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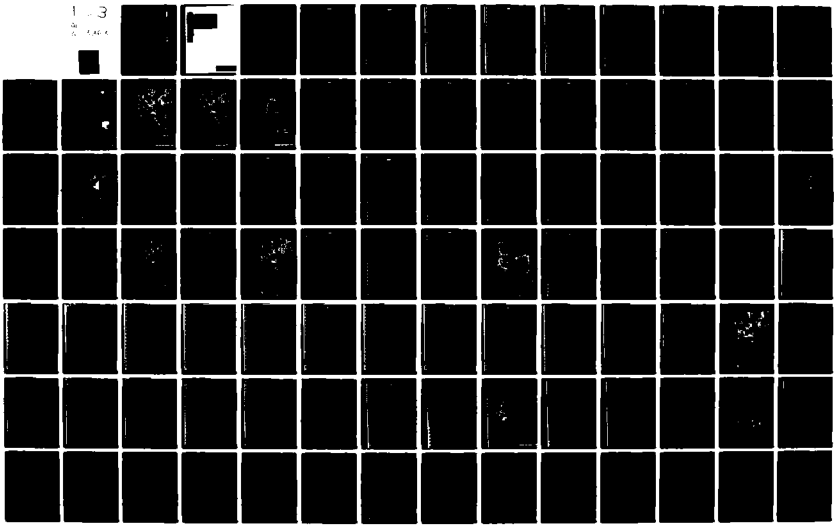

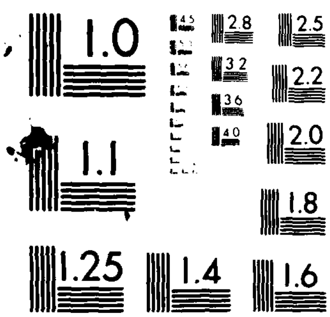

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

The Overall Geotechnical Evaluation Investigation dealt with two Bureau of Land Management areas and one Department of Defense co-use area; the Gila Bend Group + White Sands Missile Range Extension.

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7 May 1976

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1.0 INTRODUCTION

1.1 SUMMARY

This report was prepared for the Department of the Air Force, Space and Missile Systems Organization (SAMSO), in compliance with conditions of the statement of work as part of Contract No. F0 4701-74-D-0013 and deals with siting of the MX Land Mobile Advanced ICBM system.

This report was prepared for SAMSO by Steven L. Scott, Charles E. Partlow and James R. Miller, with final graphics preparation by Rod V. Jay and James A. Henneman. Technical review and partial preparation of this report was performed by Kenneth L. Wilson, Senior Geologist and Kenneth D. Hill, Senior Engineer. TRW Systems personnel monitored the study for SAMSO.

The overall Geotechnical Evaluation Investigation dealt with two Bureau of Land Management (BLM) areas and one Department of Defense (DoD) co-use area (Figure 1); the Gila Bend Group (GB) and White Sands Missile Range Extension (WE) are the subjects of this report (Volume IIB). The Gila Bend Group is the designation given to those BLM and associated lands in southwestern Arizona which lie north and east of the Yuma Proving Ground (Figure 2). The White Sands Missile Range Extension area is the name given to the co-use land which lies north of the White Sands Missile Range, New Mexico (Figure 3). For further discussions of the Extension area, or the siting study in general, BLM will be meant to include co-use.

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Sections 2.0 and 3.0 deal with the Gila Bend Group and 4.0 and 5.0 with the Extension area. Text discussion of the Extension area is abbreviated and limited to factors which contrast significantly with the DoD geotechnical report, Volume IIA on White Sands Missile Range/Fort Bliss Military Reservation (WSMR/FBMR).

Results of studies for the Nellis Group, Nevada (Volume IIA) are presented separately.

Results of the study are presented in a written format and as large (37" x 42") map and overlay graphics. Written materials for this Geotechnical Evaluation Investigation are presented in four volumes which specifically consist of:

- Volume I - Siting Evaluation Report for the BLM siting areas.
- Volume IIB - Geotechnical Report Gila Bend Group and White Sands Missile Range Extension.
- Volume III - Recommended Geotechnical Field Investigations for the BLM siting areas.

The purpose of this investigation and the general content of each of the volumes is contained in Section 1.2.

Large map and overlay graphics (with Explanation) were prepared for use with the three volumes cited above. The overlay graphics consist of base maps, designated GB-1 through GB-10 (Figure 2), and WE-1 through WE-3 (Figure 3) and five overlays for each map. Titles of the overlays are:

1. Trench

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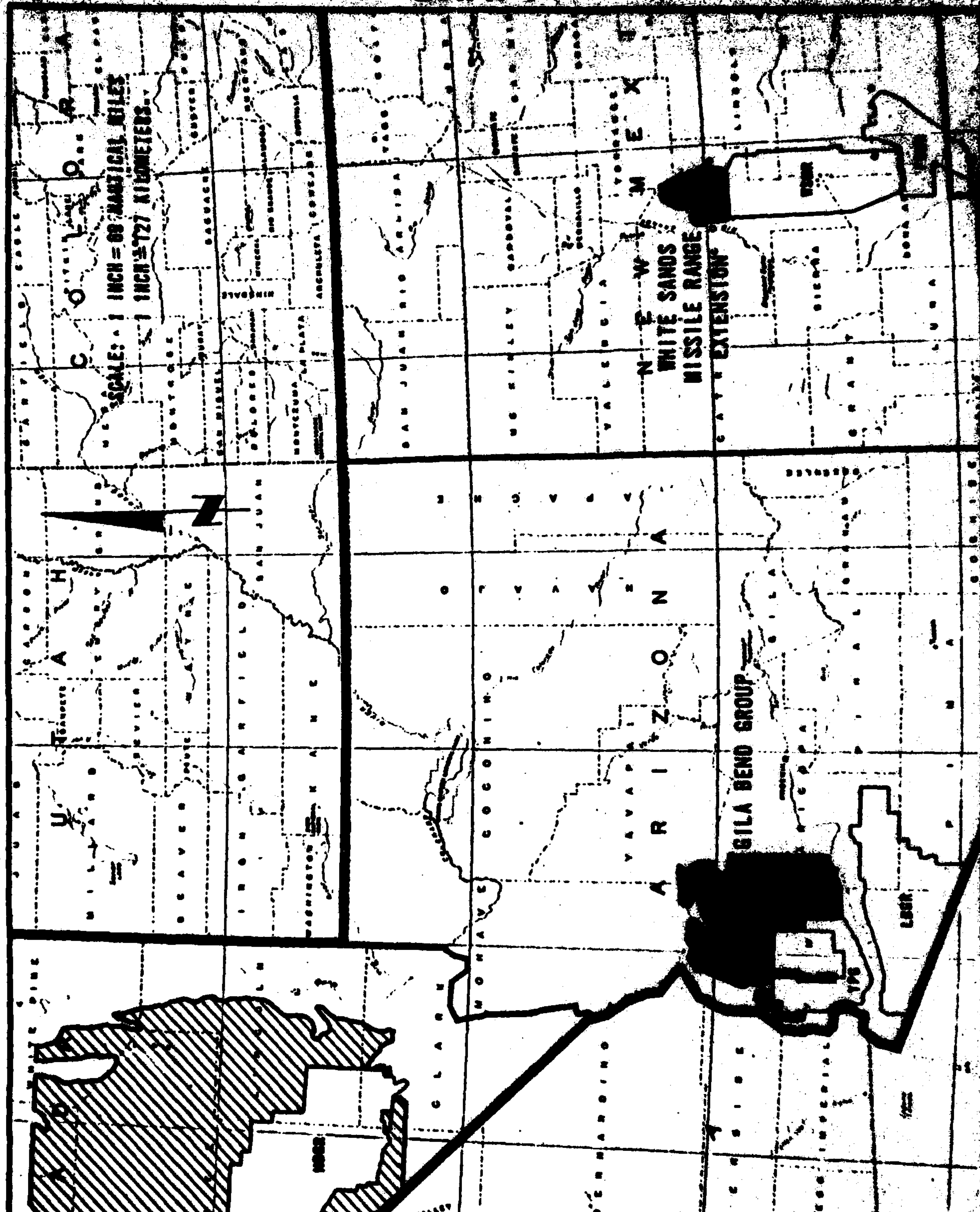

SITING AREA LOCATIONS

MX SITING INVESTIGATION

FIGURE 1

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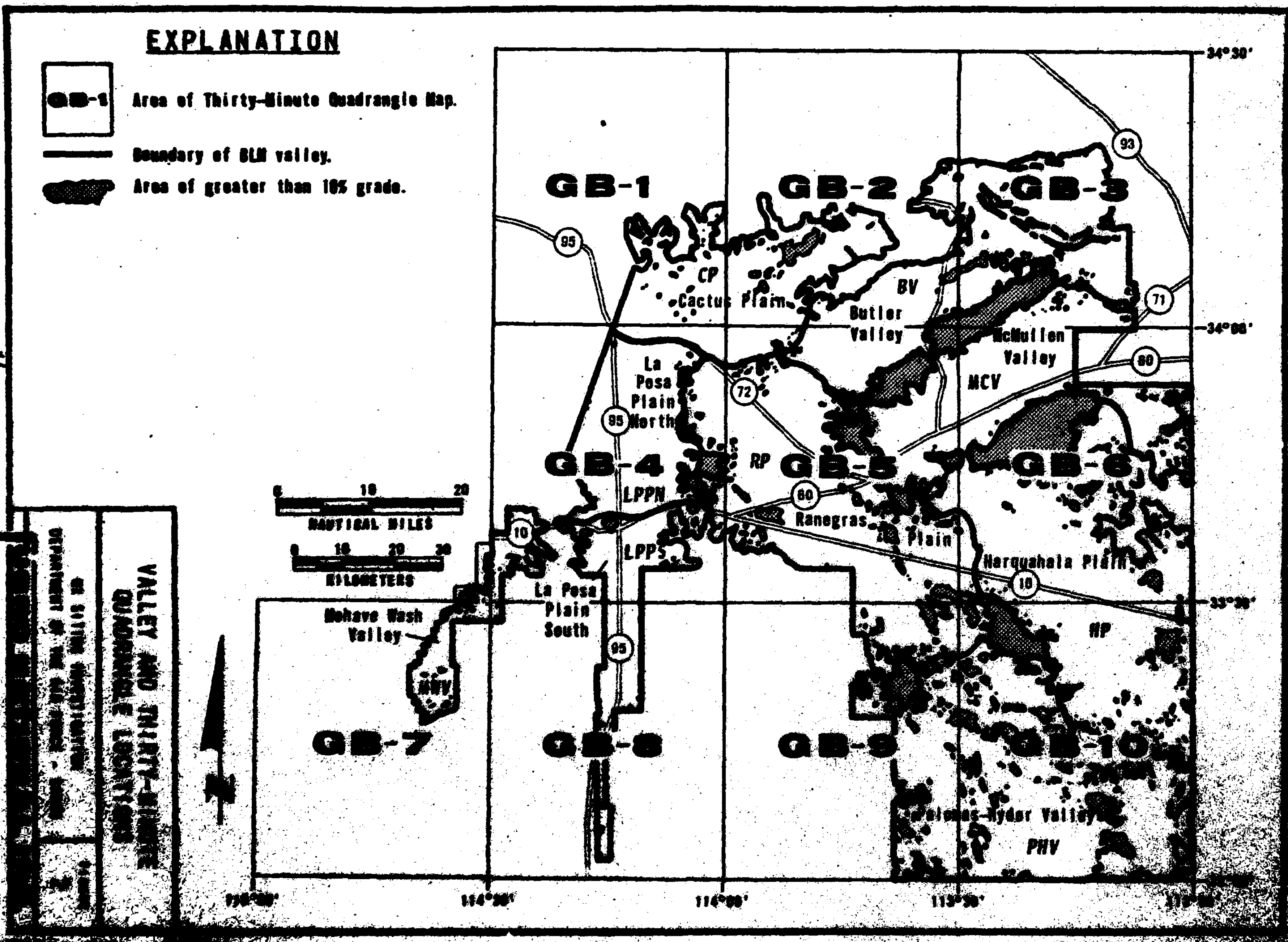

VALLEY AND THIRTY-MINUTE QUADRANGLE LOCATIONS

FIGURE 2

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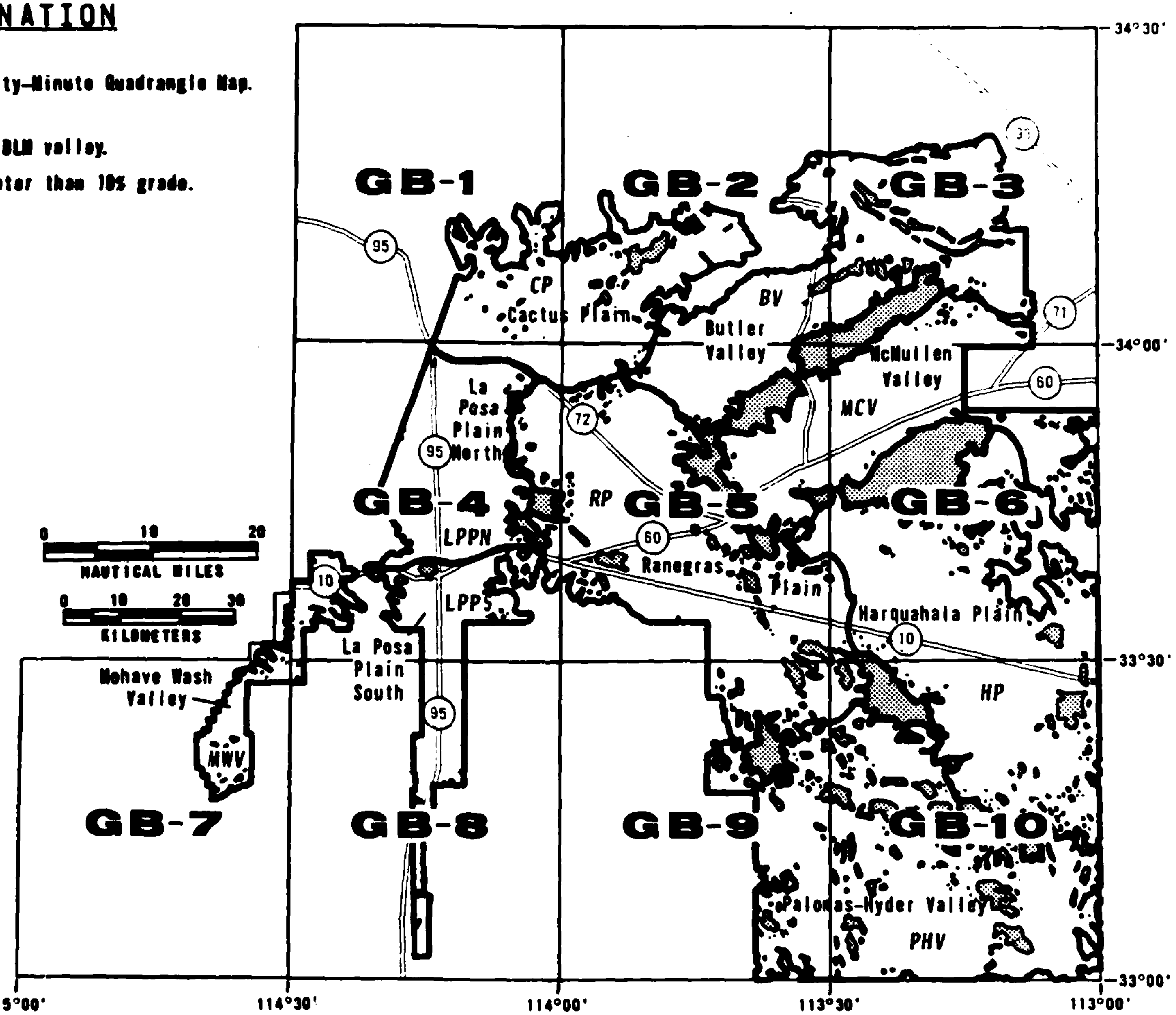
EXPLANATION

GB-1 Area of Thirty-Minute Quadrangle Map.

Boundary of BLM valley.

Area of greater than 10% grade.



VALLEY AND THIRTY-MINUTE QUADRANGLE LOCATIONS

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 2

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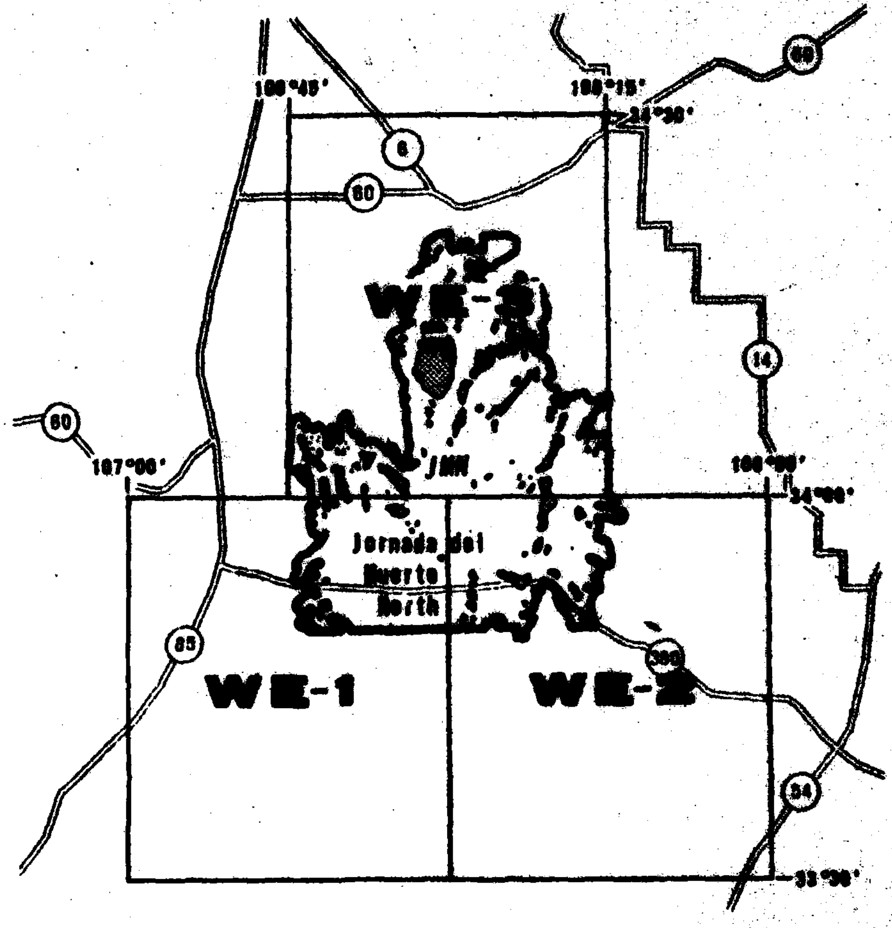

EXPLANATION

WE-1 — Area of Thirty-Minute Quadrangle Map.

Boundary of BLM valley.

Area of greater than 10% grade within BLM valley.

N

VALLEY AND THIRTY-MINUTE QUADRANGLE LOCATIONS

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2. Shelter

3. Hydrology

4. Geology and Soils Engineering

5. Ownership, Topography and Cultural Features.

The first two overlays show non-specific locations of trenches (line system) and shelters (aim-point system). The Gila Bend Group graphics have been divided and bound into four individual volumes, which are identified as follows:

Graphics Volume IIB-1 - (GB-1 through GB-4)

Graphics Volume IIB-2 - (GB-5 through GB-7)

Graphics Volume IIB-3 - (GB-8 through GB-10)

The White Sands Missile Range Extension graphics have been bound into a single volume identified as:

Graphics Volume IIB-4 - (WB-1 through WB-2)

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1.2 PURPOSE

The purpose of this phase of the study was to:

1. Collect and analyze available geotechnical and related data including:
   - a. Geology and Seismology
   - b. Topography and Terrain Analyses
   - c. Soils and Soils Engineering
   - d. Hydrology (surface and groundwater)
   - e. Climatology
   - f. Ownership and Cultural Features and Land Utilization

   For convenience, data for these categories are hereafter referred to as geotechnical data.
2. Report the results of data collection in a useful and informative format (Volumes IIA, IIB and overlays);
3. Locate potential sites for shelters and [illegible] using judgement based upon the results of items 1 and 2 above and criteria developed with SAMSO for the non-excluded areas (Volume I);
4. Evaluate and rank the BLM land areas from a geotechnical viewpoit according to their suitability for siting of the MX system (Volume I);
5. Based on items 1, 2, 3 and 4 determine in general what techniques and methods should be [illegible] geotechnical field investigations in [illegible] areas (Volume III).

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2.3 SCOPE

The scope of the study is presented in Task 13, with details in Tasks 1 through 16, of the "Program Plan for Geotechnical Services" prepared by Fugro National, Inc. (revised 9 February, 1976) in conjunction with SAMSO and TRW and includes:

1. Collection and analysis of available geotechnical data and selected environmental data (Tasks 1, 2, 3, 7, 8 and 13);
2. Analysis of available aerial photographs (Tasks 2, 3 and 13);
3. Brief ground and aerial reconnaissance of the siting area to collect additional data and verify geotechnical conditions determined during the literature research (Tasks 8 and 13);
4. Depiction of the data onto large and small graphics and written description of data within the text and on Data Summary Sheets (Tasks 4, 5, 6, 9, 10 and 13);
5. Identification, evaluation and ranking of potential siting areas for the land mobile system (Tasks [illegible] and 13).

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1.4 STUDY APPROACH AND METHODS

The collection and evaluation of existing geotechnical data from all available sources prior to commencement of field activities was a primary factor controlling the study approach. Data were collected from many agencies, institutions and individuals. Data collection activites included trips to Phoenix and Tucson, Arizona; Denver, Colorado; St. Louis, Missouri; and Vicksburg, Mississippi. A limited aerial and ground reconnaissance of the Gila Bend Group lands supplemented these collection trips. No data collection trips were conducted specifically for the Extension area. The data collected as a result of the DoD study for WSMR/FBMR (Fugro National, Inc. 1975a) were adequate for description of conditions in the Extension area.

Collected geotechnical data were evaluated to determine their specific applicability to siting parameters for the MX land mobile system before inclusion in any of the project reports. General and region-wide analyses, useful in the overall understanding of a siting area, were kept as limited as possible.

Compiled geotechnical data have been depicted primarily on base maps and overlays of the size defined by four fifteen-minute U. S. Geological Survey topographic maps [illegible] a thirty-minute map (also referred to as a four-[illegible]). Where fifteen-minute maps were not available, [illegible] or enlargements of other maps were used to obtain the [illegible] scale. Although such data were collected, [illegible] extensively depicted in [illegible]

[illegible]

generally exceeding ten percent (Section 2.1.[illegible]) or areas defined by significantly large quantity-distance explosions (Section 2.1.5). The relative locations of the thirteen four-quad sheets (GB-1 through GB-10 and MB-1 through MB-3) are shown on the small report graphics and on the four-quad base maps. References in the text to specific overlays are by the title of the overlay followed by the appropriate drawing number (e.g., Geology, GB-1 through GB-3).

Data depicted on the overlays were derived from general regional and site-specific studies. All contacts separating distinct geologic or soils units are shown as solid lines representing data as they were collected from the literature or as interpreted from aerial photographs. Depth contours (Hydrology and Geology overlays) and boundaries of drainage channels susceptible to flooding (Hydrology overlays) are dashed and dot dashed respectively, since some interpretation or refinement of the available data were necessary for the placement of the lines. These lines are queried where continuation of the data could not be made, or where extrapolations are uncertain.

Text discussion in the Geotechnical Report is limited mainly to introductory remarks, regional familiarization, qualifying statements and summary presentation. The text, small graphics and Data Summary Sheets (Section 3.0) supplement the overlays. The Data Summary Sheets aid in the interpretation and qualification of the data displayed on the overlays. [illegible] they present data which cannot be easily [illegible] lays and normally would be [illegible]

Important to siting considerations are contiguity of and accessibility between land areas suitable for siting. The Valley Analysis Concept (Section 3.0) has been introduced to enhance data depiction and usability. A Valley (designated by capitalized "V") is a sub-area of the siting area and may be composed of portions of one or more four-quad sheets for which geotechnical data may be compiled. The Valley definition for the DoD geotechnical reports differs somewhat from the Valley definition for the BLM geotechnical reports (Table 1). The major difference is that the mountains, which comprise most of the greater than ten percent topographic grade areas in the DoD Valleys, are not part of the BLM Valleys. The siting valley is that portion of the designated Valley remaining after removal of areas with greater than ten percent topographic grade (Section 2.1.6) and non-BLM, non-DoD lands (Section 2.1.6).

Typically, a BLM Valley includes an alluvial lowland area and excludes the flanks of its bordering mountain ranges. A geographic valley, as designated and named on existing maps, may encompass a portion of, or include the entire alluvial lowland area of a Valley. Most often Valley names correspond with the appropriate geographic valley name.

There are eight Valleys within the [illegible] (Figure [illegible]) and one Valley in the [illegible] area (Figure [illegible]). [illegible] and identification of each Valley and the Valley [illegible] depicted on 1:250,000 scale maps [illegible] Analysis (Sections 3.0 and 5.[illegible]) [illegible]

[illegible]

[illegible]

[illegible] Plain 3.3

Butler Valley 3.4

McMullen Valley 3.5

La Posa Plain 3.6

Ranegras Plain 3.7

Harquahala Plain 3.8

Palomas-Hyder Valley 3.9

Mohave Wash Valley 3.10

La Posa Plain is designated by North and South on the [illegible] graphics base map to aid in correlation with the [illegible] sheets.

In the White Sands Missile Range Extension Area there [illegible] valley, the Jornada del Muerto North [illegible]

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VALLEY TERMINOLOGY - BLM - DoD STUDY AREA

DEPARTMENT OF DEFENSE LANDS

A Valley (designated by capitalized "V") is a sub-area of a DoD siting area. It is bound by one or both of the following:

1. A hydrologic drainage divide (most often the crest of an intervening mountain range); and
2. DoD boundary or any other artificially established boundaries such as public highways, township and range lines or national monument borders.

BUREAU OF LAND MANAGEMENT LANDS

A Valley (designated by capitalized "V") is a sub-area of a BLM siting area. It is bound by one or more of the following:

1. Areas of greater than ten percent topographic grade;
2. Large exclusion areas such as National Forests, Indian reservations or quantity-distance areas;
3. DoD boundary or any other artificially established boundaries such as public highways, township and range lines, latitude lines; and
4. A hydrologic drainage divide (most often at a low relief intervalley connection).

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TABLE I

VALLEY TERMINOLOGY - BLM - DoD STUDY AREA

DEPARTMENT OF DEFENSE LANDS	BUREAU OF LAND MANAGEMENT LANDS
A Valley (designated by capitalized "V") is a sub-area of a DoD siting area. It is bound by one or both of the following: 1. A hydrologic drainage divide (most often the crest of an intervening mountain range); and a 2. DoD boundary or any other artificially established boundaries such as public highways, township and range lines or national monument borders.	A Valley (designated by capitalized "V") is a sub-area of a BLM siting area. It is bound by one or more of the following: 1. Areas of greater than ten percent topographic grade; 2. Large exclusion areas such as National Forests, Indian reservations or quantity-distance areas; 3. DoD boundary or any other artificially established boundaries such as public highways, township and range lines, latitude lines; and 4. A hydrologic drainage divide (most often at a low relief intervalley connection).

2.0 REGIONAL ANALYSIS

2.1 GEOGRAPHY AND DEMOGRAPHY

2.1.1 SITING AREA LOCATION AND DESCRIPTION

The Gila Bend Group siting area is located in southwestern Arizona and encompasses approximately 3065 nm^2. It lies principally in Yuma County with approximately one-fifth of the area extending eastward into Maricopa and Yavapai Counties (Figure _).

Interconnecting valleys of the Gila Bend Group form a roughly rectangular area extending southward from the Santa Maria River for __ nm, and eastward from the Colorado River for __ nm. Palomas-Hyder, Mohave Wash, and La Posa Plain Valleys are contiguous with the Yuma Proving Grounds (YPG) DoD siting area. Valley elevations range from 250 feet in Mohave Wash Valley to 2400 feet in McMullen Valley, and average between 1000 and 1500 feet for most of the siting area.

2.1.2 USES OF LAND AND SURFACE WATER

2.1.2.1 Land

2.1.2.1.1 General

BLM is the principal controlling agency for most of Valley areas, however, portions are private (E6) or state (E7) owned land or are under the control of other federal (E8) agencies. These three categories of non-BLM ownership total approximately 678 nm^2 or 22 percent of the total study area (Table) and are not considered available siting area. The remaining area (2387 nm^2) or 78 percent is controlled totally by the BLM and is considered available siting area. Ownership conditions are

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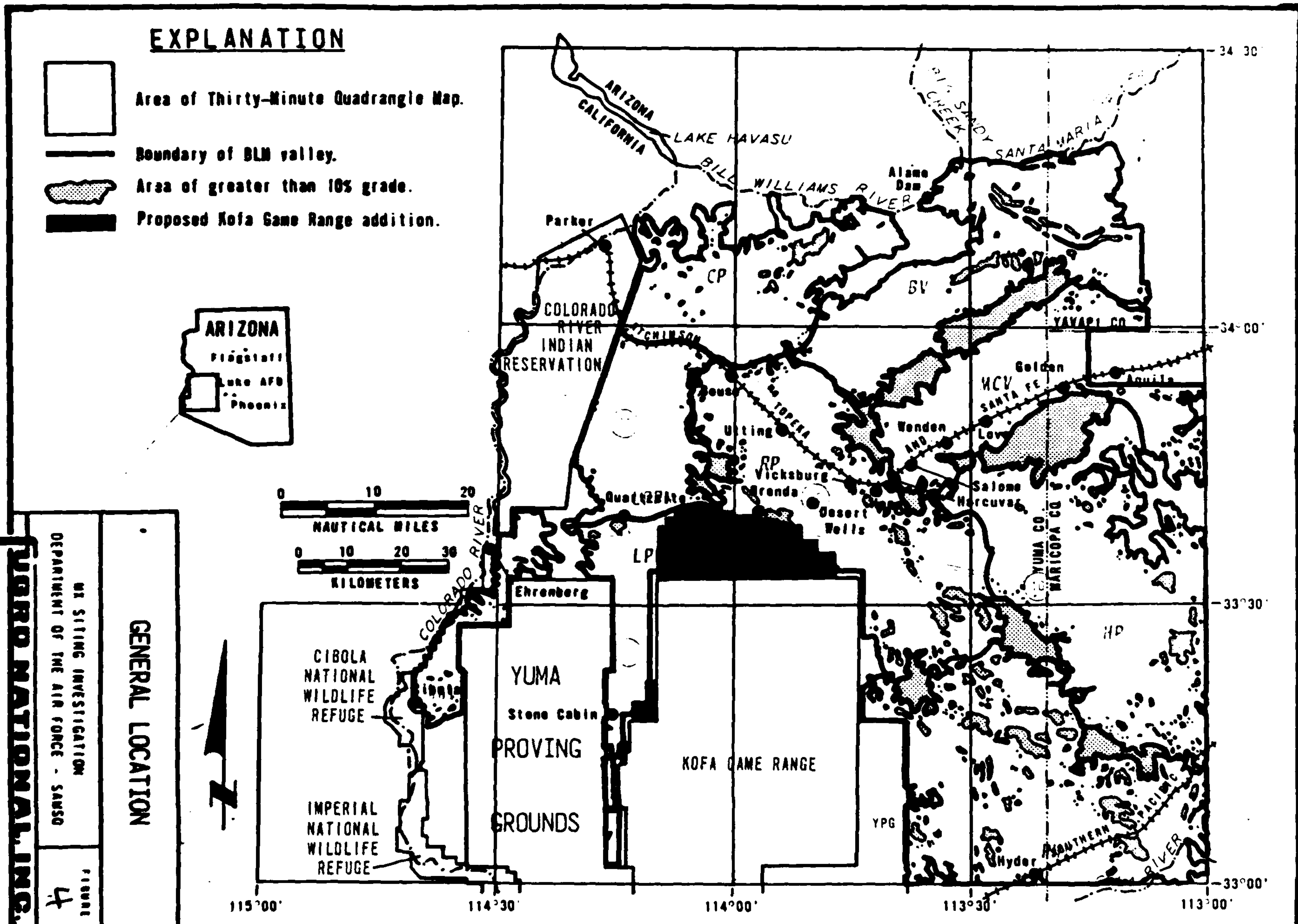

GENERAL LOCATION

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 4

FUGRO NATIONAL, INC.

depicted on the Ownership, Topography and Cultural Features overlays.

