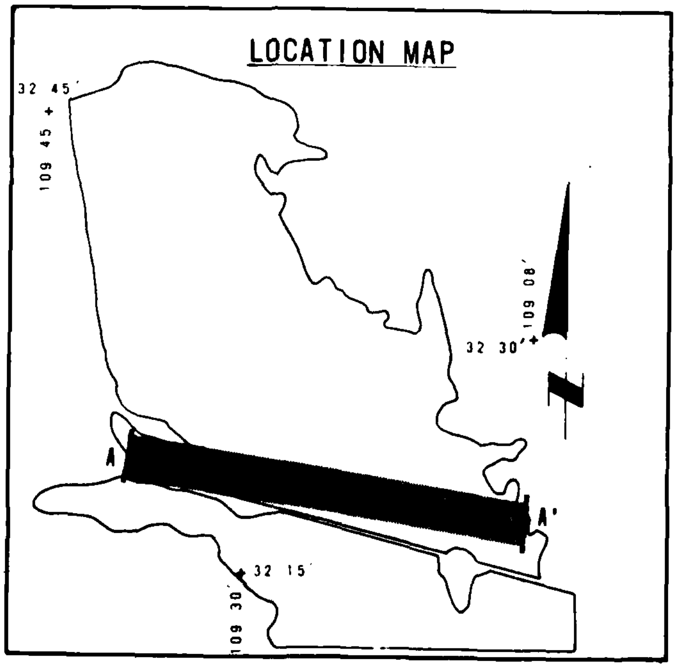
Fault, dashed where inferred from gravity interpretati

NOTES:

1 The cross section is generally representative of subsurface conditions within the band shown on the location map. Due to the limited density of available data and the sparseness of newly acquired data, the subsurface conditions are highly interpretive.

2. For a detailed description of geologic units see Table A-1.





Hori
Vert
Vert

eolian (A3) and minor older fluvial (Alo)

STATUTE MILES 0

KILOMETERS 0

k

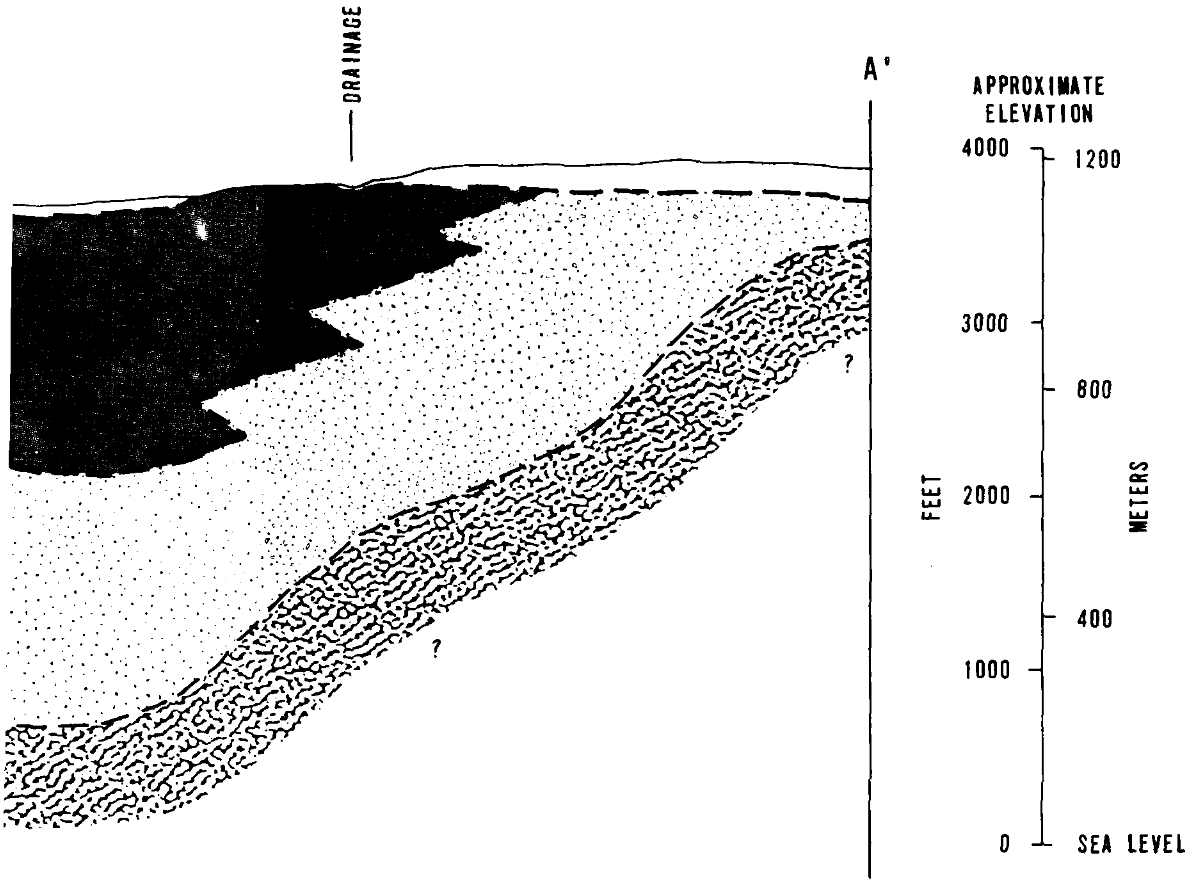
inferred

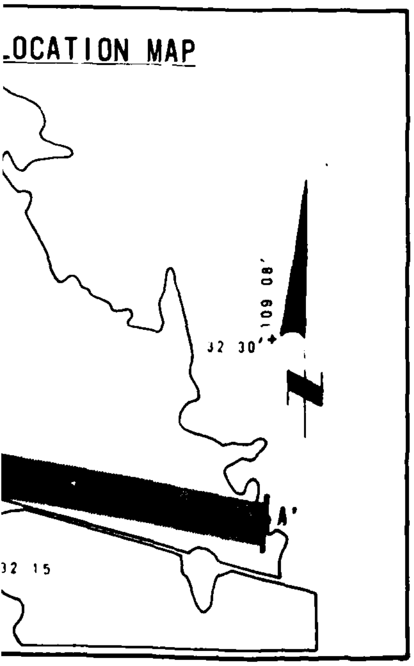
terpretation

2

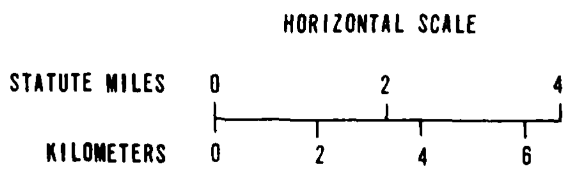
GENERA

DEPARTME





Horizontal Scale: 1" ≈ 2 Miles (3 km)
Vertical Scale: 1" = 1000' (305 m)
Vertical Exaggeration: 10.5X



GENERALIZED GEOLOGIC CROSS SECTION SAN SIMON VALLEY, ARIZONA HIGHLANDS CSP	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE SAMSO	FIGURE 14

FUGRO NATIONAL, INC.

SEISMIC LINE NO.	VELOCITY DISTRIBUTION FPS (MPS)				DEEPER REFRACTORS DEPTH / VELOCITY	* ROCK EXCLUSION DEPTH TO 7000 FPS (2134 MPS)
SS-S-1	1340 (410)	3990 (1220)			-	115 (35)
SS-S-2	1100 (340)	2280 (690)	3880 (1180)		-	152 (46)
SS-S-3	1050 (320)	1500 (460)	2180 (660)	6330 (1930)	-	96 (29)
SS-S-4	2000 (610)	4000 (1220)			-	138 (42)
SS-S-5	1400 (430)	3100 (940)			-	146 (45)
SS-S-6	1440 (430)	2260 (690)	3050 (930)		-	155 (47)
SS-S-7	1270 (390)	2290 (700)	3690 (1120)		-	166 (51)
SS-S-8	1300 (400)	2420 (740)	4750 (1450)		-	170 (52)
SS-S-9	1140 (350)	1690 (520)	5540 (1690)		-	107 (33)
SS-S-11	1320 (400)	2300 (700)	2920 (890)		-	164 (50)
SS-S-12	a	2550 (780)	5480 (1670)		-	158 (48)
SS-S-13	1150 (350)	1690 (520)	4680 (1430)		-	78 (24)
					FT (M) / FPS (MPS)	FEET (M)

a 1000 (300)

METERS 0 5 10 15 20 25 30 35 40 45

FEET 0 5 10 20 30 40 50 60 70 80 90 1^0 110 120 130 140 150

DEPTH INTERVAL

* If no refracting interface or layer with a velocity greater than 7000 fps (rock/rock-like material) was detected, a rock exclusion depth calculation was performed to determine the minimum depth at which rock could occur.

SHALLOW SEISMIC REFRACTION RESULTS
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE 14

FUGRO NATIONAL, INC.

ACTIVITY LOCATION*	AVERAGE CONDUCTIVITY (mhos m)**
R-1	0.021
R-2	0.014
R-3	0.016
R-4	0.014
R-5	0.038
R-6	0.032
R-7	0.047
R-8	0.019
R-9	0.118
R-11	0.011
R-12	0.129
R-13	0.074

*Resistivity was determined using a Schlumberger Array at each location where a seismic refraction survey was conducted.

**Conductivity is the inverse of resistivity. Numbers presented are the average of values determined to a depth of 50 feet, computed as follows:

$$\text{Average Conductivity} = (C_1 t_1 + C_2 t_2 + \ldots + C_n t_n)\ 50\ \text{feet}$$

Where

Average Conductivity = mhos/m

C_1 through C_n = Conductivity (mhos/m) of layers 1 through n

t_1 through t_n = Thickness (feet) of layers 1 through n to 50 feet

CONDUCTIVITY SURVEY RESULTS
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE 15

FUGRO NATIONAL, INC.

depths of 40 feet (12 m). Average conductivities for the upper 50 feet (15 m) of soil are between 0.011 and 0.129 mhos/m.

3.5 ENGINEERING PROPERTIES

Laboratory tests were performed to determine the engineering properties of soil samples obtained from the various geologic units. The testing program consisted of classification, consolidation, shear strength, compaction, CBR and chemical. The range of engineering and geophysical properties of predominant geologic units is presented in Table 16.

Younger and intermediate alluvial fan deposits could not be differentiated at depth, and they were combined into one unit (A5) due to their similar grain size and engineering properties. These deposits consist predominantly of dense to very dense, silty and clayey sands, and gravels which are only slightly compressible and have high shear strengths.

Older lacustrine deposits were generally encountered at depths below alluvial fan deposits. These deposits are predominantly stiff to very stiff clays and silty clays near the valley interiors and coarse sandy gravels along the periphery. Clays and silty clays are expansive when saturated, only slighty compressible and have high shear strengths. Gravels are generally coarse to very coarse and mixed with cobbles and boulders which are relatively incompressible and have very high shear strengths.

The gradation ranges of the geologic units are shown in Figure 15. Table 17 shows the results of chemical tests on

ENGINEERING AND GEOPHYSICAL PROPERTIES	Younger and intermediate alluvial fan deposits (A5i and A5y)	Older lacustrine depos
UNIFIED SOIL CLASSIFICATION SYMBOL(S)	SM, SC, GM, GC, GP, CL	CL, CH, ML, SW
GENERAL PROPERTIES		
DRY DENSITY pcf(kg m^3)	90-122 (1442-1954)	85-117 (1362-18
MOISTURE CONTENT (%)	2-28	2-30
DEGREE OF SATURATION (%)	25-85	14-90
SPECIFIC GRAVITY	2.63-2.70	2 63-2 68
DEGREE OF CEMENTATION	None to moderate	Weak to stron
COMPRESSIONAL WAVE VELOCITIES fps(mps)	1000-4680 (305-1426)	1050-2920 (320-8
ELECTRICAL CONDUCTIVITY (mhos m)	DNA	.005 - .191
GRAIN SIZE DISTRIBUTION (%)		
BOULDERS >12 inches(30cm)	0-10	0
COBBLES 3 to 12 inches(8to 30cm)	0-25	0-5
GRAVEL	0-55	0-20
SAND	0-90	0-88
SILT AND CLAY	10-97	0-98
PLASTICITY DATA		
LIQUID LIMIT	19-72	26-84
PLASTICITY INDEX	NP-44	NP-60
COMPRESSIBILITY DATA		
COMPRESSION AT 4 ksf(192kN/m^2) (%)	0.8-2.3	0.5-1.6
SWELL OR COLLAPSE UPON SATURATION (%)	0.2-1.4(Swell)	0.3-1.2 (S
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION ksf(kN/m^2)	2.0-6.9 (96-330)	3.6-34.4 (172-164
CD TRIAXIAL COMPRESSION	DNA	c =1-3 ksf(48-144 kN m^2)
DIRECT SHEAR ksf(kN/m^2)	0.4-5.7 (19-273)	0.4-3.7 (19-17
COMPACTION AND CBR DATA		
MAXIMUM DRY DENSITY pcf(kg m^3)	118-135 (1890-2162)	115-126 (1842-201
OPTIMUM MOISTURE CONTENT (%)	9.8-12.5	10.5-15.8
CBR AT 90% RELATIVE COMPACTION	20-30	6-9

DNA=DATA NOT AVAILABLE (INSUFFICIENT DATA OR TESTS NOT PERFORMED)

GEOLOGIC UNITS	
acustrine deposits (A4o)	
CL, CH, ML, SW, SP	
85-117 (1362-1874)	
2-30	
14-90	
2.63-2.68	
Weak to strong	
050-2920 (320-890)	
.005 - .191	
0	
0-5	
0-20	
0-88	
0-98	
26-84	
NP-60	
0.5-1.6	
0.3-1.2 (Swell)	
6-34.4 (172-1647)	
18-144 kN m 2), ϕ = 12°-25°	
0.4-3.7 (19-177)	
5-126 (1842-2018)	
10.5-15.8	
6-9	

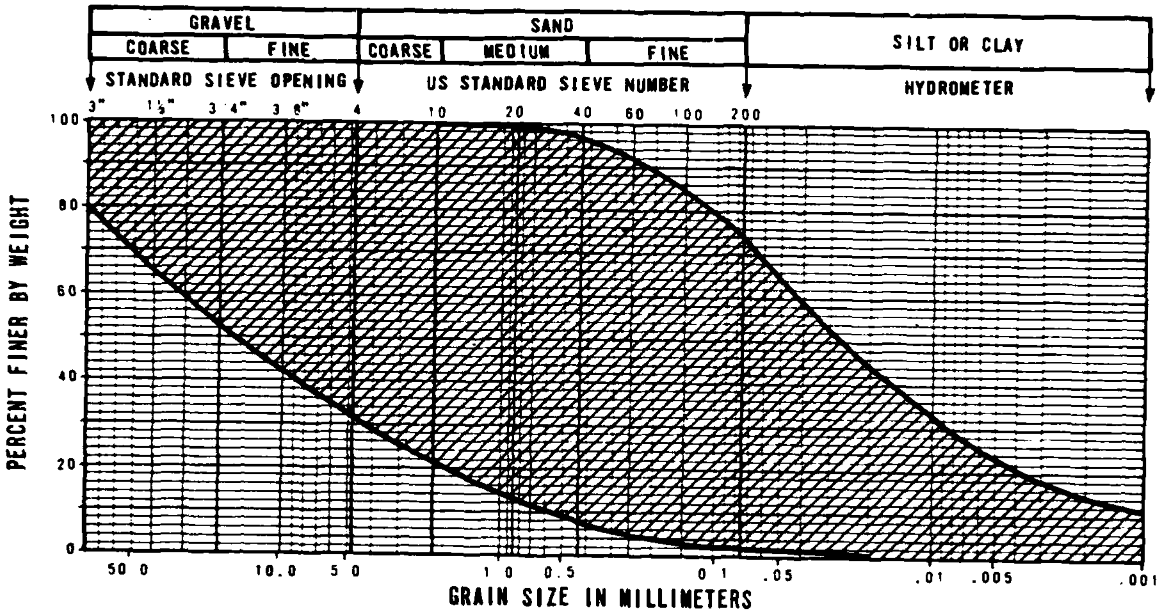
2

RANGE OF ENGINEERING
AND GEOPHYSICAL PROPERTIES
SAN SIMON VALLEY, ARIZONA, HIGHLANDS CSP

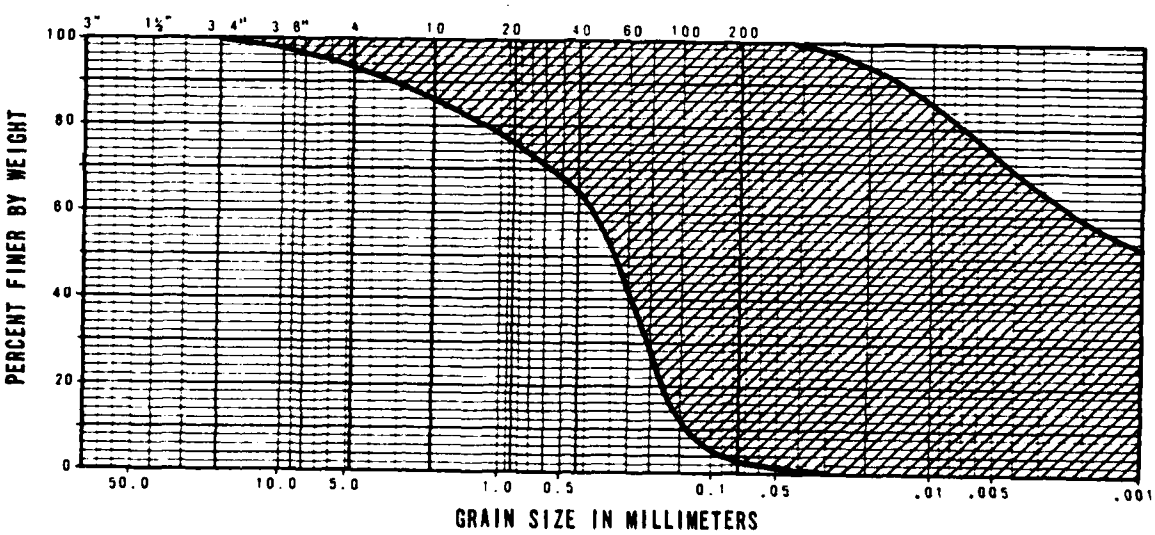
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE
16

FUGRO NATIONAL, INC.



A5



A4o

RANGE OF GRADATION OF GEOLOGIC UNITS
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMSO	FIGURE 15

FUGRO NATIONAL, INC.

BORING / TRENCH NO.	SAMPLE NO.	SAMPLE INTERVAL FEET	SAMPLE INTERVAL METERS	SOIL TYPE	pH	WATER SOLUBLE SODIUM mg/kg	WATER SOLUBLE CHLORIDE mg/kg	WATER SOLUBLE SULPHATE mg/kg	WATER SOLUBLE CALCIUM mg/kg	CALCIUM CARBONATE mg/kg
SS-B-1	P-4	20.0-20.7	6.10-6.31	CH-MH	7.9	1440	29	820	1740	1510
SS-B-4	D-5	20.0-20.5	6.10-6.25	ML	8.4	890	670	1020	320	473
SS-B-9	D-5	20.0-20.5	6.10-6.25	SM	7.7	1420	2670	920	530	1950
SS-T-1	B-3	10.0-11.5	3.05-3.50	CL-ML	7.8	890	230	560	60	180
SS-T-4	B-1	2.5-4.5	0.76-1.37	SM	6.3	470	19	370	119	476
SS-T-6	B-2	10.0-12.5	3.05-3.81	SP	7.2	540	200	640	75	227

SUMMARY OF CHEMICAL TEST RESULTS
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE 17

FUGRO NATIONAL, INC.

soil samples and they indicate that sulfate attack potential of soil on concrete is generally "negligible."

Logs of three representative borings and trenches are shown in Appendix C. Results of shear strength and CBR tests performed on soil samples from the site and a summary of all the laboratory tests performed on soil samples from boring SS-B-1 are also included in Appendix C.

4.0 DISCUSSION

4.1 JORNADA DEL MUERTO SITE

Based on regional geologic information, geotechnical conditions of the Jornada Del Muerto site are generally representative of approximately 95 percent of the Rio Grande CSP and are summarized below:

- o The eolian sheet sand, younger alluvial fan deposits, and intermediate alluvial fan deposits are the predominant surficial geologic units. (Eolian sheet sand is the most dominant).
- o Older lacustrine material is predominant within the construction zone (150 ft; 46 m).
- o The site area is generally a structural basin bounded by a potentially active fault on the east.
- o The terrain slopes gently towards closed central basin areas.

4.2 SAN SIMON SITE

Based on regional geologic information, geotechnical conditions of the San Simon site are generally representative of approximately 40 percent of the Highlands CSP and are summarized below.

- o The younger alluvial fan deposits, intermediate alluvial fan deposits and older lacustrine deposits are the predominant surficial geologic units (the younger alluvial fan deposits are the most dominant).
- o The site area is generally a down-dropped structural block (graben) bounded by potentially active faults.
- o The terrain slopes gently towards open central valleys.

5.0 CONSTRUCTION CONSIDERATIONS

In this section geotechnical factors and conditions applicable to construction of the MX system are discussed. The three basing mode concepts presently considered are vertical shelter, in-line hybrid trench, and horizontal shelter. The important geotechnical factors for a vertical shelter are primary,secondary and interconnecting roads, excavation of shelters, and drainage crossings. For the in-line hybrid trench, important geotechnical factors are excavation and backfill, roads (primary, secondary, and temporary), drainage crossings, and aggregates for roads and concrete. For the horizontal shelter, roads and drainage crossings are the important geotechnical factors. A summary of the applicable geotechnical factors is presented in the following paragraphs:

- o Terrain - Surficial slopes are typically less than one percent, requiring little preconstruction grading for roads and trenches. Depths of drainage incision are generally less than ten feet (3 m) minimizing the need for major drainage structures for roads and trenches. However, in the northeastern portion of San Simon Site depths of drainage incision are ten feet (3 m) or greater requiring major drainage structures.

- o Roads - A good network of paved and unpaved roads exists at the Jornada Site. However, no regular network of paved or unpaved roads exists at the San Simon site. Therefore, a network of new roads will be required.

Most of the surficial soils at both the sites have good to excellent subgrade characteristics when compacted, resulting in economical road sections. In approximately 25 percent of the Jornada site the surficial soils do not have good support characteristics for use as road subgrade, thus requiring thicker, more costly road sections.

- Excavation - Most of the subsurface soils are dense, weakly to moderately cemented, and possess moderately high shear strength. Except in areas close to mountain fronts, compressional wave velocities range from 1000 to 6000 fps (305 to 1830 mps) up to depths of 150 feet (46 m) below ground surface, indicating good excavatability. The soils are suitable for excavation of: vertical shelters by augers, continuous trenches (cast-in-place trench construction) by an MX trencher, and horizontal shelters using conventional equipment. In approximately 20 percent of the Jornada site, vertical walls of excavations for trenches and vertical shelters may be unstable, requiring additional expense for other excavation techniques. Approximately five percent of the area of the two sites has zones of concentrated cobbles and boulders where an MX trencher will not be able to excavate a trench suitable for cast-in-place construction.

  Depth to rock is greater than 150 feet (46 m) over a major portion of the sites, therefore, additional expense for excavation of vertical shelters is minimal. Depth to ground water is less than 150 feet (46 m) in approximately 30 and 65 percent of Jornada and San Simon sites, respectively. In areas where the depth to ground water is less than 120 feet (37 m), additional costs for excavation of vertical shelters can be expected.

- Backfill - Subsurface soils are generally suitable for backfill and compaction in trench excavations. Backfill will have to be imported from within the sites for areas of concentrated cobbles and boulders.

- Aggregates and Water - Sufficient quantities of aggregates and water required for roads and concrete of all basing modes are available within and/or adjacent to the sites, thus minimizing haul costs.

6.0 CONCLUSIONS

In summary, Jornada del Muerto and San Simon sites present favorable geotechnical conditions for deployment of any of the three present MX basing mode concepts. For the vertical shelter basing mode, cost of excavation for vertical shelters will be high in many areas due to the presence of ground water within the construction zone. As an alternative, areas with ground water in the construction zone can be excluded for the vertical shelter mode. Geotechnical conditions from the Jornada and San Simon sites can be extrapolated to approximately 95 and 40 percent of the Rio Grande and Highlands CSPs, respecively.

APPENDIX A

GENERAL GEOTECHNICAL INFORMATION

TABLE OF CONTENTS
APPENDIX A

TEXT

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF TERMS

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number; may also be used to designate a particular location in a valley.

AEROMAGNETIC DATA - Magnetometer observations made from an airplane.

ALLUVIAL BASIN - A lowland area, generally between uplifted mountain blocks, filled with alluvial deposits.

ALLUVIAL FAN - A low, outspread, relatively flat to gently sloping mass of alluvium, shaped like an open fan or a segment of a cone, deposited by a stream (especially in a semiarid region) at the place where it issues from a narrow mountain valley upon a plain or broad valley. It is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with gradually decreasing gradient.

ALLUVIAL FAN DEPOSITS - Alluvium deposited by a stream or other body of running water as a sorted or semisorted sediment in the form of a cone or fan at the base of a mountain slope.

ALLUVIAL PLAIN - A level or gently sloping tract or a slightly undulating land surface produced by extensive deposition of alluvium, usually adjacent to a river that periodically overflows its banks; it may be situated on a flood plain, a delta, or an alluvial fan.

ALLUVIUM - A general term for unconsolidated clay, silt, sand, gravel, and boulders deposited during relatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

ANOMALY - 1) A deviation from uniformity in physical properties; especially a deviation from uniformity in physical properties of exploration interest. 2) A portion of a geophysical survey which is different in appearance from the survey in general.

AQUIFER - A permeable saturated zone below the earth's surface capable of conducting and yielding water as to a well.

GLOSSARY OF TERMS (Cont.)

ARKOSIC SANDSTONE - A sandstone with considerable feldspar, such as one containing minerals from coarse-grained quartzo-feldspathic rocks (granites, granodiorites, medium or high-grade schists) or from older, highly feldspathic sedimentary rocks; specifically a sandstone containing more than 25% feldspar and less than 20% matrix material of clay, sericite, and chlorite.

ARRIVAL - An event; the appearance of seismic energy on a seismic record; a line-up of coherent energy signifying the arrival of a new wave train.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid limit (LL) - The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D423-66).

Plastic limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D424-59).

Plasticity index (PI) - Numerical difference between the liquid limit and the plastic limit.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogenous detrital material deposited in a sedimentary basin.

BEDROCK - Rock with a seismic p-wave velocity of 7000 ft (2333 m) per second or more.

BOUGUER ANOMALY - The residual value obtained after latitude, elevation and terrain corrections have been applied to gravity data.

BOULDER FIELD - Five or more rocks, each with diameters of 6 ft or more occurring within an acre.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench excavation.

c - Cohesion (Shear strength of a soil not related to interparticle friction).

CALICHE - Gravel, sand or other material cemented principally by calcium carbonate.

GLOSSARY OF TERMS (Cont.)

CALIFORNIA BEARING RATIO (CBR) - A test performed on a specifically prepared soil sample which is useful in the design of road pavement to be supported by the soil tested (ASTM D1833-73). The load is applied on the penetration piston which is penetrated into the soil sample at a constant penetration rate. The bearing ratio reported for the soil is normally the one at 0.1 inches (2.5 mm) penetration.

CANDIDATE - One of some group of regions, areas or sites being considered for MX deployment. Removal of candidate from a specifically named region, area or site term indicates selection by SAMSO/MNND.

CANDIDATE DEPLOYMENT AREA (CDA) - An area encompassing between 500 and 1000 square nautical miles of potentially suitable land with either naturally or artificially defined boundaries designated for convenience of study, discussion and data depiction. The candidate deployment area could be composed of two to four parcels and should have a specific place name description.

CANDIDATE DEPLOYMENT PARCEL (CDP) - An area of 150 to 500 square nautical miles potentially suitable for MX siting which, when aggregated with others, forms a Candidate Deployment Area. Each parcel should have a specific geographic description. (In the Basin and Range Physiographic province a parcel may correspond to a geographic valley and in Texas to some agri-economic unit.)

CANDIDATE DEPLOYMENT SITE (CDS) - A non-specific (i.e. not finally approved) site proposed for some element of the MX system within a chosen deployment area (i.e. trench or shelter site).

CANDIDATE SITING PROVINCE (CSP) - An area potentially suitable for deployment of the MX system generally encompassing more than 6000 square nautical miles which, in a broad sense, is homogeneous with respect to most of the important characteristics governing siting of a total MX system.

CANDIDATE SITING REGION (CSR) - Potentially suitable area between 4000 and 6000 square nautical miles within one, or encompassing portions of more than one, candidate siting province which allows for full MX deployment.

GLOSSARY OF TERMS (Cont.)

CAPABLE (fault) - Movement at or near the surface at least once in the past 35,000 years, and/or more than once in the past 500,000 years, (Nuclear Regulatory Commission).

CAPROCK - A resistant, moderately to strongly cemented caliche layer forming a "cap" over less resistant layers.

CD TRIAXIAL SHEAR-A type of test to measure the shear strength of an undisturbed soil sample

CLOSED BASIN - A catchment area draining to some depression or lake within its area, from which water escapes only by evaporation.

COARSE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.075 mm in diameter (passing the No. 200 U.S. size).

COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material larger than 3 inches (76 mm) in diameter.

COLLUVIAL DEPOSITS - A general term applied to any loose, heterogenous, and incoherent mass of soil material or rock fragments deposited chiefly by dislodgement and downslope transport of the material under the direct application of gravitational body stresses. Material is usually found at the base of a steep slope or cliff.

COMPACTION TEST - A type of test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D1557-70).

COMPRESSIBILITY-Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.

COMPRESSIONAL WAVE -An elastic body wave in which particle motion is in the direction of propagation; the type of seismic wave assumed in conventional seismic exploration. Also called P-wave, dilatational wave, and longitudinal wave.

CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

GLOSSARY OF TERMS (Cont.)

CONTERMINOUS UNITED STATES - The contiguous 48 states.

CORE SAMPLE - A cylindrical sample obtained with a rotating core barrel with a cutting bit at its lower end. Core samples are obtained from indurated deposits and in rock.

DEBRIS FLOW - A high-density flow of mud containing abundant coarse-grained materials (boulders, cobbles, gravel, sand) that frequently result from an unusually heavy rain.

DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.

DETECTOR - See GEOPHONE.

DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.

DISSECTION/DISSECTED (alluvial fans) - The cutting of stream channels into the surface of an alluvial fan by the movement (or flow) of water.

DISTAL - That portion of an alluvial deposit farthest from its point of origin.

DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.

ELECTRICAL CONDUCTIVITY - Ability of a material to conduct electrical current

ELECTRICAL RESISTIVITY - Property of a material which resists flow of electrical current

ENTRENCH - The process whereby a stream erodes downward to form a trench.

EOLIAN - A term applied to materials which are deposited by wind.

EPHEMERAL(stream) - A stream in which water flow is discontinuous and of short duration.

EXTERNAL DRAINAGE - Stream drainage system whose downgradient flow is unrestricted by any topographic impediments.

EXTRUSIVE (rock) - Igneous rock that has been ejected onto the earth's surface (e.g., lava, basalt, rhyolite, andesite; detrital material, volcanic tuff, pumice).

GLOSSARY OF TERMS (Cont.)

FAULT - A plane or zone of rock fracture along which there has been displacement.

FAULT BLOCK MOUNTAINS - Mountains that are formed by normal faulting in which the surface crust is divided into structural, partially to entirely fault-bounded blocks of different elevations.

FINE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.075 mm in diameter (passing the No. 200 U.S. size sieve).

FINER-GRAINED - A term applied to alluvial fan deposits, which are composed predominantly of material less than 3 inches (76 mm).

FLOODING/LOW ENERGY FLOW - Flood waters flowing on a slope of low gradient.

FLUVIAL DEPOSITS - Material produced by river action; generally loose, moderately well-graded sands and gravel.

FORMATION - A mappable assemblage of rocks characterized by some degree of homogeneity or distinctiveness

FREE AIR ANOMALY - Gravity data which have been corrected for latitude and elevation (free air correction) but not for the density of rock between the datum and the plane of measurement (Bouguer correction).

FUGRO DRIVE SAMPLE - A 2.50 inch (6.4 cm) diameter soil sample obtained from a drill hole with a Fugro Drive Sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 one-inch (2.54 cm) long brass sample rings. The sampler is advanced into the soil using a drop-hammer.

GAMMA - A unit of magnetic-field intensity. A gamma is 10^{-5} oersteds; sometimes expressed (incorrectly) as 10^{-5} gauss with which it is numerically equal.

GEOMORPHOLOGY - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features.

GEOPHONE - The instrument used to transform seismic energy into electrical voltage; a <u>seismometer</u>, <u>jug</u>, or <u>pick-up</u>.

GLOSSARY OF TERMS (Cont.)

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.075mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of the particle sizes smaller than 0.075 mm is determined by a sedimentation process, using a hydrometer.

GRAVEL - Particles of rock that pass a 3-in. (76.2 mm) sieve and retained on a No. 4(4.75 mm0 sieve

GRAVITY - The force of attraction between bodies because of their mass. Usually measured as the acceleration of gravity.

GRAVITY GRADIENT - The partial derivative of the acceleration of gravity with respect to distance in a particular direction, for which purpose the acceleration of gravity is considered as a scalar.

INTERIOR DRAINAGE - Stream drainage system that flows into a closed topographic low (basin).

INTRUSIVE (rock) - A rock formed by the process of emplacement of magma (liquid rock) in pre-existing rock. (e.g. granite, granodiorite, quartz monzonite).

LACUSTRINE DEPOSITS - Materials deposited in lake environment.

LINE - A linear array of observation points, such as a seismic line.

LIQUID LIMIT - See ATTERBERG LIMITS.

LOESS - A wind blown deposit predominantly silt or silty clay or clayey silt.

LOW ENERGY FLOW - See FLOODING.

MAGNETIC INTENSITY - A vector quantity measuring magnetic field strength. The unit of magnetic intensity commonly used in geophysical exploration is the gamma (see GAMMA).

MANTLED PLAYA - A playa surface or a portion of the surface that is covered with younger geologic material such as windblown sand, or alluvium.

MILLIGAL - A unit of acceleration used with gravity measurements; 1 milligal = 10^{-5} m/sec.^{2}. Abbreviated mgal.

GLOSSARY OF TERMS (Cont.)

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the oven-dry weight of the sample.

N VALUE - Penetration resistance, number of blows required to drive the standard split spoon sampler for the second and third six inches (0.15 m) with a 140 pound (63.5 kg) hammer falling 30 inches (0.76 m) (ASTM D1586-67).

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort

OVERBANK FLOODING - A large flow of water that overflows the sides of A stream channel.

O - Angle of internal friction

PATINA - A dark coating or thin outer layer produced on the surface of a rock or other material by weathering after long exposure (e.g., desert varnish).

PAVEMENT/DESERT PAVEMENT - When loose material containing pebble-sized or larger rocks is exposed to rainfall and wind action the finer dust and sand are blown or washed away and the pebbles gradually accumulate on the surface, forming a mosaic which protects the underlying finer material from wind attack. Pavement can also develop in finer-grained materials. In this case the armored surface is formed by dissolution and cementation of the grains involved.

PEGAMATITE DIKE - A coarse grained igneous rock of granitic composition that forms as a tabular intrusion that cuts across the planar structures of the surrounding rock.

P-WAVE - See COMPRESSIONAL WAVE.

PERIMETER SEISMIC REFRACTION SURVEY - Shallow seismic refraction measurements made around the perimeter of a valley.

PERMEABLE - The ability of liquid to pass through soil and/or rock material.

PICK-UP - See GEOPHONE.

GLOSSARY OF TERMS (Cont.)