Table 2

Land Ownership

Owner	Exclusion	Area (nm^2)	Percent of Total Valley Area
Private	E6	308	10
State	E7	267	9
Federal (Non-BLM)	E8	68	2
BLM	—	2422	79
	Total	3065	100

2.1.2.1.2 BLM Lands

The BLM was established in 1946 to control and manage all lands formerly under the General Land Office and the Grazing Service. Management of BLM lands in the study area falls under the separate auspices of the Yuma and Phoenix BLM Regional offices. Objectives of the BLM include the protection and development of national resource lands and related resources consistent with the principles of multiple use. Withdrawals and transfers of large tracts of BLM land are based on application, and on accompanying environmental impact statement, stating the intended use of the land. Congressional action, in the form of a public land order, is required if the transfer is deemed to be in the public or national interest (Personal Communication, 1976).

Gila Bend Group BLM lands are generally unimproved desert areas used primarily for wildlife habitat, watershed and limited

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Table 2

Land Ownership

Owner	Exclusion	Area (nm^2)	Percent of Total Valley Area
Private	E6	308	10
State	E7	267	[illegible]
Federal (Non-BLM)	E8	68	2
BLM	—	2422	79
	Total	3065	100

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recreation. Secondary uses include leased areas of [illegible] cattle grazing, and irrigated cropland generally situated adjacent privately owned farms predominantly in McMullen Valley, Ranegras and Harquahala Plains (Ownership, GB-4, 5, 6, 10,). Isolated, old and abandoned mines are found in rock areas of less than ten percent grade around the Valley edge.

Portions of southern La Posa Plain (21 nm^2) and Ranegras Plain (14 nm^2) are under proposal for addition to the Kofa Game Range (Ownership, GB-5, 8). If included in the Kofa, this land would be withdrawn from the public domain and would be jointly administered by the BLM and the U. S. Fish and Wildlife Service as part of the National Refuge System.

2.1.2.1.3 <u>Privately Owned or Controlled Land</u>

Privately owned lands form the largest block of non-BLM land in the siting area. Private lands are present in all Valleys with the largest tracts occurring in the central portions of Ranegras (56 nm^2), Harquahala Plain, (51 nm^2) Butler Valley ([illegible] nm^2), McMullen Valley (49 nm^2) and Palomas-Hyder Valley ([illegible] nm^2). The private lands in these five Valleys account for approximately 88 percent (236 nm^2) of all the privately owned lands in the siting area (Figure __, Location Map). These lands are primarily used for irrigated agriculture ([illegible] and citrus crops) and to a lesser extent, cattle [illegible]. A small portion of private land is used for [illegible] and homesteads.

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2.1.2.1.4 Land Values

Current land values in south-western Arizona are dependent upon the status of land development and present use. Land status categories and the respective market values are listed in Table ___. Areas of land speculation are located near existing communities and major transportation routes, with land values in these areas being extremely variable.

Table 3

Current Land Values

Land Status	Approximate Current Market Value per Acre
Agriculural Land:	
citrus	\$800 - \$1500
farmland	\$800 - \$1500
undeveloped, with water	\$150 - \$ 300
Undeveloped Land:	\$ 50 minimum

Source: Office of the Yuma County Tax Assessor, April 1976.

2.1.2.1.5 State Owned Land

State-owned lands in the siting area are present in all Valleys except Mojave Wash Valley. They generally are large tracts of land, totaling 265 nm^2, bordering the large private tracts of land in Ranegras, Harquahala, Butler and McMullen and Palomas-Hyder Valleys. Present uses of the land are generally unknown, however, large tracts were noted during the aerial reconnaissance to be either unused or apparently leased by adjacent farmers and ranchers in the Valleys.

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Table 3

Current Land Values

Land Status	Approximate Current Market Value per Acre
Agriculural Land:	
citrus	\$800 - \$1500
farmland	\$800 - \$1500
undeveloped, with water	\$150 - \$ 300
Undeveloped Land:	\$ 50 minimum

Source: Office of the Yuma County Tax Assessor, April 1976.

2.1.2.1.6 Non-BLM, Non-DoD Federal Land

U. S. Bureau of Reclamation (USBR) is the single controlling federal agency for the 103 nm^2 non-BLM, non-DoD federal lands in the study area. A portion of this land serves as a one to two nm-wide corridor for the proposed Granite Reef Aqueduct through Cactus, Ranegras, and Harquahala Valleys (Ownership GB-2, 4, and 5). The remaining __ percent (___ nm^2) is present in Mohave Wash Valley; its present use is unknown.

2.1.2.1.7 Adjoining Land

Lands adjoining the Gila Bend Group siting area include the Yuma Proving Ground (YPG), Kofa Game Range, Colorado River Indian Reservation, and state and privately owned land. All lands except state properties are restricted access areas to the public. Only private properties are fenced, the remainder are posted on improved and unimproved entry roads and at set intervals along the respective boundaries.

The Yuma Proving Ground borders the southern and western borders of the study area, directly adjacent to and contiguous with Mohave Wash Valley, southern La Posa Plain, and Palomas-Hyder Valley for a distance of ___ nm (Ownership, GB-7, 8, 9). Yuma Proving Ground was established in 1943 under the U. S. Army Corps of Engineers and later was reassigned to the U. S. Army Material Command in 1962. YPG is an active bombing and gunnery range with highly restricted ground and air entry regulations.

The Kofa Game Range is situated northwest of YPG adjacent to Palomas-Hyder Valley and southern Ranegras Plain, [illegible] border ___ nm in length (Ownership, GB-4, 8, 9). The Kofa Game Range was established in 1939 for the conservation and development of wildlife and grazing resources to be jointly administered by the BLM and the U. S. Fish and Wildlife Service. The Kofa Game Range predominantly occupies areas greater than ten percent grade.

The Colorado River Indian Reservation forms the western border of the northern La Posa Plain and the Cactus Plain, a common boundary that is __ nm in length (Ownership, GB-1, 4). It was established in 1865, and includes the Mohave, Chemehuevi, Hopi and Navajo tribes. A population of approximately 1600 persons is supported by agriculture, light industry, and recreation. It is proposed that the Colorado River Indian Tribes will withdraw from BLM a four-mile buffer zone along the existing reservation boundary (Personal Communication, 1976).

Private and state held lands are intimately mixed in complex and irregular shaped clusters which generally align with the topographically lowest and most fertile area along the Valley axis. Privately owned parcels generally compose 20 or more sections per township along primary drainages and are most densely arranged near the portions of the Valley with highest groundwater. State owned land averages approximately one to five sections per township and occur isolated within dense private clusters or more densely along the flanks of the floodplain.

2.1.2.2 Surface Water

There are no known perennial surface water occurrences within the Gila Bend Group boundaries. The only important occurrences of surface water in the vicinity of the siting area are along the Colorado, Bill Williams, Santa Maria and Gila Rivers and their respective canal systems. The sources for these waters are outside the siting area boundaries and the water rights are previously assigned. The only unappropriated surface waters occur as sheet and channel flow from seasonal flash floods. In addition, the waters of the Colorado River are controlled by interstate agreements among California, Arizona and Nevada and by international treaty with Mexico. Surface water conditions within the Gila Bend Group area are discussed in Section 2.4.

2.1.3 POPULATION AND POPULATION DISTRIBUTION

Approximately ____ people are centered in towns or small settlements within and immediately adjacent to the study area. Small towns and communities occuring within and adjacent to the area are shown in Table __. Small populations generally are located at ranches or service centers along major highways in the area. The area has a high transient population which includes persons traveling through the area along the several public highways (Figure __).

2.1.4 CULTURAL IMPROVEMENTS

Access is primarily handled to the east and west by Interstate 10 and old U. S. Highway 60-70 which form a 'Y'-shaped intersection in the central portion of the study area. U. S. Highway 95 intersects Interstate 10 near Quartzsite, and State

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Routes 781, 72, and Alamo Dam Access roads diverge from U. S. Highway 60-70 (Figure __). Numerous improved dirt and unimproved jeep trails extend from these highways into various portions of the Valleys within the Gila Bend Group siting area. Travel on the public roads is generally unrestricted. Travel on unimproved or private roads may be restricted in privately controlled areas.

Railroads include the Atchison, Topeka and Santa Fe, extending from Parker to Aguila and the Southern Pacific traversing the southern portion of Palomas-Hyder Valley (Figure __).

Major electrical transmission lines transect the siting area, subparallel to U. S. Highways 95 and 60 and State Route 72 (Figure __). Small networks of transmission lines are also present in Palomas-Hyder Valley.

A buried pipeline network owned and operated by El Paso Natural Gas Company transects the siting area subparallel to U. S. 95, Interstate 10, and the Alamo Dam Access Road (Figure ___). A portion of this pipeline network is under consideration for conversion for crude oil transport.

A buried coaxial telephone cable, property of American Telephone and Telegraph (A T & T), extends east-west across the siting area, subparallel to Interstate 10 and U. S. 60 (Figure ___). Depth of burial ranges from 30 inches to four feet and as great as eight to ten feet below major drainages such as Centennial Wash (Fehringer, Oral Communication, 1976).

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TABLE 4

POPULATION CENTERS

Population Center*	Population**	Distance from Range
Yuma, Arizona	29,077	5.0 nm
Ajo, Arizona	8,000	4.0 nm
Blythe, California	7,047	7.1 nm
Gila Bend, Arizona	2,500	2.5 nm
Wellton, Arizona	970	2.5 m
Palo Verde, California	610	7.2 nm
Quartzsite	600	7.2 nm
Tacna, Arizona	595	2.0 nm
Ehrenberg, Arizona	400	3.9 nm
Roll, Arizona	80	3.8 nm
Dateland, Arizona	50	2.0 nm
Aztec, Arizona	50	3.5 nm
Sentinel, Arizona	35	2.0 nm
Martinez Lake, Arizona	10	0.2 nm
Dome, Arizona	10	1.7 nm
Cibola, Arizona	10	3.9 nm

* Locations shown on Figure 4.

** All population figures based on 1970 census (U. S. Census Bureau).

The proposed Granite Reef Aqueduct route transects the siting area subparallel to Interstate 10 and State Route 72 (Figure ___). Development of the Aqueduct system began in 1974 and is scheduled for completion by 1983.

Several operative public and private airfields are located in the siting area, principally adjacent to population centers such as Quartzsite, Bouse, Utting, and Wenden. Several abandoned facilities are also present. The locations of these features and more information about them, where known, are presented on the Ownership, Topography and Cultural Features Overlays, base maps, and Data Summary Sheets.

2.1.5 CULTURAL AND QUANTITY-DISTANCE EXCLUSIONS

The major cultural and quantity-distance exclusions which may limit available siting area are depicted on the appropriate overlays and include:

1. A minimum distance, 1965 feet, from inhabited buildings (E-3);
2. Corridors, 1780 feet wide, on each side of Interstate 10, U. S. Highways 60, 70, and 95, State Routes 71 and 72, and the Southern Pacific and Atchison, Topeka and Santa Fe Railroads (E-4);
3. State land (E-6);
4. Private land (E-7); and
5. Non-BLM, Non-DoD Federal land such as U. S. Bureau of Reclamation land (E-8).

In addition, the following minor quantity-distance and cultural

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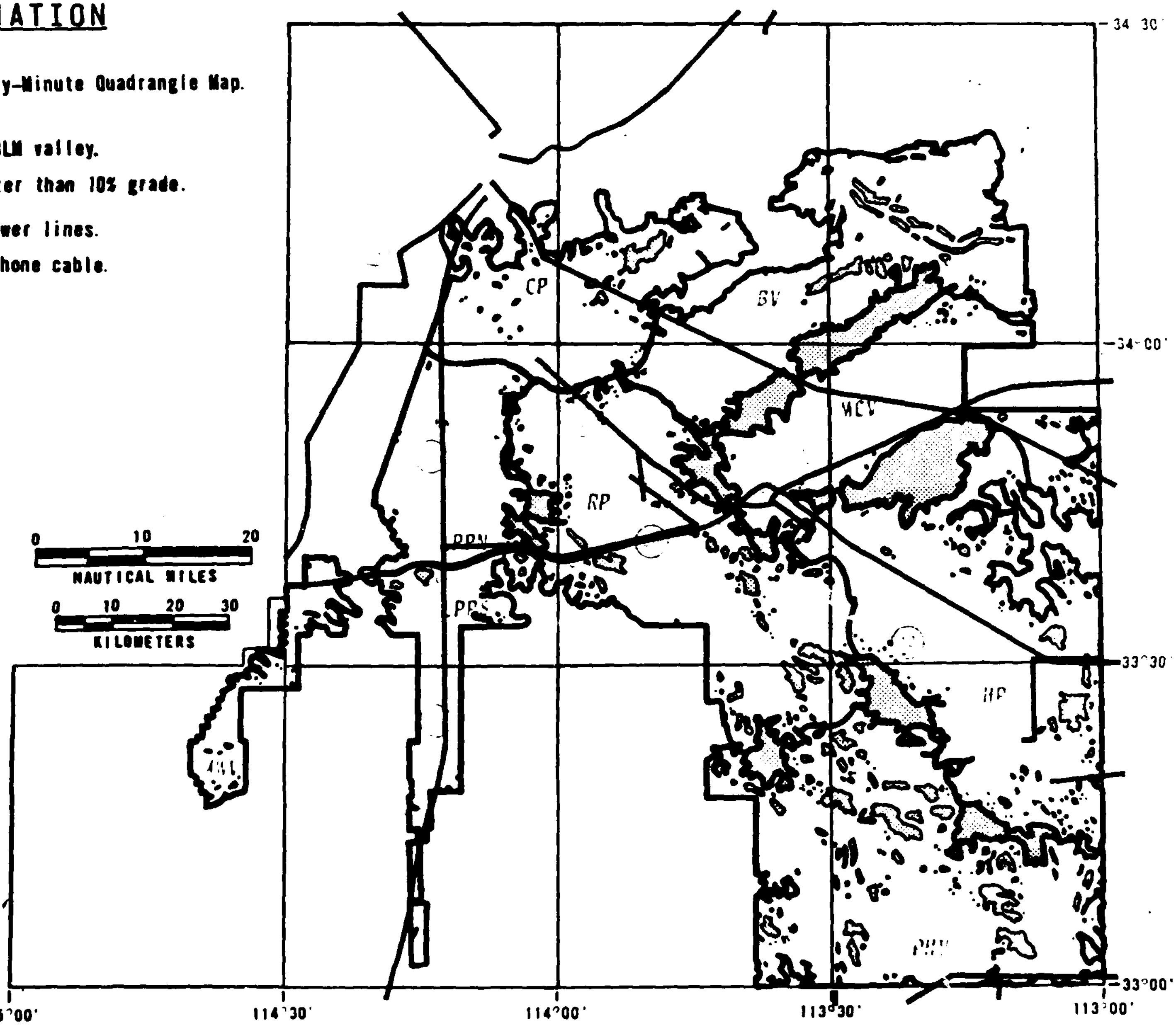
EXPLANATION

- Area of Thirty-Minute Quadrangle Map.
- Boundary of BLM valley.
- Area of greater than 10% grade.
- Electrical power lines.
- Coaxial telephone cable.



LOCATION OF UTILITY LINES

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FIGURE 5

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FIGURE
LOCATION OF UTILITY LINES

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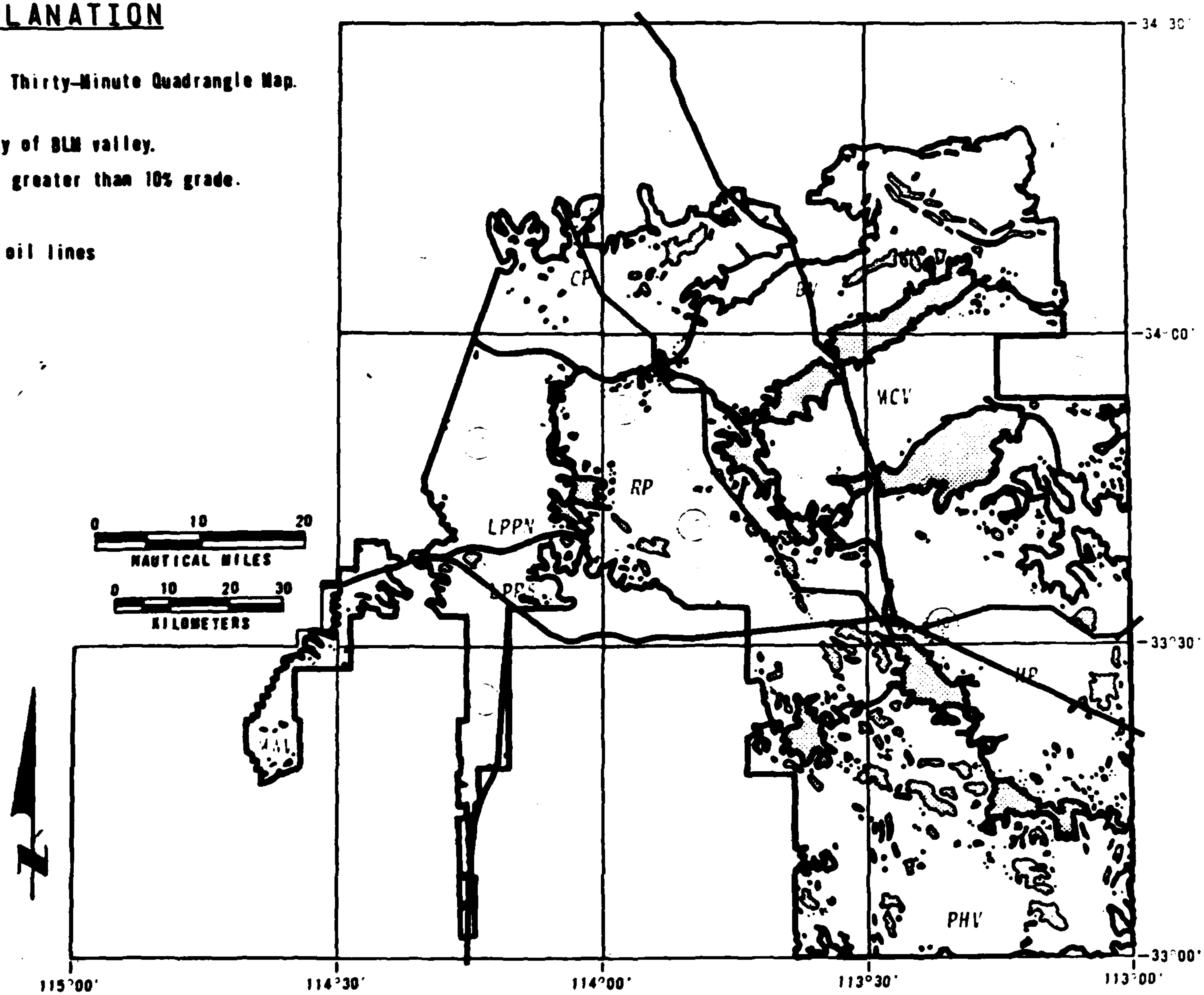
FIGURE
LOCATION OF CANALS AND PIPELINES

DATE: 31 MAY 76

EXPLANATION

- Area of Thirty-Minute Quadrangle Map.
- Boundary of BLM valley.
- Area of greater than 10% grade.
- Canals
- Gas and oil lines



LOCATION OF CANALS AND PIPELINES

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FIGURE 6

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features were identified, but are not believed restrictive to siting:

1. Several small towns and buildings initially identified on topographic maps. Field examination of several of these features showed them to be abandoned.
2. Instrumentation and monitoring sites such as water gaging stations which are only inhabited on a periodic basis.

2.1.6 GENERAL TOPOGRAPHIC CONDITIONS AND EXCLUSIONS

General topogaphic conditions of the various landforms present in the siting area are expressed in terms of topographic grade. The principal criterion for the exclusion of an area from siting considerations is the area greater than ten percent topographic grade (5° 43', 528 feet/mile). This condition occurs primarily in areas of exposed rock and topogaphically higher alluvial surfaces.

Areas exhibiting the topograhic grade ranges of zero to five percent (0° to 2° 52', 0 to 264 feet/mile) and five to ten percent (2° 52' to 5° 43', 264 to 528 feet/mile) were identified within the siting area. Locally, such as on steep leeward slopes of sand dunes, greater than ten percent grades may be present within areas of zero to five and five to ten percent topographic grade. In the Gila Bend Group the zero to five percent topographic grade range encompasses essentially all of the siting area. Landforms which predominate in this grade range include alluvial fans and washes. In addition, sand dunes, pediments, terraces, and small areas of

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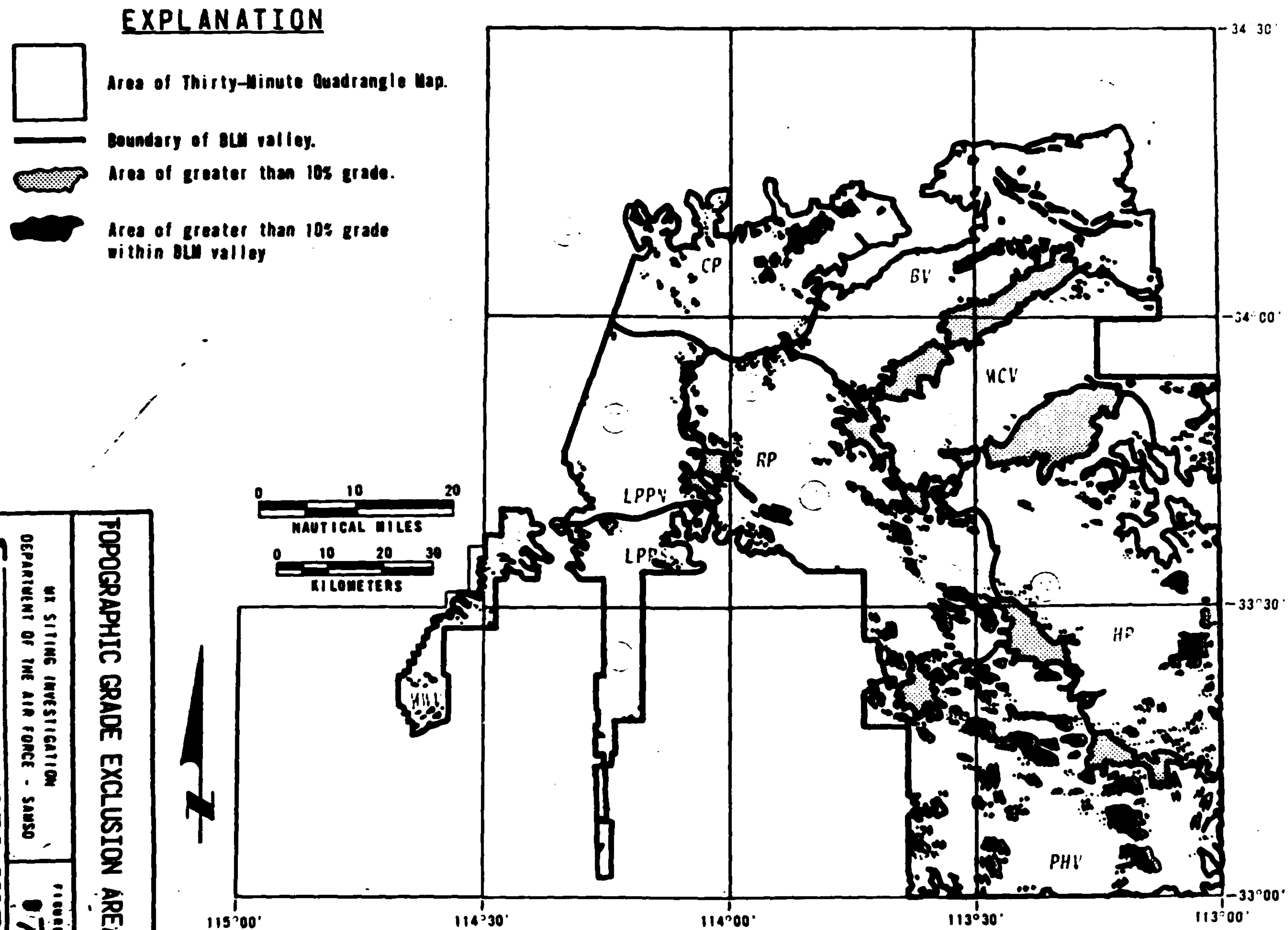

TOPOGRAPHIC GRADE EXCLUSION AREAS

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FIGURE 7

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exposed rock are also present within this grade range.

Small mappable areas of five to ten percent grade are present within areas of exposed rock and topographically higher alluvial areas, and adjacent to the siting area boundary where it is defined by greater than ten percent grade.

Approximately 2790 nm^2 (90 percent) of the siting area are included in the zero to five percent topographic grade range and approximately 270 nm^2 are included in the five to ten percent grade range. Approximately 678 nm^2 of land within the total Gila Bend Group (3065 nm^2) are non-BLM lands and account for the area excluded from siting consideration. Therefore, the remaining 2387 nm^2 comprise the total siting valley area within GB.

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2.2 GEOLOGY

2.2.1 GENERAL

Gila Bend Group BLM lands lie within the Sonoran Desert section of the Basin and Range Physiographic Province (Heindle and Lance, 1960) (Figure __). The physiography is controlled by, and therefore strongly reflects, the underlying geologic structure. This area is chacterized by eroded remnants of uplifted fault-block mountains (horsts) separated by downdropped basins (grabens) (Miller and Barnett, 1970). Unlike the major portion of the Basin and Range Province, this is an area of predominantly open-basin conditions and through-flowing drainages. Valleys within the BLM study area include Cactus Plain, La Posa Plain, Mohave Wash Valley, Palomas-Hyder Valleys, Ranegras Plain, Harquahala Plain, McMullen Valley and Butler Valley (Figures __ and __).

Mountain ranges in the study area are irregular and rugged and exhibit predominantly north to northwest trends characteristic of the Basin and Range Province. However, the northernmost ranges of the study area align east to west and northeast (Figure __). The rocks composing the mountain ranges consist predominantly of Precambrian metamorphic rock complexes, Cretaceous to Tertiary age volcanic and sedimentary rocks, and Mesozoic age granitic bodies (Table __).

The BLM Valleys occupy intermontane structural troughs and are filled with thick accumulations of Quaternary and Tertiary detritus derived from the adjacent mountains and [illegible]

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FIGURE
PHYSIOGRAPHIC DIVISIONS OF ARIZONA

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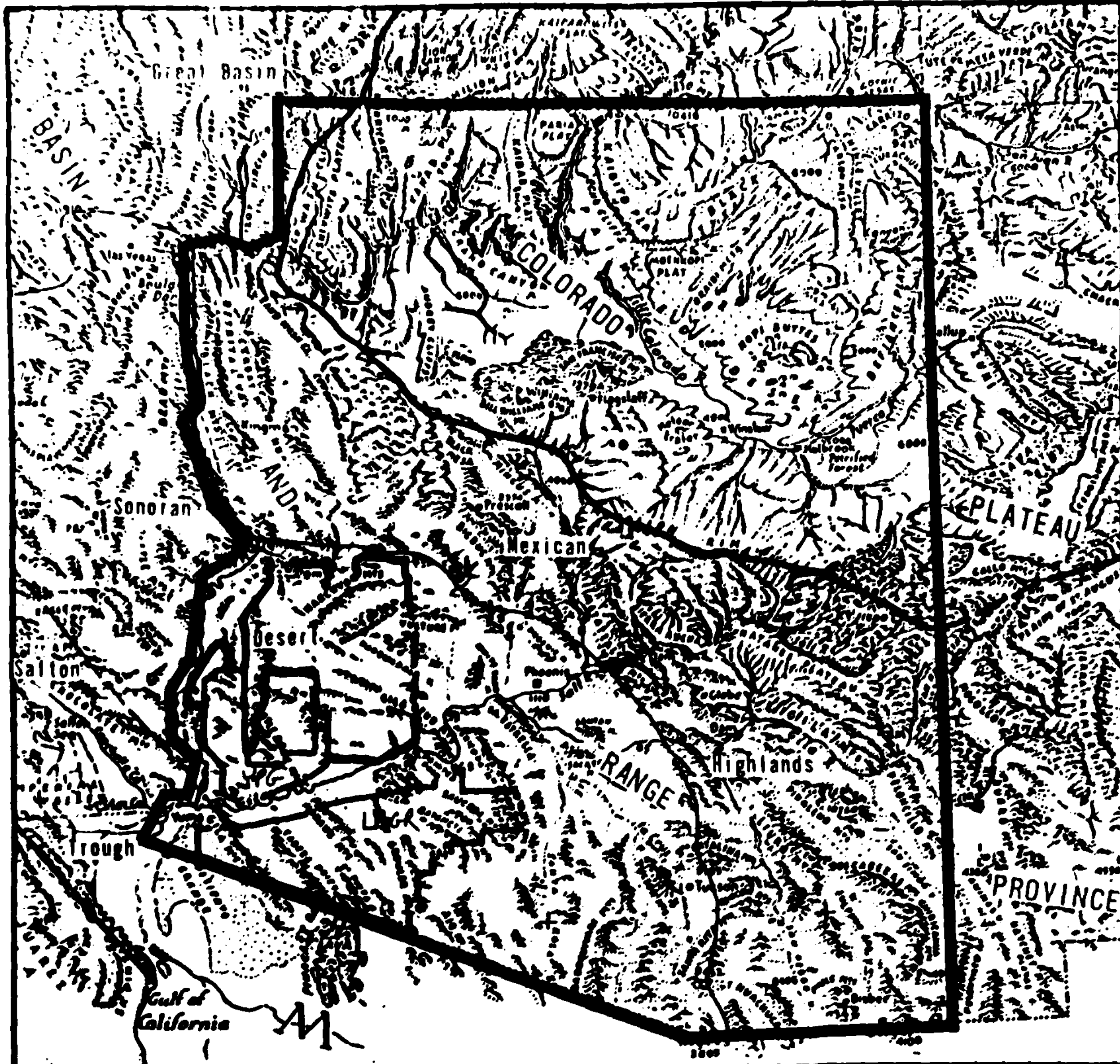

EXPLANATION

- Boundary of Bureau of Land Management Study Area.
- Boundary of Physiographic Province. Dashed where approximate.
- Section boundary of Physiographic Province. Dashed where approximate.

0 50 100
NAUTICAL MILES

0 50 100
KILOMETERS

MODIFIED AFTER: Fenneman, 1946.

PHYSIOGRAPHIC DIVISIONS OF ARIZONA

MX SITING INVESTIGATION
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FIGURE 8

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TABLE 5

Dominant Rock Types in Mountains Adjacent to Gila Bend Group Siting Area

Mountain Range	Dominant Rock Type
Buckskin Mountains	V bedrock/M basement
Dome Rock Mountains	S bedrock/M basement
Trigo Mountains	V bedrock/M basement
Chocolate Mountains	V bedrock/G basement
Castle Dome Mountains	V bedrock/G basement
Palomas Mountain	V bedrock/G basement
Tank Mountains	V bedrock/M basement
Kofa Mountains	V bedrock/G basement
New Water Mountains	V bedrock/G & M basement
Plomosa Mountains	V & S bedrock/M basement
Bouse Hills	V bedrock/G basement
Harcuvar Mountains	M basement
Granite Wash Mountains	S bedrock/G basement
Little Harquahala Mountains	S bedrock/G basement
Harquahala Mountains	M basement
Vulture Mountains	V bedrock/M basement
Big Horn Mountains	V bedrock/M basement
Saddle Mountain	V bedrock
Eagle Tail Mountains	V bedrock/M basement
Gila Bend Mountains	V bedrock/M basement
Painted Rock Mountains	V bedrock/G basement
Face Mountain	V bedrock
Oatman Mountain	V bedrock

V = Volcanic; S = Sedimentary; G = Granitic; M = Metamorphic

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TABLE __

DOMINANT ROCK TYPES IN MOUNTAINS

Mountain Range	Dominant Rock Type
Dome Rock Mountains	V and S Bedrock
Plomosa Mountains	V Bedrock
....	...
.... etc.	...

V = Volcanic; S = Sedimentary; G = Granitic; M = Metamorphic

The valleys are generally broad and elongate, with gently sloping piedmont surfaces grading toward the basin interior. Drainage in the western portion of the study area is diverted north and west to the Colorado River while the eastern portion is drained southeast to the Gila River. All BLM Valleys are connected by passes and plains of less than ten percent topographic grade (Figure __).

2.2.2 GEOMORPHIC SETTING AND SURFICIAL GEOLOGY

2.2.2.1 General

For at least the past thirty million years (Appendix B) these basins have been filled by deposits which are the products of wind, water and gravity erosion of the surrounding mountains (Olmsted, 1968). Basin-fill deposits present at the surface can be associated with various geomorphic features, including (in order of decreasing abundance) alluvial fans and bajadas (A5), ephemeral streams and flood plains (A1), sand dunes (A3), pediments (A6), and terraces (A2) (Apendix _). These landforms provide the basis for relating the distribution and nature of the surficial deposits and terrain to the suitability for siting the MX system.