PITCHER TUBE SAMPLE - An undisturbed, 2.87 inch (73 mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending upon the hardness of the material being penetrated.

PLASTIC LIMIT - See ATTERBERG LIMITS.

PLASTICITY INDEX - See ATTERBERG LIMITS.

PLAYA/PLAYA DEPOSITS - A term used in the southwest U.S. for a dried-up, flat-floored area composed of thin, evenly stratified sheets of fine clay, silt, or sand, and representing the lowest part of a shallow, completely closed or undrained, desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.

PONDING (of water) - The accumulating of water in a topographic depression.

PRIME - Modifier used to indicate the highest ranking province, region, area, or site. If not an interdisciplinary ranking, then a qualifier should be used such as "prime" geotechnical candidate siting area".

PROXIMAL - That portion of an alluvial deposit nearest to its point of origin.

REGIONAL - The general attitude or configuration disregarding features smaller than a given size. The regional gravity is the gravity field produced by large-scale variations ignoring anomalies of smaller size. See residualize.

RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.

RESIDUAL - What is left after a regional field has been removed, as in gravity or magnetic analysis. See RESIDUALIZE.

GLOSSARY OF TERMS (Cont.)

RESIDUALIZE - The process of separating a graphically depicted curve or a surface into its low-frequency parts (called the regional) and its high-frequency parts (called the residual). Residualizing is an attempt to sort out of the total field those anomalies which result from local structure; that is, to fine local anomalies by subtracting gross (regional) effects.

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

S-WAVE - See SHEAR WAVE.

SAND - Soil passing through No. 4(4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves(shear waves).

SEISMIC REFRACTION DATA: deep/shallow - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and of distance from the shot, by determining the arrival times of seismic waves which have travelled nearly parallel to the bedding in high-velocity layers, in order to map the depth to such layers.

SEISMOGRAM - A seismic record.

SEISMOMETER - See GEOPHONE.

SHEAR WAVE - A body wave in which the particle motion is perpendicular to the direction of propagation. Also called S-Wave or transverse wave.

SHEET FLOW - A process in which storm-borne water spreads as a thin, continuous veneer (sheet) over a large area.

SHEET SAND - A blanket deposit of sand which accumulates in shallow depressions or against rock outcrops, but does not have characteristic dune form.

SHOT - Any source of seismic energy; e.g., the detonation of an explosive.

GLOSSARY OF TERMS (Cont.)

SHOT POINT - The location of any source of seismic energy; e.g., the location where an explosive charge is detonated in one hole or in a pattern of holes to generate seismic energy. Abbreviated SP.

SILT AND CLAY - Fine-grained soil passing through No. 200 (0.075 mm) sieve.

SITE - Location of some specific activity or reference point. The term should always be modified to a precise meaning or be clearly understood from the context of the discussion.

SPECIFIC GRAVITY - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

SPLIT SPOON SAMPLE - A disturbed sample obtained with a split spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop-hammer.

SPREAD - The layout of geophone groups from which data from a single shot are recorded simultaneously. Spreads containing twenty-four geophones have been used in Fugro's seismic refraction surveys.

STREAM CHANNEL DEPOSITS - Materials (clay, silt, sand, gravel, cobbles, boulders) which have been deposited in a stream channel.

STREAM TERRACE DEPOSITS - Stream channel deposits no longer part of an active stream system, generally loose, moderately well graded sand and gravel.

SURFICIAL DEPOSIT - Unconsolidated residual and alluvial deposits occurring on or near the earth's surface.

TRANSITORY - A poorly defined, shallow ephemeral stream across an alluvial fan surface, the position of which is temporary and tends to shift frequently.

UNCONFINED COMPRESSION - A type of test to measure the compressive strength of an undisturbed soil sample.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) - A system which determines soil classification on the basis of grain-size distribution and Atterberg Limits. (See page A-17).

GLOSSARY OF TERMS (Cont.)

VALLEY SEISMIC REFRACTION SURVEY - Deep seismic refraction measurements made near the middle of a valley to determine seismic wave propagation velocities and thickness of basin fill.

VELOCITY - Refers to the propagation rate of a seismic wave without implying any direction. Velocity is a property of the medium and not a vector quantity when used in this sense.

VELOCITY LAYER - A layer of rock or soil with a homogenous seismic velocity.

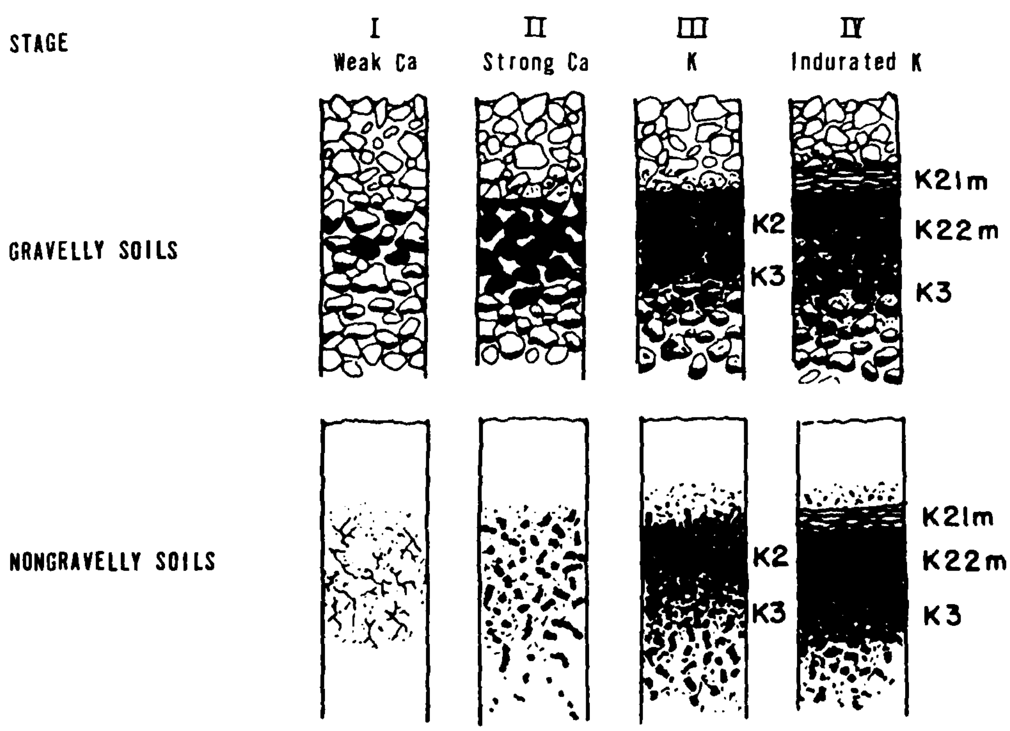
VELOCITY PROFILE - A cross-section showing the distribution of material seismic velocities as a function of depth and its configuration.

WASH SAMPLE - A sample obtained by screening the returned drilling fluid during rotary wash drilling to obtain lithologic information between samples.

Definitions were derived in part from Webster's New Collegiate Dictionary (1972 edition), Glossary of Geology (American Geological Institute, 1972), Encyclopedic Dictionary of Exploration Geophysics (Sheriff, 1973), and 1976 Annual Book Book of ASTM Standards.

DIAGNOSTIC CARBONATE MORPHOLOGY

STAGE	GRAVELLY SOILS	NONGRAVELLY SOILS
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Laminar horizon overlying plugged horizon



Stages of development of a caliche profile with time. Stage I represents incipient carbonate accumulation, followed by continuous build-up of carbonate until, in Stage IV, the soil is completely plugged.

SUMMARY OF CALICHE DEVELOPMENT	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE SAMSO	FIGURE A-1
FUGRO NATIONAL, INC.	

Reference: Gile, L.H., Peterson, F.F., and Grossman, R.B., 1965, The K horizon: A master horizon of carbonate accumulation: Soil Science, v. 99, p. 74-82

NON-ROCK UNITS

(1) AREI SYMBOLS	MX (2) GEOLOGIC UNITS	
Au, Ast	Au	Non-rock Deposits (undifferentiated); fine- to coarse-grained materials deposited by alluvial, fluvial, eolian, lacustrine, gravity or glacial processes.
Aal	A1	Fluvial Deposits; predominantly composed of poorly- to well-graded sand and gravel with lesser amounts of silt- and boulder-sized material. The unit predominantly consists of recent water-laid deposits occupying present drainages and flood plains. - Older Fluvial Deposits (A1o) are generally thicker, more extensive units deposited in ancestral fluvial systems. - Alluvial Outwash Deposits (A1w) consist of mixed, geomorphically nondescript alluvial and fluvial deposits covering large, relatively flat, river and playa basins.
At	A2	Terrace Deposits; predominantly composed of moderately to well graded, clay- to gravel-sized material principally elevated terraces bordering modern streams (A2s) and lakes playas (A2l).
	A3	Eolian Deposits; predominantly composed of poorly graded sand-sized material deposited by wind action. Deposits may consist of mixed sand, silt, and clay (A3u), or be differentiated on the basis of predominant grain size and landform. A3s d - Predominantly fine sand-sized material deposited in sheets (A3s) or dunes (A3d). A3l - Loess composed predominantly of silt-sized material with lesser amounts of clay and fine sand. A3f - Predominantly clay-sized material with lesser amounts of silt and fine sand.
	A4	Lacustrine, Estuarine, and Playa Deposits; predominantly composed of poorly graded clay, silt, and fine sand deposited in bodies of standing water. Older lacustrine, estuarine, and playa deposits (A4o) are thicker, more extensive units occupying ancestral lake basins.
Aaf	A5	Alluvial Fan Deposits; predominantly composed of well graded sand and gravel with varying amounts of silt-, cobble-, and boulder-sized material. Deposited principally by distributary channels adjacent to mountain fronts. Relative ages are indicated by o - older, i - intermediate, or y - younger.
	A6	Pediment, Pediment Deposits, and Areas of Shallow Rock; planated bedrock shelf or near surface rock generally overlain by a thin mantle of sand- to boulder-sized residual or alluvial material.
	A7	Colluvial Deposits; predominantly composed of moderately- to well-graded sand and gravel with varying amounts of silt-, cobble-, and boulder-sized material. Deposited locally by gravity and water adjacent to steep gradients.

(1) AREI SYMBOLS	MX (2) GEOLOGIC UNITS	
		Show rock type
	I	IGNE part
gr		I1
Vu		I2
Vb		I3
		I4
Su	S	SEDI some evap
Qtz		S1
Psa, Pm, Ph, Cau, Ls, Py, Par		S2
		S3
		S4
		S5
Qtz, gn	M	META sedi weat
	C	ROCK perc
		Modi (cal A3s A5y(S5to

NOTES: (1) AREI symbols were developed for use in the Aggregate Resources Evaluation Investigation (See Section 5.1 and Drawings 5.1A through 5.1C)

(2) MX Geologic units were used for Methodology, Screening, and Characterization studies.

ROCK UNITS

(1) AREI SYMBOLS	MX (2) GEOLOGIC UNITS	
		Shown in regions where rock is exposed; the areally predominant (greater than 70 percent) rock type is indicated. In those areas where two rock types occur the predominant rock type is shown followed by the subordinate rock type (e.g. S2MP I4T).
	I	IGNEOUS (UNDIFFERENTIATED). Rocks formed by solidification of a molten or partially molten mass.
gr	I1	Intrusive - Typically crystalline, formed by the solidification of molten material below the surface (e.g., granite, syenite, diorite).
Vu	I2	Extrusive (undifferentiated). Formed by solidification of molten material at or near the surface.
Vb	I3	Extrusive (flows). Extrusive rocks formed by solidification of lava (e.g. basalt, dacite) [illegible] denotes young basaltic flows which may be interbedded with bas[illegible] materials.
	I4	Extrusive (volcanicla[illegible]). Formed by accumulation, welding and or cementation of deposits of volcanic ejecta (e.g. tuff, agglomerate, lapilli).
Su	S	SEDIMENTARY (UNDIFFERENTIATED). Coarse- to fine-grained materials that exhibit some degree of cementation and were deposited by water, wind, gravity, or evaporation.
Qtz	S1	Sandstone. Composed predominantly of sand-sized particles.
Psa, Pm, Ph, Cau, Ls, Py, Par	S2	Limestone and Dolomite. Composed predominantly of carbonate material.
	S3	*Shale.* Composed predominantly of clay- and silt-sized particles (e.g. shale, siltstone, mudstone).
	S4	Evaporites. Sediments deposited from solution as a result of evaporation (e.g. gypsum, anhydrite, halite).
	S5	Clastics. Undifferentiated deposits composed of silt- to boulder-sized material. May be angular to rounded.
Qtz, gn	M	METAMORPHIC (UNDIFFERENTIATED). Rocks formed through alteration of igneous or sedimentary rock material by pressure, heat, or chemical changes below the weathered zone (e.g. gneiss, schist, slate, marble, quartzite).
	C	ROCK COMPLEXES. Indicated where no areally predominant (greater than 70 percent) rock type is present.

USEAGE

Modifying letter (r) indicates concentrations of resistant secondary carbonate (caliche), silicious, ferruginous and or gypsiferous material, e.g. A5ir.

A3s A5y - Mixed non-rock units; most areally extensive unit is listed first.

A5y(A5i) - Parenthetic unit underlies thin veneer of overlying mapped unit.

S5to - Established formations may have a supplemental letter added to distinguish formal designation (e.g. Tertiary Ogallala Fm.).

2

EXPLANATION OF GEOLOGIC UNITS

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE A-1

FUGRO NATIONAL, INC.

Major Divisions			Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 inches and basing fractions on estimated weights)			Information Required for Describing Soils
1	2		3	4	5			6
Coarse-grained Soils More than half of material is larger than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the ¼-in. size may be used as equivalent to the No. 4 sieve size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.			For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics.
			GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	Nonplastic fines or fines with low plasticity. (for identification procedures see ML below)			
			GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below).			Give typical name; indicate approximate percentages of sand and gravel, max. size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.
	Sands More than half of coarse fraction is smaller than No. 4 sieve size.	Clean Sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.			
			SP	Poorly-graded sands, gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			Example: Silty sand, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity. (for identification procedures see ML below)			
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).			
					Identification Procedures on Fraction Smaller than No. 40 Sieve Size			
					Dry Strength (Crushing characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)	
Fine-grained Soils More than half of material is smaller than No. 200 sieve size.	Silts and Clays Liquid limit less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Quick to slow	None	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium	
			OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Slow	Slight	
	Silts and Clays Liquid limit greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	Slow to none	Slight to medium	For undisturbed soils and information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.
			CH	Inorganic clays of high plasticity, fat clays.	High to very high	None	High	
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium	Example: Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).
Highly Organic Soils			Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.			

UNIFIED SOIL CLASSIFICATION SYSTEM

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE A-2

FUGRO NATIONAL, INC.

APPENDIX B

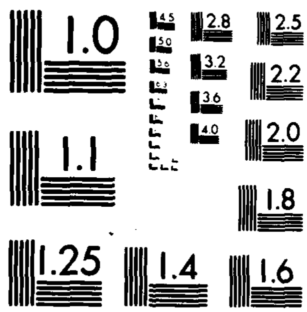
GEOTECHNICAL DATA - JORNADA DEL MUERTO

TABLE OF CONTENTS
APPENDIX B

AD-A112 404 FUGRO NATIONAL INC LONG BEACH CA F/G 8/7
MX SITING INVESTIGATION. PRIME CHARACTERIZATION SITES RIO GRAND--ETC(U)
FEB 79 F04704-77-C-0010
UNCLASSIFIED FN-TR-26C NL

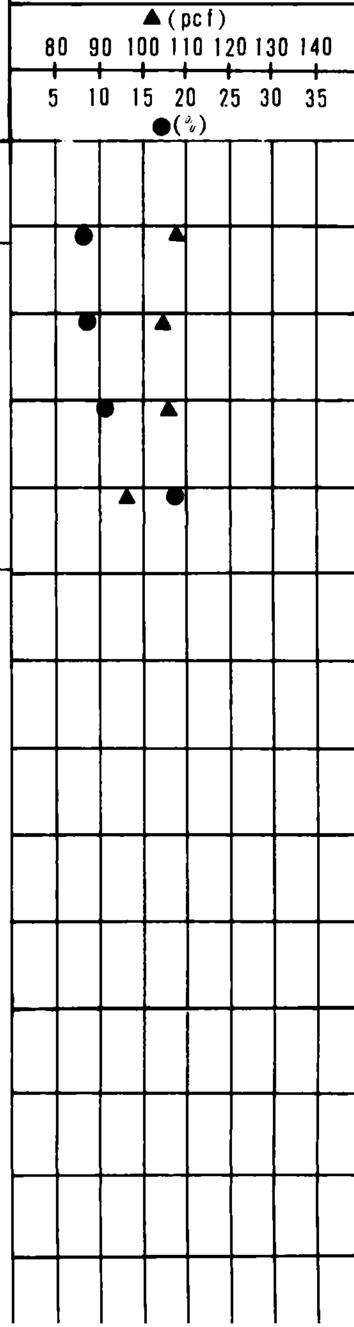
2 of 2

END
DATE
FILMED
4 82
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SAMPLE TYPE	% RECOVERY	N VALUE	DEPTH METERS	DEPTH FEET	LITHOLOGY	USCS	SOIL DESCRIPTION	SIEVE ANALYSIS GR	SA	FI	LL	PI
			0	0		GC	CLAYEY GRAVEL, brown, fine to coarse, poorly graded, loose, angular, little sand.	67	13	20		
	92							0	11	89	25	10
	88		3	10		CL	CLAY, brown, soft (3-10'), firm 10-25', slightly to medium plastic, calcareous.					
	92										26	6
	80		6	20							25	6
	NR											
			9	30								
	NR							61	19	20		
			12	40		GC	CLAYEY GRAVEL, black to brown, fine to coarse, poorly graded, dense, subangular, calcareous, little sand.					
			15	50								
			18	60								