The basin fill consists primarily of alluvial fan, talus colluvium and local ephemeral stream deposits. Near the northern, western and southern border of the study area these deposits intertongue with fluvial sediments of the Santa Maria, Colorado and Gila Rivers, respectively. Paleoplaya deposits of thick clay are encountered at depths within the basin fill of several valleys and are recognized in basins adjoining the BLM Valleys (Johnson and Cahill, 1954; Metzger, 1951, 1957; Kam, 1961; Fugro, 1974). The maximum cumulative thickness of the basin fill within the BLM study area has been determined by seismic reflection methods to be approximately 7000 feet (Proprietary data, 1974). Several logs from deep exploratory test wells (El Paso Natural Gas Company, 1968, 1970) supplemented by gravity profiles provided by the Defense Mapping Agency (DMA, 1976) indicate that the basin fill in most Valleys is at least 1000 to 3000 feet thick (Appendix __).

No measured seismic (compressional wave) velocities are known to be available for basin-fill deposits withn the study area. However, nuclear power plant investigations to the east and west of the study area have produced data for similar basin-fill materials (Fugro, 1974b, 1975a, Woodward McNeil, 1974). Measured p-wave velocities in unconsolidated detritus ranged from 1000 to 3000 feet per second (fps) in the upper 25 to 75 feet of materials, and 3000 to 6500 fps for deeper, semi-consolidated alluvial, fluvial and lacustrine deposits (Fugro, 1975a, and Woodward-McNeil, 1974). Lithified fanglomerate in the subsurface produced velocities of 7000 to 8500 fps. The presence of varying degrees of caliche cementation within the basin fill may produce higher average velocities for the aforementined units (Mattick and others, 1973; Barnett, 1975, in press).

Caliche is the most common cementing agent of near-surface exposures in the basin fill, with the degree of development varying with local conditions. Caliche appears most prevalent in the southeastern portion of the study area, where

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elevated calichified fan remnants are locally composed of volcanic rubble (Geology, GB-X). Calichified intervals may also be present at depth within the basin-fill deposits.

Determination of the extent and physical nature of the basin fill in the study area is based on limited data derived from investigations performed primarily by the U. S. Geological Survey, U. S. Bureau of Reclamation, Arizona State Land Department, Arizona Water Commission, Arizona Bureau of Mines, and the Defense Mapping Agency. Field investigations by these agencies included limited bucket auger and rotary drill sampling, test pit excavation and geophysical surveys (gravity, aeromagnetic, seismic refraction and reflection, and electrical resistivity).

In addition, aerial photographic analyses of Army Map Service black and white prints at a scale of one inch equals one mile, an aerial flyover and a brief ground reconnaissance were performed for this study.

2.2.2.2 Alluvial Fans and Bajadas

Alluvial fans are the predominant geomorphic feature in the study area, encompassing approximtely __ percent (___ nm^2) of the total area of the BLM Valleys. They occur along the flanks of all mountain ranges as wedge-shaped deposits less than a few tens of feet thick at the mountain front and up to several hundreds of feet thick in the basins.

At least three generations of alluvial fans are distinguished in the BLM study area. They are identified as $A5_O$, $A5_I$ and A5 (oldest to youngest; Appendix D) to indicate relative ages within the Valleys, but not necessarily to imply that they are correlative between Valleys, although that may be the case. These fans are tentatively correlative with fans delineated in the DoD study area as Tertiary ($A5_O$) Quaternary-Tertiary ($A5_I$) and Quaternary ($A5_Y$) in age (Fugro National, Inc., 1975c) Appendix __).

In general, the older and topographically higher fans occur nearer the mountain fronts and are moderately dissected and more deeply incised (Table _) than the more basinward, younger fan units. These alluvial fan units consist of poorly sorted, sub-angular boulders, cobbles and gravels, with sand and silt becoming more dominant further from the mountain front. These deposits are well indurated owing to diffuse and concentrated calichification which impregnates up to 25 feet or more in the older Tertiary materials flanking Saddle, Oatman and Face mountains (Geology, GB-10).

TABLE 3

DEGREE OF DRAINAGE DISSECTION AND INCISION

Drainage Density (no. streams per nm)	Depth of Drainage Incision (average in feet)
0-5	0-5
6-10	6-10
11-15	11-15
16-20	16-20
>20	>20

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TABLE 6

DEGREE OF DRAINAGE DISSECTION AND INCISION

Drainage Density (no. streams per nm)	Depth of Drainage Incision (average in feet)
0-5	0-5
6-10	6-10
11-15	11-15
16-20	16-20
>20	>20

The oldest alluvial fans ($A5_O$) are preserved as small fan remnants generally exposed in narrow or confined valleys and mountain valley re-entrants. They have their greatest areal extent in the eastern one-half of the study area, flanking the southern portions of the Buckskin, Big Horn, Saddle and Gila Bend mountains (Geology, GB-2, 3, 6 and 10). These fan deposits generally are topographically higher than the younger alluvial fans, are moderately dissected, deeply incised, have well-rounded ridge crests and may be covered by desert pavement. The $A5_O$ fans are a minimum of 500,000 years in age and most likely may range to several million years in age in the older, well-cemented fanglomerates (Lance, 1960; Fugro, unpublished, 1976).

The oldest fan deposits also include cemented fanglomerate. Although fanglomerates have limited surfce exposures, they are probably extensive in the subsurface. Several deep drill holes have encountered conglomeratic lithologies at depths of 850 to more than 1600 feet in northern McMullen Valley (Kam, 1961) and at a depth of 998 feet beneath Mohave Wash Valley (Metzger, 1973). Thick sections (up to 2100 feet) of fanglomerate have been formally described in basins bordering the study area (Metzger, 1972, 1973; Olmstead, 1973; Fugro, 1979b). The $A5_O$ fans encompass an estimated __ percent (___ nm^2) of the BLM Valleys within the study area.

Intermediate-age fan deposits ($A5_I$) are the most areally extensive fan unit in the alluvial sequence, encompassing an estimated

___ percent (___ nm^2) of the BLM Valleys. These deposits are composed of local cobble, gravel and sand-size material, with finer-grained materials increasing toward the valley axis. The unit is a composite of several complex fan generations of differing elevations and dissections, yet they remain distinctively intermediate between older ($A5_O$) and younger, still active ($A5_Y$) fans. The topographically highest and oldest $A5_I$ landforms occur as a near continuous border around most mountain fronts, forming a gentle piedmont or bajada slope which grades to approximately the same base level as younger fans ($A5_Y$) near near the central valley floor.

Characteristically, the intermediate fan deposits are moderately dissected with semi-rounded ridge crests. Incision is shallow to deep, reaching 25 feet in the higher elevations. Fan surfaces exhibit a well developed desert pavement (a thin residual of lag gravel resulting from removal of finer particles by wind or water) consisting of gravel- to cobble-size material and possessing moderate to well-developed desert varnish (a thin mineralized patina of iron and manganese oxides). Typical soil profiles have three to four inches of porous silt immediately underlying the desert pavement. This is underlain by argillic horizons and carbonate (caliche) penetration to depths as great as 60 inches in the higher elevations (Fugro, 1976, unpublished). Recent studies of correlative soil profiles indicate the intermediate fan deposits are pre-Wisconsian, a minimum of 15,000 to 500,000 years old (Fugro, 1976, unpublished).

Young alluvial fans are the lowest topographic level of fan development and are considered to be surfaces of active transport. Active fan formation is limited to the southern La Posa Plain, McMullen and Palomas-Hyder Valleys (Geology, GB-5, 6, 8 and 10) with $A5_Y$ deposits encompassing an area of approximately ___ nm. Younger fans occur approximately midway down the intermediate fan, incising and isolating elongate $A5_I$ remnants as the intermediate fan is progressively abandoned as a surface of transport. The $A5_Y$ deposits are composed of reworked $A5_I$ material, predominantly sand with scattered gravels and minor fine-sand and silt. Younger fan surfaces are expressed as braided bar and swale topography; dissection is slight and incision generally shallow, ranging from approximately five feet in the higher portions to an average of one foot. Surfaces are free of desert pavement and caliche development is slight to nonexistent. These deposits are considered post-Wisconsian in age, or 15,000 years and younger (Fugro, 1976, unpublished).

2.2.2.3 Pediments and Pediment Deposits

Pediments, as defined for this study are represented by planated rock shelves generally overlain by a thin mantle (less than ten feet thick) of sand- to boulder-size residual or alluvial material (pediment deposits). The pediment surfaces commonly serve as surfaces of transport and are characterized by moderate dissection with depths of incision less than ten feet, however, pediments on the northeast flanks of the Palomas Mountains, exhibit up to 100 feet of relief (Jemmett, 1966; Geology, GB-4). Most pediments in the study area are actively aggrading with deposits concealing the basinward extent of the planated rock shelf. The concealed nature of the pediment makes it difficult to delineate on aerial photogaphs and frequently the basinward edge must be inferred by the rolling character of the topography or presence of isolated rock outliers.

Pediments in the study area generally occur in pass areas and mountain re-entrants, developed primarily upon granitic and volcanic rocks. Large areas of mapped pediment occur along the flanks of the Harcuvar, Black, Palomas and Big Horn mountains (Geology, GB-3, 4, and 6), encompassing a minimum of _____ nm^2 or _____ percent of the siting area. Metzger (1951, 1957) suggests that pediments occur extensively along the borders of the Gila Bend and Eagle Tail mountains, Bouse Hills and along the southwestern border of the Granite Wash Mountains; pediments are less commonly cited along the flanks of the Harquahala and Saddle mountains. Although the presence of these pediments could not be confirmed by photographic analysis or the brief field reconnaissance, the 100-foot depth to rock contour was located around the inferred pediment locations (Metzger, 1951, 1957; Armstong and Yost, 1958; Kam, 1961; Bureau of Reclamation, 1974).

2.2.2.4 Playas

Playas are the lowest areas within enclosed desert drainage basins generally characterized by almost horizontal vegetation-free surfaces of fine-grained sediments that are periodically innundated (Cooke and Warren, 1973). No playas are found within the study area. All Valleys exhibit open, through flowing drainage, however, an area of temporarily ponded drainage exists in the upper reaches of Bouse Wash in southern Ranegras Plain (Geology, GB-V) where seasonal runoff is slowly dissipated due to a mild headwater gradient (less than 10 feet per mile). The presence of lacustrine-like clays and silts have been observed in a small surface exposure approximately one mile southeast of Bouse and at depths as great as 720 feet in McMullen, Ranegras, Dendora and Hyder Valleys, indicating the basins may have been subjected to interior drainage in the geologic past (Kam, 1961; Metzger, 1951; Armstrong and Yost, 1958).

2.2.2.5 Wind-Blown Sand

Extensive wind-blown sand deposits cover the Cactus Plain and northern La Posa Plain and are present in isolated patches along Cunningham Wash in Butler Valley and Ranegras Plain (Geology, GB-1, II, and V). These deposits encompass approximately ____ nm^2 or ____ percent of the siting area. The dunes are most commonly longitudinal, up to 1.75 nm in length, approximately 35 feet thick, and average 300 to 350 feet between crests. The dunes trend northeast in response to prevailing winds from the southwest. Crescent and rosette dunes and large areas of sheet sand are also present.

The eolian deposits are composed of poorly consolidated fine-grained sand with subordinate amounts of silt and medium sand. Most dunes have a moderately dense vegetation cover and appear to be at least semi-stable.

2.2.2.6 Stream Channel and Undifferentiated Floodplain Deposits

Stream channel (wash) deposits (Al_Q) encompassing approximtely ___ nm^2, are composed of loose sand, gravel, silt and minor amounts of clay. The dominant grain size depends on the volume of water discharged by the stream, rate of flow, channel configuration, source material, and grain size of the material traversed. Wash deposits average five to ten feet thick where exposed in most Valleys, however, Kam (1961) identified up to 470 feet of Centennial Wash alluvium from drill logs in McMullen Valley. Stream deposits are generally confined to the primary drainage which is situated in the axial portion of each Valley and the smaller more numerous secondary drainages which trend subparallel and downslope off the mountains and bajadas. In southern Ranegras Plain and northern Harquahala Plain drainage has been reduced to rill and sheet flow, which has scoured and reworked large areas of fan material sufficiently to be designated stream deposits (Geology, GB-5, 6).

Quaternary-Tertiary alluvium of the Colorado and Santa Maria Rivers drainages have been designated Al_{QT}. These deposits are exposed adjacent to Bouse Wash and Date Creek in the Cactus-La Posa Plains and Butler Valley, respectively (Geology, GB-1, 4, and 3). Due to the poorly lithified nature and their unknown extent in the shallow subsurface, it was most adequately categorized alluvium rather than sedimentary bedrock.

Undifferentiated floodplain deposits (A_Q) have been reserved for stripped fan or low-lying areas not possessing distinctive characteristics of sheet flow.

2.2.2.7 Terraces

Terraces are topographic benches within a river valley that usually represent former levels of the floodplain. Within the study area, the terraces ($A2_{QT}$) are related to the Colorado and Gila Rivers. Terrace deosits of the Gila River are present along the southern margin of Palomas-Hyder Valley (Geology, GB-10). The deposits are composed of sandy gravel up to 40 feet thick which extend back into the "benched" mesa up to one nm where they are buried beneath a mantle of young alluvial fan material ($A5_Y$). Areal exposure is limited to __ nm^2, however, the deposits may be more extensive in the subsurface. These deposits are clearly overlain by the Sentinal basalt flow which has been dated at 1.71 million (Fugro, 1974, Appendix B).

Terrace deposits of the Colorado River are present along the western flanks of the Dome Rock Mountains in Mohave Wash Valley (Geology, GB-8), encompassing approximately 6 nm^2. The deposits are exposed along the periphery of the mesa edge forming an erosional scarp up to 1.3 nm into the fan materials. The deposits are composed predominantly of bedded sand, silt and gravel, ten to 15 feet thick. Compressional seismic wave velocities of 1000 to 3000 fps have been recorded for correlative deposits on the western mesa of the river (Fugro, 1975). Vertebrate fossils within this unit have been dated late Pliocene to early Pleistocene or younger in age (Metzger and others, 1973; Appendix B).

2.2.3 ROCK CONDITIONS

2.2.3.1 General

For this study, material considered as rock can be subdivided into three categories; these include in order of decreasing age, basement rock, bedrock and volcanic flow rock (Appendix B). In general, each of these three rock types possess distinctive characteristics of importance for MX siting considerations, such as seismic response, blast effects, or the nature of basin-fill deposits derived from the.

The first category, termed basement rock, consists of crystalline igneous and metamorphic rocks. Igneous rocks range from monzonite to granite and commonly are slightly metamorphosed (Miller, 1970; Metzger, 1951, 1957). Metamorphic rocks include a complex assemblage of gneiss, schist, metasedimentary and metavolcanic rock. These rocks, due to their basal stratigraphic position and a few scattered radiometric age-dates are inferred to be Precambrian through Cretaceous in age ([illegible] and others, 1963; Damon, 1968; Fugro, 1975b). No seismic velocities have been recorded for basement rocks within the study area, however, similar materials from the [illegible] yielded p-wave velocities of 14,000 to 16,000 and 17,000 to 18,000 fps for granitic and metamorphic rocks, respectively (Mattick and others, 1973). Basement rocks are generally exposed along the lower mountain flanks and pediments where younger bedrock has been eroded away. Basement rock underlies bedrock and much of the basin fill in the study area (Metzger, 1951, 1973; Wilson, 1962; Miller, 1970; Kamm, 1961; Armstrong and Yost, 1958).

The second category is bedrock which includes competent volcanic and sedimentary rocks. Volcanic rocks consist of flows, plugs, dikes, tuffs and volcanic breccia, ranging from rhyolite to basalt in composition. Sedimentary rocks include shale, sandstone, conglomerate and limestone. Mattick (1973) reports similar rocks from the Yuma area possessing seismic velocities of 10,000 to 20,400 fps. Bedrock composes the predominant lithologies in rock areas of less than ten percent grade and underlies portions of the basin fill (Wilson, 1965; Armstrong and Yost, 1958; Kam, 1961; El Paso Natural Gas Company, [illegible]).

The third category, volcanic flow rock, is restricted to extrusive igneous rocks, generally basaltic in composition, which are commonly flat-lying, geologically young (Quaternary or Quaternary-Tertiary) and overlie, or are interbedded with basin-fill materials.

The Sentinel basalt flow is the only occurrence of volcanic flow rock in the siting area. It is located in the [illegible] southeastern portion of the study area ([illegible] passes approximately ____nm^2 and overlies basin-fill deposits along the Gila River. Portions of the flow have been dated as early Quaternary in age (1.71± 0.25; Fugro, 1974). The presence of such young flows suggest that other flows may be present in the subsurface.

2.2.3.2 Exposed Basement Rock, Bedrock and Volcanic Flow Rock

An estimated __ percent (___nm^2) of the total area within the BLM study area consists of basement, bedrock and volcanic flow rock, with the remaining __ percent (___ nm^2) composed of basin-fill deposits. Of the ___ nm^2 of exposed rock, approximately __ percent (___ nm^2) is basement rock, __ percent (___ nm^2) is bedrock, and __ percent (___nm^2) is volcanic flow rock.

2.2.3.3 Subsurface Rock Conditions

Detailed subsurface data are sparce for most of the study area. The distribution and composition of subsurface rock is not well known. Although there is an abundance of water well data, the wells are usually too shallow to penetrate rock. Supplementary gravity, seismic and deep exploratory well information is re-tricted to small areas within a few Valleys. Table _summarizes the types of depth to rock data available for each BLM Valley.

Gravity profiles provided by the Defense Mapping Agency (DMA) allow estimates of minimum depth to rock. The profiles are purely a gravitational interpretation showing the basin-fill/ rock contact as a smooth curve. Seven profiles through BLM Valleys in addition to a discussion of the interpretation

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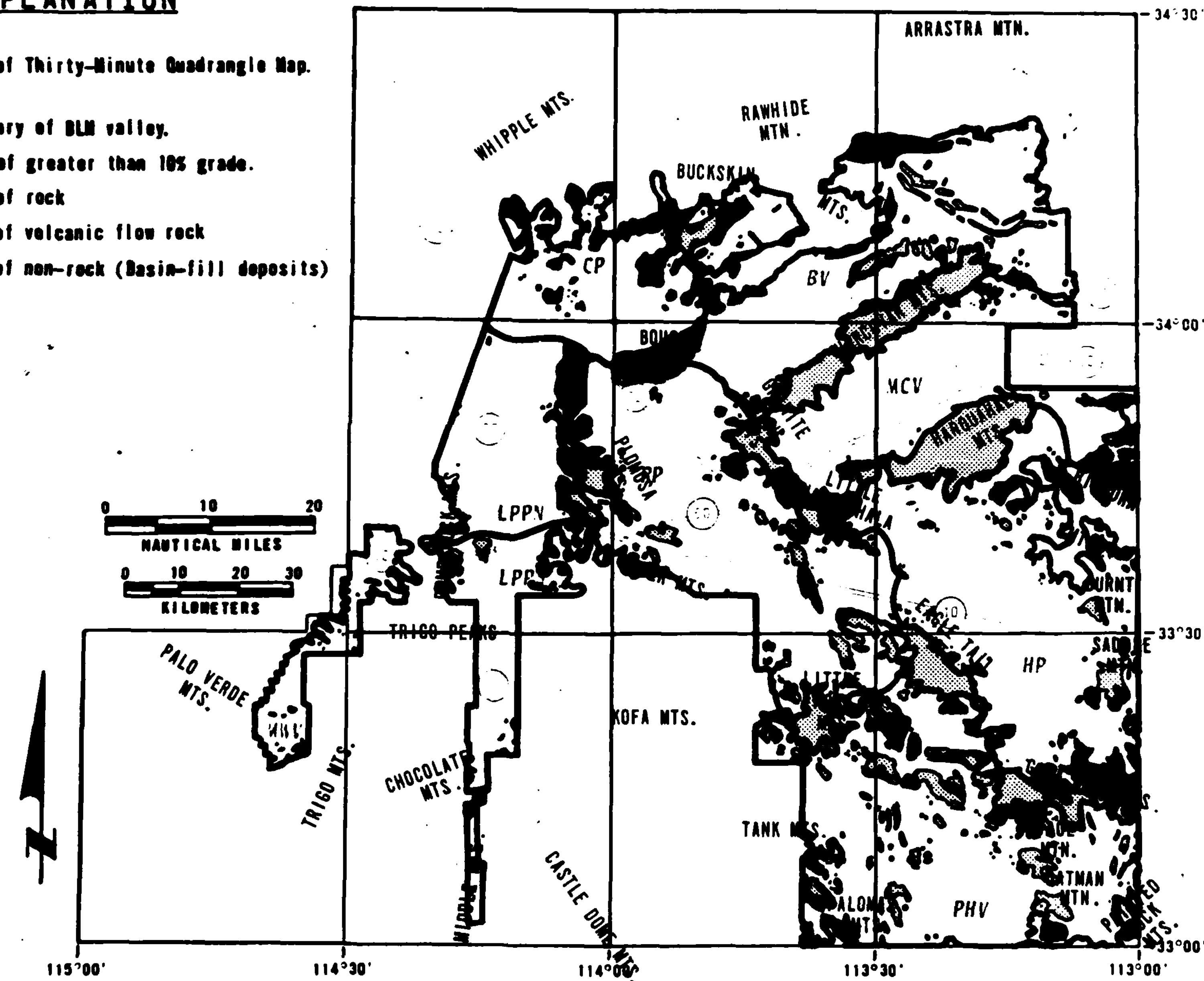

EXPLANATION

- Area of Thirty-Minute Quadrangle Map.
- Boundary of BLM valley.
- Area of greater than 10% grade.
- Area of rock
- Area of volcanic flow rock
- Area of non-rock (Basin-fill deposits)

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DISTRIBUTION OF ROCK AND NON-ROCK

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FIGURE 9

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TABLE __

SUMMARY OF DEPTH TO ROCK DATA FOR ARIZONA BLM VALLEYS

Valleys	Water Wells Encountering Rock	Deep Exploratory Gas Wells(1)	Seismic Profiles(2)	DMA Gravity Profiles(3)	Bouger Gravity
Cactus Plain					
Butler Valley					
McMullen Valley					
La Posa Plain					
Ranegras Plain					
Harquahala Plain					
Palomas-Hyder Valley					
Mohave Wash Valley					

(1) El Paso Gas

(2) Proprietary Informatin

(3) 14B2

method utilized is provided in Appendix __. Depth to rock calculations and estimated accuracy of each profile are summarized in Table _.

Interpretations of the available data indicates that basin depths and configuration vary considerably within, as well as between basins. The DMA gravity profiles indicate that the basins are slightly asymmetric, commonly skewed toward an anomalously steep buried escarpment which may be interpreted as a range bounding fault. Commonly, the basin floor is highly irregular indicating a high probability of additional normal faults producing horst

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TABLE 7

SUMMARY OF DEPTH TO ROCK DATA FOR ARIZONA BLM VALLEYS

Valleys	Water Wells Encountering Rock	Deep Exploratory Gas Wells(1)	Seismic Profiles(2)	DMA Gravity Profiles(3)	Bouger Gravity
Cactus Plain				15-B1	
Butler Valley		EPG, Bullard Wash No. 1, 1970		17-A1	
McMullen Valley					
La Posa Plain		EPG #462, 1968 EPG #459, 1968		14-A2 14-B1	
Ranegras Plain				18-A3	
Harquahala Plain				18-B1	Peterson,
Palomas-Hyder Valley			Proprietary Information		
Mohave Wash Valley		USGS LCRP-22 USGS LCRP-5			

(1) El Paso Gas

(2) Proprietary Information

(3) 14B2

and graben structure. Depths to rock in the deepest portions of the basins range from approximtely 1000 to 3000 feet with a maximum in the study area of 7000 feet in Dendora-Hyder Valley (Proprietary Data, 1974).

TABLE _

DEPTH TO ROCK ESTIMATES FROM DMA GRAVITY PROFILES

Valley	Maximum	Minimum	Estimated Accuracy
Cactus Plain			
Butler Valley			
McMullen Valley			
La Posa Plain			
Ranegras Plain			
Harquahala Plain			
Palomas-Hyder Valley			
Mohave Wash Valley			

A 100-foot depth to rock contour was constructed near the valley edges on the basis of water well logs and other existing literature. Where data were insufficient, topographic, geologic and geomorphic interpretation was used.

2.2.4 SEISMO-TECTONIC SETTING

2.2.4.1 Regional Setting

The BLM study area lies entirely within the Sonoran Desert subprovince of the Basin and Range Structural Province and is

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TABLE 8

DEPTH TO ROCK ESTIMATES FROM DMA GRAVITY PROFILES

Valley	DMA Profile	Maximum (feet)	Minimum (feet)	Estimated Accuracy (feet)
Cactus Plain	15-B1	2068	1260	± 230
Butler Valley	17-A1	4399	2707	± 410
McMullen Valley	Data not available	-	-	-
La Posa Plain	14-A2	4588	2602	± 492
	14-B1	6909	5512	± 1312
Ranegras Plain	18-A3	4536	2582	± 410
Harquahala Plain	18-B1	4431	3169	± 410
Palomas-Hyder Valley	Data not available	-	-	-
Mohave Wash Valley	Data not available	-	-	-

characterized by a relative absence of known Quaternary faults and diffuse, low magnitude seismicity that correlates with no particular areas or geologic structure. No major seismo-tectonic elements align with or transect the study area.

2.2.4.1.1 Principal Seismo-Tectonic Elements

The closest major seismo-tectonic elements that could affect the study area include; (1) the San Andreas Fault Zone, (2) the Death Valley-Furnace Creek Shear Zone, (3) the Walker Lane-Las Vegas Valley Shear Zone, and (4) the Jerome-Wasatch structural zone. None of these features transect or project toward the BLM siting area. The geographic location of the major seismo-tectonic elements with spatial distribution of associated seismicity is represented in Figure __. Table __ summarizes the structural style and proximity of each element to the study area.

2.2.4.1.2 Faults and Fault Scarps

Many inactive faults displacing Tertiary and older materials occur within the study are representing past periods of tectonism. Faults which disrupt Quaternary materials as determined from the literature or the aerial photo interpretation were categorized as being capable or potentially capable. The criteria used in this study for defining a capable fault was established by the U. S. Regulatory Commission (Appendix __). The conservative NRC criteria was utilized due to the presence of nuclear components within the MX system and the potential for damage to the system by seismic activity or ground rupture. Well-defined scarps expressed in Quaternary materials as determined from the reconnaissance level aerial photo interpretation were conservatively categorized as potentially capable faults (Geology, GB-1, 4).

The only capable fault that is known in the study area is informally referred to as the Kofa Mountain fault. It is depicted on the Yuma County Geologic Map (Wilson, 1960) as juxtaposing Quaternary basalt against older, undifferentiated volcanics in the Little Horn Mountains (Geology, GB-5). The fault trends northwest and has an unknown sence of slip. Although the entire mapped fault length of 6.8 nm occurs within the Kofa Game Range exclusion, its projected southeast extension does intersect the study area. No displacement of younger, undated alluvial materials has been observed. There is no known seismicity associated with the fault.

Two unnamed linear scarps in the northwest portion of the study area were inferred to be potentially capable faults based upon the photo-geologic analysis, literature, and personal communications. The most prominent scarp occurs along the northeastern flanks of the Plomosa Mountains forming a sublinear contact between Tertiary sedimentary rocks (Artillery Formation) and younger alluvium (Geology, GB-4). The scarp has been recognized by several authors (Jemmett, 1966; Metzger, 1951) as a fault controlling the pediment edge for 3.8 nm, and may be interpreted to have a total length of 8.2 nm. The fault trends north five degrees to ten degrees west, dips 55 degrees to the east.

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TABLE 9

Seismo-Tectonic Elements

Element (Structural Province)	Closest Approach to Gila Bend Group Siting Area	Total Length, Width or Area (and trend)
San Andreas Shear Zone (Gulf of California & others)	55 nm (west)	Approx. 600 nm in length, 30 to 100 nm in width (N40W)
Sand Hills (Gulf of California & others)	30 nm (southwest)	52 nm
Algodones (Gulf of California & others)	27 nm (southwest)	33.9 in length
Blythe Graben (Basin and Range)	10 nm (west)	3.0 nm in length
Pinacates Volcanic Field (Basin and Range)	Approx. 54 nm (southwest)	450 nm^2 total area
Jerome-Wasatch Structural Zone (Basin and Range)	Approx. 52 nm (northeast)	Greater than 200 nm in length, 25 to 50 nm in width (N40-45W)
Walker Lane-Las Vegas Shear Zone (Basin and Range)	Approx. 146 nm (northwest)	Greater than 275 nm in length, 1 to 10 nm in width (N50N to N20W)
Death Valley-Furnace Creek Shear Zone (Basin and Range)	Approx. 156 nm (northwest)	Approx. 160 nm in length, 1 to 10 nm in width (N45W)

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Age of Last (10³ years b.p.) Displacement	Volcanism	Seismicity	Remarks
Less than 1	None	Historic and Recorded	Right lateral strike-slip faulting. Numerous M=6+ events in Gulf of California province. Few N=8+ in northerly Province. Capa[illegible] zone.
Less than 1	None	Historic and Recorded	Right lateral strike slip fault Numerous M=6 to 7 events. Capabl[illegible] zone.
Approx. 11 to 15	None	No Historic or Recorded	Dip-slip faulting with 3 to 5 fee[illegible] of offset in pre-historic time. Potentially capable.
Approx. 6 to 30	None	No Historic or Recorded	Dip-slip faulting with 6 to 10 fe[illegible] of offset. Potentially capable.
Quaternary or associated faults	24(dated) less than 11(est.)	Historic and Recorded	Seismicity (M=4 to 5); asociated with Quaternary faults in area.
Less than 10	None	Historic and Recorded	Quaternary faulting in north-cent[illegible] Arizona. Events of M=5 to 5.6. Potentially capable zone.
Less than 1	Greater than 2,000	Historic and Recorded	Right lateral strike-slip faultin[illegible] Events of M=4 to 5 at closest approach. Capable zone.
Less than 2	None	Historic and Recorded	Right lateral strike-slip faults. Offsets approx. 40 nm in Quaterna[illegible] Events of M=4 to 6. Capable zone

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FIGURE

SEISMO-TECTONIC FEATURES

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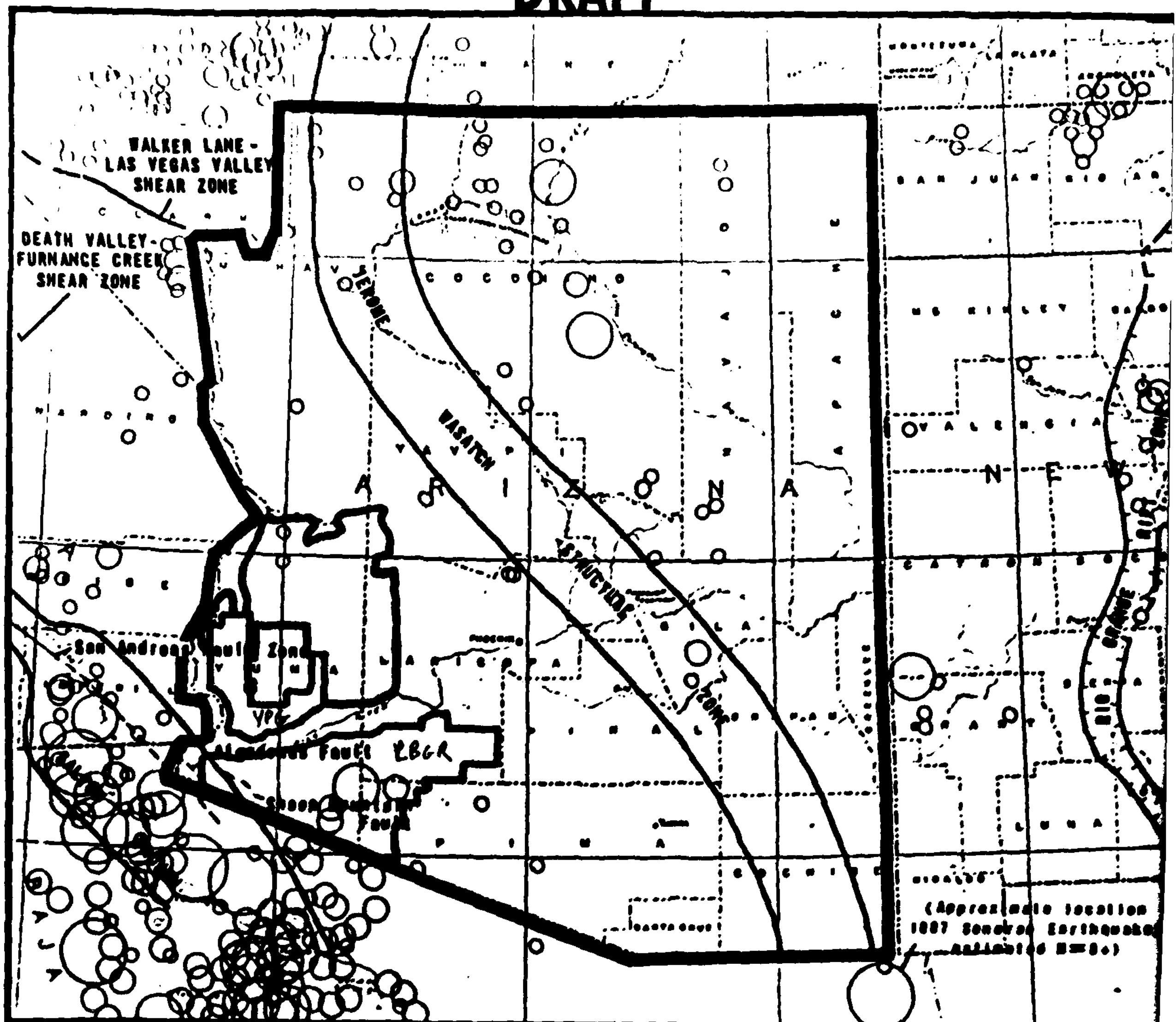

EXPLANATION

EARTHQUAKE EPICENTERS

○	M < 4.0
○	M = 4.0 - 4.9
○	M = 5.0 - 5.9
○	M ≥ 6.0

0 50 100 150
NAUTICAL MILES

0 100 200
KILOMETERS

SYMBOLS

▬▬	Boundary of Bureau of Land Management Study Area
═══	Approximate trend of structural element.
— - -	Quaternary fault lines.