Blows	Depth (m)	Depth (ft)	USCS	Description					
	21	70							
66			SM	SILTY SAND, gray, fine, poorly graded, very dense, calcareous, little fine gravel.	18	51	31		
85	24	80	SC	CLAYEY SAND, gray, fine to medium, poorly graded, very dense.	0	51	49	32	11
64	27	90	GC	SANDY GRAVEL, black to gray, fine, poorly graded, very dense, calcareous, some slightly plastic clay.	46 40	31 27	23 33	23	4
75	30	100		ROCK, fractured sandstone, light gray, stratified, 1/8" thick clay layers (104-108').					
	33	110		Total Depth 108.0' (32.9m)					
	36	120							
	39	130							

1400 1800 2200
▲(kg/m^3)

2

SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE
- CORE

ENGINEERING PARAMETERS

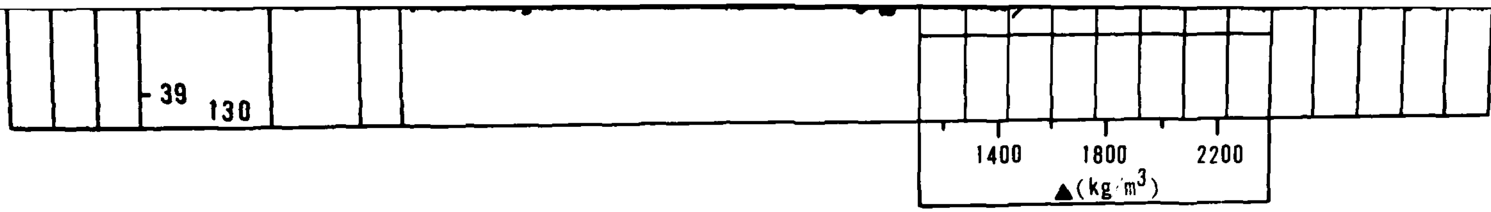
BORING DETAILS

ELEVATION : 5260' (1603m)
DATE DRILLED : 10 August 1977
DRILLING METHOD : Rotary Wash
HOLE DIAMETER : 4 7/8" (124mm)
CASING INSTALLED : 108' (32.9m)
WATER LEVEL : >100.0' (30.5m)

LOG OF BORIN
JORNADA DEL MUERT
RIO GRAND

MX SITING INVESTIGAT
DEPARTMENT OF THE AIR FORC

FUGRO NATI



SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE
- CORE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)
R - N VALUE GREATER THAN 100 BLOWS/FOOT
▲ - DRY UNIT WEIGHT (ASTM: D-2937-71)
● - MOISTURE CONTENT (ASTM: D-2216-71)
NR - NO RECOVERY

BORING DETAILS

ELEVATION	: 5260' (1603m)
DATE DRILLED	: 10 August 1977
DRILLING METHOD	: Rotary Wash
HOLE DIAMETER	: 4 7/8" (124mm)
CASING INSTALLED	: 108' (32.9m)
WATER LEVEL	: >100.0' (30.5m)

LOG OF BORING JM-B-2
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

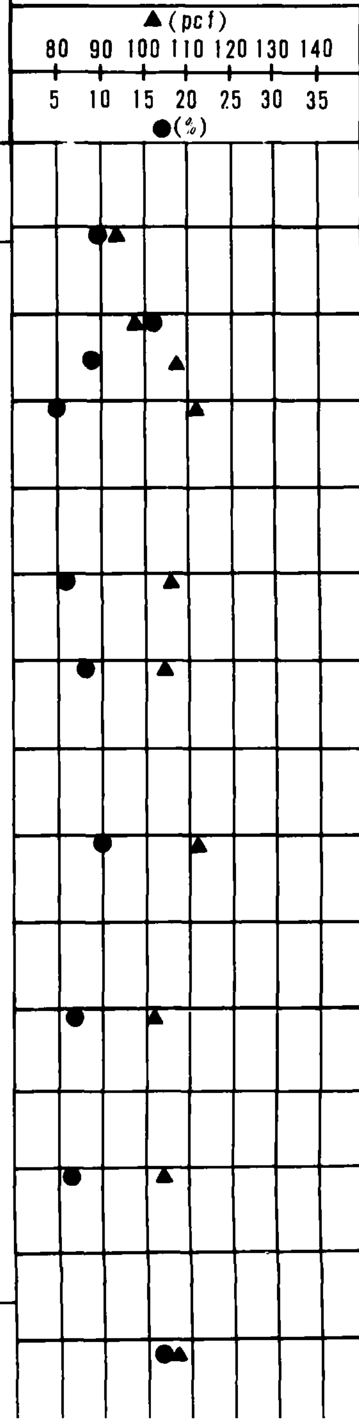
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE B-1

FUGRO NATIONAL, INC.

3

SAMPLE TYPE / % RECOVERY	N VALUE	DEPTH METERS	DEPTH FEET	LITHOLOGY	USCS	SOIL DESCRIPTION	GR	SA	FI	LL	PI
		0	0		ML	SANDY SILT, brown, soft, slightly plastic, calcareous.	0	38	62		
93										NP	
89		3	10		SP					34	18
							0	96	4		
59							0	86	14		
76		6	20				1	72	27	31	19
44										NP	
96		9	30				0	81	19		
					SM	SILTY SAND, red-brown to white, fine, dense, subrounded to subangular, calcareous, interbedded layers of highly plastic clay and slightly plastic silt.					
91		12	40							23	13
90		15	50				0	51	49		
89		18	60								
67		21	70		CL	SANDY CLAY, brown, hard, medium plastic, calcareous.	0	14	86	47	27



N	Depth (m)	Depth (ft)	USCS	Description						
67			CL	SANDY CLAY, brown, hard, medium plastic, calcareous.	0	14	86	47	27
40	24	80	SM	SILTY SAND, red-brown, fine, dense to very dense, poorly graded, calcareous.	0	70	30		
69	27	90							
89	30	100			0	90	10		
				Total Depth 100 9' (30.8m)					
	33	110							
	36	120							
	39	130							

1400 1800 2200
▲(kg/m³)

2

SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE

ENGINEERING PARAMETERS

N - STANDARD PENETRATION TEST (ASTM: D-1586-67)
R - N VALUE GREATER THAN 100 BLOWS/FOOT

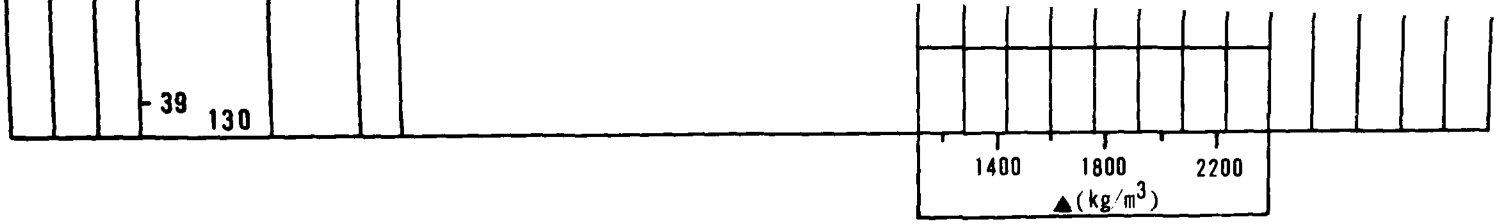
BORING DETAILS

ELEVATION	: 4790' (1460m)
DATE DRILLED	: 23 AUGUST 1977
DRILLING METHOD	: Rotary Wash
HOLE DIAMETER	: 4 7/8" (124mm)
CASING INSTALLED	: 101' (30.8m)
WATER LEVEL	: 92' (28.0m)

LOG OF BORING JM-B-
JORNADA DEL MUERTO, NEW
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMS

FUGRO NATIONA



SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE

ENGINEERING PARAMETERS

N – STANDARD PENETRATION TEST (ASTM: D-1586-67)
R – N VALUE GREATER THAN 100 BLOWS/FOOT
▲ – DRY UNIT WEIGHT (ASTM: D-2937-71)
● – MOISTURE CONTENT (ASTM: D-2216-71)
NR – NO RECOVERY

BORING DETAILS

ELEVATION	: 4790' (1460m)
DATE DRILLED	: 23 AUGUST 1977
DRILLING METHOD	: Rotary Wash
HOLE DIAMETER	: 4 7/8" (124mm)
CASING INSTALLED	: 101' (30.8m)
WATER LEVEL	: 92' (28.0m)

LOG OF BORING JM-B-6
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE B-2

FUGRO NATIONAL, INC.

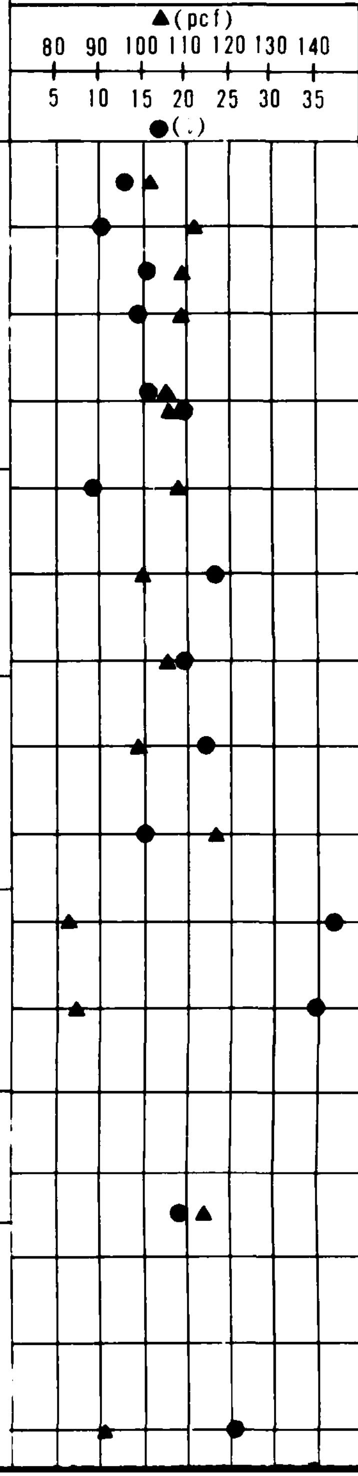
3

DEPTH (FEET)	USCS	SOIL DESCRIPTION
0	ML	CLAY and SILT, red-brown, stiff, non-plastic silt, slightly to medium plastic clay, calcareous, trace gypsum crystals; layer of gravelly sand (18'-28').
	CL	
20	SM	
	CH	
40	SP-SM	SAND, brown, fine, poorly graded, dense, subrounded, trace silt (38'-55').
	SP	
60	SC	CLAYEY SAND, gray to brown, fine to coarse, poorly graded, dense, calcareous, little fine gravel, lenses of gypsum crystals.
80	CH	CLAY, gray to brown, stiff, highly plastic, calcareous, lenses of gypsum crystals.
100		
120	SM	SILTY SAND, brown, fine, poorly graded, very dense, subrounded, calcareous.
	CH	
140	SM	
	CH	

DEPTH: METERS 0, 10, 20, 30, 40; FEET 0, 20, 40, 60, 80, 100, 120, 140

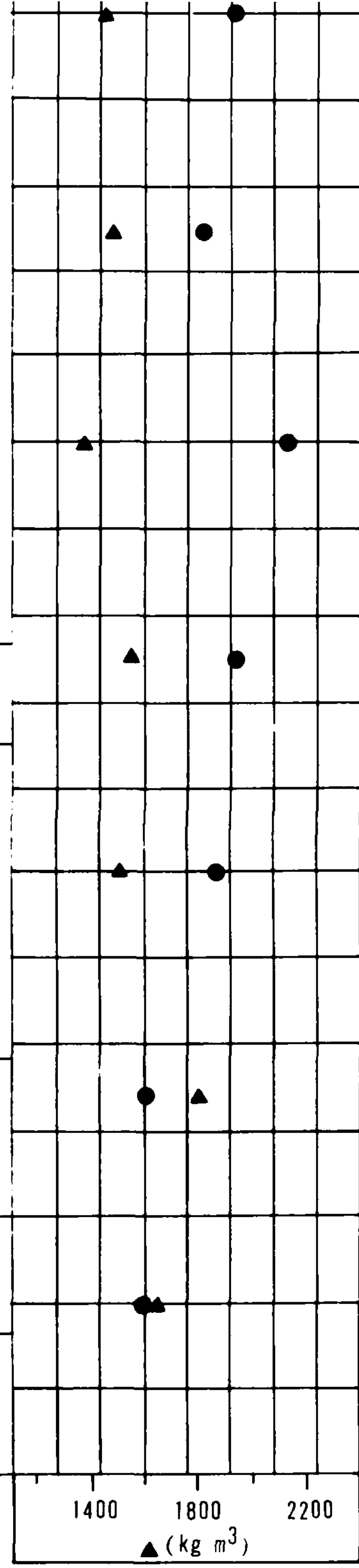
SAMPLE TYPE / % RECOVERY: 100, 100, 100, 72, NR, 100, 60, 89, 67, 100, 50, 100, 100, 100, 48, 100

N VALUE



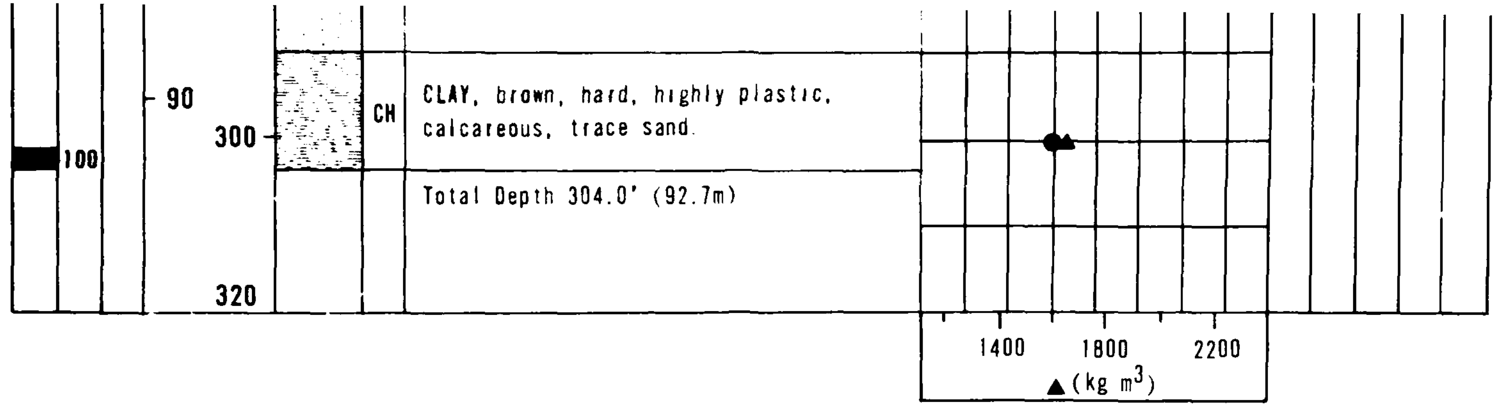
SIEVE ANALYSIS GR	SA	FI	PI	LL
0	5	95		
			23	15
33	46	21		
			28	18
			56	29
0	93	7		
0	97	3		
16	36	48	50	29
			91	59

Recovery (%)	Depth (m)	Depth (ft)	Symbol	Description
100			CH	
			SM	
100	50	160–180	CH	CLAY, brown to red-brown, stiff to very stiff, slightly to highly plastic, calcareous, interbedded with layers of silty sand, trace gypsum crystals.
			SM	
100	60	200	CH	
		220	CL	
100	70		SM	SILTY SAND, brown, fine, dense, calcareous.
100		240–260	CH	CLAY, brown, hard, highly plastic, trace gypsum crystals, trace fine sand.
60	80	280	SM	SILTY SAND, brown, fine, very dense, subrounded, calcareous.
100	90	300	CH	CLAY, brown, hard, highly plastic, calcareous, trace sand.
		320		Total Depth 304.0' (92.7m)



91	59

2



SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE
- CORE

ENGINEERING PARAMETERS

N – STANDARD PENETRATION TEST (ASTM: D-1586-67)
R – N VALUE GREATER THAN 100 BLOWS/FOOT
▲ – DRY UNIT WEIGHT (ASTM: D-2937-71)
● – MOISTURE CONTENT (ASTM: D-2216-71)
NR – NO RECOVERY

BORING DETAILS

ELEVATION : 4693' (1430m)
DATE DRILLED : 17 & 18 August 1977
DRILLING METHOD : Rotary Wash
HOLE DIAMETER : 4 7/8" (124mm)
CASING INSTALLED : 300' (91 4m)
WATER LEVEL : 87' (26.5m)

LOG OF BORING JM-B-11
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE B-3

FUGRO NATIONAL, INC.

FN-TR-26c

Depth (feet)	USCS	Consistency	Soil Description	GR	SA	FI	LL	PI
0–4.5	CL	Soft	SANDY CLAY, reddish brown, slightly plastic, calcareous, trace gravel to 3" (7.6cm), occasional cobbles to 6" (15.2cm) and boulders to 12" (30.5cm).	4	26	70	25	12
4.5–10		Stiff		10	30	60	23	10
10–15.5	GC	Medium dense	SANDY GRAVEL, red-brown, fine to coarse, well graded, subangular to subrounded, calcareous, little clay, stage II caliche layer (15.5-16.5'), cobbles to 6" (15 2cm).	63	24	13	21	8
				67	13	20		
15.5–16.5	GP	Very dense		72	24	4		NP

Column headings: BULK SAMPLE; DEPTH (METERS, FEET); LITHOLOGY; USCS; CONSISTENCY; SOIL DESCRIPTION; SIEVE ANALYSIS (GR, SA, FI); LL; PI

Total Depth 16.5' (5.0m)

Stability of Vertical Walls:
Stable

TRENCH DETAILS

SURFACE ELEVATION : 5260' (1603m)
DATE EXCAVATED : 3 August 1977
SURFACE GEOLOGIC UNIT : A1/A5i
TRENCH LENGTH : 50' (15 2m)
TRENCH ORIENTATION : EW

LOG OF TRENCH JM-T-2
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE B-4

FUGRO NATIONAL, INC.