SEISMO-TECTONIC FEATURES

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FUGRO NATIONAL, INC

DATE: 30 JUNE 1978

and is inferred to be dip-slip with the basin side down-thrown (Jemmett, 1966).

The second scarp is situated in a re-entrant along the southern flanks of the Buckskin Mountains (Geology, GB-1) near the proposed outlet portal of the Buckskin Mountain Tunnel (Dick Raymond, oral communication, 1976). This scarp is expressed in intermediate fan ($A5_I$) trending north 30 degrees west and aligns with a fault in the adjacent volcanic bedrock combining for a total length of 4.3 nm.

No seismicity has been associated with the potentially capable faults described above, however, two random epicenters of less than 4.0 magnitude have occurred within a __ nm radius (Figure __).

2.2.4.1.3 Distinct Alignments

Distinct alignments, as defined for this study, are lines of natural origin which exhibit a linear or slightly curved image on imagery, aerial photographs or topographic maps. These natural lineaments are commonly expressed as displaced drainage lines, fault scarplets, truncated spurs, ridge crests and other morphological features which may reflect underlying geologic/structural controls (i.e., faulting, joint patterns, etc. Distinct alignments were observed during the photogeologic interpretation at a scale of one inch equals one mile. A separate lineament analysis was not made to determine the nature of these phenomena.

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Distinct alignments were recognized in every Valley of the study area. The lineaments form groupings or clusters of two or more subparallel features. Generally, those situated nearer the mountains reflect the orientation of the adjacent mountain border (Geology, GB-2, 3, 5 and 8), whereas lineaments situated near the valley center are more likely to reflect more random trends (Geology, GB-5, 6 and 10). Past experience in the region (Fugro, 1974, 1975a, 1975b) indicates that the majority of these distinct alignments can be explained as erosional scarps, or subsidence features from groundwater overdraft, a nontectonic process common to southern Arizona (Section 2.4.2.7).

2.2.4.2 Potential for Surface Displacement

There are no faults within the study area with historic surface displacements (Bonilla, 1967). The only area considered to have any potential for surface rupture is in the Palomas Plain (Geology, GB-10) along the southeastern trace of the Kofa Mountain fault. However, there are no epicenters associated with this fault and no measured offsets to substantiate this potential.

2.2.4.3 Volcanic Activity

Quaternary volcanic activity is associated with the Sentinel basalt flow which is present in the southeastern portion of the study area (Geology, GB-10). A radiometric age-date from the flow indicates it is late Quaternary in age (1.71 $\pm$ 0.25 my) (Fugro,1974; Appendix B). Eastwood (1974) suggests a 2.9 percent probability for renewed volcanic activity in the next

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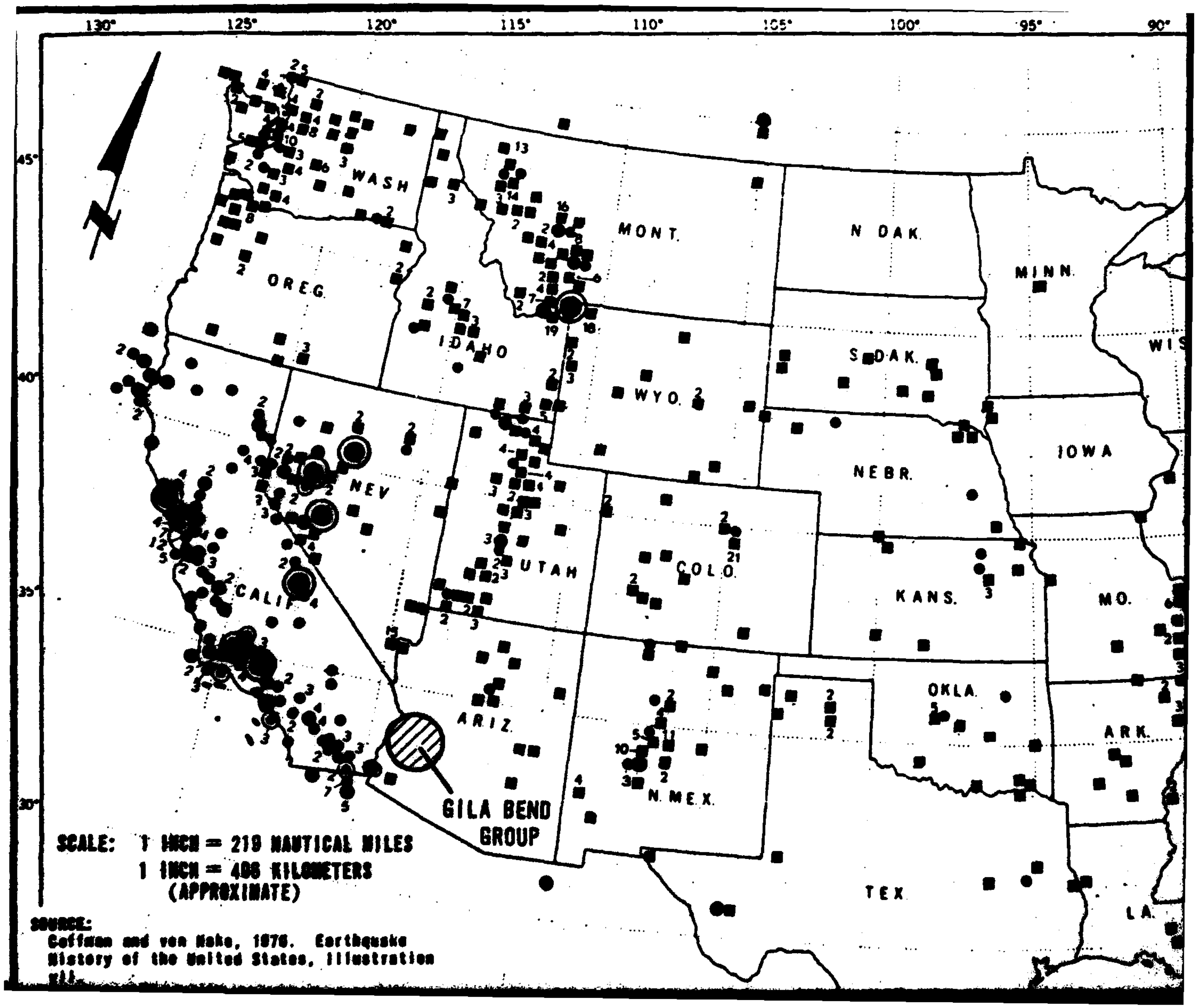
0.5 million years within the entire Basin and Range Province.

2.2.4.4 Seismicity

Judgement of the level of seismicity for a region is dependent upon the size of earthquakes that have occurred, their frequency of occurrence, and the resulting intensitites of ground shaking. Various regions of the United States have relatively high levels of seismicity (e.g., coastal California, Alaska) and others have relatively low levels. The regional seismicity of the western United States is shown in Figure __.

Prior to 1968, Arizona lacked a well-developed seismic detection network. Therefore, locations of epicenters reported prior to July 1968 are accurate to the nearest 0.1 degree (6 nm) and prior to the middle 1950's probably are accurate to the nearest 1/2 to 1/4 degree (30 to 15 nm) (Hileman, 1973). The detection threshold, or minimum magnitude earthquake recorded of this system was approximately magnitude 4.5 prior to 1945 and about 4.0 until 1968 (Fugro, 1974a, b). Since 1968, earthquake magnitudes as low as 3.0 have been recorded.

Little is known about the pre-instrumental (pre-1927) earthquake history of the southwest, including the study area, because of sparse settlement and a lack of records or earthquake effects. Historic records were first kept at Fort Yuma, Arizona in 1852, since it was the only potential reporting station in the immediate area. Table _ lists pre-1927 earthquakes reported in the vicinity of the Gila Bend Group. The


130°
125°
120°
115°
110°
105°
100°
95°
90°
45°
40°
35°
30°
WASH
OREG.
IDAHO
MONT.
N DAK.
S DAK.
MINN.
WIS
IOWA
WYO.
NEBR.
NEV
UTAH
COLO.
KANS.
MO.
CALIF.
ARIZ.
N. MEX.
OKLA.
ARK.
TEX
LA.
GILA BEND GROUP
SCALE: 1 INCH = 219 NAUTICAL MILES
1 INCH = 406 KILOMETERS
(APPROXIMATE)
SOURCE:
Coffman and von Hake, 1976. Earthquake History of the United States, Illustration

Modified Mercalli Intensities (MMI; Appendix D) are the strongest reported, and occurred at the locality listed. Richter magnitudes and distances from the study area are estimated. The largest historic earthquake (M - 8 est.) felt in the study area occurred on 3 May 1887 near, Sonora, Mexico.

The Gila Bend Group siting area is situated in an essentially aseismic zone in the central part of the Sonoran Desert geologic and physiographic subprovince (Figure __). Recorded seismicity in this zone is limited to widely scattered earthquakes of low magnitude which have not generally been associated with causative faults. The zone does not include any large pre-instrumental earthquakes (Table __).
The maximum earthquake recorded in this zone is 5.5, occurring near Prescott, Arizona, ___ nm northeast of the study area. A 4.7 magnitude earthquake was recorded near the western border of this zone in the eastern Mohave Desert, ___ nm west of the study area. The remaining 15 seismic events recorded are of magnitude 3.8 and less, two of these events fall in the Cactus-Ranegras Plains area (Geology, GB-1, 4).

A diffuse grouping of earthquakes with magnitudes ranging from 3.9 to 5.0 occur in south-central Arizona, also within the Sonoran Desert geologic and physiographic subprovince (Figure __). There is a large uncertainty in specific epicenter locations associated with known structures, however, the seismicity is coincident with the Pleistocene to Holocene Pinacate volcanic field and a number of mapped northwest trending Quaternary

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Table 10

List of Pre-1927 Earthquakes, Magnitude 6+ or Greater in the Vicinity of the Gila Bend Group Siting Area

Year	Date	Locality of MMI	Magnitude/ Max. Est. Intensity (MM)	Approximate Distance of Locality from Gila Bend Group Siting Area
1852	9 Nov.	Imperial Valley SW of Fort Yuma, Arizona	?/VIII - IX	6 nm (?)
1853	Dec.	Fort Yuma, Arizona	?/X-XI(?)	6 nm (?)
1857	8 or 9 Jan.	Fort Yuma, Arizona	8+ est./IX(?)	130 nm (?)
1871	August	Imperial Valley, California	?/IX or X	40 nm
1887	3 May	Sonora, Mexico	8 est./?	150 nm
1906	25 Jan.	Flagstaff, Arizona	?/VII-VIII	
1906	18 April	33^{0} N 115^{0} S	6+/VIII	
1915	22 June	Imperial Valley 32.8N, 115.5W	7-7.5 est./IX	6 nm
1915	20 Nov.	Imperial Valley,	?/VI	40 nm

Sources: Coffman and von Hake, 1973; Sturgul and Irwin, 1971; Bonilla, 1967; Townley and Allen, 1939.

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TABLE

PRE-INSTRUMENTAL EARTHQUAKES

faults (Merriam, 1972).

A belt of high seismicity associated with the San Andreas fault system passes within ___ nm west of the Gila Bend Group siting area (Figure __). This zone is characterized by high seismicity and continuous, generally northwest trending zones of Quaternary faults. The northeast boundary of this zone is controlled by the northeast limit of the San Andreas fault system, taken to be the San Andreas, Sand Hills, and Algodones faults.

Recorded seismicity within the zone adjacent the study area includes many earthquakes of magnitude 6.5 to 7.1 and numerous smaller events. Northern portions of the San Andreas fault system, ___ nm to the northwest, have produced two historic earthquakes with 8+ magnitudes. Therefore, the San Andreas, Sand Hills, and Algodones faults have been considered capable of producing an earthquake of magnitude 8+ within the zone adjacent the Gila Bend Group siting area.

2.2.4.5 Seismic Risk

The probability of the occurrence of potentially damaging earthquakes is of major concern in evaluating the seismic risk of a region. The factors that influence the determination of seismic risk are: (1) the size and location of capable faults; (2) the level of seismicity of the region, in particular the seismicity associated with capable faults; and (3) levels and intensities of earthquake induced vibratory ground motion caused by earthquakes in regions of concern.

Studies predicting the susceptibility of an area to relative levels of seismic intensity have been done for the western United States, and show that nearly all of the siting area has a maximum expected seismic intensity (measured on the MMI scale) of V to VI (Algermissen, 1969), with a maximum expected seismic intensity of <V to VII, increasing toward the Yuma Desert. Table _ summarizes the seismic risk associated with the zones of seismicity defined in the BLM area.

2.2.4.5.1 Levels of Vibratory Ground Motion

Maximum credible earthquakes are the largest earthquakes that faults or fault zones are thought capable of producing. These earthquakes generate maximum levels of vibratory ground motion (Table _). The maximum credible shaking that can occur is at the level that has been observed very near to the fault break during major earthquakes. Examples of this very severe level of vibratory ground motion are those experienced in San Francisco in 1906 (M = 8.3?), in the Fort Tejon area in 1857 (M - 8+) and in the Lone Pine area during the 1872 Owens Valley earthquake (M = 8+). However, becuase of the lack of accelerograms obtained very near the fault break, only estimates of the quantitative level of ground motion can be made. The estimates of different investigators show wide discrepancies; it has been estimated that peaks of acceleration ranging from one-half to more than one g (g being the acceleration due to gravity) can be expected.

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TABLE ___

LEVELS OF SEISMICITY AND SEISMIC RISK IN GILA BEND

GROUP SITING AREA

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The capability for maximum vibratory ground motion at the study area is determined by the zones of seismic activity described in section 2.2.4.4. Within the Gila Bend Group area the maximum earthquake magnitude recorded not associated with known faults is less than 4.0 (see Section 2.2.4.4). Two random events have been recorded in the Cactus-northern Ranegras Plains area. Since these events are not associated with known geologic structures, it is assumed that a random event of magnitude 4.0 or less could occur anywhere within the Gila Bend Group siting area, producing __ g level ground motion.

The Kofa Mountain fault is the only capable fault in the study area. Since no recorded seismicity has been associated with it, a __ magnitude earthquake has been assigned on the basis of its 6.8 nm length. An earthquake of this magnitude will produce shaking at the __ level.

The historic earthquakes within south-central Arizona range from less than magnitude 4 to magnitude 5.0. The closest approach of this area of seismicity to the BLM study area is approximately __ miles; The maximum historic earthquake assumed to occur on the closest Quaternary fault to the study area (__ miles) would produce shaking at the ___ level.

The San Andreas fault itself is the only feature with close proximity to the Gila Bend Group siting area that is considered capable of producing a great earthquake in the magnitude [illegible] 8+. It is located, at its closest approach to the study [illegible] a distance of about ___ nm. Historic earthquakes [illegible]

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zone at their closest approach to the study area (__) nm have been in the magnitude range of 6.5 to 7.1. The level of vibratory ground motion to be expected at the site from an earthquake of magnitude 8+ (on the San Andreas fault) at a distance of ___ miles is on the order of ____ g.

2.2.4.5.2 Teleseismic Events

Distant earthquakes (generally exceeding 100 nm) of M = 5 to 7 and large magnitude (M = 8+) teleseismic events (distances greater than 540 nm; Richter, 1958) may affect the siting area. Of primary concern are the long period waves generated by these distant earthquakes. Resonance may produce oscillation of pools of water (seiches) or damage long period structures. The most likely sources for distant large magnitude earthquakes in the seismically active portions of the western United States (Figure __) are: (1) portions of the San Andreas system lying greater than 100 nm to the northwest; (2) the Agua Blanca fault lying approximately ___ nm to the southwest; (3) the Rio Grande Rift Zone (Figure __) lying nm east of the study area; and (4) an areas of seismicity _________ nm to the north-northwest in north-central Nevada (near Reno). In addition, teleseismic events of large magnitude may be associated with the Aleutian and mid-America trenches.

2.2.4.6 Tectonic Subsidence

Subsidence within the BLM study area due to tectonism has not been reported. Postulated subsidence occurrences and mechanisms are discussed in Section 2.4.2.7.

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2.3 SOILS ENGINEERING

2.3.1 GENERAL

2.3.1.1 Data Base

The soils engineering data and design evaluation information presented here are derived from Soil Conservation Service (SCS) reports (Hartman, 1973, Richardson, 1973; Chamberlain, 1974), Arizona Materials Inventories (Scott, 1960; Higbie, 1964), data provided by the Arizona Highway Department, and Bureau of Reclamation data along the alignment of the Granitic Reef Aqueduct.

2.3.1.2 Map Units and Soils Engineering Data Sheets

The SCS and Materials Inventories reports delineate various surficial soil, rock and geologic units as generalized soil types on small-scale maps. These map units were adjusted and refined to conform to the geologic units derived by aerial photographic interpretatin and limited field observations, and are presented on the Soils Engineering/Geology overlays (GB-1 through GB-10). There are no separate Soils Engineering overlays. Soils engineering units correspond to the geologic map units. Included on the combined geology and soils engineering overlays are the specific test data points and specific test data stationing.

The Soil Conservation Service describes soils in agricultural terms which may incorporate more than one soil type as defined by the Unified Soil Classification System (USCS; Appendix [illegible]). The soil classification assigned to a map unit [illegible]

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predominant soil type, but not necessarily the only soil type within that particular map unit area. Soil classifications on the Data Summary Sheets are listed in order of decreasing areal abundance.

The Arizona Materials Inventory describes soils in geologic terms and also incorporates more than one soil type as defined by the USCS. The Materials Inventory also lists locations and tet data of sources of construction materials.

Soils Engineering Data Summary Sheets (Section 3.0) present both specific engineering data available from the literature and design evaluations based on engineering judgement using the available data The data presented deals primarily with the surficial deposits only (five feet deep or less). Design information should be considered general rather than specific for any map unit and used as general information, but not specific design. Where map units have similar soils engineering properties, the units have been combined in the Data Summary Sheets.

Specific soils engineering data from selected borings and test pits by the Arizona Highway Department and Bureau of Reclamation, within BLM Valley areas, were reviewed. These data are limited (Appendix H), consisting largely of identification properties such as grain size and Atterberg limits of the surficial deposits along major highways. The information was incorporated into the description of the related map units and onto the Soils Engineering Data Summary Sheets. Included with this data is a limited amount of subsurface data which did not allow for extrapolation of soil properties below the surficial five feet.

2.3.2 REGIONAL ENGINEERING PROPERTIES

2.3.2.1 General

The BLM Valley area can be considered, for a regional engineering discussion, to consist primarily of coarse-grained (USCS) basin-fill deposits, including alluvial fan, dune sands, pediment, terrace, floodplain, stream channel, and undifferentiated deposits (Section 2.2.2.2; 2.2.2.3, 2.2.2.5 and 2.2.2.6). All major soil types defined by the USCS are present in the BLM Valley areas. Coarse-grained basin-fill deposits generally consist of gravel-, sand-, silt- and clay-size materials (see Data Summary Sheets, Section 3.0). The wind blown sands consist of a uniform medium to fine sand.

2.3.2.2 Coarse-Grained Basin Fill

The coarse-grained basin fill encompasses 93 percent (2696 nm^2) of the siting area and is the major soil type within the BLM Valleys. Of this total, 76 percent (2056 nm^2) is alluvial fan and undifferentiated deposits, 13 percent (395 nm^2) stream channel and flood plain deposits, 8 percent (219 nm^2) sand dunes, and 2 percent (64 nm^2) pediment deposits, and less than 1 percent (11 nm^2) terrace deposits. The average grain-size distribution of the coarse-grained basin fill is 20 percent gravel, cobbles and boulders, 50 percent sand, and 30 percent silt and clay (data derived from Arizona Highway Department). These percentages will vary depending upon nearness to the mountains and/or stream channels, relative age of the geomorphic surface, the process by which the material was deposited, and the parent material.

The coarse-grained basin fill areas are considered the most suitable for siting because of the granular nature of the soils (granular soils have higher strengths and are less compressible) and the absence of near-surface groundwater and surface water. The portions of the coarse-grained areas which contain possible design problems are the pediments where rock is encountered within tens of feet of the ground surface, areas where caliche is present, collapsible soil areas, and stream channels and floodplains where a high flooding potential exists. Depth to rock ranges from zero near the mountain ranges to _______ (Section 2.2.3.3). The presence of caliche is random and widespread (Section 2.2.2.1; Arizona Highway Department). Stream channels have a high flooding potential and are moderate to highly incised (Section 2.4.1).

2.3.2.3 Wind-Blown Sand

The consistency and moisture content of the wind-blown sands (Section 2.2.2.5) are very loose to loose and dry. Construction problems in these areas include low strength values, erosion, and higher maintenance costs for certain MX design concepts.

The wind blown sand areas account for eight percent of the BLM Valley areas and the are concentrated mainly in Cactus Plain. The wind-blown sands are coarse-grained and are therefore discussed with the coarse-grained deposits. In these areas special design considerations may be required for roads, excavations and foundations and will be noted where applicable.

2.3.3 ROAD CONSTRUCTION

Specific design data for road construction, including California Bearing Ratio values, both in-situ and recompacted, (CBR; American Society for Testing and Materials, Designation D 1883), AASHO classifications (Appendix G), and shrink-swell potential, are presented in the Data Summary Sheets where available. The AASHO classifications were obtained from route studies along major highways (Arizona Highway Department, Bureau of Reclamation). Little engineering strength property data are available for actual design values and the following discussion provides some general information on road design in BLM Valley areas based on available soil data and engineering judgement. The model road section used consists of an 18" structural layer (CBR > 25) placed on compacted subgraded (CBR > 12) with a wheel load of 58 kips (TRW, 1975). Trafficability of unimproved terrain is considered in the Terrain Analysis (Section 2.6).

For most of the BLM Valley areas it is estimated that a CBR value of 10 to 20 is reasonable for in-situ material (KOA, 1970). A CBR value of greater than 20 and on the order of 30 should be obtainable by scarifying and recompacting the surface soils.

Flash flooding (Section 2.4 and Section 2.5) may occur in gullies and intermittent drainages, requiring either periodic road repairs or design of costly road structures across these areas. Maintenance to clear flood debris should also be anticipated. Paved roads with reinforced concrete aprons have been placed on channel inverts in some areas as an alternative to culverts. Roads will require periodic maintenance and in some areas have been completely washed out by flash floods (Arizona Highway Department). It is advisable that the system layout be planned as much as possible to parallel major drainages to alleviate this problem.

Wind erosion and shifting sand in the dune areas (Cactus and La Posa Plain North) will necessitate periodic road maintenance or some form of surface stabilization of adjacent dunes. Dune areas also have lower CBR values. Wind erosion and shifting soil occurs to a lesser extent (i.e., limited amount of movement, fine-grained materials only) throughout BLM Valleys, but is not considered a significant design problem.

2.3.4 EXCAVATIONS

No test data are currently available upon which to base design excavations. General considerations for making excavations involve the following factors:

1. Stability of excavation side slopes;
2. Presence of free groundwater;
3. Presence of caliche;
4. Presence of unrippable rock (Section 2.2.3); and
5. Presence of cobble- and boulder-size material.

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Based upon the engineering and geologic classifications of the surficial soils and engineering judgement, the ease of excavation for each soil map unit has been evaluated and is presented in the Data Summary Sheets. The following discussion provides some general information on excavations in the BLM siting area.

Most soils in the coarse-grained basin-fill areas can be excavated with conventional equipment at a slope angle of 45 to 60 degrees with the horizontal (SCS). In the dune areas, flatter side slopes will be required. Caliche and cobbles or boulders are widespread and occur randomly throughout the BLM Valley areas with the exception of the central portions (Arizona Highway Department). Blasting of caliche has been required in similar coarse-grained alluvial fans (Fugro, 1974, unpublished).

Near-surface rock occurs along the mountain flanks (Section 2.2.3.3). With the exception of a few seismic velocity measurements, no information was available on which to base an evaluation of the methods needed to excavate near-surface rock.

The static groundwater table is generally greater than ____ feet below the ground surface, in most Valleys (Section 2.4.2.3) and extensive dewatering of excavations need not be considered. However, perched water is known to occur in portions of the siting area (Sectin 2.4.2.4). It is not known to what extent perched water may be encountered and some local dewatering may be required.

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MX SITING INVESTIGATION. GEOTECHNICAL REPORT. VOLUME IIB. GILA --ETC(U)

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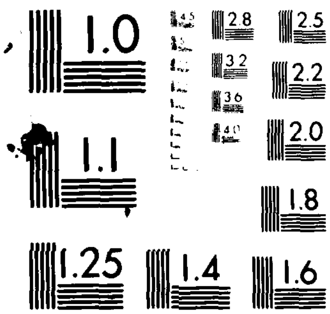

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

[illegible]

2.3.5 FOUNDATIONS AND STRUCTURAL CONSIDERATIONS

2.3.5.1 General

Depending upon the MX Siting concept selected, foundation design may or may not be critical. Important factors to be considered in foundation design include:

1. Bearing capacities;
2. Settlement and swell potential; and
3. The corrosivity of the soil.

Limited test data are available on which to base recommendations for foundation design. The information available is Standard Penetration Tests by the Bureau of Land Reclamation and included in Appendix H. Extrapolation of the limited data is not possible, therefore each map unit is evaluated qualitatively using engineering judgement to obtain foundation design parameters. The model considered for foundation support evaluation was a partially buried reinforced concrete structure with a level floor slab at approximately 24 feet below the existing ground surface (TRW, 1975). Although the soil descriptions and properties presented in the Data Summary Sheets are only considered to be applicable to a depth of five feet, the soil properties for the foundation analysis were assumed to extend to the depth of influence of the foundation. The relative shear strength, compressibility, and expansiveness of each unit are presented in the Data Summary Sheets and were considered for this analysis.

The soils within the SLM Valley are generally [illegible] the support of near-surface foundations [illegible] values on the order of 50 [illegible]. The shrink-swell potential of the soils throughout the area is generally low, and provisions in design to account for this condition should be minimal or only required locally. The alluvial fans are considered to have a moderate compressibility. An exception to this may be in areas of recent alluvium which are porous and potentially collapsible when saturated. The collapsible soil condition has been documented in several arid region studies, however, collapsible soil areas could not be differentiated within the BLM Valleys based on available information. Design of foundations in these areas will depend upon type and size of structure and the possibility of an increase in moisture content (Peck, Hanson and Thornburn, 1974).

2.3.5.2 Other Considerations

The lack of specific data and the limited scope of this report did not allow presentation of other structural design considerations such as lateral pressures on walls and footings, pile support, liquefaction, and soil-structure interaction during ground shaking due to earthquakes or blast forces.

2.3.6 SOURCES OF CONSTRUCTION MATERIALS AND SOIL STABILIZATION

2.3.6.1 General

Sand and fill and aggregate for [illegible] potential uses of construction materials [illegible] material are listed on the [illegible] and Arizona Highway [illegible]

[illegible] material.

2.3.6.2 Sand and Fill Material

The suitability of each soil map unit as a source of sand and/or fill material was evaluated, with [illegible] coarse-grained material containing few fines considered most desirable. In general, the coarse-grained alluvial fans, stream channels, and the geograhically limited (Cactus Flats and [illegible] North) sand dune areas will provide the best sources of sand and fill material. Data obtained from the Arizona State Highway Department indicate significant supplies of sand and fill material.

2.3.6.3 Aggregate for Base Course and Concrete

Well graded gravels with some sand, and little or no fines and cobbles, are considered the most desirable material for concrete aggregate and/or road base course. Stream channels are excellent sources of aggregate. Stream channel inverts have well graded gravels and some sands with little fines. Depending upon the intended use of the material, rock may [illegible] and crushed to obtain a specific size aggregate; however, the economic considerations of blasting and crushing must be [illegible]. In general, there is an adequate supply of [illegible]. The [illegible] quality and geographic distribution of caliche [illegible] spread and not well known (Section [illegible]). [illegible] blasted and crushed to obtain road [illegible] Highway Department, 1972) [illegible]

Undesirable conditions for excavating sources of aggregate include near-surface unrippable rock and groundwater, both of which limit the amount of easily obtainable material. Soil units with sulfates (deleterious to concrete) and/or high alkalinity (corrosive to uncoated steel) may be present in some materials.

2.3.6.4 Soil Stabilization

Stabilization of the various soils with the addition of cements and chemicals is possible. In general, cement can be mixed with all soils to create a stabilized soil-cement, road base or surface. Clay soils are more difficult to mix and require higher percentages of cement.

Asphalt can also be combined with granular materials to create a stabilized asphaltic concrete. Polymer compounds are available as a cementing agent for granular materials, but are generally quite costly.

Cement, lime and long-chain polymer chemicals can also be used to reduce the permeability of soils when mixed and recompacted. Testing of the reactions between the particular additive and the specific soil to be stabilized will be necessary for proper design.

[illegible]

[illegible]

[illegible] [illegible]

The Gila Bend Group [illegible] Hydrologic Basin which is divided into [illegible] Subregion, comprising approximately __ percent [illegible] total area and the Gila Subregion, comprising the [illegible] percent (___ nm^2) (Lower Colorado Region State-Federal Inter-agency, 1971).

Unlike most of the Basin and Rang Province where surface drainage is typically a closed-basin system draining into playas, the surface drainage with the study area is [illegible] the Gila, Santa Maria or Colorado rivers (Table __, Section 2.4.1.3). Surface waters within the Lower Colorado River Region have been adjudicated. The Colorado River, the [illegible] perennial stream adjacent the study area, is [illegible] interstate agreement among Arizona, California, and [illegible] national treaty with Mexico (Arizona [illegible]

2.4.1.2 Perennial Systems

Perennial systems refer to lakes, [illegible] which contain water throughout the year. [illegible] perennial systems within the [illegible] located less than 2 nm west of [illegible] Geology, GE-7) is the [illegible] [illegible]

[illegible] Ephemeral Systems

Ephemeral systems consist of playas, natural reservoirs and drainages which receive water only in direct response to seasonal precipitation. Playas do not occur within the study area, however, considerably large areas of standing water one to two feet deep form after intense precipitation in southern Ranegras Plain near Desert Wells, and on the flat between the Big Horn and Vulture mountains (Ross, 1923; Metzger, 1951; Geology, GB-5 and 6).

Primary ephemeral drainages are most commonly situated in the axial portion of the Valley diverting seasonal runoff from large watershed areas. The primary drainages are interconnected through contiguous Valleys, grading to the major trunk streams (Colorado and Gila Rivers) that flank the western and southern portions of the siting area. Channel characteristics (i.e. gradient, width, depth of incision, channel spacing and bed-material load) vary greatly along the entire length of most drainages. Table __ lists the primary ephemeral drainages, their respective Valleys and pertinent four-quad areas.

Generally smaller in size, but greater in number are the secondary ephemeral streams which drain smaller drainage basins and are the major tributaries to the primary drainages. Numerous secondary drainages occur throughout the study area providing periodic flow during and immediately following intense or long duration rainstorms. Water use restrictions due to possible [illegible] ownership of primary and secondary [illegible] [illegible] rights are not foreseen in the [illegible]

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TABLE __

BLM SURFACE DRAINAGE SYSTEMS

Valley	Primary Ephemeral Drainages	Principal Drainage Basin	Playas	Applicable Four-Quad
La Posa Plain	Tyson Wash	Colorado River		Y-I, Y-III
Mohave Wash Valley	Ehrenberg Wash Gould Wash Mohave Wash Mule Wash Pete's Wash Trigo Wash Weaver Wash	Colorado River		Y-I, Y-II, Y-III
Indian Wash Valley	Indian Wash Los Angeles Wash McAllister Wash Yuma Wash	Colorado and Gila Rivers		Y-II, Y-III, Y-VI
Castle Dome Plain	Big Eye Wash Castle Dome Wash	Gila River		Y-II, Y-VI, Y-III
King Valley	-	Gila River		Y-IV, Y-VII
Palomas Plain	Hoodoo Wash	Gila River		Y-IV
Yuma Desert	-	Colorado and Gila Rivers		Y-VI, Y-XII
Lechuguilla Desert	Coyote Wash	Gila River		Y-VI, Y-XII, Y-XIII
Mohawk-Tule Valley	Mohawk Wash	Gila River	3	Y-VIII, Y-XIII
San Cristobal Valley	San Cristobal Wash	Gila River		Y-VII, Y-VIII, Y-[illegible]
Growler-Childs Valley	Danieal Wash Growler Wash San Cristobal Wash Ten-Mile Wash	Gila River	1	Y-VIII, Y-[illegible], Y-[illegible]
Sentinel Plain	Midway Wash Ten Mile Wash	Gila River		Y-VIII, [illegible]
Gila Bend Plain	Quilotosa Wash Sauceda Wash	Gila River		Y-[illegible]
[illegible] Valley	[illegible] Wash	[illegible]		[illegible]

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TABLE 12

Gila Bend Group Surface Drainage Systems

Valley	Primary Ephemeral Drainages	Principal Drainage Basin	Applicable Four-Quad
Cactus Plain	Osborn Wash	Colorado River	GB-1, 2
Butler Valley	Date Creek Cunningham Wash Bullard Wash		GB-2, 3
McMullen Valley	Centennial Wash Tiger Wash	Gila River	GB-5, 6
La Posa Plain	Tyson Wash	Colorado River	GB-4, 8
Ranegras Plain	Bouse Wash Cunningham Wash	Colorado River	GB-5
Harquahala Plain	Centennial Wash	Gila River	GB-5, 6, 10
Palomas-Hyder Valley	Gila River Hoodo Wash	Gila River	GB-9, 10
Mohave Wash Valley	Numerous named and unnamed washes	Colorado River	GB-4, 7

Natural reservoirs are naturally occurring depressions that collect and store water (Bryan, 1920). These natural reservoirs include rock tanks (depressions formed in rock), charcos (depressions formed in fine-grained material), and sand tanks (sand-filled rock tanks). The length of time that water remains in these features depends on local conditions (i.e., permeability, source of water; Bryan, 1925a). These features are characteristic of the arid southwest and are undoubtedly present within the study area, however, they were not recognized during the brief field reconnaissance.

2.4.1.4 Surface Water Quality

Surface water in these ephemeral systems varies from fresh to moderately saline (Table _). Total dissolved solids (TDS) are generally much greater than 500 milligrams per liter (mg/l). It is probable that drainages flowing to the Gila River will be relatively higher in total dissolved solids than Colorado River inflow due to the large areas of enroute cultivation (Colorado River State-Federal Interagency Group, 1971). Principal constituents for surface waters entering the lower Colorado River consist of calcium, sodium and sulfates, whereas inflow to the Gila River near Gillespie Dam produce waters of the chloride-sodium-bicarbonate type (Lower Colorado State-Federal Interagency Group, 1971). The major contaminants of the surface waters include boron, nitrates and fluoride, with the latter averaging from three to four mg/l in the Gila River adjacent the study area (Lower Clorado River State-Federal Interagency Group, 1971).

CLASSIFICATION OF [illegible]

Water Type	[illegible]
Fresh (F)	<1000
Saline	>1000
Slightly saline (SS)	1000 to 3000
Moderately saline (MS)	3000 to 10,000
Very saline (VS)	10,000 to 35,000
Brine (B)	>35,000

Source: Robinove, Langford and Brookhart, 1958.

2.4.1.5 Flooding Potential

Qualitative flood susceptibility ratings of unknown, high (CF1, SF1) and (CF2, SF2) extreme have been assigned to the major drainages and landform surfaces within the siting area based upon the parameters shown in Tables __ and __. Susceptibility to flooding is dependent upon rainfall intensity and duration, and the size and the runoff characteristics of the contributing drainage basins. Analysis of those parameters can only be done when detailed data are available. The appropriate flood [illegible] symbol (e.g., CF2) designations [illegible]

The susceptibility of [illegible] to flooding [illegible] [illegible] discussions [illegible] [illegible] [illegible]

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TABLE 13

CLASSIFICATION OF FRESH AND SALINE WATER

Water Type	Total Dissolved Solids (mg/l)
Fresh (F)	<1000
Saline	>1000
Slightly saline (SS)	1000 to 3000
Moderately saline (MS)	3000 to 10,000
Very saline (VS)	10,000 to 35,000
Brine (B)	>35,000

Source: Robinove, Langford and Brookhart, 1958.

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CP1 drainages correspond to primary and major secondary drainages. Geologic and geomorphic evidence such as channel morphology, depth of incision, bottom roughness, overbank deposits and high water marks were evaluated along with historical structural damage to bridges, roads, culverts and check dams, to determine a probable flood susceptability rating for each drainage.

Landforms were rated based on their susceptibility to flooding, however, most areas lacked sufficient evidence to indicate flooding potential. A flood susceptibility rating can be applied in association with a landform without specific boundaries, but it will only apply locally. In general, the topographically higher, more deeply incised, pediments and fan surfaces exhibit a low to moderate flood hazard since most runoff would be channelized (Rahn, 1968). Portions of younger coalescing alluvial fans (bajadas) may have a moderate to high susceptibility to flooding because of possible overbank flooding of the numerous smaller drainages flow (Rahn, 1968).

Sheet flow predominates over channel flow in the Ranegras Plain and Harquahala Valley (Hydrology, GB-5, 6). The two Valleys exemplify the most extreme and best documented surface flooding conditions within the study area. Characteristically, well-channelized flow is generated from elevated smaller basins and mountain passes. On reaching the relatively flat (15 to 20 feet per mile) floodplain area flow velocities decrease, and become increasingly more braided with channels becoming more poorly defined to non-existent. At this point, channel flow spreads [illegible] sheet flow and may join with other tributary flows to form fronts as broad as five miles (U. S. Department of Agriculture, 1975). Inundated areas may have standing water for up to several months following a severe storm (Metzger, 1951).

2.4.1.6 Debris Flows

Debris flows are high density (large proportion of sediment load) and high viscosity (compared to stream flow) masses that generally are confined to stream channels with limited overland flow. Typically, debris flows occur following high intensity rainfalls in areas of high surface runoffs; they are of short duration (one hour or less) and may consist of either single or multiple pulses (Croft, 1967). The sediment load may be derived from soil erosion or channel degradation, or both, with the average grain size of the sediment load varying from fine-grained (mudflows) to medium-grained (mud-rock flows) to coarse-grained (rock flows) depending on the source area and stream gradient.

High intensity rainfalls (i.e., thunderstorms; Section 2.5.1.1), direct runoff rates (Section 2.4.1.5) and abundant sediment sources within the study area suggest a potential for debris flows. However, no evidence suggesting the occurrence of debris flows were observed during the brief field reconnaissance.

2.4.1.7 Runoff Characteristics

Direct runoff is defined as water received at the surface in excess of the retention (amount of water necessary for soil

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TABLE 11

Flood Potential Susceptibility Parameters
For Drainage Channels or Systems

Flood Susceptibility Rating (Overlay Symbol)	Description
Extreme (CF2)	Documented historic flooding and damage or significant geologic/geomorphic evidence (e.g., channel morphology, depth of incision, over-bank deposits) suggests periodic torrential water flow. Predominantly primary drainages.
High (CF1)	Possible evidence of historic flooding and specific geologic/geomorphic evidence suggests periodic torrential water flow. Predominantly secondary drainages.
Unknown (no symbol)	No specific evidence to indicate flooding potential, and/or drainages in area not analyzed. Predominantly minor secondary or smaller drainages.

TABLE 12

Flood Potential Susceptibility Parameters
For Landform Surfaces

Flood Susceptibility Rating (Overlay Symbol)	Description
Extreme (SF2)	Historic or significant geologic/geomorphic evidence of ponded flood waters.
High (SF1)	Historic or geologic evidence of significant overland flow or sheet flooding. Possible historic or geologic/geomorphic evidence of ponded flood waters, overland flow or sheet flooding.
Unknown (no symbol)	Insufficient evidence to estimate flooding potential.

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TABLE 14

Flood Potential Susceptibility Parameters
For Drainage Channels or Systems

Flood Susceptibility Rating (Overlay Symbol)	Description
Extreme (CF2)	Documented historic flooding and damage or significant geologic/geomorphic evidence (e.g., channel morphology, depth of incision, over-bank deposits) suggests periodic torrential water flow. Predominantly primary drainages.
High (CF1)	Possible evidence of historic flooding and specific geologic/geomorphic evidence suggests periodic torrential water flow. Predominantly secondary drainages.
Unknown (no symbol)	No specific evidence to indicate flooding potential, and/or drainages in area not analyzed. Predominantly minor secondary or smaller drainages.

TABLE 15

Flood Potential Susceptibility Parameters
For Landform Surfaces

Flood Susceptibility Rating (Overlay Symbol)	Description
Extreme (SF2)	Historic or significant geologic/geomorphic evidence of ponded flood waters.
High (SF1)	Historic or geologic evidence of significant overland flow or sheet flooding. Possible historic or geologic/geomorphic evidence of ponded flood waters, overland flow or sheet flooding.
Unknown (no symbol)	Insufficient evidence to estimate flooding potential.

saturation) loss rate (U. S. Bureau of Reclamation, 1973). Accurate calculations of the amount of direct runoff which can occur in the study area are difficult because of the paucity of accurate steam gaging data within the siting area. Some estimates can be made by studying and classifying the general soil characteristics of the basin and watershed geology and the physical cnaracteristics of the streams in the area, and by reviewing runoff studies conducted in similar environments. Estimates for direct runoff in the study area are based upon: (1) analysis of surface runoff in the western portion of the Yuma Proving Grounds (Hely and Peck, 1964); (2) analysis of existing records adjacent to the area (U. S. Geological Survey, 1964, 1965b, 1967, 1968b, 1969, 1974a; Aldridge, 1970); (3) studies done in similar desert environments (Davis, 1938; Lowdermilk, 1952; Benson, 1964; Croft, 1967; Moore, 1968; Rahn, 1968; Baker, 1973); and (4) general runoff calculations performed by the U. S. Bureau of Reclamation (1973).

These studies indicate that in the area direct runoff ranges from less than 0.02 inches to greater than 0.5 inches (less than one percent to approximately ten percent of the mean annual precipitation) in the valley areas, with the larger values generally corresponding to topographically higher portions of the Valley. Greater runoff values ranging from 0.5 inches to greater than 2.5 inches (approximately 15 percent to greater than 30 percent of the mean annual precipitation) occur in the mountainous areas of greater than ten percent grade where annual rainfall amounts range from six to greater than ten inches and infiltration is low due to the [illegible] impervious nature of the rock units exposed at the surface.

Basin areas with nearly impervious soils (playas and pediments) may have higher runoff values (Rahn, 1968) than reported by Hely and Peck (1964) for the general valley areas due to a low infiltration rate.

2.4.1.8 Design Flood Determinations

The maximum probable rainfall an area may receive is used to determine design floods. Information in this section presents maximum point rainfall values based on studies of probable maximum general-type storms. The BLM study area lies approximately 400 to 485 nm west of the 105° meridian which is the dividing line between rainfall presented as probable maximum general-type storms and probable maximum precipitatin (PMP; U. S. Bureau of Reclamation, 1973). Because PMP information is only available for areas east of the 105° meridian and there is a lack of detailed existing data for computation of such values within the Gila Bend Group, PMP values are not presented here.

The probable maximum six-hour point rainfall values for a general-type storm are based upon approximately 330 design storm analyses prepared by the Bureau of Reclamation and numerous other design storm analyses by the National Weather Service (U. S. Bureau of Reclamation, 1973). These values can be applied to areas up to 1000 square miles (754 nm^2). The probable maximum six-hour point rainfall values for the BLM study area are shown in Table __. Also included are values

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TABLE ___

RANGES OF PROBABLE MAXIMUM POINT RAINFALL VALUES

Duration (Hours)	Probable Maximum Point Rainfall Values General-Type Storms (in inches) YPG and LMBGR (West of 114° Meridian)
1	1.8
2	2.9
4	4.7
6	6.0
12	9.2
18	11.2
24	12.6
48	14.5

Duration (Hours)	Probable Maximum Point Rainfall Values for Thunderstorms (in inches) YPG/LMBGR
0.25	5.3
0.50	7.8
1	11.0
2	13.9
3	14.7

Source: U. S. Bureau of Reclamation, 1973.

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TABLE 16

RANGES OF PROBABLE MAXIMUM POINT RAINFALL VALUES

Duration (Hours)	Probable Maximum Point Rainfall Values General-Type Storm (in inches) YPG and LWBGR (West of 114° Meridian)
1	1.8
2	2.9
4	4.7
6	6.0
12	9.2
18	11.2
24	12.6
48	14.5

TABLE 17

Duration (Hours)	Probable Maximum Point Rainfall Values for Thunderstorms (in inches) YPG/LWBGR
0.25	5.3
0.50	7.8
1	11.0
2	13.9
3	14.7

Source: U. S. Bureau of Reclamation, 1973.

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for storm durations of increments less than and greater than six hours.

Thunderstorms account for the most intense rainfall that occurs in the study area over a short period of time. The rainfall values for the probable maximum thunderstorm are also shown in Table _ for areas as large as 100 square miles (75 nm^2) and increments of time less than and greater than one hour. For design purposes, the probable maximum thunderstorm rainfall should be assumed to occur over the upstream area nearest the point of interest for those drainage basins exceeding 100 square miles in the area.

The variable topography in the southwestern portions of the United States greatly influences the flooding potential and permits only limited transposition of storms. The point values presented in Table __ can be applied to areas up to 1000 square miles for general-type storms and 100 square miles for thunderstorms by multiplying the point values by the appropriate ratio shown in Table __.

Studies by the National Weather Service (U. S. Department of Commerce, 1972) have shown that the most severe thunderstorm occurring in the immediate area of the BLM study area occurred at Fort Mohave, Arizona (approximatly 35 nm northwest of Parker, Arizona) in 1898. Available records show that eight inches of rain fell in 45 minutes as a result of a severe thunderstorm. This value is actually higher than the probable maximum point rainfall estimated by the USBR for that area (Table __).

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2.4.2 GROUNDWATER HYDROLOGY

2.4.2.1 General Groundwater Conditions

The BLM study area is bissected by a sinuous north-south boundary which separates two major groundwater systems. The eastern one-half of the study area comprises the Gila subregion, with Valleys having direct groundwater flow south toward the Gila River. The Gila subregion encompasses McMullen Valley, Harquahala Plain and Palomas-Hyder Valley (Hydrology, GB-5, 6, 9 and 10). The western one-half comprises the Lower Main Stem subregion which is Valleys directing groundwater flow to the north and west toward the Colorado River. Mohave Wash and Butler Valleys, Ranegras, Cactus and La Posa Plains lie within the Lower Main Stem subregion (Hydrology, GB-1, 2, 4, 5, 7 and 8). Although Butler Valley is part of the Lower Main Stem group, it is suspected of being a closed basin (Manera, 1970). In both regions, groundwater is primarily derived from basin-fill aquifers. Perched and rock aquifers are assumed to occur within the study area, however, they do not consitute a major water bearing source. Fluctuations in the static groundwater levels have been noted in several Valleys due to groundwater pumpage and overdraft. Recharge of the groundwater is supplied by infiltration of surface runoff and direct precipitation and by underflow from bordering areas. Discharge of groundwater occurs by evapotranspiration, by pumping and by underflow to the Gila and Colorado River Valleys.

TABLE [illegible]

CONVERSION OF POINT RAINFALL VALUES TO AREA VALUES

General-Type Storm		Thunderstorm	
Area (sq. miles)	Ratio	Area (sq. miles)	Ratio
100	0.90	10	0.80
200	0.82	20	0.72
400	0.71	40	0.63
600	0.68	60	0.57
800	0.66	80	0.52
1000	0.65	100	0.47

Note: Multiply the above values by the appropriate point rainfall values for area conversion.

Source: U. S. Bureau of Reclamation, 1973.

2.4.2.2 <u>Distribution and Use of Existing Wells and Groundwater Data</u>

Approximately __ active and inactive wells occur within the study area. Table __ depicts the number, percentages and uses of water wells per BLM Valley. All wells with associated driller's or geologist's lithologic logs were obtained and recorded, and selected logs were used for rock depth determinations. The water wells used for the study were primarily selected from the master computer print-out of water wells and springs in Arizona, provided by the U. S. Geological Survey (1975) Tucson, Arizona. From these wells the most [illegible] and current data were selected for interpretation.

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The basin-fill materials comprise the principal water bearing unit within the study area (Metzger, 1951, 1957, 1973; Armstrong and Yost, 1958; Kam 1961; Manera, 1970). Quaternary and Tertiary age basin fill consists of a heterogeneous mixture of gravel, sand, silt and clay of sufficient extent and permeability to allow unconfined groundwater flow. Alluvial thicknesses generally range from 1000 to 3000 feet in most Valleys (Appendix __, Section ____), however, the upper several hundred feet of unconsolidated Quaternary gravel and sand are generally the highest yielding aquifers ranging in production of ___ to ___ (Metzger, 1951, 1957). Local areas of perched water are suspected of occurring near Quartzsite and artesian aquifers have been tapped in fanglomerate beneath Mohave Wash Valley (Hydrology, GB-4, 7) (Metzger, 1973).

Static groundwater levels range from less than 30 feet below land surface near Bouse to greater than 550 feet in the Harquahala Plains (Hydrology, GB-4, 10) (U. S. Geological Survey, 1975). In general, groundwater movement is in the direction of the slope of the water table, that is toward the respective trunk stream in the hydrologic region. The water table slope is commonly less than the surface slope, hence groundwater depths tend to increase normal to the Valley axis and toward the distal end of the Valley.

Groundwater flow is often restricted or dammed by subsurface rock forming groundwater barriers near the areas of Valley [illegible]. Groundwater is backed up until sufficient elevation [illegible]

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TABLE __

DISTRIBUTION AND USES OF EXISTING WELLS IN THE GILA BEND GROUP to "spill-over" into the adjacent Valley (Metzger, 1951, 1957). Water is at a minimum depth under these conditions, occurring at less than ___ feet below land surface in northern Ranegras Plain, ___ feet in southwestern McMullen Valley, less than 150 feet in southeastern Harquahala and ____ feet in southwestern Butler Valley (Hydrology, GB-4, 5 and 10).

Significant fluctuations in the groundwater table have occurred in recent years due to increased withdrawals for agricultural development. The southeastern Harquahala Plains and McMullen Valley are the most severe examples of groundwater overdraft in excess of the natural rate of recharge. McMullen Valley, near Aguila and Wenden have had declining water levels of 65 to 70 feet for the period of 1958 through 1965, creating two major ground water cones of depression (Briggs, 1969). The southwestern Harquahala Plains has developed a large cone of depression from excessive pumpage, declining as much as 100 feet from 1966 to 1974. These depression cones have altered, and in some cases reversed groundwater flow within the Valleys (Briggs, 1969; U.S. Department of Agriculture, 1975). Groundwater declines in the remaining BLM Valleys from 1969 to 1974 range from moderate to slight with a maximum of 23 feet west of Face Mountain in Palomas-Hyder Valley (Hydrology, GB-10) (U. S. Geological Survey, 1975).

2.4.2.3 Perched Conditions

Caliche deposits and clay layers within the basin fill may poduce perched groundwater conditions. Perched water tables have been identified in the La Posa Plain by Turner (1960) and Metzger (1973). The most extensive perched condition lies beneath the town of Quartzsite extending northward along Tyson Wash for approximately five miles (Metzger and others, 1973). Depth to water in Quartzsite ranges from ___ to ___. The amount of groundwater that can be obtained from these intervals depends on the areal extent and physical nature of these deposits, neither of which is well known. Perched water tables are suspected to exist in portions of McMullen Valley and Harquahala Plains (Kam, 1961; Stulik, 1964) (Hydrology, GB-3, 5, 6 and 10). Due to the similar character of the basin sediments, it is assumed that perched water tables exists locally in other BLM Valleys.

2.4.2.4 Groundwater in Rock Aquifers

Groundwater in rock aquifers is unconfined in fractures within the basement rocks and confined within bedrock strata. Igneous and metamorphic basement rocks are considered relatively impermeable in the study area. Groundwater movement through the basement rocks is precluded by their documented occurrence as groundwater barriers (Metzger, 1951, 1957, 1973). A few scattered deep wells have entered basement rock, but there is no potential for groundwater development (Metzger and others, 1973).

Bedrock aquifers are limited in occurrence to Tertiary sedimentary rocks in the study area. The Bouse Formation, a marine estuarine deposit is not exposed, but known to underlie large portions of the Cactus and La Posa Plains and Mohave Wash Valley (Hydrology, GB-1, 4, 7) (Metzger and others, 1973). The Bouse Formation is informally subdivided into upper and lower water bearing sand units which exhibit changes in facies, and water bearing properties over relatively short distances (Metzger, 1973).

A Tertiary sandstone sequence north of Parker (Hydrology, GB-1) underlies the Black Peak Volcanics (13.7 ± 0.7 m.y., Fugro, 1975). Shallow wells north of Parker are suspected of small yields from these rocks (Metzger, 1973). Tertiary sandstones may underlie the low volcanic outcrops in the central Cactus Plain, and probably have been encountered at depths of ___ feet in the northern La Posa Plain (El Paso Natural Gas company, 1968; Fugro, 1975).

Younger basic flows, if sufficiently fractured may be a potential source of water (Metzger, 1973).

2.4.2.5 Water Quality

Chemical analyses of groundwater from wells in the study area Valleys allowed a general separation of groundwater into fresh and saline water based on the amount of total dissolved solids (TDS) (Section 2.4.1.4, Table _).

Most all groundwater in the BLM Valleys qualify as fresh water, with total dissolved solids generally less than 1000 ppm (Metzger, 1951, 1957; Kam, 1961; Armstrong and Yost, 1958; Manera, 1970). Concentrated areas of saline water with total dissolved solids up to 12,500 ppm occur along the southern margin of Palomas-Hyder Valley, northern Ranegras Plain, southern McMullen Valley and adjacent to the town of Quartzsite in the La Posa Plain (Hydrology, GB-4, 5, and 10). Principal constituents are commonly chloride, sodium, sulfate and calcium. A primary contaminant is flouride, which ranges from approximately 1.5 ppm to 8.9 ppm in the Ranegras Plain (Metzger, 1951). Other contaminants may be present in small amounts and include iron, nitrate, boron and arsenic (Lower Colorado River State-Federal Interagency Group, 1971).

2.4.2.6 Subsidence

Subsidence due to withdrawal of fluids from the ground has been measured in the Harquahala Plains (Hydrology, GB-10) (Arizona Water Commission, 1975). A potential for subsidence with possible surface expession such as earth cracks or earth fissures exists seems probable with future lowering of groundwater levels. Subsidence has occurred in agricultural regions of Arizona and California where prolonged, heavy pumpage is accompanied by progressive drawdown of the groundwater table. Where subsidence has occurred in Arizona, it has generally equaled about four percent of the total groundwater decline, or four feet of subsidence per 100 feet of groundwater level decline with a minimum of 200 feet groundwater level decline necessary for recognizable subsidence (Central Arizona Project, 1974).

No earth cracks have been reported within the study area, however, earth cracks have been reported in Arizona since 1927 and are located primarily within a 45 nm wide band trending northwest from Tucson toward Prescott, Arizona, within approximately

__ nm of the study area. These features have been extensively investigated (Leonard, 1929; Heindl and Feth, 1955; Pashley, 1961; Robinson and Peterson, 1962; Winikka, 1964; Kam, 1965; Poland, 1967; Polad and Davis, 1969; Schumann and Poland, 1969; Mildner, 1970; Pope and others, 1972; Anderson, 1973; Bull, 1973; and Sumner, 1973).

Both the Harquahala Plain and McMullen Valley have been subjected to extensive groundwater overdraft far in excess of the natural rate of recharge. Continued groundwater overdraft may parallel documented subsidence basins, resulting in: (1) consolidation and subsidence at depth due to dewatering and lowering of the groundwater level by pumping; and (2) rapid settlement of the near-surface material due to addition of water at the surface by irrigating (Winikka, 1964). Tensional stresses produced by shrinkage result in earth cracks or fissures along potential zones of weakness, such as at the interface between alluvial fan and undifferentiated surficial deposits (Bull, 1973a). These fissures have maximum reported lengths of seven nm and depths of 60 feet and generally coincide with linear zones of steep gravity gradients that may reflect buried fault scarps (Schumann and Poland, 1969). Initially, however, the fissures appear as narrow cracks one to six inches in width with vertical offsets of zero to 12 inches (Anderson, 1973) and are reported to have split concrete roads and curbings (Robinson and Peterson, 1962; Schumann and Poland, 1969). When earth cracks transect drainages, water entering the fissures is transmitted verti-

cally and laterally along the crack causing gullying and slump-
ing (Kam, 1965). Widths of eroded fissures are commonly five
to ten feet, but may be as great as 20 feet (Anderson, 1973).

2.5 CLIMATOLOGY

2.5.1 GENERAL

Climatic conditions within the BLM study area are primarily a result of its inland location and latitudinal position. These two factors combine to produce an arid to semi-arid climate, characterized by hot summers, mild winters, relatively low humidity and long periods of aridity separated by periodic intense rainfalls. Climatic conditions are fairly uniform throughout the area, with local variations due primarily to elevation differences.

Table __ lists the climtological recording stations in the vicinity of the BLM study area; the station locations are depicted in Figure __. Climatological Data Summary Sheets (Appendix __) were compiled for selected recording stations within and adjacent to the BLM study area representing general climatic conditions within the area. Users of the Climatological Data Summary Sheets, tables, and text are reminded that conditions at locations other than the selected recording stations may be significantly different due to local terrain effects and elevation differences.

The primary sources for data presented on the Climatological Data Summary Sheets and are: (1) the National Oceanic and Atmospheric Administratin (NOAA) Environmental Data Service (1973); and (2) Sellers and Hill, 1974.

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TABLE __

CLIMATOLOGICAL RECORDING STATIONS

Station Name	Latitude N	Longitude W	Elevation (feet)	Years of Record
Aguila	33° 57'	113° 11'	2170	38
Alamo Dam 6ESE	34° 15'	113° 28'	1480	11
Blythe Airport	33° 37'	114° 36'	268	-
Bouse	33° 57'	114° 1'	930	20
Buckeye	33° 22'	112° 35'	870	41
Ehrenberg	33° 36'	114° 32'	323	31
Harquahala Plains No. 1	33° 30'	113° 04'	1260	21
Kofa Mountains	33° 16'	113° 52'	1775	20
Lake Havasu	34° 27'	114° 23'	482	5
Parker	34° 10'	114° 17'	425	41
Phoenix	33° 26'	112° 01'	1117	-
Quartzsite	33° 40'	114° 14'	890	41
Salome 6SE	33° 40'	113° 32'	1700	26
Signal 13SW	34° 22'	113° 48'	2505	9
Tonopah 2S	33° 27'	112° 56'	1090	15
Wickenburg	33° 58'	112° 44'	2095	41

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TABLE 18

CLIMATOLOGICAL RECORDING STATIONS

Station Name	Latitude N	Longitude W	Elevation (feet)	Years of Record
Aguila	33° 57'	113° 11'	2170	38
Alamo Dam GESE	34° 15'	113° 28'	1480	11
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Buckeye	33° 22'	112° 35'	870	41
Ehrenberg	33° 36'	114° 32'	323	31
Harquahala Plains No. 1	33° 30'	113° 04'	1260	21
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Tonopah 2S	33° 27'	112° 56'	1090	15
Wickenburg	33° 58'	112° 44'	2095	41

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FIGURE

LOCATION OF CLIMATOLOGICAL RECORDING STATIONS

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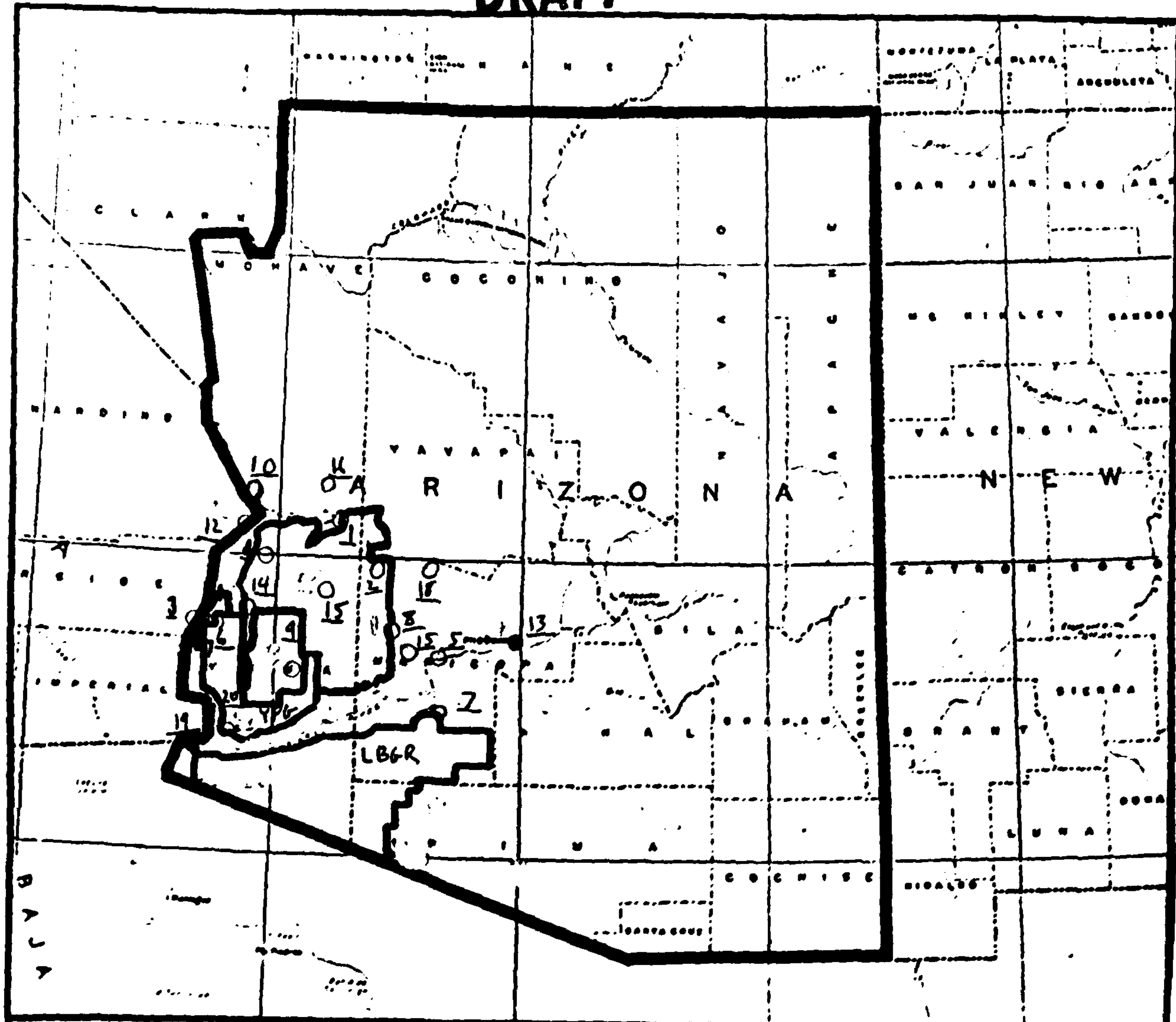

EXPLANATION

STATIONS

1 Alamo Dam 6ESE
2 Aquila
3 Blythe, Calif.
4 Bouse
5 Buckeye
6 Ehrenberg
7 Gila Bend
8 Harquahala Plains #1
9 Kofa Mountains
10 Lake Havasu
11 Painted Rock Dam
12 Parker
13 Phoenix
14 Quartzsite
15 Salome 6SE
16 Signal 13 SW
17 Tonopah 2 S
18 Wickenberg
19 Yuma
20 Yuma Proving Ground

0 50 100 150
NAUTICAL MILES

0 100 200
KILOMETERS

SYMBOLS

Boundary of Bureau of Land Management Study Area
19 ● Major recording stations
9 ○ Recording substations
1 Records compiled on data sheets.