LOGGED BY ____ CHECKED BY ____ APPROVED BY ____

FN-TR-28c

DEPTH (FEET)	USCS	CONSISTENCY	SOIL DESCRIPTION	GR	SA	FI	LL	PI
0–11.5	ML	Very stiff	SANDY SILT, white to brown, slightly plastic, calcareous, thin layers of brown, slightly plastic clay with gypsum crystals; stage I caliche (1.5–11.5').	0	28	72		NP
				0	23	77		NP
11.5–15.5	SC	Dense	CLAYEY SAND, brown, fine to coarse, angular to subangular, trace gravel, gypsum throughout.	7	51	42		NP
		Very dense		0	38	62	34	11
15.5–18	CL	Stiff	SANDY CLAY, brown, slightly plastic, gypsum crystals throughout.	1	32	67	33	10
18			Total Depth 18.0' (5.5m) Stability of Vertical Walls: Stable					

Columns: BULK SAMPLE, DEPTH (METERS, FEET), LITHOLOGY, USCS, CONSISTENCY, SOIL DESCRIPTION, SIEVE ANALYSIS (GR, SA, FI), LL, PI

TRENCH DETAILS

SURFACE ELEVATION : 4680' (1426m)
DATE EXCAVATED : 5 August 1977
SURFACE GEOLOGIC UNIT : A5y
TRENCH LENGTH : 50' (15.2m)
TRENCH ORIENTATION : EW

LOG OF TRENCH JM-T-4
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE B-5

FUGRO NATIONAL, INC.

LOGGED BY
CHECKED BY
APPROVED BY

FN-TR-26c

Depth (feet)	Depth (meters)	USCS	Consistency	Soil Description	GR	SA	FI	LL	PI
0–4.5	0–1.4	SM	Loose	SILTY SAND, brown, fine to medium, poorly graded, subrounded to subangular, calcareous, stage I caliche (5–10'), trace gravel (10–13').	.0	78	22		NP
					0	69	31		NP
4.5–13	1.4–4	SM	Medium dense		1	80	19		NP
					10	75	15		NP
13–17	4–5.2	SP-SM	Medium dense	SAND, brown, fine to coarse, poorly graded, subangular to subrounded, calcareous, trace silt (13–17').	2	91	7		NP
17–18.5	5.2–5.6	SP			2	94	4		NP

Column headings: BULK SAMPLE; DEPTH (METERS, FEET); LITHOLOGY; USCS; CONSISTENCY; SOIL DESCRIPTION; SIEVE ANALYSIS (GR, SA, FI); LL; PI

Total Depth 18.5' (5.6m)

Stability of Vertical Walls:

Unstable 0–5' (0–1.5m)
Stable 5–10' (1.5–3.0m)
Unstable 10–18.5' (3.0–5.6m)

TRENCH DETAILS

SURFACE ELEVATION : 4748' (1447m)
DATE EXCAVATED : 2 August 1977
SURFACE GEOLOGIC UNIT : A3s
TRENCH LENGTH : 40' (12.2m)
TRENCH ORIENTATION : N30°E

LOG OF TRENCH JM-T-14
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE B-6

FUGRO NATIONAL, INC.

LOGGED BY ___ CHECKED BY ___ APPROVED BY ___

BORING NUMBER	SAMPLE NUMBER (a)	SAMPLE INTERVAL		PERCENT FINER BY WEIGHT												
				STANDARD SIEVE OPENING							U S STANDARD SIEVE NO					PAR SIZE
				BLDRS.	COBBLES		GRAVEL				SAND				SILT OR	
		FEET	METERS	24"	12"	6"	3"	1½"	3/4"	3/8"	4	10	40	100	200	.005
JM-B-11	B-1A	0.0-2.0	0.00-0.61									100	99	97	95	
	P-1	5.5-6.2	1.68-1.89													
	P-2	10.5-11.2	3.20-3.41													
	P-3	15.5-16.2	4.72-4.94													
	P-4	20.7-21.4	6.31-6.52													
	B-5	25.5-26.5	7.77-8.08					100	85	76	67	60	46	27	21	
	P-6	28.0-28.7	8.53-8.75													
	P-7	31.0-31.7	9.45-9.66													
	P-8	40.2-40.9	12.25-12.47									100	97	43	7	
	P-9	50.5-51.5	15.39-15.70													
	P-10	61.0-61.8	18.59-18.84									100	80	3	3	
	P-11	71.1-71.8	21.67-21.88						100	96	83	66	54	50	48	3
	P-12	80.5-81.2	24.54-24.75													
	P-13	90.5-91.2	27.58-27.80													
	P-14	100.5-101.2	30.63-30.85													
	P-15	126.3-127.0	38.50-38.71													
	P-16	150.5-151.2	45.87-46.09													
	P-17	175.5-176.2	53.49-53.71													
	P-18	200.5-201.2	61.11-61.33													
	P-19	225.5-226.2	68.73-68.95													
	P-20	250.5-251.2	76.35-76.57													
	P-21	275.4-276.0	83.94-84.12													
	P-22	302.0-302.7	92.05-92.26													

NOTES:

(a) Sample types
- SS - Standard split spoon
- P - Pitcher
- D - Fugro Drive
- B - Bulk

(b) NP - Not Plastic

(c) USCS - Unified Soil Classification System

* Indicates that test has been performed and results are included in this report.

ARD SIEVE NO			PARTICLE SIZE (mm)		ATTERBERG LIMITS (b)			USCS (c)	IN-SITU					COMPACTED			SPECIFIC GRAVITY OF SOLIDS	TRIAXIAL	UNCONFINED COMPRESSION	DIRECT SHEAR	CONSOLIDATION
D		SILT OR CLAY							DRY UNIT WEIGHT		MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)					
40	100	200	.005	.001	LL	PL	PI		(pcf)	(kg/m^3)				(pcf)	(kg/m^3)						
99	97	95						ML													
								ML	101.3	1623	13.2	54	.66								
					23	8	15	CL	113.4	1817	11.0	61	.49						*		
								CL	108.9	1745	16.4	81	.55								
								SM	108.1	1732	13.6	66	.56							*	
46	27	21						SM													
					28	10	18	CL	105.1	1684	15.6	70	.60								*
					56	27	29	CH	112.3	1799	13.5	73	.50						*		
97	43	7						SP-SM	108.0	1730	8.8	42	.56								
								SP-SM	100.3	1607	22.7	90	.68								
60	3	3						SP	107.0	1714	18.8	88	.57								
[illegible]	50	48	3	3	50	21	29	SC	99.7	1597	19.7	77	.69						*		
								SC	116.4	1865	15.0	91	.45								
								CH	81.8	1310	37.3	95	1.06								
								CH	84.9	1360	34.3	94	.99								
								CH	103.5	1658	19.4	83	.63								
					91	32	59	CH	98.6	1580	15.4	59	71						*		
								CH	92.8	1487	21.8	72	.82								
								CH	85.5	1370	32.4	91	.97								
								SM	97.2	1557	25.7	95	.73								
								CH	94.7	1517	23.3	81	.78								
								SM	111.9	1793	15.8	84	.51								
								CH	102.8	1647	15.3	65	.64								

SUMMARY OF LABORAT
BORING J
JORNADA DEL MUERTO, NEW

MX SITING INVESTIG
DEPARTMENT OF THE AIR FO

FUGRO NAT

2

USCS (c)	IN-SITU DRY UNIT WEIGHT (pcf)	IN-SITU DRY UNIT WEIGHT (kg/m^3)	MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	COMPACTED MAXIMUM DRY DENSITY (pcf)	COMPACTED MAXIMUM DRY DENSITY (kg/m^3)	OPTIMUM MOISTURE (%)	SPECIFIC GRAVITY OF SOLIDS	TRIAXIAL	UNCONFINED COMPRESSION	DIRECT SHEAR	CONSOLIDATION	CHEMICAL	RELATIVE DENSITY
ML															
ML	101.3	1623	13.2	54	.66										
CL	113.4	1817	11.0	61	.49						*				
CL	108.9	1745	16.4	81	.55										
SM	108.1	1732	13.6	66	.56							*			
SM															
CL	105.1	1684	15.6	70	.60								*		
CH	112.3	1799	13.5	73	.50						*				
SP-SM	108.0	1730	8.8	42	.56										
SP-SM	100.3	1607	22.7	90	.68										
SP	107.0	1714	18.8	88	.57										
SC	99.7	1597	19.7	77	.69						*				
SC	116.4	1865	15.0	91	.45										
CH	81.8	1310	37.3	95	1.06										
CH	84.9	1360	34.3	94	.99										
CH	103.5	1658	19.4	83	.63										
CH	98.6	1580	15.4	59	71						*				
CH	92.8	1487	21.8	72	.82										
CH	85.5	1370	32.4	91	.97										
SM	97.2	1557	25.7	95	.73										
CH	94.7	1517	23.3	81	.78										
SM	111.9	1793	15.8	84	.51										
CH	102.8	1647	15.3	65	.64										

SUMMARY OF LABORATORY TEST RESULTS
BORING JM-B-11
JORNADA DEL MUERTO, NEW MEXICO, RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE B-1

FUGRO NATIONAL, INC.

BORING NO.	SAMPLE NO.	SAMPLE INTERVAL FEET	SAMPLE INTERVAL METERS	SOIL TYPE	UNCONFINED COMP. STRENGTH ksf	UNCONFINED COMP. STRENGTH kN/m²	DRY DENSITY pcf	DRY DENSITY kg/m³	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	HEIGHT DIAMETER
JM-B-1	P-3	14.0-14.8	4.3-4.5	CL	2.2	105	93.3	1497	16.0	53.7	2.40
	P-11	80.0-80.8	24.4-24.6	CL	2.4	116	112.7	1809	13.8	75.2	2.40
	P-13	100.8-101.6	30.7-31.0	ML	2.0	97	110.9	1780	15.6	81.1	2.40
JM-B-2	P-1	5.0-5.8	1.5-1.8	CL	2.3	111	106.9	1716	12.8	60.2	2.40
	P-4	20.0-20.8	6.1-6.3	CL	0.4	20	96.2	1544	24.3	87.4	2.00
	P-8	80.0-80.8	24.4-24.6	CL	2.4	115	117.0	1878	14.5	89.0	2.40
JM-B-3	P-1	5.0-6.0	1.5-1.8	CL	1.1	51	102.6	1647	19.3	81.2	2.40
	P-5	25.0-25.9	7.6-7.9	CL	4.4	211	114.8	1843	11.1	64.0	2.09
JM-B-4	P-1	5.8-6.4	1.8-2.0	CL	4.9	235	104.2	1672	10.7	47.0	2.09
	P-3	15.0-15.8	4.6-4.8	CL	2.9	138	109.8	1762	14.1	71.0	2.09
	P-7	50.0-50.8	15.2-15.5	CH	4.0	190	88.3	1417	31.2	92.8	2.09
	P-10	80.0-80.8	24.4-24.6	CL	1.7	80	92.3	1481	27.2	89.1	2.09
JM-B-5	P-1	5.0-5.9	1.5-1.8	CL	1.5	71	79.5	1276	20.4	49.3	2.09
JM-B-6	P-4	21.1-21.9	6.4-6.7	SC	3.4	160	117.2	1881	6.8	41.8	1.74
	P-10	70.0-70.8	21.3-21.6	CL	8.0	385	97.0	1557	25.2	92.1	2.40
JM-B-7	D-5	20.5-21.0	6.2-6.4	CL	16.0	766	113.3	1818	15.1	84.0	2.00
JM-B-8	P-10	70.0-70.8	21.3-21.6	CL	11.0	528	117.9	1892	9.4	59.1	2.40
JM-B-9	P-5	25.8-26.5	7.9-8.1	CL	2.3	108	106.8	1714	14.3	66.9	2.40
	P-10	74.8-75.5	22.8-23.0	CL	7.3	350	99.0	1589	22.3	85.7	2.40
JM-B-10	P-7	40.0-40.7	12.2-12.4	CL	3.2	155	103.2	1656	16.0	68.4	2.40
	P-15	147.5-148.2	45.0-45.2	CH	16.4	787	96.9	1555	24.0	87.6	2.40
	P-18	225.0-225.7	68.6-68.8	CL	10.8	517	104.2	1672	19.1	83.7	2.40
JM-B-11	P-2	10.5-11.2	3.2-3.4	CL	2.8	132	113.4	1820	11.0	61.4	2.40
	P-7	31.0-31.7	9.4-9.7	CL	3.5	167	112.3	1802	13.5	72.8	2.40
	P-11	71.1-71.8	21.7-21.9	CH	2.7	129	99.7	1600	19.7	77.1	2.40
	P-16	150.5-151.2	45.9-46.1	CH	9.4	452	98.6	1583	15.4	58.6	2.40
JM-B-12	P-10	70.0-70.7	21.3-21.5	CL	4.6	219	109.5	1757	16.3	81.8	2.40
JM-B-14	P-8	50.0-50.8	15.2-15.5	CL	7.1	342	99.5	1597	22.0	85.6	2.40
JM-B-15	P-14	150.0-150.9	45.7-46.0	ML	4.0	193	110.2	1769	10.0	50.9	2.40

SUMMARY OF UNCONFINED COMPRESSION TEST RESULTS
JORNADA DEL MUERTO, NEW MEXICO, RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE B-2

FUGRO NATIONAL, INC.

BORING NO.	SAMPLE NO.	SAMPLE INTERVAL		SOIL TYPE	TYPE OF TEST	DRY DENSITY		MOISTURE CONTENT (%)	CONFINING PRESSURE (σ_3)		MAXIMUM DEVIATOR STRESS ($\sigma_1 - \sigma_3$)		STRAIN RATE (%/min)	BACK PRESSURE	
		FEET	METERS			pcf	kg/m^3		ksf	kN/m^2	ksf	kN/m^2		ksf	kN/m^2
JM-B-1*	P-8	50.0-50.9	15.2-15.5	CL	CD	97.7	1568	14.6	5.0	240	10.8	517	0.03	0.0	0.0
	P-8	50.0-50.9	15.2-15.5	CL	CD	97.7	1568	14.6	7.9	378	16.7	800	0.03	0.0	0.0
	P-8	50.0-50.9	15.2-15.5	CL	CD	97.7	1568	14.6	12.2	584	30.2	1447	0.03	0.0	0.0
	P-8	50.9-51.4	15.5-15.7	SM	UU	100.8	1618	7.8	7.9	378	21.8	1044	0.9	0.0	0.0
JM-B-3	P-2	10.0-10.8	3.0-3.3	CL	CU	108.1	1735	11.6	1.0	48	5.4	259	0.1	0.0	0.0
	P-3	15.0-15.8	4.6-4.8	CL	CD	105.0	1685	13.7	5.0	240	11.8	565	0.1	0.0	0.0
	P-3	15.8-16.6	4.8-5.1	CL	CU	99.6	1599	13.7	5.0	240	9.8	469	0.1	0.0	0.0
JM-B-6	P-3	15.0-15.8	4.6-4.8	SP	CD	109.6	1759	5.7	1.0	48	5.2	249	0.1	0.0	0.0
	P-3	15.8-16.6	4.8-5.1	SP	CD	107.2	1721	6.5	6.0	288	20.9	1001	0.1	0.0	0.0
JM-B-7	P-6	27.8-28.6	8.5-8.7	CL	CU	121.2	1946	11.2	3.0	144	15.4	738	0.1	0.0	0.0
	P-6	28.6-29.3	8.7-8.9	CL	CU	122.7	1970	10.5	7.9	378	18.6	891	0.1	0.0	0.0
JM-B-8	P-5	25.0-25.8	7.6-7.9	SM	CD	104.3	1674	8.9	2.4	115	13.9	666	0.1	0.0	0.0
	P-5	25.8-26.6	7.9-8.1	SM	CD	120.5	1934	9.6	8.6	412	34.1	2299	0.1	0.0	0.0
JM-B-17	P-12	80.8-81.5	24.6-24.8	CL	CD	104.7	1681	20.3	7.9	378	12.1	580	0.1	0.0	0.0
	P-12	81.5-82.5	24.8-25.1	CL	CD	112.9	1812	14.7	15.1	723	17.3	829	0.1	0.0	0.0

* Multi-stage test

SUMMARY OF TRIAXIAL SHEAR TEST RESULTS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE B-3

FUGRO NATIONAL, INC.

BORING NO.	SAMPLE NO.	SAMPLE INTERVAL		SOIL TYPE	NORMAL STRESS		MAXIMUM SHEAR STRENGTH	
		FEET	METERS		ksf	kN/m^2	ksf	kN/m^2
JM-B-2	P-3	15.0-15.8	4.57-4.82	CL	6.0	290	3.7	177
	P-3	15.0-15.8	4.57-4.82	Cl	1.0	48	1.2	56
JM-B-5	P-5	32.3-33.0	9.85-10.06	SC	8.0	386	5.1	246
	P-5	32.3-33.0	9.85-10.06	SC	3.0	145	2.5	118
	P-9	73.0-73.7	22.25-22.46	ML	10.9	524	7.7	368
	P-9	73.0-73.7	22.25-22.46	ML	7.1	338	4.8	228
JM-B-6	P-8	50.0-50.8	15.2-15.5	SM	10.0	479	6.5	312
	P-8	50.0-50.8	15.2-15.5	SM	5.0	241	4.0	191
JM-B-7	P-7	40.0-40.5	12.2-12.3	SM	12.2	586	11.4	548
	P-7	40.0-40.5	12.2-12.3	SM	4.0	193	7.1	339
JM-B-8	P-3	15.0-15.5	4.6-4.7	SM	7.9	379	5.4	261
	P-3	15.0-15.5	4.6-4.7	SM	1.0	48	0.7	34
JM-B-9	P-1	5.0-5.8	1.5-1.8	ML	6.5	310	5.0	241
	P-1	5.0-5.8	1.5-1.8	ML	1.0	48	1.3	61
JM-B-10	P-1	5.0-5.7	1.5-1.7	ML	6.5	310	5.4	261
	P-1	5.0-5.7	1.5-1.7	ML	1.0	48	2.2	105
	P-4	20.0-20.7	6.1-6.3	SM	7.2	345	4.8	228
	P-4	20.0-20.7	6.1-6.3	SM	2.2	103	1.8	872
JM-B-11	P-4	20.7-21.4	6.3-6.5	ML	5.8	276	6.3	302
	P-4	20.7-21.4	6.3-6.5	ML	2.0	97	3.4	165
JM-B-12	P-5	25.0-25.7	7.6-7.8	SP-SM	7.9	379	5.8	275
	P-5	25.0-25.7	7.6-7.8	SP-SM	2.2	103	1.7	81
JM-B-13	P-1	5.0-5.7	1.5-1.7	SC	5.8	276	4.5	217
	P-1	5.0-5.7	1.5-1.7	SC	1.0	48	1.3	632
JM-B-14	P-1	5.0-5.7	1.5-1.7	SM	5.8	276	4.0	193
	P-1	5.0-5.7	1.5-1.7	SM	1.0	48	1.0	48
JM-B-15	P-3	17.0-17.7	5.2-5.4	SP-SM	7.9	379	5.4	260
	P-3	17.0-17.7	5.2-5.4	SP-SM	2.2	103	1.6	335
JM-B-17	P-1	5.0-5.7	1.5-1.7	ML	5.8	276	4.6	221
	P-1	5.0-5.7	1.5-1.7	ML	1.0	48	2.2	104

SUMMARY OF DIRECT SHEAR TEST RESULTS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE B-4

FUGRO NATIONAL, INC.