LOCATION OF CLIMATOLOGICAL RECORDING STATIONS

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 12

FUGRO NATIONAL, INC.

DATE: 30 JUNE 1979

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2.5.1.1 Precipitation

The low mean annual precipitation of the BLM study area is controlled by (1) the inland location of the area; (2) the rain-shadow effect of the mountain ranges on the west coast of the U. S.; and (3) the north-south trending mountain ranges within the siting area. Precipitation occurs principally in the months of July, August and September and December, January and February, and is generally in the form of rain, although traces of snow, sleet and/or hail have been recorded throughout the study area. Generally, the western area has less average rainfall (2.41 inches at Lake Havasu) than the eastern portion of the area (6.0 inches at Harquahala Plains No. 1 and 10.77 inches at Wickenburg) where elevations are also generally higher.

August is statistically the month of heaviest rainfall, although approximately two-thirds of total annual precipitation occurs during the winter months. Summer rains usually result from local thunderstorms; while in the winter, gentler rains over a large area are more common. Maximum daily precipitation of 4.0 inches in the Kofa Mountains and 3.60 inches at Alamo Dam, during the months of July and August have been recorded (Sellers and Hill, 1974).

2.5.1.2 Wind

Wind data are not particularly abundant, existing only for two recording stations (Phoenix and Yuma) adjacent to the BLM study area (Sellers and Hill, 1974). A summary of wind data from these two stations show that in the eastern portion of the study area westerly winds predominate during the summer and easterly winds prevail during the remainder of the year. In the western portion, southerly and southeasterly winds predominate during the summer, and northerly winds prevail during the remainder of the year.

Terrain has a definite effect on wind direction at any point principally due to differential heating between mountains and valleys. If winds in the free atmosphere are light, the surface wind will blow upslope or upvalley during the day and downslope or downvalley at night (Sellers and Hill, 1974). Daytime upvalley winds are normally two to three times stronger than downvalley winds.

Wind speeds annually average about ten miles per hour in the eastern portion of the study area and five to six miles per hour in the western areas. Maximum wind gusts of up to 50 to 75 miles per hour have been recorded at nearby stations (Phoenix and Yuma).

2.5.1.3 Temperature

From June to September the daytime temperature in the BLM study areas with elevations less than 5000 feet generally exceeds 90 degrees Farenheit (°F), with nighttime temperatures usually in the mid-seventies. The warmest temperatures in this portion of Arizona usually occur during the last week of June and the first two weeks of July (Sellers and Hill, 1974). Winters are mild with daytime temperatures averaging in the mid-sixties. [illegible] freezing temperatures have been reported at [illegible] in January and 30.8° F in December (Sellers and Hill, 1974).

The spring and fall months in Arizona are characterized by large daily temperature changes (Sellers and Hill, 1974). Early morning temperatures in the higher valleys (northern portions of the study area) may average near freezing, warming to afternoon maximums in the eighties. In the south and southwest section of the study area the temperature range is more likely to be from the low sixties to greater than 100 degrees.

2.5.1.4 Barometric Pressure

Daily and monthly average barometric pressure data are not available for the BLM study areas. Average seasonal levels of station pressure (in inches of mercury) for Phoenix and Yuma, respectfully, are: winter - 28.89 and 29.85; spring - 28.73 and 29.66; summer - 28.65 and 29.55; and autumn - 28.78 and 29.69. The mean annual station pressure for 1974 is 28.75 inches at Phoenix and 29.69 inches at Yuma.

2.5.1.5 Relative Humidity and Evaporation Rates

Relative humidities range from late afternoon (6:00 pm) lows of less than ten percent in May and June to greater than 60 percent during the period of December through February and in August. Early morning (6:00 am) relative humidity values range from 35 to 45 percent in May and June to greater than 65 percent during the period December through February and during August. Humidities as low as two percent have been recorded at Yuma with even lower values recorded in the Mohawk-Sentinel area.

Pan evaporation rates in the study area range between 80 and 105 inches per year. Corresponding lake or reservoir evaporation rates range between 55 to 75 inches per year (Sellers and Hill, 1974).

2.5.2 SEVERE WEATHER CONDITIONS

2.5.2.1 General

Severe weather conditions included here are unusual weather phenomena and are not extremes of the standard climatological parameters recorded in the Climatological Data Summary Sheets (Appendix __).

2.5.2.2 Fog

Fog may develop over the western portion of the study area particularly during the months of December, January and February. Although usually of short duration (less than five hours) the fog may limit visibility to less than one mile.

2.5.2.3 Thunderstorms

Thunderstorms in southwestern Arizona occur on an average of 15 days per year, primarily during the months of July through September. They result in intense rainfalls and may be accompanied by lightning, high winds, dust storms, tornados or funnel clouds, or hail. No data on average geographic extent or local intensity of these thunderstorms are available.

2.5.2.4 Dust Storms

High winds that accompany thunderstorms and low pressure storm fronts passing through the area may pick up dust and sand, creating local dust storms that can limit visibility to zero in the affected area. Dust devils or sand spouts are common in the late spring and summer in the low desert portions of the BLM study area. They are especially common in the dry months of May and June, when they form over the hot desert floor (Sellers and Hill, 1974).

2.5.2.5 Tornados and Funnel Clouds

Only two tornados have been reported in the vicinity of the BLM study area since 1960. These occurred in Yuma on 13 September 1966, and in Hyder on 4 October 1972 (National Weather Service, 1966a, 1967, 1972). The only funnel cloud reported in the area was sighted over Gila Bend on 4 October 1966. The most damaging tornados in Arizona have been observed in the Wellton-Sentinel area along the lower Gila River south of the BLM study area (Sellers and Hill, 1974).

2.5.2.6 Hail, Snow and Sleet

Hail may accompany severe thunderstorms. Since 1960, there have been only three reports of hail 0.5 inches in diameter or greater in the vicinity of the BLM study area. These occurred in Gila Bend on 15 August 1960 (1.0 inch), and in Yuma on 1 November 1963 (0.9 inch) and on 28 April 1964 (1.5 inches) (National Weather Service, 1960, 1963, 1964, 1967).

Rare and isolated occurrences of snow or sleet have been reported in the BLM study area. The greatest of these measurements were recorded at Aguila, 6.0 inches during the month of December, 1967 and at Signal, 10.0 inches during the month of November, 195

2.5.2.7 Tropical Storms

From August through October, tropical cyclonic storms (counter-clockwise similar to hurricanes) occur over the Pacific Ocean off the coast of Baja, Mexico. These tropical storms generally dissipate rapidly as they move inland. However, from 3 October to 7 October 1972, tropical storm "Joanne" moved across Arizona and is the first time in the recorded history of the state that a tropical storm has entered Arizona with its cyclonic air circulation intact (National Weather Service, 1972). The storm produced abundant precipitation (between two and three inches), resulting in extensive flooding and sustained wind speeds of 35 to 40 mph across southern Arizona. Tornados were reported in association with local thunderstorms that developed within the tropical storm system.

2.6 TERRAIN ANALYSIS

2.6.1 GENERAL

The purpose of the terrain analysis is to rank qualitatively, using quantitative methods, the various geomorphic landforms (alluvial fans, pediments, sand dunes, and terraces) within the Gila Bend Group BLM Valleys. A terrain analysis was applied to the BLM Valleys to determine terrain characteristics which may impose design limitations on, or greatly increase the cost of design and construction of the aim point or line concepts of the land mobile system. This analysis (Table __; Section 2.6.3.1) was performed on the entire siting area and not refined to the level of analyzing each Valley (Section 3.0) independently due to the lack of sufficient specific detailed data. The data and analyses presented in Table __ are based upon:

1. Limited ground and aerial reconnaissance field observations;
2. Review of aerial photographs (scale 1:30,000 and 1:60,000);
3. Pertinent literature;
4. Topographic base maps (scale 1:62,500; and
5. Application of the terrain analysis techniques described by the U. S. Army Corps of Engineers for preparing desert terrain analogs (Yuma Test Station served as the base area for these analogs; van Lopik and Kolb, 1959).

The completed terrain analysis was then compared to similar terrain and surface materials studies (Millet and Barnett, 1970; Barnett, 1975, in preparation) conducted at the Yuma Proving Grounds (YPG) DoD siting area.

Rating of the selected landforms is accomplished by:

1. Selecting the major factors to be analysed based on surface geometry and near-surface soil characteristics believed critical to siting;
2. Assigning a range of values which describes either quantitatively or qualitatively the individual factors which comprise the physical characteristics of the selected landforms;
3. Subdividing this overall range into three to six value ranges which were most suitable (or lowest total) to least suitable (highest total) condition;
4. Determining the characteristic factor value range; and
5. Totalling the ranking values for each landform.

The resultant rating represents the cumulative analysis performed on all landforms. These results presented in Table __ and Section 2.6.3 should not be considered a substitute for a more specific analysis based on detailed field related studies.

2.6.2 FACTORS USED IN THE TERRAIN ANALYSIS

The selection of the major factors for the terrain analysis discussed in the subsections below, was based on surface geometry and near-surface soil properties believed critical in a terrain study. Many of the factors and value ranges may imply more detail than is available based on data collected in this initial phase of the study. Descriptions are intended to allow planning activities to proceed until further refinement of the factors can be made based on future field investigations. Whenever value ranges for a factor overlap two rankings (Table __), the

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TABLE 19
TERRAIN ANALYSIS

ARIZONA BLM LANDFORMS	CHARACTERISTIC SLOPE IN PERCENT Value	Rank(1)	Drainage Density (Topographic Texture) Value	Rank(2)
Old	5-10	4	8-15	3
Intermediate	3-7	2	6-12	2
Undiffer-entiated	1-6	2	10->20	4
Young	1-5	1	10->20	4
Pediments	3-7	3	5-10	2
Sand Dunes	>10	5	<5	1
River	1	1	<5	1

Value Range	Rank	Value Range	Rank
0-2	1	0-5	1
2-5	2	6-10	2
5-7	3	11-15	3
7-10	4	16-20	4
>10	5	>20	5

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CHANNEL CHARACTERISTICS

Characteristic Relief Depth of Incision (Feet) Value (Avg.)	Rank (3)	Max.	Min.	Frequency of Slopes Greater than 50% (No/nm) Value	Rank (4)
15->20	5	>20	5-10	10-15	3
3-10	2	15	<1	8-12	3
<5	1	5	<1	3-10	2
<5	1	5	<1	<5	1
3-10	2	>15	1-2	5-10	2
<5	1			>20	5
<5	1			<5	1

Value Range	Rank
0-5	1
6-10	2
11-15	3
16-20	4
>20	5

Value Range	Rank
0-5	1
6-10	2
11-15	3
16-20	4
>20	5

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PLAN PROFILE

Peakedness Value (a)	Rank	Planar Shape Value	Rank	Areal Occupance Value (c)	Rank	Orientation Value (d)	Rank
I-C	3	L	1	40-60%	2	P	1
F-I	3	L-I	1	40-60%	2	P	1
N-F	2	L-I	1	>60%	1	P	1
N-F	1	L	1	>60%	1	P	1
F-I	3	I	2	40-60%	2	P	1
C	4	L	1	<40%	3	P-I	2
F	2	I	2	>60%	1	P-I	1

Value	Rank	Value	Rank	Value	Rank	Value	Rank
No prominent highs or lows (N)	1	Linear (L)	1	>60%	1	Parallel (P)	1
Flat-topped (F)	2	Intermediate (I)	2	40-60%	2	Intermediate (I)	2
Intermediate (I)	3	Non-Linear (N)	3	<40%	3	Random (R)	3
Crested (C)	4						

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SOIL PROPERTIES

Plan Profile Total=a+b+c+d	Rank (5)	CBR (in-situ) Value	Rank (6)	AASHO Classification Value	Rank (7)
7	2	>20	1	A-1	1
7	2	>20	1	A-1/A-2	2
5	1	>20	1	A-1/A-2	2
4	1	>20	1	A-1/A-4	4
8	3	>20	1	A-1	1
10	4	10-12	3	A-2/A-3	3
6	2	15-20	2	A-2/A-4	4

Total Value Range	Rank	Value Range	Rank	Value Range	Rank
4-5	1	>20	1	A-1	1
6-7	2	19-15	2	A-1 or A-2	2
8-9	3	12-15	3	A-2 or A-3	3
10-13	4	10-12	4	A-2 or A-4	4

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TABLE 19
Terrain Analysis

TERRAIN ANALYSIS RATING

Rank = 1+2+3+4+5+6+7	Evaluation
19	Poor
14	Fair
13	God
13	Good
14	Fair
22	Very Poor
12	Good

Evaluation

7-13	Good
14-16	Fair
17-20	Poor
>20	Very Poor

predominant value was used; if near equal, the more conservative (higher) value was used..

2.6.2.1 Slope Characteristics

The slope, or topographic grade of a surface may be defined in terms of its angle with the horizontal, usually expressed as the tangent of that angle. The characteristic slopes of the major landforms in the Arizona BLM Valleys are based upon the topographic grade determined by the average contour interval and topographic expression. Values ranging from 0% to 10% were rated (Table __). Characteristic slopes of the major landform surfaces typically range as follows: alluvial fans, 1% to 10%; pediments, 3% to 7%; terraces, 0% to 2%; the upper reaches of alluvial fans and pediments near the mountain front exceed 10%; and sand dunes may exceed 10%.

2.6.2.2 Channel Characteristics

Drainage density (topographic texture), characteristic channel relief (in terms of depth of incision) and frequency of channel slopes exceeding 50% are the channel characteristics utilized in this terrain analysis.

The density of drainages is de. ined as the number of distinct drainages per nautical mile determined from available topographic maps and aerial photograhs. The ratings in Table __ for drainage density have been adjusted to reflect reconnaissance field observations and data available in the literature.

2.6.2.3 Characteristic Plan Profile

The characteristic plan pofile is defined as the most common geometric profile found within the region based upon selective sampling in the area. It is the typical profile a landform may possess. Major elements of the plan profile (Figure __) are:

1. The peakedness or degree and extent of the highs versus the low areas (no prominent highs or lows, flat-topped, intermediate, or crested);
2. The planar shape of the landform highs (linear, intermediate, or non-linear);
3. The areal occupance of the crests or peaks as opposed to the lowlands (greater than 60%, 40 to 60%, or less than 40%); and
4. The degree of alignment of these landforms to each other (parallel, intermediate, or random).

2.6.2.4 Soil Properties

The terrain parameters discussed in Sections 2.6.2.1 through 2.6.2.3 deal primarily with the geometric configuration of individual landforms. Using only the geometric elements in a terrain analysis could result in a high rating for some landforms even though their near-surface soil conditions may make them less suitable. In order to adjust for this, two soil parameters were selected and applied: the California Bearing Ratio (CBR) and the AASHO classification (Appendix __).

Engineering judgement based upon the available soils information was used to estimate both the in-situ CBR values and [illegible]fication. The in-situ CBR value gives an indication [illegible]

CHARACTERISTIC PLAN PROFILE

Areal Occupance of Highs [1] — **Schematic Profile**

60% of area

40 to 60% of area

40% of area

60% of area

40 to 60% of area

40% of area

No pronounced highs or lows

ORIENTATION AND PLANAR SHAPE OF FEATURES

Non-linear and Random	Linear and Random	Non-Linear and Parallel	Linear and Parallel

[1] Highs are considered to be, (a) peaked or crested and exhibiting characteristic slopes greater than 6 degrees, or (b) flat-topped prominences on high level areas bounded by slopes in excess of 14 degrees.

Figure __. The characteristic plan profile is the typical geometric profile of a landform (van Lopik and Kolb, 1959).

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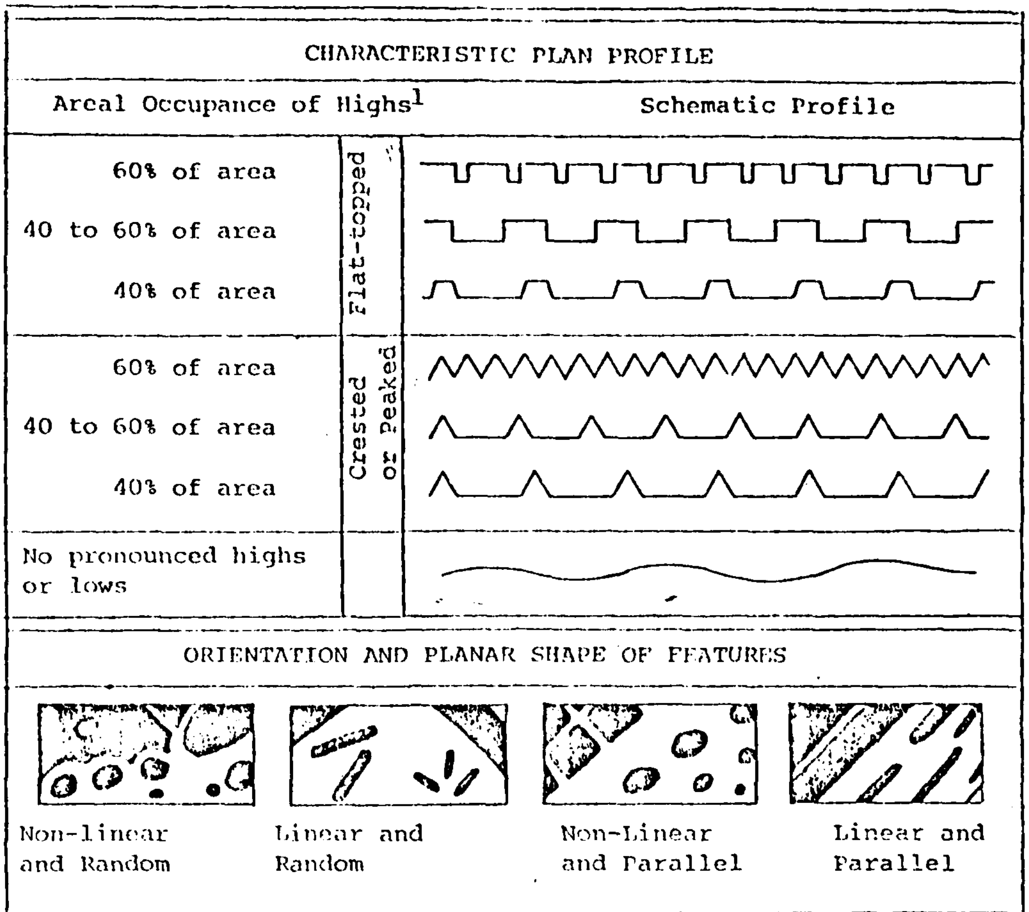

[1] Highs are considered to be, (a) peaked or crested and exhibiting characteristic slopes greater than 6 degrees, or (b) flat-topped prominences on high level areas bounded by slopes in excess of 14 degrees.

Figure 13 The characteristic plan profile is the typical geometric profile of a landform (van Lopik and Kolb, 1959).

surface soil strength; values exceeding 20 are assumed to be acceptable or would require minimal strength improvement to support loads imposed by an overland system. CBR values less than ten are considered unacceptable.

In addtion to CBR values, an AASHO classification, estimating the expected performance of near-surface materials as to workability, shrink-swell potential, shear strength, and relative drainage characteristics, was assigned. AASHO classifications A-1 and A-2 indicate materials that are assumed to be acceptable for use as subgrade, with A-6 and A-7 indicating unacceptable materials.

2.6.3 RESULTS

2.6.3.1 Evaluation Summary

Surface materials and terrain features have been studied in YPG (Millet and Barnett, 1970; Barnett, 1975, in preparation). These two studies examined geologic, geomorphic, topographic and terrain characteristics of the alluvial areas to determine their suitability for material testing. The following methods were used: 1) reconnaissance geologic mapping, 2) slope traverses (level surveys), 3) aerial photographic interpretation, 4) topo graphic map interpretation, and 5) selected soil sampling and testing, resulting in a series of 15-minute maps depicting the surficial materials and terrain features withn YPG. In general, the surface materials and terrain features identified within YPG and associated with specific landforms (Millet and Barnett, 1970; Barnett, 1975, in preparation) correspond closely with similar landforms identified within the Gila Bend Group BLM Valleys.

and thus reinforce the terrain ratings independently derived in this study (Table __).

The overall terrain analysis rating was divided into four categories: Good, Fair, Poor and Very Poor. A Good rating indicates that, in general, movement or construction of the land-based system would be feasible based upon the presence of favorable slope, channel and plan profile characteristics, and upon the judgement of favorable near-surface soil conditions. A Very Poor rating indicates that unfavorable slope, channel, plan profile and near-surface material characteristics may prohibit or greatly limit development of the system. Fair and Poor are intermediate ratings and reflect a combination of favorable and unfavorable characteristics.

Alluvial fan ratings range from Good to Poor. The old fans ($A5_o$) are rated Poor due to unfavorable slope and channel characteristics. The intermediate fans ($A5_i$) are rated fair due to unfavorable channel characteristics. The intermediate ($A5_i$) and young ($A5_y$) fans which are the predominant landforms within the study area are rated Good due to the favorable nature of all factors evaluated, except for drainage density.

Pediments (A6) are rated as Fair because of the favorable nature of the near-surface soil properties and unfavorable slope, channel and plan profile characteristics.

Sand dunes ($A3_d$) and those areas of apreciable sheet sand ($A3_s$) accumulation, thickness and extent are rated Very Poor due to unfavorable characteristic slope and plan profile and near-surface soil properties.

River terraces ($A2_r$) are rated Good due to favorable slope, channel and plan profile characteristics, even though the near-surface soil properties are less favorable. Thickness of these deposits is unknown and may be an important factor for siting.

2.6.3.2 Use of the Terrain Evaluation

The terrain analysis examines one important geotechnical aspect of MX siting. It combines an evaluation of critical geomorphic elements, such as drainage density and landform and channel morphology, with near-suface soil properties. It includes none of the other geotechncial constraints, which also have to be considered in the overall analysis of siting suitability, and no direct evaluation of the relationship of construction problems or cost related constraints.

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TABLE 20

Designated Valley Areas Within the Gila Bend Group Siting Area

Valley Name	Text Section	Total Valley Area (nm)	Area of Siting Valley (nm)	Applicable Four-Quad
Cactus Plain	3.3	237	208	GB-1, 2, 4, 5
Butler Valley	3.4	365	310	GB-2, 3, 5
McMullen Valley	3.5	317	216	GB-3, 5, 6
La Posa Plain	3.6	349	330	GB-1, 4, 8
Ranegras Plain	3.7	494	351	GB-4, 5, 9, 10
Harquahala Plain	3.8	542	351	GB-5, 6, 10
Palomas-Hyder Valley	3.9	525	424	GB-9, 10
Mohave Wash	3.10	71	61	GB-4, 7

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TABLE

DESIGNATED VALLEY AREAS WITHIN THE GILA BEND GROUP SITING AREA

3.0 VALLEY ANALYSIS

3.1 GENERAL

The Valley Analysis Concept discussed in this section was devised to allow for presentation of geotechnical data in a usefull and uniform manner unique to an individual Valley. The data are presented on Data Summary Sheets which are to be used in conjunctin with the general text and the pertinent four-quad overlays. Table __ shows the Valleys, their total land areas, the area of the siting Valley (based entirely on ten percent topographic grade exclusions and major cultural and quantity-distance exclusions), and the four-quad sheet or portion of four-quad sheets (and overlays) which the Valley occupies.

3.2 VALLEY ANALYSIS SECTIONS AND DATA SUMMARY SHEETS

Sections 3.3 through 3.10 describe the eight individual Valleys which comprise the Arizona BLM study area. Each of these sections consists of:

1. A black and white topographic base map (scale 1:250,000; 1 inch = approximately 3.5 nm) showing the Valley boundary, interior ten percent topographic grade areas, and major cultural and quantity-distance exclusions (ownership conditions not shown); and
2. Five data sheets which appear in the following order:
   a. Ownership, Topography and Cultural Features
   b. Geology
   c. Soils Engineering
   d. Surface Hydrology
   e. Groundwater Hydrology

The data presented on the Data Summary Sheets include data obtained from the literature, observations made during the brief ground and aerial field reconnaissance of the area and personal communications with individuals having specific knowledge or expertise in the Valley. Quality of data is presented at the left-hand margin and indicates:

1. Darkened circle - data derived from detailed studies,
2. Half-darkened circles - estimated values, representing either extrapolations from detailed studies or estimates from general studies, and
3. Open circle - insufficient data available for quantification, of no data known to exist.

The REMARKS section may contain numerical quantities (%; nm^2) where they are the primary response to the DESCRIPTION; a "0" (zero) indicates no occurrence in the Valley. Quantity units (nm^2; ft.) are indicated in the REMARKS sections only when they differ from those given in the DESCRIPTION. Blank spaces indicate that no data exist or that no data are available. Where conditions or featues listed in the DESCRIPTION are known not to exist, "None" is entered under the REMARKS; subheadings, which do not apply, are designated by "N/A". Abbreviations used on the Data Summary Sheets are listed in Table ___.

A single Data Summary Sheet set is used for those large BLM Valleys which have one geographic name, but are divided on the four-quad base maps into North or South. Most data shown on the Data Summary Sheets would directly apply to both areas because of similar existing geotechnical conditions. In those instances where data are unique to a single portion, it is noted by (N), for northern portion, or (S) for the southern portion, following the data entry.

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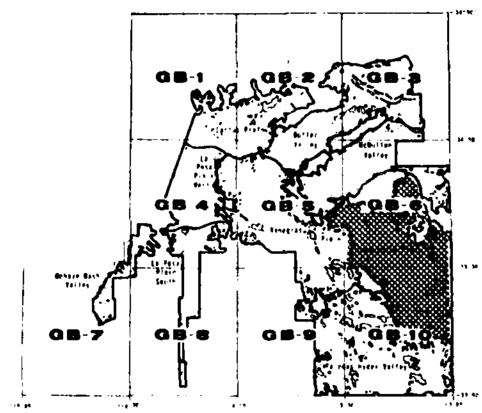
TABLE

TABLE OF ABBREVIATIONS

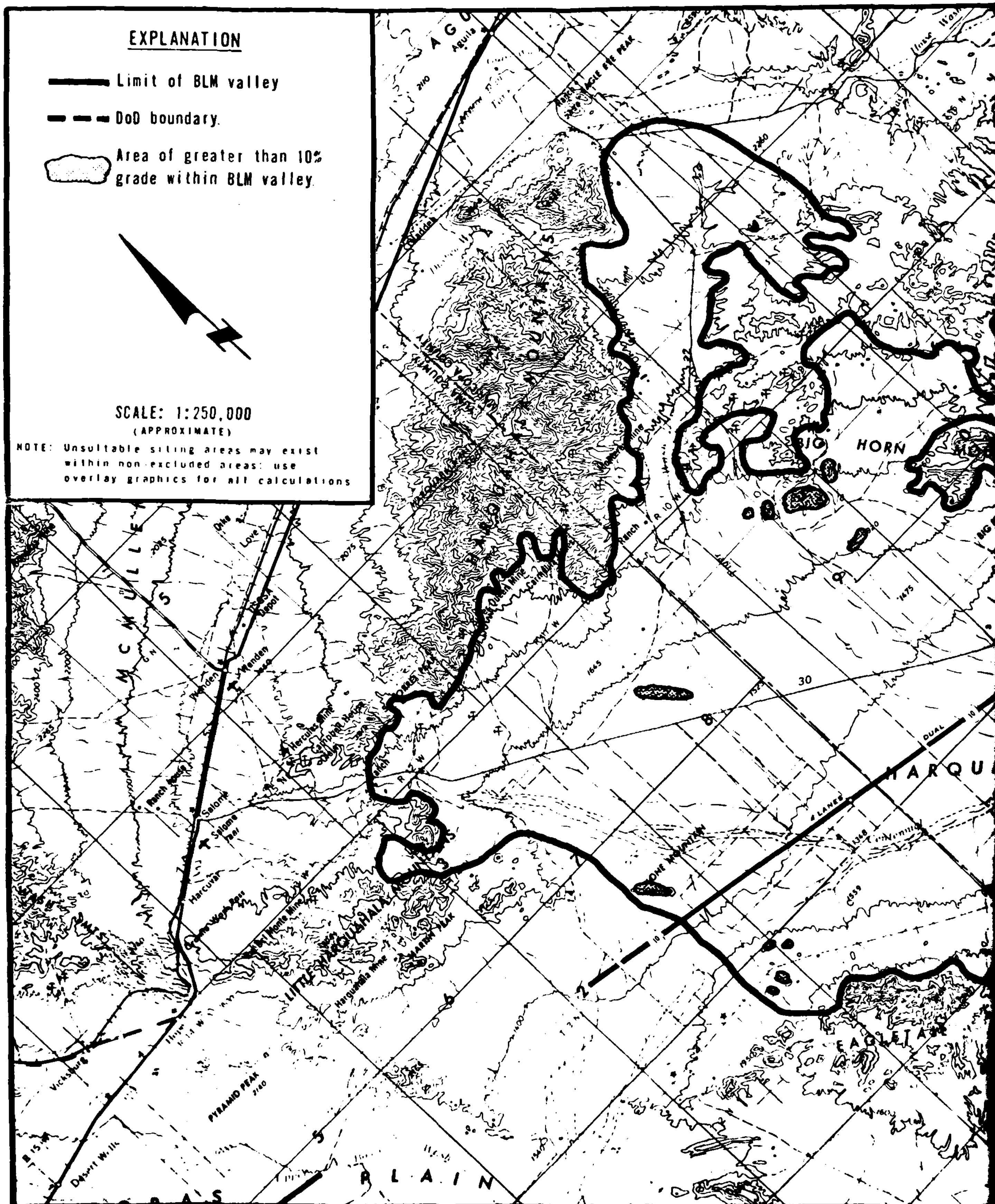
HARQUAHALA PLAIN

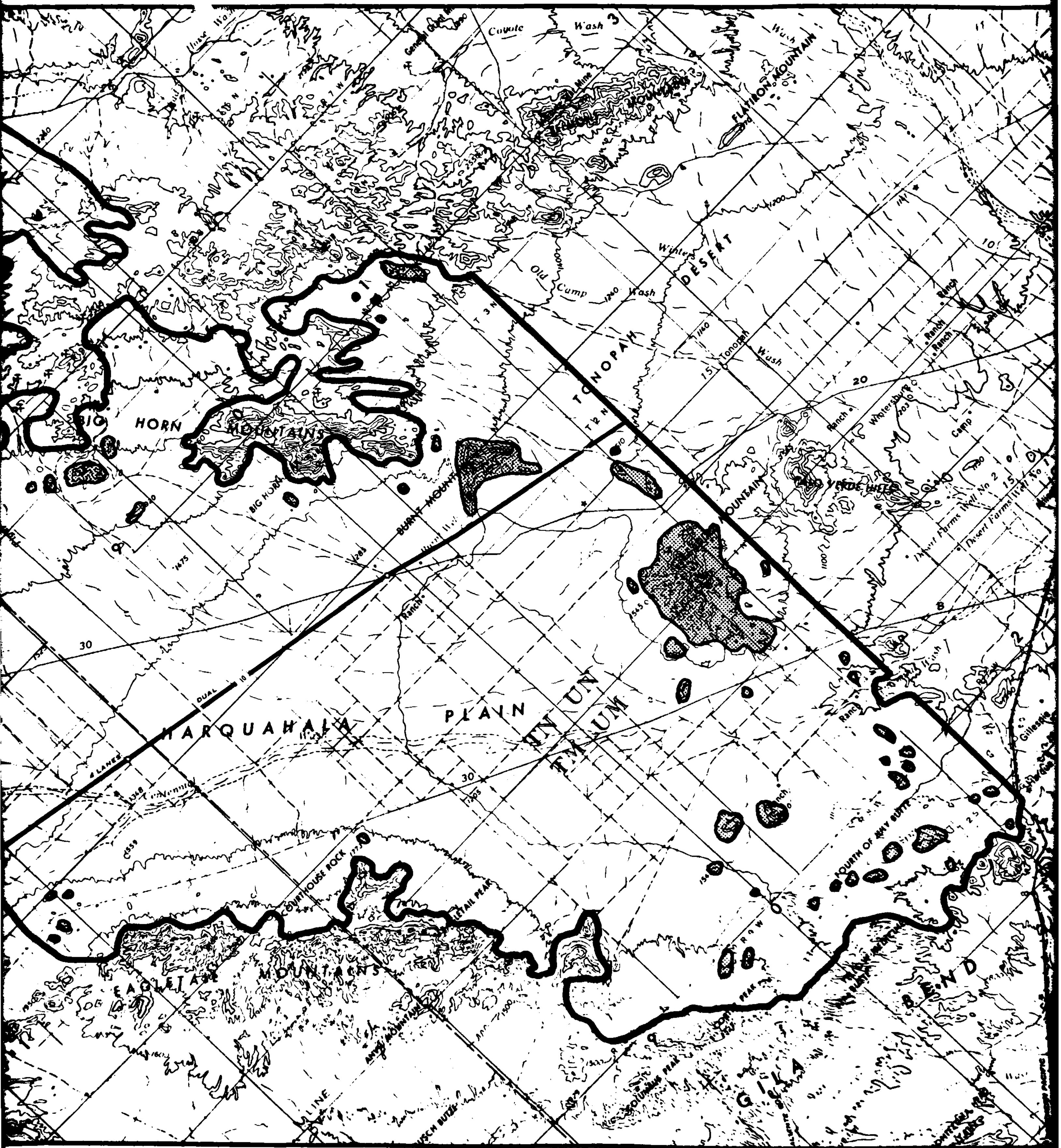


VALLEY ANALYSIS

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FUGRO NATIONAL, INC.