COMPOSITE SAMPLE NUMBER	SOIL TYPE	PERCENT PASSING #200	ATTERBERG LIMITS		SPECIFIC GRAVITY	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)	COMPACTED DRY DENSITY		COMPACTED MOISTURE (%)	PERCENT OF MAXIMUM DRY DENSITY	CBR (%)
			LL	PI		pcf	kg/m³		pcf	kg/m³			
A	SC-SM	30	24	6	2.7	135.5	2171	6.0	129.5	2074	5.0	95.6	43.7
									120.7	1933	4.7	89.1	17.5
									112.6	1804	4.7	83.1	4.9
B	SM	34		NP*	2.8	121.0	1938	9.5	120.5	1930	8.2	99.6	22.3
									113.1	1812	7.8	93.5	11.0
									104.9	1680	7.4	86.7	5.3
C	SM	14		NP*	2.65	125.3	2007	8.5	116.9	1873	7.2	93.3	39.1
									111.0	1778	6.5	88.6	12.7
									106.2	1701	7.6	84.8	8.6

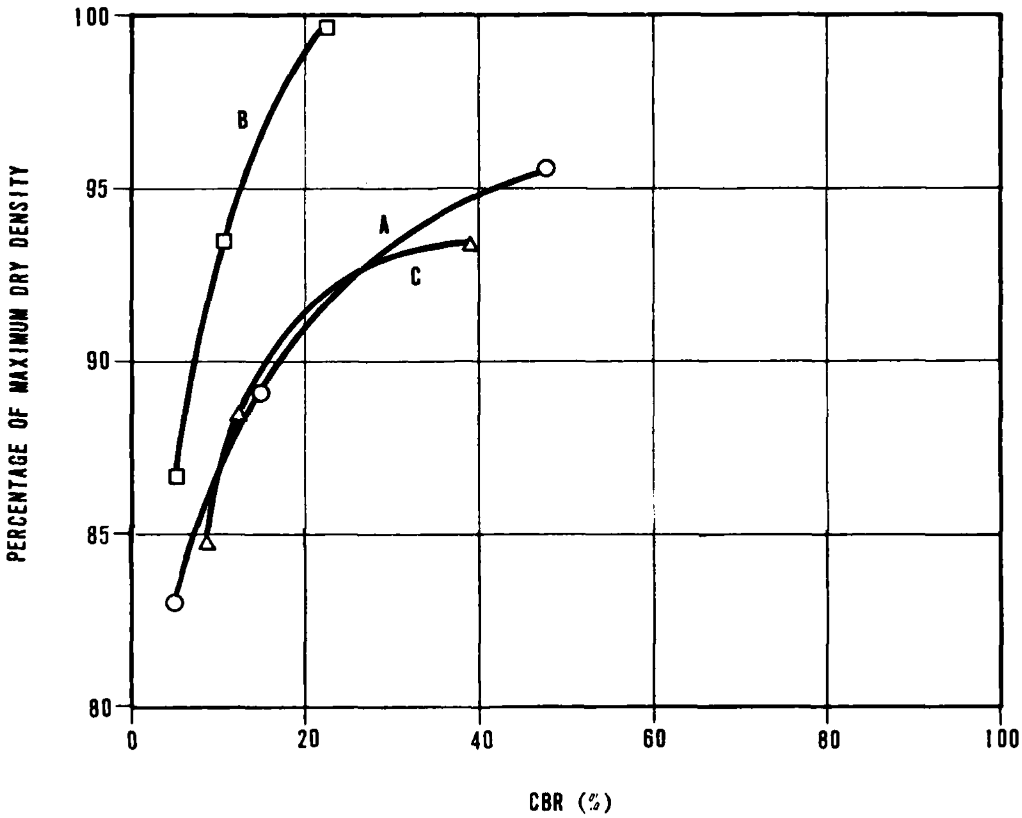
*NP NOT PLASTIC

CALIFORNIA BEARING RATIO
(CBR) TEST RESULTS
JORNADA DEL MUERTO, NEW MEXICO, RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE B-5

FUGRO NATIONAL, INC.



SYMBOL	COMPOSITE SAMPLE NUMBER	SOIL TYPE
○	A	SC-SM
□	B	SM
△	C	SM

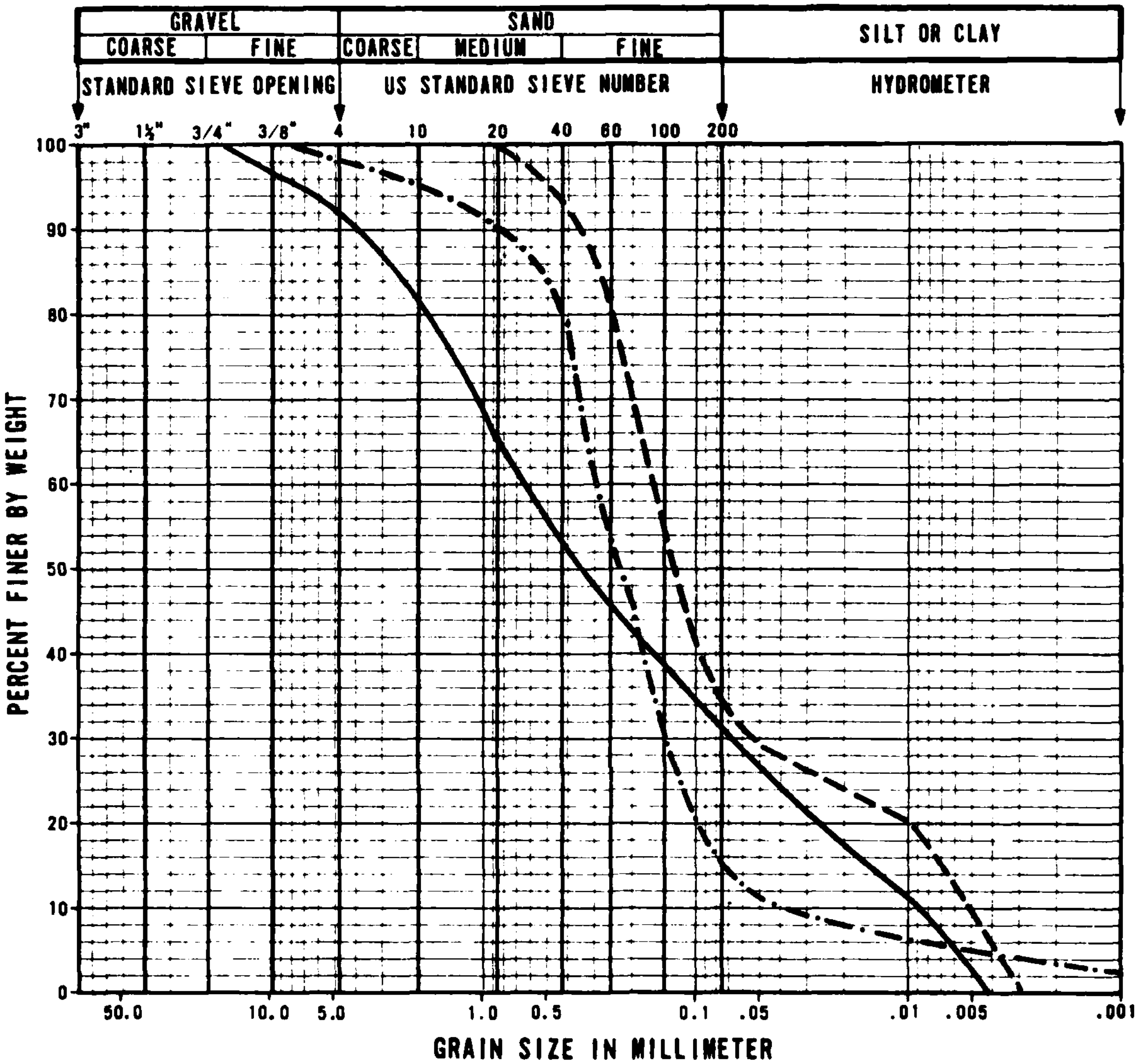
CALIFORNIA BEARING RATIO
(CBR) CURVES
JORNADA DEL MUERTO, NEW MEXICO, RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE B-7

FUGRO NATIONAL, INC.

FN-TR-26c



SYMBOL	COMPOSITE SAMPLE NUMBER	TRENCH NUMBER	SAMPLE INTERVAL		SOIL TYPE
			FEET	METERS	
———	A	JM-T-7	0.0 - 18.0	0.0 - 5.5	SC-SM
— —	B	JM-T-12	12.0 - 18.0	3.7 - 5.5	SM
-·-·-	C	JM-T-14	0.0 - 18.5	0.0 - 5.5	SM

GRAIN SIZE CURVES, CBR TESTS
JORNADA DEL MUERTO, NEW MEXICO
RIO GRANDE CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE B-8

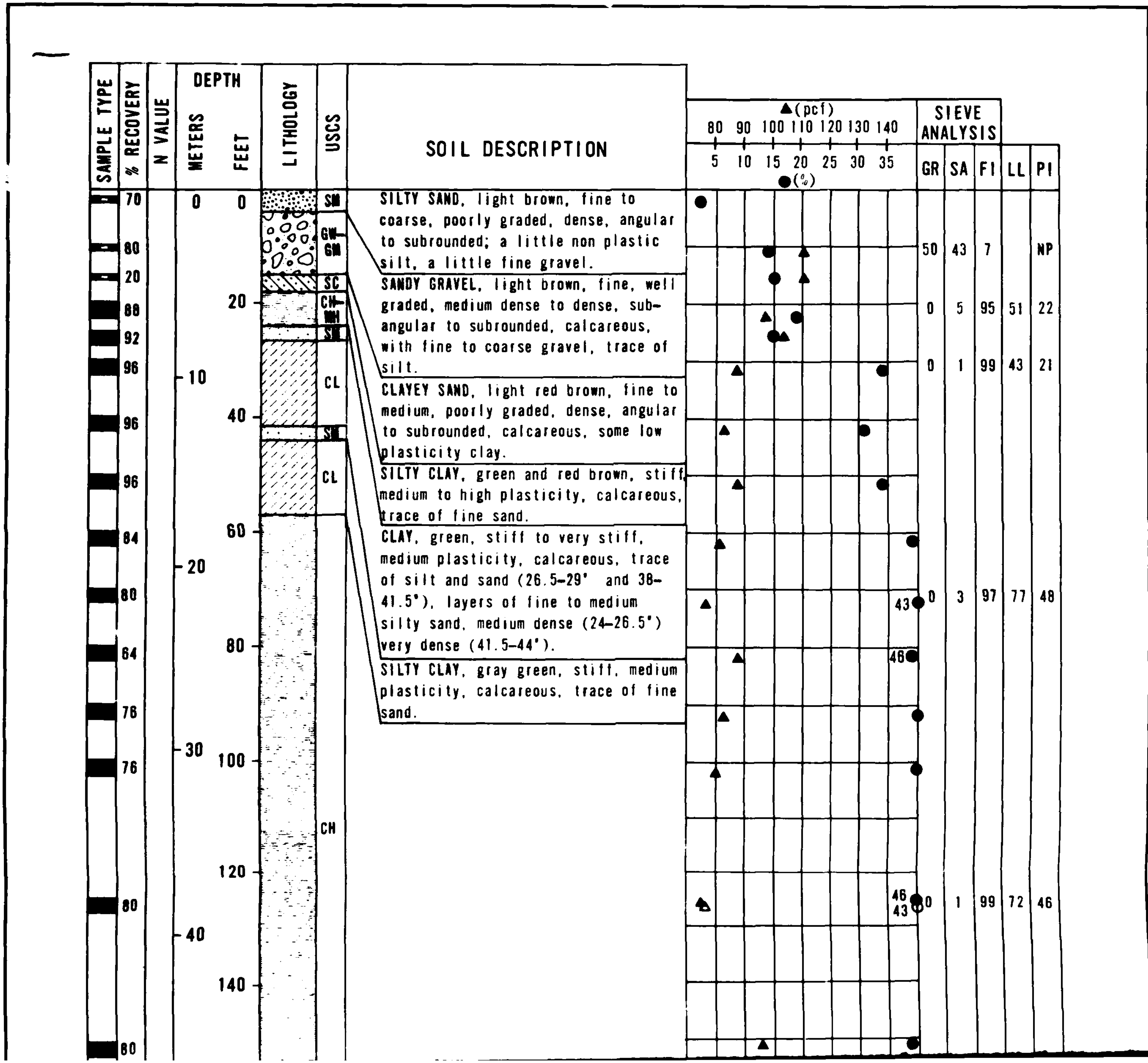
FUGRO NATIONAL, INC.

APPENDIX C

GEOTECHNICAL DATA - SAN SIMON VALLEY

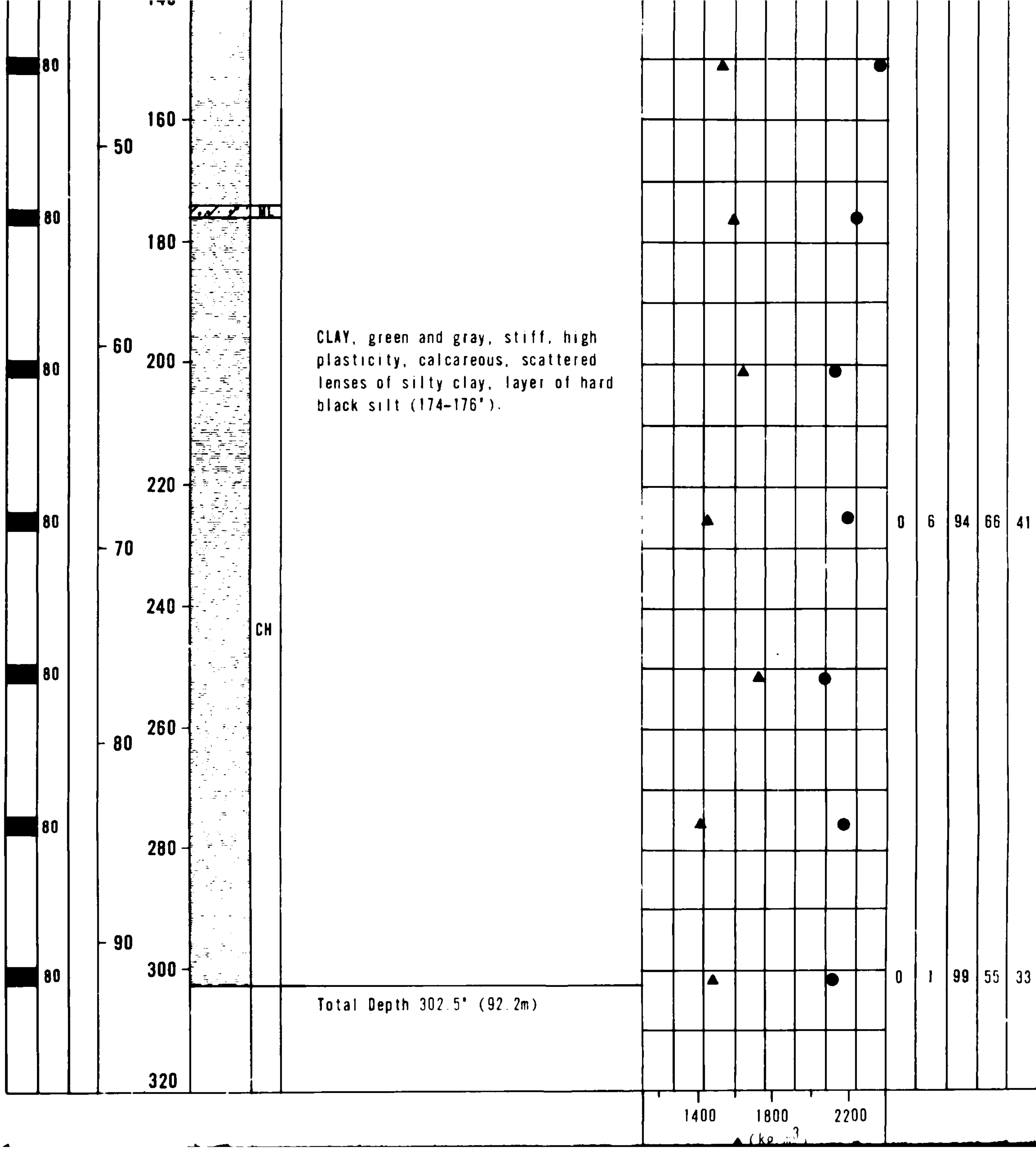
TABLE OF CONTENTS
APPENDIX C

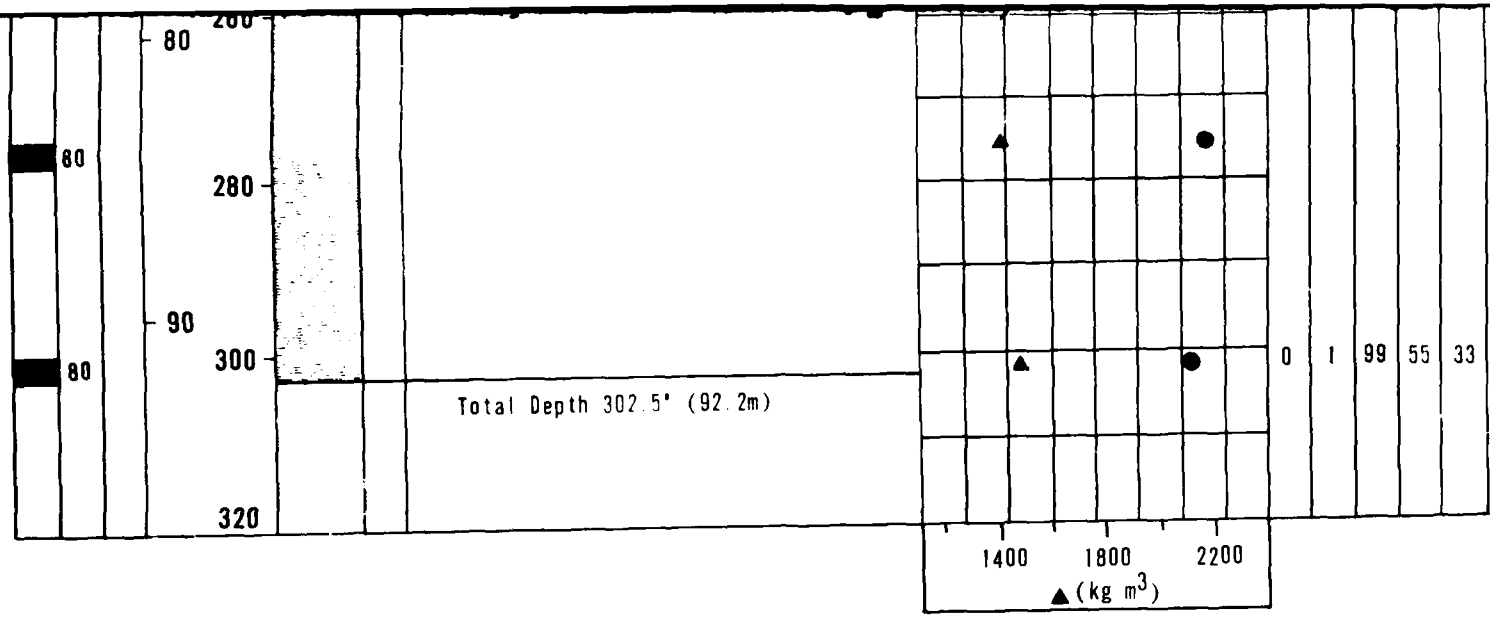
FN-TR-26c



SAMPLE TYPE
% RECOVERY
N VALUE
DEPTH
METERS
FEET
LITHOLOGY
USCS
SOIL DESCRIPTION
▲(pcf)
80 90 100 110 120 130 140
5 10 15 20 25 30 35
●(%)
SIEVE ANALYSIS
GR SA FI LL PI
70 80 20 88 92 96 96 96 84 80 64 76 76 80 80
0 10 20 30 40
0 20 40 60 80 100 120 140
SM GW-GM SC CH-MH SM CL SM CL CH
SILTY SAND, light brown, fine to coarse, poorly graded, dense, angular to subrounded; a little non plastic silt, a little fine gravel.
SANDY GRAVEL, light brown, fine, well graded, medium dense to dense, sub-angular to subrounded, calcareous, with fine to coarse gravel, trace of silt.
CLAYEY SAND, light red brown, fine to medium, poorly graded, dense, angular to subrounded, calcareous, some low plasticity clay.
SILTY CLAY, green and red brown, stiff, medium to high plasticity, calcareous, trace of fine sand.
CLAY, green, stiff to very stiff, medium plasticity, calcareous, trace of silt and sand (26.5–29' and 38–41.5'), layers of fine to medium silty sand, medium dense (24–26.5') very dense (41.5–44').
SILTY CLAY, gray green, stiff, medium plasticity, calcareous, trace of fine sand.
50 43 7 NP
0 5 95 51 22
0 1 99 43 21
43 0 3 97 77 48
46
46 43 0 1 99 72 46

2


80
80
80
80
80
80
80
50
60
70
80
90
160
180
200
220
240
260
280
300
320
ML
CH
CLAY, green and gray, stiff, high plasticity, calcareous, scattered lenses of silty clay, layer of hard black silt (174-176').
Total Depth 302.5' (92.2m)
0 6 94 66 41
0 1 99 55 33
1400
1800
2200



SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE
- CORE

ENGINEERING PARAMETERS

N – STANDARD PENETRATION TEST (ASTM: D-1586-67)
R – N VALUE GREATER THAN 100 BLOWS/FOOT
▲ – DRY UNIT WEIGHT (ASTM: D-2937-71)
● – MOISTURE CONTENT (ASTM: D-2216-71)
NR – NO RECOVERY

BORING DETAILS

ELEVATION : 3480' (1061m)
DATE DRILLED : 8-11 December 1977
DRILLING METHOD : Rotary Wash
HOLE DIAMETER : 4 7/8" (124mm)
CASING INSTALLED : None
WATER LEVEL : Not Apparent

LOG OF BORING SS-B-1
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE C-1

FUGRO NATIONAL, INC.

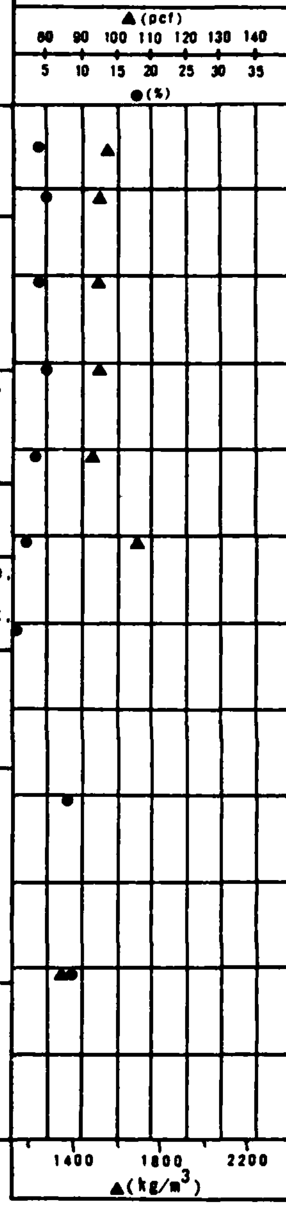
3

FN-TR-26c

Depth (Meters)	Depth (Feet)	USCS	Soil Description
0	0	SM	SILTY SAND, light brown, fine, well graded, loose (0-2'), medium dense (2'-4.5'), calcareous, some non plastic silt, trace of fine gravel.
3	10	ML	SANDY SILT, brown, firm, non plastic, calcareous; with fine to medium sand; scattered zones with a trace of fine gravel.
		SM	SILTY SAND, brown, fine to medium, medium dense, subangular to subrounded, calcareous, some low plasticity silt and clay; trace of fine gravel.
6	20	ML	SANDY SILT, brown, firm, non-plastic, calcareous; some fine sand.
		SP-SM	SAND, brown, fine to medium, dense, subangular to subrounded, calcareous, trace of non plastic silt, trace of fine gravel.
9	30	GP-SP	SANDY GRAVEL-GRAVELLY SAND, brown, fine to coarse, medium dense to dense, subangular to subrounded, calcareous, with fine to medium sand, trace of silt.
12	40	ML	CLAYEY SILT, brown, stiff, low plasticity, calcareous, trace of fine sand, layer of brown, hard, medium plasticity clay (47.5'-50') lense of very dense, silty sand (50'-50.5').
15	50	CL / ML	
			Total Depth 51.0' (15.5m)
18	60		

% RECOVERY: 100 for all samples.

GR	SA	FI	LL	PI
3	72	25		
0	47	53		
0	21	79		NP
50	48	2		



SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE

ENGINEERING PARAMETERS

N — STANDARD PENETRATION TEST (ASTM: D-1586-67)
R — N VALUE GREATER THAN 100 BLOWS/FOOT
▲ — DRY UNIT WEIGHT (ASTM: D-2937-71)
● — MOISTURE CONTENT (ASTM: D-2216-71)
NR — NO RECOVERY

BORING DETAILS

ELEVATION : 3320' (1012m)
DATE DRILLED : 12 December 1977
DRILLING METHOD : Hollow Stem Auger
HOLE DIAMETER : 6 5/8" (168mm)
CASING INSTALLED : None
WATER LEVEL : Not Apparent

LOG OF BORING SS-B-4
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

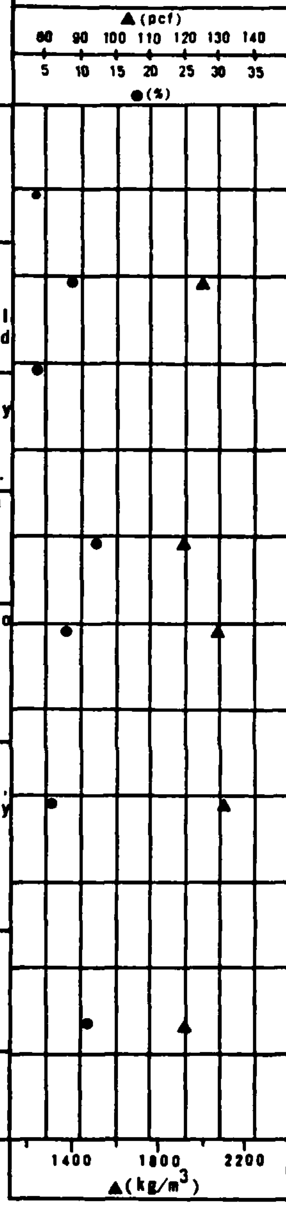
FIGURE C-2

FUGRO NATIONAL, INC.

FN-TR-26c

% RECOVERY	DEPTH (FEET)	USCS	SOIL DESCRIPTION	GR	SA	FI	LL	PI
70, 75	0	GC-GM	SANDY GRAVEL, red brown, fine to coarse, poorly graded, dense to very dense, subangular to subrounded, calcareous, some medium to coarse sand, some low plasticity clay and silt.	41	33	28	20	5
60	10	SC	GRAVELLY SAND, red brown, fine to coarse, poorly graded, very dense, subangular to subrounded, calcareous, some fine to coarse gravel some low plasticity clay, scattered cobbles.					
100		GC	SANDY GRAVEL, dark yellow brown, fine to coarse, poorly graded, very dense, subangular to subrounded calcareous, some fine to medium sand, a little low plasticity clay.					
100	20	GP						
100		SC	SANDY GRAVEL, dark red brown, fine to coarse, poorly graded, very dense, calcareous, a little fine to coarse sand, trace of low plasticity silt.	13	44	43		
60	30	SC	CLAYEY SAND, red and white, fine to medium, poorly graded, very dense, subangular to subrounded, calcareous; with low plasticity clay, a little fine gravel, stage I to stage II caliche.					
20	40	SC	GRAVELLY SAND, red brown and white, fine to coarse, poorly graded, very dense, subangular to subrounded, calcareous, some fine gravel, some low plasticity clay, scattered caliche nodules.					
80	50	SC	CLAYEY SAND, yellow red, fine to medium, well graded, very dense, subangular to subrounded, calcareous, with low plasticity clay, trace of fine gravel.	2	52	46	35	12
	60		Total Depth 54.0' (16.5m)					

Depth scale: METERS 0, 3, 6, 9, 12, 15, 18; FEET 0, 10, 20, 30, 40, 50, 60.



SAMPLE TYPES

- STANDARD PENETRATION TEST
- FUGRO DRIVE
- BULK
- PITCHER TUBE

ENGINEERING PARAMETERS

N — STANDARD PENETRATION TEST (ASTM: D-1586-67)
R — N VALUE GREATER THAN 100 BLOWS/FOOT
▲ — DRY UNIT WEIGHT (ASTM: D-2937-71)
● — MOISTURE CONTENT (ASTM: D-2216-71)
NR — NO RECOVERY

BORING DETAILS

ELEVATION : 3940' (1201m)
DATE DRILLED : 13 December 1977
DRILLING METHOD : Rotary Wash
HOLE DIAMETER : 4 7/8" (124mm)
CASING INSTALLED : None
WATER LEVEL : Not Apparent

LOG OF BORING SS-B-8
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE C-3

FUGRO NATIONAL, INC.

FN-TR-26c

BULK SAMPLE	DEPTH METERS	DEPTH FEET	LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS GR	SA	FI	LL	PI
	0	0		GC	Loose	SANDY GRAVEL, brown, fine to coarse, poorly graded, subangular to subrounded; dry, non-stratified, non cemented, a little cobbles and boulders, maximum size 1.0', some fine to coarse sand, some low plasticity clay and silt, stage I to stage II caliche.	41	31	28		
	1, 2	2, 4, 6, 8		GW-GM	Very dense	SANDY GRAVEL, gray, fine to coarse, well graded, subangular to subrounded, calcareous, dry, non stratified, moderately to strongly cemented stage II to stage III caliche, some cobbles and boulders, maximum size 1.2', with fine to coarse sand, trace of silt.	49	40	11		
	3	10		CL-ML	Very stiff	SILTY CLAY-CLAYEY SILT, light brown, low to medium plasticity, calcareous, dry, homogeneous, non cemented, a little fine to coarse sand, trace of fine gravel, scattered hard clay nodules.	5	17	78	44	17
	4, 5, 6	12, 14, 16, 18, 20, 22				Total Depth 11.5' (3.5m) Stability of Vertical Walls: Stable					

TRENCH DETAILS

SURFACE ELEVATION : 3400' (1036m)
DATE EXCAVATED : 10 December 1977
SURFACE GEOLOGIC UNIT : A5i
TRENCH LENGTH : 29' (8.8m)
TRENCH ORIENTATION : NS

LOGGED BY ______ CHECKED BY ______ APPROVED BY ______

LOG OF TRENCH SS-T-1
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE C-4

FUGRO NATIONAL, INC.

FN-TR-26c

BULK SAMPLE	DEPTH METERS / FEET	LITHOLOGY	USCS	CONSISTENCY	SOIL DESCRIPTION	SIEVE ANALYSIS GR	SA	FI	LL	PI
	0 / 0		SM	Loose	SILTY SAND, light brown, fine to medium, well graded, subangular, calcareous, dry, non stratified, non cemented, some low plasticity silt and clay, trace of fine gravel.	1	67	32		
			CH	Very stiff	SILTY CLAY, light brown, medium to high plasticity, calcareous, dry, homogeneous, weakly cemented to non cemented, some fine sand.	0	25	75	57	37
			CL	Hard	SANDY CLAY, gray, low plasticity, calcareous, dry, homogeneous, moderately to strongly cemented, some fine to medium sand, stage II to stage III caliche, trace of gravel.	6	38	56		
			SC	Dense	CLAYEY SAND, brown, fine to coarse, well graded, angular to subangular, with low plasticity clay and silt, trace of gravel.	1	58	41		
	3.7 / 12				Total Depth 12.0' (3.7m) Stability of Vertical Walls: Stable					

Depth scale: Meters 0, 1, 2, 3, 4, 5, 6; Feet 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22

TRENCH DETAILS

SURFACE ELEVATION : 3540' (1079m)
DATE EXCAVATED : 11 December 1977
SURFACE GEOLOGIC UNIT : A5y
TRENCH LENGTH : 31' (9.4m)
TRENCH ORIENTATION : NS

LOG OF TRENCH SS-T-3
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE C-5

FUGRO NATIONAL, INC.

FN-TR-26c

Depth (feet)	USCS	Consistency	Soil Description	Sieve Analysis GR	Sieve Analysis SA	Sieve Analysis FI	LL	PI
0–3.0	SC-SM	Medium dense	CLAYEY SAND-SILTY SAND, light brown, fine, poorly graded, calcareous, dry (0-0.5'), slightly moist (0.5' to 3.0'), non stratified, non cemented, with low plasticity clay and silt.	0	55	45	26	7
3.0–6.0	SP-SM	Medium dense	SAND, light brown, fine to medium, poorly graded, calcareous, dry, stratified, gravel increases with depth from a trace at 3' to a little at 6', non-cemented, trace of non plastic silt.	10	82	8		
6.0–6.5	CL	Stiff	SILTY CLAY, gray, low plasticity, calcareous, dry, homogeneous, non cemented.					
6.5–12.5	SM	Medium dense	SILTY SAND, light brown, fine, poorly graded, calcareous, dry, stratified with lenses of sandy silt, non cemented, some non plastic silt; trace of fine, rounded gravel.	1	66	33		
12.5			Total Depth 12.5' (3.8m) Stability of Vertical Walls: Stable					

TRENCH DETAILS

SURFACE ELEVATION : 3320' (1012m)
DATE EXCAVATED : 11 December 1977
SURFACE GEOLOGIC UNIT : A4e
TRENCH LENGTH : 28' (8.5m)
TRENCH ORIENTATION : N75W

LOG OF TRENCH SS-T-5
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE C-6

FUGRO NATIONAL, INC.