EXPLANATION
Limit of BLM valley
DoD boundary
Area of greater than 10% grade within BLM valley
SCALE: 1:250,000
(APPROXIMATE)
NOTE: Unsuitable siting areas may exist within non-excluded areas: use overlay graphics for all calculations
BIG HORN
HARQU
EAGLETAIL
PLAIN
PYRAMID PEAK
LITTLE HARQUAHALA
MCMULLEN
Wenden
Salome
Harcuvar
Vicksburg
Aguila
Hercules Mine
Harquahala Mine
30
DUAL
4 LANES


Coyote Wash
FLATIRON MOUNTAIN
Old Camp Wash
WINTERSBURG
DESERT
TONOPAH
Tonopah Wash
BIG HORN MOUNTAINS
BIG HORN
BURNT MOUNTAIN
MOUNTAIN
PALO VERDE HILLS
Wintersburg
Ranch
Camp
Desert Farms Well No 2
Desert Farms Well No 1
HARQUAHALA PLAIN
DUAL
4 LANES
COURTHOUSE ROCK
FOURTH OF JULY BUTTE
EAGLETAIL MOUNTAINS
GILA BEND
Gillespie
ROW
LINE
30
20

2

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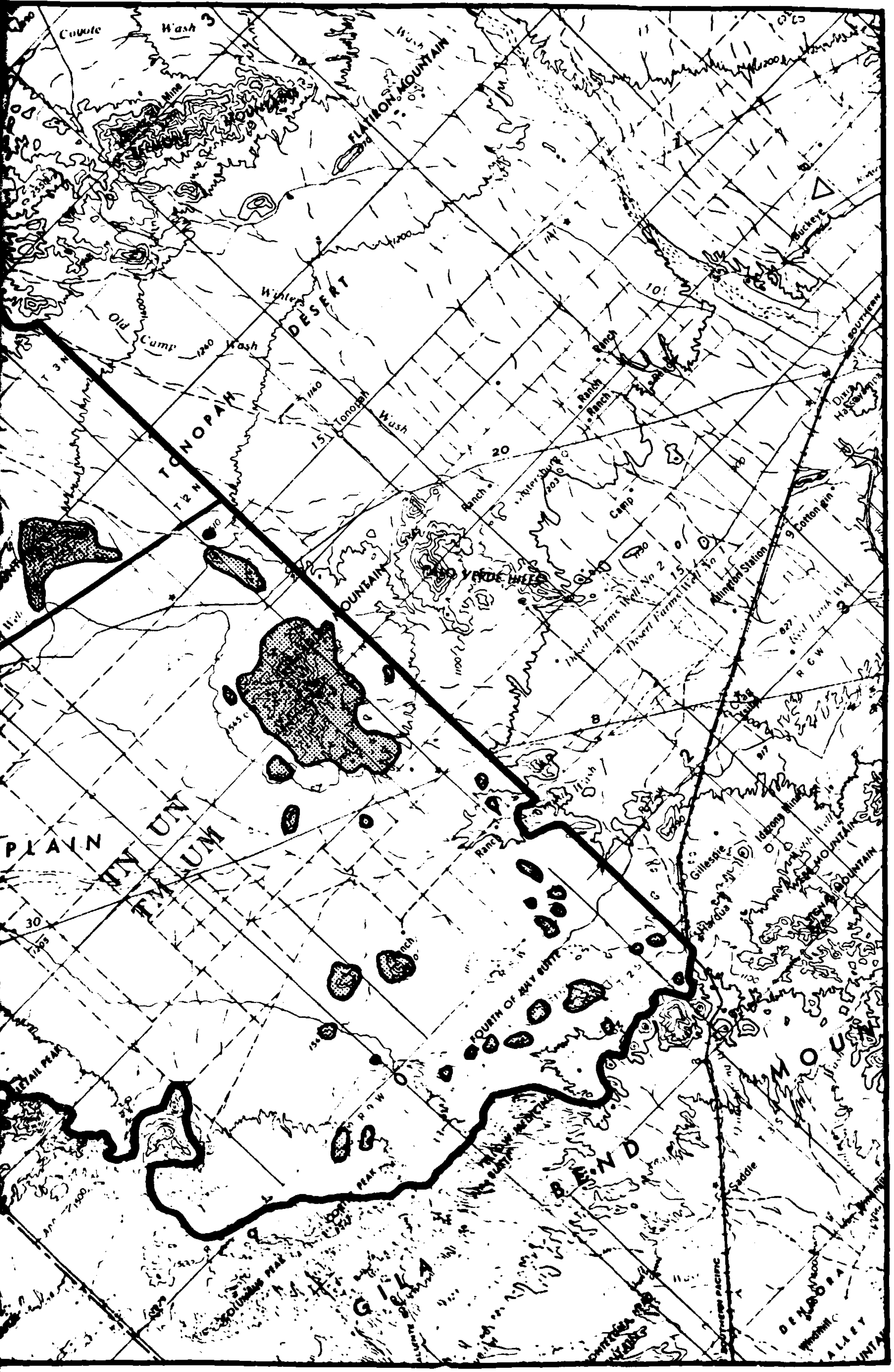
Coyote
Wash
FLATIRON MOUNTAIN
Old
Camp
Wash
Winters
DESERT
TONOPAH
Tonopah
Wash
Ranch
Camp
PALO VERDE HILLS
Desert Farms Well No 2
Desert Farms Well No 1
Arlington Station
Cotton gin
Buckeye
Gillespie
FOURTH OF JULY BUTTE
PLAIN
GILA
BEND
Saddle
SOUTHERN PACIFIC

QUALITY OF DATA	DESCRIPTION	
	A. VALLEY AREA, OWNERSHIP AND LAND UTILIZATION	
O	1. Area of Valley (nm^2)	542
O	2. Area of Valley not Controlled by BLM or DoD (nm^2)	191
O	a. Excluded public-use land (E-5)	0
O	1) present use	N/A
O	b. State owned land (E-6)	51
O	1) present use	Cattle ran
O	c. Privately owned land (E-7)	123
O	1) present use	Cattle ran
O	d. Non-DoD, non-BLM Federal land (E-8)	17
O	1) present use	U.S. Burea
O	3. Area of Siting Valley (A.1 minus A.2: nm^2)	351
O	a. Present use	Public dom
	B. VALLEY TOPOGRAPHIC CONDITIONS	
O	1. Area with 5 to 10% Grade (nm^2)	41
O	2. Area with 0 to 5% Grade (nm^2)	501
O	3. Location of Intervalley Connections Having Less Than 10% Grade	Western p Southern
	C. VALLEY CULTURAL CONDITIONS	
O	1. Population Centers (E-2, E-3)	
O	2. Roads/Railroads (E-4)	Interstat
O	a. Relative location	Central p
O	b. Type and use	Improved,
O	3. Utilities (type)	Buried na
O	a. Relative location	Northwest
O	b. Type and use	
O	4. Other	Granite R
	D. CONTIGUOUS DoD OR CO-USE LAND	
O	1. Name (map area in nm^2)	None
O	2. Present Use	None
	E. ADDITIONAL REMARKS	

Quality of Data

● Data derived from detailed studies

◒ Estimated values

O Insufficient data available

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42	100%
91	35%
0	0%

/A

51	9%

attle ranching (?)

23	23%

attle ranching (?)

17	3%

.S. Bureau of Reclamation (USBR) corridor for Granite Reef Aqueduct

51	65%

ublic domain; portions of Valley may be leased for cattle ranching

41	8%
01	92%

estern portion of Valley contiguous with Ranegras Plain
outhern portion of Valley contiguous with Palomas-Hyder Valley

nterstate 10	Numerous unnamed roads and trails	Southern Pacific
entral portion of Valley	Randomly transect entire Valley	Southeastern portion of Valley
mproved, public	Improved, unpaved, public, private	Railroad, commercial
uried natural gas line	Buried coaxial telephone cable	Electrical power lines
orthwestern portion of Valley	Central portion of Valley	Southeastern portion of Valley

ranite Reef Aqueduct, central portion of Valley

one

one

QUALITY OF DATA	DESCRIPTION	
	A. ROCK CONDITIONS IN VALLEY (BR=Basement, B Bedrock, VF=Volcanic Flows)	
○	1. Exposed Rock (category/symbol/lithology)	
○	a. Map area in nm^2 and relative location	11
○	b. Seismic velocity (p/s in fps)	
○	c. Other	
○	2. Pediments (category/symbol/lithology)	BR/M_{PG}(?)/gnei
○	a. Map area in nm^2 and location	9
○	b. Distance into valley from rock exposures (max./avg. in nm)	3.5/
○	c. Other	Extensive pedi Tail Mountains
	B. SUBSURFACE ROCK CONDITIONS IN VALLEY (BR=Basement, B=Bedrock, VF=Volcanic Flows)	
○	1. Depth to Rock (map area in nm^2; category/symbol/lithology; physical properties)	
○	a. 0 to 100 feet (excluding pediments)	143
○	b. 100 to 250 feet	
○	c. 250 to 500 feet	
○	d. 500 to 1000 feet	
○	e. Greater than 1000 feet	
○	f. Unknown	399
○	2. Rock Type(s) (category/symbol/lithology)	DMA gravity p 3169 feet nea the southwest 1995 feet.
○	3. Physical Properties of Rock	

Quality of Data
- ● Data derived from detailed studies
- ◒ Estimated values
- ○ Insufficient data available

DRAFT

		BR/M_{PC}/gneiss, schist;	BR/Il_{MP}/granite and related rocks;
11		Northern, southern and eastern portions of Valley	Northern portion of Valley
		17000-18000	14000-16000

BR/M_{PG}(?)/gneiss, schist

9		Along northern flanks of the Big Horn Mountains

3.5/

Extensive pediments have been cited along the flanks of the Gila Bend and Eagle Tail Mountains and less commonly adjacent to the Harquahala and Saddle Mountains

143	%	
399	%	Depth to rock greater than 100 feet

DMA gravity profile 18-B1 indicates maximum depth to rock to be approximately 3169 feet near the south-central portion of the Valley. A deep water well in the southwestern portion of the Valley penetrated granite basement rock at 1995 feet.

7

QUALITY OF DATA	DESCRIPTION	
O	4. Rock in Basin-Fill Deposits (map area in nm^2; category/symbol/lithology)	
O	a. Depth to (ft.)	
O	b. Thickness (ft.)	
O	c. Seismic velocity (p/s in fps)	
	C. BASIN-FILL DEPOSITS IN VALLEY	
O	1. Type (symbol)	Al_Q; 98
O	2. Map Area (nm	<10¹/
O	3. Thickness (max./avg. in ft.)	
O	4. Lithology	Sand and gravel
O	5. Seismic Velocity (p/s in fps)	
O	6. Other	
O	D. VALLEY GEOLOGIC RELATIONSHIPS	Available we interfingeri is no indica countered in
	E. CAPABLE OR POTENTIALLY CAPABLE FAULTS IN VALLEY	
O	1. Name, Total Length (nm) and Relative Location	None
O	2. Type of Faulting; Regional and Local Attitudes (strike and dip)	N/A
O	3. Minimum Age of Displacement; Associated Seismic Activity	N/A
	F. ADDITIONAL REMARKS	

Quality of Data

● Data derived from detailed studies

◒ Estimated values

O Insufficient data available

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Al_Q;98	$A3S_Q$;1	$A5_Q$;355	$A5_O$;37
<10'/		>1200'/	∿360'/200/
Sand and gravel		Gravel, sand silt and clay	
		1000-6500/	

Available well logs indicate that the basin-fill consists of interfingering coarse-grained alluvial fan deposits. There is no indication of a thick lacustrine clay at depth as encountered in adjacent basins.

None

N/A

N/A

DESCRIPTION	A1	
A. SOIL IDENTIFICATION PROPERTIES(1)		
1. Unified Soil Classification	SM, GM, ML, CL	
2. AASHO Soil Classification	A-2, A-4, A-1, A-6	A
3. Percent Passing # 4 Sieve	90	
4. Percent Passing # 40 Sieve	70	
5. Percent Passing # 200 Sieve	40	
6. Liquid Limit/Plasticity Index	17/4	
7. Consistency		
8. General Surface Moisture Condition		
B. SOIL ENGINEERING PROPERTIES(1)		
1. Dry Density (pcf)		
2. Permeability (cm/sec.)	10^{-2} to 10^{-4}	10
3. Shear Strength		
a. Angle of internal friction (degrees)		
b. Cohesion (psi)		
4. Shrink-Swell Potential		
5. Coefficient of Compressibility (in.^{2}/lb.)		
6. CBR (in-situ/recompacted)		
7. Compression/Shear Wave Velocities (fps)		
8. Water Content (percent)		
9. Deleterious Substances		
C. CONSTRUCTION PROPERTIES(1)		
1. Suitability as Source of Sand/Fill Material	Good/Good	
2. Suitability as Source of Aggregate/Base Course	Good/Good	
3. Excavation Limitations and Slope Angle	(45° - 60°)	
4. Near-Surface Foundation Design Characteristics	Moderate Strength	L
D. ADDITIONAL REMARKS	Good source of construction materials in stream channels, poor source in flood plains	P

EXPLANATION

[ ] (empty box)	No literature available and data not extrapolated
(SP-SM)	No literature available and data extrapolated
SP-SM	Data available in literature

(1) Surface soils only, depth of less than 5 feet

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	MAP UNIT				
.	A3	$A5_i - A5_u$	$A5_o$		
CL	SP-SM	SM, GM, ML	GM-SM		
A-6	A-2, A-3	A-1, A-2, A-4	A-1, A-2, A-4		
		75			
		50			
		30			
		21/7			
	Loose				
-4	10^{-1} to 10^{-3}	10^{-1} to 10^{-3}			
		1000-3000/			
	Good/Good	Good/Good	Fair/Good		
	Poor/Fair	Fair/Fair	Fair/Fair		
P)	Sloughing	Difficult (45^o - 60^o)	Difficult (possible ripping)		
ength	Low Strength	High Strength	High Stength		
of mat- ream or ood	Possible wind erosion	Limited localized caliche	Abundant caliche		

QUALITY OF DATA	DESCRIPTION	
	A. SURFACE WATER IN VALLEY	
○	1. Playas; Intermittent or Perennial Lakes	None
○	a. Duration of surface water (wks.)	N/A
○	b. Maximum extent (nm^2)	N/A
○	c. Water depth (max. in ft.)	N/A
○	d. Source of water	N/A
○	e. Water quality	N/A
○	2. Rivers, Streams, or Springs	Centennial Wa
○	a. Duration of flow (wks.)	Ephemeral (no of the time e
○	b. Estimated maximum flow rate (gpm/season)	14,500 ft^3/s
○	c. Water quality	
	B. HYDROLOGIC CHARACTERISTICS OF VALLEY	
○	1. Drainage Channel (PR=Primary; S=Secondary)	Centennial Wa
○	a. Depth of incision (max./avg. in ft.)	/>5
○	b. Width (max./avg. in ft.)	/2640
○	c. Gradient (ft./mi.)	20 to 80
○	d. Channel bottom characteristics	Sand, gravel
○	e. Channel cross-section (schematic)	
○	f. Channel spacing (avg. in ft.)	Primary chan
○	g. Preliminary flood susceptibility rating	CF_2
○	2. Historic flooding	Historic flo documented o 25 years. F have been as cfs.
	C. ADDITIONAL REMARKS	

Quality of Data

- ● Data derived from detailed studies
- ◒ Estimated values
- ○ Insufficient data available

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ntennial Wash	Several unnamed and named stream channels
hemeral (no flow most the time each year)	Ephemeral
,500 ft^3/s	

ntennial Wash (PR)	Several unnamed and named stream channels (S)
5	10 />5
640	/5-10'
to 80	30 to 120
nd, gravel	Sand
rimary channel	20,000
2	
istoric flooding is well ocumented over the past 5 years. Peak discharges ave been as high as 7000 fs.	Historic flooding on Tiger Wash

7.

QUALITY OF DATA	DESCRIPTION	
	A. DEPTH TO GROUNDWATER WITHIN BASIN-FILL MATERIA[L] IN VALLEY (Map area in nm^2)	
O	1. 0 to 50 Feet	N/A
O	a. 0 to 25 feet	N/A
O	b. 25 to 50 feet	N/A
O	2. 50 to 100 Feet	N/A
O	3. Greater than 100 Feet	
O	4. Unknown or Not Present	
	B. AQUIFER CHARACTERISTICS IN VALLEY	
O	1. Type of Aquifer (B=Basin Fill; P=Perched; R=Rock; u=unconfined; c=confined)	Bu
O	a. Map area (nm^2) and extent	
O	b. Depth to aquifer (ft.)	<150 to >55
O	c. Thickness range (ft.)	250 to 1200
O	d. Composition	Sand, grave
O	e. Porosity (%)	
O	f. Specific yield (%)	10 to 20
O	g. Transmissivity ($ft.^2$/day)	
O	h. Specific capacity (gpm/ft. of drawdown)	3 to 80/1
O	i. Permeability (gpd/$ft.^2$)	
O	j. Total pumpage (ac. ft./unit time)	109,000/ye
O	k. Groundwater ownership rights	
	C. WATER BUDGET FOR VALLEY	
O	1. Total Recharge (ac. ft./unit time)	Several th
O	2. Total Discharge (ac. ft./unit time)	Several th
	D. ADDITIONAL REMARKS	(a) Total

Quality of Data
- ● Data derived from detailed studies
- ◐ Estimated values
- O Insufficient data available

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N/A	
N/A	
N/A	
N/A	

Bu

<150 to >550

250 to 1200

Sand, gravel, clay, silt

10 to 20

3 to 80/1

109,000/year See Additional Remarks (a)

Several thousand/year

Several thousand/year

(a) Total pumpage in 1968 was 200,000/year

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WHITE SANDS MISSILE RANGE EXTENSION

4.0 SITING AREA ANALYSIS

4.1 GENERAL

Conditions in the White Sands Missile Range Extension which are of interest for this investigation relate very closely to those present in the White Sands Missile Range (WSMR) DoD area immediately adjacent and to the south. Data pertaining to the regional analysis presented in Volume IIA of the DoD Geotechnical Report for WSMR/FBMR describe for the most part conditions in the Extension. No data collection trips were made related specifically to the Extension area, although numberous telephone discussions were held with persons knowledgeable of conditions in the area.

Section 4.0 describes those geotechnical factors specifically related to the Extension area which add to or contrast with the regional analysis data presented in the DoD Volume IIA. All major headings from the regional analysis of the DoD Volume IIA are presented here. Section 5.0 is the Valley Analysis which introduces and precedes the Data Summary Sheets for Jornada del Muerto North Valley.

4.2 GEOGRAPHY AND DEMOGRAPHY

4.2.1 SITING AREA LOCATION AND DESCRIPTION

The White Sands Missile Range Extension area (WE) is a roughly rectangular area lying north of the White Sands Missile Range military reservation (WSMR). The Extension area lies principally in the Jornada del Muerto basin area and occupies portions of Socorro and Torrance counties (Figure ____). The Extension area has a total of ___ nm^2, with maximum dimensions of ___ nm east-west and ___ nm north-south.

The portion of the Extension area studied is contiguous with WSMR and was a topographic grade generally less than 10 percent. Elevations range from ___ feet to ___ feet and average between ____ and ____ feet in the siting valley. This area accounts for ____ percent of the total area of the Extension, or ____ nm^2.

4.2.2 USES OF LAND AND SURFACE WATER

The White Sands Missile Range Extension area is one of three safety areas adjacent to WSMR and is composed of state, private and Bureau of Land Management (BLM) land. It is used periodically as an impact and safety area for long range missiles fired from launch areas in the southern portions in WSMR. A maximum of 25 operations annually are permitted under current co-use agreements with WSMR (EDAW, 1975). All residents living in the area are evacuated prior to any operation. The Federal government compensates the evacuees for the temporary interruptions caused by range operations.

FIGURE __

General Location Map

White Sands Missile Range
Extension Area

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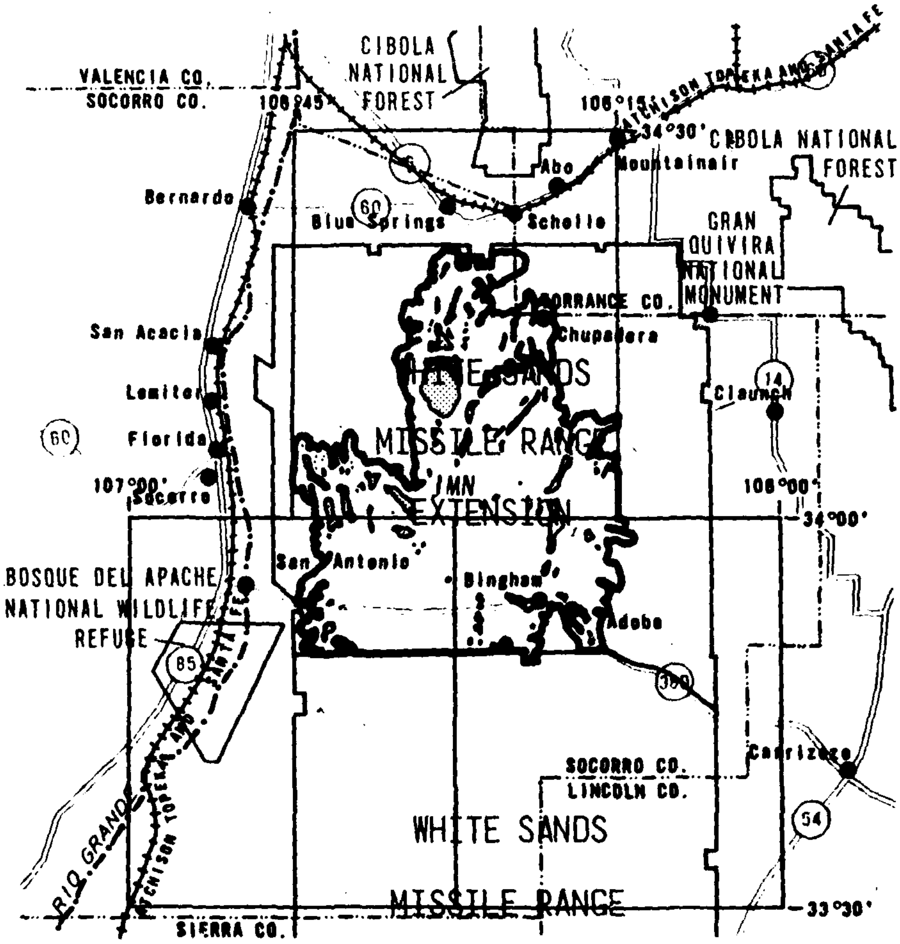
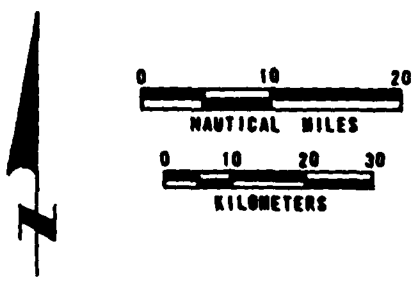


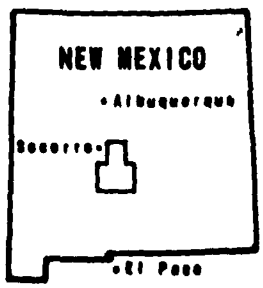
EXPLANATION

Area of Thirty-Minute Quadrangle Map.

Boundary of BLM valley.

Area of greater than 10% grade within BLM valley.





GENERAL LOCATION

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE
1

FUGRO NATIONAL, INC.

DATE: 31 MAY 78

Table ___ summarizes the total area for each of the three categories and their known uses.

TABLE __

Land Use - White Sands Missle Range Extension Area

Category	Total Area (nm^2)	Percent of Total Area	Present Use
Bureau of Land Management	203	47	Leased grazing
State of New Mexico	126	29	Unknown
Private	102	24	Cattle ranching; limited agriculture
TOTALS	431	100	

Private and state lands are mixed in complex and irregular shaped clusters with the BLM land (Ownership, WE-1, WE-2, WE-3). State lands, in most instances, include Sections 2, 16, 32 and 36 per township with particularly large parcels located in the vicinity of Bingham. Privately owned lands compose two or more sections per township with large tracts located in thenortheastern portions of the siting area.

The majority of land bordering the siting area is Federally or State owned and include the WSMR, Gran Quivera National Monument, Cibola National Forest and Busque del Apache National Wildlife Refuge.

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TABLE WE-I

Land Use - White Sands Missle Range Extension Area

Category	Total Area (nm^2)	Percent of Total Area	Present Use
Bureau of Land Management	203	47	Leased grazing
State of New Mexico	126	29	Unknown
Private	102	24	Cattle ranching; limited agriculture
TOTALS	431	100	

Remaining lands include the Sevilleta Land Grant and unidentified small and large land parcels. Table ___ summarizes land use for these categories of land.

No significant occurrences of surface water exist in the Extension area. Unappropriated water sources consist only of flood and sheet flows, spring flows, irrigation return waters, drainage waters or sewage effluents.

4.2.3 POPULATION AND POPULATION DISTRIBUTION

Approximately ___ people are known to habitate the towns and small settlements within and immediately adjacent to the study area (Table ___; and Figure ___). Small populations are generally located at ranches and service stops along the major highways in the area. A moderate transient population includes individuals traveling to the recreation areas in the vicinity and military personnel monitoring long-range missile firings in the area. Average daily traffic values for U. S. Highway 380 ranges between 460 and 1290 units (EDAW, 1975).

4.2.4 CULTURAL IMPROVEMENTS

Access to the Extension area is provided primarily by U. S. Highway 380 in the south and State Highway 60 in the north (Figure ___). Numerous unimproved dirt and jeep trails extend from these highways into various portions of the siting area. Travel on the public roads is believed to be unrestricted.

The Atchison, Topeka and Sante Fe Railroad provides service to the small communities within and adjacent to the study area.

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TABLE III

Population Centers

Population Center*	Population**	Distance from Range
El Paso, Texas	322,261	0 nm
Las Cruces, New Mexico	37,857	8 nm
Alamogordo, New Mexico	24,180	5 nm
Tularosa, New Mexico	2,851	3 nm
Anthony, Texas	1,728	4 nm
Organ, New Mexico	400	1 nm
Orogrande, New Mexico	60	1 nm
Newman, Texas	25	0 nm

* Locations shown on Figure 4.

** All population figures based on 1970 census (U. S. Census Bureau).

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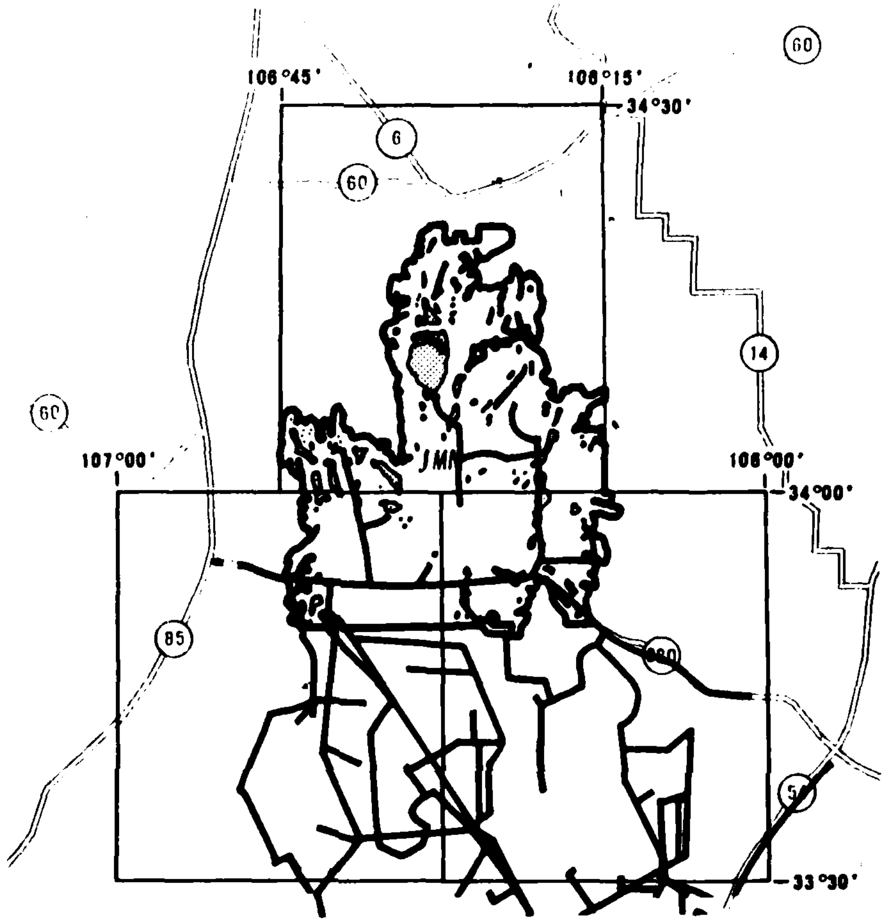
FIGURE
LOCATION OF UTILITY LINES



EXPLANATION

- Area of Thirty-Minute Quadrangle Map.
- Boundary of BLM valley.
- Area of greater than 10% grade within BLM valley.
- Electrical power lines.
- Telephone lines

0 10 20
NAUTICAL MILES

0 10 20 30
KILOMETERS

N

LOCATION OF UTILITY LINES

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 2

FUGRO NATIONAL, INC.

DATE: 31 MAY 78

TABLE __ - Use of Adjacent Lands

LAND AREA	RELATIVE LOCATION	PRESENT USE	ADMINISTRATOR
Federal			
White Sands Missile Range	Southern border	Missile Range and test area	U.S. Army
Bureau of Land Management	Borders all portions		BLM
Gran Quivera National Monument	Northeast	Archeological and historic site	National Park Service
Busque del Apache National Wildlife Refuge	West, southwest	Wintering, feeding and resting habitat for migratory waterfowl	
State			
Numerous large and small land tracts	Borders all portions	Unknown	State of New Mexico
Private			
Sevilleta Grant	Northwest	Mexican land grant	-
Numerous large and small tracts of private land	Borders all portions	Limited ranching and agriculture	-

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TABLE II - Use of Adjacent Lands

LAND AREA	RELATIVE LOCATION	PRESENT USE	ADMINISTRATOR
Federal			
White Sands Missile Range	Southern border	Missile Range and test area	U.S. Army
Bureau of Land Management	Borders all portions		BLM
Gran Quivera National Monument	Northeast	Archeological and historic site	National Park Service
Busque del Apache National Wildlife Refuge	West, southwest	Wintering, feeding and resting habitat for migratory waterfowl	
State			
Numerous large and small land tracts	Borders all portions	Unknown	State of New Mexico
Private			
Sevilleta Grant	Northwest	Mexican land grant	
Numerous large and small tracts of private land	Borders all portions	Limited ranching and agriculture	

Major lines parallel U. S. Highways 85 and 68 adjacent to the siting area (Figure ___).

Major electrical transmission and telephone lines are present in portions of the siting area (Figure ___). The major electrical lines are subparallel to U. S. Highway 380 with branch lines leading north into the Valley area.

Only one permanent mobile instrumentation site is known to be present in the area, however, temporary sites may be moved into the area as needed for range operations (EDAW, 1975).