LOGGED BY
CHECKED BY
APPROVED BY

BORING NUMBER	SAMPLE NUMBER (a)	SAMPLE INTERVAL		PERCENT FINER BY WEIGHT												
				STANDARD SIEVE OPENING							U S STANDARD SIEVE NO					PART SIZE
				BLDRS.	COBBLES		GRAVEL				SAND				SILT OR C	
		FEET	METERS	24"	12"	6"	3"	1½"	3/4"	3/8"	4	10	40	100	200	.005
SS-B-1	D-1	2.0-2.5	0.61-0.76													
	D-2	10.0-10.5	3.05-3.20					100	84	69	50	36	23	12	7	
		10.0-10.5	3.05-3.20													
		10.0-10.5	3.05-3.20													
	D-3	15.0-15.2	4.57-4.63													
	P-4	21.4-22.2	6.52-6.77									100	99	98	95	27
	P-5	25.0-25.7	7.62-7.83													
	P-6	30.0-30.7	9.14-9.36													
		30.7-31.4	9.36-9.57										100	99	99	[illegible]
		31.4-32.4	9.57-9.88													
	P-7	40.7-41.4	12.41-12.62													
	P-8	50.7-51.4	15.45-15.67													
	P-9	60.7-61.4	18.50-18.71													
	P-10	71.4-72.[illegible]	21.76-21.[illegible]4									100	99	98	97	[illegible]
	P-11	80.7-81.6	24.60-24.87													
	P-12	90.7-91.4	27.64-27.86													
	P-13	100.7-101.4	30.69-30.91													
	P-14	125.0-125.7	38.10-38.31										100	99	99	[illegible]
		125.9-126.4	38.37-38.53													
		126.4-127.0	38.53-38.71													
	P-15	150.0-150.7	45.72-45.93													
	P-16	175.7-176.4	53.55-53.77													
	P-17	200.0-200.7	60.96-61.17													
	P-18	225.7-226.4	68.79-69.01									100	[illegible]	96	94	[illegible]
	P-19	250.7-251.4	76.41-76.63													
	P-20	275.7-276.4	84.03-84.25													
	P-21	300.7-301.4	91.65-91.87										100	99	99	[illegible]

NOTES:

(a) Sample types
- SS - Standard split spoon
- P - Pitcher
- D - Fugro Drive
- B - Bulk

(b) NP - Not Plastic

(c) USCS - Unified Soil Classification System

(d) * Indicates that test has been performed and results are included in this report.

PARTICLE (mm) CLAY .001	ATTERBERG LIMITS (b) LL	PL	PI	USCS (c)	IN-SITU DRY UNIT WEIGHT (pcf)	(kg/m³)	MOISTURE CONTENT (%)	SATURATION (%)	VOID RATIO	COMPACTED MAXIMUM DRY DENSITY (pcf)	(kg/m³)	OPTIMUM MOISTURE (%)	SPECIFIC GRAVITY OF SOLIDS	TRIAXIAL (d)	UNCONFINED COMPRESSION	DIRECT SHEAR	CONSOLIDATION	CHEMICAL	RELATIVE DENSITY
				SM			2.4												
			NP	GW-GM	110.3	1767	2.8	14.3	0.53							*			
				GW-GM												*			
				GW-GM												*			
				SC	110.3	1767	15.6	79.8	0.53										
[illegible]	51	29	22	CH-MH	97.5	1562	18.9	70.2	0.73						*		*	*	
				SM	104.1	1668	14.8	64.7*	0.62										
				CL										*					
[illegible]	43	22	21	CL	87.7	1405	34.0	99.7	0.92				2.68	*					
				CL										*					
				CL	83.3	1334	31.0	91.9	1.0										
				CL	87.3	1398	34.0	98.5	0.93										
				CH	81.2	1301	39.2	96.5	1.1										
	77	29	4[illegible]	CH			42.7												
				CH	87.7	1405	39.0	100	0.92										
				CH	82.6	1323	46.1	100	1.0										
				CH	80.4	1288	39.8	98.2	1.1										
[illegible]	72	26	46	CH			45.9							*					
				CH			45.1							*					
				CH											*				
				CH	96.3	1543	38.2	100	0.75										
				ML	99.4	1592	36.3	100	0.70										
				CH	10[illegible]	1655	31.8	100	0.63										
[illegible]	66	25	41	CH	90.8	1455	32.7	100	0.86						*				
				CH	107.9	1719	29.3	100	0.56										
				CH	88.9	1424	33.3	100	0.89										
[illegible]	55	22	33	CH	92.6	1483	31.8	100	0.82						*				

2

SUMMARY OF LABORATORY TEST RESULTS
BORING SS-B-1
SAN SIMON VALLEY, ARIZONA, HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

TABLE C-1

FUGRO NATIONAL, INC.

BORING NO.	SAMPLE NO.	SAMPLE INTERVAL FEET	SAMPLE INTERVAL METERS	SOIL TYPE	UNCONFINED COMP. STRENGTH ksf	UNCONFINED COMP. STRENGTH kN/m^2	DRY DENSITY pcf	DRY DENSITY kg/m^3	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	HEIGHT/DIAMETER
SS-B-1	P-4	21.6-22.2	6.58-6.77	CH-MH	3.6	172	90.3	1447	25.9	81.0	2.4
	P-18	225.9-226.4	68.76-69.10	CH	11.3	541	91.1	1459	31.8	100	2.4
	P-21	300.9-301.4	91.71-91.87	CH	11.4	546	93.3	1495	30.4	100	2.4
SS-B-6	D-3	10.0-10.5	3.05-3.20	SC	7.2	344	107.4	1721	10.2	48.6	2.4
SS-B-7	D-1	2.5-3.0	0.76-0.91	CL	13.7	656	109.0	1746	10.0	49.4	2.4
SS-B-9	D-9	47.0-47.5	14.33-14.48	CL	5.5	263	110.8	1775	13.3	69.2	2.4
SS-B-11	P-3	10.9-11.4	3.32-3.47	CL	9.7	464	93.4	1496	13.5	45.3	2.4
SS-B-12	D-7	30.0-30.5	9.14-9.30	CL-ML	6.5	311	95.4	1528	10.1	35.7	2.4
	D-10	60.0-60.5	18.29-18.44	CH	34.4	1647	94.8	1519	22.7	78.8	2.4

SUMMARY OF UNCONFINED COMPRESSION TEST RESULTS

SAN SIMON VALLEY, ARIZONA, HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE C-2

FUGRO NATIONAL, INC.

FN-TR-26c

BORING NO.	SAMPLE NO.	SAMPLE INTERVAL		SOIL TYPE	TYPE OF TEST	DRY DENSITY		MOISTURE CONTENT (%)	CONFINING PRESSURE (σ_3)		MAXIMUM DEVIATOR STRESS ($\sigma_1 - \sigma_3$)		STRAIN RATE (% min)	BACK PRESSURE	
		FEET	METERS			pcf	kg/m^3		ksf	kN/m^2	ksf	kN/m^2		ksf	kN/m^2
SS-B-1	P-6	30.7-31.4	9.34-9.57	CL	CD	93.4	1496	28.7	3.3	158	14.2	680	0.1	0	0
	P-6	31.9-32.4	9.72-9.88	CL	CD	94.7	1517	27.4	13.2	632	26.8	1283	0.1	0	0
SS-B-11	P-9	50.2-50.7	15.30-15.45	SC-CL	CD	115.6	1852	9.4	10.1	484	22.7	1087	0.1	0	0
	P-9	51.1-51.6	15.58-15.73	SC-CL	CD	126.4	2025	8.0	10.1	484	49.3	2361	0.1	0	0

SUMMARY OF TRIAXIAL SHEAR TEST RESULTS
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE C-3

FUGRO NATIONAL, INC.

BORING NO.	SAMPLE NO.	SAMPLE INTERVAL		SOIL TYPE	NORMAL STRESS		MAXIMUM SHEAR STRENGTH	
		FEET	METERS		ksf	kN/m^2	ksf	kN/m^2
SS-B-1	D-2	10.0-10.5	3.05-3.20	GW-GM	1.0	48	1.3	62
	D-2	10.0-10.5	3.05-3.20	GW-GM	2.0	96	1.6	77
	D-2	10.0-10.5	3.05-3.20	GW-GM	4.0	192	2.8	134
SS-B-2	D-1	2.0-2.5	0.61-0.76	CH	0.2	10	1.6	77
	D-1	2.0-2.5	0.61-0.76	CH	0.5	24	2.0	96
	D-1	2.0-2.5	0.61-0.76	CH	1.0	48	4.8	230
	P-3	10.9-11.4	3.32-3.47	SC	1.0	48	1.7	81
	P-3	10.9-11.4	3.32-3.47	SC	2.0	96	3.4	163
	P-3	10.9-11.4	3.32-3.47	SC	4.0	192	5.7	273
SS-B-3	D-3	10.0-10.5	3.05-3.20	SM	1.0	48	0.8	38
	D-3	10.0-10.5	3.05-3.20	SM	2.0	96	1.5	72
	D-3	10.0-10.5	3.05-3.20	SM	4.0	192	3.7	177
SS-B-4	D-1	2.5-3.0	0.76-0.91	SM	0.2	10	0.4	19
	D-1	2.5-3.0	0.76-0.91	SM	0.5	24	0.5	24
	D-1	2.5-3.0	0.76-0.91	SM	1.0	48	0.8	38
SS-B-6	D-1	2.5-3.0	0.76-0.91	CL	0.2	10	0.6	29
	D-1	2.5-3.0	0.76-0.91	CL	0.5	24	0.9	43
	D-1	2.5-3.0	0.76-0.91	CL	1.0	48	3.7	177
SS-B-11	D-1	2.0-2.5	0.61-0.76	SM	0.2	10	0.5	24
	D-1	2.0-2.5	0.61-0.76	SM	0.5	24	0.5	24
	D-1	2.0-2.5	0.61-0.76	SM	1.0	48	2.0	96
SS-B-13	D-2	5.0-5.5	1.52-1.68	SC	0.5	24	1.5	72
	D-2	5.0-5.5	1.52-1.68	SC	1.0	48	2.0	96
	D-2	5.0-5.5	1.52-1.68	SC	2.0	96	4.3	206

SUMMARY OF DIRECT SHEAR TEST RESULTS
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE C-4

FUGRO NATIONAL, INC.

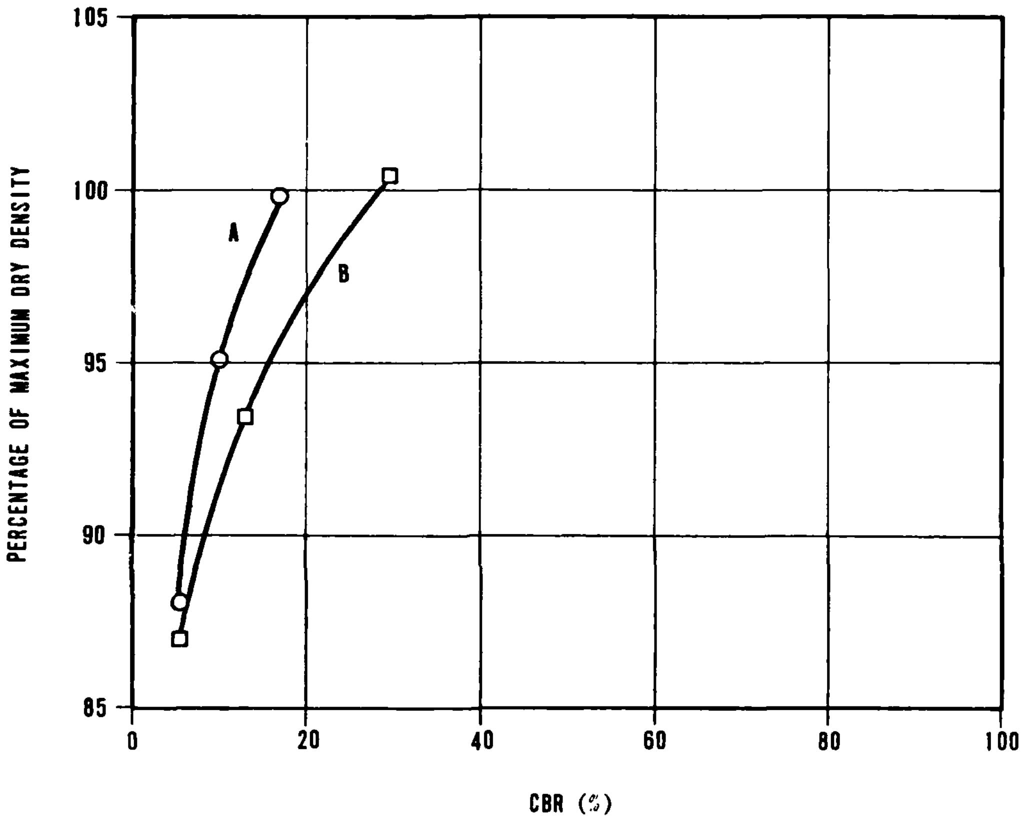
COMPOSITE SAMPLE NUMBER	SOIL TYPE	PERCENT PASSING #200	ATTERBERG LIMITS		SPECIFIC GRAVITY	MAXIMUM DRY DENSITY		OPTIMUM MOISTURE (%)	COMPACTED DRY DENSITY		COMPACTED MOISTURE (%)	PERCENT OF MAXIMUM DRY DENSITY	CBR (%)
			LL	PI		pcf	kg/m3		pcf	kg/m3			
A	SC	38				125.8	2015	10.5	110.8	1775	10.5	88.1	6
									119.6	1916	10.2	95.1	10
									125.5	2011	10.6	99.8	17
B	SC-SM	45	26	7		122.2	1958	12	106.3	1703	12.2	87.0	6
									114.3	1831	12.1	93.5	13
									123.1	1972	12.0	100.7	30

CALIFORNIA BEARING RATIO
(CBR) TEST RESULTS
SAN SIMON VALLEY, ARIZONA, HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE
C-5

FUGRO NATIONAL, INC.



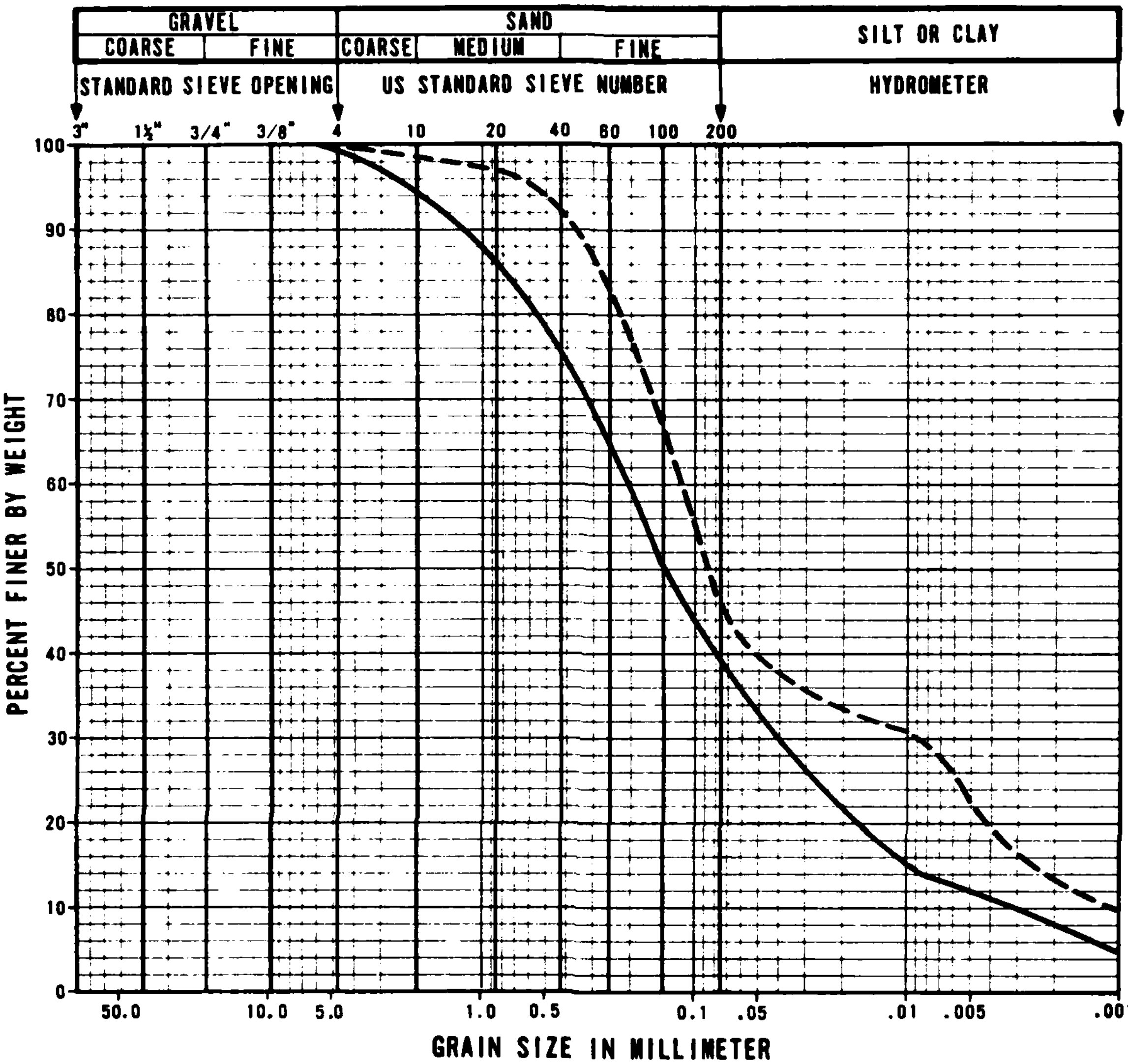
SYMBOL	COMPOSITE SAMPLE NUMBER	SOIL TYPE
○	A	SC
□	B	SC-SM

CALIFORNIA BEARING RATIO
(CBR) CURVES
SAN SIMON VALLEY, ARIZONA, HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE
C-7

FUGRO NATIONAL, INC.



SYMBOL	COMPOSITE SAMPLE NUMBER	TRENCH NUMBER	SAMPLE INTERVAL FEET	SAMPLE INTERVAL METERS	SOIL TYPE
———	A	SS-T-2	0.5 – 2.0	0.15 – 0.61	SC
		SS-T-3	10.0 – 12.0	3.05 – 3.66	
– – –	B	SS-T-5	1.0 – 2.5	0.30 – 0.76	SC-SM

GRAIN SIZE CURVES, CBR TESTS
SAN SIMON VALLEY, ARIZONA
HIGHLANDS CSP

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE C-8

FUGRO NATIONAL, INC.

END

DATE
FILMED
4-82

DTIC