4.2.5 CULTURAL AND QUANTITY DISTANCE EXCLUSIONS

The only cultural or quantity-distance exclusion which limits siting area potential is a corridor, 1780 feet wide, on each side of Highway 380 (Ownership WE-_).

In addition, minor quantity-distance and cultural features not restrictive to siting include:

1. Several small buildings whose locations were determined primarily from old topographic maps; and
2. Several semi-permanent military instrumentation and monitoring sites which are inhabited on a periodic basis.

4.2.6 GENERAL TOPOGRAPHIC CONDITIONS AND EXCLUSIONS

General topographic conditions for the various landforms present in the siting area are expressed in terms of topographic grade. A criterion for the exclusion of an area from

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iting consideration is a greater than ten percent topographic grade (5°43'; 528 feet/mile; Figure ___). This condition occurs primarily in areas of exposed rock and areas where thin basin-fill materials overlie rock near the base of mountains and hills, and may also include the topographically higher, older alluvial fan surfaces. Areas of five to ten percent grade (2°52' to 5°43'; 264 to 528 feet/mile) commonly occur near the mountains generally bordering the areas of greater than ten percent grade. Pediments, and older and younger alluvial fans comprise the greatest percentage of landforms in this five to ten percent topographic grade range. The zero to five percent topographic grade range (0° to 2°52'; 0 to 264 feet/mile) most commonly occurs in the central portion of the basins. Landforms which predominate in this grade range are playas, younger alluvial fans, alkali flats, and major washes.

The ten percent topographic grade exclusion combined with the cultural and quantity-distance exclusion totals ____ nm^2 or ___ percent of the siting valley. Of the remaining area, approximately ___ nm^2 (____ percent) is included in the five to ten percent topographic grade range and ___ nm^2 (____ percent) in the zero to five percent range.

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FIGURE

TOPOGRAPHIC GRADE EXCLUSION AREAS

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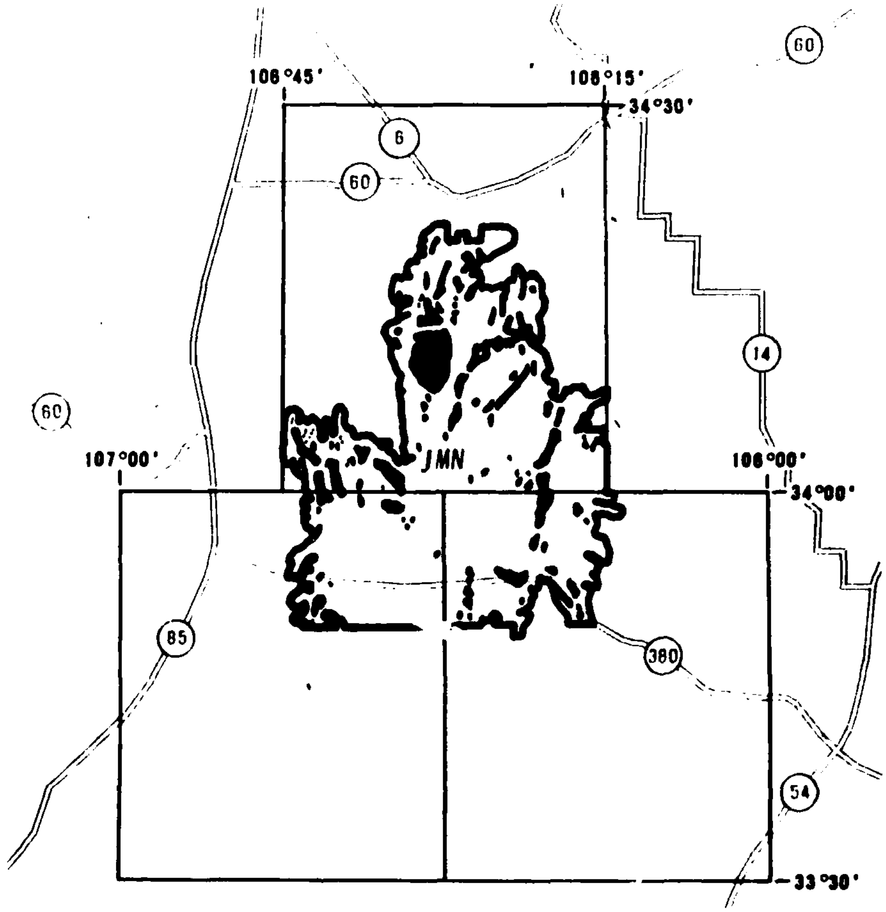
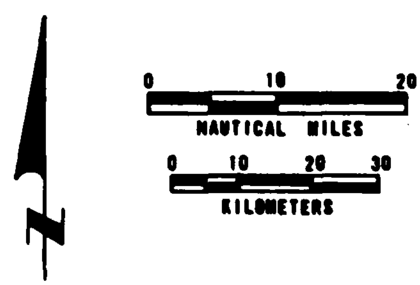


EXPLANATION

Area of Thirty-Minute Quadrangle Map.

Boundary of BLM valley.

Area of greater than 10% grade within BLM valley.



TOPOGRAPHIC GRADE EXCLUSION AREAS

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DEPARTMENT OF THE AIR FORCE - SAMSO

FIGURE 3

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4.3 GEOTECHNICAL CONDITIONS

4.3.1 GENERAL

Geotechnical conditions in the Extension area are very similar to those described in the Geolog y, Soils Engineering, and Hydrology Sections of the DoD Volume IIA report for the northern portions of the WSMR, in particular the Jornada del Muerto North DoD siting valley.

Specific information for the Extension area was derived from:

1. Regional studies applicable to both DoD lands and the Extension area;
2. Preliminary studies in the area by the New Mexico Highway Department (19__); and
3. Studies performed by Fugro National in the vicinity of the area.

Neither an aerial photo analysis nor ground or aerial survey were conducted in the area.

4.3.2 GEOMORPHIC SETTING AND SURFICIAL GEOLOGY

The basin-fill deposits which are primarily coarse-grained with lesser fine-grained sediments, probably attain a cumulative thickness of less than 500 feet for most of the Jornada del Muerto North valley (Herrick and Davis, 1965). Seismic wave velocities (p = compressional) in basin-fill materials in adjacent DoD areas range from 1000 to 10,000 feet per second (fps) (Ballard, 1963; Zohdy and others, 1969; Air Force Weapons Laboratory, 1973). The higher seismic velocities

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FIGURE
PHYSIOGRAPHIC DIVISIONS OF ARIZONA

AD-A113 363 FUGRO NATIONAL INC .LONG BEACH CA F/G 13/2
MX SITING INVESTIGATION. GEOTECHNICAL REPORT. VOLUME IIB. GILA --ETC(U)
MAY 76 F04701-74-Q-0013
UNCLASSIFIED FN-TR-11-VOL-2B NL

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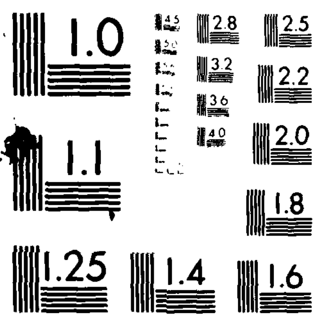
1.0
4.5
2.8
2.5
3.2
2.2
3.6
4.0
1.1
2.0
1.8
1.25
1.4
1.6

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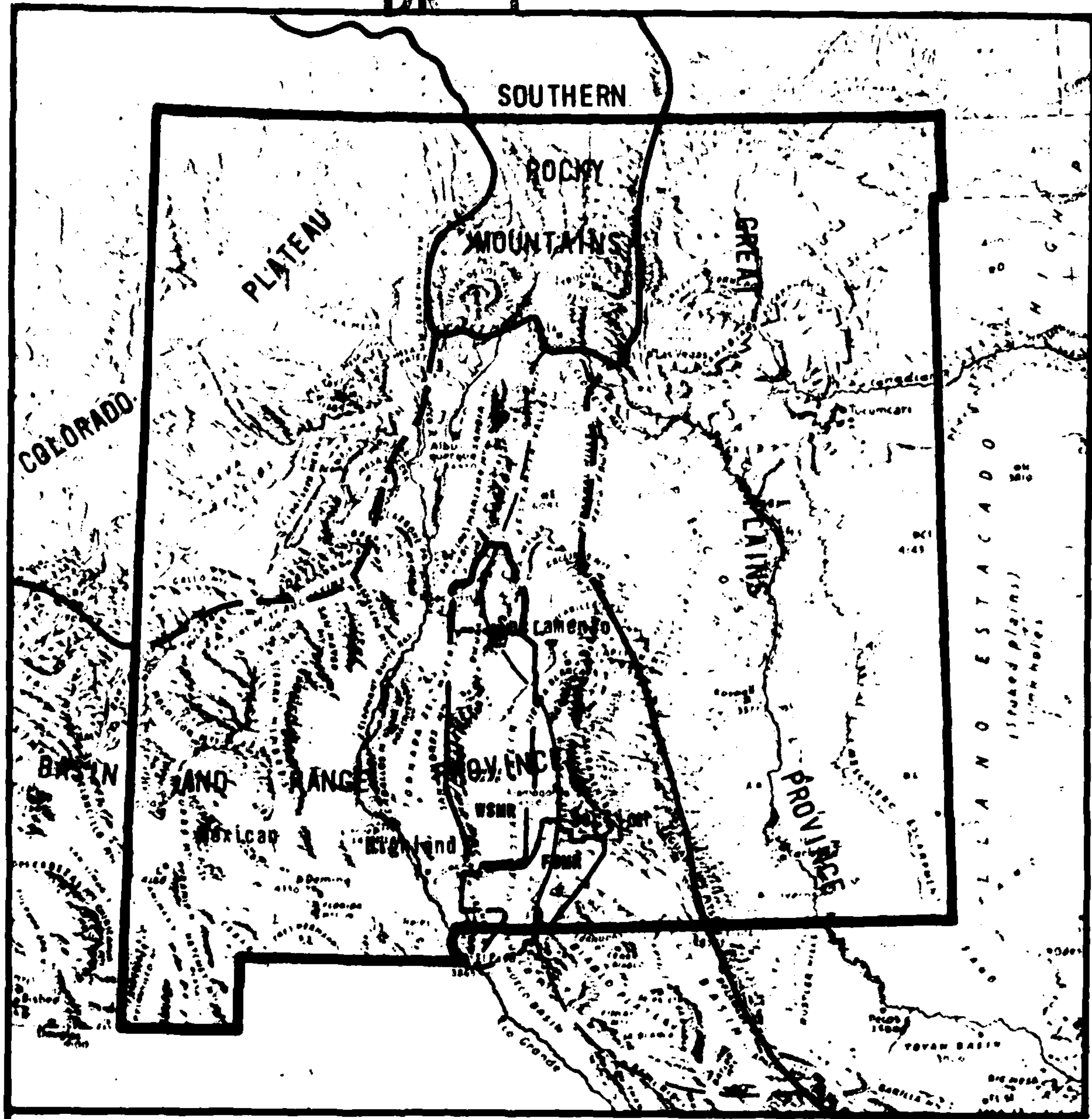

EXPLANATION

Boundary of White Sands Missile Range Extension Area

Boundary of Physiographic Province Dashed where approximate

Section boundary of Physiographic Province. Dashed where approximate

0 50 100 NAUTICAL MILES

0 50 100 KILOMETERS

MODIFIED AFTER: Fenneman, 1946.

PHYSIOGRAPHIC DIVISIONS OF NEW MEXICO

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FIGURE 4

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(10,000 tpa) for [illegible] deposits may reflect [illegible] higher degrees of cementation (Mallery, oral communication, 1974).

These basin-fill deposits can be associated with various geomorphic features including alluvial fans (A_5), pediments ($A_{[illegible]}$), stream channel and floodplains (A_1) and sand dunes ($A_{[illegible]}$). These units, their relative percentages and specific characteristics are summarized in Table ____.

4.3.3 **ROCK CONDITIONS**

4.3.3.1 Exposed Basement Rock and Bedrock

Sedimentary bedrock forms the largest category of exposed rock in the study area totaling ____% or ____ nm^2 of the total study area. Particularly large exposures of rock occur in the northern, western and eastern portions of the area (Figure ____).

4.3.3.2 Subsurface Rock Conditions

Little is known of the subsurface rock conditions in the study area. Subsurface data indicating depth to rock in any portion of the area is very sparse. Available data does show that depth to rock is probably no greater than 500 feet for most portions of the general area (Herrick and Davis, 1965).

A 100-foot depth to rock contour was estimated for all valley areas on the basis of general geologic, geomorphic and topographic conditions.

[illegible]

Dominant Rock Types in and adjacent to the White Sands Missile Range Enclosure

Mountain Range	Dominant Rock Types
Manzano Mts	
Jumanos Mesa	
Chupadera Mesa	S bedrock
Oscura Mts	S bedrock
Magdalena Mts	
Los Piños Mts	S bedrock
San Andres Mts	S bedrock

V = Volcanic ; S = Sedimentary ; G = Granitic ; M = Metamorphic

TABLE ___ - General Basin-Fill Properties

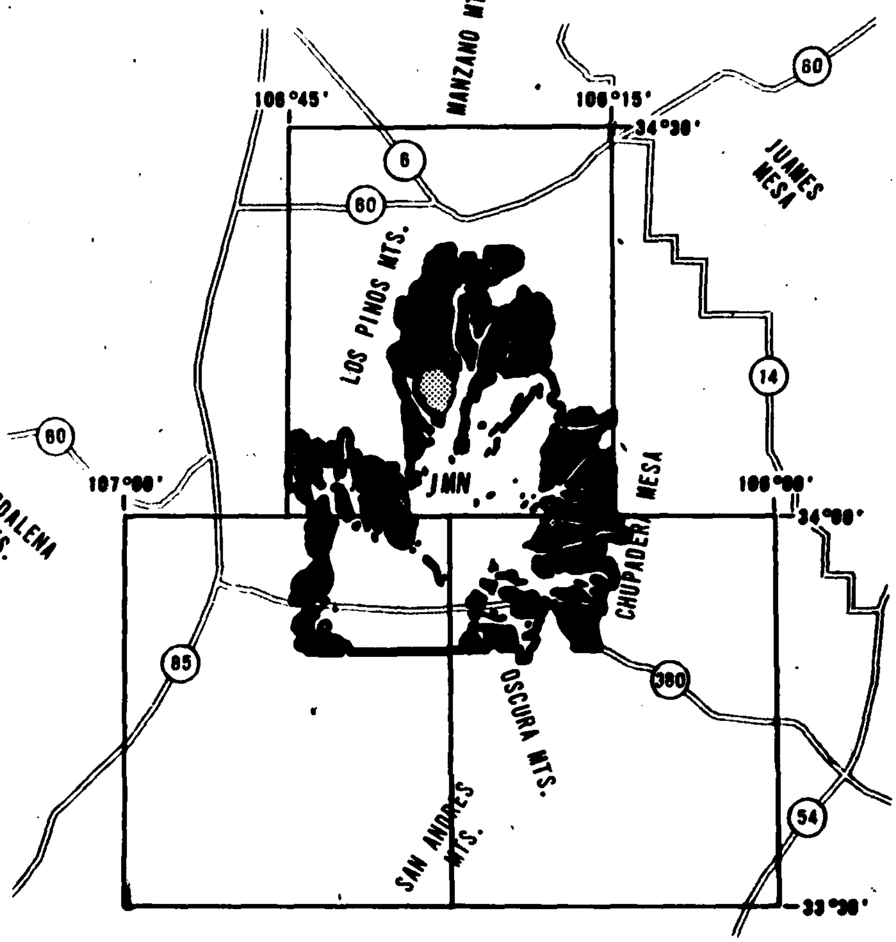
Basin-Fill Unit	Area/Percent	Predominant Lithology	Degree of Cementation	Dissection	[illegible]

TABLE [illegible] - General Basin-Fill Properties

Basin-Fill Unit	Area/Percent	Predominant Lithology	Degree of Cementation	Dissection	Incision	[illegible]
Basin Fill [illegible] (A)	[illegible]	Gravel, sand, silt	None	[illegible]	[illegible]	
[illegible]		Gravel, sand	None.		[illegible]	
[illegible]		Sand, gravel, silt				
[illegible]		Sand				
[illegible]		Clay, silt				
[illegible]		Gravel, sand, silt				
[illegible]		Gravel, sand				

FIGURE ___

Rock vs Non-Rock Areas



EXPLANATION

Area of Thirty-Minute Quadrangle Map.

Boundary of BLM valley.

Area of greater than 10% grade within BLM valley.

Area of rock.

Area of non-rock (Basin-fill deposits).

0 10 20
NAUTICAL MILES

0 10 20 30
KILOMETERS

DISTRIBUTION OF ROCK AND NON-ROCK

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FIGURE 5

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[illegible] faults have been reported.

4.3.5 SOILS ENGINEERING

Data available on the soils engineering characteristics of the Extension area are sparse. Generally conditions are similar to those of the northern WSMR and have been noted on the Soils Engineering Data Summary Sheet.

4.3.6 HYDROLOGY

4.1.6.1 Surface Hydrology

Surface drainage in the study area is generally from the highland areas in the north and east to the Rio Grande River which borders the western boundary of the [illegible]. No perennial systems are known to occur in the area.

[illegible] Groundwater Hydrology

[illegible]

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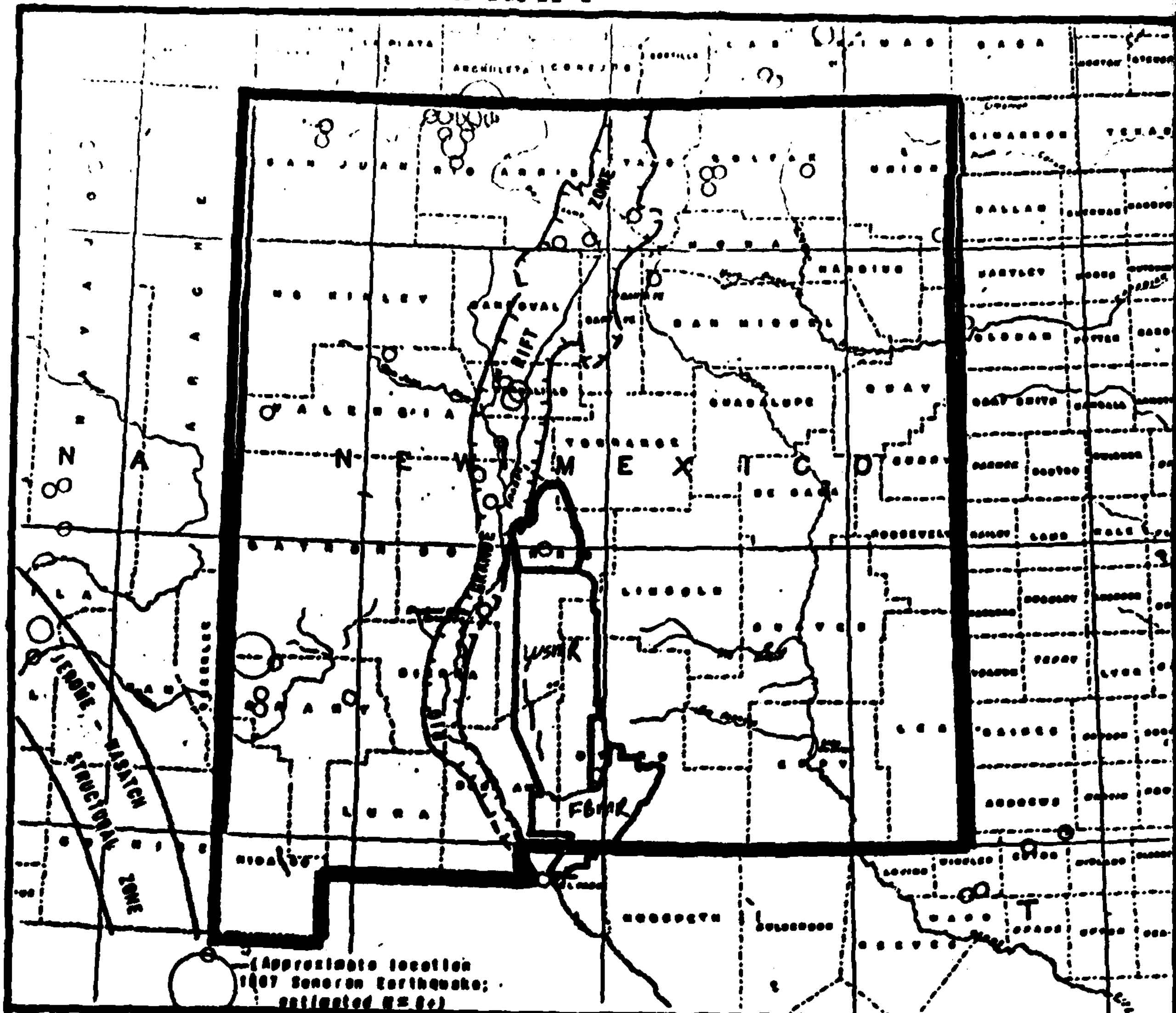

EXPLANATION

EARTHQUAKE EPICENTERS

- M < 4.0
- M=4.0 - 4.9
- M=5.0 - 5.9
- M ≥ 6.0

0 50 100 150
NAUTICAL MILES

0 100 200
KILOMETERS

N

SYMBOLS

- Boundary of *Bureau of Land Management Study Area*
- Approximate trend of structural element.
- Quaternary fault lines.

SEISMO-TECTONIC FEATURES

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FIGURE 6

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FIGURE ___

Regional Seismicity

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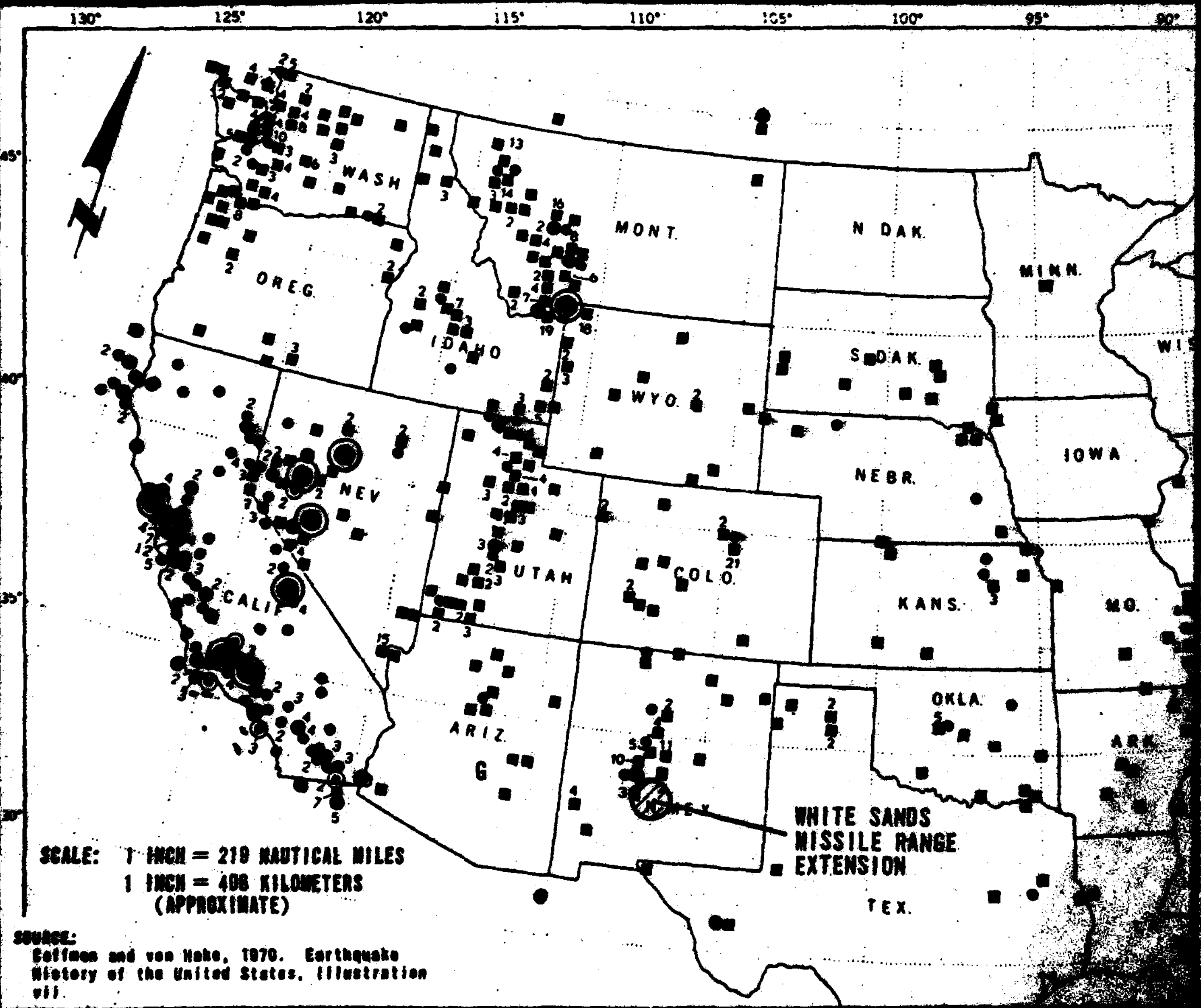
EXPLANATION*

- INTENSITY V–VII (except California)
- INTENSITY VII–VIII
- INTENSITY VIII–IX
- INTENSITY IX–X
- INTENSITY X–XIII

*Earthquakes through 1970 (Modified Mercalli Intensity V and above)



SOURCE:
Coffman and von Hake, 1970. Earthquake History of the United States, Illustration vii.

SEISMIC INTENSITIES IN WESTERN UNITED STATES

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DEPARTMENT OF THE AIR FORCE – SAMSO

4.3.7 CLIMATOLOGY

Climatic conditions in the Extension area will not vary considerably from those described for the WSMR DoD area. Climatological data were collected from major recording stations and substations throughout the south central portions of New Mexico (Figure ____). The Climatological Data Summary Sheets from the DoD volume IIA report have been included in Appendix ___.

4.3.8 TERRAIN ANALYSIS

Terrain characteristics for the geologic, topographic and soils conditions in the Extension do not vary greatly from those in the WSMR area to the south.

The terrain analysis worksheet from the DoD report has been included in Appendix _____.

FIGURE

LOCATION OF CLIMATOLOGICAL RECORDING STATIONS

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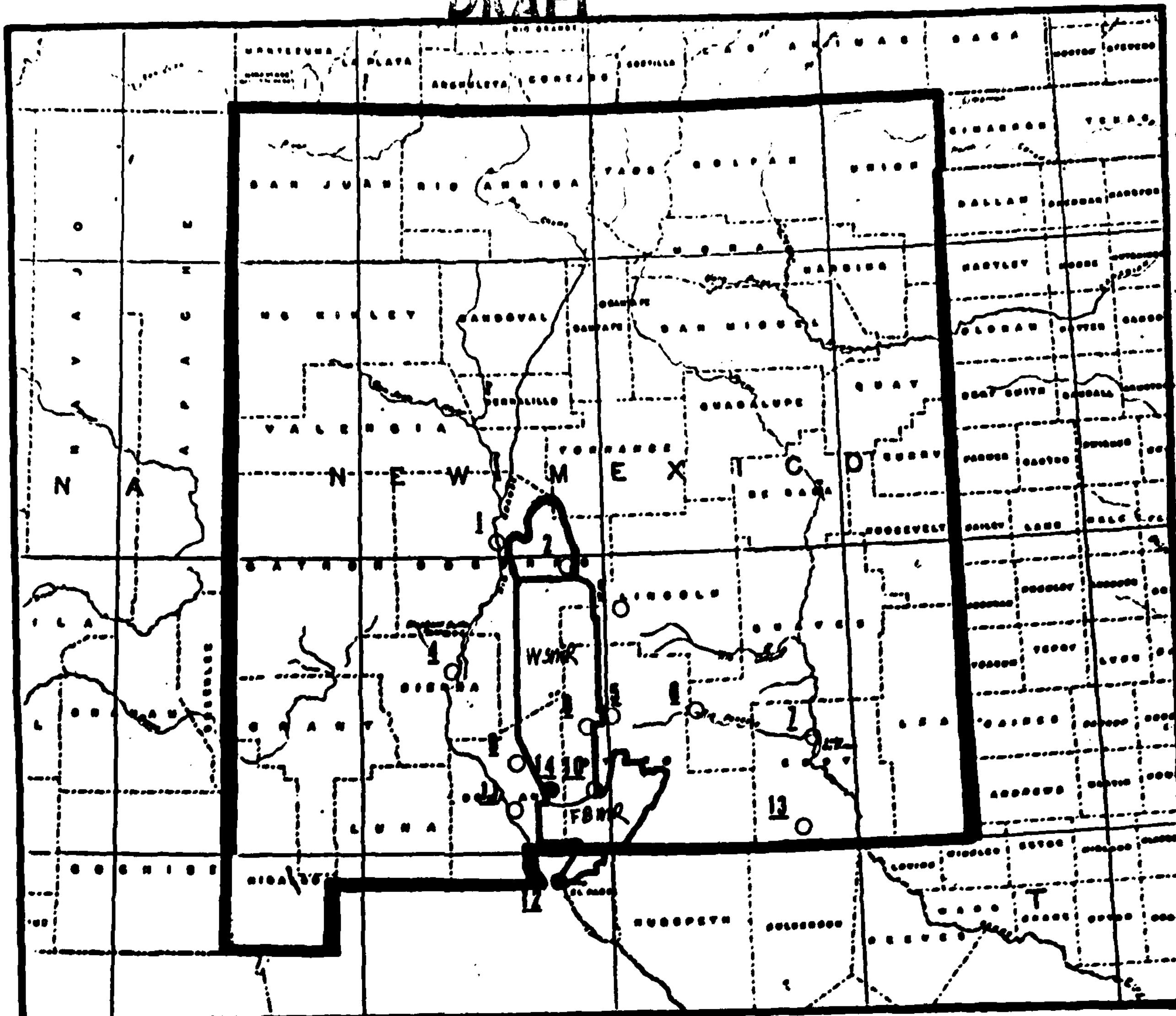

EXPLANATION

STATIONS

1 Socorro
2 Bingham
3 Carrizozo
4 Truth or Consequences FAA A-P
5 Alamogordo
6 Elk 3E
7 Artesia 6S
8 White Sands National Monument
9 Jornada Experimental Range
10 Orogrande
11 State University
12 El Paso WSO
13 Carlsbad Caverns
14 Headquarters Area WSMR "A" Station

0 50 100 150
NAUTICAL MILES

0 100 200
KILOMETERS

SYMBOLS

Boundary of Bureau of Land Management Study Area

12 ● Major recording stations.

10 ○ Recording substations.

10 Records compiled on data sheets.

LOCATION OF CLIMATOLOGICAL RECORDING STATIONS

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE SAMSO

FIGURE 8

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DATE: 30 JUNE 1979

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3.0 VALLEY ANALYSIS

The description of the valley analysis concept from [illegible] 3.0 of this report applies to the only valley in the Tularosa area, Jornada del Muerto North Valley. A black and white base map (1:250,000) shows the valley boundary, location of the topographic grade areas and major cultural or proximity-distance exclusions. The set of five data summary tables and all coded with the appropriate quality of data symbols. All abbreviations and notations from Section 1.2 of this report are applicable.

[illegible]

[illegible]

TABLE OF [illegible]

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TABLE 21

Abbreviations on Data Summary Sheets*

a	active	g	acceleration due to gravity	P	Perched
AASHO	AASHO Soil Classification System (Appendix E)	g/cc	grams per cubic centimeter	p/s	p: primary wave velocity/ s: secondary wave velocity
ac.	acre	gal.	gallons	pcf	pounds per cubic foot
ac.-ft.	acre feet	gpd/ft	gallons per day per foot	PR	Primary
avg.	average	gpm	gallons per minute	psi	pounds per square inch
B	Bedrock	in.	inches	R	Rock
BF	Basin Fill	$in^2/lb.$	square inches per pound	r	river
BLM	Bureau of Land Management	l	lake	S	Secondary
[illegible]	[illegible]	M	Richter Magnitude	u	unconfined
CBR	California Bearing Ratio	m	mantled	USCS	Unified Soil Classification System (Appendix [illegible])
cm/sec	centimeters per second	max.	maximum	VF	Volcanic Flows
comp.	compressibility	mi.	mile	[illegible]	[illegible]
[illegible]	[illegible]	min.	minimum	[illegible]	[illegible]
[illegible]	[illegible]	mod.	moderate	#	[illegible]
[illegible]	[illegible]	N/A	Not Applicable	%	[illegible]
[illegible]	[illegible]	[illegible]	nautical mile		
		nm^2	square nautical miles		

*[illegible]